OPTIMIZATION OF LEAN MANUFACTURING IN SHEET METALS

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Submitted by

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CANDIDATE'S DECLARATION

I hereby declare that the project entitled **"OPTIMIZATION OF LEAN MANUFACTURING IN SHEET METALS"** being submitted by me is an authentic work carried out under the supervision of **Dr. A.K Madan**, Associate Professor, Production Engineering Department, Delhi Technological University, New Delhi.

Jatin Kumar

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CERTIFICATE

This is to certify that the report entitled **“OPTIMIZATION OF LEAN MANUFACTURING IN SHEET METALS”** submitted by **Jatin Kumar (2K15/PIE/06)** in partial fulfillment for the award of Masters of Technology in Production and Industrial Engineering, is an authentic record of student’s own work carried out under my guidance and observation.

It is also certified that the report has not been submitted to any other institute/university for the honor of any degree.

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ABSTRACT

The term “lean” was coined by James P. Womack and Daniel T. Jones in the book **“The Machine That Changed the World”**, Lean manufacturing denotes to a manufacturing enhancement process based on the ultimate goal of **Toyota production system** in order to diminish or eradicate waste though maximizing production flow. Many industrial organizations realize the significance of implementing lean techniques. However, few organizations apply lean techniques with the necessary knowledge and proven tools to achieve it. A value stream contains all the operations and processes to transform raw materials into finished goods or services, including non-value accumulating activities. Value stream management is a management execution for planning a production procedure including lean initiatives through methodical data acquisition and analysis. It is a confirmed process for designing and developments that will allow companies to implement lean practices.

Today’s business development is entirely reliant on the productivity and the customer satisfaction through in-time delivery and services. This thesis addresses the application of lean manufacturing in sheet metal industry. The aim of this study and practical analysis is to investigate how to improve the productivity and in time delivery as expected by customers. In a sheet metal industry, there is always a big challenge for improvement in the productivity of the plant.

In this project work carried out is totally an Industry based, Sigma-SMS was visited by me on the weekly basis by the written permission of our Pro V.C S.K Garg, where many sheet metal processes such as blanking, punching, bending, drawing, trimming, riveting of sheets etc. are carried out, there after studying and closing observing these different operations I found out a part named CN-30, this part is the male part of drum brake of Ford motors, on that part 14 operations are carried out after that it goes to the Continental Automotive for brake pad assembly.

During the manufacturing of this part on the 7th operation of trimming area of trimming seen was more which with the help of employs working in Sigma-SMS was reduced by simply reducing the initial blank size, by change in the die that are fabricated in the tool room with the direct consultation of the design and development department.

After the successful change in the die design, the trimmed part got reduced and hence leads to a direct cost saving of the company; hence data was collected for the part production, scrap elimination and from there Taguchi optimization tool was applied on the variables of scrap going out to the market fluctuating rates/Kg of mild steel to get correlations between the values so as to maximize the profit as per when to produce and how much to produce as the monthly production goes upto around ten thousand.

Finally a regression analysis was also applied to calculate cost equation and graphical correlations for leading factors.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBRIVATIONS USED

JIT - Just in Time Production

DOE – Design of Experiments

DPMO - Defects per million opportunities

TQM – Total Quality Management

LCV – Light commercial Vehicle

HCV – Heavy commercial Vehicles

BOM – Bill of Materials

LPS – Lean Production System

Lean Production system

DMAIC - Define, Measure, Analyze, Improve and Control

CIP - continuous improvement process

PMI - Project management system

LM – Lean Manufacturing

MAJAICO - Malaysia Japan Automotive Industries Cooperation

SME - Small and medium-sized enterprises

TPS – Toyota production System

TPM - Total productive maintenance

CHAPTER 1

1. INTRODUCTION

1.1 Lean Manufacturing

The major theory behind Lean Manufacturing is to give better quality items to more Customers at an altogether bring down cost and to add to a more prosperous society. It is essential to assemble a Company generation framework in view of this theory. Lean Manufacturing has attempted to support creation by: Completely eliminating waste in the production process

- To build quality into the process
- To reduce costs - productivity improvements
- To create its own exclusive approach regarding corporate management
- To develop integrated techniques that will donate to corporate operation.

This is Lean Manufacturing [1].

1.2 Lean Manufacturing in sheet metals

Sheet metal shops contrast broadly in measure, number of representatives, and sorts of items. In setting up this prologue to lean creation, we have attempted to represent the way that no two sheet metal shops are similar and to show the data in a way that is helpful to practically everybody. To do that, we have utilized lightweight rectangular ventilation work fittings as our case all through. We trust it makes utilization of a procedure that any shop occupied with tedious work can identify with. The way toward making a fitting is by and large the same in any shop. We cut the pieces, harden the expansive pieces, frame corners, and shape the associating edges, cut and paste protection, lastly, gather the piece. A flowchart of the process looks like this:

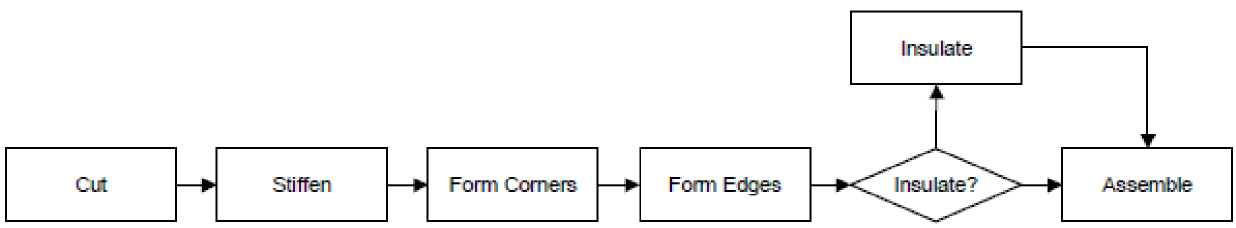


Fig 1.1 Flow chart of Lean Manufacturing

Shapes vary. Dimensions vary. Job sizes vary. Nevertheless, the process for creating a fitting is the same everywhere. Most shops have able specialists and satisfactory hardware to play out the means routinely and with great quality. It is uncommon that cutting, solidifying, and alternate strides in the process exhibit huge difficulties. Nor does the procedure itself exhibit much test. The sequence of steps is the same in every shop [2].

So, why do we have glitches? We have a objectively straightforward production sequence, competent workers and satisfactory machinery. Yet we all harbor the feeling that we aren't doing as well as we could, that we could be more efficient, more profitable. We are right to think so. It is tempting to blame customers for our problems. They are an easy target. Customers have different due dates for their orders. They don't order one fitting, they order various quantities. Sometimes they change their minds. Sometimes they fail to anticipate their needs and have an emergency. Because they are customers, we do all we can to help. We juggle the workload, putting scheduled work aside to work on hot jobs. After all, if we don't, there is a shop down the street that will. If we don't satisfy our customers, we won't be in business.

Lean identifies opportunities for process improvement by defining seven kinds of waste. They are [2]:

1. The waste of imperfections (poor quality) – scrap, rework, late deliveries.
2. The waste of overproduction – making product that surpasses customer's demands, over-specification.
3. The waste of inventory – cash secured up in raw material; work in practice or unsold finished goods.
4. The waste of waiting – product not being worked on, anticipating in a queue, people or machinery delaying for work to do.
5. The waste of transport – the movement of product between value added steps.
6. The waste of motion – unnecessary worker activity such as stooping and walking, looking for things, unnecessary rework.
7. Waste in processing – waste hidden within value added activity [2].

1.3 The Goals of Lean Manufacturing

- Cost Reduction by Elimination of Waste [3]

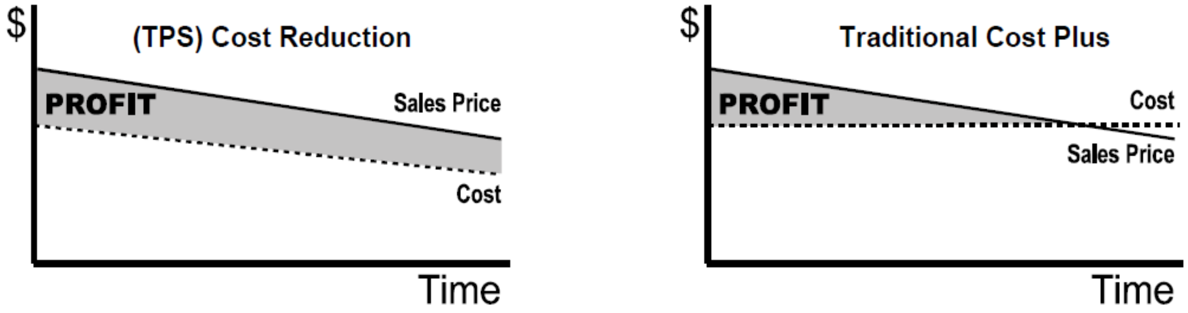


Fig 1.2 Cost vs Time graph

- Creating Conditions to Guarantee Product Quality
  - Quality First

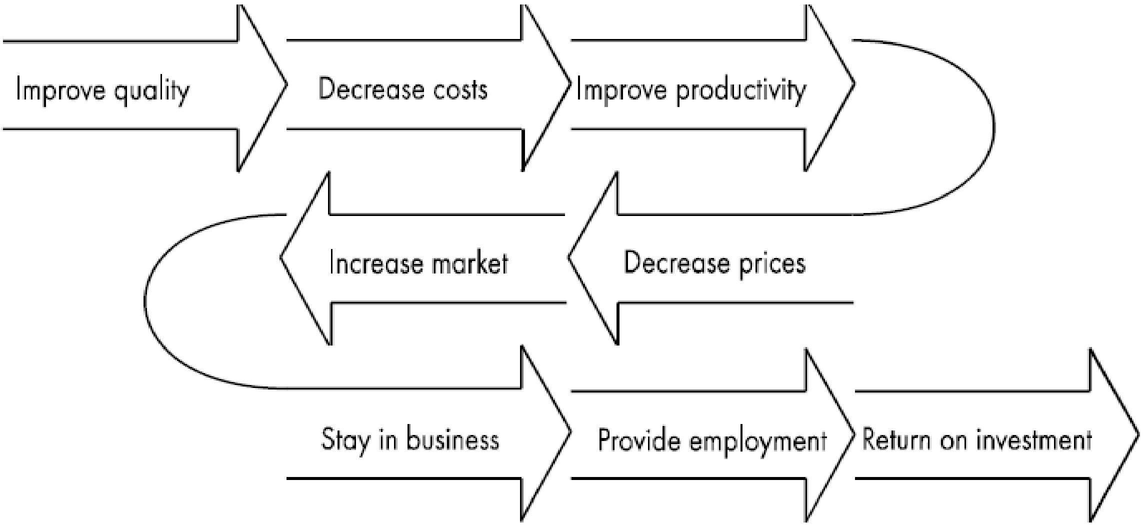


Fig 1.3 Quality to investment flow chart

  - Ensuring Quality of all Products
  - Building In Quality at Each Process
  - Inspection Work
  - The Added Value of Repairs
- Creating a Work Site with Operators in Mind
  - Creating a Flexible Work Site

- Awareness of Waste
- Cost and the Method of Production
- Work and Waste [4]

    1. Work
        - Value Added Work
        - Incidental work
        - Waste
    2. Wastes
        - Waste of defect repair
        - Waste of overproduction
        - Waste of waiting
        - Waste in delivery and conveyance
        - Waste in processing
        - Waste of inventory
        - Waste of motion

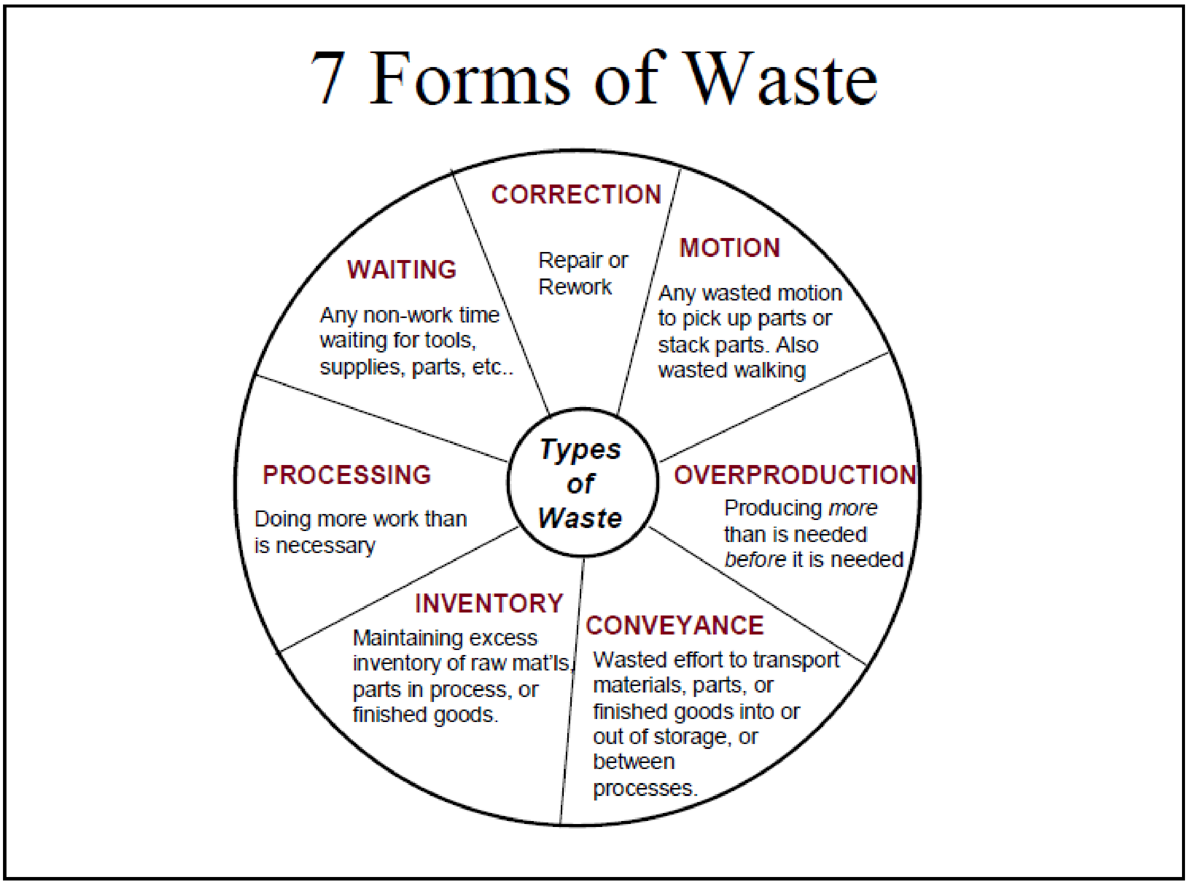


Fig 1.4 Types of Wastes

1.4 The Just-in-Time (JIT) Production

Producing and/or delivering only the necessary parts, within the necessary time in the necessary quantity using the minimum necessary resources [5].

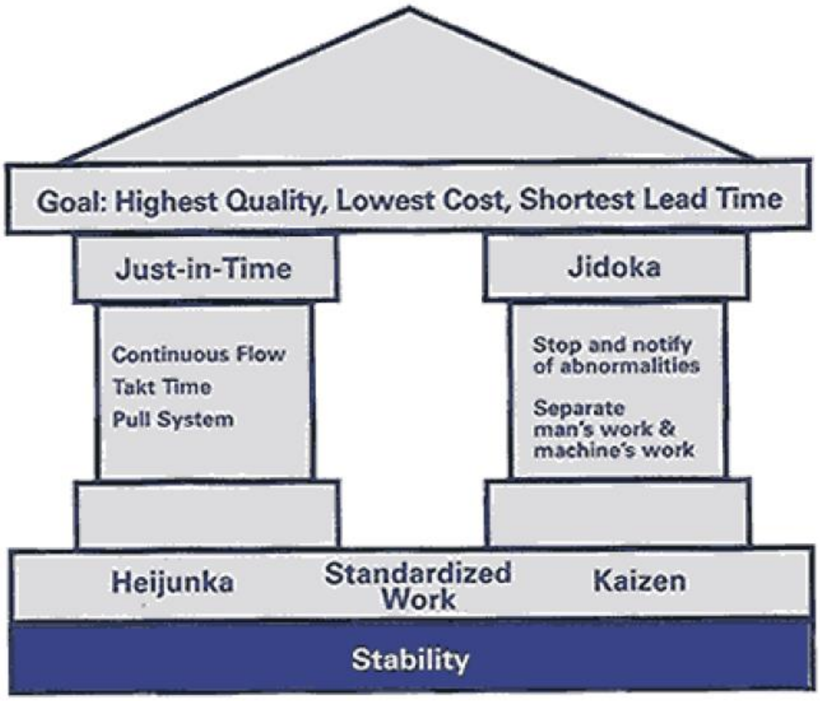


Fig 1.5 Toyota JIT system

1.5 Jidoka

Jidoka is a revolutionary 100 percent inspection technique, developed by Toyota. It is done by machines not men, using such techniques as *poka-yoke* (error proofing), which will prevent defects from advancing in the system by isolating bad materials and/or implementing line shutdowns. It is also a continuous improvement tool because as soon as a defect is found, immediate problem solving is initiated, which is designed to find and remove the root cause of the problem. In the design case, the line does not return to normal operation until it has totally eliminated this defect-causing situation. This powerful concept has been in place at Toyota since its inception as an automaker. In the Toyoda family, it was first implemented in 1902 when it was applied to looms to trigger shutdowns automatically when a thread snapped. Since then, *jidoka* has been continually evolving to higher levels of sensitivity. It is truly a revolutionary concept [5]. A great deal has been written about *jidoka* in cultural terms, with such topics as the interworkings of men and machines, which allow the machines to do the repetitive simple checking and let men do the higher-value work, such as problem solving. Ohno called it “autonomation,” and he speaks of it in terms of “respect for humanity.” Here is also where the revolutionary concept of “shutting down the line by the operator for production problems” is also manifest.

1.6 Kanban

A visual sign or flag that passes on an arrangement of guidelines to either pull back parts or deliver a given item is known as a kanban. Kanban is for the most part perceived as a card that goes between forms, imparting data in the matter of what materials to renew [5]. To additionally characterize kanban, one might say that there are two fundamental classes:

- Withdrawal kanban: a permit to take from a stores or focal market territory, or
- Instruction or flag kanban: a permit to make an item, for example, advising an embellishment machine to run a set number of item B.

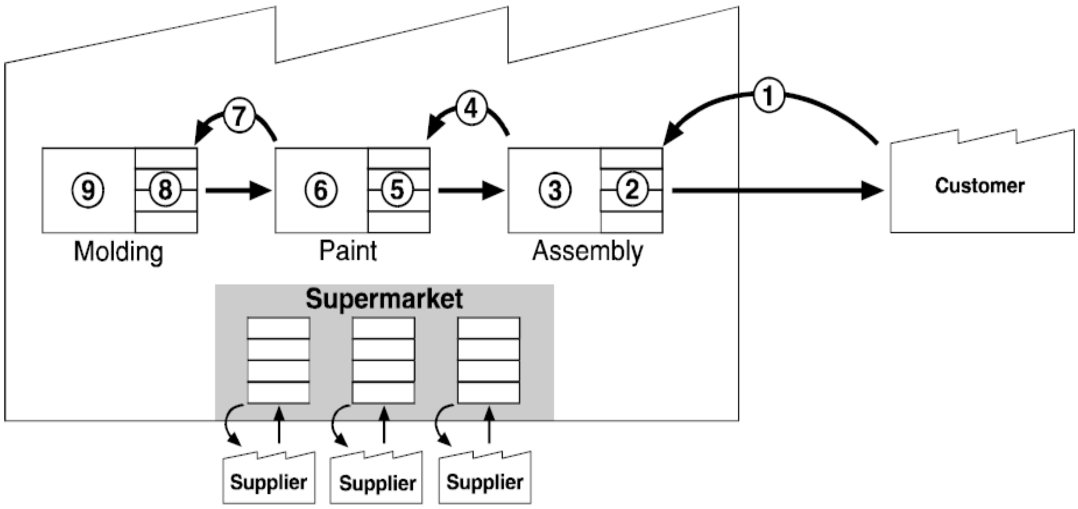


Fig 1.6 Depiction of Kanban

1.7 The 5 S’s

Much of Lean manufacturing is applying “common sense” to manufacturing environments. In implementing Lean, 5 S’s are frequently used to assist in the organization of manufacturing. The 5 S’s are from Japanese and are:

•Seiri - sort

•Seiton - set-in-order

•Seison - sweep

•Seiketsu - standardize

•Shitsuke - sustain

Fig 1.7 the 5'S'

1.8 The Five Steps of Lean Implementation

The process used to implement lean manufacturing is a straightforward one. However it is critical that lean is implemented in a logical manner. The steps associated in implementing lean follow [5]:

I. Specify Value:

Characterize an incentive from the point of view of the last customer. Express an incentive as far as a particular item, which addresses the customer's issues at a particular cost and at a particular time.

II. Map:

Distinguish the esteem stream, the arrangement of every particular activity required to bring a particular item through the three basic administration errands of any business: the critical thinking undertaking, the data administration assignment, and the physical change undertaking. Make a guide of the Current State and the Future State of the esteem stream. Distinguish and classify squander in the Current State, and dispense with it.

III. Flow

Make the remaining steps in the value stream flow. Eliminate efficient barriers and develop a product-focused organization that dramatically increases lead-time.

IV. Pull:

Let the customer demand products as needed, eradicating the need for a sales forecast.

V. Perfection:

There is no limit to the way toward diminishing exertion, time, space, cost, and mix-ups. Come back to the initial step and start the following lean change, offering an item that is perpetually about what the client needs.

1.9 Six Sigma

Six Sigma is a quality change strategy created by Motorola in 1986 to enhance fabricating forms and dispense with abandons. Motorola still possesses the administration and exchange marks for the name Six Sigma. Six Sigma alludes to 3.4 imperfections for each million open doors. For reference, Five Sigma is 230 DPMO and Four Sigma is 6,210 DPMO. Three Sigma is 66,800 DPMO or 93.32% great open doors for every million [6].

Most people recognize Six Sigma by the Green Belts and Black Belts. In an organization fully committed to Six Sigma there are also Champions (responsible for implementation across the organization) and Master Black Belts (in-house coaches for Black and Green Belts). Black Belts are typically dedicated full time to the process and Green Belts take Six Sigma implementation along with other responsibilities.

The weakness, in our view, is that practitioners become so enamored with the process that they over analyze and fail to act.

1.10 Taguchi Experimental Design

The Taguchi strategy includes diminishing the variety in a procedure through powerful outline of tests. The general goal of the technique is to deliver excellent item requiring little to no effort to the producer. The Taguchi strategy was created by Genichi Taguchi. He built up a technique for outlining tests to explore how distinctive parameters influence the mean and difference of a procedure execution trademark that characterizes how well the procedure is working. The exploratory plan proposed by Taguchi includes utilizing orthogonal exhibits to arrange the parameters influencing the procedure and the levels at which they ought to be fluctuated. Rather than testing every conceivable mix like the factorial plan, the Taguchi strategy tests sets of blends. This takes into account the gathering of the vital information to figure out which considers most influence the item quality with a base measure of experimentation, consequently sparing time and assets [7]. The Taguchi strategy is best utilized when there is a middle of the road number of factors (3 to 50), couple of associations amongst factors, and when just a couple of factors contribute essentially.

The quality of a product (or process) is one of the main factors which affect the buying decision of consumers. Dr. Taguchi was one of the pioneers who advocated the use of experimental design for product (or process) quality improvement.

The central idea in Taguchi's philosophy is reduction of variability around a target (or nominal) value. This target is the expected quality characteristic of a product (or process). For eg. A 51 O-gram box of cereal should weigh 510 grams. In this case, the nominal value is 510 grams per box which is how much cereal the consumer expects to get in a 51 O-gram box of cereal. Taguchi recommends that statistical experimental design methods be employed to reduce variation and move quality characteristics closer to the target. Any departure from this nominal value is a loss to consumer or society.

From Taguchi's point of view, there are three sequential stages for optimizing a product (or process): system design, parameter design, and tolerance design. The system design stage occurs when new concepts or methods are introduced to a new product or process. The parameter design stage is for improving the uniformity of a product. At this stage, Taguchi believes that the performance parameters of a product (or process) should be set to make the performance less sensitive to environmental (uncontrollable) conditions such as road temperature or humidity. Tolerance design stage is for determining the acceptable range of variability around the nominal value determined in the parameter stage. The activities at this stage may include selecting alternative raw materials or operation procedures [8].

At the parameter design stage, Taguchi utilizes traditional method like ANOVA and orthogonal arrays with a new class of statistics called signal-to-noise ratios in designing an experiment. He calls these types of designs methodology "Taguchi robust design". For implementation of Taguchi Methods, please refer to chapter 6 of SAS/QC software: ADX Menu System for Design of experiments. The following is a brief introduction of Taguchi robust design concept.

1.10.1 S/N Ratio

In Taguchi's outline technique the plan parameters (calculates that can be controlled by architects) and clamor elements (figures that can't be controlled by fashioners, for example, ecological elements) are viewed as persuasive on the item quality. The Signal to Noise (S/N) proportion is utilized as a part of this examination which takes both the mean and the fluctuation of the exploratory outcome into account. The S/N proportion relies upon the quality attributes of the item/procedure to be advanced. More often than not, there are three classes of the execution attributes in the investigation of the S/N proportion; the lower-the-better, the higher-the-better, and the ostensible the-better. The S/N proportion for every reaction is registered diversely in view of the classification of the execution qualities and subsequently paying little heed to the classification the bigger S/N proportion compares to a superior execution trademark. In the present investigation the arch stature and diminishing element are the-higher-the-better execution qualities. When the greater part of the S/N proportions have been processed for each keep running of a trial, Taguchi advocates a graphical way to deal with break down the information. In the graphical approach, the S/N proportions and normal reactions are plotted for each element against each of its levels [7]. From the charts, higher the better the qualities were chosen and the affirmation tests were led.
What is regression?
Regression is a factual technique to decide the straight connection between at least two factors. Relapse is basically utilized for figure and causal derivation. In its easiest shape, relapse demonstrates the connection between one free factor (X) and a needy variable (Y), as appeared in the equation given underneath:

$$Y = \beta_0 + \beta_1 X + u$$

The magnitude and direction of that relation are given by the slope parameter (1), and the status of the dependent variable when the independent variable is absent is given by the intercept parameter (0). An error term (u) captures the amount of variation not predicted by the slope and intercept terms. The regression coefficient (R2) depicts how well the values fit the data.

The linear regression model: The simple (or bivariate) LRM model is designed to study the relationship between a pair of variables that appear in a data set. The multiple LRM is designed to study the relationship between one variable and several of other variables.

10.11 Research Gap

Lean manufacturing constantly stresses how important it is to "achieve cost reduction by complete elimination of waste", as the way we think about waste can have significant consequences. The criterion to determine what is and is not waste varies depending on differences in background and context, and the same thing can be said about the evaluation of efficiency. Thus, the way we think about and judge waste or efficiency is quite important. It has been said that only two things exist when doing work at the work site - things one must do and things one must not do. Whatever our activity, we must never forget to consider the true purpose of the activity and the best means to accomplish that purpose. We always produce "products in response to sales" and carry out the work by aiming at improvement of quality, cost reductions and increased work safety. In so far as we manufacture with the same equipment, materials and methods as other companies, there is no way to gain competitive ascendancy. Keeping one step ahead of the other companies will, however, make the difference between the victory and a failure in the competitive war.

CHAPTER 2

LITERATURE REVIEW

A considerable number of studies have investigated how lean manufacturing is playing a vital role in the industries these days with the application of JIT by Toyota, Six Sigma by Motorola, 5S, Kaizen etc. These studies have been briefly discussed for the variations observed experimentally.

- ***R. Carvalho et al.:*** This paper presents a work undertaken in a metal structures production system in a company producing several assorted products for the civil construction. The work aim was to improve the production process, solving several productive problems encountered in the production system, such as: deliveries delays, long lead times, too many material handling, high stocks, errors and defects in metal structures assembly and production, and unnecessary motions. The identified problems were analyzed and improvement actions were scheduled and subsequently implemented. These improvement actions were based on Lean production organizational model and some Lean tools. The 5S methodology was implemented in the workplace as well as mistake proofing mechanism, standardized procedures, production activity control system and layout reconfiguration. These actions led to a reduction of the lead time, work in progress, transports, delivery delays, defects and errors in assembly and production.

  The better organized system "putting things in the right places", the facilitation to find out the raw-materials and the tools, the cleanness and enjoyable environment promoted by the 5S implementation led to reduced motions and waits. The layout reconfiguration and one-piece-flow reduced the transport time and promoted the continuous flow. The distances travelled were reduced in 25%. One-piece-flow also permitted the semi-finished products delivery to the subcontracted surface finishing company. CONWIP implementation limited the system load, promoted the exact quantity to be produced and facilitated the stocks control and raw-material orders. The mistake proofing mechanism reduced significantly the errors and defects and avoided the frames transport and returns to the company due to erroneous point holes in the civil construction local. All these implementations reduced the wastes and the lead-time.This was reduced to 2 days, i.e., 80% related to the previous lead-time [9].

- ***Gaurav Kumar et al.:*** Today's business growth is totally dependent on the productivity and the customer satisfaction through in-time delivery and services. This Paper addresses the application of lean manufacturing in sheet metal industry. The goal of this research is to investigate how to improve the productivity and in time delivery as expected by customers. In a sheet metal industry, there is always a big challenge for improvement in the productivity of the plant. M/s ABC sheet metal industry manufacturing rim for automotive vehicles have faced the productivity problem from the last three years. The collected data and the observations reveal that the level of production is low and very much in line with non-motivational environment. There is intentional slow down despite the fact that all operations are practically having capacity just double of what is being produced. However, there are three operations which need to be improved along with the suggestions incorporated in this thesis. The implementation of suggestion as a whole shall cut down the wastages at various stations and improve productivity approximately up to 50% . The material handling has to be dedicated type and tailor made to suite the requirement at the lowest possible cost [10].
- ***Athalye1 Anuroop:*** In this paper, industrial engineering and management tools like TQM, TPM, JIT, Value Analysis & Value Engineering, Lean manufacturing, Kaizen etc. have been studied and analyzed for cost reduction in a specific production process of an auto ancillary industrial firm. For this a case study was performed on sheet metal stamping process of LCV/HCV body parts at XYZ Company at Pithampur (Indore)M.P.. A survey in interview form was conducted among managerial and engineering professionals from various similar type industries. The survey is based on cost reduction techniques, related challenges, market role etc. Attempts have been made to investigate the role of vendors in cost reduction and the problems faced from their side. Application of job plan in investigating the problems in productivity improvement has also been studied. The outcomes have been analyzed and discussed in details.

  The study is conducted in press shop of an automotive stamping part supplier unit, to check the scope in productivity improvement, scrap utilization on the concept of lean manufacturing & Kaizen, studied during this project. During the study, there are 300 types of press parts manufacturing in press shop as per bill of material (BOM). Dimensions, weight of die and tonnage requirement are selected from operation standard for productivity improvement. The part Reinforcement Cab stay LH/RH is having die is selecting for tool trial. After finding the ok part the die Operation no. 3/4 upper half is require to increase its height by 20mm. The O.E.E. for the day FTD is 90.21%, which is more than month till date MTD 89.65%. The improved SPM (strokes per minute) of the 600 T press machine for the day is 5.74 which is maximum SPM from last 09 days production. The die change is minimum for the day FTD is 04 and the no. of strokes for the day for two shifts are 4992, which are higher than the target strokes per two shifts 4927 [11].

- ***Norani Nordin et al.:*** The findings show that most of the respondent firms are classified as in-transition towards lean manufacturing practice. These in-transition firms have moderate mean values for each of the five lean manufacturing practice categories. It is also found that these firms spend more attentions and resources in internal areas such as firms' operation and management, compared to external relationships with suppliers and customers. These firms believe that the factors that drive the implementation of lean manufacturing are the desire to focus on customers and to achieve the organization's continuous improvement. The results from this survey also revealed the main barriers that prevent or delay the lean implementation. The main barriers to implement lean manufacturing system are the lack of understanding lean concepts and shop floor employees' attitude.

  The results show that most of the respondent firms have implemented lean manufacturing system up to a certain extent. Cluster analysis is performed to classify the respondent firms in groups to signify the extent of lean manufacturing implementation or their status from five lean manufacturing practice categories. Majority of the respondent firms are classified as in-transition towards lean because of having moderate mean values for each of the five variables. The firms should aware and understand the lean concept and purpose, because the main barriers of these firms are the lack of real understanding of lean manufacturing concept and employees' attitude. This finding has implication for the firms as it provide a mean to help them to identify the factors that hinder or delay the implementation process. The management should understand and emphasis the importance to overcome these resistance for the successful implementation of lean manufacturing system in their firms [12].

- ***U. Dombrowski et al***.: Lean Production system (LPS) has become state of art in production facilities. But still, few enterprises succeed in maintaining a sustainable continuous improvement process (CIP). In many LPS, solely methods and tools are in focus of the implementation. But they merely represent the superficial elements of LPS. The actual key success factor is the involvement of employees in daily improvement. This can be achieved through a different way of leadership, the lean leadership. Although the importance of lean leadership has already been emphasized by many authors, so far no consistent structure or definition of this approach exists.

The importance of self-development has apparently not been identified so far. This principle is the foundation for the development of employees and enables the lean leader to conduct a convincing gemba management. The importance of gemba seems to be widely known but enterprises might need new methods for the specific application. The five golden gemba rules give lean leaders a first impression and guideline for applying gemba. Most enterprises have some sort of employee qualification but they should integrate methods like coaching and mentoring in their existing qualification systems. Especially in Germany, hoshin kanri is scarcely known. Existing metrics and reward systems should be redesigned regarding lean leadership principles. In summary, enterprises have realized the importance of lean leadership but have not adapted their leadership system so far. In order to truly understand the actual application of improvement culture in today's enterprises further analysis is necessary [13].

- ***Alexandra Tenera et al***: This have been attempted through Lean Management and Six Sigma integrated approaches in their managerial and production processes in which, Lean focus mainly on the waste elimination, using simple and visual techniques whenever possible and Six Sigma on the control and processes variability reduction, using statistical tools for this purpose. The present article proposes a Lean Six Sigma (LSS) project management improvement model supported by the DMAIC cycle and integrating an enlarged and adapted set of statistical tools, given the nature of the project management main variables and the involved processes. The proposed model was tested in a Portuguese telecommunication company context which project management processes system are based on Project Management Institute (PMI) standards. The model allowed identifying company's main project management problems and associated causes and the selection of the causes to be first attended. The proposed model also permitted to systematically address the actions and solutions to be implemented in order to keep, in the long run, the continuous improvement of the project management processes in the organization. The present article presented a Lean Six Sigma (LSS) project management process improvement model and a case study test developed in a real enterprise environment which has a formal and established project management system PMI based. The LSS proposed approach is a DMAIC cycle-based proposal. Given the nature of the project management available data, some classical six sigma tools have been tested and also adapted during the implementation of the DMAIC cycle-based proposal, including the integration of nonparametric tools on the classical statistical six sigma analyses and that new tools like text mining can be useful to support factual data treatment [14].

- ***D.T. Matt, E. Rauch:*** The introduction and implementation of Lean Production Principles over the last twenty years has had a notable impact on many manufacturing enterprises. The practice shows that lean production methods and instruments are not equally applicable to large and small companies. After the implementation in large enterprises belonging to the automotive sector the concept of lean thinking was introduced successfully in medium sized enterprises. Small enterprises have been ignored for a long time and special investigations about this topic are rarely. In the introduction of this paper was illustrated how important are small enterprises for the whole economy. They are not only numerous (16% of all enterprises in Italy) but create also about 25% of the total Italian sales volume in the industry.
- ***U. Dombrowski et al.:*** The implementation of Lean Production Systems is more than redesigning some production processes. The most seminal change has to be made in people’s knowledge. Otherwise, the changes will not be sustainable. Most implementation processes describe the sequence of necessary tasks but do not regard the integration of knowledge in the organization. Therefore, it is necessary to analyze how knowledge and knowledge flows can be described.

  It has been concluded that the development of a detailed reference model of knowledge flows is not possible so far because LPS implementation offers too many possible knowledge flows. The analysis of several actual implementations showed that the roles in implementation could be generalized as a basis for specific descriptions and further research [15].
- ***Daryl Powell et al.:*** For many years, lean production has been successfully applied in large companies producing high volumes of standardized products. However, companies which operate in dissimilar environments have yet to expose a suitable model for pursuing the lean ideal, adapted and fine-tuned to the diverse characteristics demonstrated by producers of, for example, highly customized, engineer-to-order products. The aim of this paper is to examine the evolution of lean principles with the

primary goal of converging towards a new set of principles that are more clearly aligned for the deployment of lean in engineer-to-order manufacturers. We analyzed the evolution of lean principles across a range of application areas (lean production, lean construction, lean product development), and restructured various elements through the use of a qualitative content analysis technique in order to propose a new set of principles for pursuing the lean ideal in ETO manufacturers [16].

- ***Noor Azlina Mohd.Salleh et al.:*** Study on TQM in Malaysia is first reported in 1997 while LM in 2010. Since then, voluminous studies reported that TQM and LM can bring more benefits to a company but there is still lack of case study on company that has implemented both initiatives. Preliminary status of Integrating TQM and LM has been established from survey conducted on the highly practices LM in Malaysian automotive companies in 2011. The findings from the survey are used in order to evaluate the Integrated TQM and LM in a Malaysian Automotive Company. An Integrated Total Quality Management (TQM) with Lean Manufacturing (LM) is a system comprises TQM and LM principles. This system focuses in achieving total customer satisfaction by removing eight wastes available in any process in an organization. This paper presents the Integrated TQM and LM practices by a forming company. The integrated practices are an adaptation combination of four models award, ISO/TS16949 and lean manufacturing principles from Toyota Production System, SAEJ4000 and MAJAICO Lean Production System. Delmia Quest Simulation has proven to be able to simulate the manufacturing process. More improvement activities can be done to measure the consistency between the simulation and the actual result for other type of process and other industry. The usage of Delmia Quest Simulation is not available for the company due to the high cost of purchasing the software. Besides the software provider, it is recommended that there is another centre that can provide services to the local automotive companies to simulate the process improvement as the university is only granted for academic license [17].
- ***Amelia Natasya Abdul Wahab et al.:*** Lean manufacturing or also known as lean production has been one of the most popular paradigms in waste elimination in the manufacturing and service industry. Thus, many firms have grabbed the benefits to practice lean manufacturing in order to enhance quality and productivity. However, previous research shows that there are various sets of tools or techniques that had been adopted at a certain degree across firms according to their own understanding of

lean manufacturing. The scenario resulted with varying leanness measures in order to measure lean practices. This paper describes a preliminary study in developing a conceptual model to measure leanness in manufacturing industry. Thorough literature survey, books and report analysis contribute to the main preliminary analysis of this study. This study was undertaken to design the conceptual model for lean manufacturing measurement in the manufacturing industry. Initially, the factors or determinants that contribute to the measurement of lean practices have been identified. Similar practices/tools/techniques with the same characteristics are grouped into the same dimension. Thus, the result of this research has shown that there are seven main dimensions that contribute to leanness measurement in manufacturing. We limit our model development by considering and selecting the practice/tool/technique that is proposed by the empirical approach or a combination of both quantitative and qualitative approaches as the aim of the study is to provide a general guideline for all companies and industries in the manufacturing sector [18].

- ***Nor Azian Abdul Rahman et al.:*** Lean manufacturing has been the buzzword in the area of manufacturing for past few years especially in Japan. The Kanban system is one of the manufacturing strategies for lean production with minimal inventory and reduced costs. However, the Kanban system is not being implemented widely by manufacturing companies in Malaysia. Thus, the objectives of this case study are 1) to determine how does the Kanban system works effectively in multinational organization; and 2) to identify factors hindering Malaysian small and medium enterprises (SME) from implementing Kanban. Findings of the study suggest that top management commitment, vendor participation, inventory management and quality improvement are important for Kanban deployment and towards lean manufacturing. In conclusion, the Kanban system implemented in this manufacturing company was found to be adequate due to the many benefits such as the operational costs, wastes, scraps and losses were minimized, over production stocks were controlled with flexible work stations. The factors that hinder SME companies from implementing the Kanban system are identified as ineffective inventory management, lack of supplier participation, lack of quality improvements and quality control and lack of employee participation and top management commitment. Implication of this study suggest that further research needs to be done on more SMEs so as to have more conclusive findings on Kanban implementation and barriers faced by the SME entrepreneurs. Other than that, the company must develop standard operating procedures for all processes involved in production line by improving the existing policy in order to make production process more efficient in future and it can be implemented by other manufacturing companies [19].

- ***Daryl Powell et al.:*** For many years, lean production has been successfully applied in large companies producing high volumes of standardized products. However, companies which operate in dissimilar environments have yet to expose a suitable model for pursuing the lean ideal, adapted and fine-tuned to the diverse characteristics demonstrated by producers of, for example, highly customized, engineer-to-order products. The aim of this paper is to examine the evolution of lean principles with the primary goal of converging towards a new set of principles that are more clearly aligned for the deployment of lean in engineer-to-order manufacturers. We take insight in lean production, lean project management, and lean product development in order to develop a set of principles which we suggest is more clearly suited for the deployment of lean thinking in engineer-toorder manufacturers [20].

- ***Rajesh Kumar MEHTA et al*.:** At present scenario, Lean Manufacturing has become a worldwide phenomenon. It is quite successful in drawing the attention of companies of all sizes. A large number of organizations are following Lean technologies and experiencing vast improvements in quality, production, customer service, and profitability. Lean Manufacturing is a systematic approach to identifying and eliminating waste through continuous improvement. The manufacturing industry in India must also look to leverage its advantages, its large domestic market, good conditions in terms of raw materials and skilled labour, and the quality focus. In India at the state level, there are few companies that are implementing Lean manufacturing techniques. In Dewas city, the industrial town of Madhya Pradesh, some of the automobile companies are vigorously following the Lean manufacturing techniques to eliminate waste and downsize the cost. Hence, all these factors prompted the researchers to analyze and study the implication of Lean Manufacturing Practices in Automobile Industries. To implement LMS successfully, the XYZ Company should customize its communication programs take employees well beyond their day-to-day perspectives and move them to understand, own and commit to associated initiatives. An effective communication plan should be built to create and maintain involvement and buy-in from people at all levels. Management must work with and educate people to align their thinking and behaviors with the redesigned processes, systems and management approaches to achieve positive change. It is also observed that the XYZ Company has non-effective use of staff talents and underutilization of expertise, skills, creativity, innovation, leadership, Motivation, drive. It is better to empower and give them responsibility to manage their work areas [21].

- ***A. P. Chaple et al.:*** Today, principles and practices of Lean manufacturing are widely used by industries to eliminate waste and make the process more efficient. Lean has been recognized as one of the key approaches in enhancing the productivity and hence the competitiveness of an organization. This paper presents a review of lean principles and practices in the Indian manufacturing industries. The paper contributes by identifying enablers & barriers in implementing the lean principles and practices, methodologies used in leanness measurement of an organization in the Indian manufacturing industry. Finally, the diffusion of lean in the Indian manufacturing industries has been given The main focus of lean manufacturing is to eliminate waste, doing things better in half of the resources as mass production requires, providing higher quality with lesser cost. More and more facets of lean manufacturing will come forth as researchers are keenly bringing through continual research. The good understanding of lean principles and practices is required for successful implementation of lean as lean practices without knowing lean principles can give short term success but may fail as long term strategy. The paper tried to present best way for lean implementation available in literature along with discussion that lean is applied successfully in different sectors than automobile sector such as service sector, discrete manufacturing, etc. [22].

- ***Roman BEDNÁR:*** The methods of lean manufacturing primarily designed for businesses dealing with serial production, are also used in other types of production. However the concept of lean production was not designed for these types of businesses, they are utilized only partially. Paper focuses on applying methods of lean concept in companies which are dealing with mass production and their options of exchange for other methods in the event of disagreement. Basis of the article is a list of lean methods with its description and its utilization in practice. The questionnaire was utilized to identify information from the practice. Based on this survey were identified the critical methods that are no longer appropriate for companies dealing with mass production. However, there are alternative methods of describing the problem. It is possible to say that companies are trying to get closer to their goal by modification of the basic concepts. And the concept of Lean Enterprise serves as a standard. Methods of lean concept support this type of production, with the exception of management bottlenecks. However, despite of the supportive character of these methods businesses dared to go in that direction. The stocks have the biggest impact on reducing the costs in mass production. The most important part of the production is the prediction of demand. In this case, mass production can save relatively higher costs compared to applying lean methods. However, the small improvement may prove after years as a significant cost savings [23].

- ***Sundareshan S D et al.:*** The available research papers in area of Lean are studied to know the implementation level of different lean tools, barrier and benefits of implementation are also considered in the review .The commonly used lean tools in the various organization, most common barriers and benefits have been identified and listed in this paper. Most common barrier is also components of quality of work life. Lean is applicable for all the type of the organization irrespective of their size, lot of work has been carried out in manufacturing sector that to in different functional areas, the level of implementation varies across the sectors and their size. It is evident from the research paper studied that kanban, continuous flow and TPS are the most commonly used lean tools in the organization [24].

EXPERIMENT SET UP

3.1 Press

3.1.1 Mechanical Press:

The traditional mechanical press can achieve the greatest production speeds, especially when running relatively flat parts with simpler, shallower forming requirements. These parts are typically processed from coil stock through a progressive or transfer die. Many automotive, appliance, and hardware parts fall into this category.

3.1.2 Mechanical Servo Press:

The mechanical servo press offers much of the versatility of the hydraulic press, at production speeds often approaching traditional mechanical presses. The stroke, slide motion, slide position, and speed are programmable to allow many different combinations that can work with a wide variety of dies, part types, and production speeds.

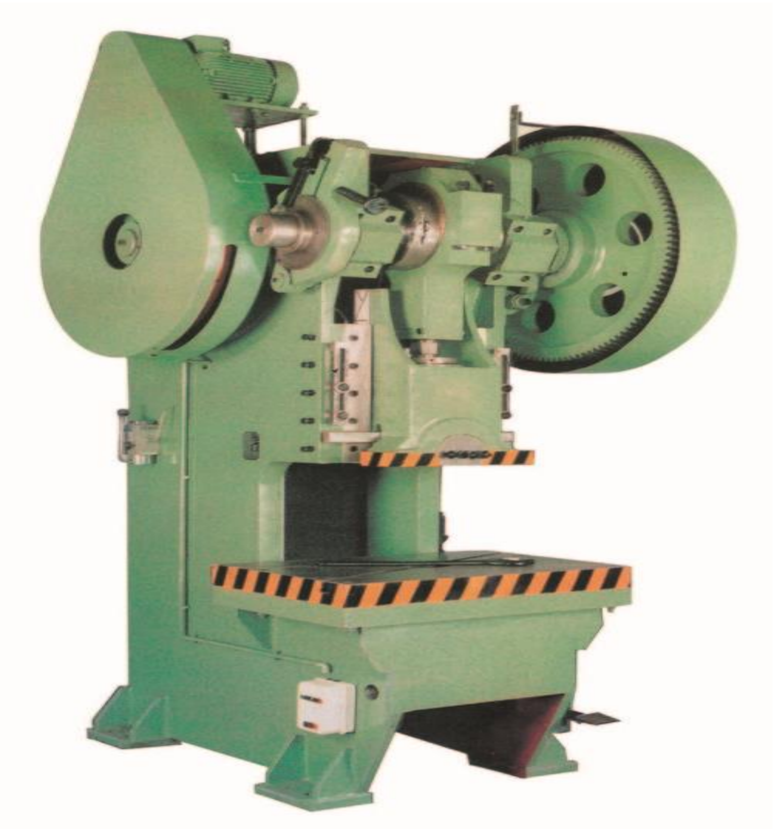


Fig 3.1 Mechanical press

3.2 Experimental Process

Here we are using a 20 tonne press for this operation.

TECHNICAL SPECIFICATIONS

									Unit : mm	
MODEL	5 Ton	10 Ton	20 Ton	30 Ton	50 Ton	80 Ton	100 Ton	150 Ton	200 Ton	250 Ton
Crank Shaft Dia	50	58	73	83	95	114	127	152	158	165
Stroke Adjustment	6 TO 25	6 TO 50	10 TO 62	13 TO 75	13 TO 100	13 TO 112	13 TO125	13 TO 125	165	165
Slide Adjustment	30	40	50	50	50	60	60	60	70	70
Hole In Ram	19	25	32	38	51	51	55	60	63	63
Hole In Bed	51	70	89	102	127	127	191	200	216	229
Length & Width of Bed	230 X 142	381 X 288	455 X 250	508 X 355	650 X 400	750 X 500	800 X 650	800 X 650	1016 X 736	1067 X 778
Dis To Bed To Ram	150	203	230	266	350	450	450	450	519	544
H.P/r.p.m	0.75 / 1440	1 / 1440	2 / 1440	3 / 1440	5 / 1440	7.5 / 1440	10 / 1440	15 / 1440	20 / 1440	25 / 1440
Weight Of Approx Kg.	255	525	1100	1300	2300	3000	4500	5500	9100	11700

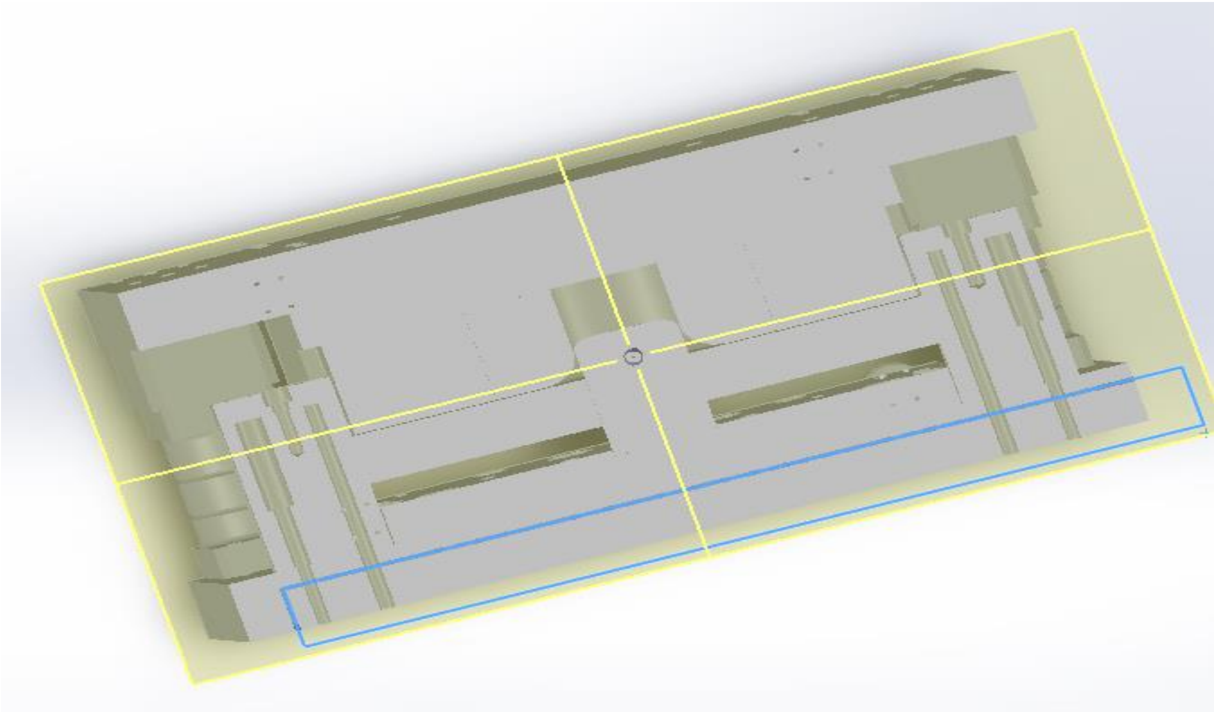
Fig 3.2 Technical specification of Mechanical Press

3.2.1 This part we are making is the drum brake male part of ford motors, which consists of the following operations:

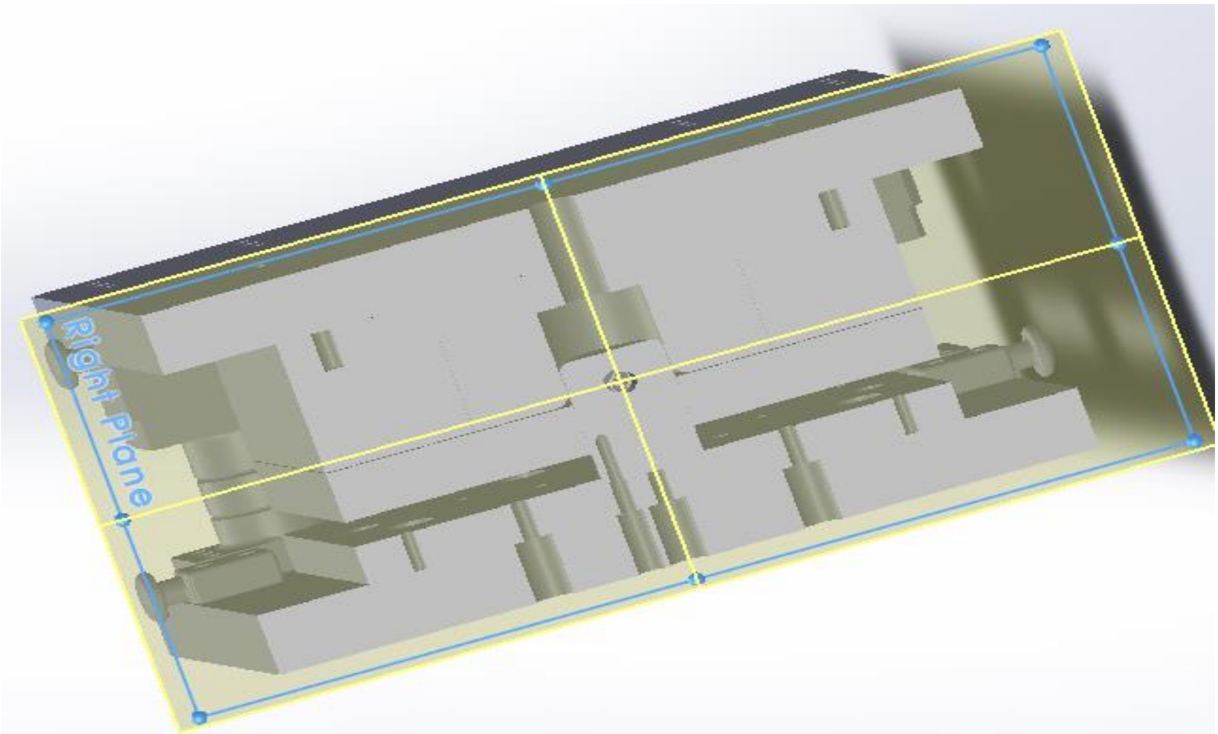
1. Blanking
2. First draw
3. Second draw
4. Third draw
5. Fourth draw
6. Fifth draw
7. Trimming
8. Flange down
9. Curling
10. Restrike
11. Riveting
12. Leak testing
13. Coating
14. Inspection

3.2.2 Some of these operation's tools are depicted in the respective figures:

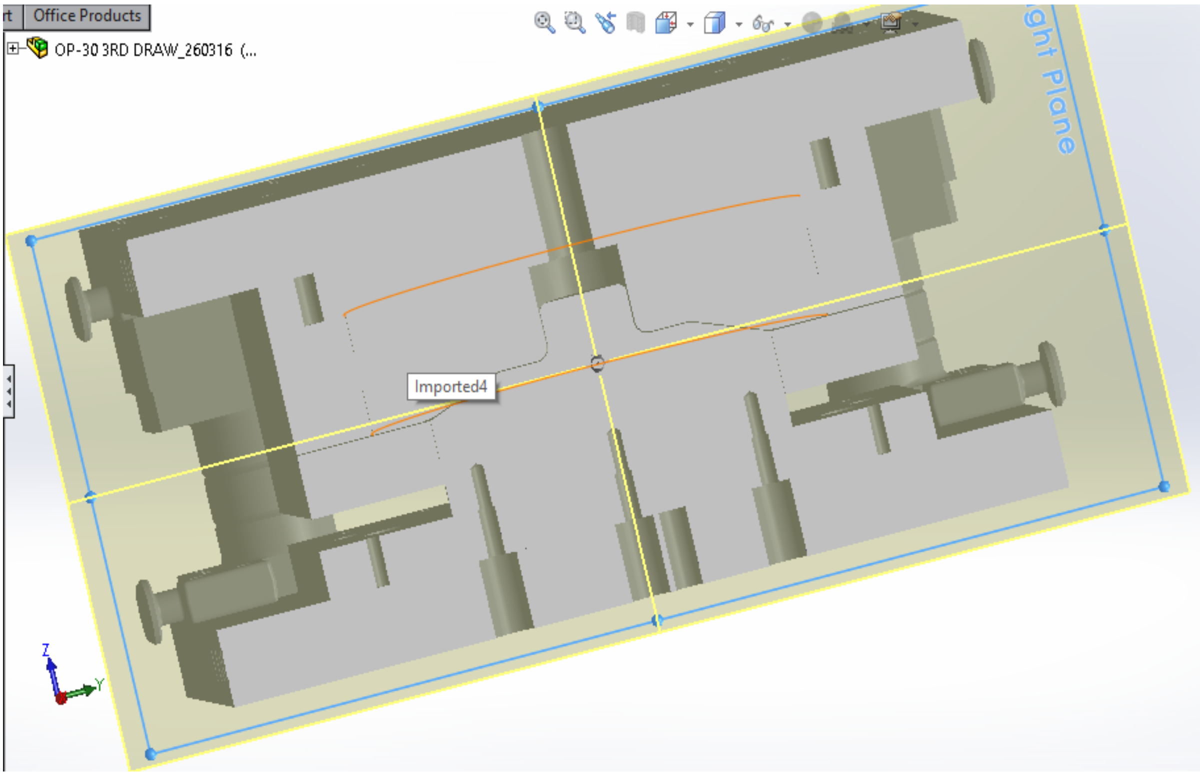
1. **First draw**



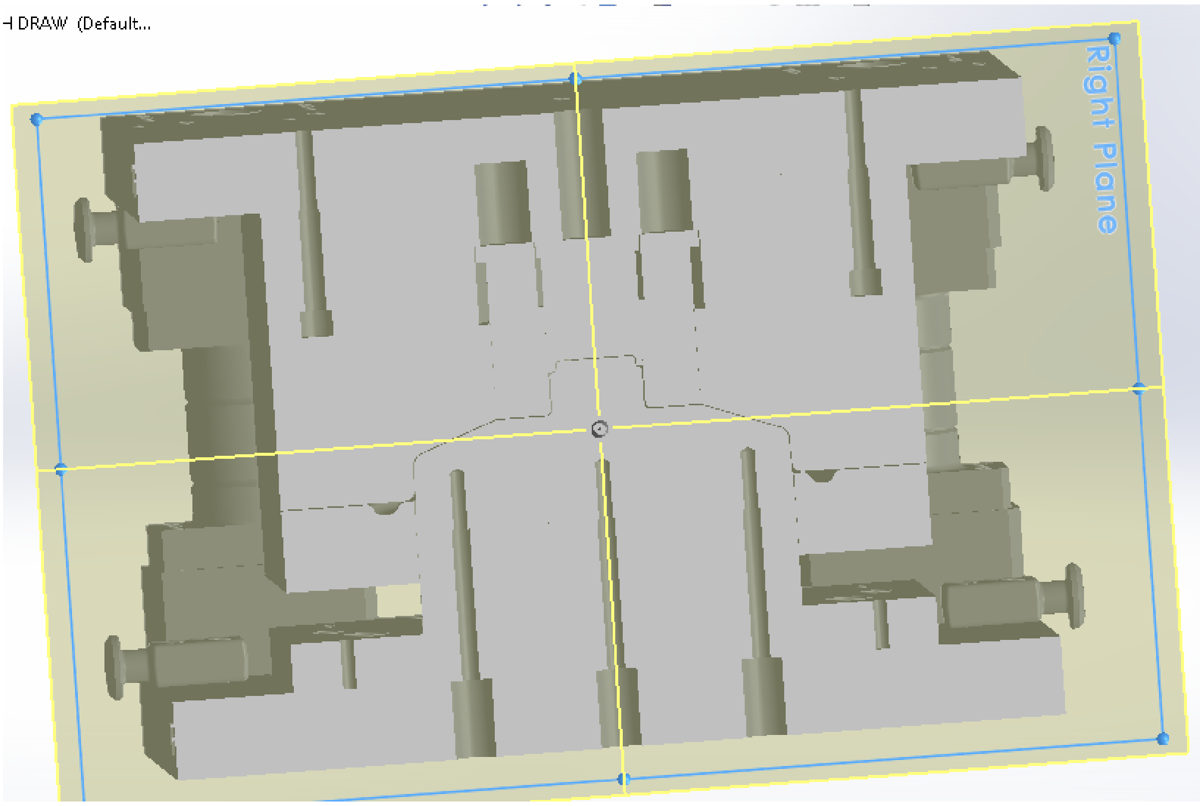
2. **Second draw**



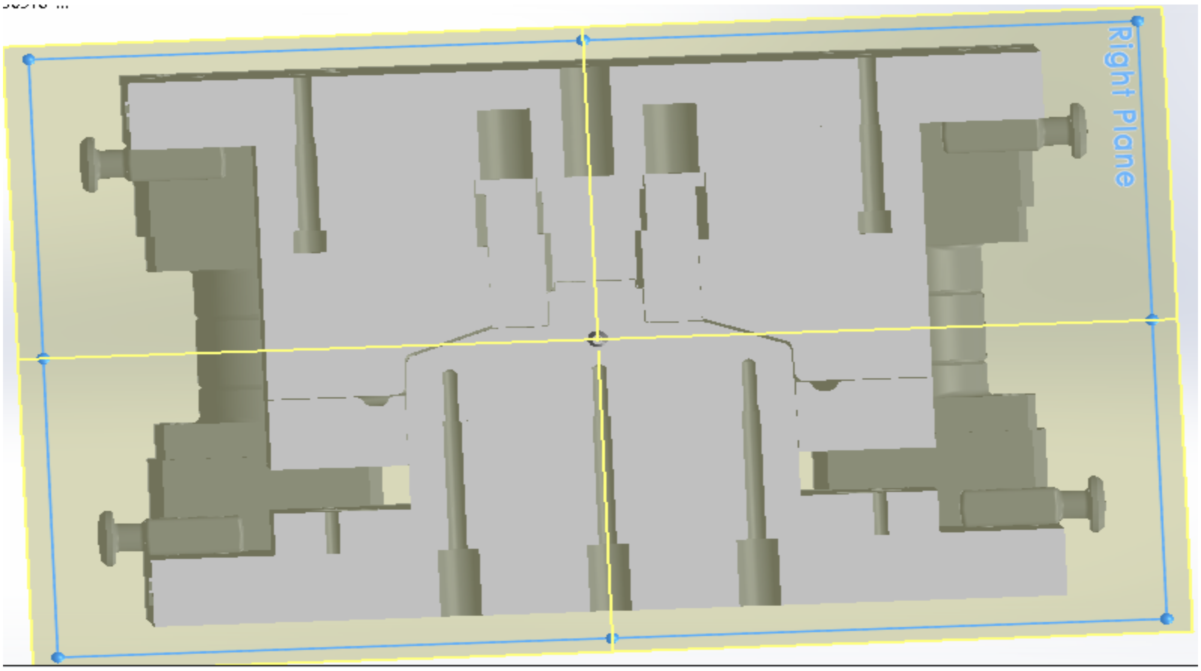
3. Third draw



4. Fourth draw



5. Fifth draw



6. Trimming

This is the operation which is playing the vital role for the analysis, the bold line is the part and the edges are the tools which are used for trimming.

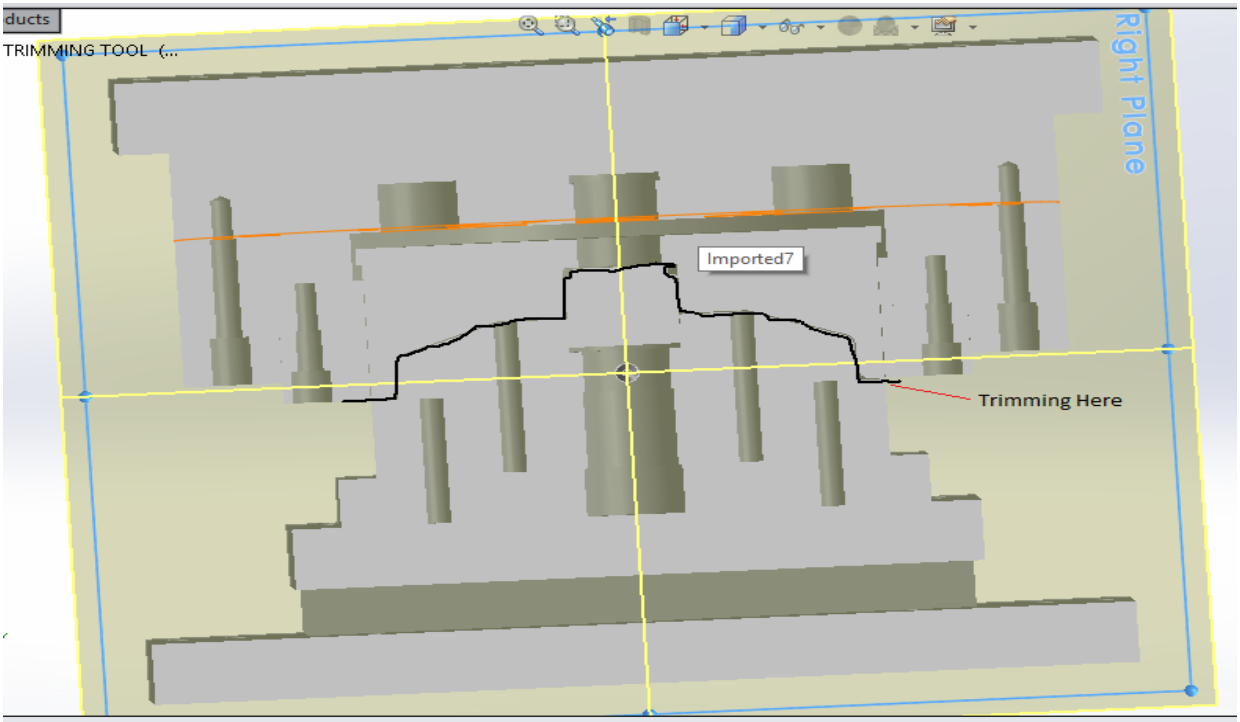
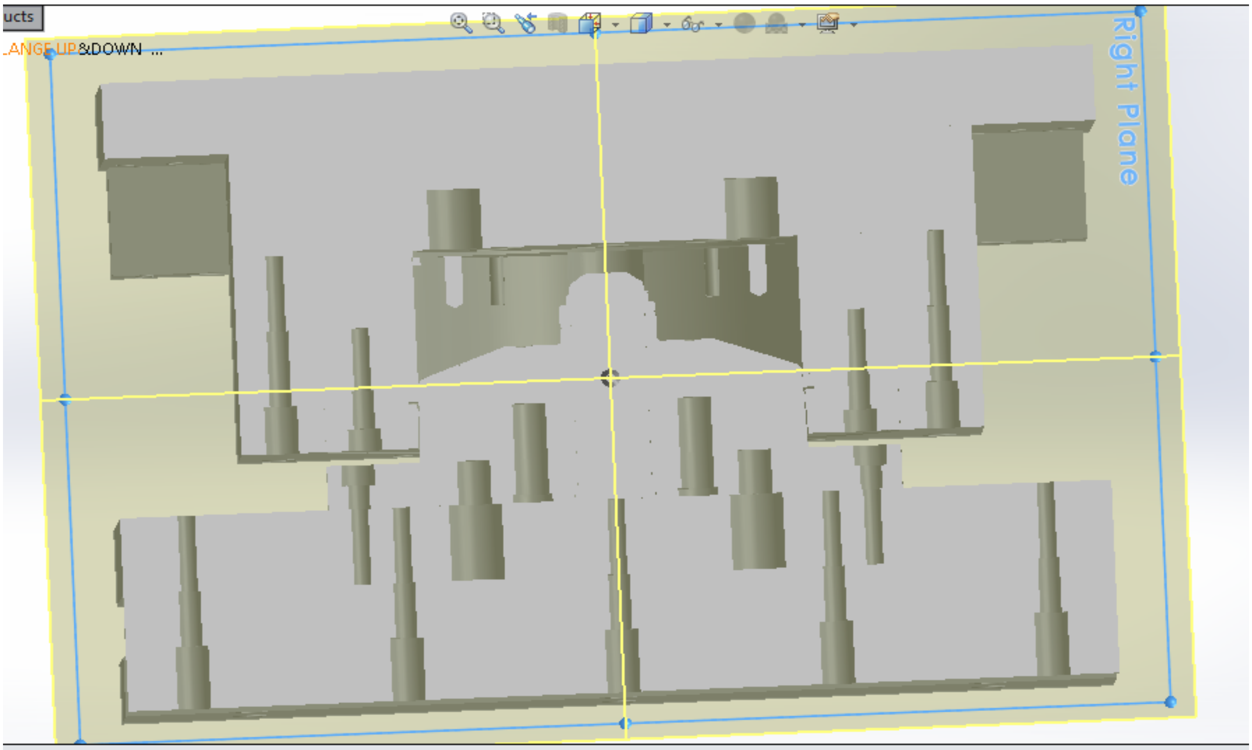
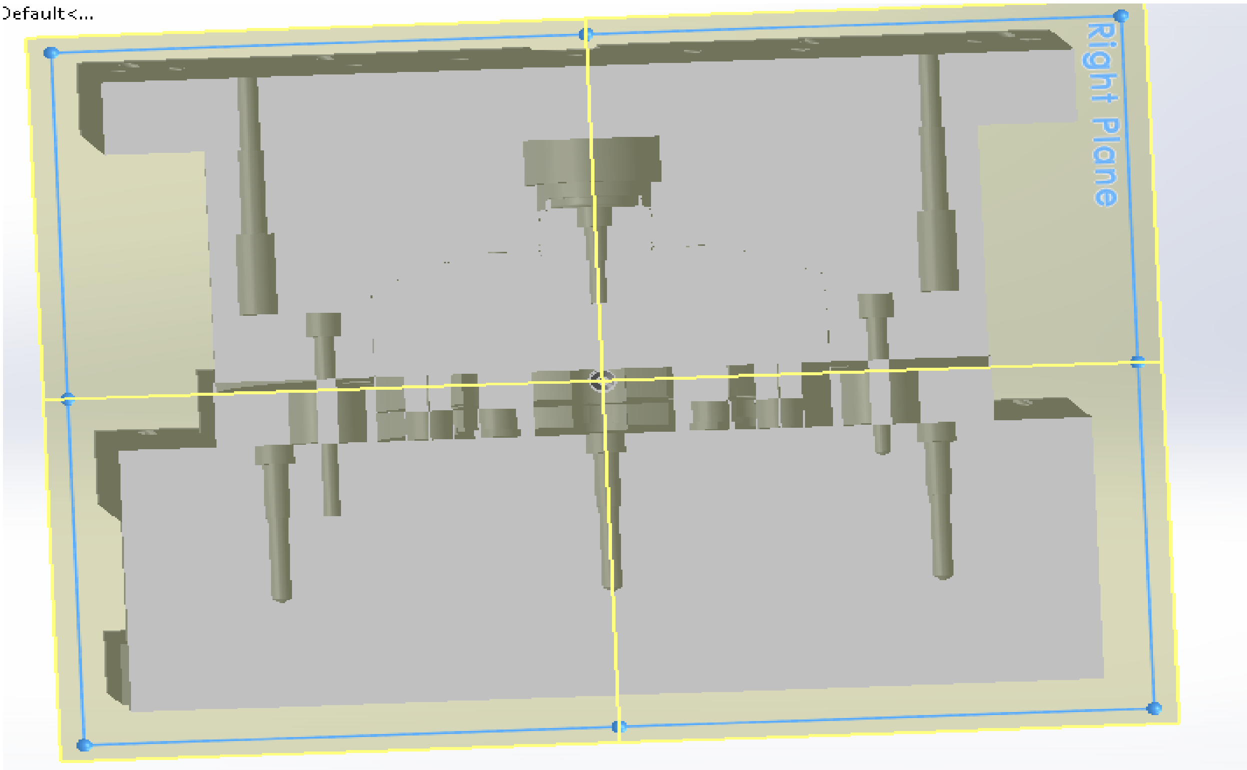


Fig 3.3 Main trimming operation

7. Flange up down



8. Restrike Tool



3.3 Change in the operation

Here we have changed the die of the initial blank which was initially having the diameter of 365 mm has now been reduced to 312 mm which will directly lead us to the material saving in the 7th operation of our experimental process.

These are the respective figures of the CAD models which make a clear picture.

1. **The 365 mm blank:**

   This blank was prepared initially before our experimental process started this was the die that was to be reworked to produce a blank of 312 mm.

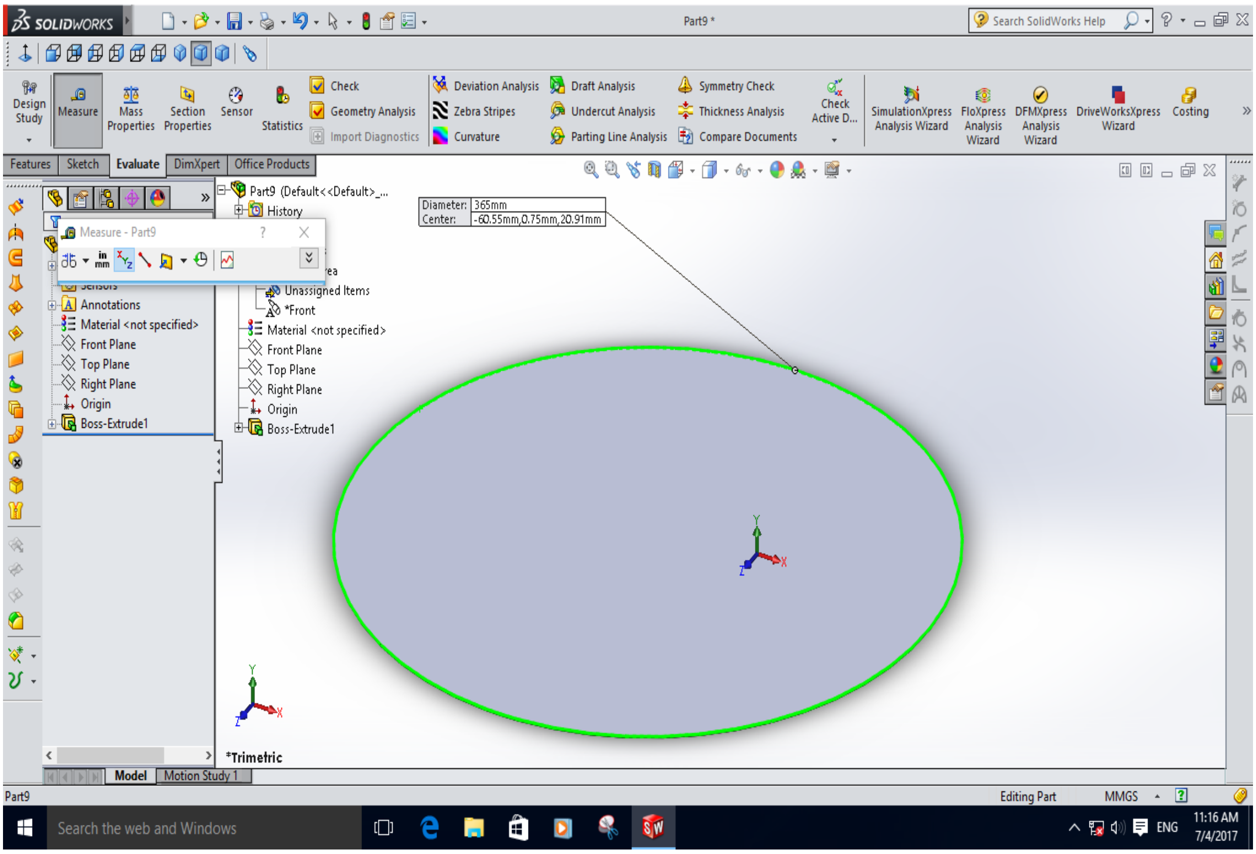


Fig 3.4 CAD model for blank before

2. The 312 mm blank:

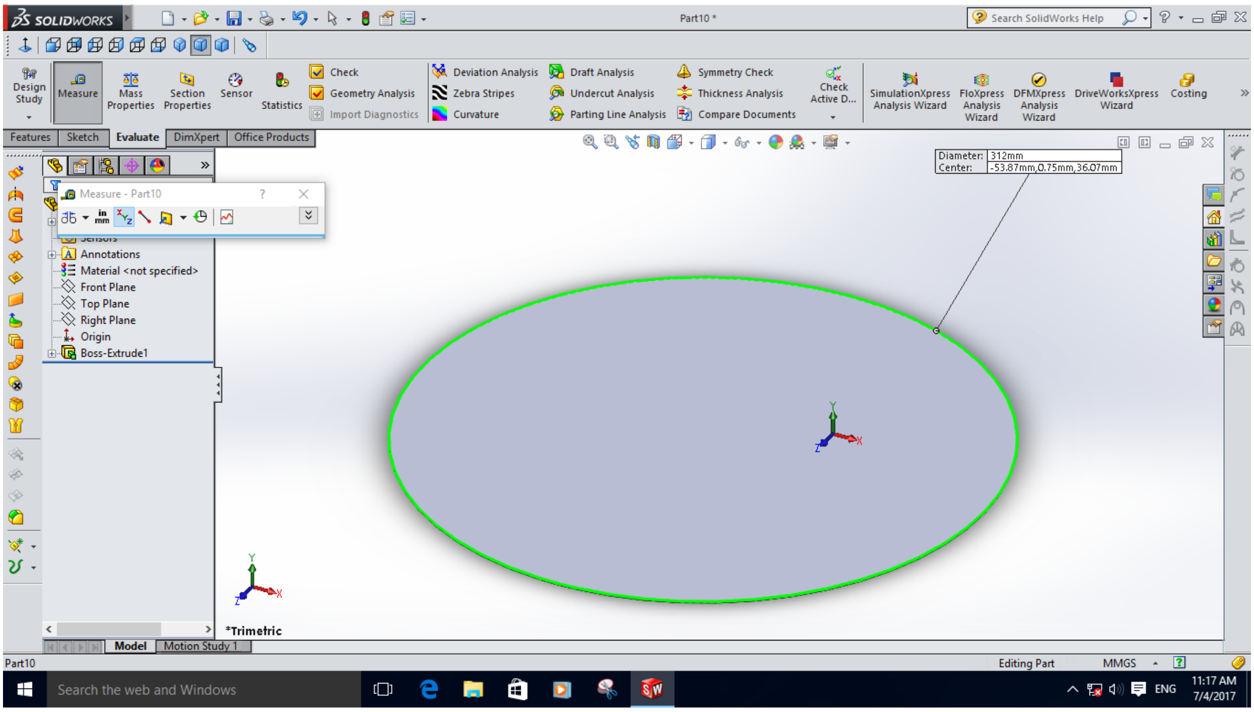


Fig 3.5 CAD model for blank after

3. After that we changed the die and made a 312 mm blank, then the results were compared with the initial blank size of 365 mm and a CAD generated result is shown below.

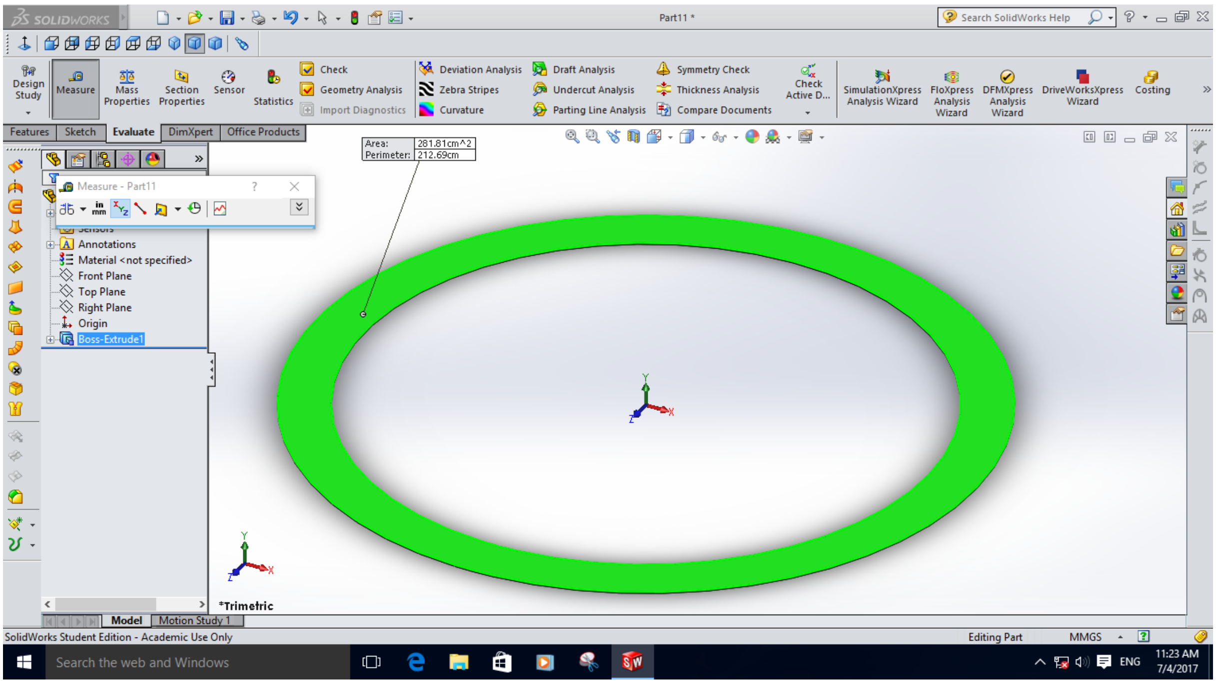


Fig 3.6 CAD model of scrap saved

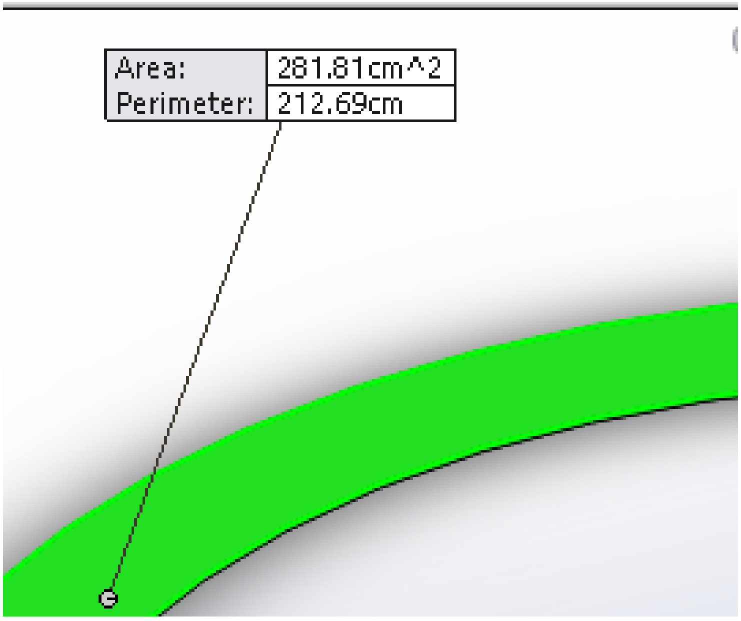


Fig 3.7 Calculated area of scrap saved

4. This figure is the most important one this gives the actual value of the mass got saved by our change in the first blanking operation by applying the mass properties to the modeling.

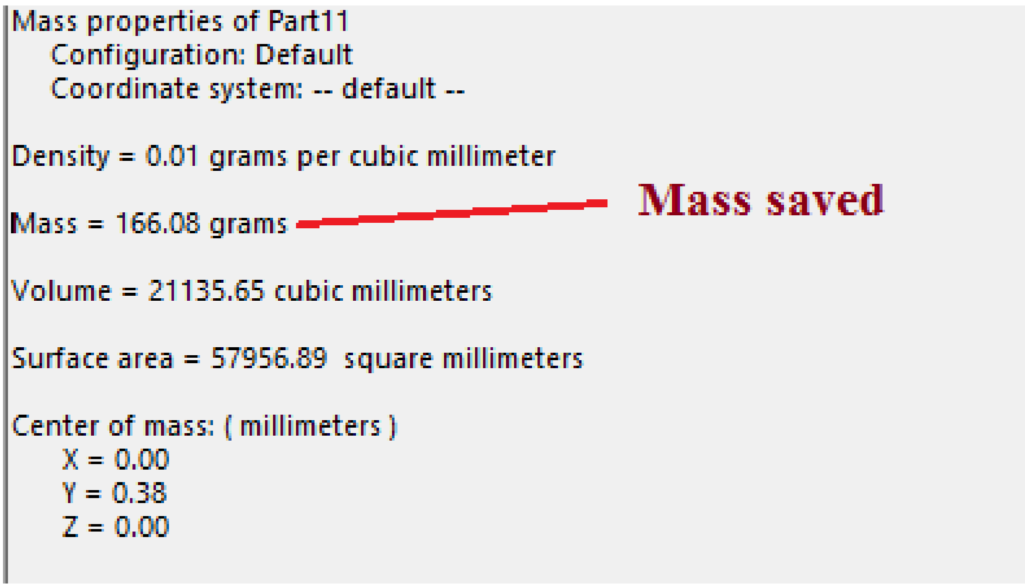


Fig 3.8 CAD calculation of mass saved

5. The CAD data was also compared after the respective changes this can be seen the upcoming figure.

I. Before

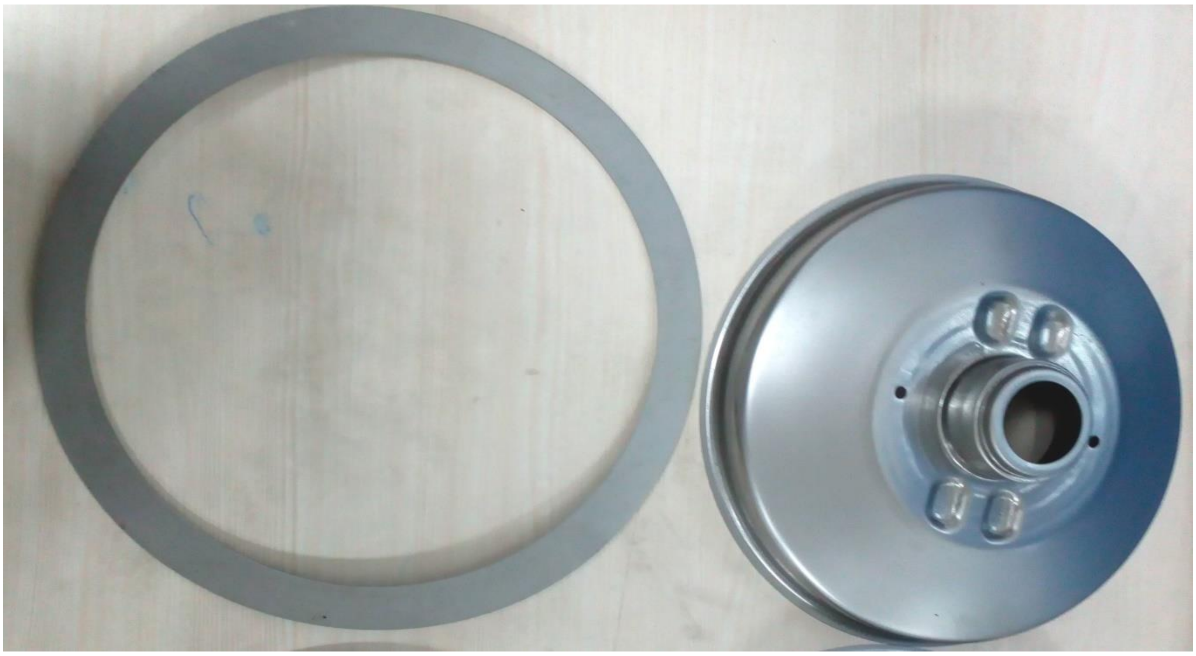


Fig 3.9 Part produced before

II. After

Fig 3.10 Part produced after

3.4 Data Collected for the analysis

After the trim weight got reduced by around **166 grams/ piece** it lead to a cost saving average value of **Rs. 7.5/ piece**. Then I have collected the production details of this part in the month of April and May.

Simultaneously the market fluctuating rates of mild are also noted as the company operates 6 days a week the scrap going out of the company for this part takes place on Sunday, then the values of the production to scrap with fluctuating market rates of the steel are taken for analysis.

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Month	No. of Parts	Rate/Part	Cost of finished product
April			
3-Apr-17	384	121.46	46640.64
4-Apr-17	384	121.46	46640.64
4-Apr-17	96	121.46	11660.16
6-Apr-17	204	121.46	24777.84
7-Apr-17	384	121.46	46640.64
8-Apr-17	252	121.46	30607.92
10-Apr-17	480	121.46	58300.8
11-Apr-17	288	121.46	34980.48
12-Apr-17	192	121.46	23320.32
13-Apr-17	96	121.46	11660.16
13-Apr-17	192	121.46	23320.32
14-Apr-17	282	121.46	34251.72
14-Apr-17	96	121.46	11660.16
15-Apr-17	192	121.46	23320.32
15-Apr-17	192	121.46	23320.32
17-Apr-17	288	121.46	34980.48
19-Apr-17	288	121.46	34980.48
20-Apr-17	288	121.46	34980.48
21-Apr-17	288	121.46	34980.48
21-Apr-17	192	121.46	23320.32
22-Apr-17	288	121.46	34980.48

25-Apr-17	144	121.46	17490.24
26-Apr-17	288	121.46	34980.48
27-Apr-17	222	121.46	26964.12
27-Apr-17	96	121.46	11660.16
28-Apr-17	192	121.46	23320.32
29-Apr-17	288	121.46	34980.48
29-Apr-17	288	121.46	34980.48
May			
1-May-17	258	121.46	31336.68
2-May-17	522	121.46	63402.12
3-May-17	60	121.46	7287.6
3-May-17	96	121.46	11660.16
5-May-17	240	121.46	29150.4
6-May-17	288	121.46	34980.48
8-May-17	162	121.46	19676.52
8-May-17	192	121.46	23320.32
9-May-17	288	121.46	34980.48
9-May-17	162	121.46	19676.52
10-May-17	144	121.46	17490.24
11-May-17	180	121.46	21862.8
11-May-17	120	121.46	14575.2
12-May-17	96	121.46	11660.16
12-May-17	252	121.46	30607.92
13-May-17	384	121.46	46640.64
13-May-17	192	121.46	23320.32
15-May-17	288	121.46	34980.48
15-May-17	192	121.46	23320.32
17-May-17	192	121.46	23320.32
18-May-17	252	121.46	30607.92
19-May-17	96	121.46	11660.16
20-May-17	192	121.46	23320.32
20-May-17	192	121.46	23320.32

22-May-17	576	121.46	69960.96
22-May-17	270	121.46	32794.2
23-May-17	192	121.46	23320.32
24-May-17	96	121.46	11660.16
25-May-17	96	121.46	11660.16
27-May-17	24	121.46	2915.04
27-May-17	300	121.46	36438
29-May-17	384	121.46	46640.64
30-May-17	192	121.46	23320.32
30-May-17	108	121.46	13117.68
31-May-17	96	121.46	11660.16
31-May-17	180	121.46	21862.8

Table 3.1 depicting the production values for the month of April and May

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No. pf parts	Scrap saved(Kg)	Cost saved	Labour Wage	Net Profit(Final)
1704	282.86	12162	2130	10032
2010	331.65	14692	2840	11852
1632	272.176	12247	1775	10472
1518	252.28	11604	1630	9974
1464	247.5	11137	1420	9717
2172	369.25	16985	3100	13885
2260	375.87	17214	3430	13784
1554	260.76	11890	1480	10410
960	159.36	7171.2	880	6291.2

Table 3.2 depicting weekly data of production scrap rates of steel labour waves and net profit

3.5 Design of experiments

As the labour wages are fixed in the company i.e Rs 8500/12 hr shift that is taken out of analysis the main role is played by 2 factors ie. The weight of scrap and the fluctuating steel rates.

The table gives the information regarding that:

Scrap saved(Kg)	**Steel Rates(weekly)**	**Cost saved**
282.86	45	12728.7
331.65	46	15255.9
272.176	45.6	12411.23
252.28	45	11352.6
247.5	43	10642.5
369.25	44.3	16357.78
375.87	46	17290.02
260.76	45.8	11942.81

Table 3.3 Shows cost saved

- After the two month analysis got these factors and their levels for DOE

Symbol	**Parameters**	**Units**	**Level 1**	**Level 2**
A	**Weight of Scrap**	**Kg**	**200**	**400**
B	**Rate of Steel**	**Rs/Kg**	**40**	**50**

Table 3.4 DOE

ANALYSIS AND RESULTS

4.1 Graphs from Taguchi

4.1.1 Signal-to-Noise: In the Taguchi method, the term ‘signal’ represents the desirable value (mean) for the output characteristic and the term ‘noise’ represents the undesirable value (S.D.) for the output characteristic. Therefore, the S:N ratio is the ratio of the mean to the S.D. Taguchi uses the S:N ratio to measure the quality characteristic deviating from the desired value.[4]

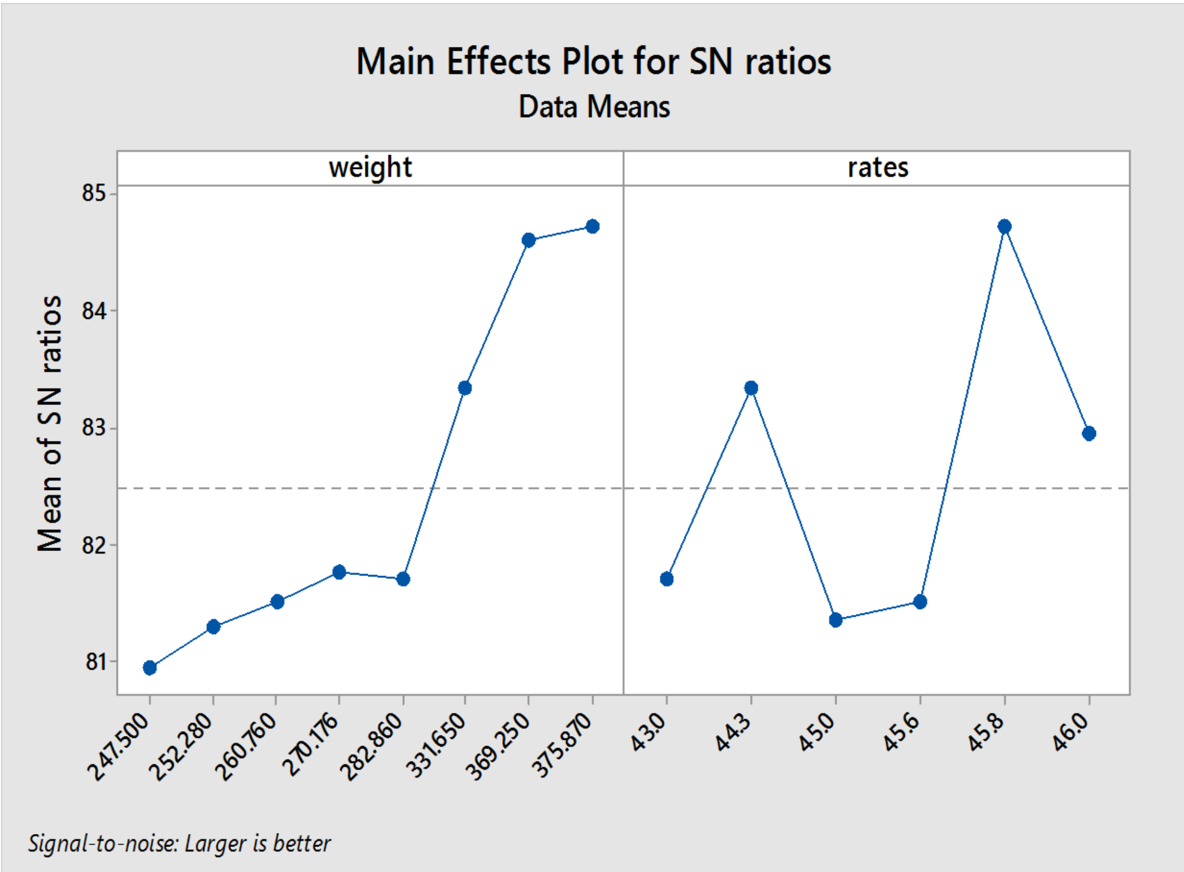


Fig 4.1 Signal to noise graph

- Formula for the S/N ratio larger is better is given by:

$$S/N = -10 * \log(\Sigma (1/Y^2)/n)$$

4.1.2 Mean: The main effect plots are used to determine the optimal cost gives us the following results.

At scrap weight 375.87 Kg and Steel Rate 45.8Rs/Kg we get maximum cost saved.

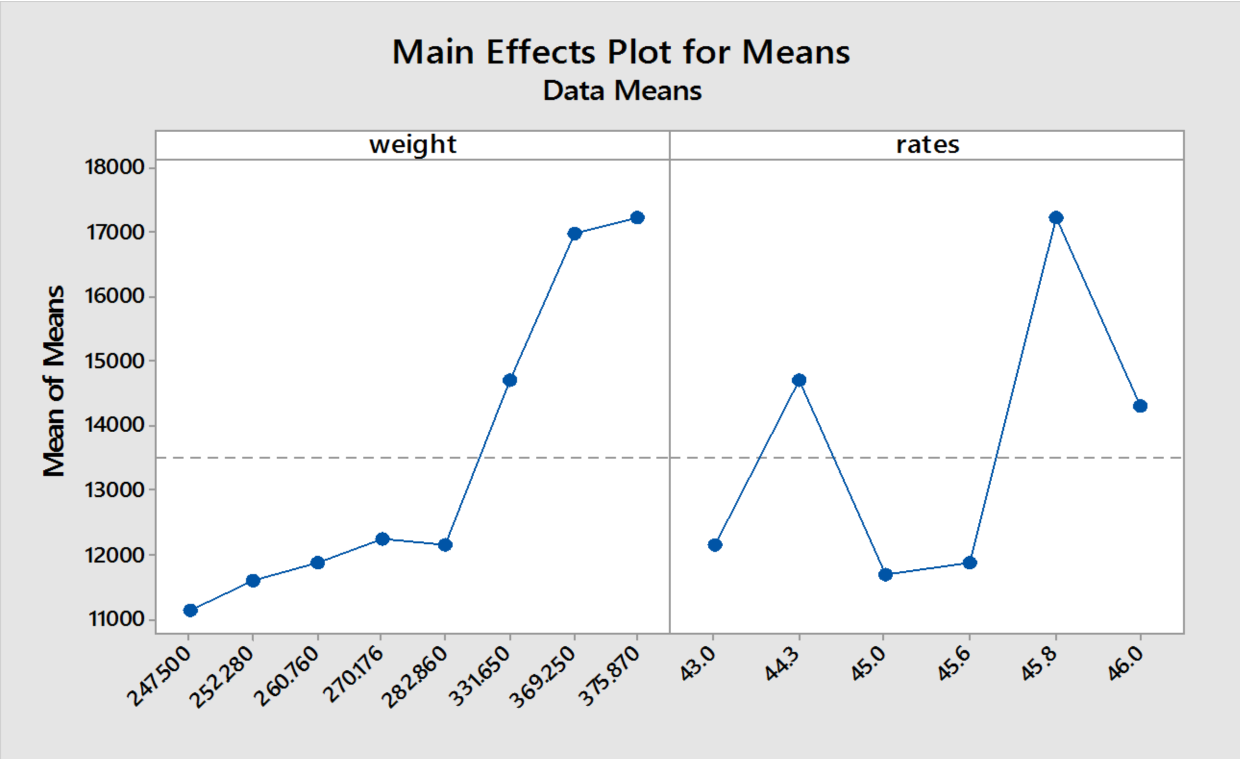


Fig 4.2 Mean Chart

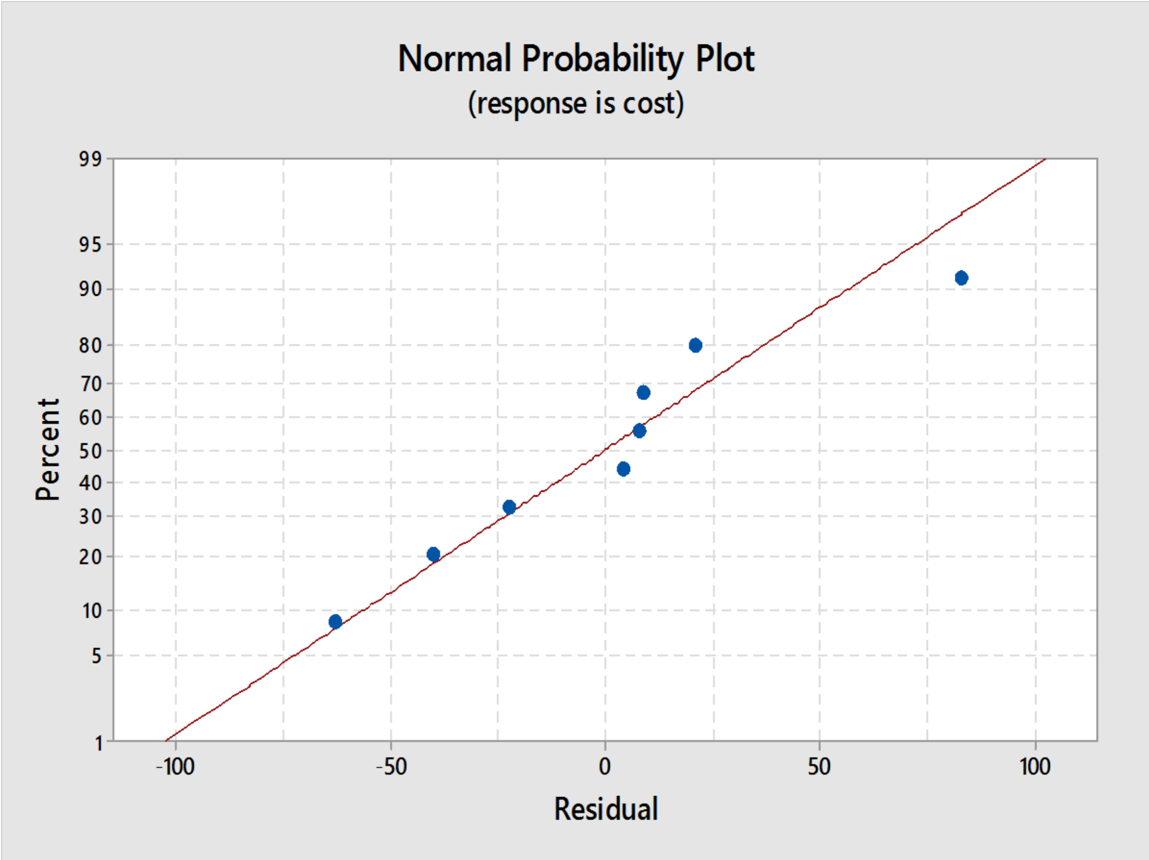
❖ After the Taguchi application following Fits and residiual values are generated

Scrap Saved	Rates of Steel	Cost Saved	FITS1	RESI1
282.86	45	12162	9987.03461	44.965391
331.65	46	14692	12041.3295	-189.3295
272.176	45.6	12247	10339.3594	132.64059
252.28	45	11604	9995.85666	-21.856662
247.5	43	11137	9507.8463	209.153695
369.25	44.3	16985	14023.1184	-138.11837
375.87	46	17214	13790.9954	-6.9953582
260.76	45.8	11890	10151.5906	258.409431
159	45	7171.2	6580.06922	-288.86922

Table 4.1 Experimental results for S/N ratio by Taguchi method

4.2 Regression Analysis

4.2.1 Normal probability plot of Residuals

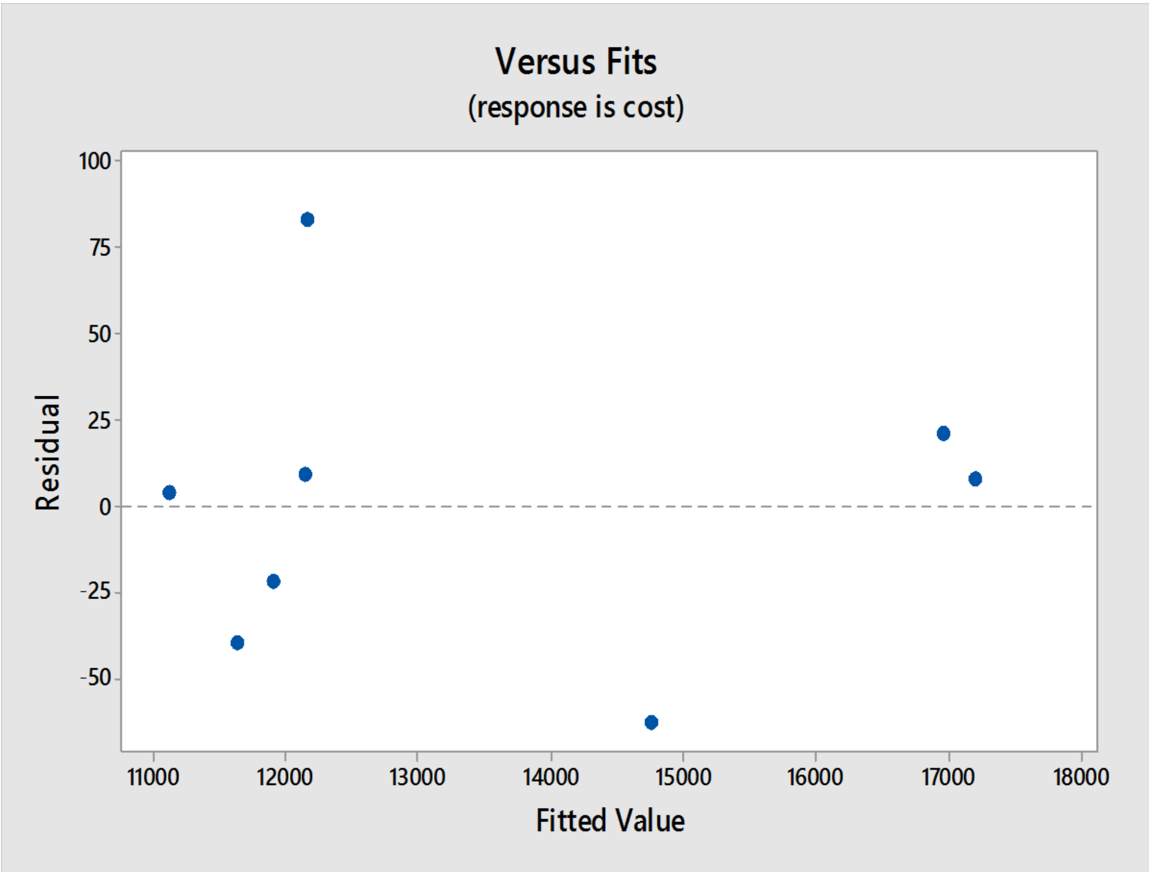


The points in this plot should generally form a straight line if the residuals are normally distributed. If the points on the plot depart from a straight line, the normality assumption may be invalid. As in this project work data have less than 50 observations, the plot may show bend in the tails even if the residuals are normally distributed. As the number of observations drops, the probability plot may show substantial difference and nonlinearity even if the residuals are normally distributed.

4.2.2 Residuals vs Fits for Cost Saved

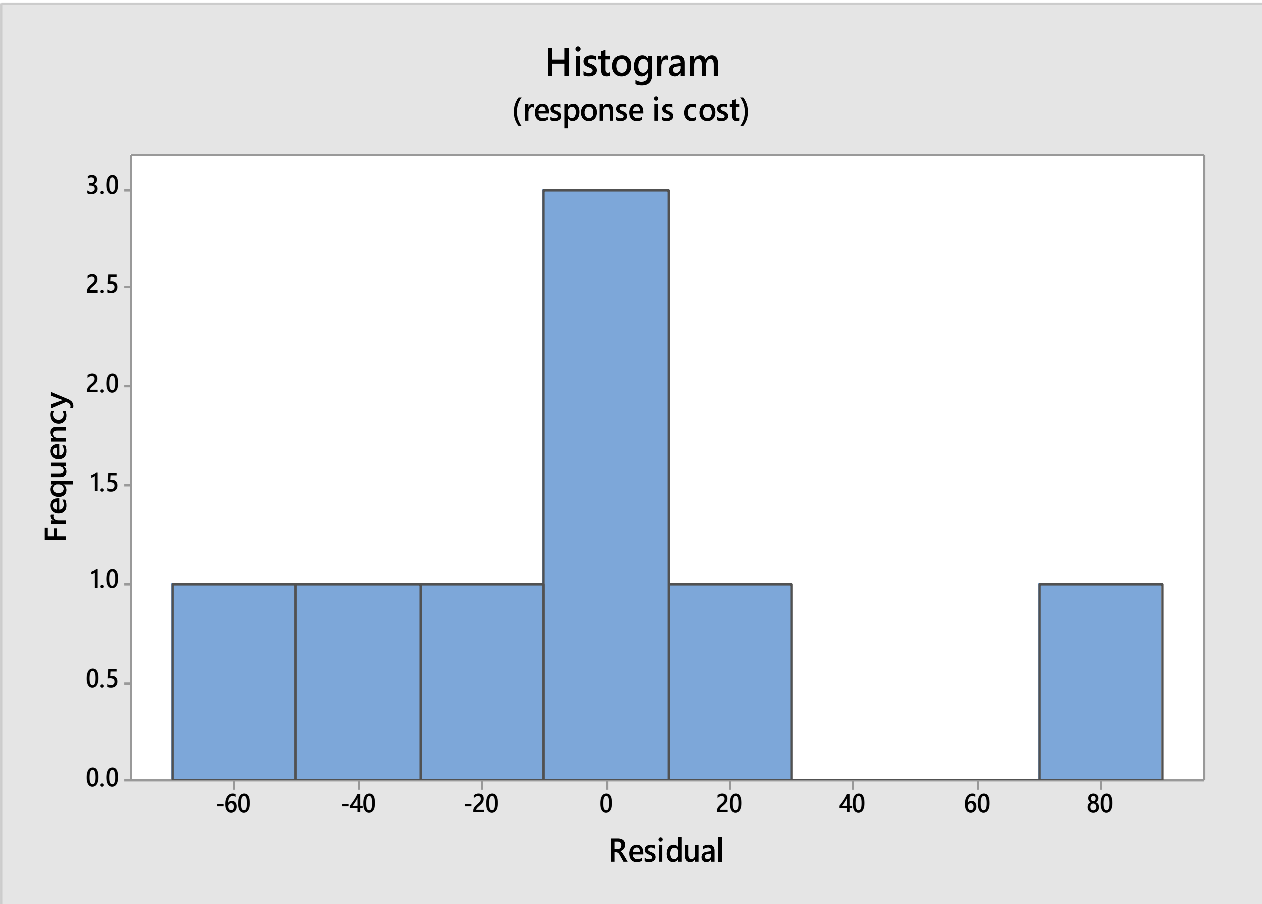
This plot should display a random pattern of residuals on both sides of 0. If a point lies distant from the majority of points, it may be an outlier. Also, there should not be any familiar patterns in the residual plot. The following may show error that is not random:

- A series of increasing or decreasing points
- A majority of positive residuals, or a majority of negative residuals
- Patterns, such as increasing residuals with increasing fits



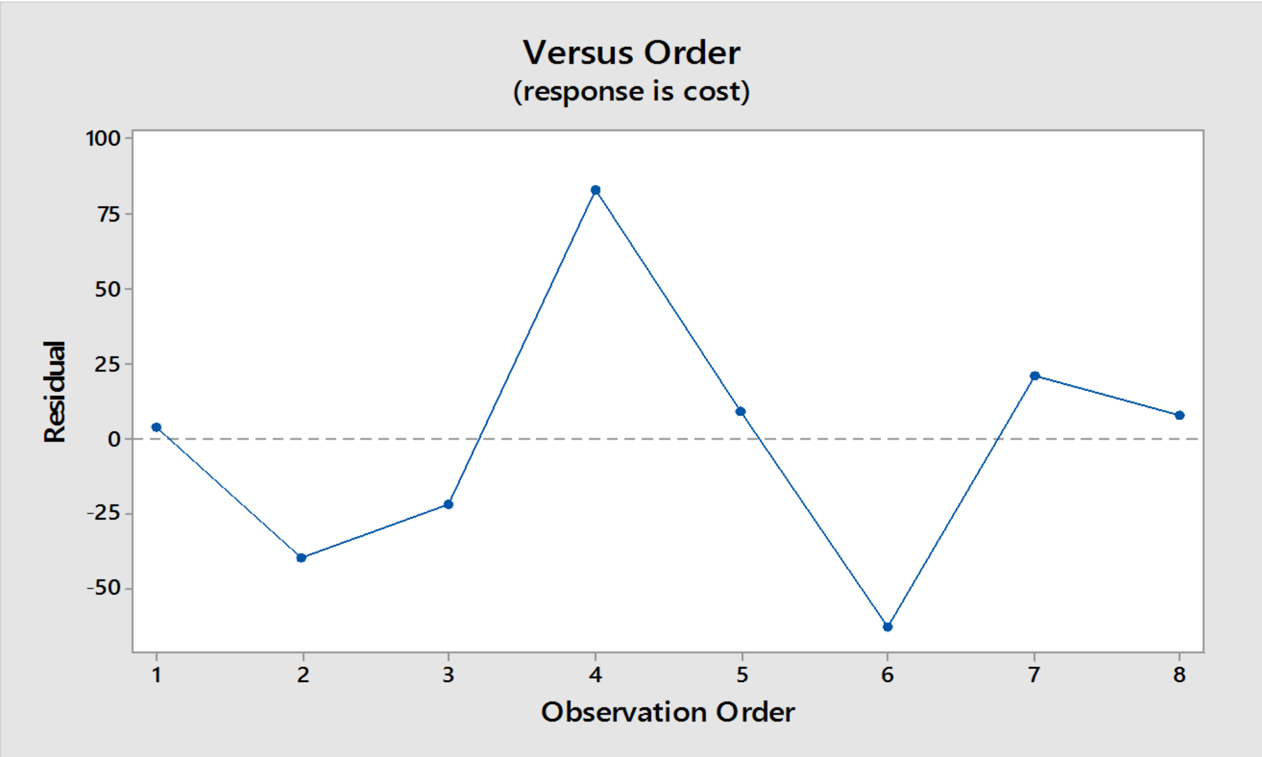
4.2.3 Residual Histogram for Cost Saved

Long tails in the plot may indicate skewness in the data. If one or two bars are far from the others, those points may be outliers because the appearance of the histogram changes depending on the number of intervals used to group the data



4.2.4 Residuals vs Order for Cost Saved

This is a plot of all residuals in the order that the data was collected and can be used to find non-random error, especially of time-related effects. A positive correlation is indicated by a clustering of residuals with the same sign and a negative correlation is indicated by rapid changes in the signs of consecutive residuals.



From graphs above, it can be concluded that all the values are within the control range, indicating that there is no obvious pattern and unusual structure and also the residual analysis does not indicate any model inadequacy. Hence these values yield better results in future predictions.

Symbol	Source	DF	Adj SS	Adj MS	F	P	Contribution (%)
	Regression	2	42474035	21237017	7841.27	0.000	
A	**weights**	1	38487753	38487753	14210.69	0.000	98.38
B	**rates**	1	618562	618562	228.39	0.000	1.58
Error		5	13542	2708			0.007
Total		7	42487577				100

Table 4.2 Analysis of Variance

4.3 Regression Equation

Cost = -13347 + 45.480 weight + 293.9 rates

Weight	Rates	Cost	Calculated cost	Error
247.500	45.0	11137.5	11134.8	-2.7
252.280	46.0	11604.9	11646.0944	41.2144
260.760	45.6	11890.7	11914.2048	23.5488
270.176	45.0	12247.9	12257.06448	9.14448
282.860	43.0	12163.0	12155.1728	-7.8072
331.650	44.3	14692.1	14756.212	64.117
369.250	46.0	16985.5	16965.89	-19.61
375.870	45.8	17214.8	17208.1876	-6.6584

Table 4.3 Calculated cost by regression equation

❖ The following regression analysis gives an error of around 0.1%.

CHAPTER 5

CONCLUSION FROM RESULT

5.1 Conclusions

This thesis has presented an application of the parameter design of the Taguchi method in the optimization of Lean manufacturing in sheet metals. The Taguchi experimental design was used to obtain optimum production as per the fluctuating rates as the production values are 1500-2000 weekly i.e. around 6000 is the demand from the Customer end.

Also the regression analysis was done to obtain an equation of the above two variables to calculate the profit that can earned with very less error of 0.1% and 98% contributing factor is for the scrap and 2% for rates of steel.

5.2 Future scope of the experiment

The study is aimed at developing strategic analysis using Regression and Taguchi methodology for Indian manufacturing organizations and various manufacturers have been treated alike irrespective of the type of products manufactured. Another direction for future research is developing sector-wise implementation of these programs. Thus, individual case study could be conducted for different sectors of manufacturing industry and accordingly the typical methodologies for individual sectors can also be evolved in future.

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