# **Proofs for Faculty publications in conferences (Faculty-wise and Year Wise)**

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# Silhouette Based Human Fall Detection Using Multimodal Classifiers For Content Based Video Retrieval Systems

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***Abstract*—Automatic human fall detections are proving the need of time in emergency situations for elderly persons falling on the floor injuring them, sometimes with bone fracture or more severely at times being alone while performing their daily activities. Recent advancement in image processing and therein activity identification is seeing rising trend of research. Present paper aims at putting forward a fall detection system which uses human silhouettes, as processed from depth cue based on camera footages, to extract curvature scale space (CSS) features. Human actions thus finally rendered into CSS are classified with the help of standard machine learning classifier techniques such as support vector machine (SVM) and extreme learning machine (ELM). Moreover, the paper distinctively puts forward the benefit of augmented ELM classifier with help of sparse representation for image frame classification (SRC) technique. The system had been tested with standard dataset as established in literature for human action classification. The results presented in form of confusion matrix comprising of detecting semantic activities like walking, idle sitting, standing and falling demonstrate that the developed system has an edge in terms of higher accuracy compared to similar state of the art methods as reported in literature.**

***Keywords—Fall Detection, Support Vector Machine, Extreme Learning Machine, semantic, Content Based Video Retrieval System***

## I. INTRODUCTION

Average citizen age has been seeing a continuous rising graph with growing healthcare facilities and infrastructure in most of developed and developing nations. While this has been a positive change, there is also a growth of nuclear families and lone elderly people in the society worldwide. Such scenarios where most of the elderly people living a lonely life or alone most of the time, in homes or day care centers, doing daily household routines by themselves, are often exposed to danger of accidental hurts to themselves by falling on hard tiled floors. The situation is equally subjective to infants playing without any personal supervision or medical patients and wheel chaired persons who are unable to move without extra aid. The fall can be an accidental, due to, stroke or momentary loss of conscience. A more serious danger poses in occurrences of such causalities the subject falls and being alone in house or room cannot get an attention or raise an alarm for immediate help. Many of modern day researchers and engineers are working with primary objective of detecting the human falling actions. The engineering problem thus stated is subset of detection and classification of generic action semantics of humans. Action semantics in video can be understood from appearance, topological &spatio-temporal cues [1].

Most popular, precise and convenient state of the art semantic content based video retrieval systems(CBVR)for identifying the human activity from a video involves image processing, spatio-temporal analysis, and high level machine learning algorithms to classify and detect the actions in the video. Very recently in 2014, Ma et al. [2], presented such a system capable of detecting the falling actions of elderly persons. The system was cost effective as it promised the use of Kinect type of depth based camera which reduces the hardware cost. Furthermore the salient feature of their system included a mutual employment of two different approaches of post processing. One was the use of detecting the falling action by analyzing the human body shape. This is achieved by extracting curvature scale space (CSS) as feature from the human silhouettes. Human silhouettes are extracted from the camera feed. Secondly, their system made use of advanced machine learning classifier program, such as extreme learning machine (ELM). The ELM classifier is learning based computational classification algorithm which needs to be trained. The process of the system was simple to understand. As the CSS features are extracted from silhouettes, they are assigned with a bag of CSS words. The ELM is trained to classify the human action thus captured on the basis of CSS words identifying the bag of CSS words (BoCSS).

Present paper tries to demonstrate a similar system for human fall detection. Here we choose to make use of depth cue

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Conferences > 2019 International Conference...

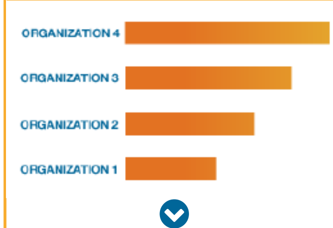
# Resource Centric Characterization and Classification of Applications Using KMeans for Multicores

**Publisher: IEEE**

2 Author(s) Preeti Jain ; Sunil K Surve **View All Authors**










**Abstract**



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**Abstract:** The knowledge on the behavior of an application program towards consumption of shared resources in multicore systems could assist in characterizing and classifying these ... **View more**

### Metadata

**Abstract:**
The knowledge on the behavior of an application program towards consumption of shared resources in multicore systems could assist in characterizing and classifying these programs. Further categorizing applications assists in predicting optimal coschedules for multicores, which eventually leads to lower contention and enhance performance. The proposed work characterizes applications on the basis of variations in IPC due to various resource allocations. Further classification is done based on parameters of cache memory and Dram bandwidth utilization obtained using hardware counters. A statistical approach is used for classifying the applications. The variance values obtained for an application's behavior towards different resource allocations is considered to build training and test set and KMeans learning algorithm is applied to classify the workloads. The accuracy obtained with the proposed method is 85.71%.

**Published in:** 2019 International Conference on Information Networking (ICOIN)

**Date of Conference:** 9-11 Jan. 2019 **INSPEC Accession Number:** 18691048

**Date Added to IEEE *Xplore***: 20 May 2019 **DOI:** 10.1109/ICOIN.2019.8717981

**ISBN Information:** **Publisher:** IEEE

**Print on Demand(PoD) ISSN:** 1976-7684

Conferences > 2017 International Conference...

# Modeling resource constrained solo applications using logistic growth model

**Publisher: IEEE**

2 Author(s) Preeti. N. Jain ; Sunil. K. Surve **View All Authors**







**Abstract**





**Abstract:** In any system when the resources are limited they need to be utilized efficiently. In the present work the multi-core system is considered to be running solo applications... **View more**

## Metadata

**Abstract:**

In any system when the resources are limited they need to be utilized efficiently. In the present work the multi-core system is considered to be running solo applications and uses limited resources. The analysis considers the impact of consumption of two resources viz LLC and main memory bandwidth on multi-core systems. A logistic model is presented and validated for characterizing various SPEC 2006CPU applications using sniper simulator on the basis of their resource utilization. We support the work with statistical approach to distinguish applications following such a logistic model. Under certain conditions, the multi-core model provides a good approximation to the analysis predicted by the logistic model.

**Published in:** 2017 International Conference on Advances in Computing, Communication and Control (ICAC3)

**Date of Conference:** 1-2 Dec. 2017

**Date Added to IEEE *Xplore*:** 19 March 2018

**ISBN Information:**

**INSPEC Accession Number:** 17634125

**DOI:** 10.1109/ICAC3.2017.8318751

**Publisher:** IEEE

**Conference Location:** Mumbai, India

# Error propagation in linear and non-linear systems for False Data Injection Attack

**Publisher: IEEE**

3 Author(s) Sindhuja Mangalwedekar ; Sunil K. Surve ; H.A. Mangalvedekar **View All Authors**



**Abstract:** Due to technological advancement, the integration of cyber systems with the physical power system has increased security concerns. The cyber security issues and the impac... **View more**

### Metadata

**Abstract:**

Due to technological advancement, the integration of cyber systems with the physical power system has increased security concerns. The cyber security issues and the impact of various attacks on the smart grid have become an integral part of the smart grid. False Data Injection Attack (FDIA) is one of the many ways to compromise a system. In this, measurements are biased by deliberate addition of errors, which in turn, affect the state variables of the system. This paper discusses the impact of FDIA on the smart grid. The paper analyses the effect of FDIA on the non-linear state estimator. It further compares the impact of FDIA on the non-linear state estimator with that of the linear state estimator. This comparison is explained using propagation of error.

**Published in:** 2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI)

**Date of Conference:** 10-13 Aug. 2015

**Date Added to IEEE *Xplore*:** 28 September 2015

**ISBN Information:**

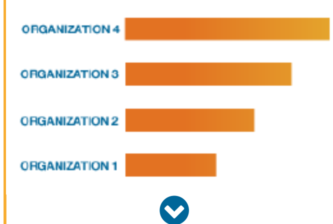
**INSPEC Accession Number:** 15486882

**DOI:** 10.1109/ICACCI.2015.7275686

**Publisher:** IEEE

**Conference Location:** Kochi, India





Conferences > 2015 Annual IEEE India Confer...

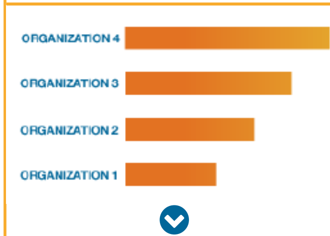
# False Data Injection Attacks and detection scenarios in the power system

**Publisher: IEEE**

3 Author(s) Sindhuja Mangalwedekar ; Sunil K. Surve ; H.A. Mangalvedekar **View All Authors**










**Abstract**





**Abstract:** False Data Injection Attacks (FDIA) in smart grid is an object of extensive investigation. Attack strategies and detection methodologies have been proposed by various res... **View more**

### Metadata

**Abstract:**

False Data Injection Attacks (FDIA) in smart grid is an object of extensive investigation. Attack strategies and detection methodologies have been proposed by various researchers. The aim of the attacker is to bias the state estimate. This paper proposes to calculate a figure of merit of the bias in the state variables introduced by the attacker, known as Aberration Index. Normalised residues indicate the effect of the attacks on the measurements. This paper discusses the detection of attacks using Aberration Index and Normalised residues for different attack scenarios.

**Published in:** 2015 Annual IEEE India Conference (INDICON)

**Date of Conference:** 17-20 Dec. 2015

**Date Added to IEEE *Xplore*:** 31 March 2016

**ISBN Information:**

**Electronic ISSN:** 2325-9418

**INSPEC Accession Number:** 15888109

**DOI:** 10.1109/INDICON.2015.7443817

**Publisher:** IEEE

**Conference Location:** New Delhi, India

# Localization and tracking of indoor mobile robot with beacons and dead reckoning sensors

**Publisher: IEEE**

6 Author(s) Allan Lobo ; Ronit Kadam ; Shabeeha Shajahan ; Keshad Malegam ; Kranti… **View All Authors**









**Abstract:** Autonomous robots must be able to localize themselves in an environment. We are interested in the real time pose estimation of a single surveillance robot based on the Od... **View more**

### Metadata

**Abstract:**

Autonomous robots must be able to localize themselves in an environment. We are interested in the real time pose estimation of a single surveillance robot based on the Odometry algorithm and Dead Reckoning using Inertial Measurement Unit (IMU) sensors. This approach is subjected to accumulated errors due to slippage and drift respectively. Algorithm proposed in this paper uses Trilateration with Extended Kalman filter. We found that our approach reduces the error.

**Published in:** 2014 IEEE Students' Conference on Electrical, Electronics and Computer Science

**Date of Conference:** 1-2 March 2014

**INSPEC Accession Number:** 14255016

**Date Added to IEEE *Xplore*:** 24 April 2014

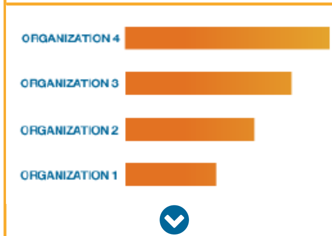
**DOI:** 10.1109/SCEECS.2014.6804452

**ISBN Information:**

**Publisher:** IEEE

**Conference Location:** Bhopal, India





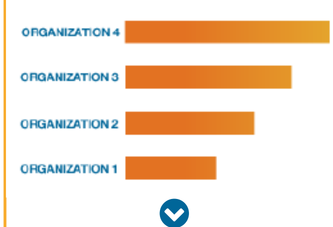
# Measurement sets in power system state estimator in presence of false data injection attack

**Publisher: IEEE**

2 Author(s) Sindhuja Mangalwedekar ; Sunil K. Surve **View All Authors**














**Abstract:** False data injection attacks (FDIA) on smart grid is a popular subject of current research. The presence of FDIA and other such attacks in smart grid is partly due to the... **View more**

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**Abstract:**

False data injection attacks (FDIA) on smart grid is a popular subject of current research. The presence of FDIA and other such attacks in smart grid is partly due to the combination of Information and Communication Technology with Power Systems. The FDIA on linear model of power system has been extensively analyzed in literature. However the non linear system model has not received the same amount of attention. This paper proposes the concept of balanced and unbalanced measurement set for the purpose of corrupting the state variables in linear and non-linear power system state estimators. The effect of balanced and unbalanced measurement sets for targeted constrained and unconstrained attacks are analyzed for linear and non-linear state estimators.

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Volume 49, 2015, Pages 170-177

# HTML5 Based Virtual Whiteboard for Real Time Interaction ☆

Swati Ringe, Rishabh Kedia, Anuj Poddar, Sahil Patel

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## Abstract

Meetings and classrooms demand the presence of the person in the room if he wants to participate. A tool widely used in such places is a whiteboard. A whiteboard has limited creativity and interactivity options and hence it needs to be replaced with better tools. In this paper we develop a web application to increase collaboration without restricting him to any location, operating system platform or device. Our application allows users to interact and share information via drawings, images, chat, audio and video. They can create individual rooms and share the room id with only certain people. Users only need access to web browsers and internet to make use of the application. There is no limit on the number of users allowed to participate and no plug-in needs to be downloaded. We have implemented this system by using HTML5, Node.js and WebSocket. WebSocket support concurrency in real-time transmission of information. All the users can simultaneously interact with the system. The experimental results demonstrate the high scalability of our system. As evident from the experiments, the response delay is extremely low, the system is fast and provides real-time experience to the users.

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## Keywords

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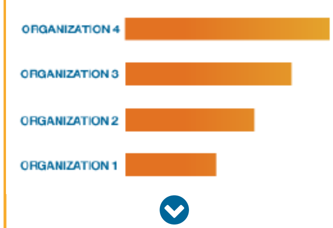
# An IOT Based Smart Cubicle System for Effective Power Usage and Employee Monitoring in Offices

**Publisher: IEEE**

4 Author(s) Slavvy Coelho ; Ruchita Rozario ; Rohit Sharma ; Mahendra Mehra **View All Authors**














**Abstract:** In today's world of rapid changes in technology and new inventions and updates being implemented every second, human beings while running for the bigger concerns are negl... **View more**

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**Abstract:**

In today's world of rapid changes in technology and new inventions and updates being implemented every second, human beings while running for the bigger concerns are neglecting the trivial aspects which may cause them a fortune if such profligate use is continued. One such example is the reckless usage of electricity. In this paper, we present a Smart Lighting System which aims at curbing this problem using IOT. Internet of Things has captured this era of computing technology. It is made up of advanced technology components that have the ability to transmit, analyze and interpret information and function in accordance to the human behavioral inputs. Here we propose an energy efficient system for lighting up a room based on the occupancy of the room and the intensity of the light using PIR sensors and other components such as LDR and Raspberry Pi. The lighting system of the room is based on a grid format and when a person is in the vicinity or the range of a particular bulb, only then will it be lit. The introduction of Raspberry Pi in the model will also allow monitoring of employee work-patterns. Our proposed system will eliminate the human errors such as leaving the buttons on due to negligence. The advent of such a system will conserve energy, enhance customer service and aid economic development.

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Sanjiv K. Bhatia · Shailesh Tiwari ·
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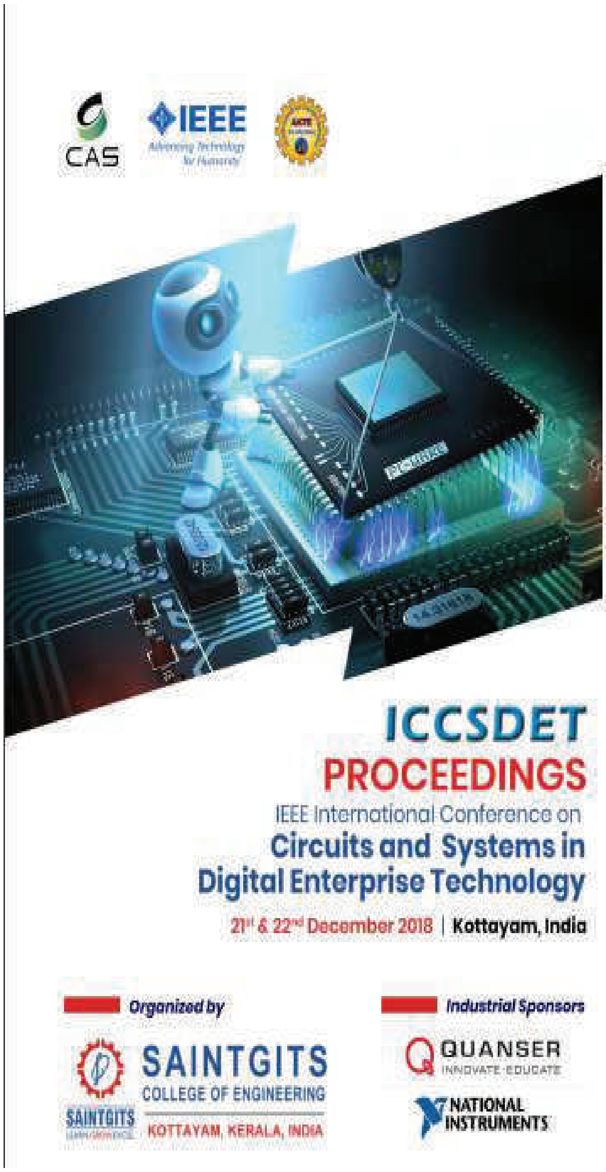


# A novel hybrid technique for user navigation pattern prediction using KHM and FP growth


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*Abstract*—A huge amount of data is available on the web. Several users tend to access the data available on the internet. This makes it difficult to understand the browsing behavior of the user. The browsing history of the user is recorded in the web server log files. Such log files need to be analyzed. The approach described in this paper is based on a novel hybrid technique for analyzing the browsing patterns. It involves a novel and hybrid approach based on clustering and pattern mining algorithm. The approach discussed in this paper is being implemented and the results are analyzed and compared with other related system using two different datasets. The results are also compared concerning the execution time, accuracy and number of frequent patterns.



*Keywords*— web log files, web usage mining, clustering, pattern mining, FP growth, KHM, [illegible]


## I. Introduction

Web mining involves using data mining techniques for identifying useful information from the web documents or services. There are certain categories of information that can be discovered by web mining.

Web activity data – discovered from the web server log files and the users navigation pattern.

Web graph – discovered from the links between web pages and the users and other data.

Web content – discovered from the data found on web pages.

User's navigation data is recorded in the web log files. Such web activity data is used further for understanding user's browsing behavior. While analyzing the browsing behavior the web activity has to undergo three important phases i.e. preprocessing of the data, discovery of browsing patterns and pattern analysis. It is then used for predicting the future browsing pattern of the user. The results obtained are useful in several areas like recommendation, prediction of future

5. Applying frequent pattern mining techniques to identify user's patterns and association rules from the clustered data.
6. Using the association rules to predict the pages likely to be visited by the user.

The organization of the paper is as follows: Section II explains the literature survey done in this area, Section III describes the methodology of the proposed system. In Section IV the results obtained and the result analysis and a comparative analysis of the proposed system with other related system is provided and finally in Section V the conclusion and future scope is discussed. The papers covered in [4][7] describe the proposed system with its objectives and shows its comparative results with the existing system. However the results are evaluated only on the basis of execution time. In this paper our goal is to evaluate the results of the proposed system with existing system with respect to multiple datasets and with several comparison parameters. The result analysis part is an innovative part and extension to [7].

## II. Related Work

The existing approaches for prediction of user's navigation patterns are discussed in this section. Most of the approaches use a combination of clustering and pattern mining algorithms [4] [17].

The K-means clustering algorithm along with Apriori pattern mining algorithm and Markov model for prediction is used in [1]. K-means is a clustering method based on a distance measure, Apriori algorithm is used for identifying patterns and further the users future request are predicted using the Markov model.

A combination of k-means for clustering and FP growth for pattern mining is discussed in [4], [10]. In [5] the Markov model is used for prediction of future request.

In [7], [3] the frequent patterns are identified using FP-

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# Teachers- Engineering Emotions in the Classrooms

**Dr. Trehan Khushbu**
Assistant Professor,
Mumbai,
Maharashtra, India.

**About Author:**
Assistant Professor (Communication Skills), Humanities and Science Department
Father Conceicao Rodrigues College of Engineering, Mumbai, India
Doctorate in Canadian Literature (Ph.D. Course Work with 72%), Certified Dale Carnegie Trainer, completed 220 hours Advanced Diploma Program in TESOL from American TESOL with Specialization in Business English Teachers' Training.
-Conducted lectures and trained hundreds of students to hone their Presentation skills, Group discussion attributes and personal interview techniques to excel in campus placements.

*"School is an emotional caldron : a constant stream of academic and social challenges that can generate feelings ranging from loneliness to euphoria."*

**- Marc Brackett**
(A senior research scientist in psychology at Yale University)

The chrysalis of any nation depends primarily on the absolute standards of its educational institutions. In this tech-saturated Google era, the education in our country has witnessed revolutionary changes during last decade. On one hand, there is stupendous explosion of knowledge and inclusion of information, communication and technology in education; on the other hand, it has increased the challenges and responsibilities of the teacher. Furthermore, the digital era has greatly influenced the teaching patterns in educational institutions thereby making teaching profession quite a challenging one than it was a few decades ago.

Teachers are the ones who shape this whole process of education by creating interest in students to develop progress and achieve whatever they aim for. Thus they are the sole factor for the resurgence and strengthening of the education system. An effective teacher is required to interact with the students, influence them and enable them to achieve better, become good citizens through academic and personal-social interaction with them by understanding and handling the situation with emotions in the right way at the right time. This paper is an attempt to substantiate the fact that by being emotionally intelligent helps teachers managing students' emotions in particular situations that makes the difference.

**Key Words:**

*Emotions, Effective [illegible] Personal-Social Inte[illegible]*

**Introduction:**

Life not only gives individuals professional challenges (to be solved theoretically) but also the challenges connected with personal emotions (the interpersonal problems connected with family and institutional relationships).

Both the problems (personal and professional), more often than not, are resolved by the psychic balance of an individual and the way he responds to solve these problems. And thus, the success of interpersonal relationships depends not only on the intellectual abilities, but also on the emotional development (the way an individual manages is own and the other peoples' emotions). People who are emotionally intelligent are able to effectively connect with others, have strong inter-personal relationships, productive in their work and are more satisfied during their life. This satisfaction level helps them build a positive self-image and self- esteem. Those who are not able to understand and manage their emotions are largely dominated by their emotions and find it difficult to adapt to certain situations in life.

**Theoretical Substantiation:**

The concepts of "emotion" and "intelligence" have been debated throughout history. Both Aristotle and Plato emphasized that "low level emotions have no direction and need to be directed by the logic." Descartes, with his hypothesis "I think therefore I am," claimed that emotions arise together with thoughts. Affected by the philosophy of reason, Descartes defined emotions as primitive elements that need to be controlled (Graves, 1999, Çakar, 2002:9-

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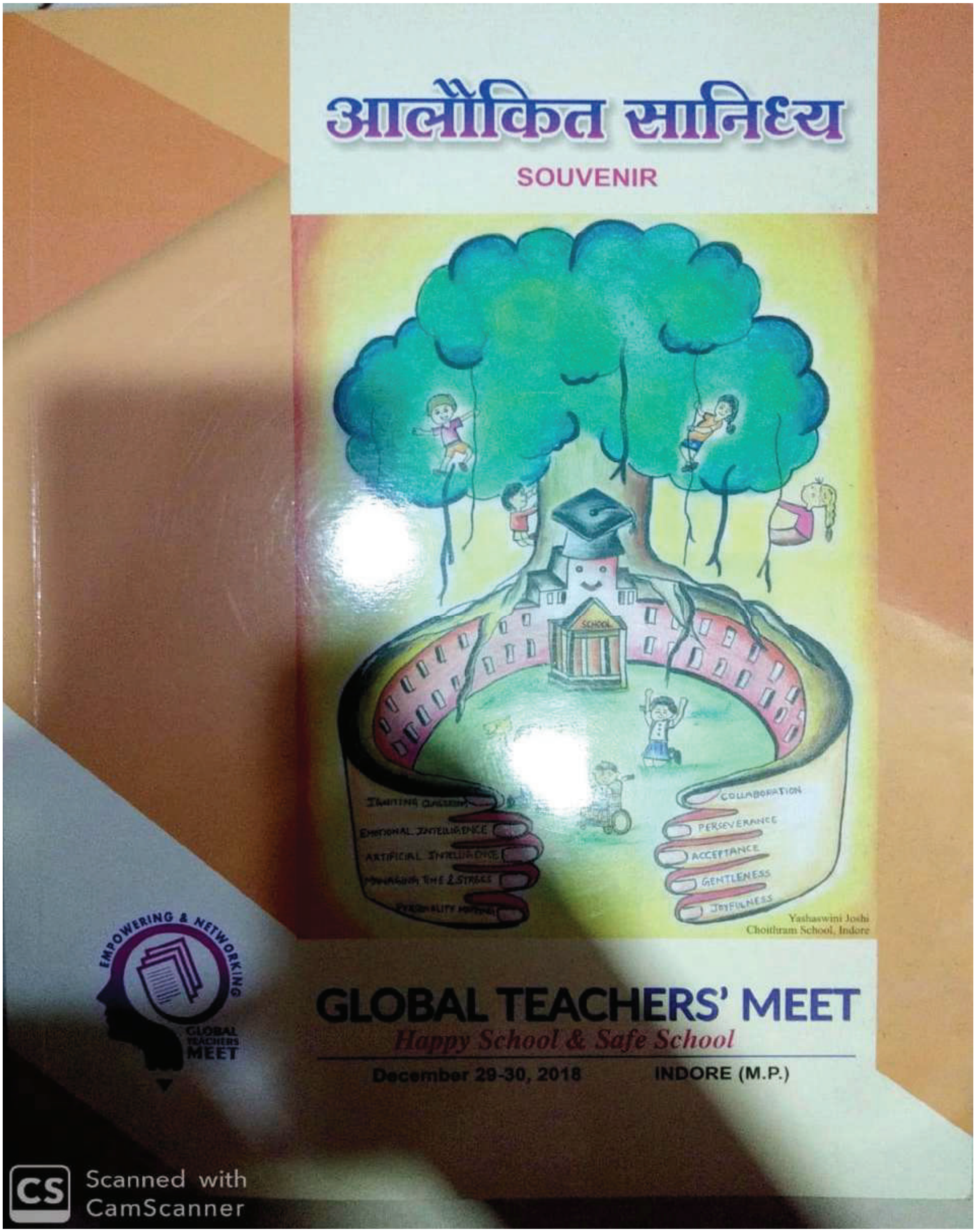
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# Exploring Science in Black Fiction; A Study of Octavia Butler's *Parable Series*

Khushbu Trehan and Naeemul Haq
Research Scholars, School of Studies in English,
Vikram University, Ujjain (M.P)

**Abstract**

*Octavia Estelle Butler was born on June 22, 1947, in Pasadena, Calif. As a girl, she was known as Junie. Octavia E. Butler, an internationally acclaimed science fiction writer whose evocative, often troubling, novels explore far-reaching issues of race, sex, power, fall and death. The researcher aims at exploring the elements and aspects of science fiction in the novel Parable of the Sower of Octavia Butler. Set in a future where government has all but collapsed, Parable of the Sower centers on a young woman named Lauren Olamina who possesses what Butler dubbed hyperempathy – the ability to feel the perceived pain and other sensations of others – who develops a benign philosophical and religious system during her childhood in the remnants of a gated community in Los Angeles. Civil society has reverted to relative anarchy due to resource scarcity and poverty. When the community's security is compromised, her home is destroyed and her family murdered. She travels north with some survivors to try to start a community where her religion, called Earthseed, can grow. Throughout Ms. Butler's career, the news media made much of the fact that she was an African-American woman writing science fiction, traditionally a white male bastion. Set in time periods ranging from the historical past to the distant future, Ms. Butler's books were known for their controlled economy of language and for their strong, believable protagonists, many of them black women. She wrote a dozen novels, including "Parable of the Sower" (Four Walls Eight Windows, 1993); "Parable of the Talents" (Seven Stories Press, 1998); and, most recently, "Fledgling" (Seven Stories), which appeared last year.*

**Key Words: Science, Racial Issues, Black Fiction, Social Issues, Community**

When we read or hear the term Science Fiction, it comes to our mind that it is a type of genre which deals with robots, graphics, futurism, and distant planets inhabited by aliens. But Black Science Fiction highlights a variety of activities within the science fiction, fantasy, and horror genres where people of the African diaspora take part or are depicted. In the late 1990s a number of cultural critics began to use the term Afrofuturism to depict a cultural and literary movement of thinkers and artists of the African diaspora who were using science, technology, and science fiction as means of exploring the black experience.

Science fiction novelist Octavia Butler dreamed up fantastic worlds and religions, made-up creatures and futuristic plots in her novels. Then, in her stylistic prose, she used them to tackle the social issues she was most passionate about. *Parable of the Talents*, a futuristic story about a utopian community ravaged by civil war, explored modern-day issues of intolerance, the growing gap between rich and poor, and environmentalism. In her first novel, *Kindred*, she plunged into racial issues when a modern-day character was transported into the body of a pre-Civil War slave. In 2000, she received the Nebula Award for her novel *Parable of the*

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# 09.CLASS ROOM ADMINISTRATION OF FRESHER FACULTIES IN ENGINEERING COLLEGE

Dr. Joseph Rodrigues
Lokmanya Tilak College of Engineering, Navi-Mumbai

***Abstract:***

Faculties play a very important role in shaping the career of students. Quality education has a pivotal role in this ever progressing world. Though engineering institutes scrutinize the fresher candidates as per their subject knowledge, they seriously lack Class administration. This paper highlights the weaknesses of the fresher faculties of Engineering colleges to handle this noble profession thereby degrading the quality of teaching.

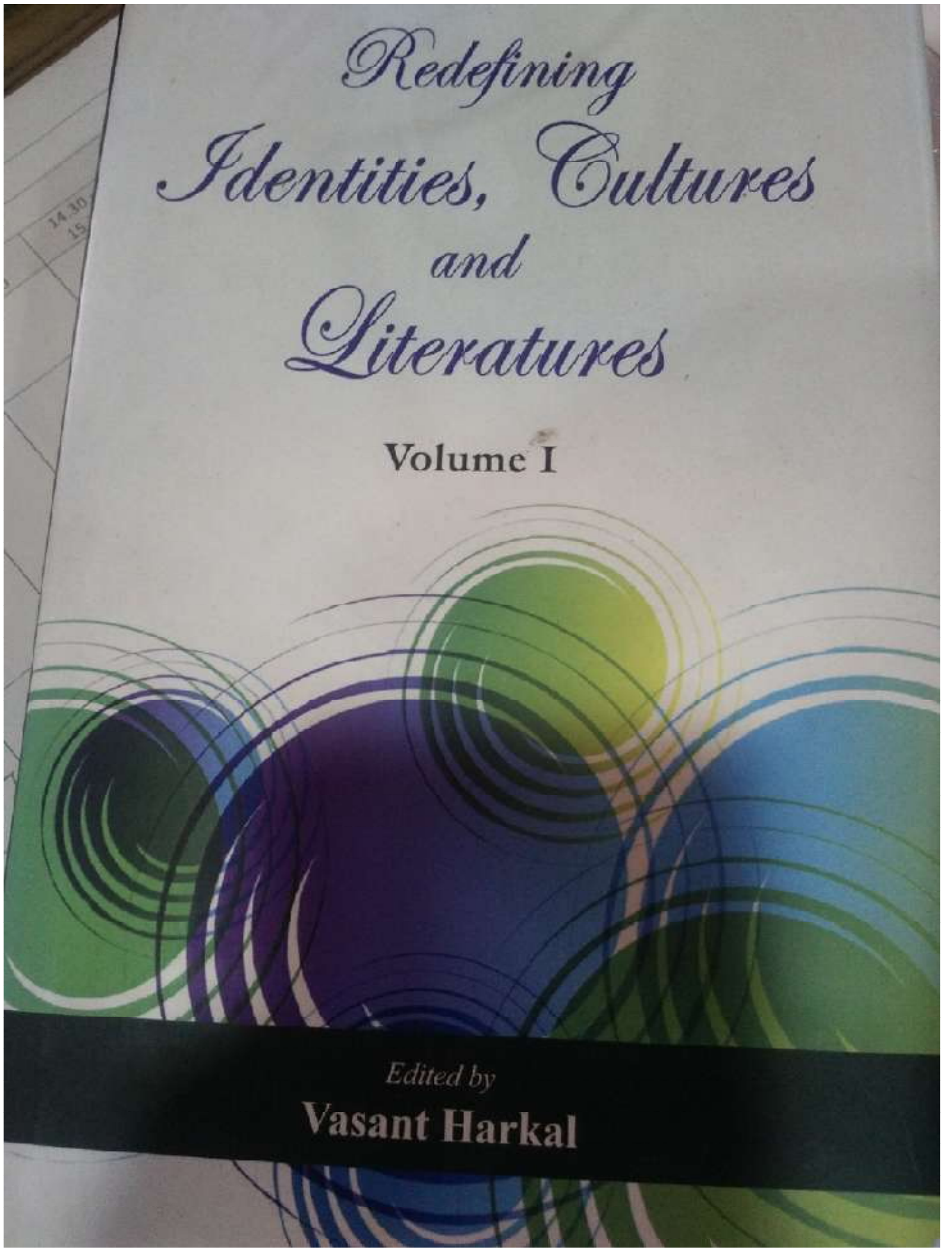
(Key words: Fresher Faculties, lack class administration, degrading quality of teaching)

## Background

With the blooming of engineering institutes, it looks for aspirant candidates to join as Assistant Professor. With the competitive world, the qualification criteria are also increasing day by day. Earlier, a candidate with Bachelor of Engineering (B.E) was eligible to work as a lecturer. But within a decade, the minimum criteria to choose teaching as a profession in engineering college are Master of Engineering (M.E) with First class. A candidate with mere B.E qualifies for getting a post of Lab. Asst. Candidate with Master's degree with no proficiency in class administration are given opportunities in engineering college. This has totally degraded the teaching and handling of class in professional colleges.

## Problem

Due to crises in the market, many M.E job aspirants do not get job in the industries. With the passing of time, due to frustration of waiting for job in Industry; the candidates move to colleges for teaching profession as their last option. They have to select this job to make their living. Uninterested, they enter this profession with no goal in life. This has not only spoilt the teaching quality of our country but also the reputation of colleges. The feedback of the college students gives a crucial turn to the admission process too. With mouth to mouth advertising, the society inquires about the college to students of the college. If the feedback of the college is bad, no one wishes to take admission to the college because of teaching quality.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CRITICAL RESPONSES TO DIASPORIC LITERATURES IN ENGLISH
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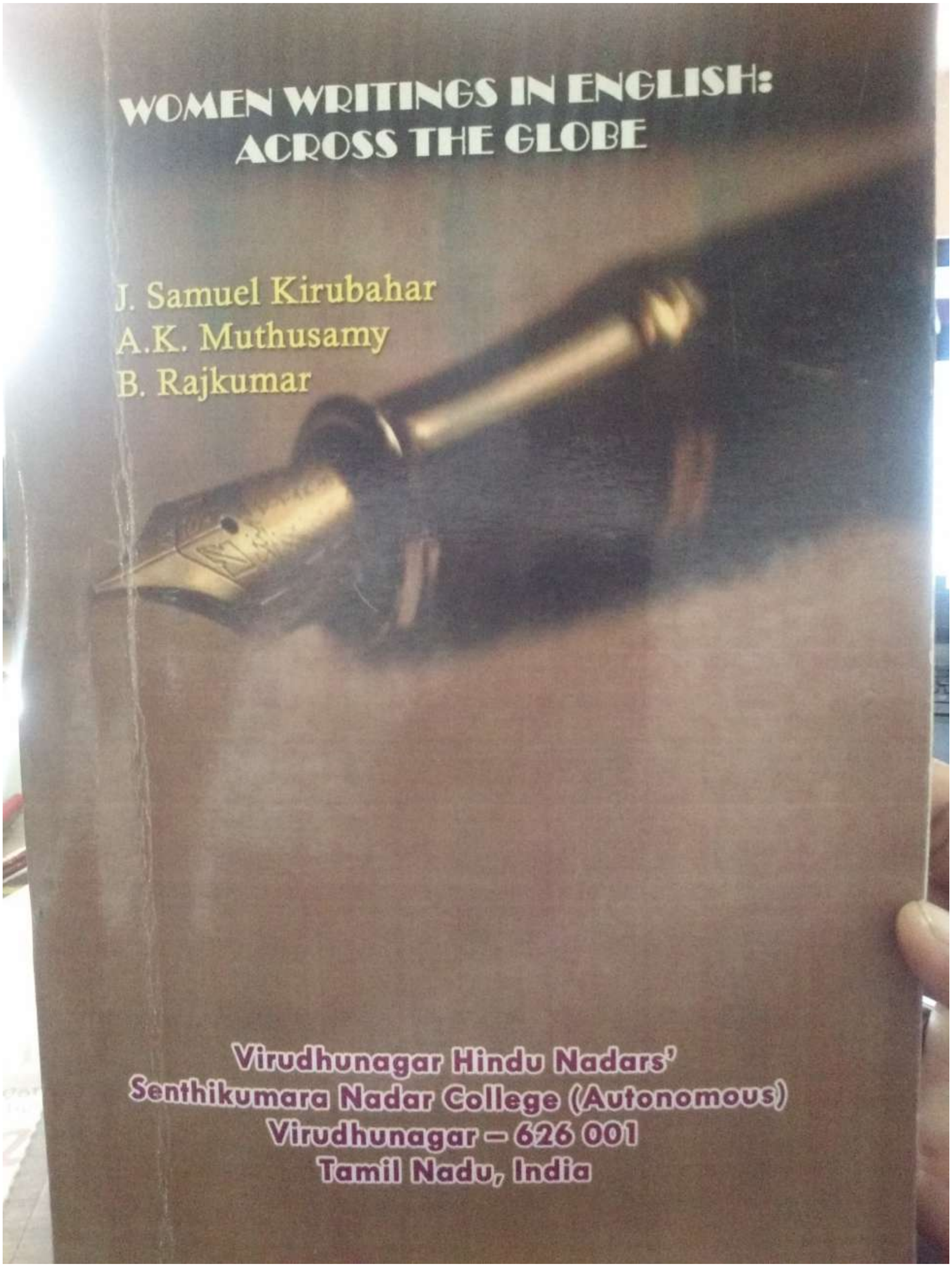
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# Design and Simulation of High SNR Varying Thickness Embedded Strain Sensing Polymer Microcantilever for Biosensing Applications

P. V. Kasambe, K. S. Bhole, D. V. Bhoir



+ Author Information

**Paper No:** DETC2018-85731, V004T08A004; 7 pages

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To convert induced surface stress of a bio-functionalized microcantilever into an electrical signal; U shaped piezoresistive detection technique is mostly preferred over other techniques due to its several advantages. But the inherent disadvantage of this technique is thermal stress sensitivity as a source of noise which reduces its signal to noise ratio [SNR]. Polymer microcantilever has larger stress sensitivity due to its low youngs modulus

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# Design and Simulation of High SNR Varying Thickness Embedded Strain Sensing Polymer Microcantilever for Biosensing Applications

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# SINGLE PRECISION FLOATING POINT DIVISION

[1]NAJIB GHATTE, [2]SHILPA PATIL, [3]DEEPAK BHOIR

[1,2,3]Fr. Conceicao Rodrigues College of Engineering, Fr. Agnel Ashram, Bandstand, Bandra (W), Mumbai: 400 050, India

**Abstract-** Binary Division is one of the most crucial and silicon-intensive and of immense importance in the field of hardware implementation. A Divider is one of the key hardware blocks in most of applications such as digital signal processing, encryption and decryption algorithms in cryptography and in other logical computations. Being sequential type of operation, it is more prominent in terms of computational complexity and latency. This paper deals with the novel division algorithm for single precision floating point division Verilog Code is written and implemented on Virtex-5 FPGA series. Power dissipation has been reduced. Moreover, significant improvement has been observed in terms of area-utilisation and latency bounds.

**Keywords-** Single precision, Binary Division, Long Division, Vedic, Virtex, FPGA, IEEE-754.

## I. INTRODUCTION

The term floating point implicates that there is no fixed number of digits before and after the decimal point; i.e. the decimal point can float. Floating-point representations are slower and less accurate than fixed-point representations, but can handle a larger range of numbers. Because mathematics with floating-point numbers requires a great deal of computing power, many microprocessors come with a chip, called a floating point unit (FPU ), specialized for performing floating-point arithmetic. FPUs are also called math coprocessors and numeric co-processors. Floating-point representation has a complex encoding scheme with three basic components: mantissa, exponent and sign. Usage of binary numeration and powers of 2 resulted in floating point numbers being represented as single precision (32-bit) and double precision (64-bit) floating-point numbers. Both single and double precision numbers as illustrated in Fig. 1 are defined by the IEEE 754 standard.

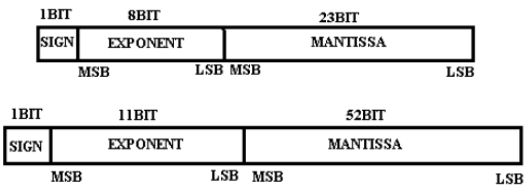


**Fig. 1 IEEE-754 Floating-point Representation Standards**

For a single precision format, 8-bits are reserved for exponent thereby having a bias value of +127 and 23 bits are reserved for mantissa.

When sign bit is 1, it indicates negative number and when it is 0, it argues as a positive number.

The similar explanation is extended for double precision format where exponents are biased to +1023. Binary division operation is of much significance in the area of hardware implementation of signal processing, high quality graphics rendering, filter applications, etc. It is the most important goal of a designer to enhance the performance of the ALU thereby reducing its design complexity to have better figure of merit. Many algorithms were proposed and implemented to reduce the latency of binary division. In algorithmic and structural levels, a lot of division techniques had been developed to reduce the latency of the divider circuitry; which reduces the iteration aiming to reduction of latency but the principle behind division was same in all cases.

Vedic math is known to more optimised and efficient than algorithms based on conventional logic. The sutras defined can be used in digital design to improve the performance of ALUs based on conventional logic. Nikhilam Navatashcaramam Dashatah Sutra and the Paravartya Sutra deals with the division. These sutras find its limitations when number of bits are increased as this paper deals with IEEE-754 floating-point representation.

## II. VARIOUS DIVISION ALGORITHMS

Researchers have proposed many algorithms and procedural architectures to carry out division in order to reduce the computational time and thus enhancing the performance.

*A.* Restoring Division

Restoring division operates on fixed-point fractional numbers and depends on the following assumptions: (a) $D < N$ and (b) $0 < N, D < 1$.The quotient digits q are formed from the digit set {0, 1}. The basic algorithm for binary (radix 2) restoring division is:

To compute a/b, put a in register A, b in register B and 0 in register P.

1. Shift the register pair (P, A) one bit left.
2. Subtract the content of Register B from register P.
3. If the result of step 2 is negative, set the $A_0$ to 0, otherwise to 1.

4. If the result of step 2 is negative, restore the old value of P by adding the contents of register B back into P.

After repeating the algorithm, n times, register A will have quotient and register P with reminder.

*B.* Non-Restoring Division

Non-restoring division uses the digit set {−1, 1} for the quotient digits instead of {0, 1}. The basic algorithm for binary (radix 2) non-restoring division is:

If P is negative,

1a. Shift (P,A) one bit left.

2a. Add the content of register B to P.

else

1b. Shift (P,A) one bit left.

2b. Subtract the contents of register B from P.

3. If P is negative, set the low-order bit of A to 0, otherwise set it to 1.

Repeat the above procedure n times. After n cycles, register A will have the quotient and if P is positive, it is the remainder, otherwise it has to be restored (add B to it) to get the remainder.

*C.* SRT Division

Named for its creators (Sweeney, Robertson, and Tocher), SRT division is a popular method for division in many microprocessor implementations. SRT division is similar to non-restoring division, but it uses a lookup table based on the dividend and the divisor to determine each quotient digit. The basic algorithm for binary (radix 2) non-restoring division is:

1. Load a and b into A and B registers (Figure A.2)
2. If B has k leading zero, shift B and (P,A) left k bits
3. For l=0, n-1,
   a) If top 3 bits of P are equal, set qi=0 and shift (P,A) one bit left.
   b) If top 3 bits of P are not equal and P is negative, set $q_i$=-1 (write as $\bar{1}$ ) shift (P,A) one bit left, add B.
   c) Otherwise, set $q_i$=1, shift (P,A) one bit left, sub B.
4. If final remainder is negative, correct the remainder by adding B; correct the quotient by subtracting 1 from q0.
5. Shift remainder k bits right.

*D.* Vedic Architecture: Nikhilam Sutra

Vedic Sutra, Nikhilam can be further extended to carry out Binary Division as an alternative to conventional algorithm. Assume that, A and B are dividend and divisor respectively. Dividend is n-bits wide. The flowchart diagram can be executed as follows:

a) Initialize the incrementer with ‘0’.
b) Determine the complement B with respect to 2n assume the complemented result is equal to B’.
c) Add B’ with A. If the carry is ‘1’, then feed the result to the adder.
d) Increment the content of the incrementer by one.
e) Repeat step-3 until the result is less than B.
f) The final result of the incrementer is the quotient and result from the adder is the remainder.

## III. PROPOSED DIVISION ALGORITHM

This paper deals with the efficient algorithm which incorporates the positive attributes of the division architectures mentioned. The division algorithm find its limitations with the wide increase in the number of bits as this paper deals with the floating point representation where mantissa of dividend and divider are each 23-bit wide.

The basic algorithm for the proposed design as follows:

First and foremost, the sign-bit of result is obtained by performing logical XOR of sign bits of dividend and divisor. The Exponent is evaluated by subtracting 8-bit exponent of divisor from 8-bit dividend and then adding the bias value (+127). Lastly, 23-bit mantissa of the result is computed using division logic for which stepwise procedure enlisted below.

1. Pad leading zeroes before the dividend making its width, double the width of mantissa.
2. Pad a leading zero before a divisor and trailing zeroes after the divisor making its width, double the width of mantissa.
3. Perform subtraction of dividend and divisor.
4. If the difference is negative Put 0 in the quotient else 1.
5. Right Shift divisor
6. Left Shift quotient

Fig. 2 shows the example based on proposed algorithm where a decimal number 12 is divided by decimal number 3. Architectural block diagram of the proposed design is shown in Fig. 3.

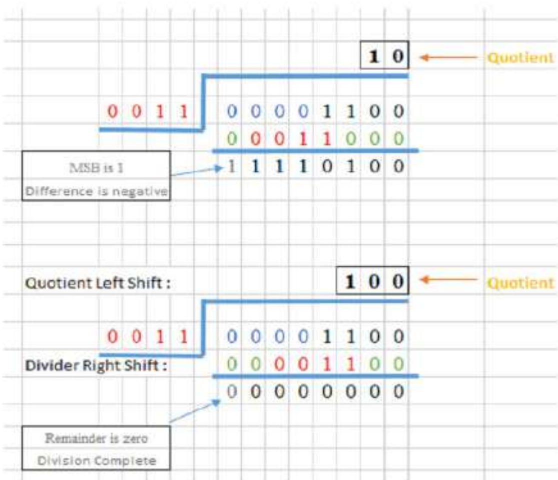


**Fig. 2 Floating point Vedic Divider Illustration 12 divided by 3**

## IV. DESIGN IMPLEMENTATION

Verilog HDL code for Division of IEEE-754 Single Precision Numbers is being developed and then is simulated using ModelSim SE Plus 6.5. Verilog HDL code was break down into modules which deals with the division of 23-bit dividend and 23-bit divisor. code is also written for exponent addition and normalisation process. Top module connects all of them as shown in Fig. 4. Various sets of inputs are fed to the top modular block to get the results. The further part of the document deals with simulation and synthesis results.

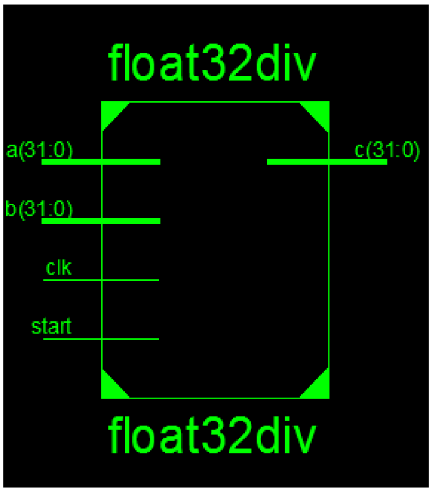


**Fig. 4 Single Precision Vedic Divider: Block Diagram**

A. ModelSim Simulation

Consider division of two decimal numbers, 73.68 and 73.68 fed as A = 73.68 (0 10000101 00100110101110000101001) and B = 73.68 (0 10000101 00100110101110000101001) were fed to the algorithm to get the desired output as C = 1 (0 01111111 00000000000000000000000) as shown in Fig. 5.

B. Xilinx ISE Synthesis

Verilog HDL Code for division of IEEE-754 Single Precision (32-bit) numbers are then synthesized for device XC5VLX30 having package as FF324 of Virtex™-5 FPGA family. From the datasheet cited in, this device has following attributes manifests in Table I.

TABLE I
XILINX VIRTEX™-5 XC5VLX30 ATTRIBUTES

| Device | CLB Array (One CLB = Four Slices × 2) | | | Total Slices | Max. User I/O |
|---|---|---|---|---|---|
| | Rows | Column | Total | | |
| xc5vlx30 | 80 | 30 | 4800 | 19,200 | 220 |

Table II shows the Device Utilisation Summary of the Verilog HDL code, so written, it is been observed that number of device parameters used are very less. Hence, an optimum Device Utilisation is obtained.

From the timing report obtained, it is found that the maximum combinational path delay is 5.405 ns. Maximum combinational path delay is only for paths that start at an input to the design and go to an output of the design without being clocked along the way. Also, it is estimated that it can operate with the maximum frequency of 326.163 MHz.

## V. PERFORMANCE ANALYSIS: VEDIC VERSUS CONVENTIONAL

It can be easily deduced from the Table III which shows the performance analysis of the Vedic divider with that of conventional dividers that Vedic dividers are more optimistic.

TABLE II
FLOATING POINT VEDIC DIVISION (SINGLE PRECISION):

| Device Utilization Summary | | | |
|---|---|---|---|
| **Slice Logic Utilization** | **Used** | **Available** | **Utilization** |
| Number of Slice Registers | 120 | 19,200 | 1% |
| Number used as Flip Flops | 120 | | |
| Number of Slice LUTs | 159 | 19,200 | 1% |
| Number used as logic | 159 | 19,200 | 1% |
| Number using O6 output only | 155 | | |
| Number using O5 and O6 | 4 | | |
| Number of occupied Slices | 54 | 4,800 | 1% |
| Number of LUT Flip Flop pairs used | 182 | | |
| Number with an unused Flip Flop | 62 | 182 | 34% |
| Number with an unused LUT | 23 | 182 | 12% |
| Number of fully used LUT-FF pairs | 97 | 182 | 53% |
| Number of unique control sets | 2 | | |
| Number of slice register sites lost to control set restrictions | 4 | 19,200 | 1% |
| Number of bonded IOBs | 98 | 220 | 44% |
| Number of BUFG/BUFGCTRLs | 1 | 32 | 3% |
| Number used as BUFGs | 1 | | |
| Average Fanout of Non-Clock Nets | 2.37 | | |

TABLE III
PERFORMANCE ANALYSIS:
PROPOSED WORK (VEDIC) VERSUS CONVENTIONAL

| Parameters | This Work | [6] | [9] | |
|---|---|---|---|---|
| Number of bits | 23 | 9 | M | |
| Target Device | Virtex 5 XC5VLX30 -3 FF324 | Spartan 3 XC3S100E -5 VQ100 | Spartan 3E XC3S500E | |
| | | | Restoring | Non - Restoring |
| Number of Slices | 54 | 103 | 229 | 447 |
| Number of 4-input LUTs | 159 | 176 | --- | --- |
| Number of IOBs | 98 | 38 | --- | --- |
| Maximum Frequency (MHz) | 326.163 | --- | 12.63 | 53.77 |

Number of slice LUTs used in the design are pretty less, 159 whereas other algorithms based dividers are normally hooked to 176. Also one can visualize that this proposed divider is just consuming 54 number of slices compared to other algorithms which utilize minimum of 103 to 447 number of slices. Thus, there is near about 12% improvement in the utilisation of the resources, thereby enhancing the packaging density. This proposed design can be operated on the processor clocked with 326.16 MHz, Thus, computational speed is more as compared to other design which operates with maximum frequency of 53.77 MHz. The maximum combinational delay incurred is just a meagre value of 5.405 nanoseconds. Power consumption of proposed design is drastically reduced to 2 mW, whereas traditional ALUs are consuming more power. Since, proposed design consumes less power, so bulky heat-sinks or extensive blowers can be eliminated. This makes the installation of processor simple and can be equipped with portable or mobile devices.

## CONCLUSION

The importance and usefulness of floating point format nowadays does not allow any discussion. Any computer or electronic device, which operates with real numbers, implements this type of representation and operation. Division is one of the most important arithmetic operation. Various architectures were proposed which include recursive iterations to increase the computational performance of the ALU. The proposed design uses ancient Math technique which pad zeroes for dividend. By means of logical shift, the estimated results were obtained. Synthesis results obtained provides better results in terms of computational speed and area utilization thereby reducing the size of silicon dye used. Also reduces the size and cost of the device. Moreover, less time delay incurred leads to fast computation and speedy calculations. Power dissipation has been reduced, which can eliminate the need of extensive cooling mechanism comprising thermal gels and blowers. Thus, proposed divider is more efficient than traditional ALUs and serve as better optimisation technique as per today's need and wants.

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[9] Bojan Jovanovic, Milun Jevtic, "FPGA Implementation of Throughput Increasing Techniques of the Binary Dividers" in International Scientific Conference, Gabrovo, Nov. 2010.

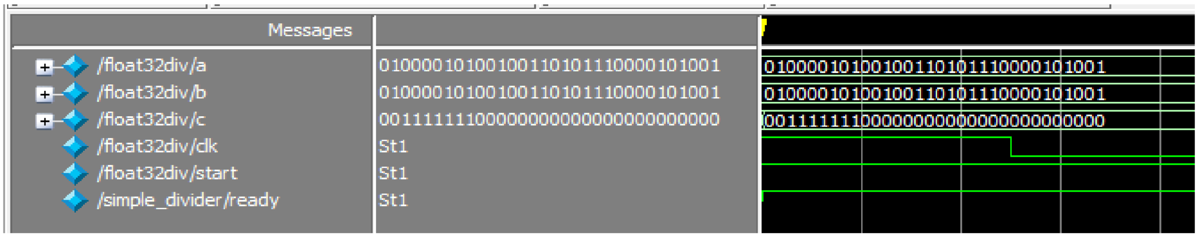
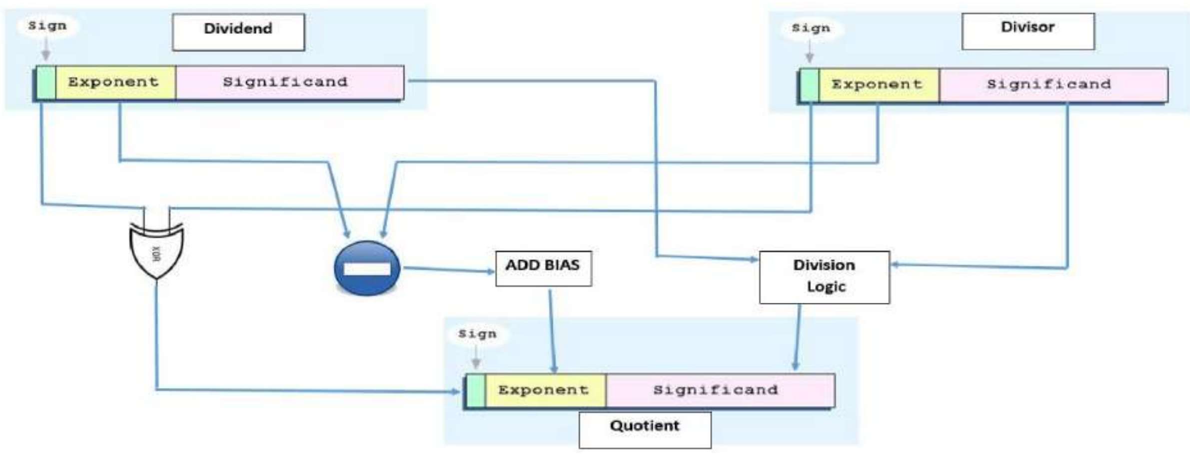




**Fig. 5 Floating Point Vedic Division (Single Precision): Timing Diagram 73.68 ÷ 73.68 = 1**



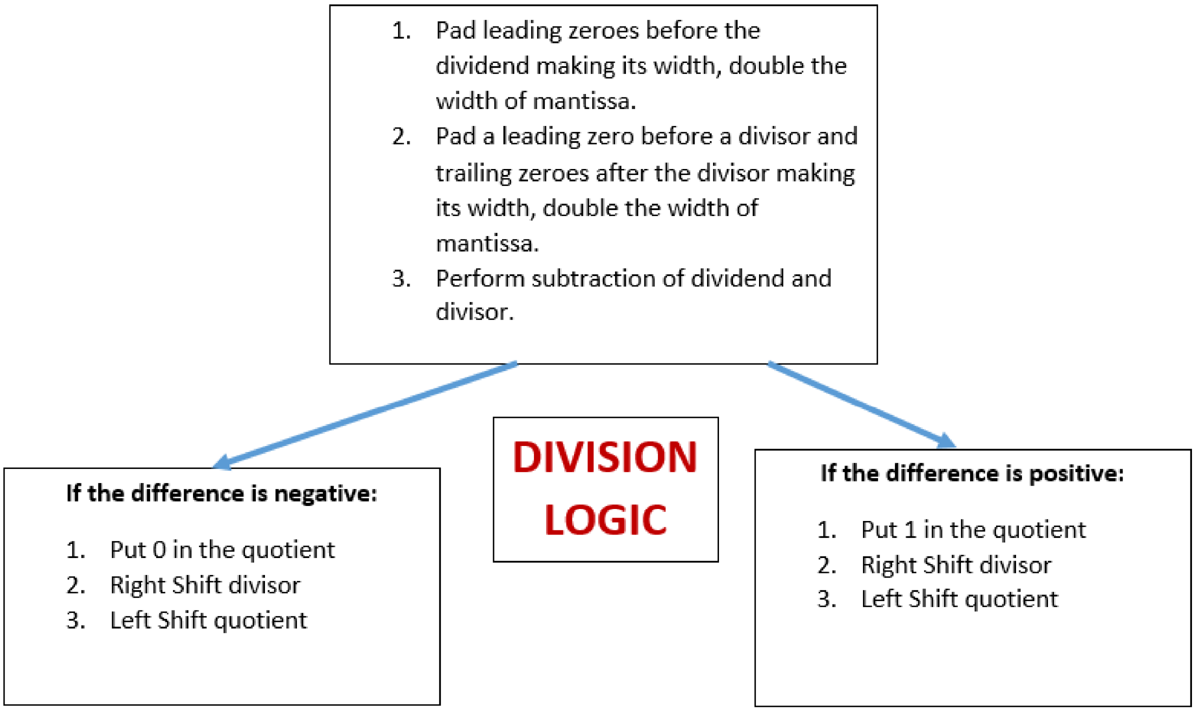



**Fig. 3 Floating Point Vedic Division: Architectural Block Diagram**

★★★

# An ANN-Based Detection of Obstructive Sleep Apnea from Simultaneous ECG and SpO2 Recordings

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DOI: 10.1007/978-3-030-00665-5_60
In book: Proceedings of the International Conference on ISMAC in Computational Vision and Bio-Engineering 2018 (ISMAC-CVB), pp.603-613


**Meghna Punjabi**

**Sapna Prabhu**
2.75 · Fr. Conceicao Rodrigues College of Engineering



## Abstract

Obstructive sleep apnea (OSA) is one of the most common sleep disorders characterized by a disruption of breathing during sleep. This disease, though common, goes undiagnosed in most cases because of the inconvenience, cost, and/or unavailability of opting for polysomnography (PSG) and a sleep analyst. Many researchers are working on devising an unsupervised, cost-effective, and convenient OSA detection methods which will aid the timely diagnosis of this sleep disorder. Commonly used signals to detect OSA are ECG, EEG, pulse oximetry (SpO2), blood oxygen saturation (SaO2), and heart rate variability (HRV). In this work, an attempt to detect the OSA using simultaneously acquired ECG and SpO2 signals has been presented. Various features from the RR intervals of ECG, and a couple of features—namely, CT90 and delta index—from the SpO2, were extracted as indicators of OSA. The features were then fed to a trained artificial neural network (ANN) which classified the signals as OSA positive or OSA negative. The proposed technique boasts a very high accuracy of 98.3%, which is superior to other competing techniques reported so far.

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# Frequency estimator to improve short range accuracy in FMCW radar

**Publisher: IEEE**

3 Author(s) Anuja Chaudhari ; Sapna Prabhu ; Raymond Pinto **View All Authors**



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Frequency Modulated Continuous Wave (FMCW) radars have been widely used for short and medium range detection. Applications of FMCW radar, where measuring short distances is critical, need to have a high accuracy. In the FMCW radar systems, the received signal is a delayed version of the transmitted signal. The range is calculated by measuring the beat frequency of the received signal. The range resolution of radar is inversely proportional to the transmitting bandwidth of the radar. In order to achieve a better range resolution we need to increase the bandwidth, which has its own limitations. To increase the bin resolution of FFT of the beat signal, the sampling frequency must be increased which increases the system complexity. A frequency estimator is implemented to enhance the accuracy of short range detection in FMCW radar without increasing the bandwidth or sampling frequency of the system. It compensates the error by calculating an offset value to provide fine beat frequency.

**Published in:** 2015 International Conference on Advances in Computing, Communications and Informatics (ICACCI)

**Date of Conference:** 10-13 Aug. 2015

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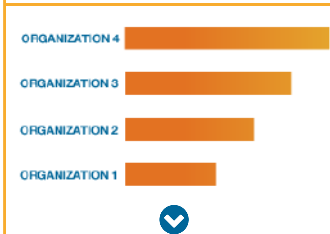
**INSPEC Accession Number:** 15487177

**DOI:** 10.1109/ICACCI.2015.7275682

**Publisher:** IEEE





# Improving the scalability of shared cache multi-core systems

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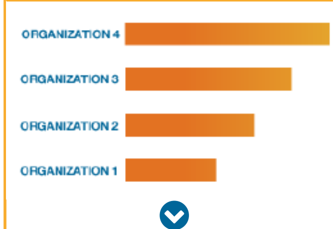




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Resource sharing in multi-core processors leads to performance variability due to cross-core interference between the cores. To minimize the effects of cross-core interference, dynamic cache partitioning can be applied at run-time. Cache partitioning can be applied to improve the utilization of the shared cache. However, this scheme must be scalable as the number of cores increases. The Lotka-Volterra competition model is a popular model in biology which models population growth based on species' interactions. This paper uses a mathematical model of the shared-cache multi-core processor based on the Lotka-Volterra (LV) competition model and investigates the effectiveness of the dynamic cache partitioning scheme as the number of cores sharing the cache increase. Based on the results of the investigations, the paper proposes an improved cache topology which increases the overall system throughput with partitioning.

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**Date Added to IEEE *Xplore*:** 05 February 2015

**ISBN Information:**

**ISSN Information:**

**INSPEC Accession Number:** 14904040

**DOI:** 10.1109/INDICON.2014.7030574

**Publisher:** IEEE

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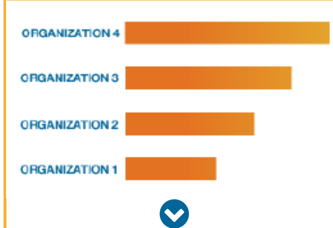








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The multi-core industry is facing a number of challenges which need to be addressed to achieve optimal performance from the multiple cores. One of the dominant causes of performance degradation that arises in multi-core processors is due to hardware resource sharing between cores. The degradation in performance is largely dependent on the nature of the applications. To minimize this degradation, application characteristics need to be analyzed and based on this, a solution can be devised to reduce degradation. This paper aims at presenting a consolidated survey of present classification schemes and propose a new classification scheme which can be applied on-line. Also, using this scheme, a dynamic cache partitioning mechanism has been proposed. The experimentation has been conducted by constructing workloads using the SPECCPU 2006 benchmark suite and experimentation has been conducted on SIMICS (full system simulator).

**Published in:** 2014 International Conference on Advances in Computing, Communications and Informatics (ICACCI)

**Date of Conference:** 24-27 Sept. 2014

**Date Added to IEEE *Xplore*:** 01 December 2014

**INSPEC Accession Number:** 14779344

**DOI:** 10.1109/ICACCI.2014.6968243

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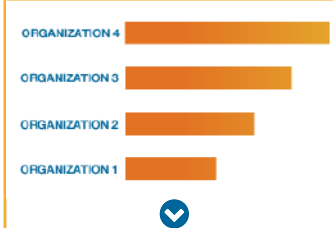
# Compressive Sensing in Channel Estimation for SISO and MIMO OFDM Systems

**Publisher: IEEE**

2 Author(s) Ami Munshi ; Srija Unnikrishnan **View All Authors**









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In this paper, we have explored the effectiveness of compressive sensing (CS) for channel estimation in SISO and MIMO OFDM system. We have developed a hybrid LS-CS estimation technique. On comparing this technique with Least Square (LS) estimation, we infer that by sensing only few channel coefficients, the transmitted data can be estimated from the received data when hybrid LS-CS estimation technique is implemented. By sensing lesser percentage of total channel coefficients in hybrid LS-CS estimation, BER obtained in SISO OFDM scenario is less at a particular SNR, while in case of MIMO OFDM it is comparable to LS estimation. Another significant observation made is that if the channel is sparser, then the hybrid LS-CS estimation technique yields superior results.

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**ISSN Information:**

**INSPEC Accession Number:** 18487667

**DOI:** 10.1109/TENCON.2018.8650423

**Publisher:** IEEE

**Conference Location:** Jeju, Korea (South), Korea (South)

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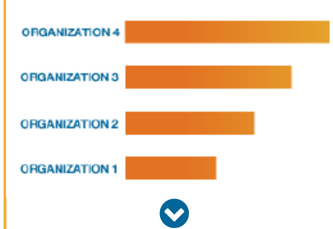








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Technological advancements in low power integrated circuits and wireless communications have made it possible to use efficient, low cost, low power small devices in remote sensing applications. This has led to the feasibility of using a network of sensors to be used for the collection, processing, analysis and distribution of important information, collected in a wide variety of environments. Sensor nodes in a wireless sensor network transmit data in single or multi-hop to a central node called the base station. A very important issue in wireless sensor networks is the scarcity of power and hence optimal use of available power is of prime importance. It is seen that in any sensor node, switching from idle to busy state and vice versa takes up a major portion of the power. We study and analyze a technique that aims to reduce the number of these in order to reduce the consumption of power. In this technique the radio of the sensor node is switched on only when the number of packets in a queue exceed a certain threshold as opposed to the general tendency of transmitting a packet as soon as it is available for transmission. We analyze the performance of this system with respect to the power consumption. The simulations performed show that the simulation results are close to the theoretical results thus indicating the validity of the technique studied.

**Published in:** 2017 International Conference on Advances in Computing, Communication and Control (ICAC3)

Procedia Computer Science
Volume 49, 2015, Pages 235-243

# Vehicle to Vehicle Communication Using DS-CDMA Radar ☆

Ami Munshi [a], Srija Unnikrishnan [b]

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https://doi.org/10.1016/j.procs.2015.04.249 

## Abstract

Tremendous amount of research is going on in the area of Intelligent Transport System. The automotive companies like General Motors, Toyota, Mercedes etc have announced launch of high end vehicles with inbuilt V2X(Vehicle to infrastructure/Vehicle) systems. In this paper we have proposed a scheme to implement vehicle to vehicle communication using Direct Sequence Spread Spectrum Code Division Multiple Access radar (DS-CDMA). The system is capable of performing ranging as well as communication with multiple targets.

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V2X communication; Spread Spectrum; CDMA; Intelligent Transport Systems

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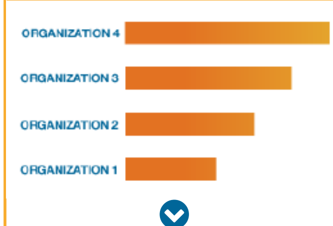


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**ISBN Information:**

**INSPEC Accession Number:** 17634100

**DOI:** 10.1109/ICAC3.2017.8318774

**Publisher:** IEEE

**Conference Location:** Mumbai, India

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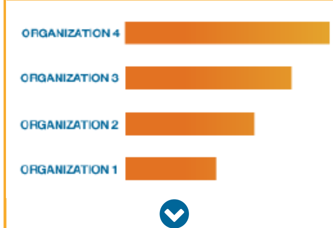








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With financial, business and personal transactions shifting to the mobile domain, Mobile Computing and Wireless Communication technologies are on focus. One of the major challenge is to provide best connectivity across heterogeneous networks, in fast moving vehicles, without knowledge and disturbance to the user. An Intelligent system is required for seamless vertical handover, with less battery consumption and with best connectivity. The Vertical Handover process can be optimized for different criteria like cost, bandwidth, signal strength etc. This paper aims to develop a best solution framework for VHO in vehicular networks where OMNeT++ (Objective Modular Network Testbed in C++) can be used for evaluating and testing along with Veins (Vehicles in Network Simulation) software for the simulation of Inter-Vehicular Communication (IVC) framework, which is composed of an event-based network simulator and a road traffic micro simulation model.

**Published in:** 2017 International Conference on Advances in Computing, Communication and Control (ICAC3)

**Date of Conference:** 1-2 Dec. 2017

**Date Added to IEEE *Xplore*:** 19 March 2018

**ISBN Information:**

**INSPEC Accession Number:** 17634119

**DOI:** 10.1109/ICAC3.2017.8318791

**Publisher:** IEEE

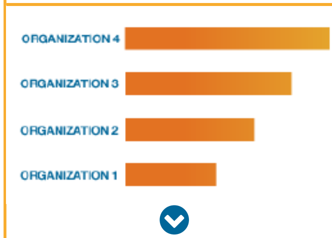
**Conference Location:** Mumbai, India

# Modeling and simulation of MIMO-OFDM systems with classical and Bayesian channel estimation

**Publisher: IEEE**

2 Author(s) Ami Munshi ; Srija Unnikrishnan **View All Authors**








**Abstract**

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**Abstract:** In this paper, we have modeled, simulated, analyzed and compared the performance of variants of MIMO OFDM systems under Classical channel estimation scenario and Bayesian... **View more**

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**Abstract:**
In this paper, we have modeled, simulated, analyzed and compared the performance of variants of MIMO OFDM systems under Classical channel estimation scenario and Bayesian channel estimation scenario. We observe that performance of MIMO system under Bayesian channel estimation scenario is slightly better than the Classical channel estimation over a range of signal to noise ratio. However, we observe that the performance of SISO system is the same under both the channel estimation set up.

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**DOI:** 10.1109/ICAC3.2017.8318789

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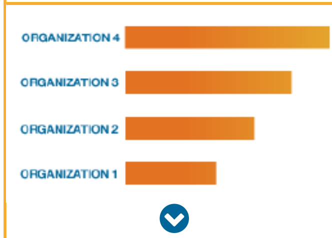




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**Abstract:**

The important problem in integration of grid and power converter is how to synchronize the inverter with the grid that is one is before connecting an inverter to the grid and other is during operation. The energy transfer between an inverter and grid is improved by proper design of synchronization techniques. The challenges associated with the design is how fast the voltage, phase angle and frequency are estimated and synchronized under ideal and non-ideal conditions. For effective estimation of above quantity, various synchronization methods have been proposed. In this paper, theory of single phase PLL is outlined and design and simulation of Synchronous Reference Frame Phase Locked Loop and the obtained simulation results for various non-ideal conditions like harmonics, voltage dip, phase jump and frequency variations are presented.

**Published in:** 2017 International Conference on Advances in Computing, Communication and Control (ICAC3)

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**DOI:** 10.1109/ICAC3.2017.8318790

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**Conference Location:** Mumbai, India

**NATIONAL SYMPOSIUM ON INNOVATIONS IN TEACHING - LEARNING PROCESS**

# UNDERSTANDING SEMICONDUCTOR DEVICE GEOMETRY & CONSTRUCTION WITH 3-D MODELING


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## ABSTRACT

This paper introduces the teaching methodology of constructing 3-D based physical models for understanding the geometry of various semiconductor devices & its associated effects, along with its construction. By using ordinary coloured modeling clay, students constructed 3-D models of different types of semiconductor devices which primarily helped them in understanding the nuances of the device fabrication process for the subject of 'IC Technology'. They were also able to gauge & have a visual understanding of associated short-channel effects in field-effect devices. This exercise conducted during laboratory sessions helped students to understand the device constructional details.


## INTRODUCTION

For subjects such as VLSI & IC Technology which are the core contents of an under-graduate electronic engineering course, the study of semiconductor devices is a must. It is imperative to fully understand the device or IC fabrication process, in which several layers are involved. The fabrication process in itself results in an extremely complex device geometry & construction, which is usually difficult for students to understand by simply looking at the plain images or figures in a reference book or on a webpage. 3-D modeling of a particular semiconductor devices helps students to understand how different types of layers are formed during the device fabrication process along with their placement in the structure [1]. Outcome achieved is a better understanding of the device construction & geometry, which in turn greatly influences knowing the device operation with a better understanding of its characteristics [2][3]. The 3-D modeling is also instrumental in understanding various short-channel effects taking place in field-effect devices since students are now in possession of a complete 360° view of the semiconductor device under consideration.

FIG 1: Students demonstrating their constructed model

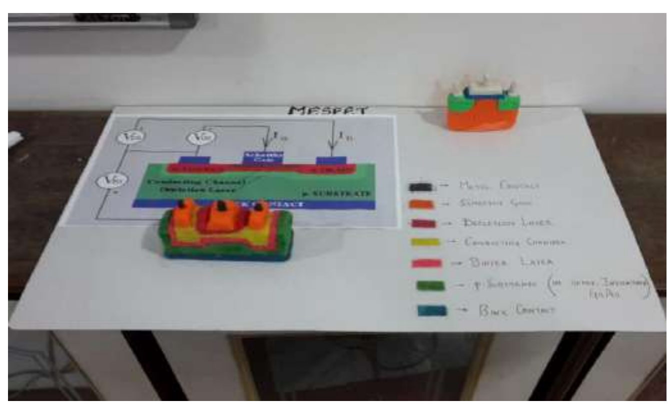

FIG 2: A 3-D model constructed of MESFET device

## METHODOLOGY

The whole class was divided into several groups, with each group having minimum of 2 members & maximum of 4 members. The device models to be constructed were then made available to entire groups in open auction format, where each of them had to register for the same. Coloured modeling clay was provided to all the student groups. The group members approached the subject I/Cs for technical doubts. During the actual presentation, a reasonably good effort was seen from almost all the groups in term of creativity, team work, presentation, co-ordination & addressing questions. Rubrics for grading were based on construction, organization, addressing & presentation [3].

## RESULTS & DISCUSSIONS

The outright result was a thorough understanding of the semiconductor device geometry & construction in terms of its complexity & characteristics. By using different coloured clay, students familiarized themselves with various colours used for different layers in the semiconductor fabrication process. Discussions carried out where mostly based on the device appearance after the 3-D model was constructed.

## RESEARCH FINDINGS

Students were able to relate the semiconductor device shape, size & constructional characteristics with what they actually observed in the reference books. They were also able to understand processes like masking, etching, lithography etc. much better since they constructed the 3-D model in almost the same sequence [4]. Students were able to have an approximate measure about the density & doping levels of various individual p-type & n-type layers by simply observing their geometry. Other findings include improvement between students to work as a team, displaying professionalism, showing sense of responsibility & above all, sharpening their effective communication skills which all contributes to life-long learning.

## CONCLUSIONS

Overall it could be concluded that the 3-D semiconductor device modeling activity for the subject of 'IC Technology' familiarized the students thoroughly with the entire layer-based fabrication process. Students also understood device geometry, construction & characteristics which was observed during the viva-voce examination. They were also able to explain some of the short-channel effects occurring in field-effect devices by simply observing 3-D nature of the device. Since it involved a fun-filled & direct participation by all the students, it was informally considered a better medium of instruction by them over the more conventional mode of assignments, quizzes & video lectures showing the IC fabrication process.

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NATIONAL SYMPOSIUM ON INNOVATIONS IN TEACHING - LEARNING PROCESS

# TEACHING SMALL SIGNAL (AC) AMPLIFIERS USING BLOOM'S TAXONOMY

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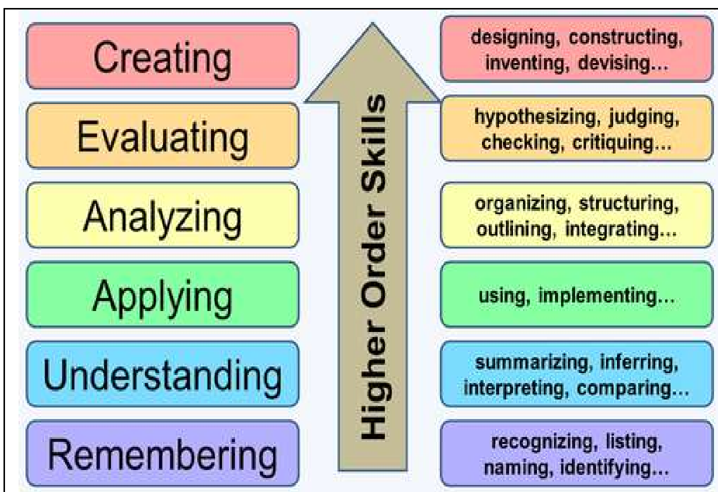
## ABSTRACT

This paper introduces an innovative teaching methodology for small signal (AC) amplifiers based on Bloom's Taxonomy approach; irrespective of the device used or the biasing circuit or the amplifier configuration. It follows a bottoms-up approach where students are introduced to simple, fundamental concepts which later on lay foundation to construct, design & analyze small signal amplifiers. This technique proved to be extremely beneficial to students as they were able to sketch/draw, describe & later on evaluate DC & AC characteristics of transistor-based amplifiers (BJT/FET/MOSFET).

## INTRODUCTION

For subjects such as Electronic Devices & Circuits which are the core contents of an under-graduate electronic engineering course, the study of small signal (AC) amplifiers is a must. It is imperative for the students to fully understand the nuances of small signal amplifiers, their operation & working, DC & AC characteristics apart from being able to analyze & design them. The instructors observed that a vast majority of students faced difficulties in sketching a basic amplifier circuit for a given active device, biasing circuit & configuration. This was compounded due to the fact that transistor-based amplifiers use BJT/FET/MOSFET with each having their own biasing techniques & own operating configurations [1]. Hence the need was felt to introduce the concept over a two-semester course (1 year) course of Electronic Devices & Circuits - I & II in a systematic manner wherein the students could not only understand the fundamental concepts but also build, design & analyze any small signal amplifier configuration [2].




| | |
|---|---|
| **Creating** | Designing small signal amplifiers with respect to the given specifications |
| **Evaluating** | AC analysis & calculation of the small signal parameters ($R_i$, $R_o$, $A_v$ & $A_i$) |
| **Analyzing** | DC analysis & operating point (Q) for various biasing configurations |
| **Applying** | Application of different biasing circuits to active devices (BJT/FET/MOSFET) |
| **Understanding** | Amplifier models - voltage, current, trans-resistance & trans-conductance |
| **Remembering** | Ideal & practical voltage & current source concepts, internal resistance |

FIG 1: The Bloom's Taxonomy

FIG 2: Mapping of concepts with Bloom's Taxonomy

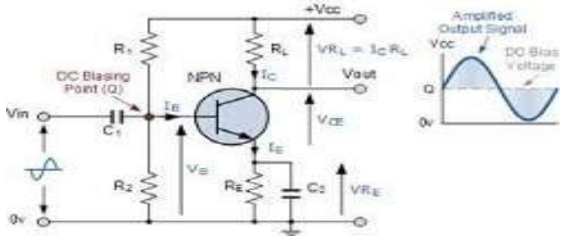



FIG 3: Small Signal (AC) BJT Amplifier

| | |
|---|---|
| **Active Devices** | BJT / JFET / MOSFET |
| **Biasing Circuits** | Depend upon selected active device input & output characteristics |
| **External Interface** | Coupling & bypass capacitors, load resistor & AC signal voltage source |

FIG 4: Typical Components of Small Signal Amplifier

## METHODOLOGY

With reference to Fig. 1 & 2, students were made comfortable with fundamental concepts of mathematical modeling, types of voltage & current sources, dependent & independent sources & then moving on to the biasing circuits [4]. Here the entire small signal (AC) amplifier was dissected into three major parts - the active device, the biasing circuit & the external interface. Students were systematically taught how to draw/sketch, analyze & identify different amplifier configurations based on above points. They were also able to explain & justify the functional use of each & every single component used in the construction & its overall effect on the amplifier's performance [3].

## RESULTS & DISCUSSIONS

Classroom discussions were held in which the students were given multiple circuit diagrams from where they were correctly able to identify the device used, the biasing circuit & the amplifier configuration. Using a Bloom's Taxonomy approach, analysis & evaluation of DC & AC parameters was successfully done following the above mentioned steps. The discussion saw whole-hearted participation from the entire class in solving the given problem, often in groups.

## RESEARCH FINDINGS

A major research finding was drastic improvement in the students' ability to draw/sketch small signal (AC) amplifiers of any configuration with any active device used & any biasing circuit. This wasn't possible earlier as they struggled with respect to where to start sketching, where to apply the input signal, from which terminal to connect the output signal from, which component is bypassed etc. Bloom's Taxonomy approach made the process more streamlined.

## CONCLUSIONS

It can be concluded that using Bloom's Taxonomy approach was highly instrumental in making students understand the construction, working, operation & analysis of small signal (AC) amplifiers. There was sharp increase in the number of students being able to sketch/draw, analyze & evaluate small signal amplifiers for a configuration without any external prompting or help. The earlier dilemma of students unable to recall or remember on how to approach the problem was resolved. By simply breaking the entire module into small 'digestible' pieces, students were made aware of the individual functions of the active device, the biasing circuit & the external interface.

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# POSTER PRESENTATION FOR A PARTICIPATIVE LEARNING EXPERIENCE

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## ABSTRACT

The objective of poster presentation activity was to hone students' presentation skills & unleash their creativity by preparing A1/A2 size posters of various discrete topics in which the students would embark upon a self-study culture by presenting & explaining their work through the poster medium in front of the whole class. In this technique students were given the complete liberty to not only explore topics at their own pace, but to also question the topic contents by referring to any other verified alternate means. It gave them a sense of belonging in the course by inculcating freedom of expression rather than being dictated to in monotonous manner, as in traditional approaches.

## INTRODUCTION

To impart engineering education in the 21st century to the millennial stakeholder students, it is extremely imperative that a full duplex communication channel be established between the teacher & the student [1]. This is to ensure that the subject topic or module under consideration is not only appreciated, understood & accepted well by the students, but also they also get to be a part of a 'live' process which inculcates a feeling of participation wherein their efforts are taken into account & a feedback is established so that students get an active feeling & satisfaction that they are an integral part of the activity or process [2]. Keeping this in mind, the poster presentation activity was conducted for the module of 'Special Semiconductor Devices' in subject of 'Electronic Devices & Circuits - II' where students were an active & integral part of the teaching-learning process having done their own research, followed up their own homework, designed their own 'curriculum' & presented their own views to the whole class on the subject topic that was allocated to them. The subject teachers assisted them in solving technical queries they faced.

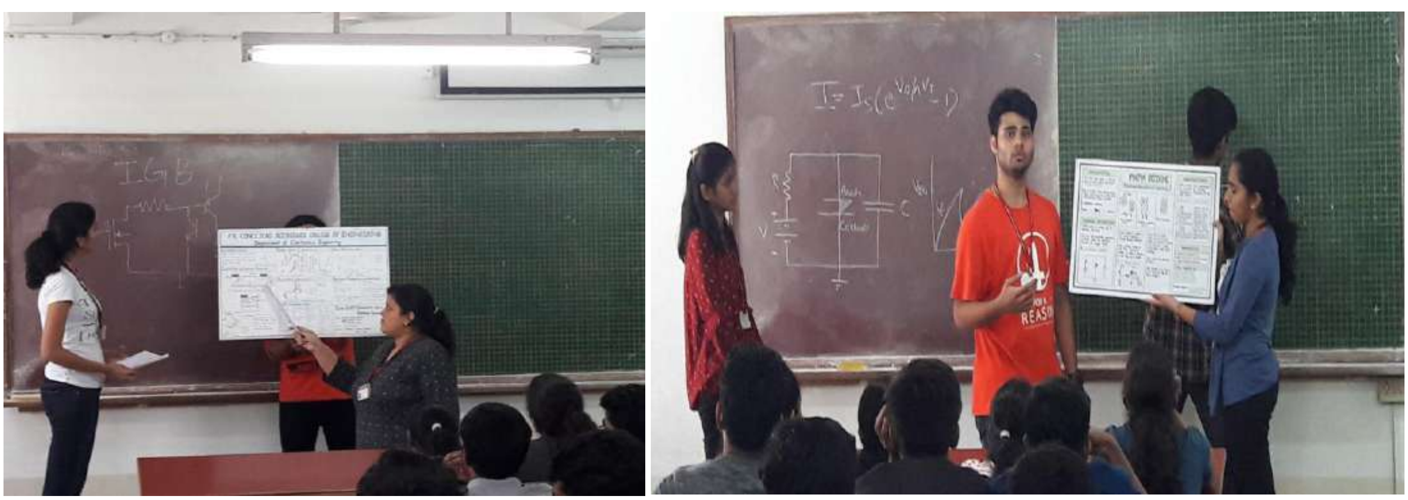

FIG 1: Students engaged in poster presentation activity for participative learning

## METHODOLOGY

The whole class was divided into several groups, with each group having minimum of 2 members & maximum of 4 members. The topics were then made available to entire groups in an open auction format, where each of them had to register for the same. Announcement for the same was made well in advance which gave groups almost 2-month time frame to study, plan, prepare & materialize the posters. Few of the group members approached the subject I/Cs for technical doubts. During the actual presentation, a reasonably good effort was seen from almost all the groups in term of creativity, team work, presentation, co-ordination & addressing questions. Rubrics for grading were based on contents, graphics, organization, addressing, mechanics & presentation [3].

## RESULTS & DISCUSSIONS

It was observed that the poster presentation activity was a highly successful one as the audience also participated whole-heartedly by paying attention throughout the session & asking a relevant questions or getting their doubts cleared about certain topics perceived to be difficult in course of studies. The entire activity was conducted with proper discipline, decorum & a sense of academic professionalism.

## RESEARCH FINDINGS

The first & foremost finding points to the fact that the students enjoyed their whole-hearted participation, maybe buoyed by the fact that they 'achieved' something completely on their own or perhaps contributed at least something, no matter how much significant to the teaching-learning process. Other findings include improvement between the students to work as a team, displaying professionalism, showing sense of responsibility & above all, sharpening their effective communication skills which all contributes to life-long learning.

## CONCLUSIONS

The poster presentation activity achieved its goal of being a participative teaching & learning experience wherein students actively took part on & off the stage. Since the overall research about the topic to be presented was initiated by them, they displayed exemplary academic seriousness, showed willingness to adapt to situations during making the poster & also while presenting it & took in several questions directed by the audience; answered back in highly convincing manner. Informally the whole class appreciated the poster presentation activity since they felt they were an active & integral part of the teaching-learning process showing involvement.

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# RF Signal Generation for MRI System Using PS-PL Communication in FPGA Over Ethernet

Publisher: IEEE

4 Author(s) Aditi S Deshpande ; Imran Sheikh ; Kranti Wagle ; Dharmesh Verma View All Authors



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# FPGA based RF Signal Generation for MRI Systems

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***Abstract*—RF signal generation is an essential part of magnetic resonance imaging (MRI) system. Many commercial MRI systems are now available. However, they are usually expensive and complex. This paper presents a digital RF transmitter which enables signal modulation in a Magnetic Resonance Imaging (MRI) system. Radio frequency (RF) pulse is generated with the High speed DAC. In this paper, RF generation is done using Zynq board XC7Z020 and further the ZC702 board is interfaced with DAC (Digital to Analog Converter) (AD9122) using SPI (Serial Peripheral Interface) protocol through ACE(Analysis Control Evaluation) software and analog signal is achieved at the output of the DAC board. Compared to the conventional design, by combining field programmable gate array (FPGA) and digital signal processing (DSP) technique the MRI system is built in a digital manner with high performance and accuracy. The system consists of comparatively low expensive and highly-integrated components which make it low-cost and compact. The RF transmitter has been successfully designed and demonstrated by the experimental result.**

***Keywords—ACE (Analysis Control Evaluation), accuracy, compact, DAC (Digital to Analog Converter), DSP (Digital Signal Processing), FPGA (Field Programmable Gate Array), highly-integrated, high performance, low-cost, low expensive, MRI (Magnetic Resonance Imaging), pulse sequence decoding, RF (Radio Frequency), RF pulse, RF transmitter, signal modulation, SPI (Serial Peripheral Interface), Zynq***

## I. Introduction

Magnetic resonance imaging (MRI) is a biomedical technique that uses the body's natural magnetic properties to produce detailed images from any part of the body. For imaging purposes the hydrogen nucleus is mainly used as it is found in abundance in water and fat.[3] The hydrogen proton can be found in similar to the planet earth, which spins on its axis, with a direction in accordance to north-south pole. In this manner it behaves like a small bar magnet.[3] Under normal circumstances, these hydrogen protons spin in the human body with their axes randomly aligned. When the body is placed in a strong magnetic field, as in case of a MRI scanner, the hydrogen proton's axes align themselves in a straight line.[3] Thus a magnetic vector oriented along the axis of the MRI scanner is created by the uniform alignment of hydrogen protons. MRI scanners are available today in different field strengths, usually between 0.5 and 10 tesla. When additional energy (in the form of a radio frequency wave) is added to the magnetic field, the magnetic vector is deflected.[3] The radio wave frequency (RF) that is dependent on the element sought (hydrogen) and the strength of the magnetic field is the reason that causes the hydrogen nuclei to resonate. The strength of the magnetic field can be varied in an electronic manner starting from head to toe using a series of gradient electric radio frequency coils, and thus different slices of the body will resonate as different frequencies are applied by altering the local magnetic field by these small increments.[3] When the radiofrequency source is switched off the magnetic vector returns to its original rest state, and this causes a signal, in this case a radiofrequency wave to be emitted. It is this signal which is used to create the MR images.[1] Receiver coils are used to act as aerials around the body part to improve the detection of the emitted signal. Thus the cross sectional images are built up by plotting the intensity of the received signal on a grey scale plot.[2] Multiple transmitted radiofrequency pulses can be used in sequence to emphasise particular tissues or abnormalities present in the human body.[2] As different tissues relax at different rates when the transmitted radiofrequency pulse is switched off, different emphasis occurs. Thus time taken for the hydrogen protons to fully relax and attain its original state is measured in two ways. The first is the time taken for the magnetic vector to return to its resting state and the second is the time required for the axial spin of the proton to return to its resting state.[6] The first is called as the T1 relaxation time and the second is called as the T2 relaxation time. An MR examination thus constitutes of a series of pulse sequences. Different tissues (such as fat and water) present in the human body have different relaxation times and thus can be identified separately. By using a "fat suppression" pulse sequence from the group of other pulse sequences, the signal from fat will be removed, leaving behind signal from any abnormalities lying within it.[3] Thus MRI proves to be the most sensitive test for the detection of disease as most diseases manifest themselves by an increase in water content. A careful study of the MR images obtained by a radiologist will often lead to yield the correct expected result. There are no known biological hazards of MRI scanning as, MRI uses radiation in the radio frequency range which is present all around the human body and it does not damage tissue as it passes through unlike other scanning techniques like x-ray and CT scans.[7] Pacemakers, metal clips, and metal valves can be dangerous because of potential movement in MRI scanners within a strong magnetic field. Metal joint prostheses are of a least problem, although some distortion of the image close to the metal may occur. MR imaging departments always go for a safety check for implanted metal and can advise on the same.[6]

## II. RF SIGNAL GENERATION

MRI involves the absorption and emission of radio frequency energy by hydrogen nuclei at a specific resonant frequency which is known as the Larmor Frequency. The Larmor frequency scales directly with main static magnetic field strength ($B_o$) and thus for clinical MRI scanning this frequency lies in the range of tens to hundreds of MHz. These frequencies are a part of the electromagnetic spectrum which are commonly used for radio transmission. This paper mainly focuses on producing an RF pulse using FPGA technology.[14]

### A. *Larmor Frequency:*

Every proton precesses or wobbles, and number of times it precesses is called Larmor or Precessional frequency. The frequency of precession is related to the strength of the magnetic field, $B_o$.[15] The precessional frequency of nuclei placed in a static magnetic field is calculated from the larmor equation as follow;

$$\omega_o = \gamma \, B_o \tag{1}$$

where $\omega_o$ is the Larmor frequency expressed in MHz, $\gamma$ is the gyromagnetic ratio of hydrogen proton in MHz/tesla and $B_o$ is the strength of the static magnetic field having units as Tesla. Thus in this paper, we have to calculate Larmor frequency for a static magnetic field of 1.5T where the gyromagnetic ratio is defined for hydrogen as 42.58MHz/T.

$$\omega_o = 42.58 \text{ MHz/T} \times 1.5\text{T} \tag{2}$$

$$\omega_o = 63.87 \text{ MHz} \tag{3}$$

### B. *RF-Front End:*

For MRI, a time-varying RF field, must be first transmitted into the spin system which is commonly referred to as $B_1$ magnetic field, near the Larmor frequency. In addition to having specific defined frequency, the $B_1$ field must also be applied perpendicular to the main magnetic field $B_o$. Thus by driving electrical currents through specialized RF-transmit coils, the $B_1$ field is produced.[14] These coils are located either within the inner walls of the scanner or as free-standing devices connected by cables placed on or near the patient. A sophisticated electronic "RF-Front End" is responsible for generating, shaping and modulating the electrical currents required to produce the $B_1$ field.[6][14]

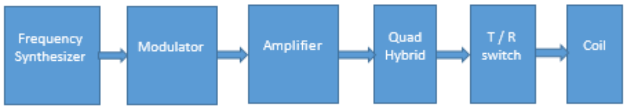


Fig. 1. Block diagram of RF Front-End circuitry.

Frequency Synthesizer produces a continuous sinusoidal carrier wave at or near about the designed Larmor frequency. The Frequency synthesizer utilizes a numerically controlled oscillator (NCO). The output from the synthesizer is further sent to the pulse modulator for shaping. The $B_1$ fields used in nearly all clinical MR imaging applications are not transmitted as continuous waves, but in short (1–5ms) bursts, called RF-pulses.[14] The contours of each RF pulse are specified using data points, and are therefore of low frequency. The pulse-shape data obtained from the pulse modulator is used to modulate the carrier wave so that the resultant output is a mixture of frequencies centered on the carrier. The high power amplifier that helps in generating large currents are necessary to drive the RF transmit coils.[14] The output of the power amplifier is typically split into two equal parts by means of a quadrature hybrid coupler device. The resultant outputs are 90º out of phase with one another and are used to feed the two ports of the quadrature transmit coils. The two outputs of the coupler are commonly known as I and Q, standing for "in phase" and "quadrature" respectively.[15] The currents in I and Q outputs of the coupler is now headed for the RF-transmitter coils. Additionally, sometimes the same coils are used to both transmit and receive the MR signal. For these coils a special T/R switch is required to isolate the two functions and make sure the powerful electric currents used for transmission do not go into and burn up the sensitive receiver circuitry.[14]

## III. DIGITAL TO ANALOG CONVERTER

### A. *General Description*

The AD9122 is a dual data rate, 16-bit wide, digital-to-analog converter (DAC) of high dynamic range that provides a sample rate of 1200 MSPS, which allows for multicarrier generation of up to the Nyquist frequency.[11] The AD9122 TxDAC includes features optimized for direct conversion transmit applications, including complex digital modulation, and gain and offset compensation. The DAC outputs are optimized to interface smoothly and continuously with analog quadrature modulators, such as the ADL537x F-MOD series modulators.[11] A 4-wire serial port interface available on-chip provides for programming of many internal system parameters. Full-scale output current can be programmed over a range of 8.7 mA to 31.7 mA. The AD9122 comes in a 72-lead LFCSP.[11]

### *B. Comparison with other existing DACs:*

As compared to the other existing DACs, AD9122 works on double data rate allowing to transfer data on both the positive as well as the negative clock cycle. It has a dual digital signal path and dual DAC structure which allows for an easy interface with the quadrature modulators for designing single sideband transmitters.[11] In comparison with the previously available DACs, the speed and performance of AD9122 allows for wider bandwidths and thus more carriers to be synthesized. In addition to this, AD9122 includes a low-power, 32-bit complex numerically controlled oscillator (NCO) that helps in increasing the ease of frequency placement anywhere in the given bandwidth.[11] AD9122 offers features for simplified synchronization with incoming data and as well as with multiple devices. AD9122 evaluation board also comes with the facility of inbuilt auxiliary DACs provided on chip.[11] The auxiliary DACs are used for providing output dc offset compensation and for gain matching. AD9122 communicates with other external devices via serial ports. The serial port is a flexible, synchronous serial communication port which is compatible with SPI protocols. The AD9122 contains 2-channel, 16-bit wide, 8 word deep FIFO designed to relax the timing relationship between the data arriving at the DAC input ports and the internal DAC rate clock.[11] AD9122 follows the digital data-path process which includes a pre-modulation block, three half band interpolation filters, a quadrature modulator with fine resolution NCO, phase and offset adjustment blocks and an inverse sinc filter.[11] The AD9122 DAC comes with an on-chip sample error detection technique that helps in simplifying the verification of the input data interface.[11]

## IV. USED FPGA PLATFORM

The FPGA ZC702 evaluation board provides system-on-chip platform for hardware environment required for developing and evaluating designs.[12] With the use of VITA-57 FPGA mezzanine cards (FMC) attached to either of two low pin count (LPC) FMC connectors, other features can also be supported. The XC7Z020 consists of processing system (PS) and programmable logic (PL).[12] This memory system is connected to the XC7Z020 processing system (PS) memory interface bank. For providing interface to user-logic access to general purpose nonvolatile SDIO memory cards and peripherals ZC702 board includes a secure digital input/output (SDIO). The ZC702 board also comes with three clock sources for the XC7Z020.[13]

## V. PROPOSED BLOCK DIAGRAM

This section of the paper mainly focuses on the detailed block diagram of the working principle of RF signal generation which is based on Field Programmable Gate Array (FPGA). Further it also gives a description of interfacing FPGA with DAC using FMC connectors. In Fig 2 interfacing of FPGA with DAC is shown. In this stored sample of sinc pulse is played out using DAC AD9122 and modulated using in built NCO available in AD9122 evaluation board. This will successfully complete the RF signal generation.

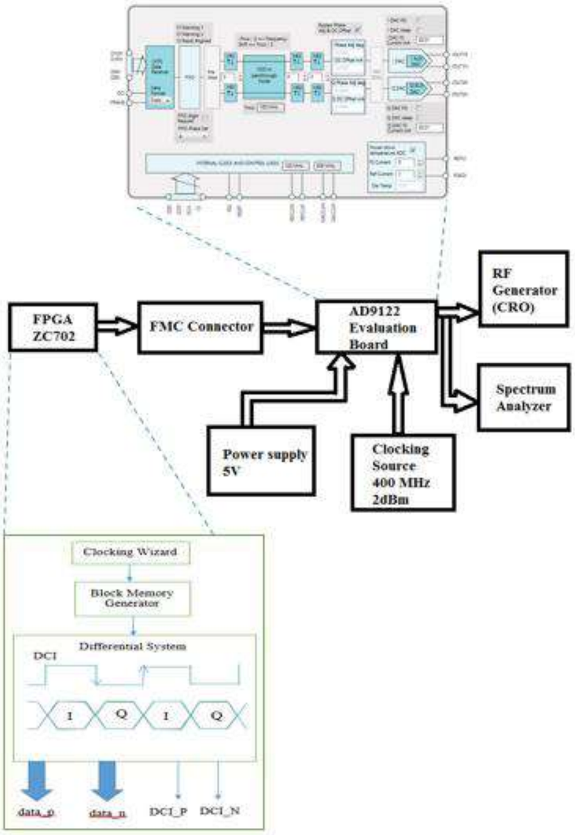


Fig. 2. Block diagram of RF signal generation using FPGA.

## VI. NUMERICALLY CONTROLLED OSCILLATOR

Numerically Controlled Oscillators (NCO) offer several advantages in terms of accuracy, stability and reliability over other types of oscillators. NCOs provide a flexible architecture that enables easy programmability such as on-the-fly frequency/phase [11].

### *Principle of NCO:*

The NCO generates a sine waveform using the concept of direct digital synthesis. In direct digital synthesis, the samples of the sine wave are stored in memory and are read out to generate the output sine wave. The frequency of the output sine wave is controlled by the clock speed and appropriate skipping of intermediate data points. In the simplest scenario, the sampled data for one full wave period is stored in memory and is directly used for the output. However, other enhanced methods are frequently used to reduce the memory size requirements. The full wave corresponding to one period of the sine wave is divided into N segments. The incremental angle for each segment, denoted as $\Delta\theta$, is equal to $2\pi/N$ and the phase values corresponding to one period are given by:

$$\Theta_i = \frac{2\pi i}{N} \qquad i = 0, 1, 2, \ldots, N-1 \qquad (1)$$

The output values corresponding to the phase sequence, given in Equation 2, are stored in the look-up table.

$$d_i = \sin\theta_i = \sin\frac{2\pi i}{N} \qquad (2)$$

Here the phase index, i is generated either in sequential manner or in increments and is further used to address the memory addressof the look-up table. The output of the look-up table is the sine wave sample. The index increment can be any value greater than zero, including fractional values [15].

Fig. 3. Sine wave generated using DDS and plotted on CRO

The above Fig. 3 shows generated sinusoidal waveform plotted on CRO. This waveform is obtained using DDS which has 64MHz frequency. Also, with reference to this waveform, sinc pulse is implemented which has the same frequency component. With reference to the generation of sine wave, sinc wave is generated through DDS with the help of MATLAB tool. Inorder to generate sinc wave, filters and modulators are required to set the output sinc waveform to a particular desired frequency. Thus, using fdatool command in MATLAB, coefficients of the filters are designed and obtained and accordingly are set to quantize the filter. The following two images give information regarding the sinc wave generation obtained on CRO and also using VIVADO software tool which needs MATLAB tool to design and obtain the filter coefficients.

Fig. 4. DDS output as sinc wave obtained on CRO

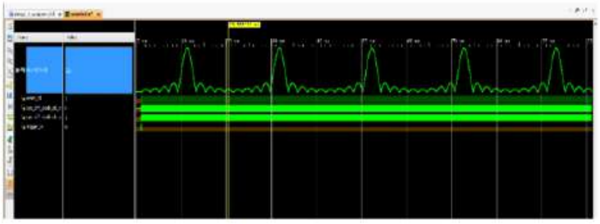

Fig. 5. Simulation result of Vivado for sinc wave generation (DDS)

## VII. Digital Up Converter

Digital up-conversion is well known sample rate conversion process in Digital Signal Processing. This technique is widely used for converting a baseband signal to band pass signal. For the baseband signal to be transmitted, it needs to be modulated on to an IF/RF carrier frequency[1] [2] . Nyquist theorem states that the sampling rate should be at least twice the highest frequency component. Hence the base band signal, whose sample rate might be very less compared to IF/RF carrier signal sampling rate, needs to have the sampling rate to match the IF/RF carrier signal sampling rate.

DUC is the up conversion of the signal in the digital transmission path from the FPGA to the coil. The transmitter path has to interpolate the incoming signal to the required sampling rate for the default clock rate. In the implementation, two half-band filters are present prior to the lowpass filter if the interpolation rate is a factor of four. If the interpolation rate is a factor of two, then only one half-band filter is used. If the interpolation factor is odd, then no half-band filters are used. There are two transmit paths for the in-phase and the quadrature phase components. Following figure shows the generalized block diagram of Digital Up converter.

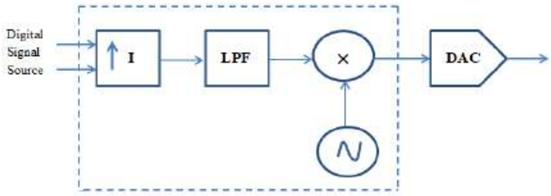


Fig. 6. Generic DUC Architecture

### *Implementation of NCO:*

DDS use digital control methods to produce different output frequencies from reference frequency source. In the figure below, FIR filter is designed which filters the input digital data and the output of which is given to the mixer. Another input to the mixer is obtained from NCO which is nothing but DDS. Here, DDS produces a waveform which is phase shifted by 90° out of phase. In this figure, FIR filter is designed using fdatool command in MATLAB. This tool is used to design, analyse and modify the existing filter designs. The Filter Design and Analysis Tool (FDATool) is a interface which provides a platform for designing and analyzing filters. FDATool enables you to quickly design digital FIR or IIR filters by setting filter performance specifications, by importing filters from your MATLAB workspace, or by directly specifying filter coefficients. FDATool also provides a technique used for analyzing filter parameters such as magnitude and phase response plots and pole-zero plots. The Filter Design and Analysis Tool also integrates advanced filter design methods from the DSP System Toolbox software.

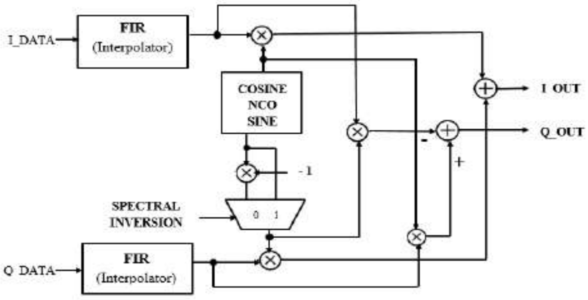


Fig. 7. Digital Numerically Controlled Oscillator / DDS

## VIII. Results And Experimental Observations

To verify the working of the designed and proposed system, a laboratory setup is prepared and analyzed. The system here works on 400MHz system clock rate and an amplitude modulated sinc waveform is obtained which is of 64MHz peak frequency. Fig 8 (a) and (b) shows the modulated sinc waveform and the output of the frequency spectrum at 64MHz as observed on spectrum analyser.

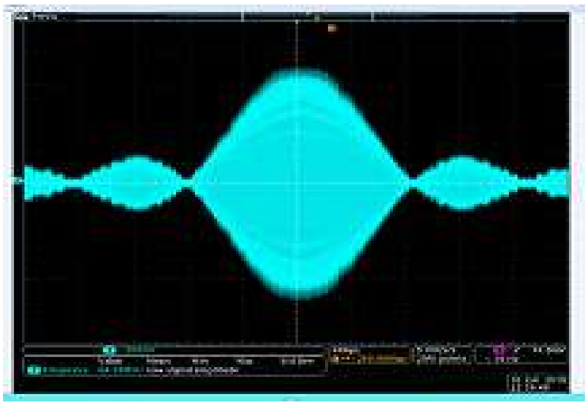

Fig. 8. (a) Modulated Sinc Waveform

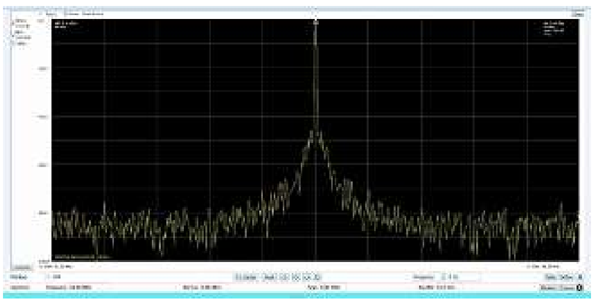

Fig. 8. (b) Output of sinc wave as a spectrum on Spectrum Analyzer

The experimental setup for RF signal generation using FPGA and Digital to Analog Converter using Interposer Card is as shown in Fig 9. (a) and Fig 9 (b).

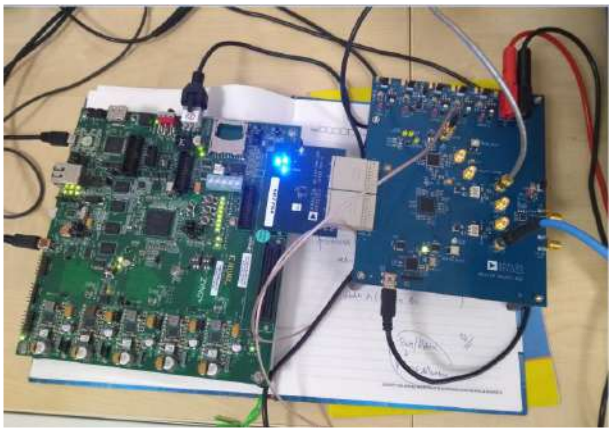

Fig. 9. (a) Interfacing of FPGA and DAC through Interposer Card

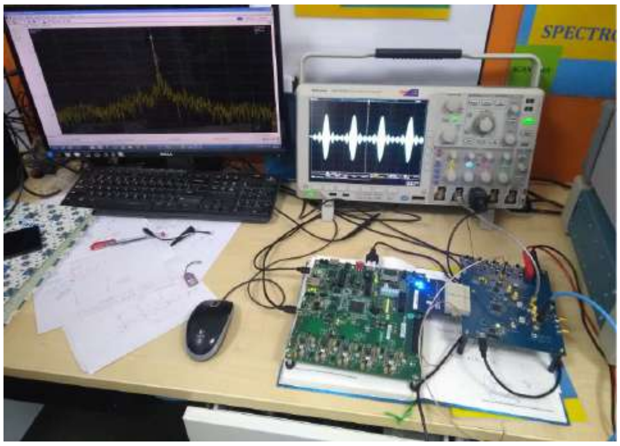

Fig. 9. (b) Experimental Setup

## IX. Conclusion

The generation of RF signal based on FPGA technology is achieved and presented successfully using softwares like VIVADO, ACE and MATLAB. The DAC used for RF generation verifies satisfactory results and performance. Thus, it can be concluded that the results and output obtained from the above experimental procedure is modest and better than other previous work of others. The experimental results show effectiveness of system and functionality of algorithms followed throughout the procedure.

## Acknowledgment

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# Localization and Tracking of Indoor Mobile Robot with Beacons and Dead Reckoning Sensors

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***Abstract*—Autonomous robots must be able to localize themselves in an environment. We are interested in the real time pose estimation of a single surveillance robot based on the Odometry algorithm and Dead Reckoning using Inertial Measurement Unit (IMU) sensors. This approach is subjected to accumulated errors due to slippage and drift respectively. Algorithm proposed in this paper uses Trilateration with Extended Kalman filter. We found that our approach reduces the error.**

***Index Terms*—Localization, Odometry, Dead Reckoning, Inertial Measurement Unit(IMU), Trilateration, Kalman filter.**

## I. INTRODUCTION

To navigate reliably in indoor environments, a mobile robot must know where it is. Thus, reliable position estimation is a key problem in mobile robotics. Location information is essential for planning and decision making processes. In open outdoor environments, differential GPS systems can provide precise positioning information. However, there are many applications in which GPS cannot be used, such as indoor, underwater, extraterrestrial, or urban environments. For situations when GPS is unavailable, localization using Odometry [3] [5] and Dead Reckoning using IMU sensors [4] [6] may provide an alternative. However, Odometry is subjected to accumulated errors over time and is insufficient for many tasks [1]. Most current localization methods make use of range or angle measurements with respect to other nodes (pre-deployed beacons or other robots) to constraint Dead Reckoning error growth [2].

Odometry and Dead Reckoning using IMU sensors show errors in the readings due to wheel slippage and drift respectively. These errors can be overcome by using Trilateration which calculates discrete and real time coordinates of mobile robot using pre defined active beacons. However, the results from Trilateration can be further refined using Kalman Filter, which uses Linear Quadratic Estimate w.r.t multiple readings taken in a given instance [11]. These readings are contaminated with random noise and the resultant estimate is error-free as compared to that obtained in a single reading in a given instance of time. Kalman filtering is used to estimate dynamic variables (that may or may not be directly measurable) in the presence of noise. Kalman Filters work by taking noise, such as slight drift produced in the accelerometer inside the IMU sensors into consideration as well as taking into account the most accurate information about position. This technique takes advantage of additional information regarding the system, in particular, a dynamic model of the system. Kalman Filter technique is extensively used for localization [14] and/or tracking [13] for mobile robot movement. Comparative study of localization techniques using Kalman filter is given in [12].

In this paper, we present localization algorithm for indoor robots which uses Odometry measurements, Dead Reckoning using IMU sensors coupled with Extended Kalman filter refined Trilateration technique for accurate position estimation. Our approach is based on a field of static nodes that communicate within a limited distance. The mobile agents are assumed to have been previously localized by a static localization algorithm using Odometry and/or Dead Reckoning using IMU sensor approach. A mobile agent moves through this field, passively obtaining position using onboard sensors and listens to broadcasts from the static nodes. Based on this information, and an upper bound on the speed of the mobile node, our method recovers an estimate of the path traversed. As additional measurements are obtained from beacons, this new information is propagated backwards to refine previous location estimates. We found that our algorithm finds optimal localization regions i.e. the smallest regions that must contain the mobile node.

## II. MODEL

### A. Robot Kinematic Model

Localization problem is defined as determination of the robot position $x_k = [x_k^R, y_k^R, \theta_k^R]$ towards global coordinate system in given time step $k$. Linear and angular velocities $[u_k^R, w_k^R]$ are calculated from Odometry readings.

Due to the imperfection of the motion model and measurement errors, the position is represented using simple unimodal Gaussian approximation [2]. Mathematically, it can be presented as

$$\begin{cases} x_{k+1} = & f(x_k, u_k, k) + \mathbf{v}_k \\ y_k = & h(x_k, k) + \mathbf{w}_k \end{cases} \tag{1}$$

where $\mathbf{v}_k$ is white Gaussian noise (representing errors due to imperfect sensors and wheel slippage) with zero mean and covariance matrix $\mathbf{V}_k$, $y_k$ is system output, $w_k$ is white Gaussian measurement noise with zero mean and covariance matrix $\mathbf{W}_k$, $f$ and $h$ are continuously differentiable non-linear functions. The state transition function $f$ defines how the state of robot changes

$$\mathbf{x}_{k+1} = f(\mathbf{x}_k, \mathbf{u}_k) + \mathbf{v}_k = \begin{pmatrix} cos\theta_k^R u_k^t \triangle(t) + x_k^R \\ sin\theta_k^R u_k^t \triangle(t) + y_k^R \\ u_k^t \triangle(t) + \theta_k^R \end{pmatrix} \quad (2)$$

The position of beacons is defined as

$$\mathbf{X}_{bi} = [x_{bi}, y_{bi}], \qquad i = 1, 2, \ldots, N \quad (3)$$

The output with respect to $i^{th}$ beacon is defined as

$$y_{ik} = [h_i(\mathbf{X}_k, \mathbf{X}_{bi})] + [\mathbf{W}_{ik}] \quad (4)$$

where

$$h_i(\mathbf{X}_k, \mathbf{X}_{bi}) = \begin{cases} ((x_k - x_{bi})^2 + (y_k - y_{bi})^2)^{1/2} \\ atan2(y_k^R - y_{bi}, x_k^R - x_{bi}) - \theta_k^R \end{cases} \quad (5)$$

The position of the robot cannot be determined exactly.

### B. Relative and Absolute Localization

We use Odometric measurements for finding relative (local) localization. The new position is given as [5]

$$X_j = \begin{pmatrix} x_j \\ y_j \\ \theta_j \end{pmatrix} = \begin{pmatrix} cos\theta_i & -sin\theta_i & 0 \\ sin\theta_i & cos\theta_i & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} x_{ij} \\ y_{ij} \\ \theta_{ij} \end{pmatrix} \quad (6)$$

where

$$X_{ij} = X_i^{-1} X_j = \begin{pmatrix} x_{ij} + \mathbf{v}_{x_{ij}} \\ y_{ij} + \mathbf{v}_{y_{ij}} \\ \theta_{ij} + \mathbf{v}_{\theta_{ij}} \end{pmatrix} \quad (7)$$

Mobile agent receives localization information from $n$ beacons. Out of $n$ beacons, agent uses information of nearest 3 beacons. The Trilateration method can be used for position estimation. Mathematically, this problem can be solved with the following three simultaneous equations,

$$d_i^2 = (x - x_{ri})^2 + (y - y_{ri})^2 + h^2 \quad (8)$$

where $x$ and $y$ are the position coordinates, $d_i$ is the distance to beacon $i$, $x_{ri}$ and $y_{ri}$ are coordinates of beacon $i$, $h$ is the height at which beacons are placed.

### C. Error Correction using Trilateration Technique

Trilateration is a complex method of triangulation which determines the 2D position of points in a communicating network or a test bed. It works in a similar methodology as GPS receivers by calculating the unknown positions of autonomous robots by obtaining readings from the test environment using pre-installed sensors. For Trilateration to effectively take place, the receiver needs to calculate the distance between the transmitting sensors which can be beacons placed at discrete intervals and the mobile robot. This distance can be calculated with the help of the sending and the receiving time span of the signal. Trilateration can effectively take place once distances with respect to the nearest three beacon transmitters are obtained. When three different circles are centred on these points, their point of intersection, gives the location of the mobile robot. The test bed has multiple active beacons whose coordinates have been pre-calculated using GPS.

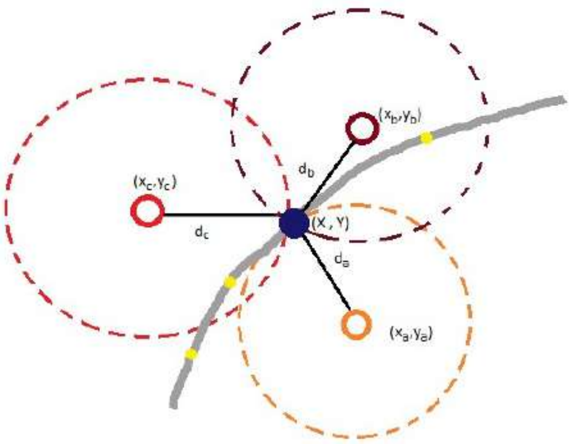


Fig. 1. Trilateration Model

Considering the basic formula for the general equation of a sphere as shown in equation (9):

$$d^2 = x^2 + y^2 + z^2 \quad (9)$$

For a sphere centred at a point $(x_a, y_a, z_a)$ the equation is simplified as shown as in equation (10);

$$d^2 = (x - x_a)^2 + (y - y_a)^2 + (z - z_a)^2 \quad (10)$$

Since one assumes that all nodes span out on the same plane, consider the three anchor nodes (a, b and c) that have distance $(d_a, d_b, d_c)$ to the blind node as illustrated in Fig.1; The formula for all spheres on one plane is shown below in the following equations [11]:

$$d_a^2 = x^2 - 2x.x_a + x_a^2 + y^2 - 2y.y_a + y_a^2 \quad (11)$$

$$d_b^2 = x^2 - 2x.x_b + x_b^2 + y^2 - 2y.y_b + y_b^2 \quad (12)$$

$$d_c^2 = x^2 - 2x.x_c + x_c^2 + y^2 - 2y.y_c + y_c^2 \quad (13)$$

The three equations (11), (12) and (13) are independent non-linear simultaneous equations which cannot be solved mathematically; However, using method proposed by Dixon [10] to obtain radical plane for sphere intersection, equation (13) was subtracted from equation (12) to get the following linear equation:

$$d_b^2 - d_c^2 = 2x(x_c - x_b) + x_b^2 - x_c^2 + 2y(y_c - y_b) + y_b^2 - y_c^2 \quad (14)$$

And subtracting equation (11) from equation (12), the following linear equation is obtained:

$$d_b^2 - d_a^2 = 2x(x_a - x_b) + x_b^2 - x_a^2 + 2y(y_a - y_b) + y_b^2 - y_a^2 \quad (15)$$

Rearranging the equation (14) to produce a new equation and a new variable as follows,

$$x(x_b - x_c) + y(y_b - y_c) = \frac{(d_b^2 - d_c^2) - (x_b^2 - x_c^2) - (y_b^2 - y_c^2)}{2} = v_a \quad (16)$$

Rearranging the equation (15) to produce a new equation and a new variable as follows,

$$x(x_a - x_b) + y(y_a - y_b) = \frac{(d_b^2 - d_a^2) - (x_b^2 - x_a^2) - (y_b^2 - y_a^2)}{2} = v_b \tag{17}$$

Resolve the equation (16) and equation (17) to gain the intersection point x and y:

$$y = \frac{v_b(x_c - x_b) - v_a(x_a - x_b)}{(y_a - y_b)(x_c - x_b) - (y_c - y_b)(x_a - x_b)} \tag{18}$$

$$x = \frac{v_a - y(y_c - y_b)}{(x_c - x_b)} \tag{19}$$

The values for x and y gives us the accurate position in two dimension (2D) for the blind node. But these values cannot be obtained without the signal propagation model.

### D. *Refining using Extended Kalman Filter*

Extended Kalman filtering [1] [2] is a well known technique for state and parameter estimation. It is a recursive estimation procedure that uses sequential sets of measurements. Prior knowledge of the state (expressed by the covariance matrix) is improved at each step by taking the prior state estimates and new data for the subsequent state estimation. In recent years, Extended Kalman filter based localization has become common practice [1] [2] [9] in the robotics literature.

The Extended Kalman filter consists of two different steps - prediction and update. The equations for the prediction step are [2]:

$$\begin{cases} \widehat{\mathbf{X}}_{k+1|k} = f(\widehat{\mathbf{X}}_{k|k}, u_k, k), \\ \mathbf{P}_{k+1|k} = \mathbf{F}_k \mathbf{P}_{k|k} \mathbf{F}_k^T + \mathbf{V}_k \end{cases} \tag{20}$$

Update is given as:

$$\begin{cases} \widehat{\mathbf{x}}_{k+1|k+1} = \widehat{\mathbf{x}}_{k+1|k} + \mathbf{K}_{k+1} \widehat{y}_{\mathbf{k}+1} \\ \widehat{\mathbf{P}}_{k+1|k+1} = \widehat{\mathbf{x}}_{k+1|k} - \mathbf{K}_{k+1} \mathbf{H}_{k+1} \mathbf{P}_{k+1|k} \end{cases} \tag{21}$$

where

$$\widehat{\mathbf{y}}_{k+1} = \mathbf{y}_{k+1} - h(\widetilde{\mathbf{x}}_{k+1|k}, k+1), \mathbf{K}_{k+1} = \mathbf{P}_{k+1|k} \mathbf{H}_{k+1}^T \mathbf{S}_{k+1}^{-1}$$

$$\mathbf{S}_{k+1} = \mathbf{H}_{k+1} \mathbf{P}_{k+1|k} \mathbf{H}_{k+1}^T + \mathbf{W}_{k+1}, \mathbf{H}_{k+1} = \frac{\delta h}{\delta x}$$

$$\mathbf{F}_k = \left( \frac{\delta f}{\delta f} \bigg|_{x = \widehat{x}_{k|x}} \right)$$

To obtain $x_{ij}$ and $y_{ij}$, the covariance matrix is given as

$$\mathbf{P} = \begin{pmatrix} \sigma_x^2 & 0 & 0 \\ 0 & \sigma_y^2 & 0 \\ 0 & 0 & \sigma_\theta^2 \end{pmatrix} \tag{22}$$

Fig. 2. Test Bed Area

## III. Algorithm for Discrete Error Detection and Correction.

We assume that beacons are capable of transmitting their position. Also, we assume that the robot is equipped with sufficient number of sensors/receivers to receive the information from beacons and wheel encoders to calculate wheel velocities. The algorithm for localization is as follows:

1) Calculate position estimates using Odometry sensors.
2) Refine position estimates using IMU sensors to overcome slippage errors.
3) Recalculate position estimates using Trilateration methods to remove Dead Reckoning induced drift errors.
4) Further, refine the position estimates using Extended Kalman Filter.
5) Replace position tuple by refined position tuple.

## IV. Simulation

Local coordinates are obtained by moving the robot manually, in the test bed region. These local coordinates were converted to global coordinates as shown in Fig.2 which are used for simulation. The algorithm is simulated in MATLAB and compared with methods like localization using Odometry, Dead Reckoning using IMU sensors and Trilateration method. The comparison and experimental results are shown in Fig.3 and Table 1 respectively. We found that Odometry method induces an approximation error of 34% whereas Dead Reckoning using IMU shows improvement by 4%. The Trilateration technique minimizes error to 5% which is improved to 2% using Extended Kalman filter with Trilateration.

## V. Conclusions

We have presented a simple and efficient algorithm for localization and tracking. We have shown that well calibrated Odometry and beacon data provide a backup system that proves to be very useful in the case when absolute positioning sensors are unavailable. Nowadays, most outdoor robots use GPS, but given the constraints on indoor robots, GPS is

TABLE I
SAMPLE READINGS FOR COMPARISON BETWEEN ODOMETRY, ODOMETRY+IMU, TRILATERATION AND TRILATERATION WITH EKF

| | **Original** | **Odometry** | **Odometry with IMU** | **Trilateration** | **Trilateration with EKF** |
|---|---|---|---|---|---|
| 1. | (6.6729,7.6446) | (7.896,7.6497) | (6.7879,8.6459) | (7.2757,7.8103) | (6.673,7.736) |
| δ(x%,y%) | | (-18.33,0.067) | (-1.75,-13) | (-9,-2.16) | (-0.0015,-1.1956) |
| 2. | (11.678,24.6315) | (19.6779,21.3672) | (12.9621,24.8383) | (13.2365,23.3636) | (11.67,24.31) |
| δ(x%,y%) | | (-69.00,13.285) | (-11.00,-0.839) | (13.34,51.47) | (0.0685,1.305) |
| 3. | (16.4976,16.9869) | (24.1071,10.6224) | (18.9325,14.9000) | (17.6178,16.3641) | (16.49,16.96) |
| δ(x%,y%) | | (-46.12,-37.46) | (-14.75,12.28) | (-6.97,3.66) | (0.046,0.1583) |
| 4. | (22.2442,10.1928) | (27.8092,-0.4259) | (25.719,5.4224) | (22.9732,10.1434) | (22.95,9.7) |
| δ(x%,y%) | | (-25.00,104.17) | (-15.62,46.80) | (-3.27,0.484) | (-0.026,4.8347) |
| 5. | (11.678,4.247) | (13.8418,3.6928) | (11.8061,3.2817) | (12.0827,4.6994) | (11.69,4.567) |
| δ(x%,y%) | | (-18.52,13.04) | (-1.09,22.72) | (-3.46,-10.65) | (-0.1027,-7.5818) |
| 6. | (4.8195,2.5482) | (3.7483,4.4548) | (3.7538,-2.57) | (5.136,3.144) | (4.343,2.562) |
| δ(x%,y%) | | (-22.22,-42.79) | (22.11,114.89) | (-6.56,-13.37) | (9.8869,0.5415) |

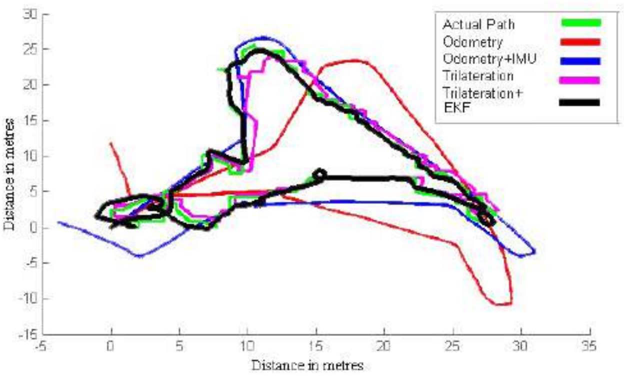


Fig. 3. Comparative analysis of localization algorithm

available intermittently. If good Odometry is available then the robot can rely on it for some time but when it has moved a sufficiently long distance, error correcting techniques using Trilateration and Extended Kalman filtering implemented with active beacons can be used for absolute localization. We have obtained very good results in localization accuracy and robustness.

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# SINGLE PRECISION FLOATING POINT DIVISION

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**Abstract-** Binary Division is one of the most crucial and silicon-intensive and of immense importance in the field of hardware implementation. A Divider is one of the key hardware blocks in most of applications such as digital signal processing, encryption and decryption algorithms in cryptography and in other logical computations. Being sequential type of operation, it is more prominent in terms of computational complexity and latency. This paper deals with the novel division algorithm for single precision floating point division Verilog Code is written and implemented on Virtex-5 FPGA series. Power dissipation has been reduced. Moreover, significant improvement has been observed in terms of area-utilisation and latency bounds.

**Keywords**- Single precision, Binary Division, Long Division, Vedic, Virtex, FPGA, IEEE-754.

## I. INTRODUCTION

The term floating point implicates that there is no fixed number of digits before and after the decimal point; i.e. the decimal point can float. Floating-point representations are slower and less accurate than fixed-point representations, but can handle a larger range of numbers. Because mathematics with floating-point numbers requires a great deal of computing power, many microprocessors come with a chip, called a floating point unit (FPU ), specialized for performing floating-point arithmetic. FPUs are also called math coprocessors and numeric co-processors. Floating-point representation has a complex encoding scheme with three basic components: mantissa, exponent and sign. Usage of binary numeration and powers of 2 resulted in floating point numbers being represented as single precision (32-bit) and double precision (64-bit) floating-point numbers. Both single and double precision numbers as illustrated in Fig. 1 are defined by the IEEE 754 standard.

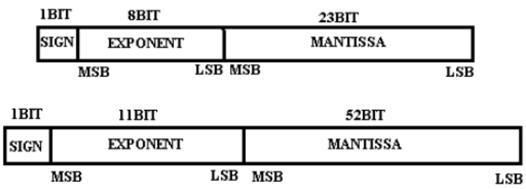


**Fig. 1 IEEE-754 Floating-point Representation Standards**

For a single precision format, 8-bits are reserved for exponent thereby having a bias value of +127 and 23 bits are reserved for mantissa.

When sign bit is 1, it indicates negative number and when it is 0, it argues as a positive number.

The similar explanation is extended for double precision format where exponents are biased to +1023. Binary division operation is of much significance in the area of hardware implementation of signal processing, high quality graphics rendering, filter applications, etc. It is the most important goal of a designer to enhance the performance of the ALU thereby reducing its design complexity to have better figure of merit. Many algorithms were proposed and implemented to reduce the latency of binary division. In algorithmic and structural levels, a lot of division techniques had been developed to reduce the latency of the divider circuitry; which reduces the iteration aiming to reduction of latency but the principle behind division was same in all cases.

Vedic math is known to more optimised and efficient than algorithms based on conventional logic. The sutras defined can be used in digital design to improve the performance of ALUs based on conventional logic. Nikhilam Navatashcaramam Dashatah Sutra and the Paravartya Sutra deals with the division. These sutras find its limitations when number of bits are increased as this paper deals with IEEE-754 floating-point representation.

## II. VARIOUS DIVISION ALGORITHMS

Researchers have proposed many algorithms and procedural architectures to carry out division in order to reduce the computational time and thus enhancing the performance.

### *A.* Restoring Division

Restoring division operates on fixed-point fractional numbers and depends on the following assumptions: (a) $D < N$ and (b) $0 < N, D < 1$.The quotient digits q are formed from the digit set {0, 1}. The basic algorithm for binary (radix 2) restoring division is:

To compute a/b, put a in register A, b in register B and 0 in register P.

1. Shift the register pair (P, A) one bit left.
2. Subtract the content of Register B from register P.
3. If the result of step 2 is negative, set the $A_0$ to 0, otherwise to 1.

4. If the result of step 2 is negative, restore the old value of P by adding the contents of register B back into P.

After repeating the algorithm, n times, register A will have quotient and register P with reminder.

*B.* Non-Restoring Division

Non-restoring division uses the digit set {−1, 1} for the quotient digits instead of {0, 1}. The basic algorithm for binary (radix 2) non-restoring division is:

If P is negative,
1a. Shift (P,A) one bit left.
2a. Add the content of register B to P.
else
1b. Shift (P,A) one bit left.
2b. Subtract the contents of register B from P.
3. If P is negative, set the low-order bit of A to 0, otherwise set it to 1.

Repeat the above procedure n times. After n cycles, register A will have the quotient and if P is positive, it is the remainder, otherwise it has to be restored (add B to it) to get the remainder.

*C.* SRT Division

Named for its creators (Sweeney, Robertson, and Tocher), SRT division is a popular method for division in many microprocessor implementations. SRT division is similar to non-restoring division, but it uses a lookup table based on the dividend and the divisor to determine each quotient digit. The basic algorithm for binary (radix 2) non-restoring division is:

1. Load a and b into A and B registers (Figure A.2)
2. If B has k leading zero, shift B and (P,A) left k bits
3. For l=0, n-1,
   a) If top 3 bits of P are equal, set qi=0 and shift (P,A) one bit left.
   b) If top 3 bits of P are not equal and P is negative, set $q_i$=-1 (write as $\bar{1}$ ) shift (P,A) one bit left, add B.
   c) Otherwise, set $q_i$=1, shift (P,A) one bit left, sub B.
4. If final remainder is negative, correct the remainder by adding B; correct the quotient by subtracting 1 from q0.
5. Shift remainder k bits right.

*D.* Vedic Architecture: Nikhilam Sutra

Vedic Sutra, Nikhilam can be further extended to carry out Binary Division as an alternative to conventional algorithm. Assume that, A and B are dividend and divisor respectively. Dividend is n-bits wide. The flowchart diagram can be executed as follows:

a) Initialize the incrementer with ‘0’.
b) Determine the complement B with respect to 2n assume the complemented result is equal to B’.
c) Add B’ with A. If the carry is ‘1’, then feed the result to the adder.
d) Increment the content of the incrementer by one.
e) Repeat step-3 until the result is less than B.
f) The final result of the incrementer is the quotient and result from the adder is the remainder.

## III. PROPOSED DIVISION ALGORITHM

This paper deals with the efficient algorithm which incorporates the positive attributes of the division architectures mentioned. The division algorithm find its limitations with the wide increase in the number of bits as this paper deals with the floating point representation where mantissa of dividend and divider are each 23-bit wide.

The basic algorithm for the proposed design as follows:

First and foremost, the sign-bit of result is obtained by performing logical XOR of sign bits of dividend and divisor. The Exponent is evaluated by subtracting 8-bit exponent of divisor from 8-bit dividend and then adding the bias value (+127). Lastly, 23-bit mantissa of the result is computed using division logic for which stepwise procedure enlisted below.

1. Pad leading zeroes before the dividend making its width, double the width of mantissa.
2. Pad a leading zero before a divisor and trailing zeroes after the divisor making its width, double the width of mantissa.
3. Perform subtraction of dividend and divisor.
4. If the difference is negative Put 0 in the quotient else 1.
5. Right Shift divisor
6. Left Shift quotient

Fig. 2 shows the example based on proposed algorithm where a decimal number 12 is divided by decimal number 3. Architectural block diagram of the proposed design is shown in Fig. 3.

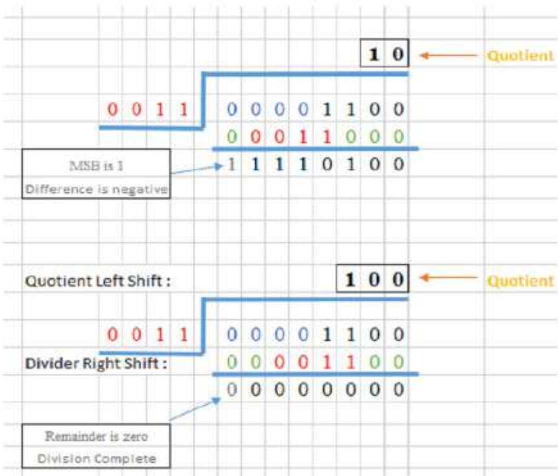


**Fig. 2 Floating point Vedic Divider Illustration 12 divided by 3**

## IV. DESIGN IMPLEMENTATION

Verilog HDL code for Division of IEEE-754 Single Precision Numbers is being developed and then is simulated using ModelSim SE Plus 6.5. Verilog HDL code was break down into modules which deals with the division of 23-bit dividend and 23-bit divisor. code is also written for exponent addition and normalisation process. Top module connects all of them as shown in Fig. 4. Various sets of inputs are fed to the top modular block to get the results. The further part of the document deals with simulation and synthesis results.

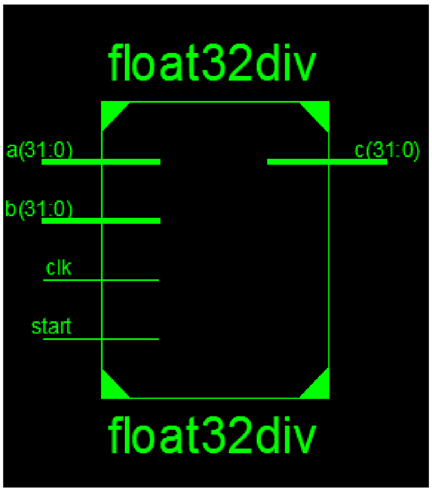


**Fig. 4 Single Precision Vedic Divider: Block Diagram**

A. ModelSim Simulation

Consider division of two decimal numbers, 73.68 and 73.68 fed as A = 73.68 (0 10000101 00100110101110000101001) and B = 73.68 (0 10000101 00100110101110000101001) were fed to the algorithm to get the desired output as C = 1 (0 01111111 00000000000000000000000) as shown in Fig. 5.

B. Xilinx ISE Synthesis

Verilog HDL Code for division of IEEE-754 Single Precision (32-bit) numbers are then synthesized for device XC5VLX30 having package as FF324 of Virtex™-5 FPGA family. From the datasheet cited in, this device has following attributes manifests in Table I.

TABLE I
XILINX VIRTEX™-5 XC5VLX30 ATTRIBUTES

| Device | CLB Array (One CLB = Four Slices × 2 | | | Total Slices | Max. User I/O |
|---|---|---|---|---|---|
| | Rows | Column | Total | | |
| xc5vlx30 | 80 | 30 | 4800 | 19,200 | 220 |

Table II shows the Device Utilisation Summary of the Verilog HDL code, so written, it is been observed that number of device parameters used are very less. Hence, an optimum Device Utilisation is obtained.

From the timing report obtained, it is found that the maximum combinational path delay is 5.405 ns. Maximum combinational path delay is only for paths that start at an input to the design and go to an output of the design without being clocked along the way. Also, it is estimated that it can operate with the maximum frequency of 326.163 MHz.

## V. PERFORMANCE ANALYSIS: VEDIC VERSUS CONVENTIONAL

It can be easily deduced from the Table III which shows the performance analysis of the Vedic divider with that of conventional dividers that Vedic dividers are more optimistic.

TABLE II
FLOATING POINT VEDIC DIVISION (SINGLE PRECISION):

| Device Utilization Summary | | | |
|---|---|---|---|
| Slice Logic Utilization | Used | Available | Utilization |
| Number of Slice Registers | 120 | 19,200 | 1% |
| Number used as Flip Flops | 120 | | |
| Number of Slice LUTs | 159 | 19,200 | 1% |
| Number used as logic | 159 | 19,200 | 1% |
| Number using O6 output only | 155 | | |
| Number using O5 and O6 | 4 | | |
| Number of occupied Slices | 54 | 4,800 | 1% |
| Number of LUT Flip Flop pairs used | 182 | | |
| Number with an unused Flip Flop | 62 | 182 | 34% |
| Number with an unused LUT | 23 | 182 | 12% |
| Number of fully used LUT-FF pairs | 97 | 182 | 53% |
| Number of unique control sets | 2 | | |
| Number of slice register sites lost to control set restrictions | 4 | 19,200 | 1% |
| Number of bonded IOBs | 98 | 220 | 44% |
| Number of BUFG/BUFGCTRLs | 1 | 32 | 3% |
| Number used as BUFGs | 1 | | |
| Average Fanout of Non-Clock Nets | 2.37 | | |

TABLE III
PERFORMANCE ANALYSIS:
PROPOSED WORK (VEDIC) VERSUS CONVENTIONAL

| Parameters | This Work | [6] | [9] | |
|---|---|---|---|---|
| Number of bits | 23 | 9 | M | |
| Target Device | Virtex 5 XC5VLX30 -3 FF324 | Spartan 3 XC3S100E -5 VQ100 | Spartan 3E XC3S500E | |
| Number of Slices | 54 | 103 | Restoring | Non - Restoring |
| | | | 229 | 447 |
| Number of 4-input LUTs | 159 | 176 | --- | --- |
| Number of IOBs | 98 | 38 | --- | --- |
| Maximum Frequency (MHz) | 326.163 | --- | 12.63 | 53.77 |

Number of slice LUTs used in the design are pretty less, 159 whereas other algorithms based dividers are normally hooked to 176. Also one can visualize that this proposed divider is just consuming 54 number of slices compared to other algorithms which utilize minimum of 103 to 447 number of slices. Thus, there is near about 12% improvement in the utilisation of the resources, thereby enhancing the packaging density. This proposed design can be operated on the processor clocked with 326.16 MHz, Thus, computational speed is more as compared to other design which operates with maximum frequency of 53.77 MHz. The maximum combinational delay incurred is just a meagre value of 5.405 nanoseconds. Power consumption of proposed design is drastically reduced to 2 mW, whereas traditional ALUs are consuming more power. Since, proposed design consumes less power, so bulky heat-sinks or extensive blowers can be eliminated. This makes the installation of processor simple and can be equipped with portable or mobile devices.

## CONCLUSION

The importance and usefulness of floating point format nowadays does not allow any discussion. Any computer or electronic device, which operates with real numbers, implements this type of representation and operation. Division is one of the most important arithmetic operation. Various architectures were proposed which include recursive iterations to increase the computational performance of the ALU. The proposed design uses ancient Math technique which pad zeroes for dividend. By means of logical shift, the estimated results were obtained. Synthesis results obtained provides better results in terms of computational speed and area utilization thereby reducing the size of silicon dye used. Also reduces the size and cost of the device. Moreover, less time delay incurred leads to fast computation and speedy calculations. Power dissipation has been reduced, which can eliminate the need of extensive cooling mechanism comprising thermal gels and blowers. Thus, proposed divider is more efficient than traditional ALUs and serve as better optimisation technique as per today's need and wants.

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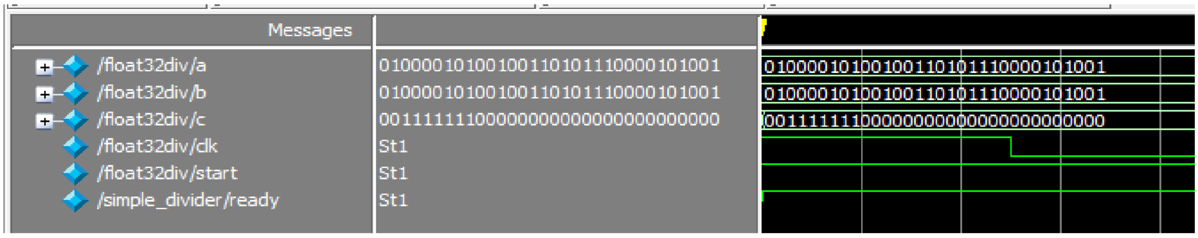
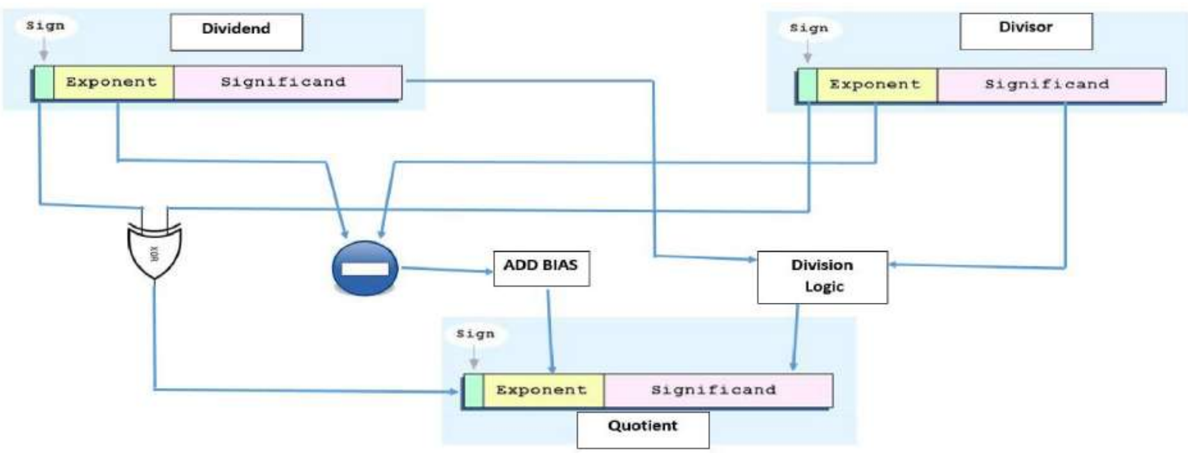



**Fig. 5 Floating Point Vedic Division (Single Precision): Timing Diagram 73.68 ÷ 73.68 = 1**



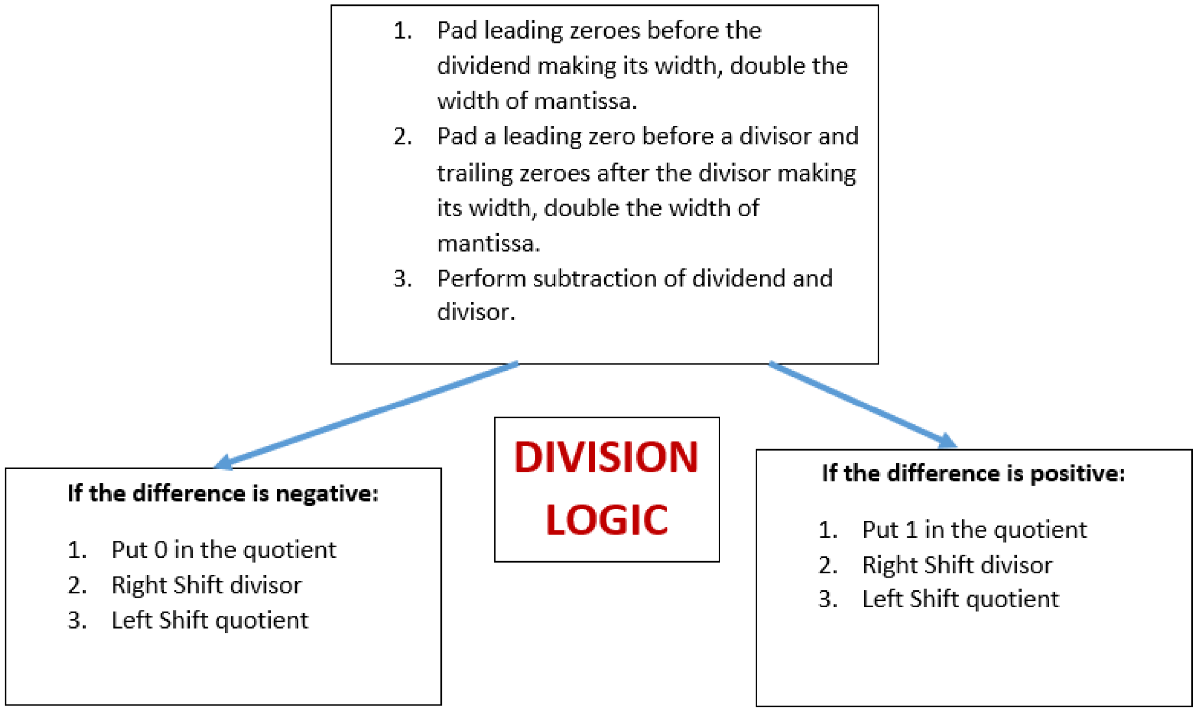



**Fig. 3 Floating Point Vedic Division: Architectural Block Diagram**

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# SOUVENIR

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# INTERACTIVE TEACHING-LEARNING METHODOLOGY USING MOODLE

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## ABSTRACT

This paper introduces the teaching methodology of "Database Management System" for the electronics engineering students of Fr. Conceicao Rodrigues College of Engineering, Mumbai using Learning Management System (LMS) such as Modular Object Oriented term Developmental Learning Environment (Moodle). Our analysis shows that features of Moodle not only help students in self learning the subject but it also helps teachers in conducting various activities like quiz and flipped classroom and generate report of the activities automatically. The Moodle activities not only saves the paper because all the activities will be carried out Online but it also saves teacher's time for evaluation

## INTRODUCTION

Because of various advantages including flexible learning times and effective learning, LMS has been widely used in higher education. Modular Object Oriented term Developmental Learning Environment (Moodle) [1], also recognized as a LMS, and is a course management system through the Internet / Intranet. There are number of advantages using Moodle, for example, student-teacher interactions, student independence, and allow students more flexible time for learning, etc. Moodle can be installed at any number of servers without any cost and it is no need to pay maintenance costs for enhancing the system. From the students' perspective, Moodle provide them with the ability to access the course materials, delivered by the instructors, and use communication and interactive features in their learning activities. Educational institutions widely use this system to enhance their traditional teaching. The users around the world, such as universities, schools, teachers, instructors, courses, and societies, use this learning platform [1]. This research aims to investigate the use of Moodle management system as a part of teaching process related to "Database Management System", to improve the teaching and learning techniques and to know the usefulness of Moodle usage

## METHODOLOGY

On our Moodle users were created class-wise. Every user was having user-id and password, which can be linked to password management system such as LDAP. The "Database Management System" course was created by Moodle administrator and students were assigned by the administrator as users. Fig. 1 shows Main course page of "Database Management System", Fig. 2 shows assignment and expt. page, Fig. 3 shows some features of Moodle. Multiple choice questions were asked in timer-based quiz with automatic grading. Crosswords were formed using short answer questions.

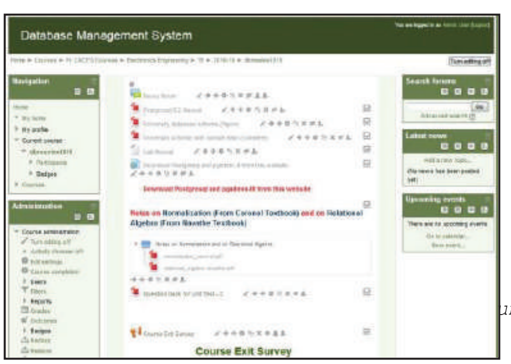


Figure 1 Main course page


Figure 2 Expt., assignment, and crossword

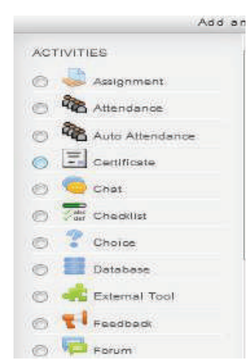


Figure 3 Moodle features

# POSTER PRESENTATION FOR A PARTICIPATIVE LEARNING EXPERIENCE

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## ABSTRACT

The objective of poster presentation activity was to hone students' presentation skills & unleash their creativity by preparing A1/A2 size posters of various discrete topics in which the students would embark upon a self-study culture by presenting & explaining their work through the poster medium in front of the whole class. In this technique students were given the complete liberty to not only explore topics at their own pace, but to also question the topic contents by referring to any other verified alternate means. It gave them a sense of belonging in the course by inculcating freedom of expression rather than being dictated to in monotonous manner, as in traditional approaches.

## INTRODUCTION

To impart engineering education in the 21st century to the millennial stakeholder students, it is extremely imperative that a full duplex communication channel be established between the teacher & the student [1]. This is to ensure that the subject topic or module under consideration is not only appreciated, understood & accepted well by the students, but also they also get to be a part of a 'live' process which inculcates a feeling of participation wherein their efforts are taken into account & a feedback is established so that students get an active feeling & satisfaction that they are an integral part of the activity or process [2]. Keeping this in mind, the poster presentation activity was conducted for the module of 'Special Semiconductor Devices' in subject of 'Electronic Devices & Circuits - II' where students were an active & integral part of the teaching-learning process having done their own research, followed up their own homework, designed their own 'curriculum' & presented their own views to the whole class on the subject topic that was allocated to them. The subject teachers assisted them in solving technical queries they faced.

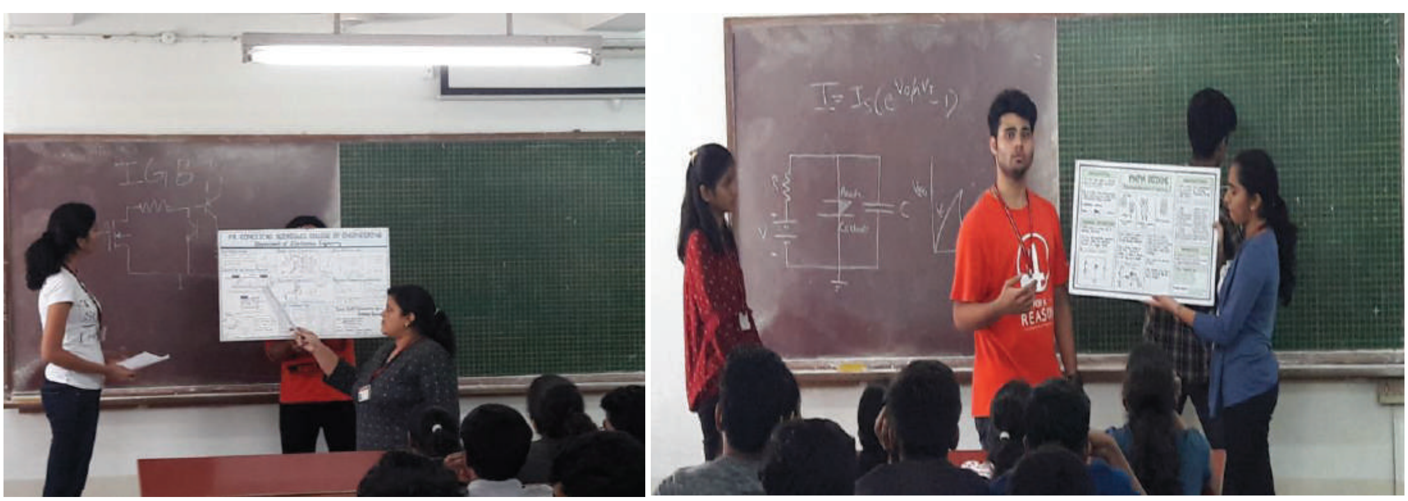

FIG 1: Students engaged in poster presentation activity for participative learning

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# Power Consumption and Delay in Wireless Sensor Networks Using N-Policy M/M/1 Queuing Model

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***Abstract*—Technological advancements in low power integrated circuits and wireless communications have made it possible to use efficient, low cost, low power small devices in remote sensing applications. This has led to the feasibility of using a network of sensors to be used for the collection, processing, analysis and distribution of important information, collected in a wide variety of environments. Sensor nodes in a wireless sensor network transmit data in single or multi-hop to a central node called the base station. A very important issue in wireless sensor networks is the scarcity of power and hence optimal use of available power is of prime importance. It is seen that in any sensor node, switching from idle to busy state and vice versa takes up a major portion of the power. We study and analyze a technique that aims to reduce the number of these in order to reduce the consumption of power. In this technique the radio of the sensor node is switched on only when the number of packets in a queue exceed a certain threshold as opposed to the general tendency of transmitting a packet as soon as it is available for transmission. This however introduces delay in the processing of the packets. We analyze the performance of this system with respect to the power consumption and mean waiting time. The simulations performed show that the simulation results are close to the theoretical results thus indicating the validity of the technique studied.**

*Keywords — Wireless Sensor Network; Queuing Theory;*

## INTRODUCTION

A WSN comprises of a large number of sensor nodes that are typically distributed over a wide area. The WSN also comprises of a node that acts as an information collector and is referred to as the sink node. These sensor nodes usually consist of a sensing unit, a battery and a radio. In typical deployment scenarios, the sensor nodes may be deployed in remote, unattended, and hostile environment in large numbers. In some applications, the physical size of a sensor node is kept as small as possible for stealthy missions and cost cutting. In most cases, sensor nodes in WSN are fitted with non-rechargeable batteries and have a limited lifetime. It may be difficult to recharge or replace their batteries due to their remote or hostile locations. This fact gives rise to major design issues in WSN, which is to reduce power consumption and to increase the lifetime of sensor nodes as much as possible [1][2].

Data packets usually originate at the sensor nodes as a result of its sensing activities. Moreover the sensor also behaves as a router to route the packets that arrive from other nodes. The data that are generated at the sensor nodes as well

as the ones routed by the nodes must all reach a sink node in sensor network. The traffic in a wireless sensor network usually has a many-to-one pattern, where nodes that are located nearer to the sink bear a heavy burden of the traffic. As a result, it is seen that the nodes around the sink would consume their energy much faster, leading to the eventual death of the node. This problem is known as the energy-hole problem [3]. If an energy hole appears, then packets cannot be delivered to the sink anymore. The longevity of a WSN entirely depends on the life of sensor nodes that are closer to the sink of the WSN. As described in [4], there are four main sources of power consumption: collision, overhearing, control packet overhead, and idle listening.

Overhearing and idle listening use power by keeping the radio receiver in an ON state without actually getting any useful information. However, compared with the other three types of power consumption for a generic node, packet collisions lead to energy waste which is much more. Medium contention in a contention-based protocol is one of the main reasons of packet collisions among sensor nodes. Shih et al [5] have demonstrated that power consumption is very high in case of the radio transmitter switching from one mode to another. Here, we study an approach to alleviate total average times of both medium contention and mode switching of radio receiver [3]. The approach discussed here is based on N-policy M/M/1 queuing model.

The nodes located near the sink of the WSN use more energy than other nodes because of the larger forwarding burden. This would lead to a faster depletion of the battery and eventually to the failure of the WSN. From the angle of queuing theory, the larger forwarding burden implies that the average arrival rate of packets at the nodes closer to the sink is higher than that of nodes farther away from the sink. To alleviate this problem, an optimal N criterion is adopted for a queue based scheme. A queue threshold, N, is specified which would imply that the node will wake up only after the node's buffer has at least N packets and the node switches back to idle state when there are no packets to be transmitted, in other words, the buffer becomes empty. In this scheme, when the node buffer is filled with N packets, the sensor node triggers its transmitter and starts transmitting the packets in the buffer in a burst. The optimal threshold value (N*) of N at which the sensor nodes use the least power is also determined.

In this paper, we present the mathematical expressions for the queue based approach and also data simulations with MATLAB tool are conducted on optimal queued values for mitigating power consumption. We also have conducted simulation of the queue based approach using MATLAB and the results are presented here that confirm the power saving achieved by the queue based scheme.

The rest of the paper is organized as follows: In section II, we present the system model. In section III, we discuss the mathematical preliminaries and provide numerical expressions for the average power consumption of a sensor node and the optimum value of N. We provide the values of various parameters used for evaluating the power consumption and also discuss the simulation of the system model in section III. We discuss the results of evaluation and simulation in Section IV. In section V, we provide the conclusion of our work.

## II. SYSTEM MODEL

Here the operation of radio server in an N-policy M/M/1 queuing process under steady-state conditions is studied. The sensor node turns the transmission of radio on at a packet's arrival and off at service completion epochs. We have made an assumption that packets arrive at a node following a Poisson process with mean arrival rate λ. The radio service times follow an exponential distribution and has a mean 1/μ. A scheme is studied in which a sensor node switches to busy state i.e. starts its radio transmitter when the node's buffer is filled at least with number of packets equal to the threshold (N) and the node switches to the idle state when there are no packets to be transmitted remaining in the buffer. Such switching actions between idle state and busy state and vice versa are referred to as transitions. Since the main aim is to minimize the power consumption of individual sensor nodes by reducing the number of transitions, we study the behavior of a single sensor node when this scheme is implemented.

Let's first have a look at the mathematical preliminaries for the N-policy Markovian queuing system [6]. The analytic steady state results are presented for a single sensor node. For our analytical model, the following notations are used.

n Number of packets in the sensor node's buffer
N Threshold number of packets
λ Mean arrival rate per node
1/μ Mean service time
PI (n) Probability that the sensor is in idle state when
there are 'n' packets
PB (n) Probability that the sensor is in busy state when
there are 'n' packets
PI Steady state probability that the sensor is in idle state
PB Steady state probability that the sensor is in busy state
L Mean number of packets in the sensor node's buffer

The state-transition-rate diagram for the N-policy M/M/1 queuing system is shown in Fig.1. InFig.1, there are two chains of horizontal circles associated with the state of the radio server. The upper and lower chains represent the idle state and the busy state of the radio server, respectively. Each circle with number in it denotes that the number of data packets queued in the sensor node for that state.

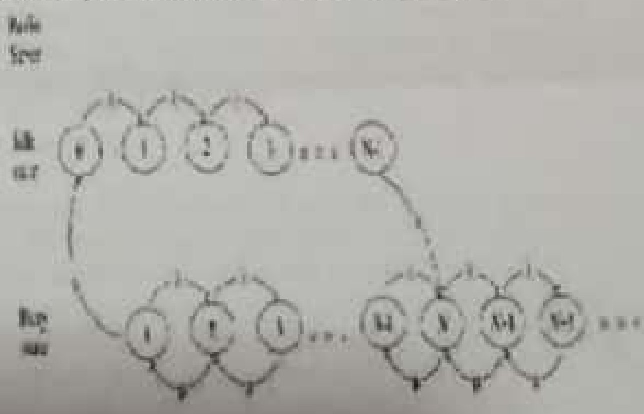

Fig. 1. State-transition diagrams for the N-policy M/M/1 queuing [3]

The value λ is the mean arrival rate of data packets into the sensor node, and the value μ is the mean service rate of radio server. The steady-state equations for PI (n) and PB (n) are as follows:

The probability generating function (PGF) may be used to obtain analytic solution PI (0) since solving

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# Using GRBL-Arduino-based controller to run a two-axis computerized numerical control machine

**Publisher: IEEE**

**2 Author(s)** Sakib Shaukat Sarguroh ; Arun Bhiva Rane **View All Authors**








**Abstract:** The proprietary control of CNC machines results in the inability to control and enhance inputs because the program codes cannot be modified owing to their distribution by... **View more**

### Metadata

**Abstract:**
The proprietary control of CNC machines results in the inability to control and enhance inputs because the program codes cannot be modified owing to their distribution by vendors in the compiled form. In this paper, we present a method to utilize a GRBL-Arduino based controller to run a simple two-axis computerized numerical control (CNC) machine. We obtained drawing file by converting a JPG or PNG image of a hexagon or a circle into a drawing file using the software application Img2CAD. Two-dimensional manufacturing was carried out on the obtained drawing file to generate the G-code file by the CAD/CAM software application UG NX. The G-code file generated is given as input to the GRBL-Arduino based controller using the Java-based Windows application Universal GcodeSender (UGS). UGS is linked to the Arduino Uno and GRBL shield V5 hardware via a serial communication port. Before executing the G-code program, the circle or hexagon to be drawn can be visualized using G-code visualizer option in UGS. G-code program was executed through UGS to run two 2.6 kg-cm stepper motors for motion along x and y-axis direction via drivers incorporated on the GRBL-Arduino controller. These stepper motors were part of a simple two-axis CNC machine comprising aluminum angle brackets, chromed chords, linear motion bearings, a timing belt, and a timing pulley. Stepper motors cause motion of the mentioned mechanical components to draw desired image of circle or hexagon. This work can be extended to develop a three-axis CNC machine by utilizing the third inbuilt stepper driver of the GRBL shield V5; in this study, we used only two of the three inbuilt stepper drivers for the stepper motors. Using the third driver will facilitate the use of a third axis so that the machine can function as a milling machine. Hardware for the third axis must be developed to incorporate a z-axis motor.

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# Improving the performance of assembly line: Review with case study

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**4 Author(s)** Arun.B. Rane ; D.S.S. Sudhakar ; Vivek k. Sunnapwar ; Santosh Rane **View All Authors**





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## Metadata

**Abstract:**

Context: Continuous Improvement in manufacturing to attain manufacturing excellence is today's requirement. It gives cutting edge over the competitors. This has developed lot of interest for the researchers during the last few years. Vehicle Assembly Line being the most complex Assembly line has been active area of research over years and has attracted many researchers. Objective: This paper systematically identifies and unfolds the important parameters by systematic review. Goal of this Research is to develop a novel classification of literature on Assembly Line and to improve the performance of vehicle assembly line using Lean implementation and Simulation approach. Methodology: Total of 116 referred journal articles in the domain of Vehicle assembly are reviewed here. Data is sourced from 40 publications, majority of which includes Elsevier, IEEE, and Springer. Further a mathematical model is developed considering the effect of number of resources, Break time, Downtime of machines and Absenteeism. A real world case study is done for a period of one year in a reputed vehicle assembly manufacturing plant. Results: Analysis of research on Assembly Line Balancing and optimization within many different industrial scenarios has been done her. This paper contributes to existing domain by classifying and comparing the means for input data, constraints and methodology used. It has been classified into five heads. A real world case study is done in reputed Company. Cycle time was reduced from 110 seconds to 100 seconds. Conclusion: It is difficult to perform the experiments like Design of Experiments (DOE) in complex manufacturing systems. Simulation allows us to test different concepts, various options without having to build prototypes. A case study done in Vehicle assembly shows the importance of Simulations to improve its performance measures. Limitations of the Research: The research does not completely optimize the production parameters. It improves the production sy...

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# Optimization of Tube Hydroforming Process (without Axial feed) by using FEA Simulations

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**Abstract**

Tube hydroforming is the process of manufacturing light weight automotive components by applying fluid pressure. Success of Tube hydroforming process depends on best combination of material properties, process parameters, process sequence, and die geometry. Analysing the tube in square cross section die is simplest of hydroforming operation and the parameters effect can be further used for more complex hydroforming operation. In this work 3-D Finite Element model for the Tube Hydroforming (THF) developed using Creo Parametric 2.0, pre-processed using HyperMesh and solved using LS-DYNA explicit solver. This paper aims at identifying important parameters that affect the THF process without Axial feed. Taguchi's Design of Experiment technique is used to understand the effect of individual parameters as well as interaction of hydroforming process parameters such as die corner radius, length of tube, thickness of tube, internal pressure.

Peer-review under responsibility of the organizing committee of ICIAME 2016

*Keywords:* Hydroforming; Process Parameters; DOE; Taguchi method; FEA Simulations; ANOVA

## 1. Introduction

The automotive industry demands of reduced emissions, improved performance and a more sustainable carbon footprint with more fuel efficient designs. These targets are achieved by developing lighter vehicles structure along with improved aerodynamics, more efficient engines. In order to achieve lighter structure, a developing novel shaping techniques called Tube Hydroforming is used nowadays for Manufacturing of tubular components of the a modern Vehicle. Tube Hydroforming is being used by automotive industry in past two decades, typically it involves tubular components in engine and exhaust systems, chassis, body, closing doors, hoods, etc. The main advantage that


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the process offers is the ability to optimize the structure for weight and strength, while often offering at the same time superior crashworthiness.

Tube Hydroforming technique is well advanced manufacturing technique in which the tube to be formed is placed inside a die and internal pressure is applied by the fluid generally taken as water with non-corrosive additives [1]. for Successful hydroforming, the optimization of process parameters is required and process should fit in to the Forming limit Diagram (FLD). Detailed investigation of design and process parameters and selection of their optimal values is very crucial as it influences the quality and cost of the component produced and also affects the cost and quality of the final product. Finite element analysis is being preferred over experimental approach being economic and equally effective in predicting the process outputs subjected to various input parameters. Many researchers and industries are effectively using finite element approach for optimizing the hydroforming process.

Finite Element Analysis (FEA) permits arbitrary combinations of input parameters including design parameters and process conditions to be investigated with limited expense. Additionally FEA simulations are planned to further enlarge the knowledge base about particular parts using predetermined parameters varied over practical ranges, (Muammer Koc et.al (2000) [2]). The Taguchi method is applied to design an orthogonal experimental array, and the virtual experiments are analyzed by the use of the finite element method (Bing Li (2006) [3]). G.T.Kirdli, et.al [4], concluded that the thickness variation reduces if die corner radius is increased and tube wall thickness is affecting internal pressure, while maintaining the same thinning pattern. Matteo Strano, et.al [5], said shorter the tube length, the obtained protrusion height is larger. Sung-Jong Kang, et.al [6], they discussed the effect of changing tube diameter by using FEA simulations LS-DYNA as a FE code by taking vehicle bumper rail section as product after hydroforming. They concluded that by changing tube diameter slightly by 10% (increasing), remarkable reduction to about one-third in thinning rate and more uniform thickness distribution were predicted whichever loading path was applied to the prediction. Hossein Kashani Zadeh, et.al (2006) [7], simulated the effect of friction coefficient, strain hardening exponent and fillet radius on protrusion height, thickness distribution and clamping and axial forces for an unequal T joint using ABAQUS/EXPLICIT 6.3-1. The results were compared with experimental results and were found to in agreement with them, hence they concluded that FEM can be used as a reliable tool in designing tube hydroforming process to reduce costly experimental trials. A. Alaswad, et.al (2006) [8], they modeled bulge height and wall thickness reduction of a bi-layered T-shape component as a function of geometric factors using finite element modeling (FEM) and response surface methodology (RSM) for design of experiments(DOE). On the similar lines they analyzed formability and failures of T shape bi-layered tube hydroforming using ANSYS LS-DYNA pre-processor and LS-DYNA solver as a function of certain material properties and initial blank geometry and provided an optimum operating condition.

Kristoffer Trana (2002) [9], Lihui Lang et.al (2004) [10], Nader Abedrabbo et.al (2009) [11], studied the effect of axial feed and internal pressure on the thickness distribution using FEA simulations and found that the results were in good agreement with experimental findings. Shijian Yuan et.al (2006, 2007) [12,13] T. Hama, et.al (2006) [14], studied the wrinkling behaviour in THF using FEA. Muammer Koc (2003) [15], studied loading paths and effect of material properties on process output using FEA simulations verified by Experiments. Asheesh Soniu (2014) [16], investigated the effect of internal pressure on stress distribution using LS-Dyna Explicit solver. P. Ray et.al (2004) [17], Sung-Jong Kang et.al (2005) [6], M. Imaninejad et.al (2005) [18] Yingyot Aue-U-Lan, et.al (2004) [19], determined optimal loading path for THF process using simulations. Ken-ichi Manabe and Masaaki Amino (2002) [20], investigated the effect of Process parameters (friction coefficient, stress ratio) and material variables (n- and r-values) on thickness distribution using LS-Dyna. Bathina Sreenivasulu, et.al (2014) [21], proved experimentally that the strain hardening coefficient has higher influence over formability of the tubes so that for forming of materials with higher value of “n”, lower internal pressure needed. E. Chu, et.al (2002) [22], proposed and established the theoretical "Process Window Diagram" (PWD) based on mathematical formulations for predicting forming limits induced by various defects such as buckling, wrinkling and bursting of free-expansion tube hydroforming process. Kuang-Jau Fann, et.al, (2003) [23], carried out THF simulations and concluded that sequential optimization can lead to better forming results as loading path is having close control on process output. Fuh-Kuo Chen, et.al (2007) [24], found that the relation between hydraulic pressure and outer die corner radius predicted agrees well with FEM. The hydraulic pressure required to deform a tube into a desired part shape depends on the material properties of the tube, tube thickness, and the minimum corner radius of the part shape. B.Sreenivasulu, et.al (2013) [25], modelled free bulge shaped tube die using Auto CAD, simulated THF using DEFORM-3D and found that wall thickness and the branch height are most sensitive to friction, axial load, and internal pressure. A. Aydemir, et.al (2005) [26], they developed an adaptive design method for T-shape tube parts based on finite element method using ABAQUS/Explicit, to avoid wrinkling and necking.

From the above literature review, it is evident that the Finite Element simulations are capable of predicting accurate behaviour of tube hydroforming process and can be used to reduce experimental efforts. The objective of this paper is to investigate and study the effect of significant process parameters and their interactions in order to improve the quality of Hydroformed tube.

## 2. Methodology

Taguchi method gives three stages in the process development: (1) system design, the engineer uses scientific and engineering principles to determine the basic configuration. (2) Parameter design, in this stage the specific values for the system parameters are determined (3) Tolerance design, it is used to specify the best tolerances for the parameters [3]. From these, Parameter design is the most important step in Taguchi method towards achieving high quality without increasing cost. So, in order to obtain the high Hydroformablity, the parameter design approach proposed by Taguchi Method is adopted in this paper.

The Basic steps in the methodology are shown in the fig.1. Firstly the Quality characteristics and the controllable forming parameters are selected, and accordingly the Orthogonal array has been constructed. Based on the Orthogonal Array selected the finite element simulations are performed and results are tabulated in terms of average response for each factor. Statistical Analysis of variance (ANOVA) is performed to see the significant parameters. And then it is modified with the interaction of the significant parameters to obtain more information of their effect on the quality characteristics.

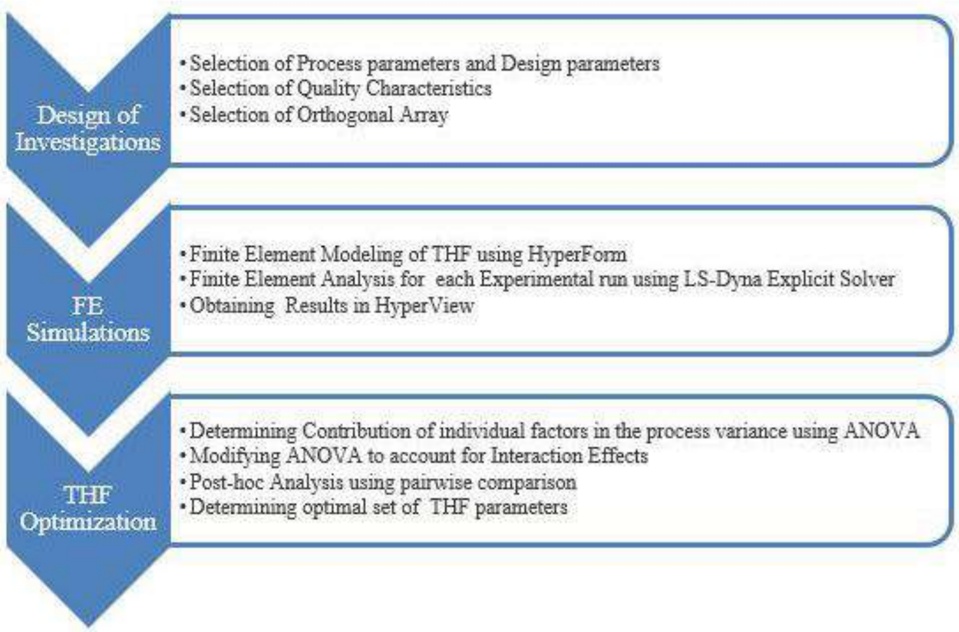


Fig. 1 Methodology for Optimization of Tube Hydroforming

### *2.1. FE Simulation Methodology*

The tube and die geometry are prepared using CREO Parametric 2.0, then it is imported in to the Preprocessor Hyperform 12.0 for applying boundary conditions. After applying boundary conditions LS-DYNA R7.0 is used as a Solver. The output of the analysis stage is viewed using Hyperview. The tube diameter is 40 mm, and taking tube thickness at three level and is blown in to die cavity which is square shape having of side 44mm. Fig. 2 shows a screenshot of output of the analysis stage. The figure shows forming limit diagram (FLD) for the deformed tube.

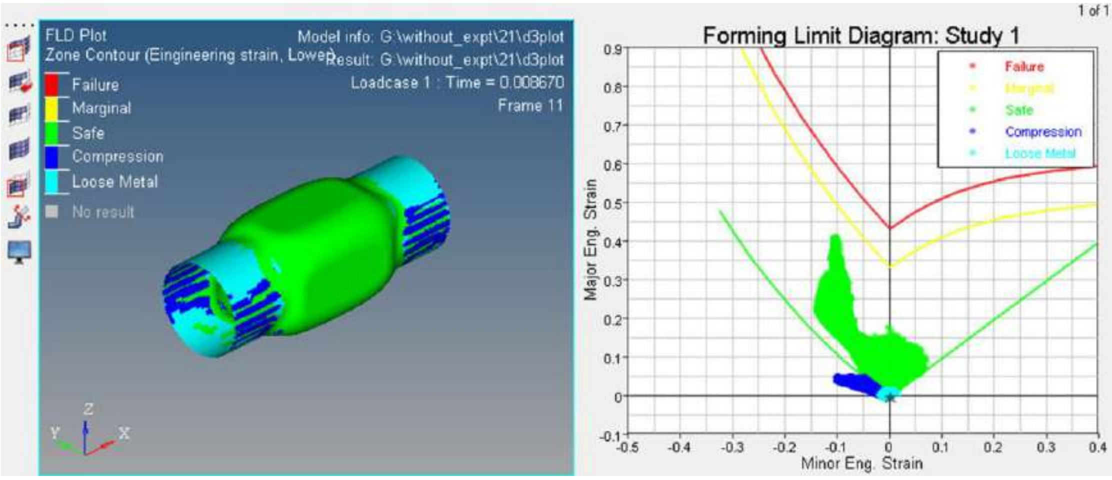


Fig. 2 Forming limit Diagram of the Hydroformed Tube

The material selected for hydroformed tube is CRDQ steel and its material properties are given in Table 1.

Table 1. Material Properties for CRDQ Steel used in the FEM Simulation

| Material Parameters | Value |
|---|---|
| Density ρ (kg/m$^3$) | 7800 |
| Young's Modulus E (GPa) | 210 |
| Hardening Coefficient *K* (MPa) | 550 |
| Hardening Exponent n | 0.21 |
| Poisson's Ratio μ | 0.3 |
| Lankford Coefficient R | 1.6 |

### *2.2. Determination of Quality Characteristic, Selection of Parameters and construction of Orthogonal Array*

In the tube hydroforming process the primary requirement is to conform the shape of the die by the tube blank without any failure. The three main failure of this process are bursting, buckling, wrinkling. Among these three failures only wrinkling and buckling are recoverable. Bursting is fracture and hence cannot be recovered and causes necking because of which the percentage thickness reduction becomes an important output to be measure. Hence the Percentage thickness reduction is selected as a Quality characteristic.

Hydroformablity is dependent on three categories of parameters viz., Geometry Parameters, Material Parameters, and Process Parameters (Table 2). The Four forming parameter are chosen at three levels each and Orthogonal Array $L_{27}$ is selected for the present study according to Taguchi's Method.

Table 2. Forming parameters with their levels.

| Designation | Forming Parameters | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| A | Die Corner Radius (mm) | 4 | 6 | 8 |
| B | Length of tube (mm) | 120 | 140 | 160 |
| C | Thickness of Tube (mm) | 1 | 1.2 | 1.4 |
| D | Internal Pressure (psi) | 6000 | 6200 | 6400 |

## 3. Data Collection and Analysis

The Experiments are performed as per Taguchi's OA $L_{27}$ and the Average responses for maximum percentage thickness reduction for individual factors are as given in table 3 below.

Table 3. Average response for Percentage thickness reduction.

| Factors | | Average Response (% thickness Reduction) | | |
|---|---|---|---|---|
| | | Level 1 | Level 2 | Level 3 |
| A | Die corner radius | 20.0467 | 17.9811 | 20.2244 |
| B | Length of Tube | 18.8344 | 18.2633 | 21.1544 |
| C | Thickness of Tube | 20.2511 | 20.2100 | 17.7911 |
| D | Internal Pressure | 19.4211 | 19.4044 | 19.4267 |

The Fig. 3 shows Individual factors effect and clearly indicates that the percentage thickness reduction decreases as the level of factor A and B (Die corner radius and length of tube) changes from 1 to 2 and then increase as the level changes from 2 to 3. The percentage thickness reduction remains fairly constant for all levels of factor D (internal pressure). Whereas Percentage thickness reduction remains fairly constant for levels of the factor C (thickness of tube) from 1 to 2 and then decreases from 2 to 3.

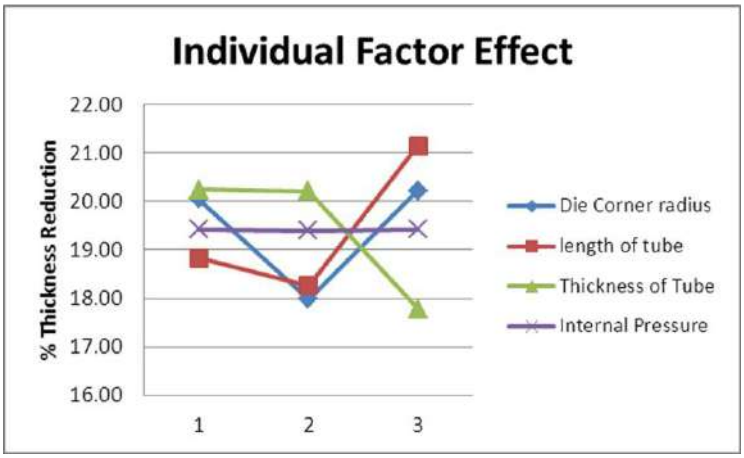


Fig. 3 Individual Factors Effect on Percent Thickness Reduction

The results of Analysis of the variance by considering the main effects of individual parameters as well as their interactions are shown below table 4. It clearly indicates that the factor A, B and C are significantly affecting the process and their interaction AXB is affecting as well. In order to study the interaction effects pair-wise comparisons are useful. For this study, we need to make a distinction between focal independent variable and moderate variable. The assigned independent variable i.e. a characteristic intrinsic to the participant such as Tube Length, tube thickness can be chosen as moderate variable and the active independent variable i.e. the one assigned or designed by the researcher such as die corner radius, internal pressure can be considered as the focal independent variable.

Table 4. Modified ANOVA Table for Percentage thickness reduction.

| | **SS** | **D.F** | **MSS** | **F** | **F critical at α = 0.10** | **Remark** |
|---|---|---|---|---|---|---|
| $SS_A$ | 27.9920 | 2 | 13.9960 | 7.1569 | 3.46 | SIGNIFICANT |
| $SS_B$ | 42.2013 | 2 | 21.1006 | 10.7899 | 3.46 | SIGNIFICANT |
| $SS_C$ | 35.7129 | 2 | 17.8565 | 9.1310 | 3.46 | SIGNIFICANT |
| $SS_D$ | 0.0024 | 2 | 0.0012 | 0.0006 | 3.46 | INSIGNIFICANT |
| $SS_{AXB}$ | 30.8593 | 4 | 7.7148 | 3.9450 | 3.18 | SIGNIFICANT |
| $SS_{AXC}$ | 1.8408 | 4 | 0.4602 | 0.2353 | 3.18 | INSIGNIFICANT |
| $SS_{BXC}$ | 15.1306 | 4 | 3.7827 | 1.9343 | 3.18 | INSIGNIFICANT |
| $SS_E$ | 11.7336 | 6 | 1.9556 | | | |
| $SS_T$ | 165.4729 | 26 | | | | |

In this paper, Tube length is designated as moderate variable and die corner radius is designated as focal independent variable. As AXB interaction is only significant so it is studied furthermore. For each Tube Length, One-way ANOVA is carried out for interaction AXB to decide the effect and hence post-hoc analysis by doing pairwise comparison is carried out to determine the optimal values of the factors. The Details are given in the table 5.

Table 5. Pair-wise comparison (AXB) for Percentage thickness reduction at level 1 of Factor B (Tube length)

| **Pair-wise comparison** | **Difference** | **95 % confidence interval** |
|---|---|---|
| Level 1 - Level 2 | 4.5433 | (1.6287, 7.4580) |
| Level 2 - Level 3 | -2.9400 | (-5.8546, -0.0254) |
| Level 1 - Level 3 | 1.6033 | (-1.3113, 4.5180) |

Table 5 shows that the difference between level 1 and level 3 is insignificant and the mean for the level 2 of the factor A (Die Corner Radius- 6mm) is significantly lower (16.34) than the other two level values.

Similarly to find out the pair-wise comparison of the interaction AXB at level 2 and level 3 of factor B, One-way ANOVA is carried out and found that there is no significant variation. So, the level at which mean thickness reduction is comparatively lower can be selected.

## 4. Conclusion

From the results of the FEM analysis and the effect of parameters study using Taguchi method, some prediction can be drawn

- The Die corner radius, length of tube and thickness of tube are significantly affecting the process.
- The Internal pressure can be set at the higher end in order to achieve good hydroformed component.
- The interaction between the die corner radius and the tube length is found to be significant.
- The optimum combinations of the selected significant parameters are suggested based on results obtained by ANOVA analysis.
- Summary of the optimal combination of selected parameters for minimum percentage thickness Reduction is tabulated in table 6 below.

Table 6. Summary of Optimal Combinations for Minimum Percentage Thickness Reduction

| **Sr. No.** | **Details of Requirement** | **Optimal Combination of Factors and level for the minimum percent thickness reduction** | |
|---|---|---|---|
| 1 | When Tube length is 120mm | Factor A | Level 2 |
| | | Factor B | Level 1 |
| | | Factor C | Level 3 |
| | | Factor D | Level 3 |
| 2 | When Tube length is 140mm | Factor A | Level 2 |
| | | Factor B | Level 2 |
| | | Factor C | Level 3 |
| | | Factor D | Level 3 |
| 3 | When Tube length is 160mm | Factor A | Level 1 |
| | | Factor B | Level 3 |
| | | Factor C | Level 3 |
| | | Factor D | Level 3 |

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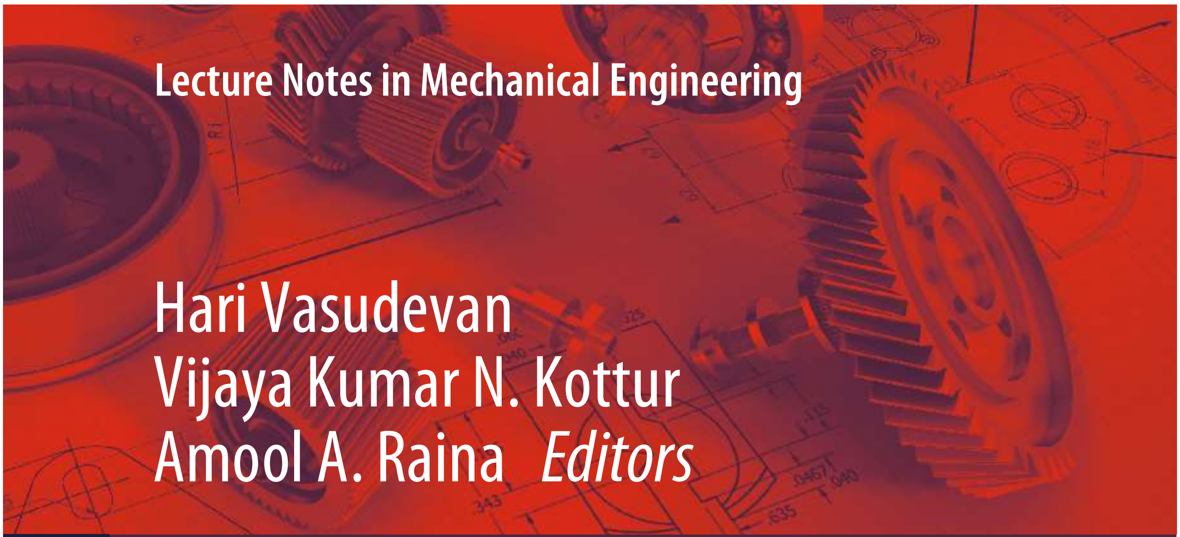

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# A Perspective of Integrated Machine Vision Based-Multivariate Statistical Process Control

**Ketaki N. Joshi and Bhushan T. Patil**

**Abstract** Machine vision systems have proven their potential of effectively inspecting objects under consideration for surface and dimensional defects using various texture analysis techniques. However, current use of machine vision systems in industry is broadly limited to acceptance or rejection of product based on its quality. Their potential of providing complete solution to quality is not completely explored and utilized. Hence their exist opportunities for utilizing machine vision systems not only for inspection, but going one step ahead and using it for quality control. The information extracted by machine vision systems, over the period, can be analysed for monitoring production processes and detecting out-of-control signals. This paper provides a review of the attempts made by various researchers in the direction of integrating machine vision techniques with statistical quality control methods for providing vision based solution for quality control.

**Keywords** Machine vision · Multivariate techniques · Statistical process control

## 1 Introduction

Automatic inspection systems using computer vision and image processing techniques are capable of accurate inspection and effective process monitoring. There has been a significant development in the field of machine vision systems (MVS) and have proven their potential to replace the traditional measurement systems. There exists an opportunity to extend their current usage for inspection to monitoring of

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production processes and utilizing this data in order to control the system before non-conformities occur.

Woodall and Montgomery [1] have stated that use of images for process monitoring is one of the latest trends in the area of quality control. The images of the products are often used in the industry for inspection, i.e. to separate non-conforming items from conforming items. However, they clearly stated the opportunity of developing solutions for detection of quality changes before non-conforming items are actually produced in the system by encouraging investigations and research in the area of control charting using image data.

Vining et al. [2] have also stated that currently the image data is being primarily used for quality inspection purpose; however, the future scope for research in the field of machine vision lies in exploring the opportunity of using this information to improve quality of the processes. Hence they enforce on development of statistical monitoring methodologies for image data to be the next logical step in the near future.

In the present paper, authors attempt to survey the current state of research progress achieved in the field of machine vision-based multivariate statistical control. The paper presents a review of developments in multivariate statistical quality control techniques, integration of MVS with control charting techniques and its implementation in various product and process industries carried out by various researchers.

### *1.1 Integration of Machine Vision Systems and Statistical Process Control*

Applications of modern industrial machine vision systems can be broadly categorized in four types of inspections: dimensional quality, surface quality, structural quality and operational quality [3].

Dimensional quality characteristics can be extracted by processing images of the product under inspection using various image processing techniques and feature extraction techniques. Inspection for surface quality using MVS is based on the principle that, an image is a two dimensional image intensity function characterized by the amount of light incident on the object under observation (illumination) which is dependent on the light source and the amount of light reflected from the object (reflectance) which is dependent on the characteristic of the surface of object [4]. Structural quality refers to correct assembling, which can be extracted from images of the assemblies using statistical techniques based on greyscale levels, template matching or various stochastic model-based algorithms. Operational quality deals with accuracy with which a particular operation is carried out.

Effective management of quality involves three activities namely quality planning, quality assurance and quality control and improvement [5]. Quality control and improvement is one of the philosophical pillars of quality and can be achieved primarily by using statistical process control (SPC).

Traditional process monitoring and quality control from univariate perspective is based on the assumption that only one process output is of prime concern. However in practice, a product's utility value depends on a number of quality characteristics all of which need to be controlled in the production process in order to avoid rejection of components based on non-conformance to quality. Univariate approach also affects the joint probability of sample means lying within the control limits when the process is actually in control, calculated as $(1 - \alpha)^p$, with $\alpha$ being the individual probability of sample means lying in the control limits and $p$ being number of variables. This increases the probability of type I errors. Also, the above formula is applicable only if all the characteristics are truly independent in nature, which is rarely the case in actual practice.

In these scenarios, multivariate quality control provides a more effective way to monitor process quality by simultaneously monitoring all the variables under consideration. Multivariate techniques not only extract the information on individual characteristics but also extract and monitor correlations among data [5]. The method is suitable for processes with quality characteristics up to ten in number. However, it can also be used with more variables after reducing the dimensionality using principal component analysis [6].

The multivariate process control techniques can be effectively used to monitor a process involving multiple output characteristics. If this technique is integrated with machine vision system, can provide a very effective automated system for process monitoring and control. Researchers have made an attempt to use machine vision system with multivariate statistical techniques for process control. Most of the researchers have used this technique for surface quality control whereas very few have used it for dimensional aspects of quality. It can be concluded that integration of machine vision systems and statistical process control techniques can provide a very effective, economic and reliable tool for facilitating quality control in the industries.

## *1.2 Methodology for Developing MVS Based-Process Monitoring and Control*

Methodology developed by Rogalewicz and Poznańska [7] can be adopted for developing machine vision-based multivariate quality control system.

It consists of three phases: planning phase, process capability study phase and process monitoring phase. In planning phase, process to be controlled is studied and the variable critical to its quality are selected with their tolerance limits and targets. Then the data acquisition system is to be built, which for machine vision-based approach, will include system for acquisition of images using camera and transferring them to computer systems for further analyses. Then the measurement system is to be developed, which for machine vision-based approach, will include the use of image processing techniques for measurement of quality parameters. Then in the process capability study phase, sample data with suitable sample size and sampling frequency is to be collected, analysed, then plotted using proper control chart and further analysed for examining the process stability and capability. The last phase is process monitoring phase, where control limits are to be calculated followed by process monitoring and diagnosis of out of control scenarios.

## 2 Multivariate Control Charts

Most widely used multivariate quality control charts are Hotelling $T^2$ charts. These charts use information from current sample and hence are insensitive to small and moderate shifts in process mean. Multivariate exponentially weighed moving average (MEWMA) charts overcome this limitation [8].

### 2.1 Hotelling $T^2$ Chart

Hotelling $T^2$ control chart developed by Hotelling [9] is the most widely used method for multivariate quality control. This method is a direct analogue of univariate Shewart chart. Hotelling $T^2$ charts for subgroup data can be represented using control region or chi-square chart with an upper control limit. First method suffers from loss of time sequence of data and complexity for more number of variables. Second method overcomes these limitations by plotting the statistics value for all samples. These charts can be extended for estimating population mean and standard deviation, charts in which case are called Hotelling $T^2$ charts.

$$T^2 = n\left(\bar{x} - \bar{\bar{x}}\right)' S^{-1}\left(\bar{x} - \bar{\bar{x}}\right)$$

Two distinct phases in the use of control charts have different control limits based on the usage as proposed by Alt. Phase-I has the objective to obtain in control observations in order to establish control limits for phase-II. Whereas phase-II is for monitoring the production. Accordingly, the control limits set for two phases are as follows:

| Control limits for phase-I: | Control limits for phase-II: |
|---|---|
| UCL $= \frac{p(m-1)(n-1)}{mn-m-p+1} F_{\alpha,p,mn-m-p+1}$ | UCL $= \frac{p(m+1)(n-1)}{mn-m-p+1} F_{\alpha,p,mn-m-p+1}$ |
| LCL = 0 | LCL = 0 |

Interpretation of out of control signals is the most critical step in the use of Hotelling $T^2$ charts as it differs from univariate approach. Runger et al. [10] suggested the use of decomposition method where $T^2_{(i)}$ indicates the $T^2$ statistics for all process variables except the $i$th one. Then $d_i$ calculated as $T^2 - T^2_{(i)}$ indicates the relative contribution of each parameter to the overall statistics.

Other methods include use of principal component analysis (PCA), partial least squares (PLS) for dimensionality reduction or discriminant analysis for classification of observations into groups [8, 11, 12]. PCA and projection of latent structure allow systematic examination and interpretation of highly correlated high-dimensional data [13]. Bersimis et al. [14] have discussed all the types of multivariate control charts, autocorrelation, dimensionality reduction using PCA and PLS and interpretation of out of control signals in detail.

### 2.2 *Multivariate Exponentially Weighted Moving Average (MEWMA) Chart*

Multivariate exponentially weighted moving average (MEWMA) chart developed by Lowry et al. [15] can sense the small or moderate shift in the mean vector over period as compared to Hotelling $T^2$ chart. MEWMA statistics is given as follows:

$$Z_i = \lambda x_i + (1 - \lambda) Z_{i-1}$$

where λ lies between 0 and 1 and $Z_0 = 0$

Quality term plotted on the chart is given as follows:

$$T_i^2 = Z_i' \sum_{zi^{-1}} Z_i$$

where covariance matrix

$$\sum_{zi} = \frac{\lambda}{2 - \lambda}\left[1 - (1 - \lambda)^{2i}\right] \sum$$

## 3 Literature Review

Horst and Negin [16] used two charge-coupled devices and computer server for inspecting thickness of textile and plotting control charts for mean and standard deviation in real time.

Nembhard et al. [17] implemented integrated model for statistical and vision monitoring in order to monitor the colour transition of the extruded polymer at different levels as it cools down in order to identify quality improvement opportunities. The colour transition data was captured by processing images of the polymer taken at predetermined intervals and then plotted using EWMA control chart in order to detect process shift.

Jiang et al. [18] proposed machine vision-based inspection of TFT-LCD panels for mura defects using colour/greyscale values in different regions of the panel using

EWMA chart. The positions of mura defects were easily located using EWMA chart which were further analysed for classification. Lin and Chiu [19] proposed use of Hotelling $T^2$ chart to determine the regions of small colour variation representing the mura defects. According to the survey on use of automated visual inspection in the field of semiconductors by Huang and Pan [20], semiconductor products including wafers, TFT-LCDs and LEDs are inspected for defects using many multivariate techniques one of which is the use of Hotelling statistics for texture analysis.

Tong et al. [21] used machine vision approach integrated with Hotelling $T^2$ chart to monitor wafer (IC) production process. The quality characteristics selected for charting included number of defects and clustering indices to be monitored for inspection purpose.

Liu et al. [22] developed an MVS system for capturing patterns such as stripes, swirls and ripples with different dimensions. They used wavelet transformation and principal component analysis for texture analysis and Hotelling $\mathrm{T}^2$ and SPE charts for detection of off-specification countertops.

Lin [23, 24] used wavelet characteristics for describing texture properties and Hotelling $T^2$ control charts of different texture parameters to detect existence of ripple defects in SBL chips of ceramic capacitor. Lin et al. [25] compared the capabilities of a wavelet-Hotelling $T^2$ control chart approach with that of wavelet-PCA-based approach in detecting surface defects in light-emitting diode (LED) chips and found wavelet-PCA-based approach to be more effective.

Tunak and Linka [26] extracted GLCM features energy, correlation, homogeneity, cluster shade and cluster prominence and plotted using multivariate $T^2$ charts for detecting the occurrence and location of woven defects.

Tunak et al. [27] used 2D discrete Fourier transform (DFT) and its inverse processed further for getting the images containing only warp and weft. The restored images were then used for assessing weaving density with the help of $X$-bar control chart in order to locate the sites of potential defects.

Lyu and Chen [28] integrated image processing technologies and multivariate statistical control chart for a component type having two concentric circles. The diameters of the two circles were obtained using image processing techniques and results of 35 samples were plotted in $T^2$, $X^2$ and MEWMA chart. Out of control signals were interpreted using Fuchs and Benjamin's MSSD (mean square successive difference) method [29] and Doganaksoy method [30]. They stated that the future scope for this research to use various inspection techniques, different shaped components and develop testing rules for analysing the process using control charts.

Megahed et al. [31] reviewed the work on image monitoring as a special case of spatiotemporal surveillance and use of control charts for process monitoring. Megahed et al. [32] applied spatiotemporal methods for analysis of the image data.

Grieco et al. [33] used integrated machine vision-based control charting approach for monitoring leather cutting process wherein the shape of the monitored profile was compared with baseline model using image data and deviation area was used as the quality characteristic for monitoring. Univariate and multivariate control charting approaches were simulated by using deviation area of the entire profile in first case

**Table 1** Summary of research work in MVS-based process monitoring, control

| Charting technique | Researcher | Product/process under monitoring |
|---|---|---|
| Hotelling $T^2$ | Horst and Negin [16] | Thickness of textile |
| | Lin and Chiu [19] | Mura defects in TFT-LCD panels |
| | Tong et al. [21] | Wafer (IC) production process |
| | Liu et al. [22] | Patterns-stripes, swirls and ripples |
| | Lin [24] | Ripple defects in SBL chips of ceramic capacitor |
| | Lin et al. [25] | Surface defects in LED chips |
| | Tunák and Linka [26] | Woven defects |
| | Tunák et al. [27] | Weaving density |
| | Lyu and Chen [28] | Component with 2 concentric circles |
| EWMA | Nembhard et al. [17] | Colour transition of extruded polymer |
| | Jing et al. [18] | Mura defects in TFT-LCD panels |
| MEWMA | Lyu and Chen [28] | Component with 2 concentric circles |
| Shewhart | Grieco et al. [33] | Leather cutting process |

and deviation area vector for different segments of profile in the multivariate case. They concluded that multivariate approach provides better results.

The summary of previous research work in the field is tabulated in Table 1.

## 4 Conclusion and Future Scope

An integrated approach of machine vision-based control charting can effectively facilitate process control. Multivariate approach will be beneficial over univariate in industrial practices due number of variables determining final quality and utility value of the product. Machine vision systems have been successfully used for inspection and can be implemented further for real time monitoring of production processes to detect out of control signals and shifts in process means to predict the probability of occurrence of non-conformities and control the processes before non-conformities occur.

From the literature reviewed, it is clear that MVS-based process monitoring and control is explored by very few researchers and their results indicate that the approach is feasible. It needs to be explored further for providing a mature vision-based multivariate statistical control solution to the industry [1, 2]. Most of the attempts have been made to implement this technique for quality control in electronic products and process industries. Their application in mechanical industries is still not explored to the extent required for acceptance of this technique by the industry. The research gaps identified from the literature review include application of MVS-based multivariate control charting technique to various mechanical components and assemblies for identifying dimensional errors and assembly errors, respectively. Further research in this direction would provide a new dimension to industrial quality control systems.

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# Evaluation of Surface Roughness by Machine Vision Using Neural Networks Approach

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**Abstract** Surface quality of industrial components is critical from operational, ergonomics and esthetics point-of-view. Surface roughness measurement using traditional contact-type instruments may not be feasible in the industries insisting on 100% inspection and monitoring. Machine vision-based machine learning has a potential of facilitating automated inspection of manufactured components for their surface quality. The paper presents a machine vision-based machine learning approach that works on the principle of surface texture characterization by vision-based texture analysis techniques followed by supervised machine learning using multilayer feed-forward artificial neural network with backpropagation for fitting the response (surface roughness) with the inputs (vision-based texture parameters). Performance of various texture analysis techniques based on the histogram, gray level co-occurrence matrix, Fourier and wavelet transform used for generating the training data and training algorithms used for training the networks are compared. The approach can be potentially used to estimate surface roughness of industrial components.

**Keywords** Surface roughness · Machine vision · Texture analysis · Artificial neural networks

## 1 Introduction

Evaluation of surface roughness (Ra) using machine vision-based machine learning approach is based on the principle of surface texture characterization of machined surface images using texture analysis techniques and machine learning to establish

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# Recent Advances in Mechanical Infrastructure

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# Development of JOLIS GC3000 Gas Cutter Joint Ordinate Linear Interpolation System CNC Machine

Stephen Joseph K , Ragini Joshi, Pratiksha Gangawane, Sana Kanvinde, D.S.S.Sudhakar

***Abstract*—JOINT ORDINATE LINEAR INTERPOLATION SYSTEM is an automation solution that improves the speed, accuracy and cost effectiveness of the traditional system. The basic concepts of Oxyacetylene cutting is still preserved, but operation is optimized with a motion-controlled system. JOLIS-GC-3000 is a 2 $\frac{1}{2}$ axes system that provides the torch freedom to be interpolated in various profiles. JOLIS is a controller independent system that allows the integration of PLC, PCI based, or Micro controller based Controllers. It is portable, accurate to 0.1mm, user friendly and extremely cost effective, hence suitable for all fabrication and production oriented businesses.**

***Index Terms*—CNC, Motion Control, Gas Cutter**

## I. Introduction

The design of JOLIS was developed on the basis of problems and issues that were faced by medium scale industries which use manual hand-operated gas cutting tool. It incorporates a cantilever frame structure unlike the gantry style which is preferred in CNC machines. As the structure of the gantry system would be sturdy and bulky,but the system had to be compact, portable, accurate and fast thus the design of the system was based on a cantilever system. JOLIS has a wide range of cuts spans that maybe incorporated depending on customer needs. Unlike other portable CNC systems, JOLIS need not be dismantled to be transported. It is mobile and can be swiveled for easy storage when not in use. JOLIS system is completely independent of the type of controller (PLC, Micro controller, PCI port, etc.) hence accuracy and cost can be adjusted as per customer requirements. It is extremely user-friendly especially when interfaced with a controller, which has its own library of predetermined shapes that the user could use. Hence, operators do not require extensive training or experience in operating a CNC or G and M code programming knowledge.

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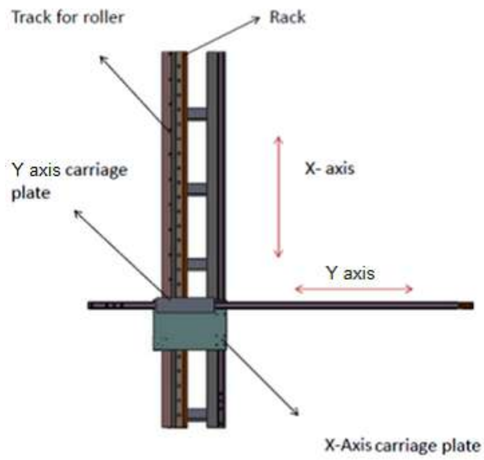


Fig. 1. Basic design of JOLIS system

## II. DETERMINATION OF FRAME DIMENSIONS

JOINT ORDINATE LINEAR INTERPOLATION SYSTEM (JOLIS) suggests the system works on the principle of producing the desired tool motion by the simultaneous fluctuations in both the X and Y-axis. The JOLIS GC 3000 is an economical solution to automation of small and medium scale industries, reducing effort and time required for production. Its high accuracy and high-speed performance ensures high productivity and quality.

### A. *Determination of Y Axis Beam*

While calculating the dimension of the Y-axis slide, it is important that the system is designed for the worst possible scenario, which is when the slide is extended to its extreme length. In that case, the system will behave like a Cantilever system.

Let us consider a composite beam made of Aluminum and Mild Steel that has been bolted together to form a single beam. Now as the dimension of the Aluminum beam is fixed, the mild steel bars can be machined onto it.

The objective it to calculate the dimension of the steel beam required to keep the deflection of the entire system below 0.1mm.

$$\delta_T = \delta_W + \delta_L$$

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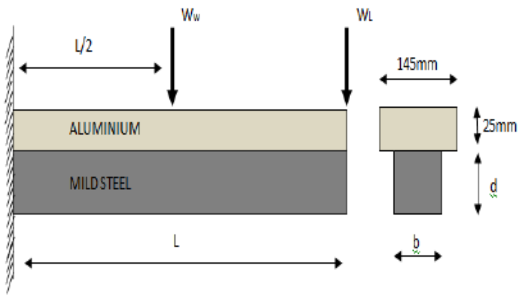


Fig. 2. Composite beam

$\delta_W = \frac{W_W l^2}{6EI}\frac{5l}{2}$

$\delta_L = \frac{W_L l^3}{6EI}$

Where:W=Weight,L=Length.

Assume the maximum deflection to be 0.1mm, therefore:

$\delta_T = \frac{W_W l^2}{6EI}\frac{5l}{2} + \frac{W_L l^3}{3EI}$

$= \frac{l^3}{3EI}\frac{5W_W + W_L}{4}$

$0.0001 = \frac{2.3^3}{3EI}\frac{5W_W + 58.84}{4}$

Now as the two beams are stacked one on top of the other, and the forces are acting perpendicular to both of them, the Effective Young's Modulus is given by:

$\sum_{i=1}^{n}\frac{V_i}{E_i} = \frac{V_{MS}}{E_{MS}} + \frac{V_{Al}}{E_{Al}}$

where MS= mild steel and AL= Aluminium

$E = b \times d \times 1.15 \times 10^{-11} + 1.21 \times 10^{-12}$

$= \frac{b\times d\times 2.3}{200\times 10^9} + \frac{0.145\times 0.25\times 2.3}{69\times 10^9}$

Now the total weight of the entire beam system, $W_w$ is given by:

$W_w = [(b_{Al} \times d_{Al} - 2\pi r^2) \times \rho_{Al} + 2\pi r^2 \times \rho_{MS} + b_{MS} \times d_{MS} \times \rho_{MS}] \times L$

where:
$b_{AL} = 0.145m$
$d_{AL} = 0.025m$
$\rho_{AL} = 2700kg/m^3$
$\rho_{MS} = 7750kg/m^3$
$r = 0.022m$

$W_w = [(0.145 \times 0.025 - 2\pi(0.022)^2) \times 2700 + 2\pi(0.022)^2 \times 7750 + b_{MS} \times d_{MS} \times 7750] \times 2.3$

$W_w = [7.735 + 5.892 + 7750 \times b_{MS} \times d_{MS}] \times 2.3$

$W_w = [31.342 + 17.825 \times 10^3 \times b \times d]$

Moment of Inertia of system is calculated by the derivation:

$I_X = \int y^2 dA$

Now calculate the moment of inertia of the composite system , use parallel axis theorem:

$I_x = (\overline{I_x} + d^2A)_{AL} + (\overline{I_x} + d^2A)_{MS}$

$\overline{y} = \frac{(b\times d\times y)_{AL} + (b\times d\times y)_{MS}}{(b\times d)_{AL} + (b\times d)_{MS}}$

$= \frac{(0.145\times 0.025\times(d+0.0125)) + (b\times d\times \frac{d}{2})}{(0.145\times 0.025) + (b\times d)}$

$\overline{y} = \frac{\frac{b\times d^2}{2} + 3.265\times 10^{-3}(d+0.0125)}{3.265\times 10^{-3} + bd}$

Now for the simplification of calculation, assume that:

$b = d$

$\overline{y} = \frac{\frac{d^2}{2} + 3.265\times 10^{-3}(d+0.0125)}{3.265\times 10^{-3} + d^2}$

The Moment of Inertia is:
$I_x = (\overline{I_x} + d^2A)_{AL} + (\overline{I_x} + d^2A)_{MS}$

$I_x = [\frac{0.145\times 0.025^3}{12} + 0.145 \times 0.025(d + 0.0125 - \overline{y})] + [\frac{d^4}{12} + d^2(\overline{y} - \frac{d}{2})]$

Now substituting $\overline{y}$ and differentiate $I_x$ with respect to d, we get:

$\frac{d(I_x)}{d(d)} = A' + B' + C'$

where
$A = \frac{0.145\times 0.025^3}{12} + 0.145 \times 0.025(d + 0.0125 - \overline{y})$
$B = \frac{d^4}{12}$ and $C = d^2(\overline{y} - \frac{d}{2})$

Thus the resultant equation is:
$d^4 + 3.66 \times 10^{-3}d^2 - 1.83 \times 10^{-4}d + 2.62 \times 10^{-5}$

Now equating it to zero, as this would give the maximum value of $I_x$ , which would give the least amount of material required to keep the deflection below 0.1 mm.

$d^4 + 3.66 \times 10^{-3}d^2 - 1.83 \times 10^{-4}d + 2.62 \times 10^{-5} = 0$

The above expression is derivated w.r.t d and equated to zero to find optimized value of d. Thus, the real solution obtained is d=0.03637 m
Compare this result with various cross-sections in regard with the moment of inertia equivalent with the study carried out on FEA Software it was determined that rectangular cross-section provides the best alternative, requiring least material

for equivalent deflection.
Hence,MS 60 x 40 x 2.6 beams are selected.

## B. MOTOR SELECTION

Now the Rack and Pinion system that has been recommended for the high precision solutions such as a CNC machine is:

**Rack:**
Material: Stainless Steel,Grade 416
Treatment: Hardened to 35-45 HRc
Pressure Angle: 20

**Pinion:**
Material: Stainless Steel,Grade 17-4 PH
Treatment: Hardened 36/40 HRc
Pressure Angle: 20

**Load Torque Calculation:**
$F = F_A + mg(\sin\theta + \mu\cos\theta)$
Where:
F:Force of moving direction.
$F_A$:External Force.
m:Total mass of table and load.
$\theta$:Tilt angle in degree.
g:gravitational acceleration.

Where $\mu$ between stainless steel-stainless steel is (0.5-0.8) Now calculating for the worst possible scenario, consider $\mu$ = 0.8
$T_L = \frac{F}{2\pi\eta} \times \frac{\pi D}{i} \times \frac{FD}{2\eta i}$

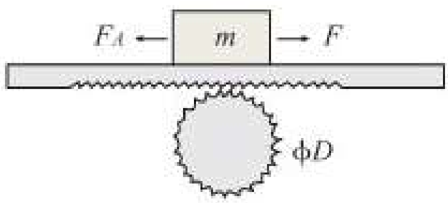


Fig. 3. Rack and pinion for Y-axis beam

Where:
F=Force of moving direction.
$\mu^0$=Internal Friction coefficient of preload nut(0.1∼ 0.3)
i=Gear Ratio(This is the gear ratio of mechanism)
$P_B$=Ball screw lead.
$F_A$=External Force.
m=Total mass of the table and load.
$\mu$=Friction coefficient of sliding surface(0.05).
$\theta$=Tilt angle(Degree).
D=Final Pulley Diameter.
g=Gravitational Acceleration.

## C. Dimensions of X axis Beam

**Load Torque Calculation:**
$F = 0 + 23.88 \times 9.81 \times 0.8 = 187.41N$
$T_L = \frac{187.41 \times 0.047}{2 \times 0.85 \times 1} = 5.181Nm$

Therefore the required torque for X axis system is: 5.181 N-m

**X axis slide system:**

Now the total weight of the carriage and X slide system is:
W = Y beam + Torch mounting + Y motor
$= 36.37^2 \times 2300 \times 0.00785g/mm^3 + 6kg + 5.4kg$
$= 35.28Kg$

**Load Torque calculation:**
$F = 0 + 35.28 \times 9.81 \times 0.8 = 276.90N$
$T_L = \frac{276.90 \times 0.047}{2 \times 0.85 \times 1} = 7.655Nm$

**Motor selection:**
As the maximum desired Torque is 7.65 N-m, 8.7 N-m Bipolar Stepper Motor is selected. Thus the motor selected is
Model : 34H-155-50-4A
Type : Bipolar

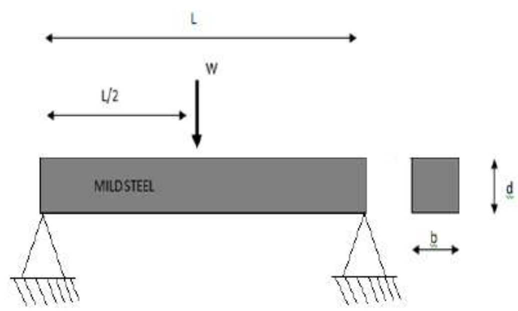


Fig. 4. Simply Supported Beam

W = Y beam + Torch mounting + Carriage + X motor + Y motor
=23.88kg + 6kg + 20kg + 5.4kg + 5.4kg
= 60.68kg
Assume that various components (i.e. welds, nut and bolts, etc.) add up to this weight. Thus W ≈70kg .
The maximum deflection of a simply supported beam is at its mid-point:
$\delta = \frac{-Wl^3}{48EI}$

Equating it to 0.1mm and by assuming that

b = d,

Therefore symbol
$$0.0001 = \frac{(27475d^2+343.23)3.5^3)}{48\times 210\times 10^9\,\frac{d^4}{12}}$$

Reducing the above equation and solving:
$1.96 \times 10^5 d^4 + 27475d^2 + 343.23 = 0$
d = 0.117 m
Compare this result with various cross-sections in regard with the Moment of Inertia equivalent; find the best alternative with least material consumption.

Hence from the study carried out on FEA Software it was determined that rectangular cross section provides the best alternative, requiring least material for equivalent deflection.

Hence, MS 80 x 40 x 4.8 beams are selected.

### D. Selection of Optimum Beam Cross-section using FEA Software

FEA Software is used for analyzing various cross-sections. These can be used as an alternative for the calculated square beams. This is done by finding the dimensions required to sustain a maximum deflection of 0.1 mm.
Weight of Material required = (Area) x L X Density of Mild

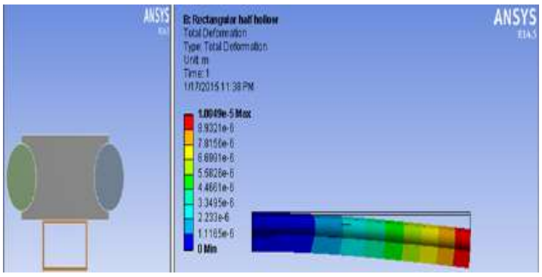


Fig. 5. FEA Analysis

Steel = 28.893024 kg
**Tabulating the results,**

TABLE I
COMPARISON BETWEEN VARIOUS CROSS-SECTIONS

| Type of C/S | Volume ( $10^4 mm^3$) | Weight (kg) | Deflection ($10^{-3}$mm) | Stress (Mpa) | Rating Factor $10^{-3}$ |
|---|---|---|---|---|---|
| Rect- -angular Hollow | 0.6582 | 51.6687 | 5.81 | 0.1532 | 3.826 |
| Half Rect Hollow | 0.3680 | 28.8930 | 10.04 | 0.22115 | 3.698 |
| H Flat Plate | 0.36 | 28.26 | 15.044 | 0.17343 | 5.415 |
| C section | 0.4 | 31.4 | 10.21 | 0.2841 | 4.087 |
| V Flat Plate | 0.48 | 37.68 | 10.01 | 0.29395 | 4.806 |

Comparing the results on the basis of deflection to weight proportion, the Rating Factor was devised, which is basically the product of volume and deflection. Lower the Rating factor, better the alternative solution. From the table it is clear that the half rectangular pipe beam provides the best

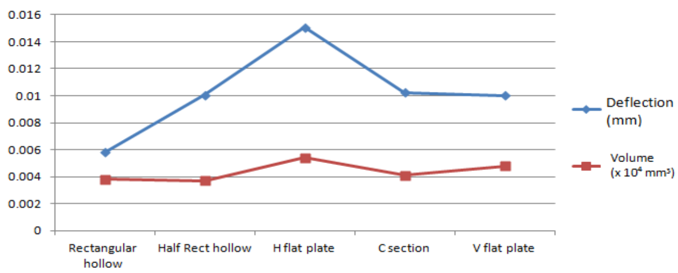


Fig. 6. Plot of the values of various cross-sections

solution. Hence, rectangular pipe beam of<u>MS 60 x 40 x 2.6</u> is selected.

## III. CONCLUSION

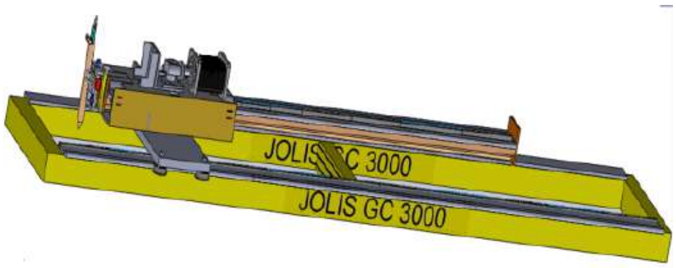


Fig. 7. Final Design of JOLIS GC 3000

Fig. 8. Final Design of JOLIS GC 3000

As the structure of the JOLIS GC 3000 is designed and analyzed with the help of FEA Software, the deflections due to static loading are less than 0.1mm. These deflections were measured with the help of laser calibrators. Successful trial runs of the system were done by triggering the X and Y slide motors, initially with the help of a PLC system. This trial run proved that the system was as designed and all loading conditions were met. ANSYS simulations results were seen to be identical, implying that the models were accurate. The completion of the project entails the calibration of the Controller, Gas torch and Z-axis motor. Till now, the project seems to be running smoothly and on time. Recent tests that were conducted resulted in an accuracy of ± 1mm. The JOLIS GC 3000 was able to produce a variety of simple and complicated shapes that were available in the controller's library. Further, all the initial desired key features are incorporated and functioning as desired. Future improvements such as weight reduction, introducing sensors and height compensation to provide a closed loop, complicated controls modeled by better mathematical formulations like NURBS can be implemented. JOLIS GC 3000 provides an easy, fast, reliable and accurate automation solution for Gas Cutting.

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Fig. 9. Final Build

Fig. 10. Prep for First cut

Fig. 11. First cut of JOLIS GC 3000

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# Computer Aided Design And Analysis of Volatile Separating Device

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**Abstract**

Volatiles in the current context are molecules with boiling point up to $200^{O}C$. Conventional methods for separating volatiles are biased towards one of the physical or chemical properties of the molecule and hence are not complete. So volatiles separated from the mother matrix will contain fewer molecules and even the most precise instruments can resolve only fewer molecules. On the other hand a better sampling device utilizing thermal desorption, kinetic desorption, solubility in steam, desorption by microwave, desorption by magnetic induction or laser can separate larger number of molecules and hence can enhance the efficiency of instruments like MS. A sampler using thermo-kinetic desorption was fabricated in house and comparative study was conducted against conventional techniques. A 25 percent increase in peaks was observed when analysed with GC. The possibility of thermal decomposition was ruled out by conducting GC- MS studies.
The aim of the current study is to develop a highly precise sampling device with global standards and has wide applications in the field of aromatic, analytical, biological and medical fields.

Peer-review under responsibility of organizing committee of the 4th International Conference on Advances in Computing, Communication and Control (ICAC3'15)

*Keywords:* Desorpter Cartridge Heaters; Turbulent Kinetic Energy; Turbulent Intensity; Turbulence Dissipation Rate; Peltier Chips; Heat Sink; Linear Motor.

## 1. INTRODUCTION

This Report describes a new design approach that came from a volatile separation technology. The conventional methods, separated volatiles from materials from Organic matters are biased to any single physico-chemical properties of the volatile and are efficient to separate low boiling fractions only. The goal of this new design approach is to

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provide better heating and cooling modes, Equipment, maintaining of inert atmosphere in envelope, well stabilized desorption-adsorption process for volatiles from the provided organic matter.

Volatile is a substance which can change state from a solid or liquid to vapour. Gas chromatography (GC) is the instrument used to study volatiles and it can analyse molecules whose boiling points are as high as $250^{O}C$ or more. But it is necessary to make sure that Non-volatile material should not enter into the GC column. So there is a requirement of a safe sampling device for GC. Sampling device is separator unit, which will extract the molecules or volatiles from the given sample.

The Prototype device for this is already manufactured, which is a POC (Proof of Concept). The goal of this report is to reduce the size of complete equipment, modular design. For the purpose of heating the envelope electrical heaters are used with sensor for establishment of feedback control system. Also for cooling the purpose electric cooling chip are used, which works on peltier effect.

This report also analyses influence of the internal geometry design over flow path of nitrogen gas and turbulence created by pressurized nitrogen gas, with the help of CFD software.

## 2. Literature Review

Following literature describes the prototype of Volatile Extraction Device developed previously. This device works on thermo-Kinetic Principle of extraction. The equipment contains following parts [4]:

1. PID Controller.
2. Electrical Circuit.
3. Flow and Temperature control.
4. Desorpter and Condenser.
5. Absorbent.
6. Heating and cooling Media.
7. Critical components of the system are design and geometry of Desorpter and Condenser, selection of heating and cooling media, absorbent material, and feedback control system for governing temperature, flow and Pressure.

### 2.1. Working

A solid or semisolid sample containing volatiles is heated using multiple sources in a current of dry or moist (controlled) Nitrogen and the effluents are driven to a frigid cartridge pre-loaded with appropriate adsorbent. Once the adsorption is complete, the cartridge can be flash heated and the pneumatics drive the volatiles through appropriate membrane filters to the GC for analysis. Membrane filters are used to selectively detain water molecules and molecules of particular choice. Fig.1 shows the typical layout of existing system.

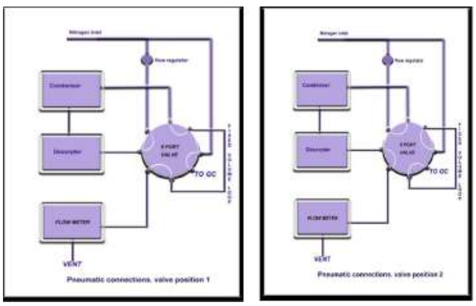


Fig. 1. Typical Layout of Existing System. [4]


Fig. 2. Protoype Desorpter. [4]

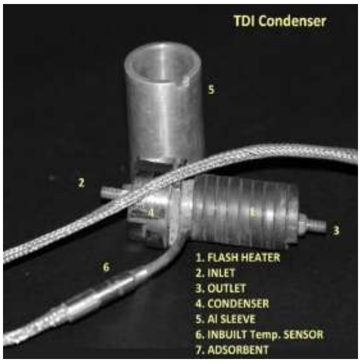


Fig. 3. Prototype Condenser. [4]

### 2.2. *Description of various sub-systems*

1. **Desorpter:** Fig.2 shows desorpter unit, which is a single piece unit carved out of 316 grade stainless steel (food and surgical grade, ideal for pressure reactors and boilers and is corrosion resistant) and fitted with screw cap for sample load. A GC septum or O rings secured airtight sealing. Holes are drilled in the body to accommodate the cartridge type heaters and temperature sensors. The heaters and sensors are connected to the thermostat and can be programmed from ambient temperature to $350^{O}C$in multi steps.
2. **Condenser:** Fig.3 shows the condenser unit is slightly more complex than the desorpter both in functioning and in construction. The main body is 316 stainless steel cylinders with a 1cm x 6cm hole drilled in. The adsorbent material is packed in here. A special heater with inbuilt thermo sensors is wound around the condenser tightly. This heater is capable of heating the condenser to $250^{O}C \pm 1^{O}C$ in just 5 seconds. The cooling system consists of two aluminium boxes with cylindrical slit at its centre. These boxes are driven with a lever system to separate them from the condenser or to bring them close to the aluminium sleeve. The coolant used is a mixture of dry ice and acetone.

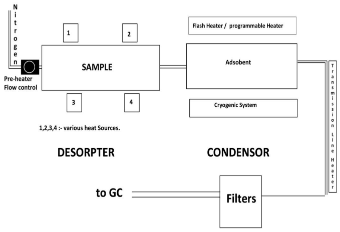


Fig. 4. Proposed Volatile Separator Systems. [4]

## 3. Method

Fig.4 shows proposed modular system, in which desorpter can be heated by various sources like coil, cartridge, lasers, induction heaters. Condenser unit is separately cooled followed by flash heating.

### *3.1. Desorpter Design*

CFD Analysis on Previous Design:
Fig.5 shows the CAD model of previously developed desorpter. The sample is kept in bore and closed with cap which is threaded. At the inlet nitrogen gas of room temperature and at pressure of 2 Bar enters into the chamber. Two Cartridge heaters of 100 watts each placed heat up the internal volume. These cartridge heaters provide temperature up to $250^{O}c$ in 20 minutes.

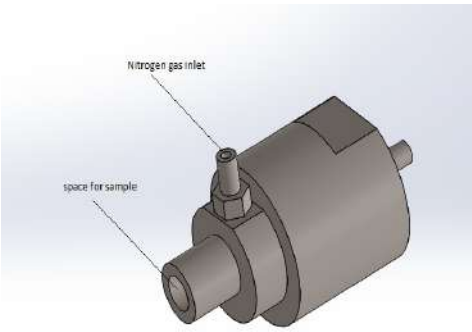


Fig. 5. CAD Model of Old Desorpter.

Boundary Conditions for flow Analysis:
Inlet Pressure- 2Bar
Inlet temperature-300k
Wall Temperature-623k
Outlet temperature-300k
Viscous Model- K-epsilon

Result:
In fig.6, At the inlet pressure is around$1.83e^{05}$ pa. After impact pressure reduces to $1.62e^{05}$ pa. When gas travels through outlet, the cross section is reduced to 2 mm due to which pressure drops further to $1.04e^{04}pa$ which is nearly atmospheric pressure.
In fig.7, It is observed that in the velocity profile flow direction is perpendicular to sample bore axis. Due to straight impact of nitrogen stream with pressure value 2 bars, the flow is dispersed and lot of turbulence is created. Maximum

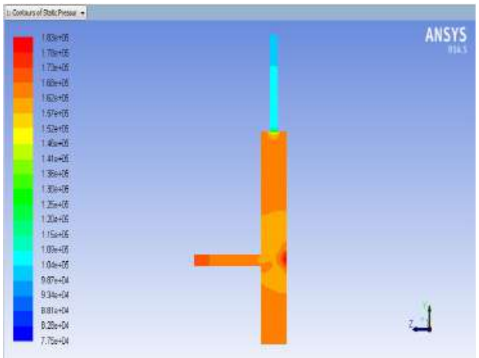


Fig. 6. Pressure contour.

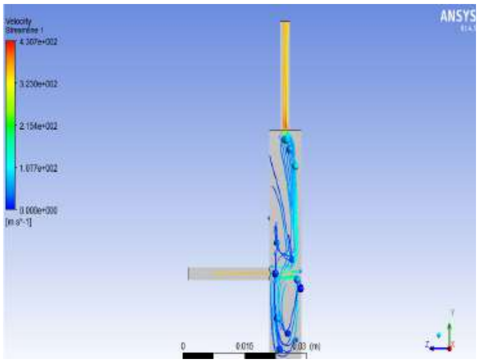


Fig. 7. Velocity contour for old design.

velocity is at outlet, which is approximately around 420 m/s which is very high.

Fig.8 shows that at outlet where the cross section is suddenly reduced is having maximum turbulence Kinetic energy.

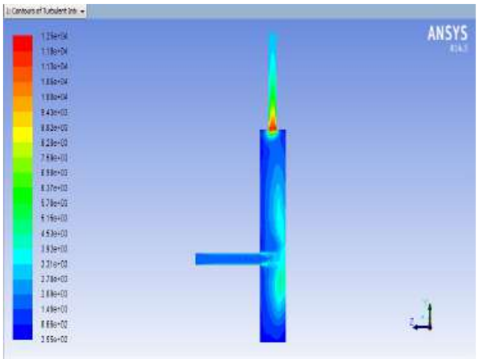


Fig. 8. Turbulence Kinetic energy.

But the flow should be less turbulent to carry the volatiles out of the chamber. Hence it is very necessary to streamline the flow once volatiles are extracted.

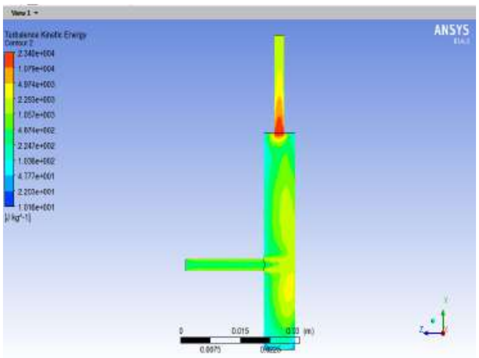


Fig. 9. Turbulence Intensity energy.

Fig.9 shows that the range of turbulence intensity in the unit after nitrogen gas enters is around $2.55e^2$ to $1.25e^4$. This contour also shows that the region where cross section area is reduced suddenly, TI value is highest around $2.55e^2$.

### 3.2. Practical Data For Old Desorpter

Pressure at outlet: Near to Atmospheric Pressure (101325 pa)
Time taken by heaters to heat the desorpter : 20 minutes

It is observed that the experimental values and Simulation values are matching. Hence we can say that the CFD simulation is Valid.

### 3.3. New Desorpter Design

We modified the design of component. In new design,the direction of flow is at an angle so that turbulence wont create backflow. Because backflow will restrict the movement of volatiles and nitrogen from inlet. There is space for sample, so that it should not be displaced due to impact of nitrogen gas. Also the outlet tube is tapered fir internal hole, to avoid backflow loop at outlet of chamber as shown in fig.10.

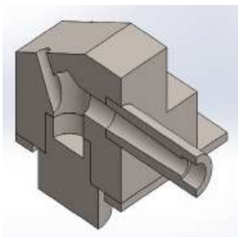

Fig. 10. CAD model of Modified Design of Desorpter.

### 3.4. Heaters Selection

To improve the heat generation rate and minimise the heating time we used following equation for raising the temperature of unit up to temperature of $250^O C$ in 10 minutes, the wattage of heater is given by:

$$KW = \frac{Wt.C_p.\Delta T}{3412.H} \quad (1)$$

Wt = weight of material to be heated
Cp = Specific Heat of Stainless steel
T = Temperature rise.
H= Heating time in Hours.
It is decided to use two heaters of 150 watts power.

### 3.5. Simulation of New Desorpter Design with CFD

Boundary condition:
Inlet Pressure : 2 Bar
Internal Temperature: 623 k
Turbulence Equation: K-epsilon model.

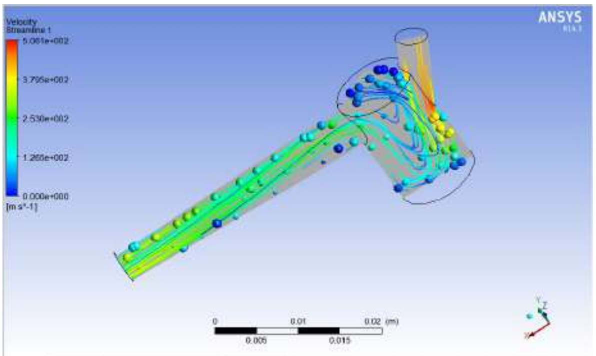


Fig. 11. Velocity Streamline for modified design.

The fig.11 shows the path of nitrogen gas travels from inlet to outlet. It is reduction from 506 to 379 m/s approximately.

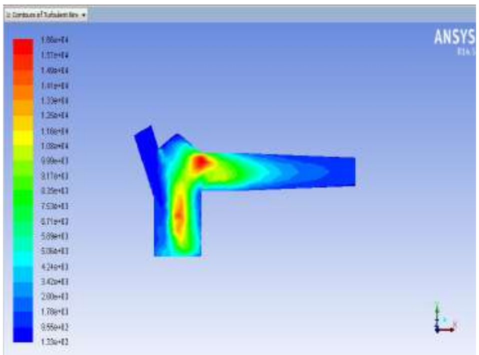


Fig. 12. Turbulent Kinetic Energy Contour.

In fig.12, The range of TKE is from 49.3 to 16500 $m^2/s^2$. It is maximum where the stream of nitrogen gas is coming from inlet of diameter 4mm and entering in suddenly enlarged region of diameter 15mm. This is where we need maximum turbulence to occur. As soon as it strikes on sample with full kinetic energy, the path of gas molecules is disturbed. As compared to old design the TKE at outlet is decreased due gradual decreasing cross section area towards outlet.

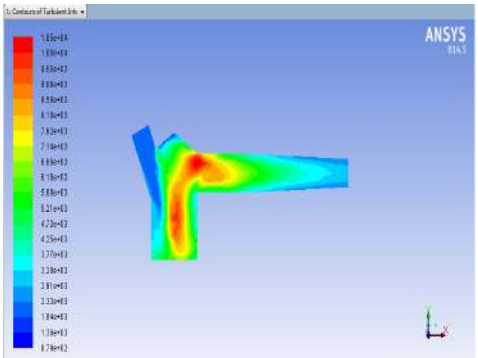


Fig. 13. Turbulence Intensity.

The goal of this design was to allow turbulence at sample space and avoid it at outlet zone. Fig.13 shows that new design will satisfy this requirement of the process. As it show that turbulence intensity at sample space around 10500 $m^2/s^3$ and at the outlet it is very less.

### 3.6. Turbulence model

The k- $\varepsilon$ model has become very popular due to the important role played by  in the interpretation of turbulence in addition to the fact that  appears directly in the transport equation for k. This turbulence model provides a good compromise between generality and economy for many CFD problems. The exact transport equation for the turbulent kinetic energy, k, can be deduced from the equation for the kinetic energy by Reynolds decomposition and reads.

$$\frac{\partial k}{\partial t} + U_j * \frac{\partial k}{\partial x_i} = -(U_i U_j)\frac{\partial U_i}{\partial x_i} - V(\frac{\partial U_i}{\partial x_i} * \frac{\partial U_i}{\partial x_i}) + \frac{\partial}{\partial x_i}(V\frac{\partial k}{\partial x_i} - \frac{<U_i U_{iiU_j}>}{2} - \frac{<U_j p}{\rho}) \tag{2}$$

The exact $\varepsilon$ equation can be written as:

$$\frac{\partial \varepsilon}{\partial t} + U_j * \frac{\partial \varepsilon}{\partial x_j} = C_{\varepsilon_1} V_T \frac{\varepsilon}{k}[(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{x_j})\frac{\partial U_i}{\partial x_j}] - C_{\varepsilon 2}\frac{\varepsilon^2}{k} + \frac{\partial}{\partial x_j}[(V + \frac{V_T}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_j})] \tag{3}$$

Where,
k-Kinetic Energy
$U_i$- Velocity in X-direction
$U_j$-Velocity in Y-direction
v- Kinematic Viscosity
$\rho$-Density
C-Constant
$v_T$-local turbulent viscosity
$\sigma_\varepsilon$- Prandtl-Schmidt number

This model is suited for flows in which the turbulence is nearly isotropic and flows in which the energy cascade proceeds in local equilibrium with respect to generation. Furthermore, the model parameters in the k-$\varepsilon$ model are a compromise to give the best performance for a wide range of different flows. The accuracy of the model can therefore be improved by adjusting the parameters for particular experiments. As the strength and weaknesses of the standard k-$\varepsilon$ model have become known, improvements have been made to the model to improve its performance.

### *3.7. Condenser Design:*

The function of condenser is to concentrate the volatiles by first cooling them up to $-30^{O}C$ and trapping it with in absorber. Absorber is a porous material which only allows nitrogen gas to pass through and will trap volatile. Again to release the volatiles absorber is flash heated up to $250^{O}C$. Then it delivers the volatile in GC machine. Fig. 14 shows the sectional 3D view of previous condenser and porous absorbent material.

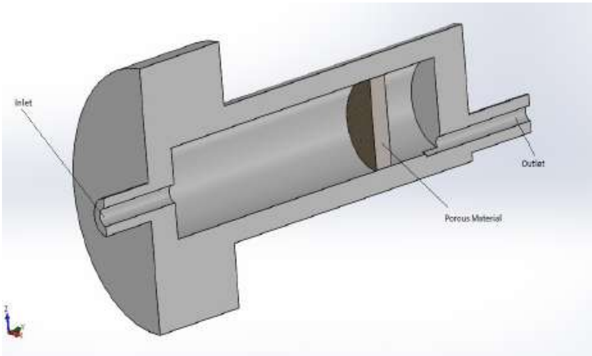


Fig. 14. 3D Model of Condenser.

Specifications of Old Condenser: Inlet Diameter = 4mm
Outlet Diameter = 4mm
Internal Space Diameter = 12mm
Total Length = 85mm
Porous disc Size =$\phi$ 12 x 3 mm
Porous disc Material = Bentonite
Component Material = SS316 (Food Grade)
Mass = 180 gms.

### *3.8. Heating and Cooling Set-up*

Dry ice-acetone system which is a cooling bath is a liquid mixture used to maintain low temperatures, typically between 13 to -78$^{O}$C was used to cool the condenser. It uses mixture of 3 components. Components are cooling agent (dry ice), a liquid carrier (Acetone) and an additive to depress the melting point of system.

Cooling process, the volatiles are trapped in the porous disc. So to release them and transport them to GC machine, the temperature of fluid domain need to be raised to 250$^{O}$ C within 2 minutes. So to flash heat the condenser, special coil heaters are made, which fits on the condensers outer surface.

### *3.9. Condenser System Design*

For cooling purpose it is decided to use Peltier chip for ease of manufacturing and operation. Fig.15 represents 3D model of new condenser designed to accommodate the cartridge heaters and peltier chips. Fig.16 shows typical 3D model of peltier chips and carrier arrangement. Peltier chip works on reverse principle of peltier effect.
In order to cool the condenser up to -30$^{O}$c, we need to know how much heat is to be extracted from condenser when it is in room temperature. So the heat to be extracted from condenser:

$$Q = m.C_p.\Delta T = 19,960J \tag{4}$$

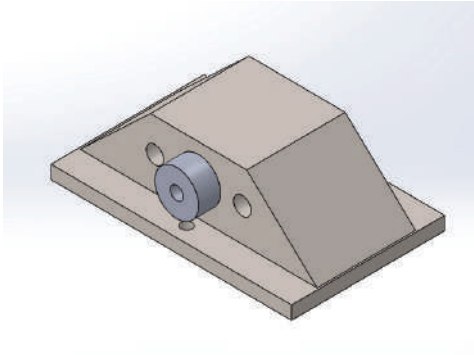

Fig. 15. 3D Model of New Condenser.

Total heat to be extracted from condenser is 166.33 watts. But a single peltier chip would be insufficient. hence It is decided to use 3 peltier chip. According to available peltier chip in the market, the following specifications are best suited for the purpose:
Model - TEC01-12704
Size - 40X40X4.7 mm
Imax - 4 Amp.
Voltage - 15 V
Qmax -37.7 watts.
$\Delta$T- 67 k

Peltier chips will get damaged when exposed to temperature exceeding $100^{O}$c. Hence to prevent chips from getting damaged, it needs carrier of thermally conductive material. When carrier is in contact with condenser surface, it will transfer heat from condenser to chip and when condenser is flash heated it will break the contact with condenser by means of mechanical linkages.

So to move peltier along with carrier, we have used linear motor. This linear when energized, moves its shaft in linear vertically upward direction. The figure below shows typical arrangement of Condenser, Linear motor, Brackets, Peltier chip, Carrier, Heat sink in set up.

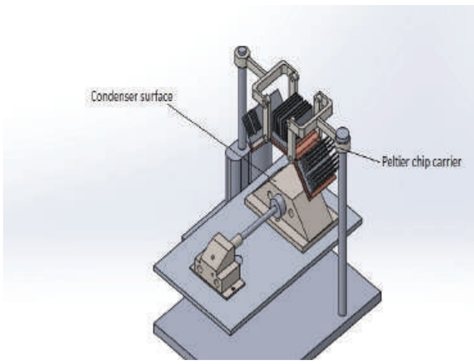


Fig. 16. Peltier chip in Disengaged position.

*3.10. Heat Sink Selection*

Application of Heat sink in this is the same, i.e. Dissipation of heat. the heat which generated on top side of peltier chip can dissipated by using Heat Sink and Blowing fans.

To select the heat sink, we need to determine the Junction to ambient thermal Resistance. Thermal resistance for junction to ambient:

$$R_{j-a} = \frac{T_j - T_a}{Q} \tag{5}$$

$R_{j-a}$ = Resistance junction to ambient = 1.31 $^{O}$c /w
Tj = Junction Temperature = 67$^{O}$c
Ta = Ambient temperature = 20$^{O}$c
Q = Total heat developed = 36 watts

### *3.11. Thermal Analysis of Heat Sink*

Heat generated by Peltier chip

$$Q = m.C_p(t_2 - t_1) = 925J \tag{6}$$

Where, m- Mass of device
cp - Specific heat of Silicon
$t_2$- Hot side temperature of peltier chip
$t_1$- Room Temperature Heat Dissipated by fins:

$$Q_{fin} = KA_c m(t2 - t1)[\frac{h \cosh mL + mk \sinh mL}{mk \cosh mL + h \sinh mL}] = 307.05Watts \tag{7}$$

Where,
k = Thermal conductivity of Aluminium.
$A_c$= Surface area.
h = Heat transfer coefficient.
L = Length of Fins.

### *3.12. Convective heat transfer coefficient*

$$G_r = \frac{gL^3\beta t_2 - t_1}{V2} = 13.74E6 \tag{8}$$

Where,
g = Acceleration of gravity
$\beta = Airthermalexpansioncoefficient = \frac{1}{t_1}$
v = Kinematic Viscosity

Prandtl number:

$$P_r = \frac{\mu C_p}{k} = 0.83 \tag{9}$$

Where,
$\mu$ = Dynamic Viscosity of air
$c_p$ = Air Specific heat
k = Thermal Conductivity of air

Rayleigh number:

$$R_a = G_r P_r = 11.40E6 \tag{10}$$

Where,
$G_r$ = Grashof number
$P_r$ = Prandtl number

Nusselt number:

$$N_u = 0.27R_a^{0.25} = 15.68 \quad (11)$$

Convective heat transfer Coefficient:

$$h_c = \frac{N_U k}{L} = 8.6Watt \quad (12)$$

### *3.13. Heating of Condenser*

After cooling process, the volatiles are trapped in the absorber porous material. Further these volatiles need to be released from the porous zone. In order to release them, we need to heat the condenser up to temperature $250^O c$ in 3 minutes.
Wattage calculation for Cartridge heaters:

$$W = \frac{W_t C_p \Delta T}{3412H} = 471.86Watt \approxeq 500Watt. \quad (13)$$

Wt = weight of material to be heated = 0.7 kg
$C_p$ = Specific Heat of Stainless steel = $500 j/kg^O$k
$\Delta T$ = Temperature rise = $230^O$c
H= Heating time in Hours = 0.05

### *3.14. Selection of Absorbent Material*

After heating the condenser, flow of nitrogen gas at atmospheric pressure is passed through cold trap. This flow drives the released volatiles out of the condenser and moves them towards GC.

The absorbent material selected is bentonite.
Specifications of bentonite:
Particle size - mesh 2-3 mm.
Surface Area - $\frac{61m^2}{g}$
Temperature range - good stability over $350^O$c
Pore size -59.31 A.

### *3.15. Mechanism to move the Peltier chip unit.*

It is necessary to keep the peltier set up away from the condenser, when it is heated. So we decided to use the linear motor for the purpose. The total load to be lifted is approximately 0.7 kg.

Specification of Linear Motor:
Brand - Progressive Automations
Model - PA-14 Linear Actuator
Voltage - 12V
Current - 5A
Load Capacity - 35 lbs
Stroke Length - 3 Inches

In fig.17, the Linear Motor is kept on one side of the condenser. Carrier and shaft of Linear motor connected by a bracket; so that when shaft moves upside, simultaneously the carrier will move in same direction disengage the cooling process. If cooling process need to engage again, then shaft movement will be downward.

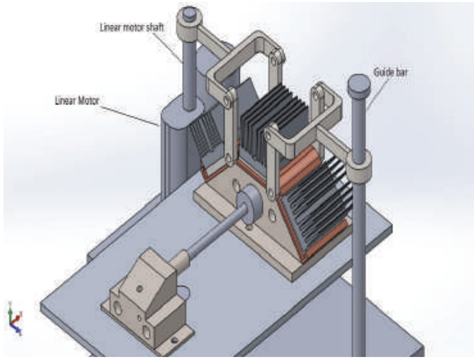


Fig. 17. Peltier set up moving Mechanism.

### 3.16. Heat transfer Analysis for Condenser

To determine the heat distribution analytically, we had transient thermal transient analysis for new condenser model. Fig.18 shows the arrangements of cartridge heaters placed in the bores. Following boundary condition were applied:

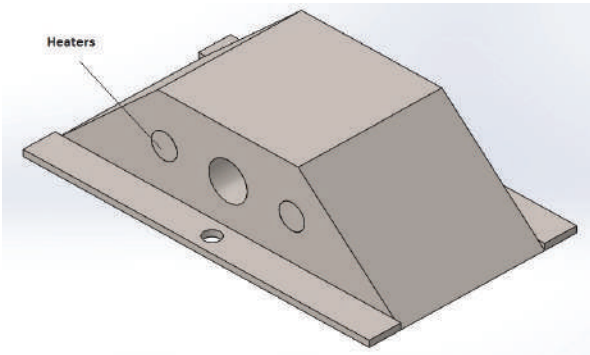


Fig. 18. Condenser model with 2 Heaters.

Initial Temperature - $20^{O}C$
Maximum Temperature - $250^{O}c$
Heat Transferred from heaters to Condenser:

$$Q = mC_p(t_2 - t_1) = 80.5KW \tag{14}$$

Where,
m = Mass of Condenser Body
$c_p$ = Specific heat of stainless steel
Time of heating = 300 seconds

### 3.17. Result:

Fig.19 shows the relation between time and temperature rise. So the graph shows that after 100 seconds the temperature of condenser reaches near $250^{O}c$.

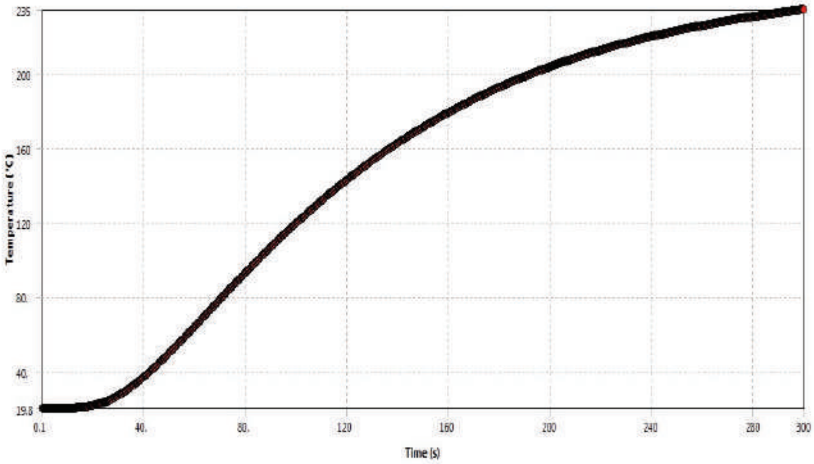


Fig. 19. Graph of Temperature Vs. Time for Condenser.

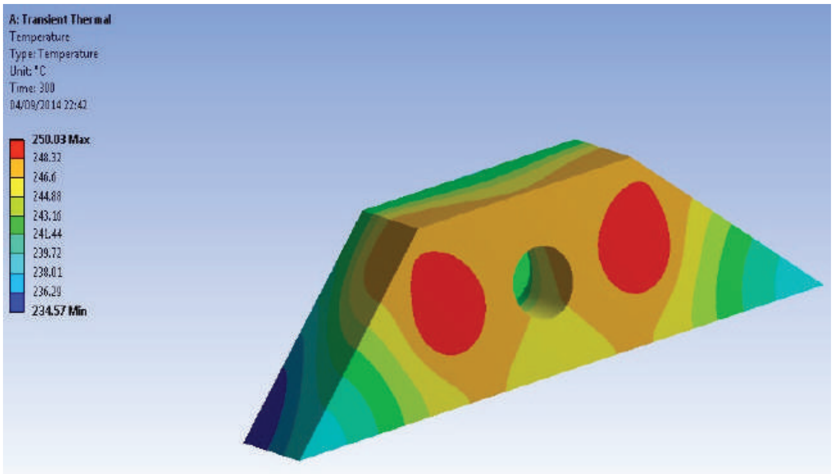


Fig. 20. Temperature contour for condenser.

Fig.20 shows temperature contour for condenser. The temperature $300^{O}c$ is given to the heaters and analysis shows that the complete unit will heat up near $299^{O}c$ in 5 minutes. The radiation, conduction, convection losses are not considered as unit size is small.

## 4. Conclusion

In a desorpter, the volatiles are desorbed by thermo-kinetic principle. The pattern of the turbulence generated in this is investigated using CFD tools.

After analysing data simulated from desorpter, it is observed that the turbulence in the sample chamber is function of Geometry of chamber and outlet of desorpter.

In desorpter design, after modelling geometry it is found that using $k-\varepsilon$ two equations turbulence model is sufficient to predict the flow and turbulent intensity in chamber. The previous desorpter unit is also analysed using same equations, after which the output data from practical experimentation and CFD simulation are matched. Using CFD tool number of experiment conducted to select best geometry. One of the important selection parameter is turbulence intensity in sample chamber and pressure magnitude at output, which should be near to atmospheric pressure.

In the new condenser set up, the geometry needs to be change to accommodate the peltier chips set up for cooling it below $O^O c$. Also the cartridge heaters as heating element are used instead of coil heaters. While designing the system, precautions are taken to avoid the exposure of peltier chip to temperature exceeding $100^O c$. Because peltier chips are delicate instrument which may damage by temperature above $100^O c$. Condenser function is to cool internal mixture then flash heating it upto $250^O c$. So while heating the condenser at such higher temperature, we need to move the peltier set up away from condenser. For this purpose, Linear motor mechanism is used. This mechanism is used as it is compact and easily controlled by embedded controllers.

In the future scope, the volatile separating mechanism can be further developed by improving some factors like heating sources and more efficient peltier chips.

Heating sources like Induction, magnetic, microwave and laser heating may have different results, depending on nature sample to be used in order desorb out more molecules.

Also using more efficient peltier chip will avoid the need of moving mechanism. This will benefit in terms of size and weight of the overall system.

In existing design, for heating purpose cartridge heaters are used. This heating process can be replaced by other heating processes Induction, Magnetic, laser in order to desorb out more molecules from sample matrix.

Using more efficient and high temperature resistant peltier will avoid use of Moving mechanism, so that system size and costing can be further reduced, which will allow system to be very compact and light weight.

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# Improving the performance of assembly line: Review with case study

**Publisher: IEEE**

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**Abstract:** Context: Continuous Improvement in manufacturing to attain manufacturing excellence is today's requirement. It gives cutting edge over the competitors. This has developed... **View more**

## Metadata

**Abstract:**
Context: Continuous Improvement in manufacturing to attain manufacturing excellence is today's requirement. It gives cutting edge over the competitors. This has developed lot of interest for the researchers during the last few years. Vehicle Assembly Line being the most complex Assembly line has been active area of research over years and has attracted many researchers. Objective: This paper systematically identifies and unfolds the important parameters by systematic review. Goal of this Research is to develop a novel classification of literature on Assembly Line and to improve the performance of vehicle assembly line using Lean implementation and Simulation approach. Methodology: Total of 116 referred journal articles in the domain of Vehicle assembly are reviewed here. Data is sourced from 40 publications, majority of which includes Elsevier, IEEE, and Springer. Further a mathematical model is developed considering the effect of number of resources, Break time, Downtime of machines and Absenteeism. A real world case study is done for a period of one year in a reputed vehicle assembly manufacturing plant. Results: Analysis of research on Assembly Line Balancing and optimization within many different industrial scenarios has been done her. This paper contributes to existing domain by classifying and comparing the means for input data, constraints and methodology used. It has been classified into five heads. A real world case study is done in reputed Company. Cycle time was reduced from 110 seconds to 100 seconds. Conclusion: It is difficult to perform the experiments like Design of Experiments (DOE) in complex manufacturing systems. Simulation allows us to test different concepts, various options without having to build prototypes. A case study done in Vehicle assembly shows the importance of Simulations to improve its performance measures. Limitations of the Research: The research does not completely optimize the production parameters. It improves the production sy...

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# Finite Element Analysis of Conformal Cooling for Reduction of Cycle Time to Enhance Performance in Plastic Injection Molding Process

Recent Advances in Mechanical Infrastructure pp 255-264 | Cite as

Conference paper

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## Abstract

The use and improper placement of conventional cooling channels leads to uneven cooling of the mold surfaces, which results in defects like sink marks, warpage, and thermal residual stresses. The design variables considered for the cooling are mold and melt temperature, injection time, cooling time, cooling temperature, packing time, and packing pressure. Conformal cooling channels are used to improve the cooling system design and to reduce the defects. Temperature distribution along the mold cavity is studied in this paper. In the proposed design method, the cooling channel is produced by the design tool and the results have been compared with simulated results produced by ANSYS software. The transient thermal analysis in ANSYS workbench is performed to analyze the thermal response of rapid heating and cooling of mold to see the effects on mold heating and cooling efficiency and the cycle time of molding operation. The maximum temperature and minimum temperature were reduced by 18.78%. The analysis has been done for hot and cold runners.

### Keywords

Injection molding Temperature distribution Cooling efficiency Conformal cooling

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author=ABM.%20Saifullah&author=SH.%20Masood&author=I.%20Sbarski&
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# Analysis of S-4180 using computational fluid dynamics

**Publisher: IEEE**

**7 Author(s)** Vidhiksha Patel ; Dipali Bhise ; Johney Xavier ; Bharat Kumavat ; Rakesh Lo... **View All Authors**

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**Abstract**



**Abstract:** Computational fluid dynamics is Virtual method of scientific and engineering investigation, concerned with the development and application of a video-camera like tool - a... **View more**

### Metadata

**Abstract:**

Computational fluid dynamics is Virtual method of scientific and engineering investigation, concerned with the development and application of a video-camera like tool - a software - which is used to analyze a fluid dynamics as well as heat and mass transfer problem in a unified way. Here, the software is like a virtual video-camera and result in movie where each picture gives a fluid dynamics information, i.e., flow properties. The main objective of this paper is to use Computational Fluid Dynamic method for the analysis of two dimensional characteristics of airfoil s-4180 of Seligg. The coefficient of lift (Cl) and drag (CD) of s-4180 airfoil were successfully measured at an angle of attack 00-30 using CFD.

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**Contents**

## SECTION I.
## Introduction



Computational Fluid Dynamics (CFD) is the use of physics, applied mathematics and computational software to visualize how a gas or liquid flows or how it affects the object as it flows past. CFD is based on Navier-

# Evaluation of Surface Roughness by Machine Vision Using Neural Networks Approach

**Ketaki Joshi and Bhushan Patil**

**Abstract** Surface quality of industrial components is critical from operational, ergonomics and esthetics point-of-view. Surface roughness measurement using traditional contact-type instruments may not be feasible in the industries insisting on 100% inspection and monitoring. Machine vision-based machine learning has a potential of facilitating automated inspection of manufactured components for their surface quality. The paper presents a machine vision-based machine learning approach that works on the principle of surface texture characterization by vision-based texture analysis techniques followed by supervised machine learning using multilayer feed-forward artificial neural network with backpropagation for fitting the response (surface roughness) with the inputs (vision-based texture parameters). Performance of various texture analysis techniques based on the histogram, gray level co-occurrence matrix, Fourier and wavelet transform used for generating the training data and training algorithms used for training the networks are compared. The approach can be potentially used to estimate surface roughness of industrial components.

**Keywords** Surface roughness · Machine vision · Texture analysis · Artificial neural networks

## 1 Introduction

Evaluation of surface roughness (Ra) using machine vision-based machine learning approach is based on the principle of surface texture characterization of machined surface images using texture analysis techniques and machine learning to establish

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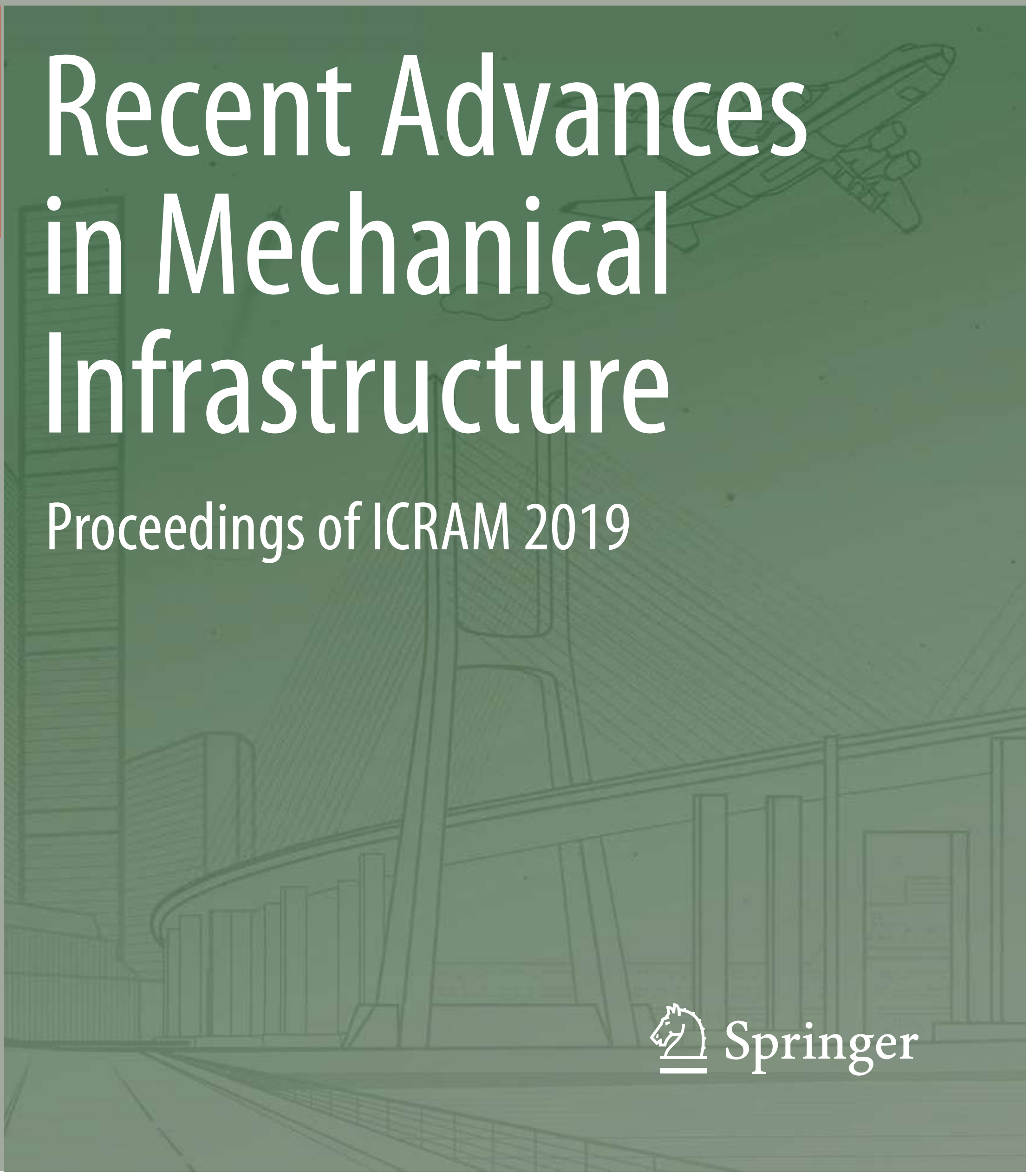

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# Proceedings of International Conference on Intelligent Manufacturing and Automation

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# A Perspective of Integrated Machine Vision Based-Multivariate Statistical Process Control

**Ketaki N. Joshi and Bhushan T. Patil**

**Abstract** Machine vision systems have proven their potential of effectively inspecting objects under consideration for surface and dimensional defects using various texture analysis techniques. However, current use of machine vision systems in industry is broadly limited to acceptance or rejection of product based on its quality. Their potential of providing complete solution to quality is not completely explored and utilized. Hence their exist opportunities for utilizing machine vision systems not only for inspection, but going one step ahead and using it for quality control. The information extracted by machine vision systems, over the period, can be analysed for monitoring production processes and detecting out-of-control signals. This paper provides a review of the attempts made by various researchers in the direction of integrating machine vision techniques with statistical quality control methods for providing vision based solution for quality control.

**Keywords** Machine vision · Multivariate techniques · Statistical process control

## 1 Introduction

Automatic inspection systems using computer vision and image processing techniques are capable of accurate inspection and effective process monitoring. There has been a significant development in the field of machine vision systems (MVS) and have proven their potential to replace the traditional measurement systems. There exists an opportunity to extend their current usage for inspection to monitoring of

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production processes and utilizing this data in order to control the system before non-conformities occur.

Woodall and Montgomery [1] have stated that use of images for process monitoring is one of the latest trends in the area of quality control. The images of the products are often used in the industry for inspection, i.e. to separate non-conforming items from conforming items. However, they clearly stated the opportunity of developing solutions for detection of quality changes before non-conforming items are actually produced in the system by encouraging investigations and research in the area of control charting using image data.

Vining et al. [2] have also stated that currently the image data is being primarily used for quality inspection purpose; however, the future scope for research in the field of machine vision lies in exploring the opportunity of using this information to improve quality of the processes. Hence they enforce on development of statistical monitoring methodologies for image data to be the next logical step in the near future.

In the present paper, authors attempt to survey the current state of research progress achieved in the field of machine vision-based multivariate statistical control. The paper presents a review of developments in multivariate statistical quality control techniques, integration of MVS with control charting techniques and its implementation in various product and process industries carried out by various researchers.

### *1.1 Integration of Machine Vision Systems and Statistical Process Control*

Applications of modern industrial machine vision systems can be broadly categorized in four types of inspections: dimensional quality, surface quality, structural quality and operational quality [3].

Dimensional quality characteristics can be extracted by processing images of the product under inspection using various image processing techniques and feature extraction techniques. Inspection for surface quality using MVS is based on the principle that, an image is a two dimensional image intensity function characterized by the amount of light incident on the object under observation (illumination) which is dependent on the light source and the amount of light reflected from the object (reflectance) which is dependent on the characteristic of the surface of object [4]. Structural quality refers to correct assembling, which can be extracted from images of the assemblies using statistical techniques based on greyscale levels, template matching or various stochastic model-based algorithms. Operational quality deals with accuracy with which a particular operation is carried out.

Effective management of quality involves three activities namely quality planning, quality assurance and quality control and improvement [5]. Quality control and improvement is one of the philosophical pillars of quality and can be achieved primarily by using statistical process control (SPC).

Traditional process monitoring and quality control from univariate perspective is based on the assumption that only one process output is of prime concern. However in practice, a product's utility value depends on a number of quality characteristics all of which need to be controlled in the production process in order to avoid rejection of components based on non-conformance to quality. Univariate approach also affects the joint probability of sample means lying within the control limits when the process is actually in control, calculated as $(1 - \alpha)^p$, with $\alpha$ being the individual probability of sample means lying in the control limits and $p$ being number of variables. This increases the probability of type I errors. Also, the above formula is applicable only if all the characteristics are truly independent in nature, which is rarely the case in actual practice.

In these scenarios, multivariate quality control provides a more effective way to monitor process quality by simultaneously monitoring all the variables under consideration. Multivariate techniques not only extract the information on individual characteristics but also extract and monitor correlations among data [5]. The method is suitable for processes with quality characteristics up to ten in number. However, it can also be used with more variables after reducing the dimensionality using principal component analysis [6].

The multivariate process control techniques can be effectively used to monitor a process involving multiple output characteristics. If this technique is integrated with machine vision system, can provide a very effective automated system for process monitoring and control. Researchers have made an attempt to use machine vision system with multivariate statistical techniques for process control. Most of the researchers have used this technique for surface quality control whereas very few have used it for dimensional aspects of quality. It can be concluded that integration of machine vision systems and statistical process control techniques can provide a very effective, economic and reliable tool for facilitating quality control in the industries.

### *1.2 Methodology for Developing MVS Based-Process Monitoring and Control*

Methodology developed by Rogalewicz and Poznańska [7] can be adopted for developing machine vision-based multivariate quality control system.

It consists of three phases: planning phase, process capability study phase and process monitoring phase. In planning phase, process to be controlled is studied and the variable critical to its quality are selected with their tolerance limits and targets. Then the data acquisition system is to be built, which for machine vision-based approach, will include system for acquisition of images using camera and transferring them to computer systems for further analyses. Then the measurement system is to be developed, which for machine vision-based approach, will include the use of image processing techniques for measurement of quality parameters. Then in the process capability study phase, sample data with suitable sample size and sampling frequency is to be collected, analysed, then plotted using proper control chart and further analysed for examining the process stability and capability. The last phase is process monitoring phase, where control limits are to be calculated followed by process monitoring and diagnosis of out of control scenarios.

## 2 Multivariate Control Charts

Most widely used multivariate quality control charts are Hotelling $T^2$ charts. These charts use information from current sample and hence are insensitive to small and moderate shifts in process mean. Multivariate exponentially weighed moving average (MEWMA) charts overcome this limitation [8].

### 2.1 Hotelling $T^2$ Chart

Hotelling $T^2$ control chart developed by Hotelling [9] is the most widely used method for multivariate quality control. This method is a direct analogue of univariate Shewart chart. Hotelling $T^2$ charts for subgroup data can be represented using control region or chi-square chart with an upper control limit. First method suffers from loss of time sequence of data and complexity for more number of variables. Second method overcomes these limitations by plotting the statistics value for all samples. These charts can be extended for estimating population mean and standard deviation, charts in which case are called Hotelling $T^2$ charts.

$$T^2 = n\left(\bar{x} - \bar{\bar{x}}\right)' S^{-1}\left(\bar{x} - \bar{\bar{x}}\right)$$

Two distinct phases in the use of control charts have different control limits based on the usage as proposed by Alt. Phase-I has the objective to obtain in control observations in order to establish control limits for phase-II. Whereas phase-II is for monitoring the production. Accordingly, the control limits set for two phases are as follows:

| Control limits for phase-I: | Control limits for phase-II: |
|---|---|
| UCL $= \frac{p(m-1)(n-1)}{mn-m-p+1} F_{\alpha,p,mn-m-p+1}$ | UCL $= \frac{p(m+1)(n-1)}{mn-m-p+1} F_{\alpha,p,mn-m-p+1}$ |
| LCL $= 0$ | LCL $= 0$ |

Interpretation of out of control signals is the most critical step in the use of Hotelling $T^2$ charts as it differs from univariate approach. Runger et al. [10] suggested the use of decomposition method where $T^2_{(i)}$ indicates the $T^2$ statistics for all process variables except the $i$th one. Then $d_i$ calculated as $T^2 - T^2_{(i)}$ indicates the relative contribution of each parameter to the overall statistics.

Other methods include use of principal component analysis (PCA), partial least squares (PLS) for dimensionality reduction or discriminant analysis for classification of observations into groups [8, 11, 12]. PCA and projection of latent structure allow systematic examination and interpretation of highly correlated high-dimensional data [13]. Bersimis et al. [14] have discussed all the types of multivariate control charts, autocorrelation, dimensionality reduction using PCA and PLS and interpretation of out of control signals in detail.

### 2.2 *Multivariate Exponentially Weighted Moving Average (MEWMA) Chart*

Multivariate exponentially weighted moving average (MEWMA) chart developed by Lowry et al. [15] can sense the small or moderate shift in the mean vector over period as compared to Hotelling $T^2$ chart. MEWMA statistics is given as follows:

$$Z_i = \lambda x_i + (1 - \lambda) Z_{i-1}$$

where $\lambda$ lies between 0 and 1 and $Z_0 = 0$

Quality term plotted on the chart is given as follows:

$$T_i^2 = Z_i' \sum_{zi^{-1}} Z_i$$

where covariance matrix

$$\sum_{zi} = \frac{\lambda}{2 - \lambda}\left[1 - (1 - \lambda)^{2i}\right] \sum$$

## 3 Literature Review

Horst and Negin [16] used two charge-coupled devices and computer server for inspecting thickness of textile and plotting control charts for mean and standard deviation in real time.

Nembhard et al. [17] implemented integrated model for statistical and vision monitoring in order to monitor the colour transition of the extruded polymer at different levels as it cools down in order to identify quality improvement opportunities. The colour transition data was captured by processing images of the polymer taken at predetermined intervals and then plotted using EWMA control chart in order to detect process shift.

Jiang et al. [18] proposed machine vision-based inspection of TFT-LCD panels for mura defects using colour/greyscale values in different regions of the panel using

EWMA chart. The positions of mura defects were easily located using EWMA chart which were further analysed for classification. Lin and Chiu [19] proposed use of Hotelling $T^2$ chart to determine the regions of small colour variation representing the mura defects. According to the survey on use of automated visual inspection in the field of semiconductors by Huang and Pan [20], semiconductor products including wafers, TFT-LCDs and LEDs are inspected for defects using many multivariate techniques one of which is the use of Hotelling statistics for texture analysis.

Tong et al. [21] used machine vision approach integrated with Hotelling $T^2$ chart to monitor wafer (IC) production process. The quality characteristics selected for charting included number of defects and clustering indices to be monitored for inspection purpose.

Liu et al. [22] developed an MVS system for capturing patterns such as stripes, swirls and ripples with different dimensions. They used wavelet transformation and principal component analysis for texture analysis and Hotelling $\mathrm{T}^2$ and SPE charts for detection of off-specification countertops.

Lin [23, 24] used wavelet characteristics for describing texture properties and Hotelling $T^2$ control charts of different texture parameters to detect existence of ripple defects in SBL chips of ceramic capacitor. Lin et al. [25] compared the capabilities of a wavelet-Hotelling $T^2$ control chart approach with that of wavelet-PCA-based approach in detecting surface defects in light-emitting diode (LED) chips and found wavelet-PCA-based approach to be more effective.

Tunak and Linka [26] extracted GLCM features energy, correlation, homogeneity, cluster shade and cluster prominence and plotted using multivariate $T^2$ charts for detecting the occurrence and location of woven defects.

Tunak et al. [27] used 2D discrete Fourier transform (DFT) and its inverse processed further for getting the images containing only warp and weft. The restored images were then used for assessing weaving density with the help of $X$-bar control chart in order to locate the sites of potential defects.

Lyu and Chen [28] integrated image processing technologies and multivariate statistical control chart for a component type having two concentric circles. The diameters of the two circles were obtained using image processing techniques and results of 35 samples were plotted in $T^2$, $X^2$ and MEWMA chart. Out of control signals were interpreted using Fuchs and Benjamin's MSSD (mean square successive difference) method [29] and Doganaksoy method [30]. They stated that the future scope for this research to use various inspection techniques, different shaped components and develop testing rules for analysing the process using control charts.

Megahed et al. [31] reviewed the work on image monitoring as a special case of spatiotemporal surveillance and use of control charts for process monitoring. Megahed et al. [32] applied spatiotemporal methods for analysis of the image data.

Grieco et al. [33] used integrated machine vision-based control charting approach for monitoring leather cutting process wherein the shape of the monitored profile was compared with baseline model using image data and deviation area was used as the quality characteristic for monitoring. Univariate and multivariate control charting approaches were simulated by using deviation area of the entire profile in first case

**Table 1** Summary of research work in MVS-based process monitoring, control

| Charting technique | Researcher | Product/process under monitoring |
|---|---|---|
| Hotelling $T^2$ | Horst and Negin [16] | Thickness of textile |
| | Lin and Chiu [19] | Mura defects in TFT-LCD panels |
| | Tong et al. [21] | Wafer (IC) production process |
| | Liu et al. [22] | Patterns-stripes, swirls and ripples |
| | Lin [24] | Ripple defects in SBL chips of ceramic capacitor |
| | Lin et al. [25] | Surface defects in LED chips |
| | Tunák and Linka [26] | Woven defects |
| | Tunák et al. [27] | Weaving density |
| | Lyu and Chen [28] | Component with 2 concentric circles |
| EWMA | Nembhard et al. [17] | Colour transition of extruded polymer |
| | Jing et al. [18] | Mura defects in TFT-LCD panels |
| MEWMA | Lyu and Chen [28] | Component with 2 concentric circles |
| Shewhart | Grieco et al. [33] | Leather cutting process |

and deviation area vector for different segments of profile in the multivariate case. They concluded that multivariate approach provides better results.

The summary of previous research work in the field is tabulated in Table 1.

## 4 Conclusion and Future Scope

An integrated approach of machine vision-based control charting can effectively facilitate process control. Multivariate approach will be beneficial over univariate in industrial practices due number of variables determining final quality and utility value of the product. Machine vision systems have been successfully used for inspection and can be implemented further for real time monitoring of production processes to detect out of control signals and shifts in process means to predict the probability of occurrence of non-conformities and control the processes before non-conformities occur.

From the literature reviewed, it is clear that MVS-based process monitoring and control is explored by very few researchers and their results indicate that the approach is feasible. It needs to be explored further for providing a mature vision-based multivariate statistical control solution to the industry [1, 2]. Most of the attempts have been made to implement this technique for quality control in electronic products and process industries. Their application in mechanical industries is still not explored to the extent required for acceptance of this technique by the industry. The research gaps identified from the literature review include application of MVS-based multivariate control charting technique to various mechanical components and assemblies for identifying dimensional errors and assembly errors, respectively. Further research in this direction would provide a new dimension to industrial quality control systems.

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# Optimization of Tube Hydroforming Process (without Axial feed) by using FEA Simulations

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**Abstract**

Tube hydroforming is the process of manufacturing light weight automotive components by applying fluid pressure. Success of Tube hydroforming process depends on best combination of material properties, process parameters, process sequence, and die geometry. Analysing the tube in square cross section die is simplest of hydroforming operation and the parameters effect can be further used for more complex hydroforming operation. In this work 3-D Finite Element model for the Tube Hydroforming (THF) developed using Creo Parametric 2.0, pre-processed using HyperMesh and solved using LS-DYNA explicit solver. This paper aims at identifying important parameters that affect the THF process without Axial feed. Taguchi's Design of Experiment technique is used to understand the effect of individual parameters as well as interaction of hydroforming process parameters such as die corner radius, length of tube, thickness of tube, internal pressure.

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*Keywords:* Hydroforming; Process Parameters; DOE; Taguchi method; FEA Simulations; ANOVA

## 1. Introduction

The automotive industry demands of reduced emissions, improved performance and a more sustainable carbon footprint with more fuel efficient designs. These targets are achieved by developing lighter vehicles structure along with improved aerodynamics, more efficient engines. In order to achieve lighter structure, a developing novel shaping techniques called Tube Hydroforming is used nowadays for Manufacturing of tubular components of the a modern Vehicle. Tube Hydroforming is being used by automotive industry in past two decades, typically it involves tubular components in engine and exhaust systems, chassis, body, closing doors, hoods, etc. The main advantage that


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the process offers is the ability to optimize the structure for weight and strength, while often offering at the same time superior crashworthiness.

Tube Hydroforming technique is well advanced manufacturing technique in which the tube to be formed is placed inside a die and internal pressure is applied by the fluid generally taken as water with non-corrosive additives [1]. for Successful hydroforming, the optimization of process parameters is required and process should fit in to the Forming limit Diagram (FLD). Detailed investigation of design and process parameters and selection of their optimal values is very crucial as it influences the quality and cost of the component produced and also affects the cost and quality of the final product. Finite element analysis is being preferred over experimental approach being economic and equally effective in predicting the process outputs subjected to various input parameters. Many researchers and industries are effectively using finite element approach for optimizing the hydroforming process.

Finite Element Analysis (FEA) permits arbitrary combinations of input parameters including design parameters and process conditions to be investigated with limited expense. Additionally FEA simulations are planned to further enlarge the knowledge base about particular parts using predetermined parameters varied over practical ranges, (Muammer Koc et.al (2000) [2]). The Taguchi method is applied to design an orthogonal experimental array, and the virtual experiments are analyzed by the use of the finite element method (Bing Li (2006) [3]). G.T.Kirdli, et.al [4], concluded that the thickness variation reduces if die corner radius is increased and tube wall thickness is affecting internal pressure, while maintaining the same thinning pattern. Matteo Strano, et.al [5], said shorter the tube length, the obtained protrusion height is larger. Sung-Jong Kang, et.al [6], they discussed the effect of changing tube diameter by using FEA simulations LS-DYNA as a FE code by taking vehicle bumper rail section as product after hydroforming. They concluded that by changing tube diameter slightly by 10% (increasing), remarkable reduction to about one-third in thinning rate and more uniform thickness distribution were predicted whichever loading path was applied to the prediction. Hossein Kashani Zadeh, et.al (2006) [7], simulated the effect of friction coefficient, strain hardening exponent and fillet radius on protrusion height, thickness distribution and clamping and axial forces for an unequal T joint using ABAQUS/EXPLICIT 6.3-1. The results were compared with experimental results and were found to in agreement with them, hence they concluded that FEM can be used as a reliable tool in designing tube hydroforming process to reduce costly experimental trials. A. Alaswad, et.al (2006) [8], they modeled bulge height and wall thickness reduction of a bi-layered T-shape component as a function of geometric factors using finite element modeling (FEM) and response surface methodology (RSM) for design of experiments(DOE). On the similar lines they analyzed formability and failures of T shape bi-layered tube hydroforming using ANSYS LS-DYNA pre-processor and LS-DYNA solver as a function of certain material properties and initial blank geometry and provided an optimum operating condition.

Kristoffer Trana (2002) [9], Lihui Lang et.al (2004) [10], Nader Abedrabbo et.al (2009) [11], studied the effect of axial feed and internal pressure on the thickness distribution using FEA simulations and found that the results were in good agreement with experimental findings. Shijian Yuan et.al (2006, 2007) [12,13] T. Hama, et.al (2006) [14], studied the wrinkling behaviour in THF using FEA. Muammer Koc (2003) [15], studied loading paths and effect of material properties on process output using FEA simulations verified by Experiments. Asheesh Soniu (2014) [16], investigated the effect of internal pressure on stress distribution using LS-Dyna Explicit solver. P. Ray et.al (2004) [17], Sung-Jong Kang et.al (2005) [6], M. Imaninejad et.al (2005) [18] Yingyot Aue-U-Lan, et.al (2004) [19], determined optimal loading path for THF process using simulations. Ken-ichi Manabe and Masaaki Amino (2002) [20], investigated the effect of Process parameters (friction coefficient, stress ratio) and material variables (n- and r-values) on thickness distribution using LS-Dyna. Bathina Sreenivasulu, et.al (2014) [21], proved experimentally that the strain hardening coefficient has higher influence over formability of the tubes so that for forming of materials with higher value of “n”, lower internal pressure needed. E. Chu, et.al (2002) [22], proposed and established the theoretical "Process Window Diagram" (PWD) based on mathematical formulations for predicting forming limits induced by various defects such as buckling, wrinkling and bursting of free-expansion tube hydroforming process. Kuang-Jau Fann, et.al, (2003) [23], carried out THF simulations and concluded that sequential optimization can lead to better forming results as loading path is having close control on process output. Fuh-Kuo Chen, et.al (2007) [24], found that the relation between hydraulic pressure and outer die corner radius predicted agrees well with FEM. The hydraulic pressure required to deform a tube into a desired part shape depends on the material properties of the tube, tube thickness, and the minimum corner radius of the part shape. B.Sreenivasulu, et.al (2013) [25], modelled free bulge shaped tube die using Auto CAD, simulated THF using DEFORM-3D and found that wall thickness and the branch height are most sensitive to friction, axial load, and internal pressure. A. Aydemir, et.al (2005) [26], they developed an adaptive design method for T-shape tube parts based on finite element method using ABAQUS/Explicit, to avoid wrinkling and necking.

From the above literature review, it is evident that the Finite Element simulations are capable of predicting accurate behaviour of tube hydroforming process and can be used to reduce experimental efforts. The objective of this paper is to investigate and study the effect of significant process parameters and their interactions in order to improve the quality of Hydroformed tube.

## 2. Methodology

Taguchi method gives three stages in the process development: (1) system design, the engineer uses scientific and engineering principles to determine the basic configuration. (2) Parameter design, in this stage the specific values for the system parameters are determined (3) Tolerance design, it is used to specify the best tolerances for the parameters [3]. From these, Parameter design is the most important step in Taguchi method towards achieving high quality without increasing cost. So, in order to obtain the high Hydroformablity, the parameter design approach proposed by Taguchi Method is adopted in this paper.

The Basic steps in the methodology are shown in the fig.1. Firstly the Quality characteristics and the controllable forming parameters are selected, and accordingly the Orthogonal array has been constructed. Based on the Orthogonal Array selected the finite element simulations are performed and results are tabulated in terms of average response for each factor. Statistical Analysis of variance (ANOVA) is performed to see the significant parameters. And then it is modified with the interaction of the significant parameters to obtain more information of their effect on the quality characteristics.

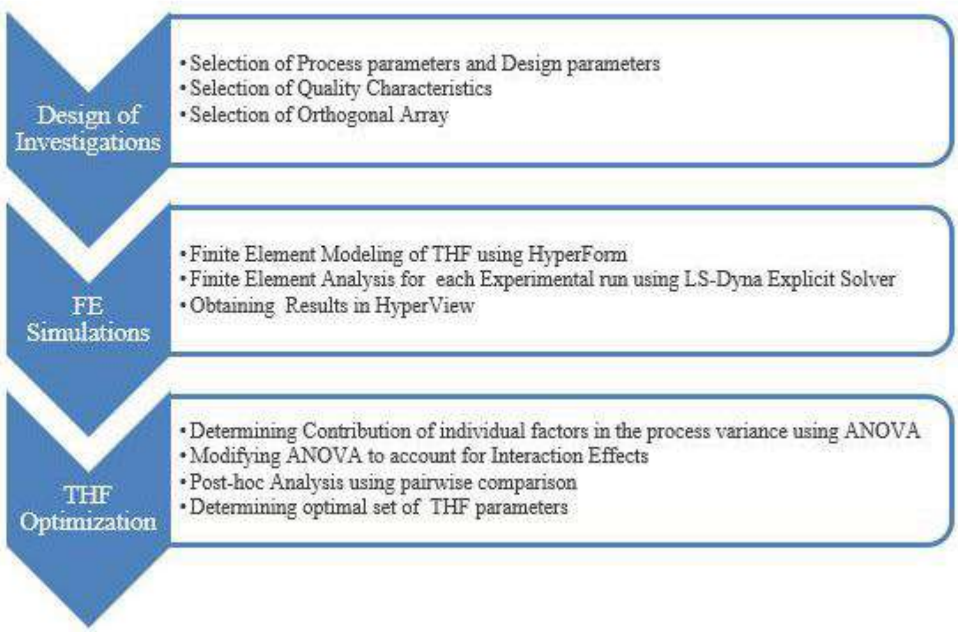


Fig. 1 Methodology for Optimization of Tube Hydroforming

### 2.1. FE Simulation Methodology

The tube and die geometry are prepared using CREO Parametric 2.0, then it is imported in to the Preprocessor Hyperform 12.0 for applying boundary conditions. After applying boundary conditions LS-DYNA R7.0 is used as a Solver. The output of the analysis stage is viewed using Hyperview. The tube diameter is 40 mm, and taking tube thickness at three level and is blown in to die cavity which is square shape having of side 44mm. Fig. 2 shows a screenshot of output of the analysis stage. The figure shows forming limit diagram (FLD) for the deformed tube.

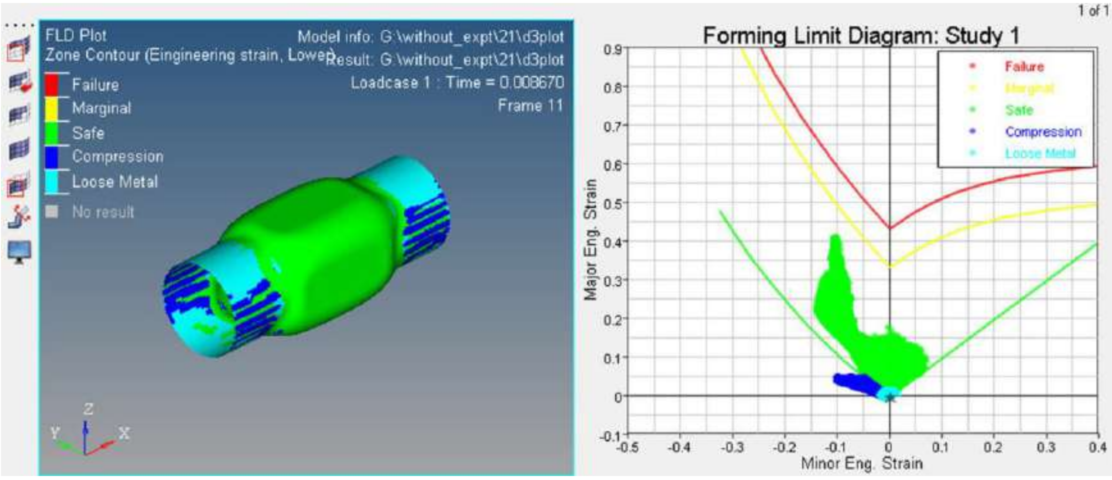


Fig. 2 Forming limit Diagram of the Hydroformed Tube

The material selected for hydroformed tube is CRDQ steel and its material properties are given in Table 1.

Table 1. Material Properties for CRDQ Steel used in the FEM Simulation

| Material Parameters | Value |
|---|---|
| Density ρ ($kg/m^3$) | 7800 |
| Young's Modulus E (GPa) | 210 |
| Hardening Coefficient *K* (MPa) | 550 |
| Hardening Exponent n | 0.21 |
| Poisson's Ratio μ | 0.3 |
| Lankford Coefficient R | 1.6 |

### 2.2. Determination of Quality Characteristic, Selection of Parameters and construction of Orthogonal Array

In the tube hydroforming process the primary requirement is to conform the shape of the die by the tube blank without any failure. The three main failure of this process are bursting, buckling, wrinkling. Among these three failures only wrinkling and buckling are recoverable. Bursting is fracture and hence cannot be recovered and causes necking because of which the percentage thickness reduction becomes an important output to be measure. Hence the Percentage thickness reduction is selected as a Quality characteristic.

Hydroformablity is dependent on three categories of parameters viz., Geometry Parameters, Material Parameters, and Process Parameters (Table 2). The Four forming parameter are chosen at three levels each and Orthogonal Array $L_{27}$ is selected for the present study according to Taguchi's Method.

Table 2. Forming parameters with their levels.

| Designation | Forming Parameters | Level 1 | Level 2 | Level 3 |
|---|---|---|---|---|
| A | Die Corner Radius (mm) | 4 | 6 | 8 |
| B | Length of tube (mm) | 120 | 140 | 160 |
| C | Thickness of Tube (mm) | 1 | 1.2 | 1.4 |
| D | Internal Pressure (psi) | 6000 | 6200 | 6400 |

## 3. Data Collection and Analysis

The Experiments are performed as per Taguchi's OA $L_{27}$ and the Average responses for maximum percentage thickness reduction for individual factors are as given in table 3 below.

Table 3. Average response for Percentage thickness reduction.

| Factors | | Average Response (% thickness Reduction) | | |
|---|---|---|---|---|
| | | Level 1 | Level 2 | Level 3 |
| A | Die corner radius | 20.0467 | 17.9811 | 20.2244 |
| B | Length of Tube | 18.8344 | 18.2633 | 21.1544 |
| C | Thickness of Tube | 20.2511 | 20.2100 | 17.7911 |
| D | Internal Pressure | 19.4211 | 19.4044 | 19.4267 |

The Fig. 3 shows Individual factors effect and clearly indicates that the percentage thickness reduction decreases as the level of factor A and B (Die corner radius and length of tube) changes from 1 to 2 and then increase as the level changes from 2 to 3. The percentage thickness reduction remains fairly constant for all levels of factor D (internal pressure). Whereas Percentage thickness reduction remains fairly constant for levels of the factor C (thickness of tube) from 1 to 2 and then decreases from 2 to 3.

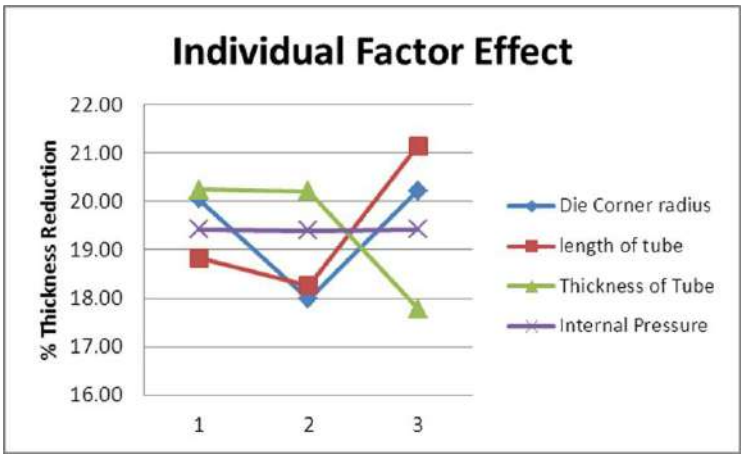


Fig. 3 Individual Factors Effect on Percent Thickness Reduction

The results of Analysis of the variance by considering the main effects of individual parameters as well as their interactions are shown below table 4. It clearly indicates that the factor A, B and C are significantly affecting the process and their interaction AXB is affecting as well. In order to study the interaction effects pair-wise comparisons are useful. For this study, we need to make a distinction between focal independent variable and moderate variable. The assigned independent variable i.e. a characteristic intrinsic to the participant such as Tube Length, tube thickness can be chosen as moderate variable and the active independent variable i.e. the one assigned or designed by the researcher such as die corner radius, internal pressure can be considered as the focal independent variable.

Table 4. Modified ANOVA Table for Percentage thickness reduction.

| | **SS** | **D.F** | **MSS** | **F** | **F critical at α = 0.10** | **Remark** |
|---|---|---|---|---|---|---|
| $SS_A$ | 27.9920 | 2 | 13.9960 | 7.1569 | 3.46 | SIGNIFICANT |
| $SS_B$ | 42.2013 | 2 | 21.1006 | 10.7899 | 3.46 | SIGNIFICANT |
| $SS_C$ | 35.7129 | 2 | 17.8565 | 9.1310 | 3.46 | SIGNIFICANT |
| $SS_D$ | 0.0024 | 2 | 0.0012 | 0.0006 | 3.46 | INSIGNIFICANT |
| $SS_{AXB}$ | 30.8593 | 4 | 7.7148 | 3.9450 | 3.18 | SIGNIFICANT |
| $SS_{AXC}$ | 1.8408 | 4 | 0.4602 | 0.2353 | 3.18 | INSIGNIFICANT |
| $SS_{BXC}$ | 15.1306 | 4 | 3.7827 | 1.9343 | 3.18 | INSIGNIFICANT |
| $SS_E$ | 11.7336 | 6 | 1.9556 | | | |
| $SS_T$ | 165.4729 | 26 | | | | |

In this paper, Tube length is designated as moderate variable and die corner radius is designated as focal independent variable. As AXB interaction is only significant so it is studied furthermore. For each Tube Length, One-way ANOVA is carried out for interaction AXB to decide the effect and hence post-hoc analysis by doing pairwise comparison is carried out to determine the optimal values of the factors. The Details are given in the table 5.

Table 5. Pair-wise comparison (AXB) for Percentage thickness reduction at level 1 of Factor B (Tube length)

| **Pair-wise comparison** | **Difference** | **95 % confidence interval** |
|---|---|---|
| Level 1 - Level 2 | 4.5433 | (1.6287, 7.4580) |
| Level 2 - Level 3 | -2.9400 | (-5.8546, -0.0254) |
| Level 1 - Level 3 | 1.6033 | (-1.3113, 4.5180) |

Table 5 shows that the difference between level 1 and level 3 is insignificant and the mean for the level 2 of the factor A (Die Corner Radius- 6mm) is significantly lower (16.34) than the other two level values.

Similarly to find out the pair-wise comparison of the interaction AXB at level 2 and level 3 of factor B, One-way ANOVA is carried out and found that there is no significant variation. So, the level at which mean thickness reduction is comparatively lower can be selected.

## 4. Conclusion

From the results of the FEM analysis and the effect of parameters study using Taguchi method, some prediction can be drawn

- The Die corner radius, length of tube and thickness of tube are significantly affecting the process.
- The Internal pressure can be set at the higher end in order to achieve good hydroformed component.
- The interaction between the die corner radius and the tube length is found to be significant.
- The optimum combinations of the selected significant parameters are suggested based on results obtained by ANOVA analysis.
- Summary of the optimal combination of selected parameters for minimum percentage thickness Reduction is tabulated in table 6 below.

Table 6. Summary of Optimal Combinations for Minimum Percentage Thickness Reduction

| **Sr. No.** | **Details of Requirement** | **Optimal Combination of Factors and level for the minimum percent thickness reduction** | |
|---|---|---|---|
| 1 | When Tube length is 120mm | Factor A | Level 2 |
| | | Factor B | Level 1 |
| | | Factor C | Level 3 |
| | | Factor D | Level 3 |
| 2 | When Tube length is 140mm | Factor A | Level 2 |
| | | Factor B | Level 2 |
| | | Factor C | Level 3 |
| | | Factor D | Level 3 |
| 3 | When Tube length is 160mm | Factor A | Level 1 |
| | | Factor B | Level 3 |
| | | Factor C | Level 3 |
| | | Factor D | Level 3 |

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ICAC3'15

# Computer Aided Design And Analysis of Volatile Separating Device

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**Abstract**

Volatiles in the current context are molecules with boiling point up to $200^{O}C$. Conventional methods for separating volatiles are biased towards one of the physical or chemical properties of the molecule and hence are not complete. So volatiles separated from the mother matrix will contain fewer molecules and even the most precise instruments can resolve only fewer molecules. On the other hand a better sampling device utilizing thermal desorption, kinetic desorption, solubility in steam, desorption by microwave, desorption by magnetic induction or laser can separate larger number of molecules and hence can enhance the efficiency of instruments like MS. A sampler using thermo-kinetic desorption was fabricated in house and comparative study was conducted against conventional techniques. A 25 percent increase in peaks was observed when analysed with GC. The possibility of thermal decomposition was ruled out by conducting GC- MS studies.
The aim of the current study is to develop a highly precise sampling device with global standards and has wide applications in the field of aromatic, analytical, biological and medical fields.

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*Keywords:* Desorpter Cartridge Heaters; Turbulent Kinetic Energy; Turbulent Intensity; Turbulence Dissipation Rate; Peltier Chips; Heat Sink; Linear Motor.

## 1. INTRODUCTION

This Report describes a new design approach that came from a volatile separation technology. The conventional methods, separated volatiles from materials from Organic matters are biased to any single physico-chemical properties of the volatile and are efficient to separate low boiling fractions only. The goal of this new design approach is to

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provide better heating and cooling modes, Equipment, maintaining of inert atmosphere in envelope, well stabilized desorption-adsorption process for volatiles from the provided organic matter.

Volatile is a substance which can change state from a solid or liquid to vapour. Gas chromatography (GC) is the instrument used to study volatiles and it can analyse molecules whose boiling points are as high as $250^{O}C$ or more. But it is necessary to make sure that Non-volatile material should not enter into the GC column. So there is a requirement of a safe sampling device for GC. Sampling device is separator unit, which will extract the molecules or volatiles from the given sample.

The Prototype device for this is already manufactured, which is a POC (Proof of Concept). The goal of this report is to reduce the size of complete equipment, modular design. For the purpose of heating the envelope electrical heaters are used with sensor for establishment of feedback control system. Also for cooling the purpose electric cooling chip are used, which works on peltier effect.

This report also analyses influence of the internal geometry design over flow path of nitrogen gas and turbulence created by pressurized nitrogen gas, with the help of CFD software.

## 2. Literature Review

Following literature describes the prototype of Volatile Extraction Device developed previously. This device works on thermo-Kinetic Principle of extraction. The equipment contains following parts [4]:

1. PID Controller.
2. Electrical Circuit.
3. Flow and Temperature control.
4. Desorpter and Condenser.
5. Absorbent.
6. Heating and cooling Media.
7. Critical components of the system are design and geometry of Desorpter and Condenser, selection of heating and cooling media, absorbent material, and feedback control system for governing temperature, flow and Pressure.

### *2.1. Working*

A solid or semisolid sample containing volatiles is heated using multiple sources in a current of dry or moist (controlled) Nitrogen and the effluents are driven to a frigid cartridge pre-loaded with appropriate adsorbent. Once the adsorption is complete, the cartridge can be flash heated and the pneumatics drive the volatiles through appropriate membrane filters to the GC for analysis. Membrane filters are used to selectively detain water molecules and molecules of particular choice. Fig.1 shows the typical layout of existing system.

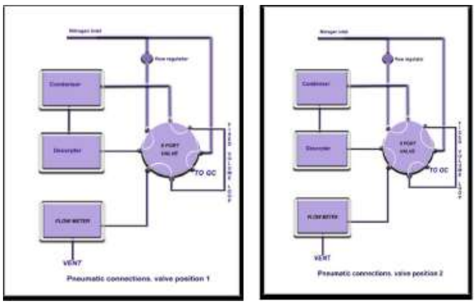


Fig. 1. Typical Layout of Existing System. [4]


Fig. 2. Protoype Desorpter. [4]

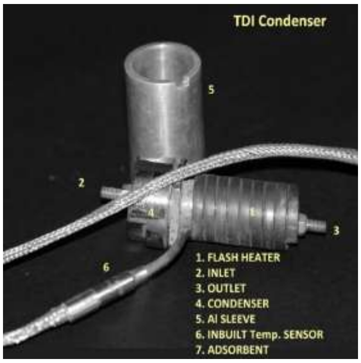


Fig. 3. Prototype Condenser. [4]

### 2.2. *Description of various sub-systems*

1. **Desorpter:** Fig.2 shows desorpter unit, which is a single piece unit carved out of 316 grade stainless steel (food and surgical grade, ideal for pressure reactors and boilers and is corrosion resistant) and fitted with screw cap for sample load. A GC septum or O rings secured airtight sealing. Holes are drilled in the body to accommodate the cartridge type heaters and temperature sensors. The heaters and sensors are connected to the thermostat and can be programmed from ambient temperature to $350^{O}C$in multi steps.
2. **Condenser:** Fig.3 shows the condenser unit is slightly more complex than the desorpter both in functioning and in construction. The main body is 316 stainless steel cylinders with a 1cm x 6cm hole drilled in. The adsorbent material is packed in here. A special heater with inbuilt thermo sensors is wound around the condenser tightly. This heater is capable of heating the condenser to $250^{O}C \pm 1^{O}C$ in just 5 seconds. The cooling system consists of two aluminium boxes with cylindrical slit at its centre. These boxes are driven with a lever system to separate them from the condenser or to bring them close to the aluminium sleeve. The coolant used is a mixture of dry ice and acetone.

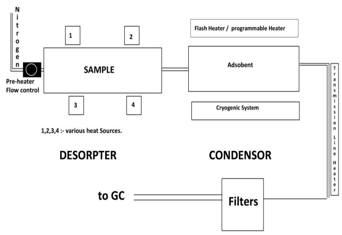


Fig. 4. Proposed Volatile Separator Systems. [4]

## 3. Method

Fig.4 shows proposed modular system, in which desorpter can be heated by various sources like coil, cartridge, lasers, induction heaters. Condenser unit is separately cooled followed by flash heating.

### *3.1. Desorpter Design*

CFD Analysis on Previous Design:
Fig.5 shows the CAD model of previously developed desorpter. The sample is kept in bore and closed with cap which is threaded. At the inlet nitrogen gas of room temperature and at pressure of 2 Bar enters into the chamber. Two Cartridge heaters of 100 watts each placed heat up the internal volume. These cartridge heaters provide temperature up to $250^{O}c$ in 20 minutes.

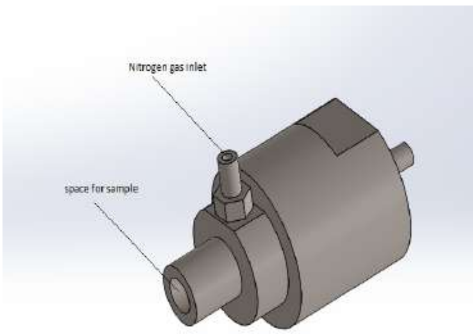


Fig. 5. CAD Model of Old Desorpter.

Boundary Conditions for flow Analysis:
Inlet Pressure- 2Bar
Inlet temperature-300k
Wall Temperature-623k
Outlet temperature-300k
Viscous Model- K-epsilon

Result:
In fig.6, At the inlet pressure is around$1.83e^{05}$ pa. After impact pressure reduces to $1.62e^{05}$ pa. When gas travels through outlet, the cross section is reduced to 2 mm due to which pressure drops further to $1.04e^{04} pa$ which is nearly atmospheric pressure.
In fig.7, It is observed that in the velocity profile flow direction is perpendicular to sample bore axis. Due to straight impact of nitrogen stream with pressure value 2 bars, the flow is dispersed and lot of turbulence is created. Maximum

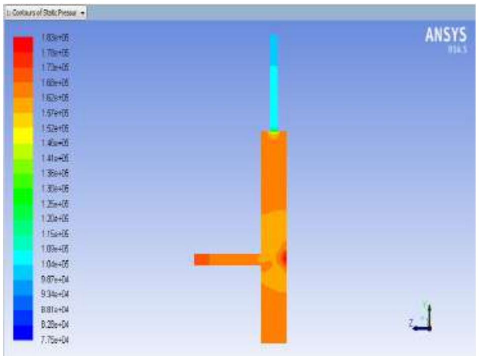


Fig. 6. Pressure contour.

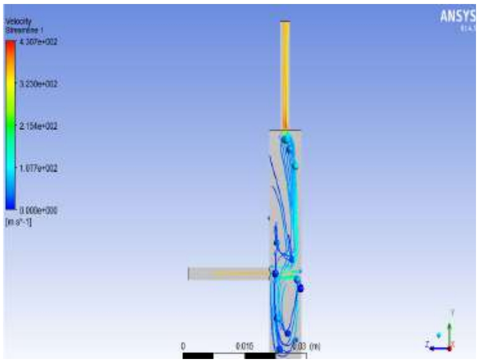


Fig. 7. Velocity contour for old design.

velocity is at outlet, which is approximately around 420 m/s which is very high.

Fig.8 shows that at outlet where the cross section is suddenly reduced is having maximum turbulence Kinetic energy.

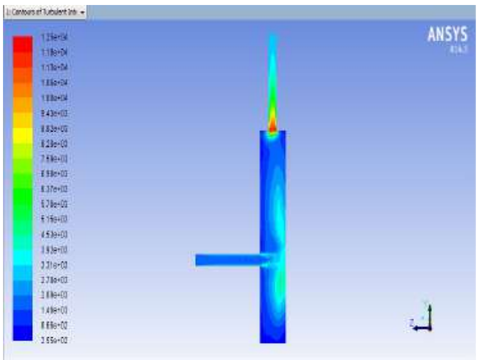


Fig. 8. Turbulence Kinetic energy.

But the flow should be less turbulent to carry the volatiles out of the chamber. Hence it is very necessary to streamline the flow once volatiles are extracted.

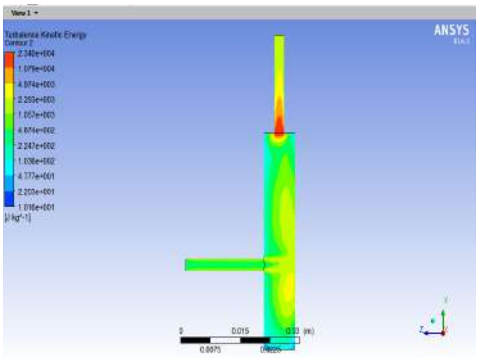


Fig. 9. Turbulence Intensity energy.

Fig.9 shows that the range of turbulence intensity in the unit after nitrogen gas enters is around $2.55e^2$ to $1.25e^4$. This contour also shows that the region where cross section area is reduced suddenly, TI value is highest around $2.55e^2$.

### 3.2. Practical Data For Old Desorpter

Pressure at outlet: Near to Atmospheric Pressure (101325 pa)
Time taken by heaters to heat the desorpter : 20 minutes

It is observed that the experimental values and Simulation values are matching. Hence we can say that the CFD simulation is Valid.

### 3.3. New Desorpter Design

We modified the design of component. In new design,the direction of flow is at an angle so that turbulence wont create backflow. Because backflow will restrict the movement of volatiles and nitrogen from inlet. There is space for sample, so that it should not be displaced due to impact of nitrogen gas. Also the outlet tube is tapered fir internal hole, to avoid backflow loop at outlet of chamber as shown in fig.10.

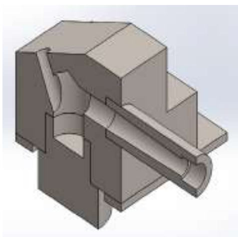

Fig. 10. CAD model of Modified Design of Desorpter.

### 3.4. Heaters Selection

To improve the heat generation rate and minimise the heating time we used following equation for raising the temperature of unit up to temperature of $250^{O}C$ in 10 minutes, the wattage of heater is given by:

$$KW = \frac{Wt.C_p.\Delta T}{3412.H} \tag{1}$$

Wt = weight of material to be heated
Cp = Specific Heat of Stainless steel
T = Temperature rise.
H= Heating time in Hours.
It is decided to use two heaters of 150 watts power.

### 3.5. Simulation of New Desorpter Design with CFD

Boundary condition:
Inlet Pressure : 2 Bar
Internal Temperature: 623 k
Turbulence Equation: K-epsilon model.

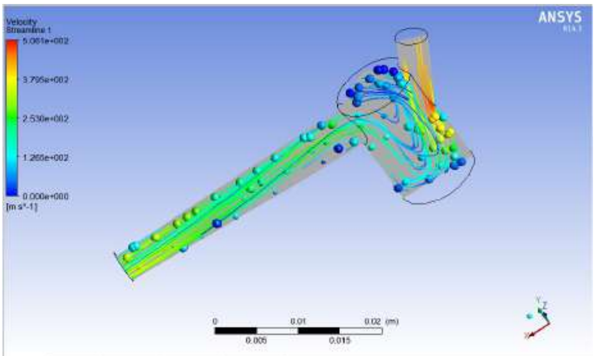


Fig. 11. Velocity Streamline for modified design.

The fig.11 shows the path of nitrogen gas travels from inlet to outlet. It is reduction from 506 to 379 m/s approximately.

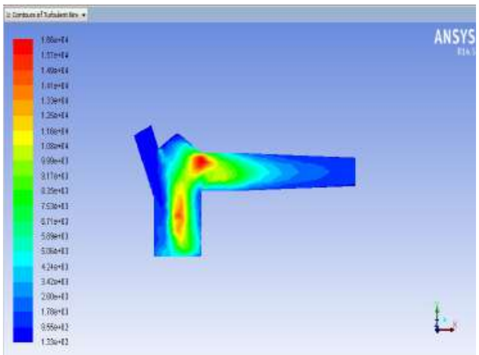


Fig. 12. Turbulent Kinetic Energy Contour.

In fig.12, The range of TKE is from 49.3 to 16500 $m^2/s^2$. It is maximum where the stream of nitrogen gas is coming from inlet of diameter 4mm and entering in suddenly enlarged region of diameter 15mm. This is where we need maximum turbulence to occur. As soon as it strikes on sample with full kinetic energy, the path of gas molecules is disturbed. As compared to old design the TKE at outlet is decreased due gradual decreasing cross section area towards outlet.

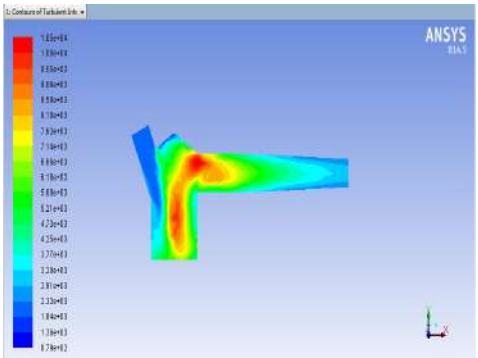


Fig. 13. Turbulence Intensity.

The goal of this design was to allow turbulence at sample space and avoid it at outlet zone. Fig.13 shows that new design will satisfy this requirement of the process. As it show that turbulence intensity at sample space around 10500 $m^2/s^3$ and at the outlet it is very less.

### *3.6. Turbulence model*

The k- $\varepsilon$ model has become very popular due to the important role played by  in the interpretation of turbulence in addition to the fact that  appears directly in the transport equation for k. This turbulence model provides a good compromise between generality and economy for many CFD problems. The exact transport equation for the turbulent kinetic energy, k, can be deduced from the equation for the kinetic energy by Reynolds decomposition and reads.

$$\frac{\partial k}{\partial t} + U_j * \frac{\partial k}{\partial x_i} = -(U_i U_j)\frac{\partial U_i}{\partial x_i} - V(\frac{\partial U_i}{\partial x_i} * \frac{\partial U_i}{\partial x_i}) + \frac{\partial}{\partial x_i}(V\frac{\partial k}{\partial x_i} - \frac{<U_i U_{iiU_j}>}{2} - \frac{<U_j p}{\rho}) \tag{2}$$

The exact $\varepsilon$ equation can be written as:

$$\frac{\partial \varepsilon}{\partial t} + U_j * \frac{\partial \varepsilon}{\partial x_j} = C_{\varepsilon_1} V_T \frac{\varepsilon}{k}[(\frac{\partial U_i}{\partial x_j} + \frac{\partial U_j}{x_j})\frac{\partial U_i}{\partial x_j}] - C_{\varepsilon 2}\frac{\varepsilon^2}{k} + \frac{\partial}{\partial x_j}[(V + \frac{V_T}{\sigma_\varepsilon}\frac{\partial \varepsilon}{\partial x_j})] \tag{3}$$

Where,
k-Kinetic Energy
$U_i$- Velocity in X-direction
$U_j$-Velocity in Y-direction
v- Kinematic Viscosity
$\rho$-Density
C-Constant
$v_T$-local turbulent viscosity
$\sigma_\varepsilon$- Prandtl-Schmidt number

This model is suited for flows in which the turbulence is nearly isotropic and flows in which the energy cascade proceeds in local equilibrium with respect to generation. Furthermore, the model parameters in the k-$\varepsilon$ model are a compromise to give the best performance for a wide range of different flows. The accuracy of the model can therefore be improved by adjusting the parameters for particular experiments. As the strength and weaknesses of the standard k-$\varepsilon$ model have become known, improvements have been made to the model to improve its performance.

### 3.7. Condenser Design:

The function of condenser is to concentrate the volatiles by first cooling them up to $-30^{O}C$ and trapping it with in absorber. Absorber is a porous material which only allows nitrogen gas to pass through and will trap volatile. Again to release the volatiles absorber is flash heated up to $250^{O}C$. Then it delivers the volatile in GC machine. Fig. 14 shows the sectional 3D view of previous condenser and porous absorbent material.

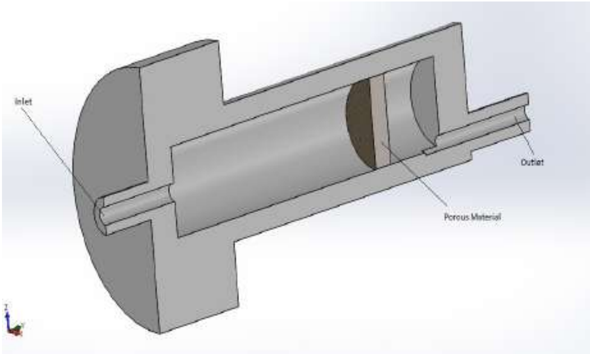


Fig. 14. 3D Model of Condenser.

Specifications of Old Condenser: Inlet Diameter = 4mm
Outlet Diameter = 4mm
Internal Space Diameter = 12mm
Total Length = 85mm
Porous disc Size =$\phi$ 12 x 3 mm
Porous disc Material = Bentonite
Component Material = SS316 (Food Grade)
Mass = 180 gms.

### 3.8. Heating and Cooling Set-up

Dry ice-acetone system which is a cooling bath is a liquid mixture used to maintain low temperatures, typically between 13 to -78$^{O}$C was used to cool the condenser. It uses mixture of 3 components. Components are cooling agent (dry ice), a liquid carrier (Acetone) and an additive to depress the melting point of system.

Cooling process, the volatiles are trapped in the porous disc. So to release them and transport them to GC machine, the temperature of fluid domain need to be raised to 250$^{O}$ C within 2 minutes. So to flash heat the condenser, special coil heaters are made, which fits on the condensers outer surface.

### 3.9. Condenser System Design

For cooling purpose it is decided to use Peltier chip for ease of manufacturing and operation. Fig.15 represents 3D model of new condenser designed to accommodate the cartridge heaters and peltier chips. Fig.16 shows typical 3D model of peltier chips and carrier arrangement. Peltier chip works on reverse principle of peltier effect.
In order to cool the condenser up to -30$^{O}$c, we need to know how much heat is to be extracted from condenser when it is in room temperature. So the heat to be extracted from condenser:

$$Q = m.C_p.\Delta T = 19,960J \quad (4)$$

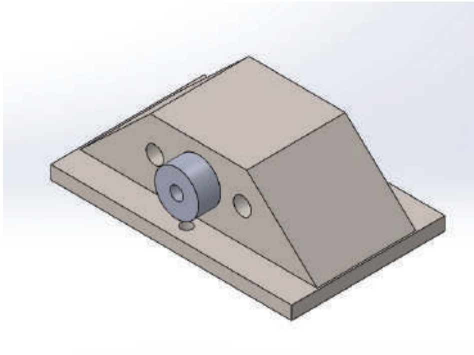

Fig. 15. 3D Model of New Condenser.

Total heat to be extracted from condenser is 166.33 watts. But a single peltier chip would be insufficient. hence It is decided to use 3 peltier chip. According to available peltier chip in the market, the following specifications are best suited for the purpose:
Model - TEC01-12704
Size - 40X40X4.7 mm
Imax - 4 Amp.
Voltage - 15 V
Qmax -37.7 watts.
$\Delta$T- 67 k

Peltier chips will get damaged when exposed to temperature exceeding $100^{O}$c. Hence to prevent chips from getting damaged, it needs carrier of thermally conductive material. When carrier is in contact with condenser surface, it will transfer heat from condenser to chip and when condenser is flash heated it will break the contact with condenser by means of mechanical linkages.

So to move peltier along with carrier, we have used linear motor. This linear when energized, moves its shaft in linear vertically upward direction. The figure below shows typical arrangement of Condenser, Linear motor, Brackets, Peltier chip, Carrier, Heat sink in set up.

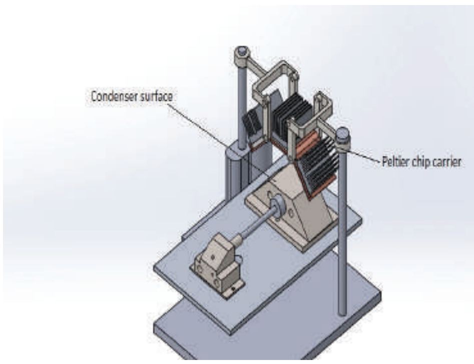


Fig. 16. Peltier chip in Disengaged position.

### 3.10. Heat Sink Selection

Application of Heat sink in this is the same, i.e. Dissipation of heat. the heat which generated on top side of peltier chip can dissipated by using Heat Sink and Blowing fans.

To select the heat sink, we need to determine the Junction to ambient thermal Resistance. Thermal resistance for junction to ambient:

$$R_{j-a} = \frac{T_j - T_a}{Q} \tag{5}$$

$R_{j-a}$ = Resistance junction to ambient = 1.31 $^O$c /w
Tj = Junction Temperature = 67$^O$c
Ta = Ambient temperature = 20$^O$c
Q = Total heat developed = 36 watts

*3.11. Thermal Analysis of Heat Sink*

Heat generated by Peltier chip

$$Q = m.C_p(t_2 - t_1) = 925J \tag{6}$$

Where, m- Mass of device
cp - Specific heat of Silicon
$t_2$- Hot side temperature of peltier chip
$t_1$- Room Temperature Heat Dissipated by fins:

$$Q_{fin} = KA_c m(t2 - t1)[\frac{h \cosh mL + mk \sinh mL}{mk \cosh mL + h \sinh mL}] = 307.05Watts \tag{7}$$

Where,
k = Thermal conductivity of Aluminium.
$A_c$= Surface area.
h = Heat transfer coefficient.
L = Length of Fins.

*3.12. Convective heat transfer coefficient*

$$G_r = \frac{gL^3\beta t_2 - t_1}{V2} = 13.74E6 \tag{8}$$

Where,
g = Acceleration of gravity
$\beta = Airthermalexpansioncoefficient = \frac{1}{t_1}$
v = Kinematic Viscosity

Prandtl number:

$$P_r = \frac{\mu C_p}{k} = 0.83 \tag{9}$$

Where,
$\mu$ = Dynamic Viscosity of air
$c_p$ = Air Specific heat
k = Thermal Conductivity of air

Rayleigh number:

$$R_a = G_r P_r = 11.40E6 \tag{10}$$

Where,
$G_r$ = Grashof number
$P_r$ = Prandtl number

Nusselt number:

$$N_u = 0.27R_a^{0.25} = 15.68 \quad (11)$$

Convective heat transfer Coefficient:

$$h_c = \frac{N_U k}{L} = 8.6Watt \quad (12)$$

### 3.13. Heating of Condenser

After cooling process, the volatiles are trapped in the absorber porous material. Further these volatiles need to be released from the porous zone. In order to release them, we need to heat the condenser up to temperature $250^{O}c$ in 3 minutes.
Wattage calculation for Cartridge heaters:

$$W = \frac{W_t C_p \Delta T}{3412H} = 471.86Watt \approxeq 500Watt. \quad (13)$$

Wt = weight of material to be heated = 0.7 kg
$C_p$ = Specific Heat of Stainless steel = $500 j/kg^{O}$k
$\Delta T$ = Temperature rise = $230^{O}$c
H= Heating time in Hours = 0.05

### 3.14. Selection of Absorbent Material

After heating the condenser, flow of nitrogen gas at atmospheric pressure is passed through cold trap. This flow drives the released volatiles out of the condenser and moves them towards GC.

The absorbent material selected is bentonite.
Specifications of bentonite:
Particle size - mesh 2-3 mm.
Surface Area - $\frac{61m^2}{g}$
Temperature range - good stability over $350^{O}$c
Pore size -59.31 A.

### 3.15. Mechanism to move the Peltier chip unit.

It is necessary to keep the peltier set up away from the condenser, when it is heated. So we decided to use the linear motor for the purpose. The total load to be lifted is approximately 0.7 kg.

Specification of Linear Motor:
Brand - Progressive Automations
Model - PA-14 Linear Actuator
Voltage - 12V
Current - 5A
Load Capacity - 35 lbs
Stroke Length - 3 Inches

In fig.17, the Linear Motor is kept on one side of the condenser. Carrier and shaft of Linear motor connected by a bracket; so that when shaft moves upside, simultaneously the carrier will move in same direction disengage the cooling process. If cooling process need to engage again, then shaft movement will be downward.

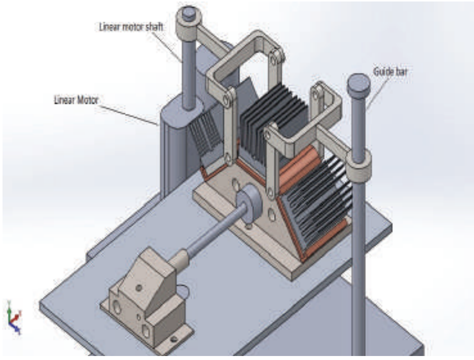


Fig. 17. Peltier set up moving Mechanism.

### *3.16. Heat transfer Analysis for Condenser*

To determine the heat distribution analytically, we had transient thermal transient analysis for new condenser model. Fig.18 shows the arrangements of cartridge heaters placed in the bores. Following boundary condition were applied:

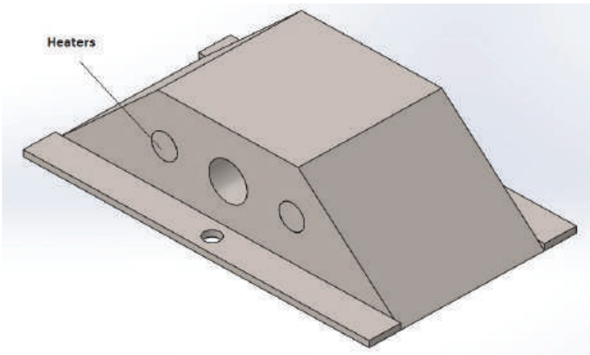


Fig. 18. Condenser model with 2 Heaters.

Initial Temperature - $20^{O}C$
Maximum Temperature - $250^{O}c$
Heat Transferred from heaters to Condenser:

$$Q = mC_p(t_2 - t_1) = 80.5KW \tag{14}$$

Where,
m = Mass of Condenser Body
$c_p$ = Specific heat of stainless steel
Time of heating = 300 seconds

### *3.17. Result:*

Fig.19 shows the relation between time and temperature rise. So the graph shows that after 100 seconds the temperature of condenser reaches near $250^{O}c$.

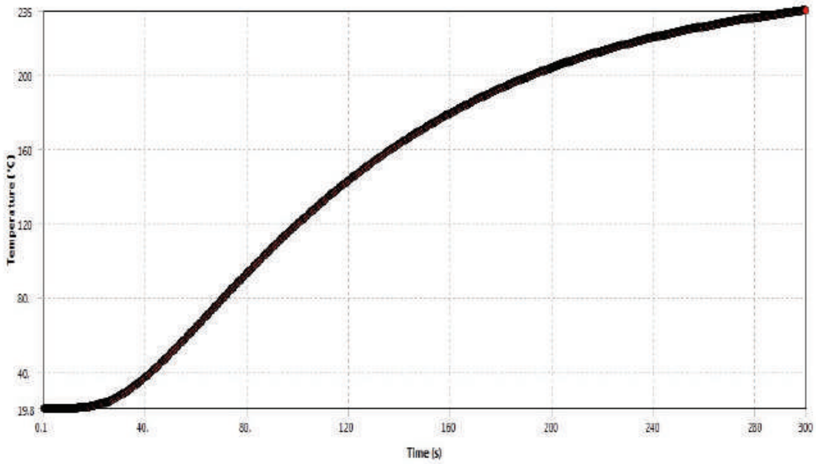


Fig. 19. Graph of Temperature Vs. Time for Condenser.

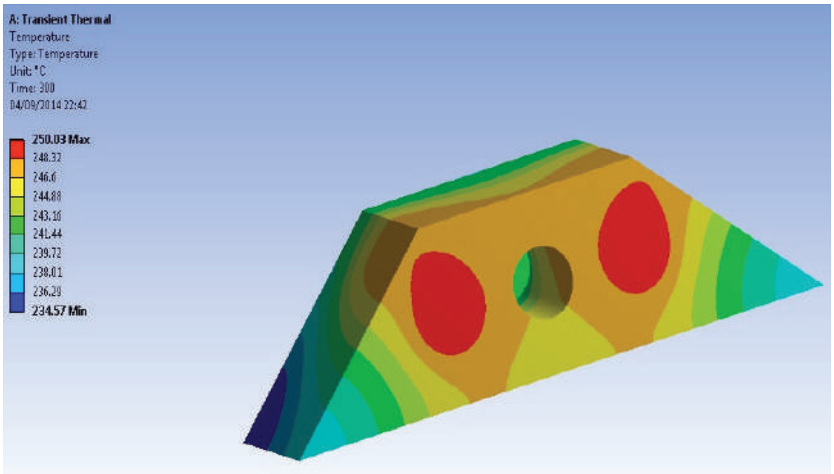


Fig. 20. Temperature contour for condenser.

Fig.20 shows temperature contour for condenser. The temperature $300^{O}c$ is given to the heaters and analysis shows that the complete unit will heat up near $299^{O}c$ in 5 minutes. The radiation, conduction, convection losses are not considered as unit size is small.

## 4. Conclusion

In a desorpter, the volatiles are desorbed by thermo-kinetic principle. The pattern of the turbulence generated in this is investigated using CFD tools.

After analysing data simulated from desorpter, it is observed that the turbulence in the sample chamber is function of Geometry of chamber and outlet of desorpter.

In desorpter design, after modelling geometry it is found that using $k-\varepsilon$ two equations turbulence model is sufficient to predict the flow and turbulent intensity in chamber. The previous desorpter unit is also analysed using same equations, after which the output data from practical experimentation and CFD simulation are matched. Using CFD tool number of experiment conducted to select best geometry. One of the important selection parameter is turbulence intensity in sample chamber and pressure magnitude at output, which should be near to atmospheric pressure.

In the new condenser set up, the geometry needs to be change to accommodate the peltier chips set up for cooling it below $O^{O}c$. Also the cartridge heaters as heating element are used instead of coil heaters. While designing the system, precautions are taken to avoid the exposure of peltier chip to temperature exceeding $100^{O}c$. Because peltier chips are delicate instrument which may damage by temperature above $100^{O}c$. Condenser function is to cool internal mixture then flash heating it upto $250^{O}c$. So while heating the condenser at such higher temperature, we need to move the peltier set up away from condenser. For this purpose, Linear motor mechanism is used. This mechanism is used as it is compact and easily controlled by embedded controllers.

In the future scope, the volatile separating mechanism can be further developed by improving some factors like heating sources and more efficient peltier chips.

Heating sources like Induction, magnetic, microwave and laser heating may have different results, depending on nature sample to be used in order desorb out more molecules.

Also using more efficient peltier chip will avoid the need of moving mechanism. This will benefit in terms of size and weight of the overall system.

In existing design, for heating purpose cartridge heaters are used. This heating process can be replaced by other heating processes Induction, Magnetic, laser in order to desorb out more molecules from sample matrix.

Using more efficient and high temperature resistant peltier will avoid use of Moving mechanism, so that system size and costing can be further reduced, which will allow system to be very compact and light weight.

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