# PRODUCTION PROCESS ANALYSIS ON MANUFACTURING OF HYDRAULIC GEAR PUMP

J.J.Kathiriya[1], V.D.Amareliya[2] ,S.H.Kapadiya[3]

[1]Department of mechanical, Shantilal Shah Engineering College, Bhavnagar, Gujarat, INDIA
[2]Department of of mechanical, Mahatma Gandhi Institute of Technical Education and Research Centre, Navsari, Gujarat, INDIA
[3]Department of of mechanical, Mahatma Gandhi Institute of Technical Education and Research Centre, Navsari, Gujarat, INDIA

***ABSTRACT***

Manufacturing Firms sometimes suffers from Productivity, Low Production rate and Delivery problems. Production time is the top priority at every manufacturing firm, and each firm wants to minimize it as much as possible to deliver their product on time to time their valuable customers. . Some of the biggest time eaters in the industry are Setup time, Manufacturing time, Material handling time, and wait time. After the brief survey at VBC Hydraulics, we have conclude that setup time, manufacturing time, and wait time can not be utilize more than current because they are already using best possible machines and technology to manufacture Gear Pumps. But, material handling time and man-machine utilization can be improved by some engineering analysis. We did man-machine utilization by using man-machine utilization charts and some brief calculations and also focused to improve the material handling in the industry by implementation of GT(Group Technology) layout as they are mainly focused to manufacturing of Gear Pumps of different specifications with bulk Production.

***KEYWORDS***

*Group Technology(GT), Rout sheet, Man Machine Utilization, Production Process Analysis, Material handling time&cost,, Plan layout ,*

## 1.Introduction

Production is most essential thing for every industry, because every firm wants to deliver the product exact on time to maintain their reputation and increase profit. Based on our engineering knowledge Productivity is defined as,

"Productivity is the ratio of obtained output to the given Input"

It means, in this particular case our input is time and money and the output is total gear pumps that are manufactured. As per our, Productivity can be Increase by following 3 different ways.

**1.Increase output for Given Input:** If the time and cost required to manufacture predefined number of gear pumps are the same as before and we increase the number of gear pumps to be manufactured.

**2.Decrease Input for Given Output:** If the number of gear pumps to be manufactured are same and we decrease time and cost to achieve it.

**3.Slightly Increase Input and Obtain high Output:** If by giving little more time and cost we can achieve sufficiently high amount of gear pumps then the productivity can be increased.
In the manufacturing firms, time can be saved at many different places. As we have listed in our report 1, time consumption can be decreased at,Setup Time

- Waiting Time
- Machining Time
- Material Handling Time

**Decreasing Setup Time:** Setup time can be decreased by purchasing better equipments and machines with low setup time. Family scheduling and some special dedicated equipment also help to decrease setup time. In the firm, they have already applied above suggestions and the setup time is nearly optimum.

**Waiting Time:** Waiting time can be decreased by Reducing transfer batch size, increasing access of resources, and by Reduction in number of queues. But, at the present time the firm has nearly optimum waiting time by having enough number of machines and decreasing possible batch size.

**Machining Time:** Machining is the most time consuming process among all of the others. This can be deduced by purchasing best possible machines and utilizing optimum design. In the firm they are using CNC machines in most of the cases, which are the best machines available at current time.

**Material Handling Time:** Material handling time can be reduce by having optimum layout and better machine arrangement based on the operation sequence and operation timing. This is something we are highly interested in, because in the firm we have detected many time consuming material handling that are not so necessary and can be deduct by some engineering analysis.

# 2. Process Analysis

## 2.1 Introductory Description of Group Technology (GT).

Generally, Group Technology can be considered a theory of management based on the principle that *"similar things should be done similarly"*. In our context, "things" include product design, process planning, fabrication, assembly, and production control. However, in a more general sense GT may be applied to all activities, including administrative functions.

The principle of group technology is to divide the manufacturing facility into small groups or *cells* of machines. The term ***cellular manufacturing*** is often used in this regard. Each of these cells is dedicated to a specified family or set of part types. Typically, a cell is a small group of machines (as a rule of thumb not more than five). An example would be a machining center with inspection and monitoring devices, tool and Part Storage, a robot for part handling, and the associated control hardware.

Group technology (GT) is a manufacturing philosophy which advocates simplification and standardization of similar entities (parts, assemblies, process plans, tools, instructions, etc .) in order to reduce complexity and achieve economies of scale effects in batch manufacturing.

To the *manufacturing engineer* GT can be viewed as a role model to obtain the advantages of flow line systems in environments previous ly ruled by job shop layouts. The idea is to form groups and to aim at a product-type layout within each group (for a family of parts). Whenever possible, *new parts* are designed to be compatible with the processes and tooling of an existing part family. This way, production experience is quickly obtained, and standard process plans and tooling can be developed for this restricted part set.

To the *design engineer* the idea of GT can mean to standardize products and process plans. If a new part should be designed, first retrieve the design for a similar, existing part. Maybe, the need for the new part is eliminated if an existing part will suffice. If a new part is actually needed, the new plan can be developed quickly by relying on decisions and documentation previously made for similar parts. Hence, the resulting plan will match current manufacturing procedures and document preparation time is reduced. The design engineer is freed to concentrate on optimal design.

- list of seven characteristics of successful groups

Table 1 : characteristics of successful groups

| **Characteristic** | **Description** |
|---|---|
| Team | specified team of dedicated workers |
| Products | specified set of products and no others |
| Facilities | specified set of (mainly) dedicated machines equipment |
| Group layout | dedicated contiguous space for specified facilities |
| Target | common group goal, established at start of each period |
| Independence | buffers between groups; groups can reach goals independently |
| Size | Preferably 6-15 workers (small enough to act as a team with a common goal; large enough to contain all necessary resources) |

Clearly, also the organization should be structured around groups. Each group performs functions that in many cases were previously attributed to different functional departments. For instance, in most situations employee bonuses should be based on group performance. Worker empowerment is an important aspect of manned cells. Exchanging ideas and work load is necessary. Many groups are allocated the responsibility for individual work assignments. By cross training of technical skills, at least two workers can perform each task and all workers can perform multiple tasks. Hence the there is some flexibility in work assignments.

The group should be an independent profit center in some sense. It should also retain the responsibility for its performance and authority to affect that performance. The group is a single entity and must act together to resolve problems.

- There are three basic steps in group technology planning:

1. coding
2. classification
3. layout.

- Grope technology and application
-

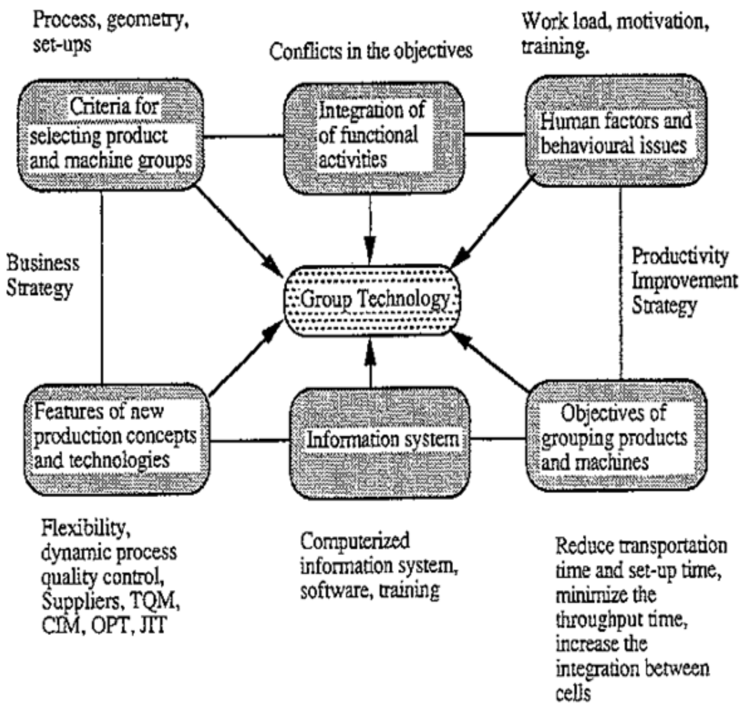


Figure 1 : Group Technology

## 2.2 Objectives

To complete our aim satisfactorily, our main focus will be on having each and every little details on the paper. Having the whole production line on paper will help us to determine the time wastage. So, the list of every readings we have planned to take is listed below.

1. Distance between machines ( to determine travelling distance per part )
2. Travelling Time per part between machines
3. Time taken by operator to complete operation for each parts
4. Time taken by machine for the machining process on the part
5. Total time consumed by every part to be manufactured
6. Assembling time of the pump

After having above all the readings listed on paper, we will move further to build some charts that are important too. Charts can explain things better than words. So, charts we decided to build are listed below.

1. Flow chart
2. Outline process chart
3. Layout of the company
4. Man machine chart

## 3. Methodology

Here method to achieve optimum processing time is quite simple and very effective. At Industry they are following process flow layout and man machine utilization is nearly random. As per study in detail about group technology layout, we decided to apply the same. Because it suites best to this firm as they are manufacturing same type of product (Gear pump with different specification). First of all we will give our best to build a root sheet and study the material flow and machining process. This study will lead us to note down very important readings like, machining time, setup time and ideal time for man and machine. This time readings will help us to create company layout with accurate distance between machines and thus we can calculate move time per part.

Using the machining time of machine and setup time for the part, we will build man machine chart which will lead us to determine the machine and man utilization percentage. Thus, we can conclude how much time of machine and man are effectively utilized in percentage. If suppose, man is working 30% of his time and for the rest of 70% time he is in ideal situation then we can possibly utilize his time to operate two machines simultaneously. This will also save firm’s cost spent behind hiring man power.

By using GT layout we will create completely new layout, and we will calculate the same for it. This will certainly help us to save some more time in material handling. We will also calculate and compare results, what was in the past and what we have achieved by implementing group technology. This project will also encourage use of group technology in similar industries which are not accepting it because of their production line is already fixed and they don’t want to change entire line.

**Assembly of SGP 12**

| No. | Parts | Quantity | Material |
|---|---|---|---|
| 11 | Circlip - ID , OD | 2 | M.S |
| 10 | 3*8 bolt (hex) | 4 | M.S |
| 9 | Cover | 1 | C.I |
| 8 | C.I Plate (Top) | 1 | C.I |
| 7 | Dowel pin | 2 | M.s |
| 6 | Seal kit | 2 | Rubber |
| 5 | Oil Seal | 1 | Rubber |
| 4 | upper Bush | 2 | Aluminum |
| 3 | Gear | 2 | M.S |
| 2 | Lower Bush | 2 | Aluminum |
| 1 | Body | 1 | Aluminum |

In above table, we have listed a part list which is required to assemble Gear Pump. Fact is they are building different gear pumps having different capacity based on customer requirement. But, we are focusing on the pump which is manufactured globally with standard dimension and the most they are working on (SGP 12). This will also help to compress our working area and improve our focus.

## 3.1 What is ROUT SHEET?

A document accounting for the output of production and tracing the sequence of operations of a batch of manufactured components. The route sheet is used in serial and especially individual production to show the worker's output, calculate the wages of the workers, and exercise operative super-vision of the movement of parts in production. The route sheet accompanies the batch of components in all manufacturing operations to aid in supervising the observance of technological discipline and the preservation of all elements. Thus the route sheet combines the features of a managing and an accounting document, since it contains standardized data (such as time standards and cost) and information about the actual movement of the manufactured components and about the worker's output in each operation. The route sheet has played a more important role since the introduction of automatic production control and of the use of network schedules.

It is a document with specific manufacturing sequence of operations. The precise route, which must be followed, is given in the route sheet. A typical route sheet contains the following information:

(a) Number and identification of work order
(b) Symbol and/or identification of a part
(c) Estimated number of pieces to be produced
(d) Number of parts in each lot
(e) Operations needed on the given part
(f) Sequence in which these operations are performed
(g) Machines or equipments to be used for each operation, and
(h) Estimates of set-up and run time per piece of production.

Different route sheets are needed for different parts. These may be used to determine the schedule for each production order. These serve as useful guiding document in the production process, as the supervisor knows that after finishing a particular operation, the part will go to which department and at what time. In essence, routing is the planning of what works are to be performed on the job, and in what sequence these would be operational.

## 3.2 Rout Sheet of SGP 12

It's Important to build it whenever production process analysis takes place. By inspecting the production step by step we have built a Rout Sheet for every part with their processes and inspection performed. We also have included which machines and materials are used inside the process and which machines are mainly utilized to complete the manufacturing of particular part. There are mainly 5 parts, Industry manufacturing by their self and other small parts are outsourced to co-industries. Detailed Rout sheet of those 5 Parts is visualized below.

Rout Sheet will help us to have a wide view of the Parts that are manufactured by industry. It will also help us to analyze what Inspection and processing frequency is, what machines and materials are used for what part.

Main parts of the SGP 12 are:

- Plate
- Cover
- Body
- Gear
- Bush

☐ **Inspection** ○ **Op[eration**

Table 2 : Root sheet

| SR. NO. | Name of Part | Operation and Inspection | Machine | Material |
|---|---|---|---|---|
| **1** | **Plate** | 1. Die Casting | | **C.I** |
| | | 2. Inspection ☐ | | |
| | | 3. Semi Turning ○ | CNC | |
| | | 4. Finished Turning ○ | CNC | |
| | | 5. Inspection ☐ | | |
| | | 6. Drilling ○ | CNC | |
| | | 7. Tapping ○ | CNC | |
| | | 8. Inspection ☐ | | |
| **2** | **Cover** | 1. Casting ○ | | **C.I** |
| | | 2. Inspection ☐ | | |
| | | 3. Turning ○ | CNC | |
| | | 4. Facing ○ | CNC | |
| | | 5. Inspection ☐ | | |
| | | 6. Drilling ○ | CNC | |
| | | 7. Inspection ☐ | | |
| **3** | **Body** | 1. Hexo Cutting ○ | HEXO | **Alumi nium** |
| | | 2. facing ○ | LATHE | |
| | | 3. Inspection ☐ | | |
| | | 4. Drilling ○ | VMC | |
| | | 5. IO diameter (side) ○ | VMC | |
| | | 6. Inspection ☐ | | |
| | | 7. Backside finishing ○ | LATHE | |
| | | 8. Inspection ☐ | | |

| SR. NO. | Name of Part | Operation and Inspection | Machine | Material |
|---|---|---|---|---|
| 4 | Gear | 1. Cutting ○ | HEXO | M.S |
| | | 2. Semi Turning ○ | CNC | |
| | | 3. Finished Turning ○ | CNC | |
| | | 4. Inspection ○ | | |
| | | 5. Hobbing □ | CNC | |
| | | 6. Inspection ○ | | |
| | | 7. Shaving ○ | CNC | |
| | | 8. Inspection □ | | |
| | | 9. Hardening ○ | | |
| | | 10. Sand Blasting ○ | | |
| | | 11. Inspection □ | | |
| | | 12. OD Grinding ○ | Grinder | |
| | | 13. Lapping ○ | | |
| | | 14. Inspection □ | | |
| 5 | Bush | 1. Die Casting ○ | | Aluminium |
| | | 2. Inspection □ | | |
| | | 3. Rough facing ○ | CNC | |
| | | 4. I.D Drilling ○ | CNC | |
| | | 5. Inspection □ | | |
| | | 6. Facing Both side ○ | CNC | |
| | | 7. Inspection □ | | |
| | | 8. OD Turning ○ | CNC | |
| | | 9. Total Langth ○ | CNC | |
| | | 10. Ispection □ | | |
| | | 11. Du bush Fitting ○ | Hyd.Press | |
| | | 12. Lapping (Finish) ○ | CNC | |
| | | 13. Inspection □ | | |

# 4. Man Machine Utilization

## 4.1 Readings of all Processes Time Required to Manufacture Cover plate

Table 3 : Mfg. Time for Plate

| Part 1. C.I Plate<br>Row material - Cast Iron | | | | |
|---|---|---|---|---|
| **Process No.** | Process | Time Taken (in second) | | |
| | | Operation | Setup | Total Time |
| **1** | Semi CNC turning | 90 | 10 | 262 |
| **2** | Finished Turning | 60 | 12 | |
| **3** | Drilling & tapping | 80 | 10 | |

Same Process Apply for Other Parts and Results are,
For C.I cover Total Time = 90 Sec.
For Body Total Time = 888 Sec.
For M.S Gear(Male & Female) Total Time =1996 Sec.
For Bush Total Time =458 Sec.
Assembly = 97 sec
setup Time for testing = 76 sec
testing Time = 278 sec

## 4.2 Man Machine Charts for Every Part with Possible utilization.

A man-machine chart graphically represents the relationship between the manual work performed by one or more operators and one or more machines involved in a manufacturing process.Given the different work steps required in a production process to load, operate and unload machines in conjunction with the process times of the machines themselves the man-machine chart is used to determine the highest production level that can be achieved given the resources available.

| Activity :- manufacture of Plate<br>Product :- Plate<br>Method :- Present<br>Chart No :- 01 | SUMMARY | | |
|---|---|---|---|
| | | Present Method | |
| | Subject | Time | Percentage |
| | MAN | 94 | 30.42 |
| | Machine | 309 | 95.37 |
| | TC/Piece | 324 | 100 |

| Time(S) | MAN | C.C | C.C | MACHINE |
|---|---|---|---|---|
| | Material from Die Casting | | | |
| 10 | Inspection (10 Sec.) | | | |
| 20 | Loading of job on CNC (10 Sec.) | | | Job has been loaded (10 Sec.) |
| 110 | CNC Semi Turning (90 Sec.) | | | Semi Turning Operation (90 Sec.) |
| 120 | Job unloading (10 Sec.) | | | Job has been unloaded (10 Sec.) |
| 132 | Loading of job on CNC (12 Sec.) | | | Job has been loaded (12 Sec.) |
| 192 | CNC Finish Turning (60 Sec.) | | | Finish Turning Operation (60 Sec.) |
| 204 | Job unloading (12 Sec.) | | | Job has been unloaded (12 Sec.) |
| 209 | Inspection (5 Sec.) | | | |
| 219 | Loading of job on CNC (10 Sec.) | | | Job has been loaded (10 Sec.) |
| 299 | CNC Drilling& Tapping (80 Sec.) | | | Drilling & Tapping Operation (80 Sec.) |
| 309 | Job unloading (10 Sec.) | | | Job has been unloaded (10 Sec.) |
| 314 | Inspection (5 Sec.) | | | |

Table 4 : Man Machine Charts

**Notation Code:**

**Independent Working** **Ideal** **Combined Working**

## 4.3 Calculation of Man Machine Utilization for Plate

Utilization of machine = cycle time - ideal time of machine

= 324 – 15

= 309(Sec.)

% Utilization of machine = $\frac{309 \times 100}{324}$

= 95.37%

Utilization of man = cycle time – idle time of man

= 324−230

= 94(Sec.)

**Conclusion:** As per above calculation, we can conclude that machine utilization is good enough and no further improvements can be done. But, when we take a look on man utilization, man is working 30.42% of his time and thus, he can still operate one more machine with 29% rest time. Same Process Apply for Other Parts and Results are,

Table 5 : Man Machine Utilization of other parts

| **Part** | Cover | **Body** | **Gear** | **Bush** |
|---|---|---|---|---|
| **Man Utilization(%)** | **40.17** | **11.77** | **22.14** | **51.72** |
| **Machine Utilization(%)** | **91.45** | **98.28** | **88.01** | **70.44** |

## 5.Material Handling Analysis

No operation can be performed without transportation! Materials handling methods link layout operations to a functioning manufacturing system. Depending on the nature of your facility, materials handling costs account for 10 to 30 percent of your total operating cost, which may be even higher in case of distribution facilities. Our materials handling course is based on Group Technology(GT), which is the most organized approach designed to analyze and evaluate materials handling methods.

During the planning phase of a material handling system it is necessary to assure, that the design fullls the operational requirements . A first check can be done by looking at the utilization of the individual elements of the design.

Present Method

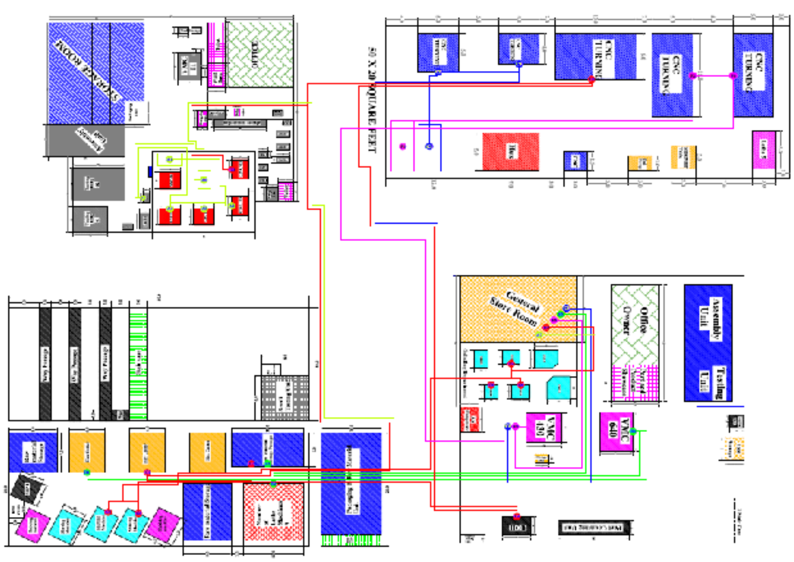

Figure 2 : Layout Diagram of Company by Present Method

This is present line diagram of Company. It represents all the process step by step. In this Method, All process perform on base of machine. After completing one process product transfer one stage to another stage for other process. It takes more time to complete product. Now, we apply Group Technology for the same product regarding same process and compare distance, time and cost.

## 5.1 Material Handling Analysis of Plate Based on GT

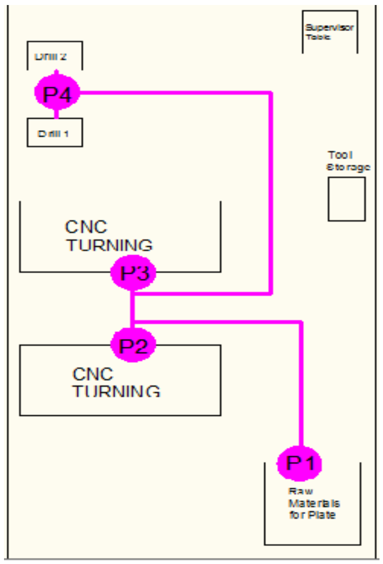


Figure 3 : Mgf.cell of Plate

## Distance, Time and Cost Estimation of Plate

Table 6 : Present Method Reading for Plate

| Readings base on Present Method | | | |
|---|---|---|---|
| **Material Handling between** | Distance (ft.) | Time (sec.) | Cost (Rs.) |
| **P1-P2** | 35.19 | 12.89 | 0.110 |
| **P2-P3** | 4.93 | 1.80 | 0.015 |
| **P3-P4** | 69.39 | 25.41 | 0.218 |
| **P4-P5** | 21.22 | 7.77 | 0.066 |
| **Total** | 130.73 | 47.87 | 0.409 |

Table 7 : Comparison of Both Method for Plate

| Readings Based on GT Method | | | |
|---|---|---|---|
| **Material Handling between** | Distance (ft.) | Time (sec.) | Cost (Rs.) |
| **P1-P2** | 12.27 | 4.49 | 0.038 |
| **P2-P3** | 5 | 1.83 | 0.011 |
| **P3-P4** | 13.18 | 4.82 | 0.041 |
| **P4-P5** | 79.05 | 28.95 | 0.248 |
| **Total** | 109.5 | 40.09 | 0.3389 |

Table 8 : Proposed Method Reading for Plate

| Difference between Present and Proposed Method | | | | |
|---|---|---|---|---|
| | Present Method | Proposed Method | Result | Percentage |
| **Distance(ft.)** | 130.73 | 109.5 | 21.23 | 16.23 |
| **Time(sec.)** | 47.87 | 40.09 | 7.78 | |
| **Cost(Rs.)** | 0.404 | 0.338 | 0.06 | |

## 5.2 Total Time Required for Plate by Using Both the Methods

Total machining Time = Semi CNC turning + Finished Turning + Drilling & tapping + Total setup time
= 90 + 60 + 80 + 32
= 262 sec.
Total material handling time = 47.83 sec.
Total Time Required for Plate = Total machining Time + Total material handling time
= 262 + 47.83
= 309.83 sec.

**Proposed Method**

Total machining Time = 262 sec. (As calculate above)

Total material handling time = 40.09 sec.
Total Time required for = Total machining Time + Total material handling time
=262 + 40.09
= 302.09 sec.

Same Process Apply for Other Parts and Results are,

Table 9 : comparison of Both Method for Gear

| Difference Between Present and Proposed Method | | | | |
|---|---|---|---|---|
| | Present Method | Proposed Method | Result | Parentage |
| **Distance(ft.)** | 83.55 | 46.27 | 37.28 | 44.61 |
| **Time(sec.)** | 30.99 | 16.92 | 14.07 | |
| **Cost(Rs.)** | 0.310 | 0.145 | 0.165 | |

Table 10 : comparison of Both Method for Cover

| Difference Between Present and Proposed Method | | | | |
|---|---|---|---|---|
| | Present Method | Proposed Method | Result | Percentage |
| **Distance(ft.)** | 208.23 | 75.67 | 132.56 | 63.6 |
| **Time(sec.)** | 76.25 | 27.70 | 48.55 | |
| **Cost(Rs.)** | 0.6526 | 0.2380 | 0.4146 | |

Table 11 : comparison of Both Method for Body

| Difference Between Present and Proposed Method | | | | |
|---|---|---|---|---|
| | Present Method | Proposed Method | Result | Parentage |
| **Distance(ft.)** | 326.7 | 145.51 | 181.19 | 55.46 |
| **Time(sec.)** | 119.65 | 53.26 | 66.39 | |
| **Cost(Rs.)** | 1.022 | 0.2432 | 0.7788 | |

As you can see in new improved GT layout, bush is already optimized and no further Improvement can be done.

Table 12 : Present method Reading for Bush

| Material Handling between | Distance (ft.) | Time (sec.) |
|---|---|---|
| **A1-A2** | 18.81 | 6.89 |
| **A2-A3** | 8.03 | 2.94 |
| **A3-A4** | 9.86 | 3.61 |
| **A4-A5** | 8.58 | 3.14 |
| **A5-A6** | 17.27 | 6.30 |
| **A6-A7** | 2171.83 | 795.54 |
| **Total** | 2234.38 | 818.42 |

**Present method**

Total time = Maximum time required to manufacture (from Plate, Gear, Cover, Body, Bush) + Assembly time + Testing time
= 2115.65 + 97 +354
= 2566.65 sec.
= 42.77 min.

**Proposed method**

Total time = Maximum time required to manufacture (from Plate, Gear, Cover, Body, Bush) + Assembly time + Testing time
= 2049.26 + 97 + 354
= 2500.26 sec.
= 41.67 min.

Total time saving in parentage = $\frac{\text{Present method} - \text{Proposed method time}}{\text{Present method}}$

$$= \frac{2566.65 - 2500.26}{2566.65} \times 100$$

= 2.58 %

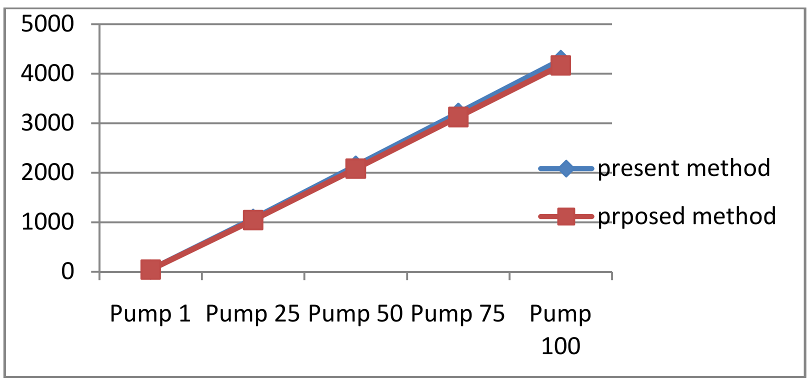


Figure 4 : Comparison between Present Method & Proposed Method

## 6. Conclusion

By Implementing Group technology layout we can deduce 2.58% time per gear pump which is not huge but noticeable difference.

By Man Machine chart we can conclude that the firm using human resource more than required. This can be deduce and optimum cost saving can be achieve.

## ACKNOWLEDGEMENT

We welcome this opportunity to express our devout appreciation and regards to Head of Department Dr. Utpal Pandya, Department of mechanical, Mahatma Gandhi Institute of Technical Education and Research Centre, Navsari, Gujarat, INDIA for his unconditional guidance. He always bestowal parental care upon us and expressed keen interest in solving our problems. An erudite teacher, a tremendous person and a strict disciplinarian, we consider ourselves fortunate to have worked under his supervision. And special thanks to VBC Hydraulics Pvt. Ltd., Ahmadabad. So that we can get good platform regarding this issue.Without their co-operation, the extensive work involved in compiling background information and preparing the paper for publication would not be possible.

## References

[1] Process Analysis and Organizational Mining in Production Automation Systems Engineering by Wikan Danar,Sunindyo Tomas,Moser Dietmar,Stefan Biffl
[2] Machine Design 2 by Prof.K.Gopinath & Prof.M.M.Mayuram Submitted at Indian Institute of Technology Madras
[3] http://www.iienet2.org/Details.aspx?id=33490
[4] Operation Research by R.Panneerselvam
[5] http://www.123eng.com/seminar/GEAR%20MFG..pdf
[6] Adoption and implementation of group technology classification and coding systems : insights from seven case studies by M. V. TATIKONDA and U. WEMMERLOV in 1992(basic review of GT)
[7] A framework for reducing manufacturing throughput time by Danny J. Johnson in 2003 (basic review)
[8] http://www.journals.elsevier.com/journal-of-manufacturing-systems
[9] http://www.worldscientific.com/worldscinet/jams

### AUTHORS

**Jatinkumar Kathiriya** received B.E. degree in Mechanical Engineering from the Gujarat Technological University, India. His area of interest covers Computational Mechanics as well as Autocad.

**Vijay Amareliya** has received B.E. degree in Mechanical Engineering from Gujarat Technological University, India. He also seeks some of his interests in Production process analysis.

**Sarvil Kapadiya** received B.E. degree in Mechanical Engineering from the Gujarat Technological University, India. His area of interest covers Operation Research and Production Process Analysis.