

# IMPLEMENTATION OF TOTAL QUALITY MANGEMENT IN PUMP INDUSTRY

[TQM TOOLS & D.O.E]

P-845

Thesis submitted in partial fulfilment of the requirements for  
the award of the degree of

**MASTER OF ENGINEERING IN MECHANICAL ENGINEERING  
(INDUSTRIAL ENGINEERING)**  
of BHARATHIAR UNIVERSITY

By

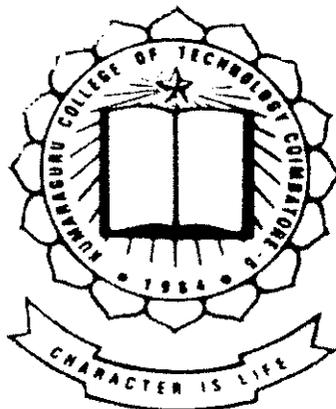
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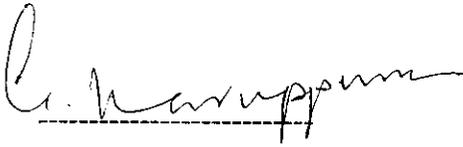
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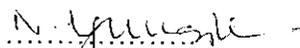
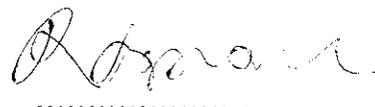
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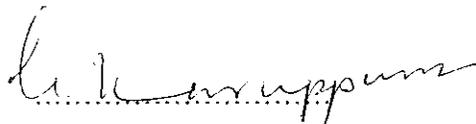
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## TO WHOM SO EVER IT MAY CONCERN

This is to certify that **Mr. S. CHANDRASEKARAN**, final year M.E. (Industrial Engineering), Kumaraguru College Of Technology, Coimbatore - 6 has done project work in our organization as per the details below.

Title of the project : IMPLEMENTATION OF TOTAL QUALITY MANAGEMENT IN PUMP INDUSTRY.

Period of the project : July 2002 – November 2002.

Area covered : R&D, Production, Quality Control, Maintenance & Purchase.

Attendance & conduct : Good.

He has diligent in his work and analytical in his approach. We wish him a successful future.

For Mahendra Submersible Pumps (P) Ltd,

**V.K. NATHAN,**  
**SENIOR MANAGER (PRODUCTION).**

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**S. CHANDRASEKARAN**

## **SYNOPSIS**

In the present trend, as the markets are globalised, every Company wants to make products of best quality, at least time, at least price and release them within the shortest time for survival in the market.

So, Company needs the systematic approach/procedure. Implementing latest concepts and its tools in the working environment and develop the quality conscious in the all area of the company and among employees totally.

**TOTAL QUALITY MANAGEMENT (TQM)** gives the guide lines to bring the systematic approach / procedure, usage of latest methodology and develops the quality conscious among all the employees of the company totally.

TQM is implemented in the MAHENDRA SUBMERSIBLE PUMPS (P) LTD, COIMBATORE-35 for better and continuous survival in the current market. The implementation of TQM in the company is divided into two phases of works.

### **I – Phase, Implementation of 7 basic QC Tools**

The Seven basic QC Tools are the fundamental tools of TQM for improving product and service quality. Generally, the performance and quality of the pumps sold are measured from customer complaints.

So, the customer complaints are collected for 3 months. It shows that the OVSM-31 product has more complaints than other products. Hence the 7 basic tools are Implemented in the production line of ovsm-31 product for bring the systematic approach and develop quality of the product and reduce the customer complaints. This work is taken as a I- phase of the project.

## **II-phase, Optimization of pump's performance by using D.O.E**

A D.O.E is the simultaneous evaluation of two or more factors (parameters) for their ability to affect the resultant average (or) variability of particular product (or) process characteristics.

Since the OVSM-31 type products has more demand in the current market, the company planned to improve the performance of the ovsm-31 pump for capture the market. The performance of the pump is generally measured in terms of head, power, discharge. In this project work, Head is taken for optimization of pump's performance by using D.O.E. This work is taken as a II-phase of the project.

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# 1. INTRODUCTION

## 1.1 Introduction to TQM Implementation

In the present trend, the business environment is going on with the heavy and globalized competition. So, every company is in a position to make products of best quality, better performance, at least cost, at least manufacturing time etc. To survival of this situation company needs systematic procedure and approach, latest concepts, continuous improvement, quality conscious among the employees of the company.

In the most of the working environment, there is a quality conscious only in the quality assurance department personnels. And also there is a conscious of continuous improvement, usage of systematic approach, quality activities in the few personnels of the company only.

**TOTAL QUALITY MANAGEMENT (TQM)** gives guides lines to bring the systematic approach & procedure, continuous improvements and also totally develops the quality conscious in the each department peoples of the total company environment.

MAHENDRA SUBMERSIBLE PUMPS (P) LTD., is one of the leading manufactures of the motors, Jet pumps, and submersible pumps in Coimbatore. For the continuous and better survival of the Mahendra Company products in the globalized market, Total quality management is implemented in the working environment of the company.

## 1.2 Profile of the Company

Mahendra group of companies are the leading manufactures of motors, pumps, monoblocks, alternators etc in the Coimbatore. In this group, there are a number of industries in and around the Coimbatore. Implementation of Total quality management is carried out in the Mahendra Submersible pumps (p) ltd. Which is located at 428/2 Kalapatty Road, Coimbatore – 35. It is an ISO 9001 certified company. This company started its operations of manufacturing of submersible pumps and jet pumps in the year of 1985. This company sells jet pumps, Submersible pumps and alternators are marketed with MAHENDRA Brand name. There are about 300 employees working in this company. At present, Mahendra Company makes their products with wide range of pump sets and motors from 0.5 HP to 20HP for various applications like domestic, agricultural and Industries. These pump sets are sales all over the country through a wide network of dealers.

The various products of the company are listed below.

1. Jet Pumps – Its range 0.5 HP to 12 HP
2. Submersible pump sets for 6” bore wells
3. Submersible pump sets for 4” bore wells
4. Open well Submersible monoblock (OVSM)
5. Alternators

## 1.3 Total Quality Management (TQM)

### Definition

TQM is defined as both a philosophy and a set of guiding principles that represents the foundation of a continuously improving organization.

### TQM

It is the application of quantitative methods and human resources to improve all the processes within an organization and meet customer needs now and in the future.

TOTAL	-	Made up of the whole
QUALITY	-	Degree of excellence a product (or) Service provides
MANAGEMENT	-	Act, art (or) manner of handling, Controlling, directing etc.,

### Concept of TQM

It means thinking about quality in terms of all functions of the enterprise and is a start to finish process that integrates interrelated functions at all levels. In the earlier stage, the peoples in QA, QC department. Were take care about quality products. Others like production peoples, maintenance people they won't take much care about quality of products, and development of quality. Say for example, the production. People is mainly concentrated and interest only in the production rate. Like wise, every department peoples were mainly concentrated in their own work.

Now-a-days most of the companies are implemented TQM, TQM gives guidelines to every department peoples for improve the quality in their own work and develops integration of all functions and processes within organization. The quality activities involved in the right from design of the product up to goods supply to customer, are improved by TQM hence the total quality of the product and total activities in the management are continuously improved.

That is the concept of TQM.

## **1.4 Implementation of TQM**

TQM is a vast area, in which, There are number of concepts, tools, procedure etc. In this TQM Implementation work. 7 BASIC QC TOOLS in TQM are planned to implement in the working environment to built up the foundation for continuous improvement of the products and services. This work is taken as a I-Phase of the project work.

One of the latest tool (or) latest sophisticated method in TQM is D.O.E for optimization the process parameters (or) product design. One of the fast moving products in Mahendra Company is OVSM-31 product. This product performance is planned to optimize by using D.O.E. This work is taken as a II-phase of the project work.

### **I-Phase**

IMPLEMENTATION OF 7 BASIC QC TOOLS

### **II-Phase**

OPTIMIZATION OF PUMP'S PERFORMANCE BY USING  
THE D.O.E

### **Main Aim of TQM Implementation**

- To achieve the continuous improvement of the products and services
- To provide a quality products to customer
- To achieve the continues customer satisfaction through efficient way by meeting the customer needs
- To survival in the world class competition

## **2. LITERATURE SURVEY FOR 7 BASIC QC TOOLS AND D.O.E**

### **2.1 Seven Basic QC Tools**

#### **2.1.1. Introduction**

The Seven basic QC Tools are the fundamental tools of TQM for improving product and service quality. These tools are originally identified by Dr. Ishikawa. In 1968, DR. ISHIKAWA wrote a book entitled 'GUIDE TO QUALITY CONTROL' for introducing QC techniques and practice to the workers of Japan.

It was designed to be "used for self study, training of employees by foremen (or) in QC reading groups" in the Japanese work place. It is in this book that the seven basic quality control tools were first presented.

These tools come in a process of continuous Improvement will assure that the product not only meet its customer's expectation but actually improves for as long as production is continued. These are Intellectual tools for collecting and display information in ways to help the human brain grasp thoughts, Ideas that when applied to physical processes causes the processes to yield better results.

Each of these tools is some form of chart for collecting and display of specific kinds of data. Through the collection and display facilities, the data become useful information – information that can be used to solve problems, keep track of work being done, even predict future performance and problem. The beauty of the charts is that they organize data so that we can immediately comprehend the message. This would be all but mountains of data flooding today's work place. Such a seven basic QC Tools are

#### **Identification Tools**

- 1) Check sheet & flow charts

#### **Prioritizing tools**

- 2) Graphs and histograms

## Analyzing tools

- |                              |                     |
|------------------------------|---------------------|
| 4) Cause and effect diagrams | 5) Scatter diagrams |
| 6) Process Capability        | 7) Control charts   |

### 2.1.2 Identification Tools

Identification Tools are used to help Identify and quantify where and what problems exist. Once a problem area has been identified by these tools, the prioritizing tools can be used. Check sheet and flow chart are the Identification tools.

### Check Sheet

Check Sheets are forms that are used to systematically collect data. They give the user a place to start and provide a structure for collecting the data. They also aid the user in organizing the data for later use. (The data gathering in a check sheet can be used in building histograms, Pareto Charts, Control charts etc.,) The primary benefits of check sheet are that they are very easy to use and understand and can provide a clear picture of the situation. Check sheets essentially allow the user to speak with facts (a fundamental tenet of total quality management) Typical check sheet as shown in the figure 1

XYZ Company Complaint Analysis April 2002 – June 2002	
Complaint Type	Total
Complaint – I	- Nos
Complaint – II	- Nos
Complaint – III	- Nos
Complaint – IV	- Nos
Prepared by :	Approved By :
Date :	Date :

Fig :- 1, Check Sheet

## Flow Chart

Flow charts are graphical representation of a process which detail the sequencing of the materials, machinery and operations that make up that process, They are an excellent means of documenting what is going on in a process and communicating that information to every one. There are many benefits to using a flow chart. First, it clearly identifies the components of a process. This helps the people who work in the process understand where they fit in and what the overall objective is. Second. It also can be used as a training tool for new workers who are brought into the process (or) for existing workers who change location within the process. Third, It also helps Identify where and when in the process measurements can be made fourth, It can be used to document a simple operation like cash sales transaction.

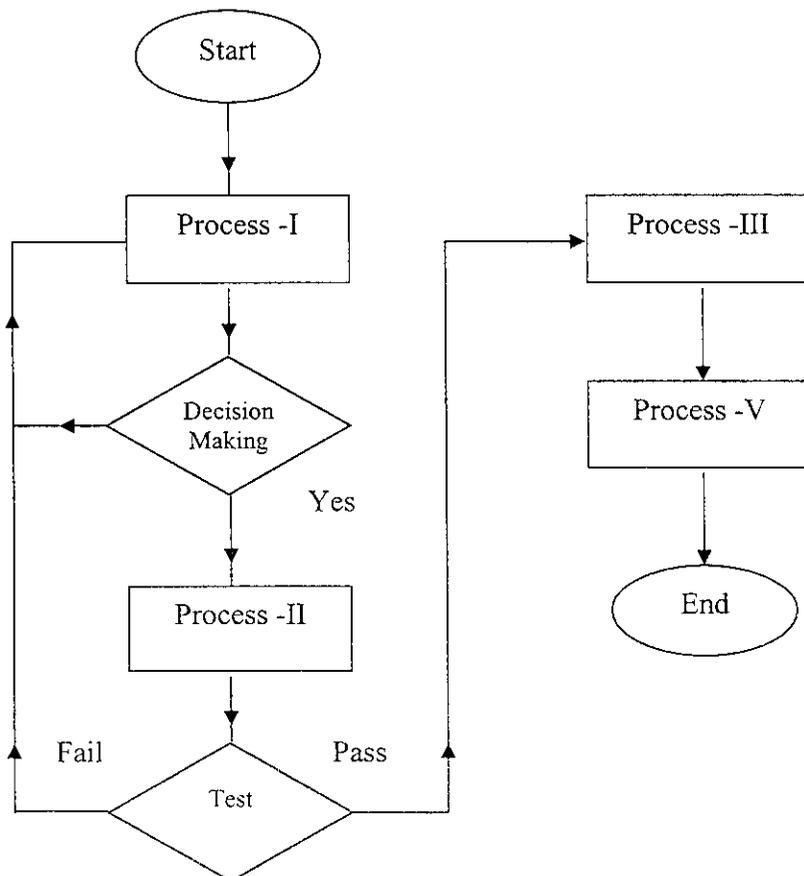


Figure : 2, Flow Chart

### 2.1.3. Prioritizing Tools

Prioritizing Tools Helps the user to organize, understand interpret and present the data gathered with this information, the user can now prioritize which problems to work on and in what order they should be addressed. Because these tools provide charts and graphs that are very easy to understand, they can also be considered the major communication tools of the group. With a specific problem selected by these tools, the analyzing tools can be used. The Important prioritizing tools are histograms, Pareto Charts, and graphs.

#### Graphs

Graphs are visual displays of data that are used to organize and summarize data. They are used to organize and summarize data. They are typically the simplest and best way of analyzing, understanding and communicating data. Therefore, they can easily be used for illustrating a problem area (or) for illustrating the new improved situation. Some of the typical graphs are shown in the figure3 & 4.

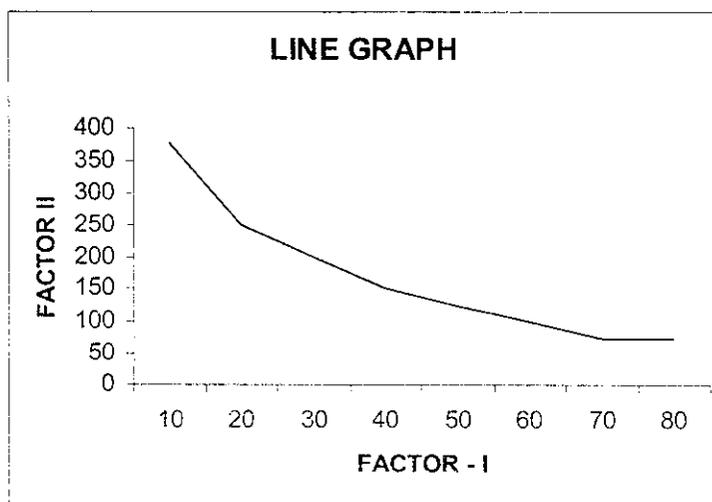


Figure -3, Line Graph

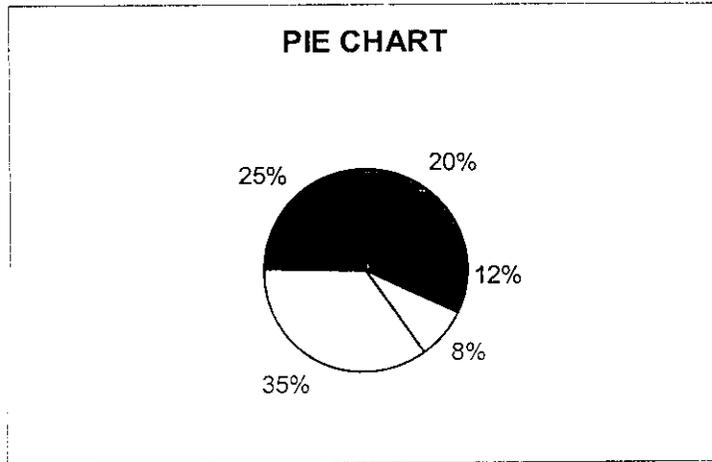
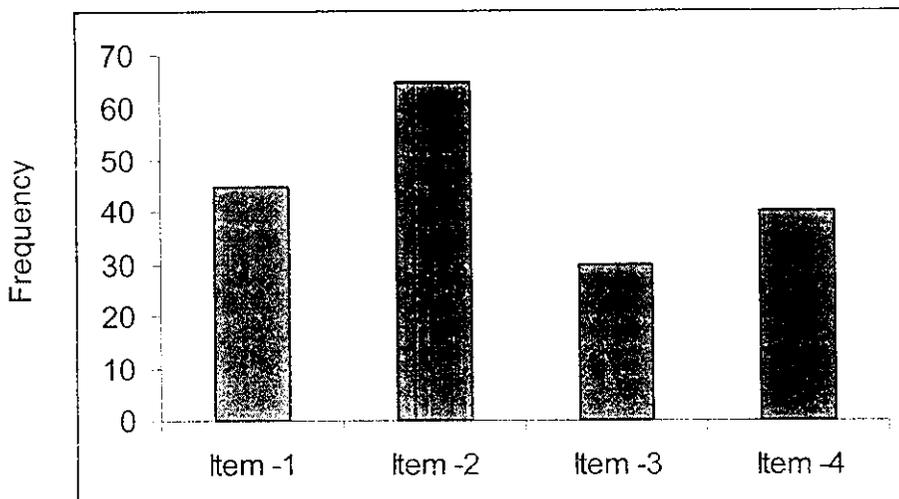


Figure – 4, Circle Graph (Pie Chart)

### Histograms

The First statistical SPC technique is the histogram. The histogram is a type of bar chart that visually displays the variability of a product (or) process. It shows the various measures of control tendency (mean, mode, average). It can be used to illustrate whether product specifications on the histogram. It graphically estimates the process capability.

A histogram can also be used to study and identify the understanding distribution of the variable being studied. The histogram merely illustrates the nature of distribution. The Typical histogram diagram is shown in the figure 5.



## Pareto Charts

Alfredo Pareto (1848-1923) conducted extensive studies of the distribution of wealth in Europe. He found that there were a few people with a lot of money and many people with little money. This unequal distribution of wealth became an Integral part of economic theory. Dr. Joseph Juran recognized this concept as a universal that could be applied to many field. He coined the phrases "Vital few and useful many". And called it the Pareto principle as a shorthand notation to convey the concept of maldistribution in the first edition of his quality control hand book he used the shorthand name Pareto principle to identify this idea, Pareto's work only dealt with the unequal distribution of wealth. Dr.Juran also acknowledged that the cumulative frequency distribution curves used in the first edition of the quality control handbook should have been attributed to Lorenz instead of Pareto. A Pareto chart is basically a bar graph in which the bars are arranged in descending order of height, starting at the left. This picture quickly highlights the vital few problems which should be worked on first. Thus it aids in identifying and prioritizing what needs to be done. It also provides a common knowledge base founded on facts instead of hunches which results in gaining the co-operation of all involved. The typical Pareto chart is as shown in the Figure 6.

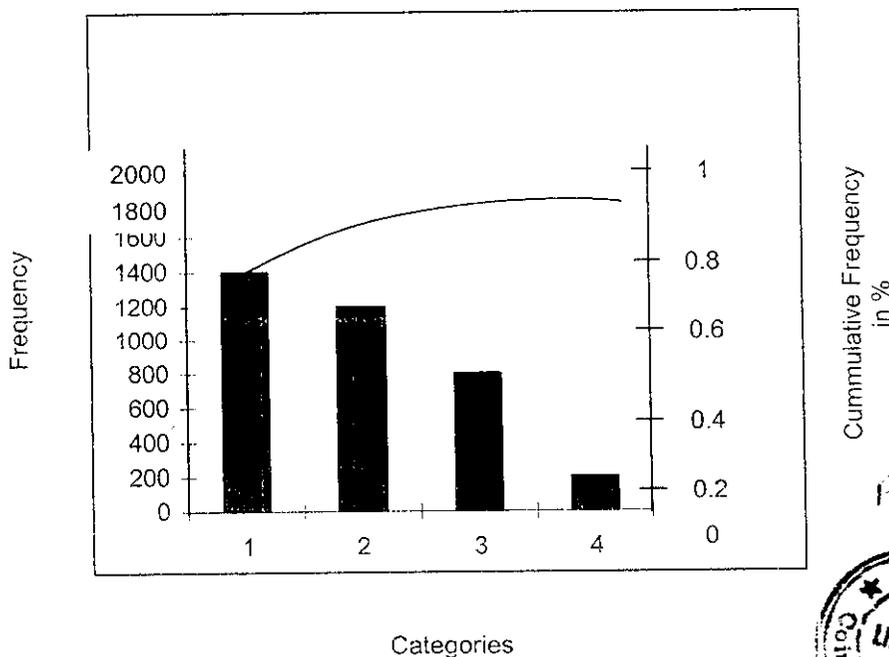


Figure 6. Pareto Chart



## **2.1.4 Analyzing Tools**

Analyzing tools are used to examine and investigate the causes of the problem. They can also suggest possible corrective actions. It should be noted that 10 to 80% of all problems can be solved by using check sheets, Pareto diagrams, and cause and effect diagrams. Some of the analyzing tools are cause and effect diagrams, scatter diagrams, control charts, process capability analysis.

### **Cause and effect diagrams**

The cause and effect diagram was developed by Dr. Kaoru Ishikawa of the University of Tokyo in the summer of 1943, while he was explaining to some engineers at the Kawasaki steel works how various factors can be sorted out and related. For this reason, this diagram is also known as the Ishikawa diagram. Its third name, the fishbone diagram, stems from the fact that a completed diagram resembles the skeleton of a fish.

The primary purpose of the CE diagram is to show the relationship between a given effect and all identified causes of that effect. In this diagram all the causes are represented in the left side of the diagram and the specific effect is represented in the right side of the diagram. The effect is the quality characteristics that need improvement. Causes are sometimes broken down into the major causes of man, machine, materials, methods, measurements, Environment. Each major cause is further subdivided into numerous minor causes.

There are typically several major causes for any given effect. Therefore, a CE diagram assists the team in (1) gathering and organizing the possible causes (2) reaching a common understanding of the problem (3) exposing gaps in existing knowledge (4) ranking the most probable causes and (5) studying each cause. The typical CE is shown in the Figure 7.

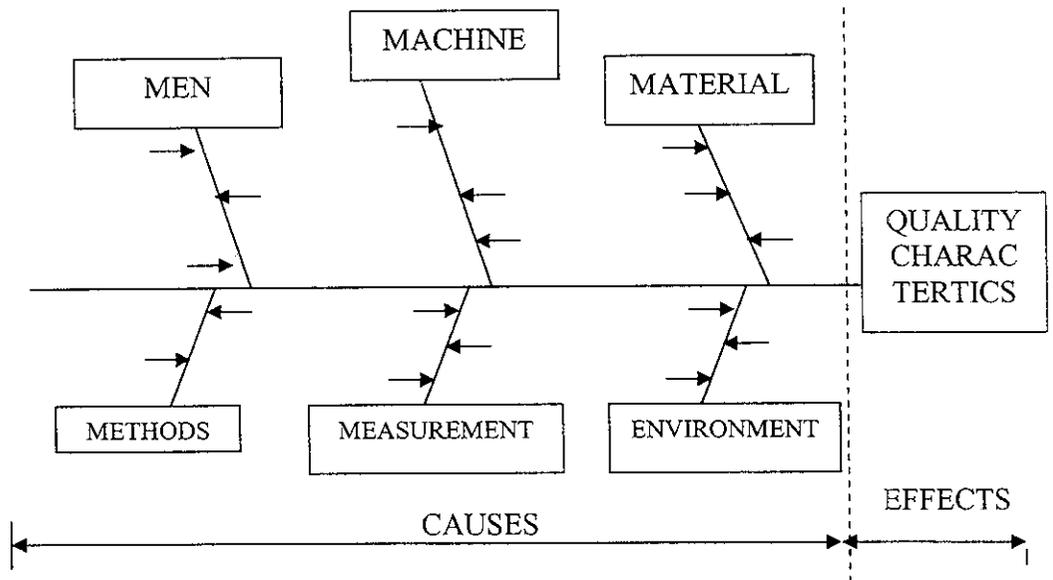


Figure -7 Causes and effect diagram

### Scatter Diagram

A scatter diagram is a graph of point plot that is used to compare two variables. The distribution of the points indicates the cause and effect relationship between two variables. In order to use a scatter diagram, paired data must be available for the two variables being studied. Scatter diagrams are very useful in that they (1) can clearly indicate whether (or) not a cause and effect relationship exists and (2) give an idea of the strength of that relationship. The typical scatter diagram is shown in the Figure 8.

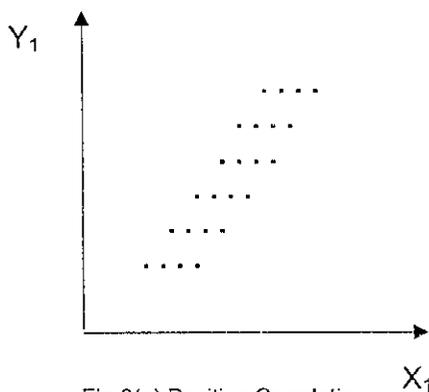


Fig 8(a) Positive Correlation

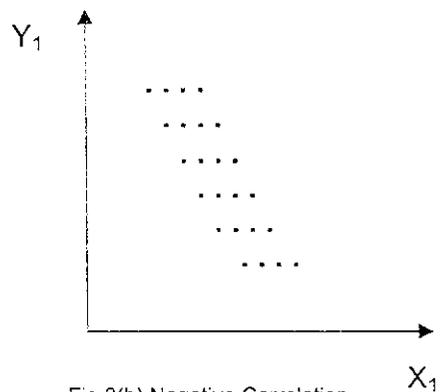


Fig 8(b) Negative Correlation

Fig 8 (a) shows that there is a strong positive relationship between  $x_1$   $y_1$  and indicates that an increase in  $y_1$  depends on increase in  $x_1$  Fig 8(b)

## Process Capability

Process capability is a tool to determine the ability of a process to meet specification limits.

Control charts cannot determine if the process is meeting specifications. The true process capability cannot be determined until the X and R charts have achieved the optimal quality improvement without a substantial investment for new equipment (or) equipment modification. When the process is in statistical control, process capability is equal to  $6\sigma/\Delta$  where  $\Delta = R/d_2$  and  $d_2$  is a factor from Appendix Table A. In the example problem, it is

$$C_p = 6[R_0/d_2] = 6 [0.079/2.059] \\ = 0.230$$

It is frequently necessary to obtain the process capability by a quick method rather than by using the X and R charts. Two widely used process capability indices are

1. The  $C_p$  index
2. The  $C_{pk}$  index

### **$C_p$ Index**

This method assumes the process is in statistical control, which may (or) may not be the case, The procedure is as follows.

1. Take 25 sub groups of Size 4, for a total of 100 measurements
2. Calculate the range R, for each subgroup
3. Calculate the average range  $\bar{R} = \sum R / g$ .
4. Calculate the estimate of the population standard deviation  $\hat{\sigma} = \bar{R} / d_2$   
Where  $d_2$  is obtained from Appendix Table A and is 2.059 for  $n=4$
5. The process capability will equal  $C_p$ .

Remember that this technique does not give the true process capability and should be used only if circumstances require its use. Process capability and the tolerance are combined to form a capability index, defined as

$$C_p = \frac{USL - LSL}{6\hat{\sigma}}$$

Where USL = Upper specification limit

LSL = Lower specification limit

$C_p$  = Capability Index

If the

Capability Index  $> 1$  [

The process is capable of meeting the specifications

Capability Index  $< 1$  [

The process is not capable of meeting the specifications

### **C<sub>PK</sub> Index**

The capability index does not measure process performance in terms of the nominal (or) target value. This measure is accomplished using CPK which is

$$C_{PK} = \text{Minimum} \left\{ \frac{X - LSL}{3\sigma}, \frac{USL - X}{3\sigma} \right\}$$

A CPK value of 1.00 is the de facto standard, with some organizations using a value of 1.33.

If CPK = 1, we declare that the process is marginally capable.

If CPK < 1, we declare that the process is incapable.

If CPK > 1, we declare that the process is capable.

The typical process capability curer for cpk and cp values are shown in the fig9.

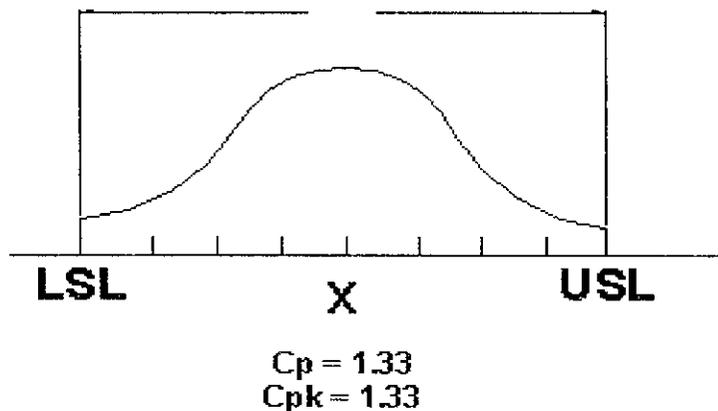


Fig 9

## Control Charts

A control chart is a special type of run chart with limits. It shows the amount and nature of variation in the process over time. It also enables pattern interpretation and detection of changes in the process.

There are three main reasons for using a control chart. First, It is used to monitor a process in order to determine if the process is operating with only chance causes of variation. If it is then the process is said to be in satisfied control. If it is not, then the process is said to be out of control. If the process is out of control, then the control chart can be used to help identify the assignable causes of variation and correct the process. Second, control charts are used to estimate the parameters of a process. Third, control charts are used in reducing the variability of a process.

The type of control chart depends on the type of data used in its construction. If the data are based on measurements (such as pounds, CM, Inches etc) then the data are said to be continuous and variables control chart is used. If the data are based on counting (such as the number of defects in a product) then the data are said to be discrete and an attributes control chart is used. There are two types of variable control charts. One is X-R chart and other is X-S chart. There are four types of control charts of attributes such as P chart, np chart C chart, Uchart.

### X-R CHART

X-R chart monitors the mean value and the variability of the quality characteristics being studied. It is used to record the variation in the average value of samples. The mean value is monitored via an  $\bar{x}$  (X) chart. Variability is measured via range (R) An X chart monitors between-sample variability and is the most common type of control chart.

## PROCEDURE TO CONSTRUCT X-R CHART

The following step by step procedure is used for develop the X-R chart

1. During normal production, record the measurement of N samples of size n. typical values for N and n are chosen. The sampling frequency depends on the volume of production. A typical frequency would be 1 sample per hour although engineering common sense and past experience with the process should indicate what the time period between sampling should be to allow the inherent process variability to express itself.
2. For each of the N samples, record the mean  $\bar{X}$  and the range R by arithmetic calculations.
3. Compute the average  $\bar{X}$  and average range by using the following formula.

$$\bar{X} = \frac{\sum_{i=1}^N \bar{x}_i}{N}$$

$$R = \frac{\sum_{i=1}^N R_i}{N}$$

4. Calculate the upper control limits (UCL) and lower control limits (LCL) for the X-Chart and the R-chart by using the following formulas.

For X-chart

$$UCL = \bar{X} + A_2R$$

$$LCL = \bar{X} - A_2R$$

For R-chart

$$UCL = D_4R$$

$$LCL = D_3R$$

The co-efficient  $A_2$ ,  $D_3$  and  $D_4$  depend on the sample size and is found from the standard table.

The band width of values covered by the control limits in the X-chart is the approximation to a band width of 6 standard deviations in the normal population of sample average.

5. Plot the values in the X-chart and R-chart

If all  $\bar{X}_i$  and  $R_i$  values fall randomly within their respective control limits the process is considered to be in control. Otherwise special causes of variability are present and have to be investigated and eliminated.

The typical X-chart and R-chart are shown in the fig 10 & 11 resp.

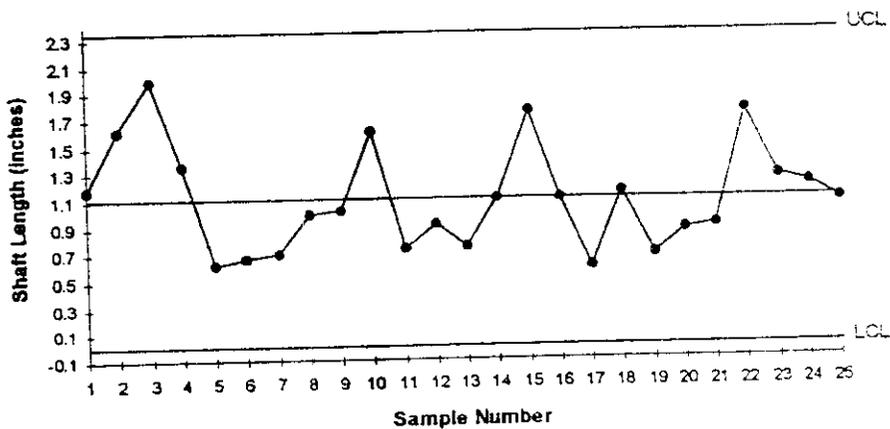


Fig 10

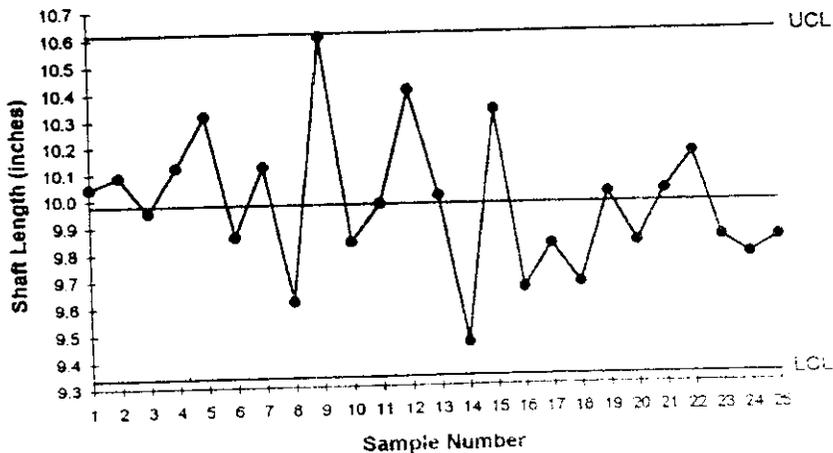


Fig 11

## **2.2 Design of Experiment (D.O.E)**

### **2.2.1 Introduction**

A D.O.E is the simultaneous evaluation of two (or) more factors (parameters) for their ability to affect the resultant average (or) variability of particular product (or) process characteristics.

Now-a-days companies is in a position to make products of best quality & to release their new products in the market within the shortest time. In practice, During the development of existing products (or) making the new products, (or) find out the best process characteristics, One way to optimize the product performance is to find out the best set of input parameters (which are directly affect the product performance) combination. It is possible only to do the more number of experiments (may be 100 or 120) in the cases of more No. of Input parameters (may be 8 or 10) affects the out put performance of the product. A D.O.E is the best and effect methodology to find out the best set of Input parameter with the minimum set of experiments (may be with 20 or 30) in the cases of more Input parameter affects the performance of the products. Also it is very much useful for find out the most influenced parameter among the number of Input parameters so, D.O.E reduces the cost involved, time involved in conducting the experiments for developing the new products (or) improving the existing products and It helps to optimize the product performance (or) process characteristics.

In the recent years, The D.O.E is popularly used by the upcoming companies for make their products of good best quality and to release new products in the market within the shortest time.

Hence, the companies are started to use the D.O.E for long period of survey of their products in the market.

### **2.2.2 Definition**

A design of experiment is the simultaneous evaluation of two or more factors (parameters) for their ability to affect the resultant average or variability of particular product or process characteristics.

### **2.2.3 The purpose of Experimentation**

The purpose of product or process development is to improve the performance characteristics of the product or process relative to customer needs and expectations. The purpose of experimentation should be to understand how to reduce and control variation of a product or process; subsequently, decisions must be made concerning which parameters affect the performance of a product or process. The loss function quantifies the need to understand which design factors influence the average and variation of a performance characteristic of a product or process. By properly adjusting the average and reducing variation, the product or process losses can be minimized.

### **2.2.4 Basis of Experimentation**

This approach is based on the use of orthogonal arrays (Taguchi) to conduct small, highly fractional factorial experiments up to larger, full-factorial experiments. The use of orthogonal arrays is just one methodology to design an experiment, but probably the most flexible in accommodating a variety of situations and yet easy for nonstatistically oriented people to execute on a practical basis.

## 2.2.5 The design of Experiments process

The DOE process is divided into three main phases, which encompass all experimentation approaches. The three phases are

(i) Planning phase

(ii) Conducting phase

(iii) Analysis phase

The planning phase is by far the most important phases for the experiment to provide the expected information. This is the most important phase of experimentation. Also the correct selection of factors and levels is non statistical in nature and is more dependent upon product and process expertise.

The second most important phase is the conducting phase, when test results are actually conducted. If experiments are well planned and conducted, the analysis is actually much easier and more likely to yield positive information about factors and levels.

The analysis phase is when the positive or negative information concerning the selected factors and levels is generated based on the previous two phases. The analysis phase is least important in terms of whether the experiment will successfully yield positive results.

The major steps to complete and effective designed experiment are listed in the following text the planning phase includes steps 1 through 9, the conducting phase is step 10 and the analysis phase include steps 11 and 12.

- 1). State the problem(s) or area(s) of concern
- 2). State the objectives of the experiment
- 3). Select the quality characteristic(s) and measurement system(s)
- 4). Select the factors that may influence the selected quality characteristics

- 5). Identify control and noise factors
- 6). Select levels for the factors
- 7). Select the appropriate orthogonal array (OA) or OAs.
- 8). Select interactions that may influence the selected quality characteristics of go back to step 4.
- 9). Assign factors to OA(s) and locate interactions
- 10). Conduct tests described by tracks in OA(s).
- 11). Analyze and interpret results of the experimental trials.
- 12). Conduct confirmation experiment.

These steps are fundamentally the same regardless of whether one is designing a Taguchi – based experiment or a classical design. This process describes one loop through the DOE process. Two or more passes through the process are often utilized; earlier rounds knowledge and a basis for later rounds of experimentation.

### **Step1: State the problem**

A problem can be viewed as any difference that exists between an ideal situation and the actual situation. For example a process may currently make all products to specification which at first may not seem like a problem. Since there is variation present in the process even though all the products may be to specification there is a problem to be addressed and that is further reduce variation.

### **Step2: State the objective**

The statement of the experimental objective provides exit criteria for the experiment; how to determine when the experimental process should be stopped and other, more important problems are addressed.

### **Step3: Select the quality characteristics and measurements system**

The selection of quality characteristics to measure as experimental outputs greatly influences the number of test that will have to be done to be statistically meaningful. Quality characteristics that are variable in nature require substantially fewer tests than quality characteristics that are attributes in nature to achieve the same level of statistical significance. The appropriate measurement system method for measuring results and the people to measure is also determined.

### **Step4: Select the factors that may influence the selected quality characteristics**

This is the most important step of the DOE process. If important from the experiment will not be in positive sense. The experiments must choose the factor to be varied in the experiment and process knowledge is required to do this. Several methods are useful for determining which factors to include in initial experiments and, they are brainstorming, flow charting and cause-effect diagram.

### **Step5: Identify control and noise factors**

The control and the noise factors should be identified correctly and separated, control factors are those factors that the manufactures can control in the design of a product, the design of a process or during a process.

Noise factors are these things that a manufactures cannot or wishes not to control for cost reason. It can be controlled temporarily during an experiment, but in an actual production it cannot be controlled at all.

### **Step6: Select levels for the factors**

Minimum of two levels are required to evaluate a factor's effect on a given quality characteristics. When screening experiments are done and several factors are under consideration then it is recommended that the experiments use only two levels where possible to keep the size of

## **Step7: Select appropriate orthogonal array**

Orthogonally means that factors can be evaluated independently of one another; the effect of one factor does not bother the estimation of the effect of another factor.

Before the orthogonal array selection it is best to review some often used test strategies.

- ❖ Typical test strategies
- ❖ Better test strategies
- ❖ Efficient test strategies

### TYPICAL TEST STRATEGIES:

- ❖ One-factor experiment
- ❖ Several factor one at a time
- ❖ Several factor all at the same time

### BETTER TEST STRATEGIES:

It is a full factorial experiment. If a full factorial experiment is used, there is a minimum of  $2^f$  possible combinations that must be tested ( $f$  = the number of factors each at two levels).

### EFFICIENT TEST STRATEGIES:

Statisticians have developed more efficient test plans, which are referred to as fractional factorial experiments (FFEs). FFEs use only a portion of the total possible combination to estimate the main factor effects and some, not all, of interactions.  $\frac{1}{2}$  FFE,  $\frac{1}{4}$  FFE,  $\frac{1}{8}$  FFE &  $\frac{1}{16}$  FFE all available certain treatment conditions are chosen to maintain the orthogonality among the various factors and interactions.

When there are several factors of interest in an experiment, a factorial design should be used. Statisticians have developed more efficient test plans, which are referred to as fractional factorial experiments. It uses only a portion of the total possible combination to estimate the effects of main factors.

Taguchi has developed a family of FFE matrices which can be utilised in various situations. Orthogonal array shows the number of trials to be conducted and level of each factor to be maintained at each trial. In this one possible matrix is the eight trial OA, named as L8 matrix. There are also L4, L12, L16, L32, L9, L18 and L27 arrays.

The selection of which OA to use predominantly depends on these items in order of priority.

- 1). The number of factors and interaction of interest
- 2). The number of levels for the factors of interest
- 3). The desired experimental resolution or cost limitations

In screening experiments, the recommended strategy is to start with the smallest OA that will accommodate the typical large number of factors under evaluation.

### **Step8: Select interactions that may influence the selected quality characteristics**

There may be factors in an experiment that are thought to have interaction potential which may be of specific interest to the experimenter. This is an iterative step; the smallest OA that will accommodate the number of factors assigned. This happens because OA size does not increase in increments of one, but in geometric progression with respect to the number of levels in the OA.

### **Step9: Assign factors to OA and locate interactions**

Taguchi has provided two tools to aid in the assignment of factors to arrays and locations of interactions in arrays.

Interaction table is mostly used. Consider L4 OA. If factor A is assigned to column 3, factor B in column 2 then the interaction AxB should be assigned to column 1.

### **Step 10: Conduct tests described by trials in OA(s)**

The experiment is then conducted as per OA. A separate sheet should be constructed for each of the eight tracks to avoid any confusion. The interactions cannot be controlled while conducting a test because they are dependent upon the main factor levels.

### **Step 11: Analyze results of the experimental trials**

The final phase of the DOE process is to analyze and interpret the experimental results to improve the performance characteristics of the product or process relative to customer needs and expectations. After all tests are conducted, decisions must be made concerning which parameters affect the performance of a product or process. These decisions are made with the assistance of various analytical techniques such as the

1. Observation method
2. Ranking method
3. Column effect method
4. Plotting method
5. Analysis of variance

Some of these methods for determining influential factors are subjective in nature and others are objective decision-making tools. Analysis of variance (AVONA) will be the predominant statistical methods used to interpret experimental data and make the necessary decisions since this method is the most objective. The other methods should be considered as

It should be noted that the determination of influential factors and their relative strengths is based on the levels chosen for those factors. This is why the selection of levels is so critical; the interpretation depends on the test conditions.

## **Analysis Of Variance**

Analysis of variance will be the predominant statistical, method used to interpret experimental data and make the necessary decisions since this method is the most objective. This method was developed by Sir Ronald Fisher in the 1930s as a way to interpret the results from agricultural experiments. ANOVA is not a complicated method and has a lot of mathematical beauty associated with it. ANOVA is a statistically based, objective decision-making tools for detecting any differences in average performance of groups of items tested. The decision, rather than using pure judgment, takes variation into account.

The discussion of ANOVA will start with a very simple case, no-way ANOVA, and build up to more comprehensive situations, three-way ANOVA. Also, ANOVA will be applied to experimental situations utilizing orthogonal arrays, although this analysis method can be used with any set of data that has some structure. The experimental designs and subsequent analyses are intrinsically tied to one another.

### **F test for variance comparison**

Statistically, there is a tool which provides a decisions at some confidence level as to whether these estimates are significantly different. This tool is called an F test, named after Sir Ronald Fisher, a British statistician, who invented the ANOVA method. The F test is simply a ratio of sample variance.

$$F = \frac{S^2_{V_1}}{S^2_{V_2}}$$

When this ratio becomes large enough, then the two sample variances are accepted as being unequal at some confidence level. F tables which list the required F ratio to achieve some confidence level are provided in the appendixes. To determine whether an F ratio of two sample variances is statistically large enough, three pieces of information are considered. One, the confidence level necessary; two the degrees of freedom associated with the sample variance in the denominator degrees of freedom has an F ratio associated with it  $F_{\alpha: d1:d2}$  is the format for determining an explicit F

$\alpha$	$\Rightarrow$	risk
Confidence	$\Rightarrow$	1-risk
D1	$\Rightarrow$	degrees of freedom associated with the numerator
D2	$\Rightarrow$	degrees of freedom associated with the denominator

Comparing the F value of the data with the table,

$$F_{\text{data}} >> F_{\alpha: d_1: d_2}$$

Statistically, this means that with at least 90% confidence the two estimates of variance are believed to be unequal.

As the F ratio is applied in the ANOVA case, the alpha risk is the chance of obtaining a ratio of at least the magnitude indicated in the table when pulling samples out of the same population (a group of items having the same mean and variance. Since the alpha risk is chosen as a small value, the experimenter would rather believe that two or more populations with different averages have been sampled when the F ratio does attain the specified magnitude.

The interpretation of ANOVA results falls into two categories initially:

1. Factors which have been an F ratio exceeding some criterion
2. Factors which have an F ratio less than some criterion

The factors which have an F ratio larger than the criterion are believed to influence the average value for the population, and factors which have an F

## **Step 12: Conduct confirmation experiment**

A confirmation experiment is performed by conducting a test using a specific combination of the factors and levels previously evaluated. The purpose of the confirmation experiment is to validate the conclusions drawn during the analysis phase. This is particularly important when screening, low-resolution, small fractional-factorial experiments are utilized. Because of the confounding within the columns, the conclusions should be considered preliminary until validated by a confirmation experiment. When a small fractional-factorial experiment OA experiment is used and several factors contribute to the variation observed, it is likely that the best combination of factors and levels was not present in the OA test combinations. The confirmation experiment also serves the purpose of testing that specific combination of factors and levels.

When full-factorial experiments are conducted, a confirmation experiments is not as critical since there is no confounding present and less opportunity for misinterpretation; however, a confirmation experiment is still recommended because of the larger sample size used to evaluate that particular combination.

In product or process development work, the first experiment conducted generally does not provide the optimum performance and may not satisfy the experimental objective (s). Further testing with significant factors may lead to increased performance which eventually does meet the stated objective (s). A confirmation experiment should be conducted between each round of factorial experimentation to verify that the experimenter is drawing the correct conclusions and is following a trial leading to increased performance of the product or process.

### **3. OBJECTIVES OF IMPLEMENTATION OF 7 BASIC QC TOOLS**

- 1) To develop the systematic quality environment in the company by implementing TQM guide lines.
- 2) To develop the systematic approach (procedures) for improve the quality of the product and quality services to the customers by implementing TQM tools.
- 3) To develop the quality conscious among the each employee of the company
- 4) To create the awareness about current status about product quality by displaying the charts in TQM.
- 5) To train the employees for how to apply the TQM Tools in the work environment.
- 6) To improve the quality of their own work in the each department by using TQM Guide lines.
- 7) To develop the Team work towards achieve quality goal of the firm.
- 8) To develop the systematic approach for maintaining the machines, Equipments, Jigs, Fixtures, Instruments in good conditions.
- 9) To reduce the customers complaints.
- 10) To reduce the rejection rate and reworks.
- 11) To develop the Goodwill of the firm among the customers by supplying quality product.
- 12) To achieve the continuous improvement in the quality and performance of the product and services.

## 4. PROBLEM DESCRIPTION

Initially, the environment of the company and existing activities, existing Systems existing procedures of the Quality department and production department were studied. In the present study it came to know that they are not using any systematic (or) latest procedures for continuous improvement of the product quality in the Quality control department and production department. They are using only sampling plan technique in their Inspection area and 100% Inspection in the Testing of the pumps area.

Especially the quality and performance of the pumps can be easily measured from the customer complaints in the pump manufacturing company. So, the customer complaints for 3months (April – June 2002), Rejection rate, reworks were collected. Due to lack of systematic approach (or) procedure, more number of customer complaints, Rejection rate, Reworks were found from the collected data.

Fundamental tools of TQM (i.e.) T basic QC Tools are planned to Implement in the working areas to bring the systematic approach and standardization in the QC department & production dept. activities, (To bring the Quality environment in the company) for improve the performance & Quality of the product and services, meantime to reduce Customer Complaint Rejection rate, Reworks etc.

This work has been taken as a I phase of the TQM Implementation.

## 5. IMPLEMENTATION OF 7 BASIC QC TOOLS

The Concept of TQM and its tools were implemented step by step in the different departments. That step by step Implementation is as follows

### 5.1 Formation of TQM Team:

There are some activities like Data Collection, recording, calculations, Preparations Implementation works, monitoring the activities etc., in the Implementation of TQM. To carry out these implementation activities, TQM Team was formed. The structure of this TQM team is as shown in the fig 12.

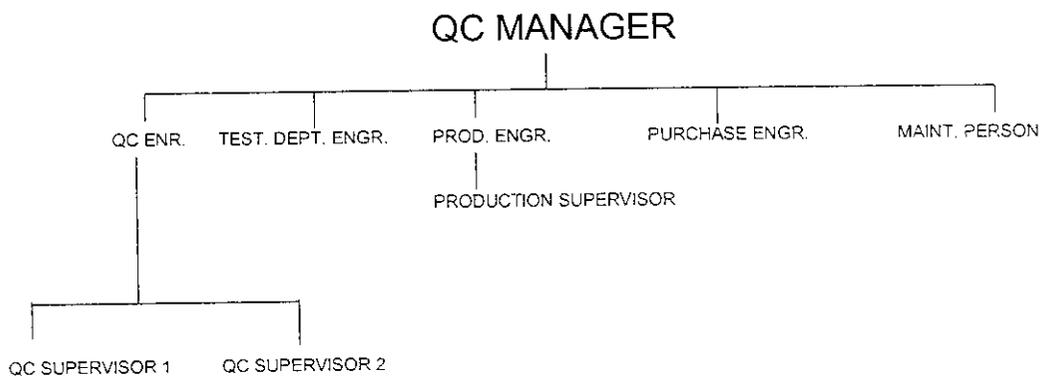


Figure - TQM Team

Fig-12,

## 5.2 Activities of TQM Team

The activities of TQM Team were defined which is listed below

Table 1

Work schedule	Time	Activities	Responsibilities
Dealing with customer complaints	3 <sup>th</sup> &4 <sup>th</sup> date of every month	<ol style="list-style-type: none"> <li>1. collect the customer complaints</li> <li>2. Prepare check sheet, pie chart, pareto chart</li> </ol>	QC-Engineer
First meeting	End of first week	<ol style="list-style-type: none"> <li>1. Display and demonstrate the quality problems by using charts</li> <li>2. Collect the causes for each effect by brain storming</li> </ol>	QC-Engineer QC-Engineer & All TQM members
Collect the present status about each causes	II – week	<ol style="list-style-type: none"> <li>1. collect the present datas about each causes</li> <li>2. Form the table for present status about causes</li> </ol>	QC-Engineer
Second meeting	End of II week	<ol style="list-style-type: none"> <li>1. Display &amp; demonstrate the table</li> <li>2. Discuss and sort out the each causes, finally find out the solutions for real causes</li> <li>3. Collect the solutions and write under the solution column in the table</li> <li>4. Allocate the TQM member for implement each solution</li> </ol>	QC-Engineer All TQM members

Implementation of solutions	III-week	<ol style="list-style-type: none"> <li>1. Implement the solutions in the each areas</li> <li>2. Maintain the documents for the results of solutions implemented</li> <li>3. Periodically show the results and get signature from the TQM Head</li> </ol>	TQM members in each areas.
Third meeting	End of III-week	<ol style="list-style-type: none"> <li>1. Show and discuss the results produced from the each solutions implemented for find the still better solution</li> <li>2. Monitor the solution's results</li> </ol>	TQM members  TQM Head
Monitoring of the solutions implemented	At any time within the month (2 or 3 or 4 times)	Physically check the implementation and then sign in documents.	TQM Head

### 5.3 Identification of the problem

#### Identification Tool – *Check Sheet*

As discussed earlier in the problem description the quality and performance of the product can be easily measured from the customer complaints especially in the pump manufacturing companies. So customer complaints for June 2002 were collected.

Check sheet is one of the Identification tool in the seven basic quality control tools. Collected customer complaints were summarized in the check sheet. Check sheet is as shown in the table 2.

**Table : 2 Check Sheet**

PRODUCT NAME	QTY IN NOS			
	MONTH			TOTAL
	JULY	JUNE	MAY	
4" KR MOTOR	3	8	4	15
4" VR PUMP	19	6	15	40
4" KR PUMP	11	8	4	23
6" MR PUMP	12	18	6	36
6" MM PUMP	15	17	18	50
4" VR MOTOR	21	6	16	43
6" MOTOR	28	35	26	89
OVSM	49	47	55	151
<b>TOTAL</b>	<b>158</b>	<b>145</b>	<b>144</b>	<b>447</b>

Check sheet clearly indicates that the products of OVSM models received more number of customer complaints. Thus the problem of poor quality, poor performance poor life in the products of OVSM models was identified by using check sheet.

## 5.4 Prioritizing among problems

### Prioritizing Tools – *Graph [pie chart] , pareto charts*

There are different types of models in OVSM such as OVSM-2, OVSM-3, OVSM-5, OVSM-31; the customer complaints received regarding OVSM was categorized further as model wise.

Graph (pie chart) is one of the prioritizing tool in the 7 basic QC tools. Model Wise Categorization was shown in the Graph (pie chart) pie chart shows in the fig 13.

CUSTOMER COMPLAINTS IN OVSM -MODELWISE DETAILS FOR THE MONTH OF MAY-JULY 2002

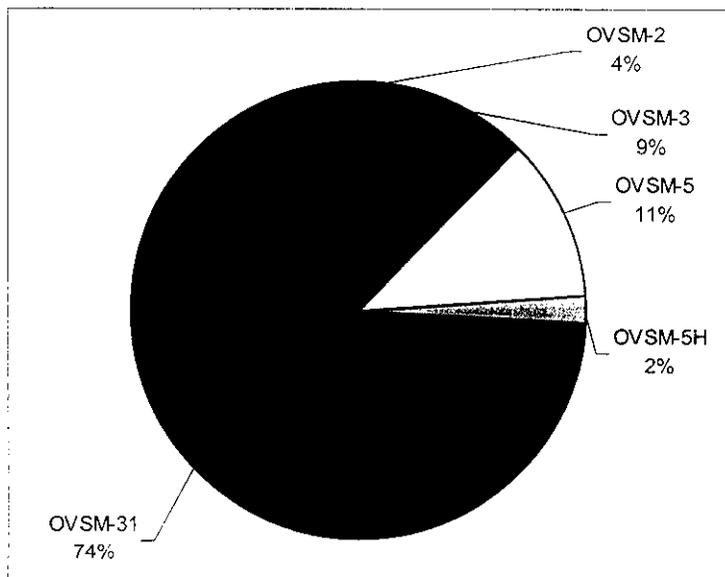
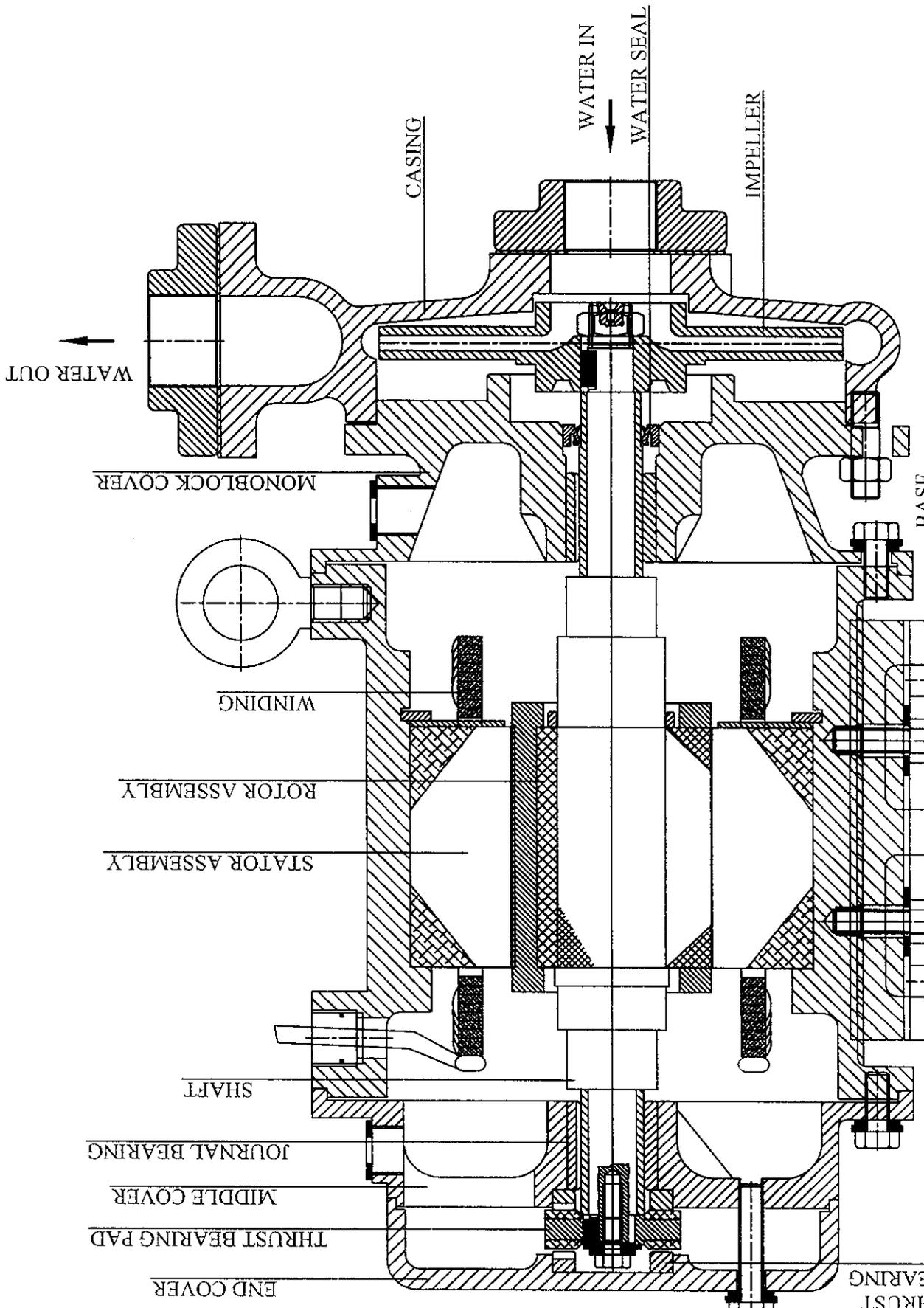


Figure 13, Pie Chart

Pie chart shows that the OVSM-31 model has received 74% customer complaints out of Total Customer complaints so, the priority given to the OVSM-31 model for solve the quality problems & improve the performance of the product. Assembly sectional view for OVSM-31 product is shown in the

ASSEMBLY CROSSSECTIONAL VIEW FOR OPENWELL SUBMERSIBLE MONOBLOCK PUMP - 31 (OVSM 31)



## Pareto Chart

There are some specific problems arises in the OVSM-31 model regularly after selling the model. Every customer complaints of the OVSM-31 was received for specific reasons [problem].

Pareto chart is the effective prioritizing tool in the 7 basic QC Tools. The customer Complaints of the OVSM-31 were categorized as a specific problem wise. This specific problem wise categorization was represented by using the Pareto chart. The Pareto chart is as shown in the fig 15.

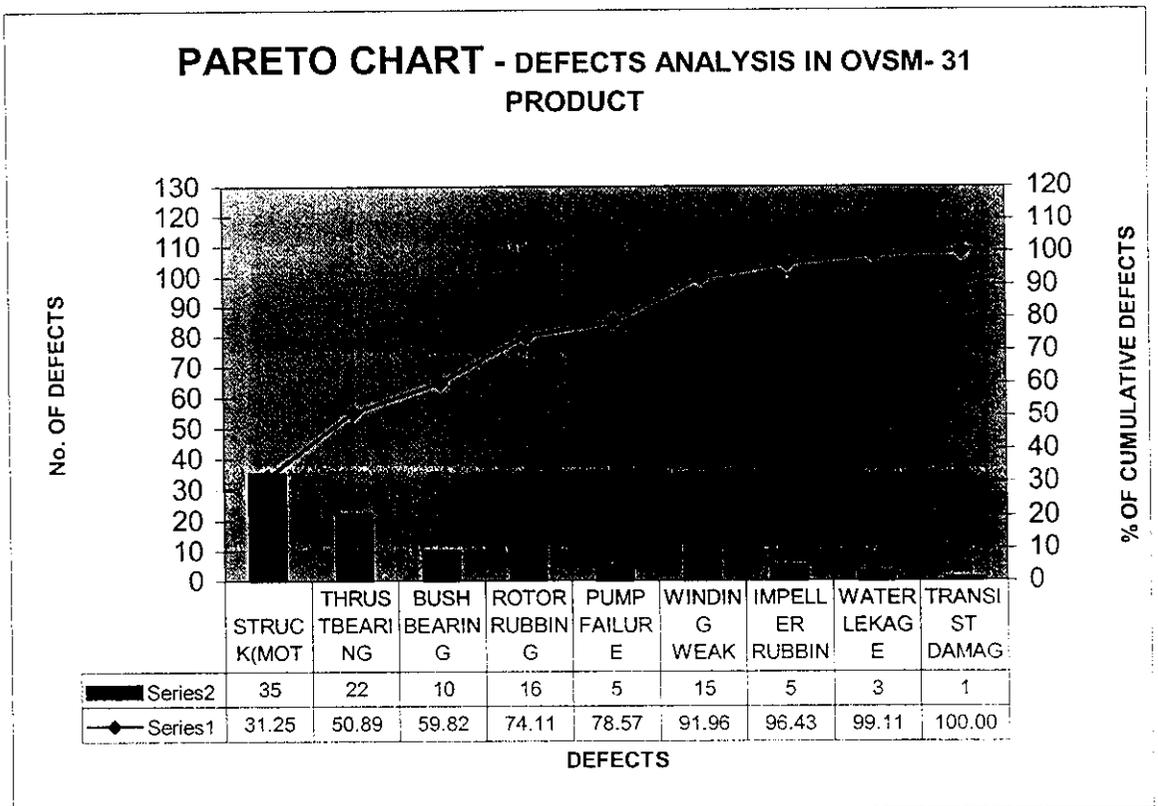


Figure :15 Pareto chart

The Pareto chart clearly indicates that the more number of customer complaints were received for the specific problem of struck [motor not running] So, this problem was taken for study & analysis and then find the solutions.

## **5.5 Analyzing the selected problem**

**Analyzing Tools – CAUSE & EFFECT DIAGRAM,**

*PROCESS CAPABILITY*

*CONTROL CHART*

### **Cause and Effect diagram**

In practice, there are several causes for one specific problem, like wise for our selected problem of struck, there may be a several causes in the existing system, existing environment, existing procedures used etc. To find out the causes, which create the problem of struck, the study were conducted in the production line [machine shop, Assembly, Testing, Inspection] of OVSM-31 product. In this study, the causes were collected and finally it was grouped under the major facilities like men, machine, materials, methods, Equipments & Instruments, Dimensions.

The Grouped Causes were taken in the TQM meeting by TQM members for discussion and analysis. In this meeting, the possible causes among totally collected causes are sort-out by Brain Storming method the possible causes under the major facilities are represented through the cause and effect diagram. This cause and effect diagram is shown in the figure 16.

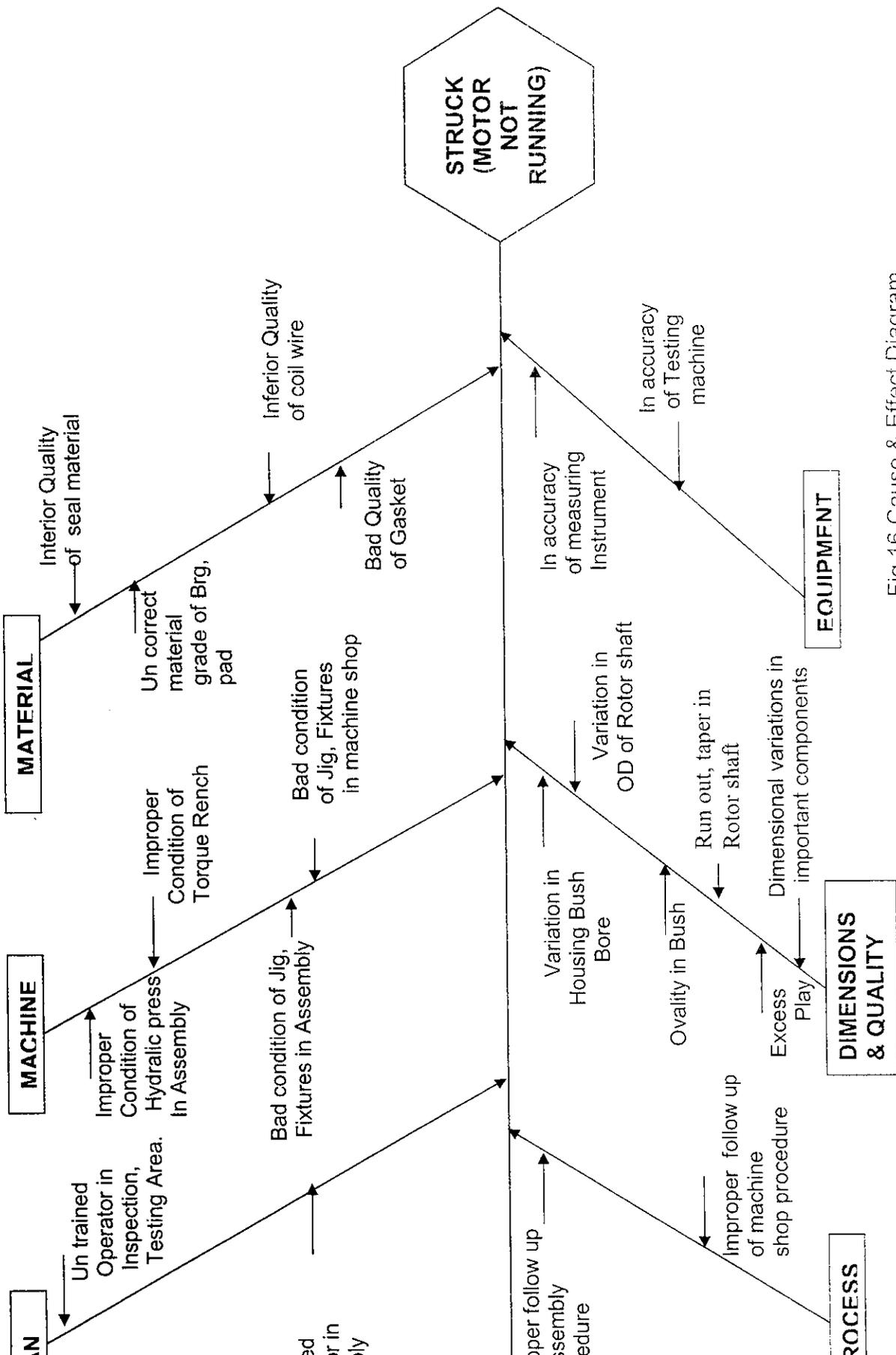


Fig 16 Cause & Effect Diagram

## **5.6 Present status of the possible causes and remedies for real causes**

All the possible causes shown in the cause and effect diagram does not create the problem of struck in the present working environment. Some of the causes only create the problem of struck because of poor machine condition, Inferior quality of materials, incorrect process/methodology etc. In the existing. Those causes are called real causes. Remaining causes in the others area of production line does not create this problem because methods, procedures system used in the those existing area are in suitable and correct one.

To find out the real causes, the study and analysis were conducted again in the each area where the possible causes anises. During the study and analysis. The present status about each causes were collected and finally it is tabulated. This present status table clearly shows that "What are all the possible causes really create the problem of struck" (i.e) real causes in TQM meeting. The tabulated details (present status) were taken for study the present status of causes and then the solutions and Remedies were found out by Brain storming method. This solutions and remedies are recorded in the present status table. The table for present status with remedies is shown in the table 3.

TABLE 3- PRESENT STATUS ABOUT POSSIBLE CAUSES AND REMEDIES

MAN				
CAUSES	PRESENT STATUS	SOLUTION	RESPONSIBLE PERSON FROM TQM TEAM	REMARKS
Untrained operator in assembly area	Some of the untrained operator are directly used	To provide one week training program in assembly	Production engineer	When ever new operators are recruited, Training Program should conduct
Untrained operator in inspection, testing areas	Some of the untrained operator are directly used	To provide 20 days Training program for handling of measuring instruments	QC_Engineer	When ever new operators are recruited, Training Program should conduct
Untrained operator in machines	No. of untrained operators are directly used	To provide 10 days training program For carry out the machining process	Production engineer	When ever new operators are recruited, Training Program should conduct

## MACHINE

CAUSES	PRESENT STATUS	SOLUTION	RESPONSIBLE PERSON FROM TQM TEAM	REMARK
Improper condition of hydraulic press assembly	Condition is ok	-	-	-
Bad condition of jig and fixtures used in assembly	( i ) Drilling jigs, Fixtures are ok  (ii) some wear out and damages are found in punches used in hydraulic press	Replace the used punches For 2 months once. and then conduct Process capability	Assembly engineer	-
Bad condition of jig fixtures used in machine shops	Condition is ok	Even though it is ok we planned to conduct process capability analysis for two months once	Production engineer	
Bad condition of M/C shop machines	Condition is ok	Periodic maintenance programs & process capability study	Maintenance engineer- PM  Prod.Engr.- process capability study	Refer annexure - II  Refer annexure - II

## MATERIAL

CAUSES	PRESENT STATUS	SOLUTION	RESPONSIBLE PERSON FROM TQM TEAM	REMARKS
Inferior quality of water seal material	Presently we are Searching for check quality	-	Purchase Engineer	-
Improper Material Grade of bearing	Material grade is ok	-	-	-
Bad quality of gasket	Material grade is ok	-	-	-
inferior quality of coil wire	No of coil burst , Coil weak are found from customer complaints and goods return for repair	Presently there are not sending the coil for material testing regularly  Send the purchase coil sample to, material testing for every lot	Purchase engineer	-

### PROCESS

CAUSES	PRESENT STATUS	SOLUTION	RESPONSIBLE PERSON FROM TQM TEAM	REMARKS
Improper follow up of assembly procedure	There is no display of work instruction sheet	Prepare and display of work instruction	Assembly engineer	
Improper follow up of M/C shop procedure	There is no display of work instruction	Prepare and display of work instruction	Production engineer	

### DIMENSION & QUALITY

CAUSES	PRESENT STATUS	SOLUTION	RESPONSIBLE PERSON FROM TQM TEAM	REMARKS
Parameters mentioned in the causes and effect diagram	There may be a chance for a variation outside/ within the limit	i) Process capability study ii) then introduction of control charts for reduce the variation in the dimensions	Process capability study- production engineer control charts - production engineer	Refer Annexure -

## EQUIPMENT & INSTRUMENTS

CAUSES	PRESENT STATUS	SOLUTION	RESPONSIBLE PERSON FROM TQM TEAM	REMARKS
In accuracy of measuring instruments	They are not sending the instruments to calibration with in the stipulated period	At any cost they should send the instruments for calibration in time	QCengineer	Refer Annexure -
In accuracy of testing machines	Proper calibration is carried out	-	-	-

## **6. RESULTS AND BENEFITS OF IMPLEMENTATION**

### **7 BASIC QC TOOLS**

As explained earlier in the problem description. The customer complaints were taken as a problem. After implementing 7 basic QC tools, results of the customer complaints can't able to measure for current months immediately. If this implementation is continued for an year, Definitely the customer complaints will be reduced. Due to this implementation, currently the following benefits were achieved.

1. The rejection rate in the machining components, assembly area are reduced.
2. The rejection rate in the components suppliers, Raw material procurements etc are reduced.
3. The reworking rates in the machine shop, assembly are reduced.
4. The quality of the components and OVSM-31 product are Improved.
5. The systematic approach and procedures are developed in the process of machine shop, assembly area, QC area etc.
6. It creates the awareness about the customer complaints in the existing, performance of quality of the product to the employees of the company.
7. Every one of you, starts to do the quality work in their own work towards get the good quality product.
8. An the activities in the working environment are going on with systematically.
9. Quality conscious among all the employees of the company were developed totally.

## **7. CONCLUSION**

### *I-PHASE, IMPLEMENTATION OF 7 BASIC QC TOOLS*

The 7 basic QC Tools of TQM were implemented in the production line of OVSM-31 product. Initially the customer complaints were taken as a problem. After implementation of 7 basic QC Tools, customer complaints are not reduced immediately on next month onwards. If the implementation of 7 basic QC Tools is continued for some period of time, customer complaints start to reduce gradually.

It developed the systematic approach / procedure for maintain the consistent quality in the products and works.

Like wise, if the other tools of TQM is implemented. The over all working environment, all functions right from starting to end in MAHENDRA SUBMERSIBLE PUMPS (P) LTD., company will be world class quality one and company can capture the market for their products. Meantime Company can get the goodwill from the customer, supplier and employees of the company.

The implementation of 7 basic QC Tools going on in the MAHENDRA SUBMERSIBLE PUMPS (P) LTD is successful one.

# 8 OPTIMIZATION OF PUMP'S PERFORMANCE BY USING D.O.E

## 8.1 Problem description

As explained earlier in the presently TQM is implementing in the production line of OVSM-31 product. Since the OVSM-31 type products has more demand in the market. The company planned to improve the performance of the pump for capture the market. The performance of the pump is generally measured in terms of Head, power, discharge. High head, more discharge, minimum power consumption are the indications of the high (good) performance of the pump. In this project, Head is taken for optimization of pump's performance by using D.O.E.

### Existing

At present, this type of pumps yields the maximum head of 24m. This existing head value is achieved for the following set of Input parameters and its values

- |  |   |       |
|--|---|-------|
| 1). Diameter of Impeller                               | - | 152mm |
| 2). Front suction boss of<br>Impeller clearance        | - | 2mm   |
| 3) Offset between impeller<br>centre and casing centre | - | 1.5mm |

### Proposed method

Initially the factors influencing the head of the pump were identified. The ranges (levels) and its values these factors were fixed as minimum & maximum. The optimum set of parameters will be found by using D.O.E software. The head will be maximized by modifying the pump design for this identified optimism level of input parameters. Thus, the pump's performance is proposed to be optimized using D.O.E software.

## **8.2 Design of Experiment - Process**

In the D.O.E process, the pump's performance is optimized in the following steps.

### **Step-1, State the problem**

The problem of optimizing the pump's performance has been taken

### **Step-2, State the objectives of the Experiment**

Objectives of the experiment are as follows

1. To maximize the head of the pump
2. To improve the performance of the pump
3. To find out the optimum set of input influenced parameters for head.
4. To find out the relationship between the input parameters with respect to head (output)
5. To find out the most influenced input parameter among the number of input parameters

### **Step-3, Select the quality characteristics and measurement system**

The quality characteristics of the pump's performance are head, discharge, power consumption etc. In which head was selected as a quality characteristic. It is measured in terms of pressure that is developed in the pump using pressure gauge and converted to meters.

### **Step-4, Select the factors that may influence the selected quality characteristics**

The influenced input parameters (factors) that affect the quality characteristics are found by brain storming method.

During brain storming, the following three influenced input parameters

1. Factor A - Diameter of Impeller
2. Factor B - Front suction boss of impeller clearance
3. Factor C - Offset between the impeller centre and casing centre

The above three factors are shown in the figure 17.

### Step-5, Identify the control and noise factors

All the selected influenced parameters (factors) are controllable one.

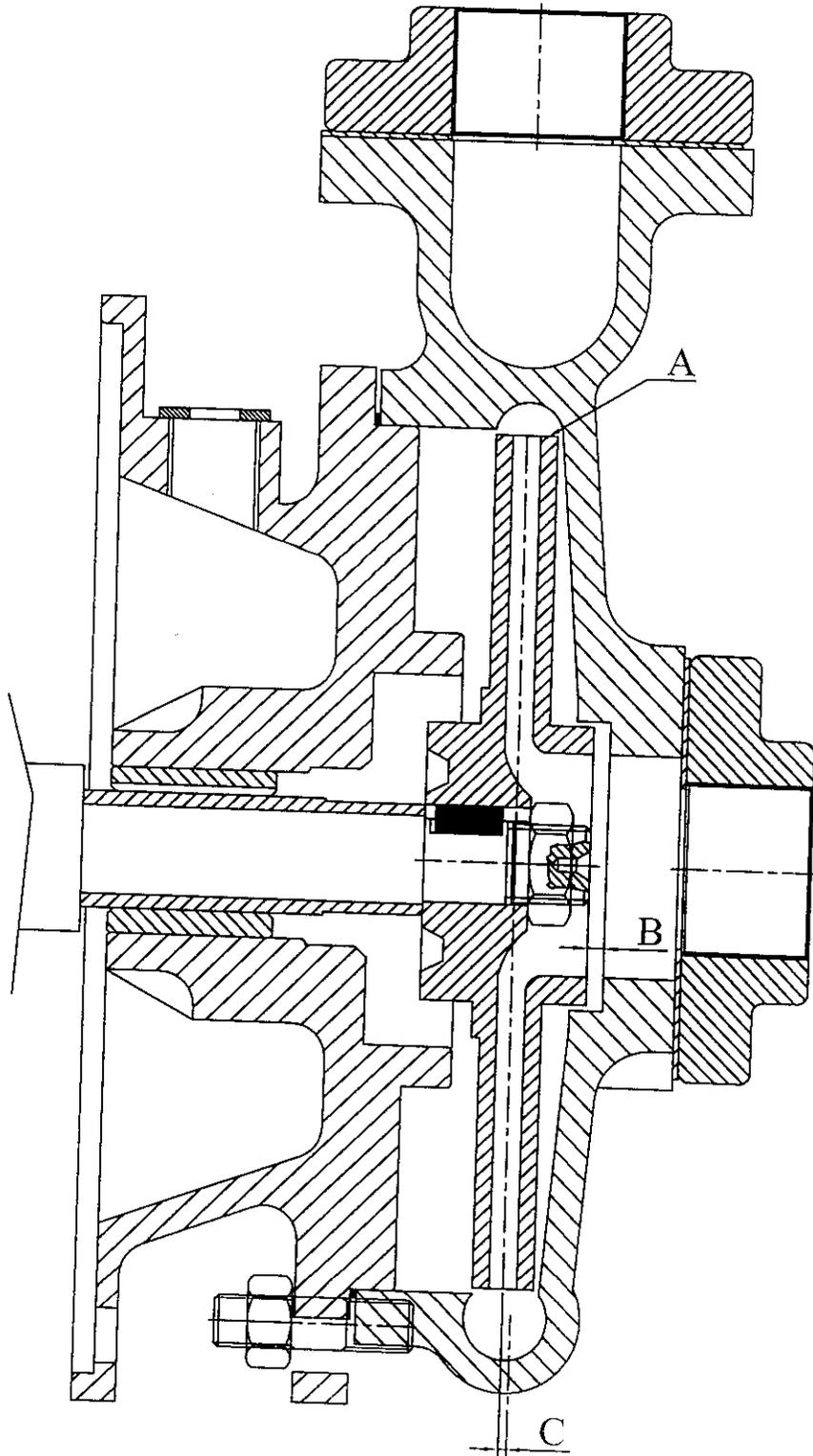
### Step-6, Select the levels for factors

Two levels are selected for 3 influenced parameters (factor). One level indicates the minimum range of values and other level indicates the maximum range of values. Two levels and its values for 3 factors are mentioned in the following table no. 4.

Table 4

SL NO.	FACTORS	NOTATION	LEVELS	
			LEVEL – I (MINI. VALUES IN MM)	LEVEL –II (MAXI. VALUES IN MM)
1	Diameter of Impeller	A	150 (A1)	154 (A2)
2	Front Suction Boss of Impeller clearance	B	1 (B1)	3 (B2)
3	Offset between impeller Center and casing center	C	1 (C1)	3 (C2)

DETAILED VIEW FOR CASING AND  
IMPELLER SIDE OF OVSM 31



FACTORS

A - Diameter of Impeller

B - Clearance in Front Suction

### Step-7, select the appropriate orthogonal arrays

Generally, the orthogonal arrays are selected on the basis of numbers of factors and its levels in the Taguchi's approach, there are some standard formats of orthogonal array for two levels one of the standard format is L8 orthogonal array, which is selected for our experiments. This array says that eight trails has to be conducted.

The L8 orthogonal array is shown in the Table 5

Table 5

Trial No.	1	2	3	4	5	6	7
1	1	1	1	1	1	1	1
2	1	1	1	2	2	2	2
3	1	2	2	1	1	2	2
4	1	2	2	2	2	1	1
5	2	1	2	1	2	1	2
6	2	1	2	2	1	2	1
7	2	2	1	1	2	2	1
8	2	2	1	2	1	1	2

### Step-8, Select interactions that may influence the selected quality characteristics

In the Taguchi's approach, there are some standard format for interaction of parameter. One of the standard format, is 2 factor interaction array which is selected and shown below.

AxB    AxG    BxC.

### Step-9, Assign factors to OA and locate interactions.

The factors and its interactions were assigned to the L8 orthogonal array.

Table 6

Trial No.	1	2	3	4	5	6
	A	B	AxB	C	AxC	BxC
1	1	1	1	1	1	1
2	1	1	1	2	2	2
3	1	2	2	1	1	2
4	1	2	2	2	2	1
5	2	1	2	1	2	1
6	2	1	2	2	1	2
7	2	2	1	1	2	2
8	2	2	1	2	1	1

#### NOTE :

Since 7<sup>th</sup> column in the L8 orthogonal array (Table 6) is belongs to 3 factor interaction array (AxBxC), That 7<sup>th</sup> column is omitted during assigning factors to OA.

### Step-10 conduct tests described by Trails in OA (5)

To conduct tests, assign the values (which is already defined in the levels, refer step No. 6) to the factors as per the trails define in the step No9 and then trails with assigned values were formulated in the table which is

Table 7

Trial No.	1	2	4	RESPONSE
	A	B	C	
1	1	1	1	R1
2	1	1	2	R2
3	1	2	1	R3
4	1	2	2	R4
5	2	1	1	R5
6	2	1	2	R6
7	2	2	1	R7
8	2	2	2	R8



Table 8

Trial No.	1	2	4	HEAD in meters
	A	B	C	
1	150 (A1)	1 (B1)	1 (C1)	<b>25.50</b>
2	150	1	3	<b>23.79</b>
3	150	3	1	<b>23.19</b>
4	150 (A1)	3 (B2)	3 (C2)	<b>24.85</b>
5	154	1	1	<b>27.13</b>
6	154	1	3	<b>26.25</b>
7	154	3	1	<b>25.68</b>
8	154	3	3	<b>25.45</b>

As per the set of factors defined for each trail in the above table, All the trails were conducted. In the ...

**Step 11, Analyze the results of the experimental trails.**

The results of the experimental trails were analyzed by using D.O.E Software. (QA SIX SIGMA SUITE, D.O.E – IV Software) The results of the analyzers carried out in the D.O.E software are as follows.

**ANOVA SUMMARY: Based on the model specified by the Interaction List**

Model	Sum of Squares (Partial SS)	df	Mean Square	F – ratio	Level of Significance
Main Factors - Linear	8.143	3	2.714	2.935	0.602
Interactions - All Linear	2.286	3	0.762	0.824	Undefin
Error	0.925	1	0.925		
Total	11.354	7			Undefin

**ANOVA SOURCES of VARIATION: Based on the model specified by the Interaction List**

Source	Sum of Squares	dof	F – Ratio	Significance
A Impellar dia	6.444	1	6.968	0.757
B Impellar clearanc	1.531	1	1.656	0.577
C offset	0.168	1	0.182	Undefin
AB	0.125	1	0.135	Undefin
AC	0.140	1	0.152	Undefin
BC	2.020	1	2.184	0.618

**REGRESSION SUMMARY**

Source	Sum of Squares	dof	Mean Square
Regression Model			
Factors	10.429	6	1.738
Residuals - Total	0.925	1	0.925
Lack of Fit	0.925	1	0.925

Statistics	F - Ratio	Probability
MS-Factors/MS-Residuals	1.880	0.502
MS-Factors/MS-Pure Error	Undefined	Undefined
MS-Lack of Fit/MS-Pure Error	Undefined	Undefined

Fitted Response	Standard Error	degrees of freedom (dof)
Head	0.962	1

#### Coefficient of Determination

#### Subgroups

R-squared	0.919	Number	8.000
R-squared, adjusted	Undefined	Average Size	1.000
Coefficient of Variation	Undefined	Minimum Size	1.000
		Maximum Size	1.000

#### FITTED PARAMETERS

Source / Parameter Transmitted	Level of Sum of Squares Significance	Levels	Coefficient t-Ratio	Standard Error	Variance
Mean	0.000	0	-78.945	0.000	0.000
0.000	0.000				
A Impellar dia	0.769	2	0.706	0.510	0.010
6.444	2.640				
B Impellar clearance	0.579	2	8.058	25.851	0.489
1.531	-1.287				
AB	0.224	4	-0.063	0.170	0.003
0.125	-0.368				
C offset	0.257	2	8.920	25.851	0.489
0.168	-0.426				
AC	0.237	4	-0.066	0.170	0.003
0.140	-0.390				
BC	0.621	4	0.502	0.340	0.006
2.020	1.478				

### CORRELATION TABLE

	A	B	AB	C	AC	BC
A	1.000	0.000	0.026	0.000	0.026	0.000
B		1.000	1.000	0.000	0.000	0.667
AB			1.000	0.000	0.001	0.666
C				1.000	1.000	0.667
AC					1.000	0.666
BC						1.000

Following Charts shows that the affect of input parameters (A, B, C) in the output responses (Head)

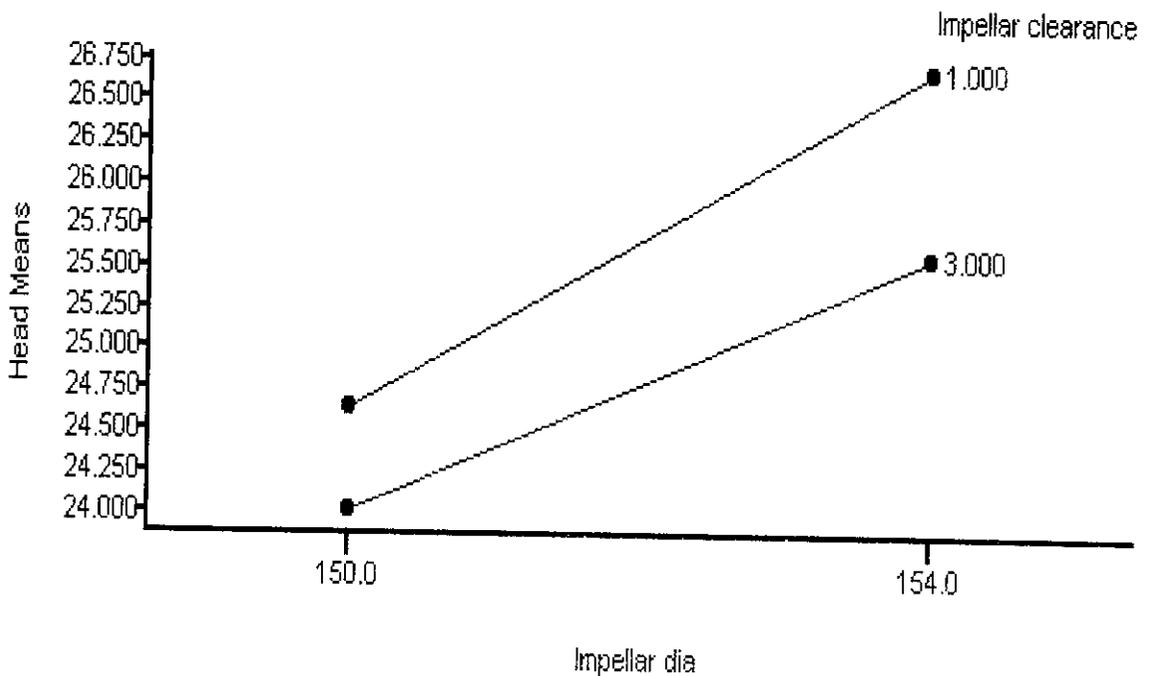


Fig 18

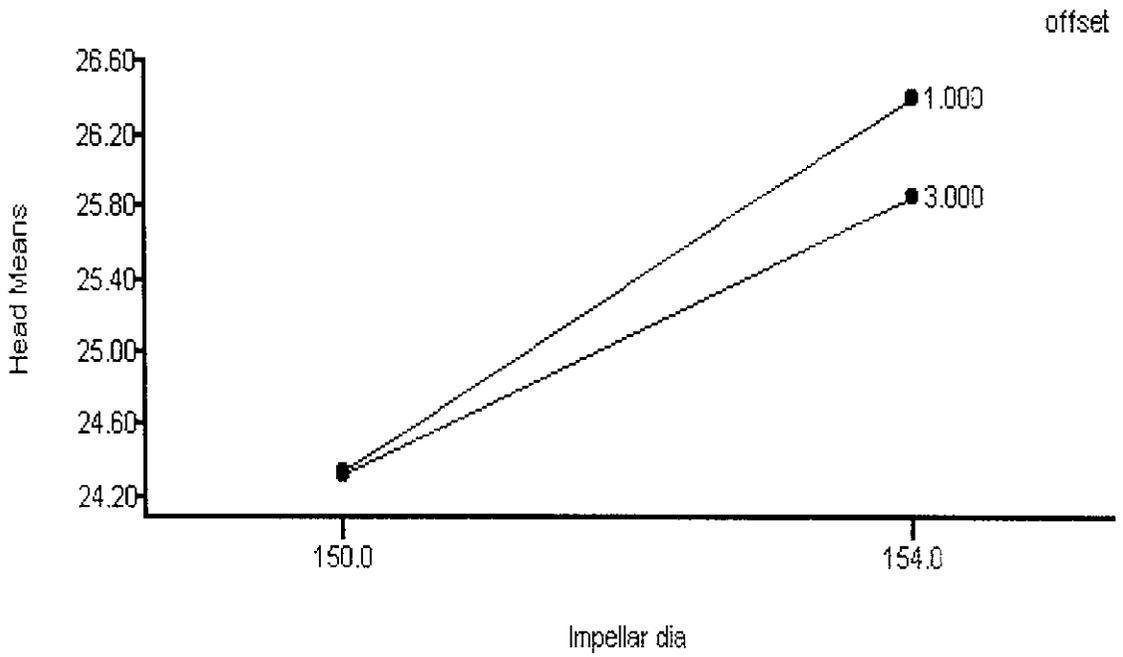


fig 19

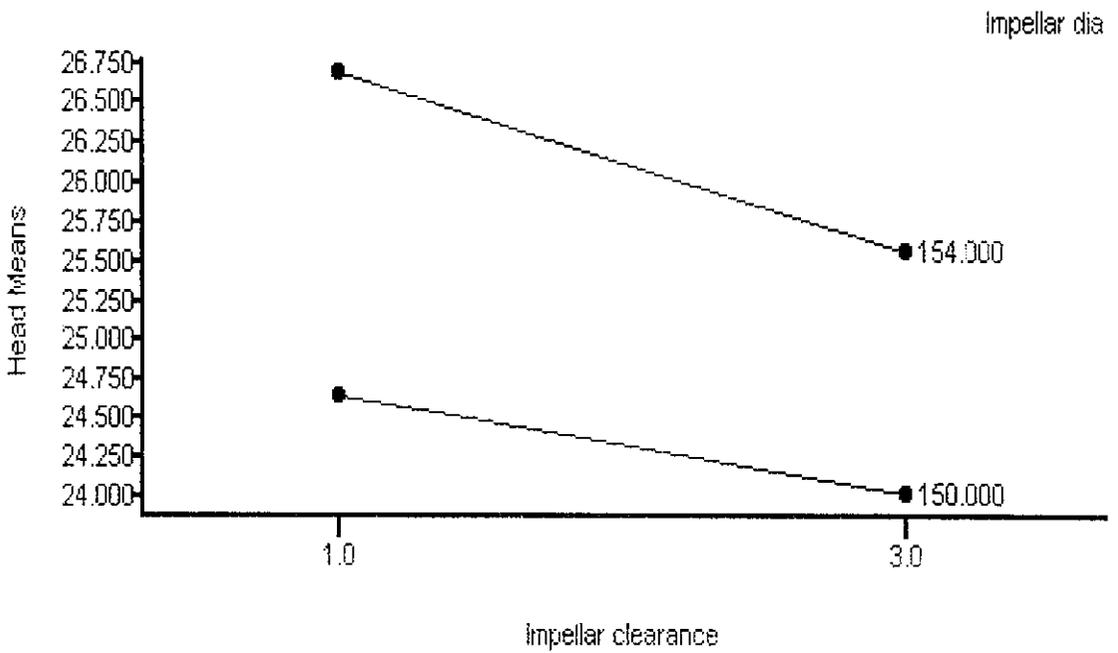


fig 20

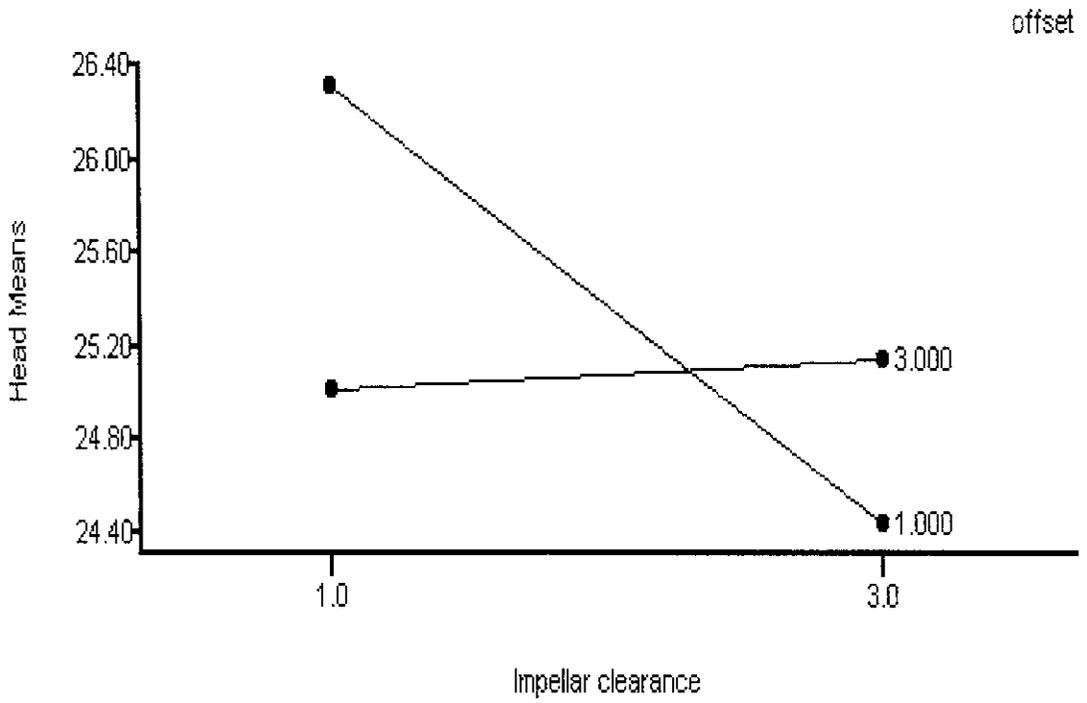
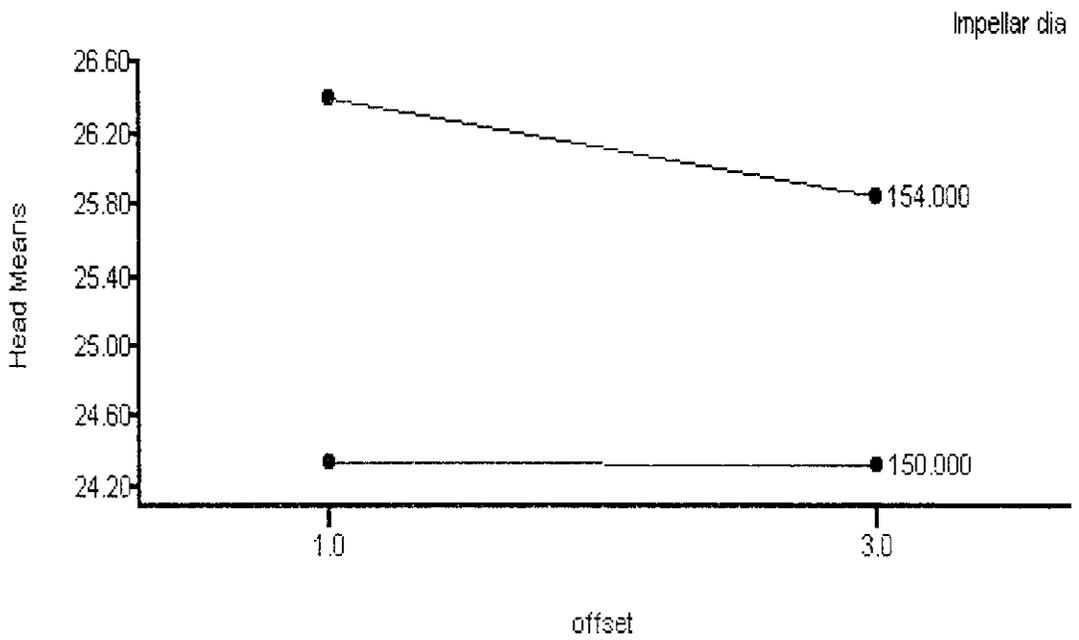
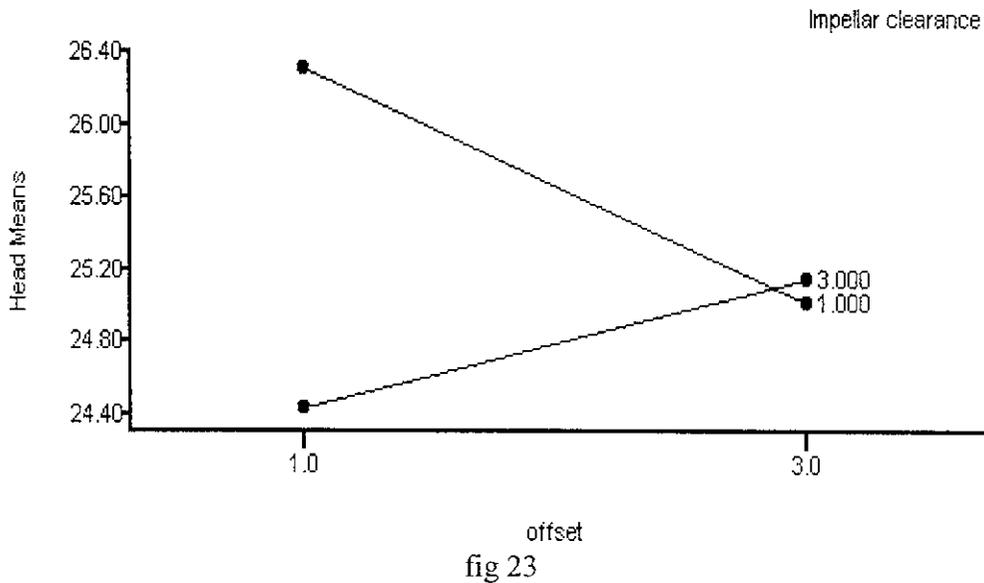


fig 21





### 8.3 Results and discussion

From the results of analysis carried out in the D.O.E Software, No. of charts were arrived. This charts represents the relationship between input factors and output response

#### From the Fig18

While increasing the diameter of the impeller, the head value also increased. Specifically, for clearance value of 1, High head value is achieved.

**Conclusion** from this chart, The best set of combination of factors are

Diameter = 154, Clearance = 1

#### From the Fig.19

While increasing the diameter of the impeller, the head value also increased. Specifically, for offset value of 1, High head value is achieved.

**Conclusion** from this chart is best set of combination of factors are

### **From the Fig.20**

While increasing the Clearance, the head value is gradually decreased. Specifically, For diameter of impeller value of 154, more head value is achieved. And for diameter of impeller value 150, less head value is achieved

**Conclusion** from this chart is best set of combination of factors are

Clearance = 1,      Diameter = 154

### **From the Fig 21.**

While increasing the Clearance value, The head value is gradually decreases. Specifically, for offset value of 1, Less head is achieved. And for the offset value of 3, More head value is achieved.

**Conclusion** from this chart is best set of combination of factors are

Clearance = 1,      Offset = 3

### **From the Fig.22**

While increasing the offset value, The head value is gradually reduced. Specifically, for diameter of impeller value of 154, More head is achieved. And for diameter of impeller value 150. Less head is achieved

**Conclusion** from this chart is best set of combination of factors are

Offset = 1,      Diameter = 154

### **From the Fig. 23**

While increasing the offset value, The head value is gradually increased in the cases of clearance value 3. While increasing offset value the head value is gradually reduced in the case of clearance value 1

**Conclusion** from this chart is best set of combination of factors are

Offset = 1,(for the case of clearance value 1)

## To find out the optimized value for factors

Best set of combination of factors are identified from the charts are listed below

**Chart I** ⇒ Diameter = 154, Clearance = 1

**Chart II** ⇒ Diameter = 154, Offset = 1

**Chart III** ⇒ Clearance = 1, Diameter = 154

**Chart IV** ⇒ Clearance = 1, Offset = 3

**Chart V** ⇒ Offset = 1, Diameter = 154

**Chart VI** ⇒ Offset = 1, (for the case of clearance value 1)

Offset = 3 (for the case of clearance value 3)

## Final, Optimized values for factors (A, B, C) are as follows

The above best set of combination shows that

The optimum value for diameter of impeller = 154

The optimum value for clearance = 1

There are two values for offset. Specifically, for the offset value of 1 yields more head than the offset value of 3. So the value of 1 for offset was selected as a optimum.

Optimum value for offset = 1

<i>Diameter of Impeller (A)</i>	=	<b>154</b>
---------------------------------	---	------------

<i>Front suction boss of Impeller clearance (B)</i>	=	<b>1</b>
---	---	----------

<i>Offset between impeller center and casing center (C)</i>	=	<b>1</b>
---	---	----------

## **From the Calculations**

The factor 'A' has a high F- ratio value from the calculation so it clearly indicates that the most influence factor is diameter of impeller (i.e) factor A. This identified most influenced factor is very much useful for varying the output results of the pumps. This variation is done by changing the values of the most influenced factor.

### **Step -12, conduct the confirmation experiment**

A confirmation experiment was performed as per the optimized values of the factors (these optimized values arrived from the step 11) The head value were checked for 4 pumps. This head value from this confirmation experiment shows that the pump yields maximum head for this identified setoff optimized values for factors A, B, C.

*Thus, the pumps performance (head) was optimized by using D.O.E processes.*

## **9. CONCLUSION**

### **II-PHASE, OPTIMIZATION OF PUMP'S PERFORMANCE BY USING D.O.E**

Initially, the OVSM-31 product yield the 24meter of head. Currently, The OVSM-31 product yields the 27meters of head for optimized set of parameter identified in the D.O.E processes. From this comparison, the pump's performance is increate to 3 meters of head. Thus the optimization of pump's performance is done by using the D.O.E processes.

Like wise, the other parameters of pump's performance (i.e) discharge of pump and power consumption of the pump will be also increased and reduced respectively by finding the optimized values for factors in the D.O.E processes. Thus the overall performance of the pumps will be increased by using the D.O.E processes. This D.O.E process is also applicable to optimize the process parameter (or) charactertics for yield more benefits.

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## Annexure – I, Training Programme

There was no Systematic Training Programmed for new operators. In this TQM Implementation, Training program having introduced for new operators when ever new operators are recruited in the machine shop, Assembly, Testing, Inspection areas etc. The Training Programme should be conducted for that selected new operators. The Training programme format is as shown in the Table 9.

Table 9

MAHENDRA SUBMERSIBLE PUMPS PVT LTD					
TRAINING PROGRAMME					
Name of the Trainee :			Trainee By :		
Employee No :			Date from :		
Department :			Date to :		
S.NO.	SECTION	PRODUCT	TRAINING DETAILS	PERIOD	PRACTICAL WORK
	Assembly	OVSM –31	1. Introduction about product. 2. Demonstration about Manufacturing process, Sequence of assembly, Testing of products. 3. Specifically trained him in rotor assembly/ stator assembly / covers assembly / casting assembly		
REMARKS					
Performance : Good      Normal      Poor      Very poor					
Signature of trainee :			Signature of the trainer :		
Date :			Date :		
Signature of the Head :					
Date :					

## **Annexure – II, Periodic maintenance programme**

Initially, there was a break down maintenance programme for maintain the machines in the company. In this program, after some period of time, the machine condition starts to deviate from the good condition at that time; suddenly we can't able to find out this deviation. Due to usage of sampling technique, there may be a chance to come the bad quality of components in the lot size, while running the machines in the deviation period. To avoid this, periodic maintenance is introduced for always maintaining the machines in good conditions, instead of break down maintenance programme. The periodic maintenance programme format is shown in the Table 10



## **ANNEXURE – III,**

### **PROCESS CAPABILITY STUDY (PCS) FOR CYLINDRICAL GRINDING MACHINE**

The key dimensions like bearing size, water seal seating size, thrust bearing size of the rotor shaft are grind in the cylindrical grinding. The past record for this key dimensions were studied, the study clearly shows that even though these dimensions came within the tolerance limit, it has a wide variation in the dimension within the specified limit. Due to usage of sampling technique in the inspection, there may be a chance to come components with dimensions having outside the specified limit in the lot because there is a wide variation in the dimensions. To avoid this mean time to know whether this machine is capable to meet the required qualities (dimensions, run out, face out, taper etc.) of the rotor shaft. Process capability study where conducted.

Fifty numbers of the grinder rotor shaft from the cylindrical grinding machine were taken for PCS. The bush bearing size of the rotor shaft were collected and tabulated.

The results of the PCS for the 50 parts are as follows

Table - 11

MAHENDRA SUBMERSIBLE PUMPS (P) LTD Coimbatore - 35	<b>PROCESS CAPABILITY REPORT</b>	Sl. No. : 1 Date : 29-08-2002 Page : 1 OF 2
--	----------------------------------	---

PART No.		DRAWING No.	:
DESCRIPTION	: ROTOR ASSY.OVSM-31	MACHINE NAME	: GRINDING MACHINE
DIMENSION	: DIA 22 e8	MACHINE No.	: G06
UTL	: 21.96	LTL	: 21.927
SAMPLE SIZE	: 50 Nos	CONDUCTED ON	: 29/8/2002
INSTR.	: MICROMETER 0-25 mm, L.C=0.001mm	OPERATOR	: Mr. S. Karuppusamy

Sl. No.	Value	Sl. No.	Value	Sl. No.	Value	Sl.No.	Value	Sl.No.	Value
1	21.911	11	21.933	21	21.937	31	21.946	41	21.952
2	21.915	12	21.933	22	21.937	32	21.946	42	21.952
3	21.922	13	21.934	23	21.938	33	21.947	43	21.952
4	21.928	14	21.934	24	21.938	34	21.948	44	21.952
5	21.929	15	21.934	25	21.939	35	21.949	45	21.954
6	21.930	16	21.935	26	21.939	36	21.949	46	21.956
7	21.930	17	21.935	27	21.939	37	21.949	47	21.957
8	21.931	18	21.935	28	21.940	38	21.950	48	21.960
9	21.932	19	21.936	29	21.940	39	21.950	49	21.966
10	21.932	20	21.936	30	21.942	40	21.951	50	21.972

R1=	0.010	R2=	0.002	R3 =	0.002	R4 =	0.0025	R5 =	0.01
R1Bar	0.0054	(R1+R2+R3+R4+R5) + 5				D4 =	2.12		
UCL =	0.011448	(D4 * R1Bar)				D3 =	0		
LCL =	0	(D3 * R1Bar)							
X1 =	21.926	X2 =	21.9345	X3 =	21.9389	X4 =	21.9485	X5 =	21.9573
X1Bar	21.94104	(X1+X2+X3+X4+X5) + 5							
UCL =	21.944156	(X2Bar + (A2 * R1Bar))				A2 =	0.577		
LCL =	21.937924	(X2Bar - (A2 * R1Bar))							



R CHART

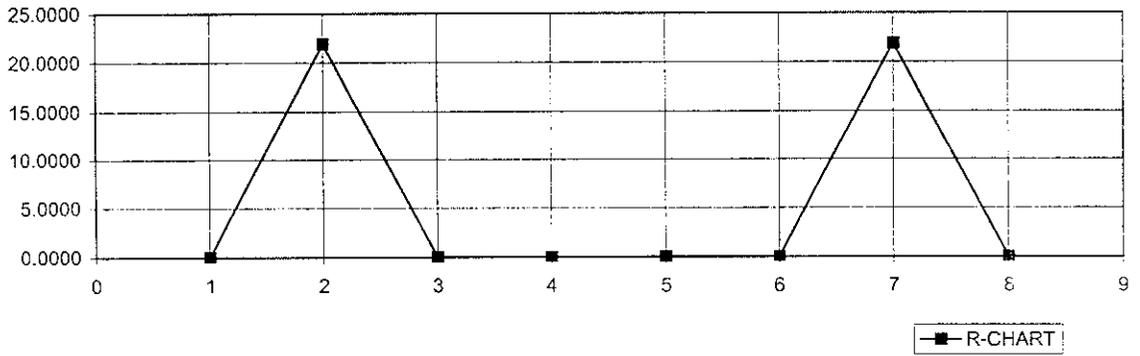


Fig : 24

X BAR CHART

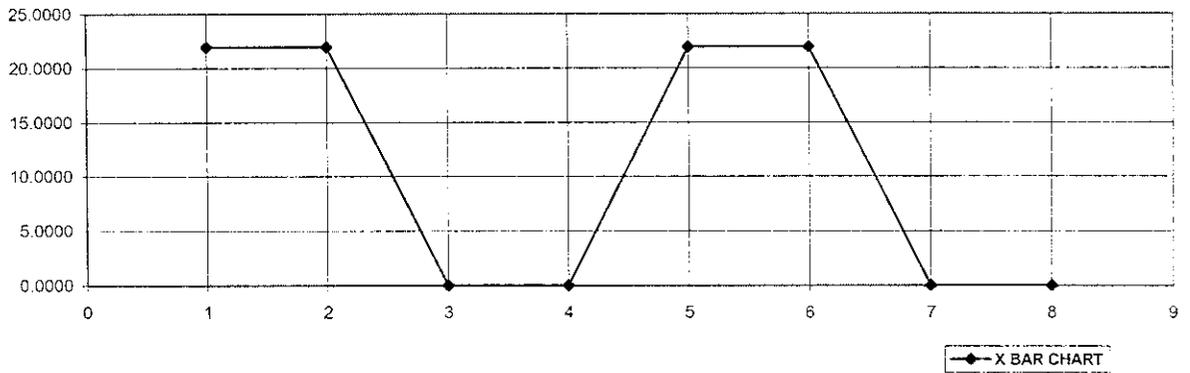


Fig 25

PROCESS CAPABILITY CHART - OVSM31 ROTOR ASSEMBLY

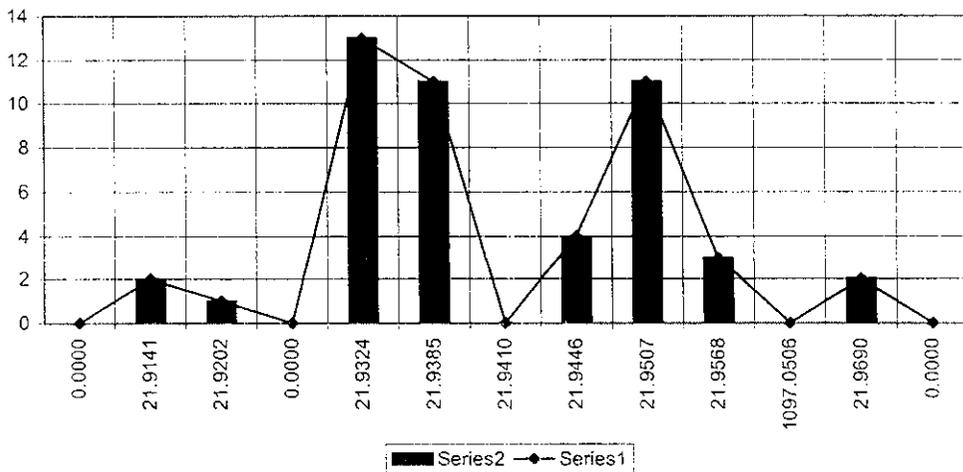


Fig 26

Since the  $C_{pk} < 1.33$  and  $C_p < 0.8$ , PCS clearly indicates that the cylindrical grinding is not capable to meet the qualities required of the rotor shaft

In TQM meeting, the results of the PCS study were taken for study and analysis. TQM members visited to the place of cylindrical grinding machine and then existing process were studied again. Existing process details was studied in the TQM meeting for find out improvement in the process. In which some of the improvements where found. Such an improvements are as follows

1. Constant depth in CC center of the rotor shaft is maintained
2. Dressing the grinding wheel is done periodically
3. Avoid the spark out by the operator

After improving the process 50 numbers of the grinded rotor shaft were taken. Dimension for the bearing size (dia 22 e8) were measured and tabulated. Calculations for  $C_{pk}$  and  $C_p$  are shown in the tables 13,14

Table - 13

MAHENDRA SUBMERSIBLE PUMPS (P) LTD Coimbatore - 35		PROCESS CAPABILITY REPORT				SI. No. : 1 Date : 23/09/02 Page : 1 OF 2			
PART No :		DRAWING No :							
DESCRIPTION : ROTOR ASSY.OVSM-31		MACHINE NAME : GRINDING MACHINE							
DIMENSION : DIA 22 e8		MACHINE No. : G06							
UTL : 21.96		LTL : 21.927							
SAMPLE SIZE : 50 Nos		CONDUCTED ON : 23/09/02							
INSTR. : MICROMETER 0-25 mm, L.C=0.001mm		OPERATOR : J.F.ARUL RAJ							
SI. No.	Value	SI. No.	Value	SI. No.	Value	SI.No.	Value	SI.No.	Value
1	21.940	11	21.942	21	21.943	31	21.944	41	21.946
2	21.941	12	21.943	22	21.944	32	21.945	42	21.946
3	21.941	13	21.943	23	21.944	33	21.945	43	21.946
4	21.942	14	21.943	24	21.944	34	21.945	44	21.946
5	21.942	15	21.943	25	21.944	35	21.945	45	21.946
6	21.942	16	21.943	26	21.944	36	21.945	46	21.947
7	21.942	17	21.943	27	21.944	37	21.945	47	21.947
8	21.942	18	21.943	28	21.944	38	21.945	48	21.947
9	21.942	19	21.943	29	21.944	39	21.945	49	21.947
10	21.942	20	21.943	30	21.944	40	21.946	50	21.948
R1=	0.001	R2=	0.001	R3 =	0.000	R4 =	0.001	R5 =	0.001
R1Bar	0.0008	(R1+R2+R3+R4+R5) - 5				D4 =	2.12		
UCL =	0.001696	(D4 * R1Bar)				D3 =	0		
LCL =	0	(D3 * R1Bar)							
X1 =	21.9416	X2 =	21.9429	X3 =	21.9439	X4 =	21.945	X5 =	21.9466
X1Bar	21.944	(X1+X2+X3+X4+X5) - 5							
UCL =	21.944462	(X2Bar + (A2 * R1Bar))				A2 =	0.577		
LCL =	21.943538	(X2Bar - (A2 * R1Bar))							



### R CHART

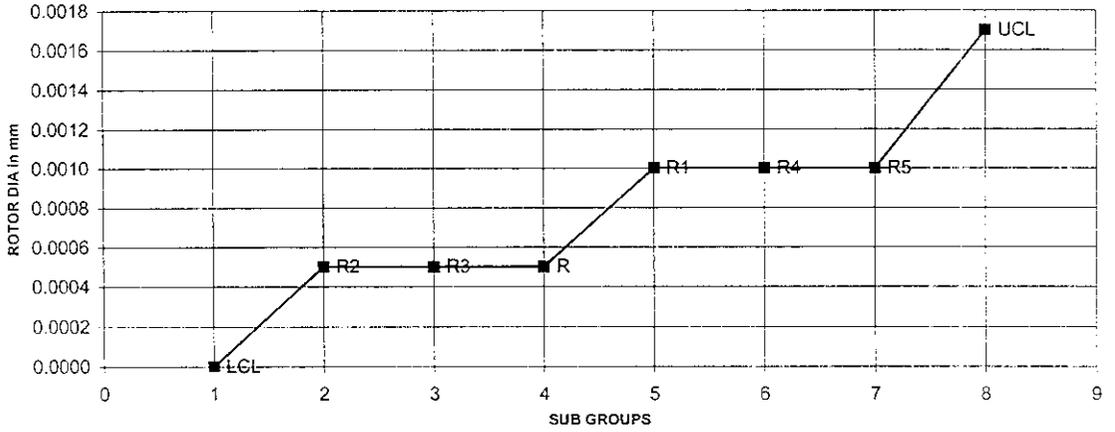


Fig 27

### X BAR CHART

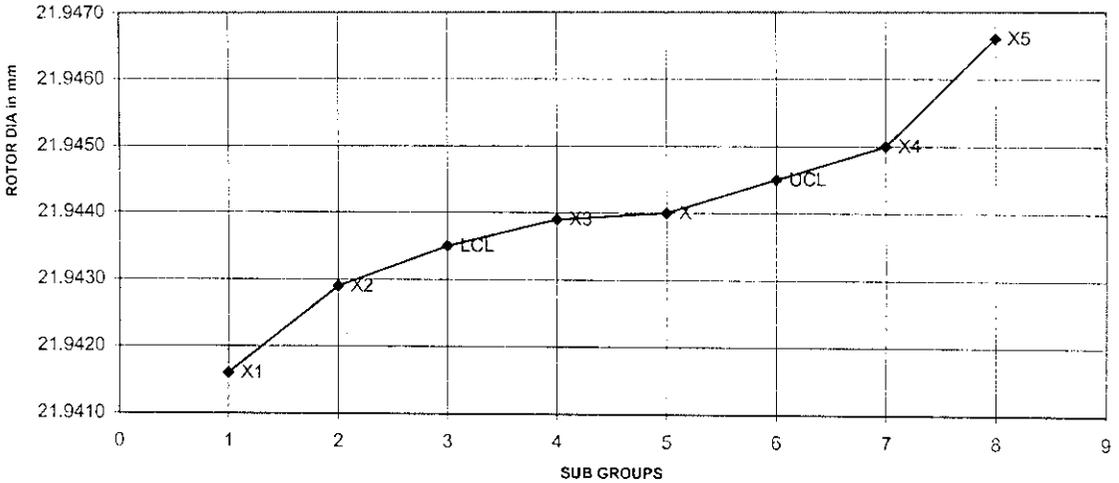
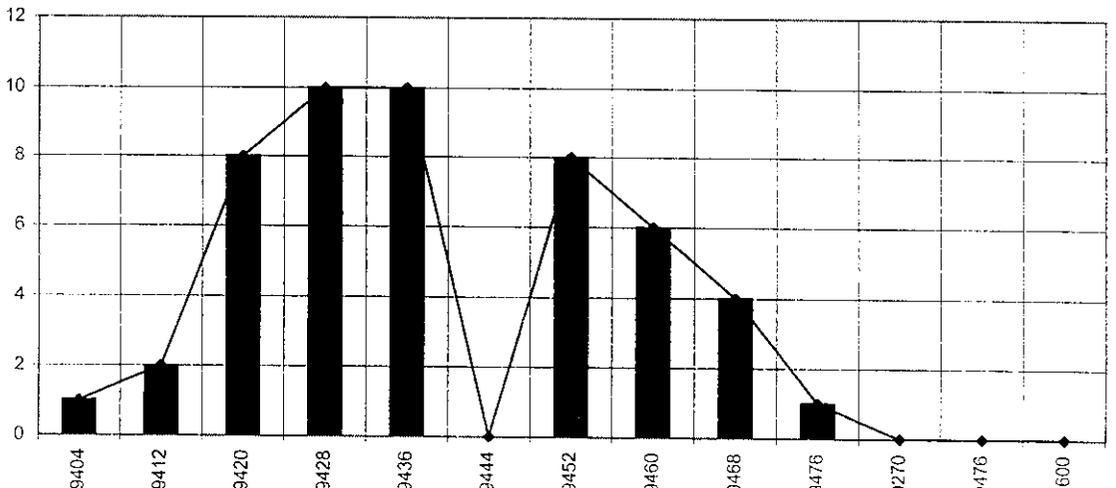


Fig 28

### PROCESS CAPABILITY CHART - OVSM31 ROTOR ASSEMBLY (AFTER)



Since the  $C_{pk} < 1$  and  $C_p < 1$  it shows that the improved process is capable one to meet the quality requirements of the rotor shaft. Meantime X chart and R chart (Fig 27, Fig 28 & Fig 29) clearly shows that the dimensions of the bearing size are close to the center line. So the wide dimension variation within the tolerance limit is reduced by the new improved methodology.

Finally Comparation for before improvement of process and after improvement of process in C.G. machine were studied

The comparison results are as shown figures 30, 31 & 32.

## Comparison Between Before Improvement of process and After

### Improvement of Process in CG Machine

R CHART- OVSM31 ROTOR ASSEMBLY (COMPARISON)

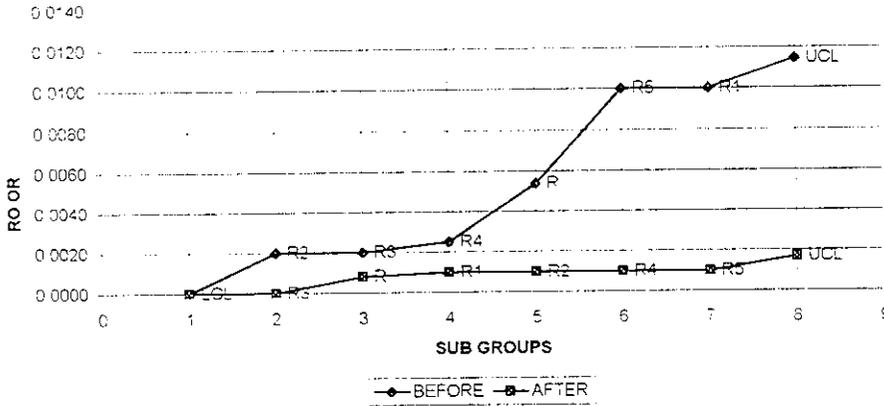


Fig 30

X BAR CHART-OVSM31 ROTOR ASSEMBLY (COMPARISON)

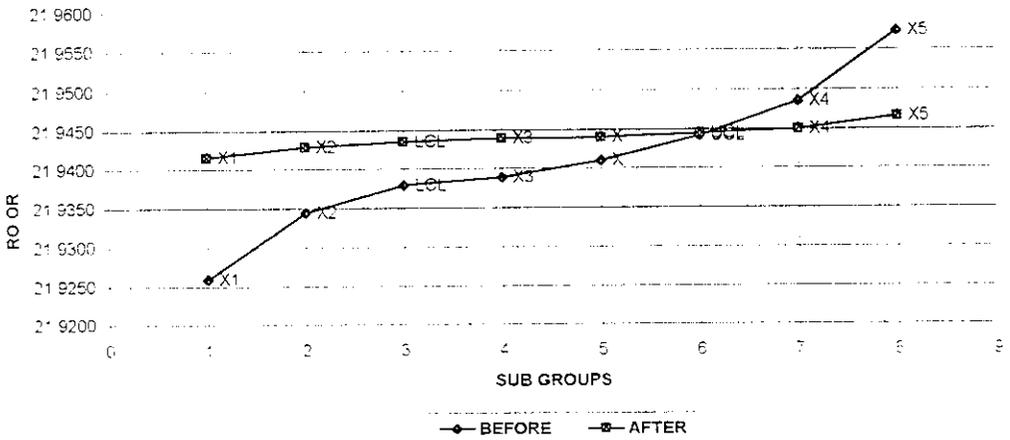
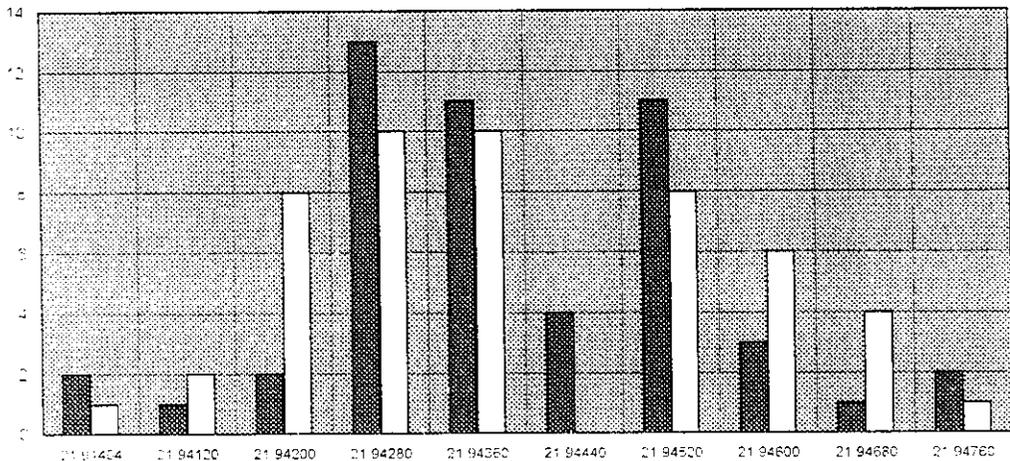


Fig 31

PROCESS CAPABILITY CHART - OVSM31 ROTOR ASSEMBLY (COMPARISON)



## **ANNEXURE - IV, CONTROL CHART**

Even though the cylindrical grinding (CG) machine is capable one to meet the quality requirements, after PCS, due to continues running of the machine there may be a chance to deviate from process set after running some period of time. So, there is a chance to produce bad quality of parts in that period. To avoid this, and to know the current process trend, control charts are introduced in the CG machine.

The implemented control charts for the dimensions of the bearing size (dia 22 e8) in the rotor shaft is as shown in the figure 33

The above control chart shows that the current process trend comes very close to the center line. Due to continue usage of control charts, the wide dimensional variation within the tolerance limit is reduced and dimensions are maintained very close to the center line.

Thus the rotor shafts and other components grinded in the CG machine are continuously produced with good quality by implementation of control charts.

MAHENDRA SUBMERSIBLE PUMPS PVT  
LTD.

CONTROL CHART

MACHINE NAME & CODE: Cylindrical grinding machine, CG101

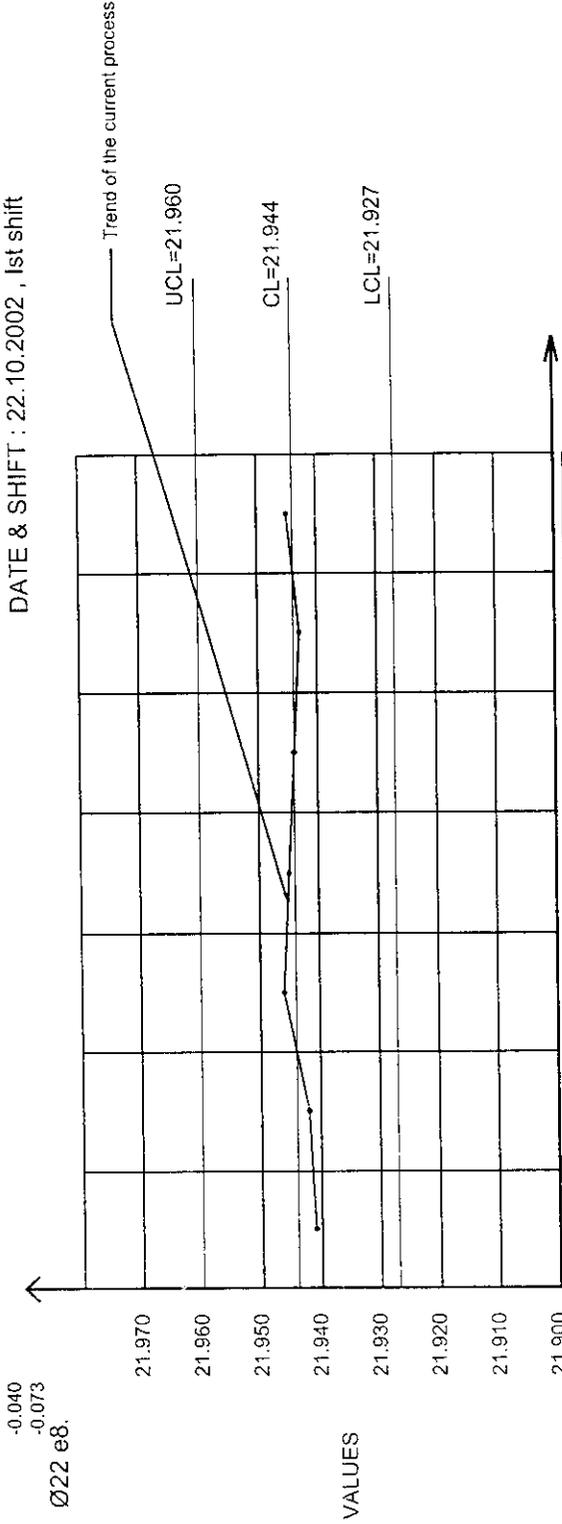
OPERATOR NAME : R.Vijayaragavan.

DATE & SHIFT : 22.10.2002 , 1st shift

COMPONENT NAME : Rotor assembly.

COMPONENT DRG.No : 60300010.

DIAMETER : Ø22 e8.



Samples	1	2	3	4	5	6	7
Average Values	21.941	21.942	21.946	21.945	21.944	21.943	21.945
Values in sample	21.942	21.941	21.946	21.945	21.945	21.944	21.944
	21.941	21.942	21.947	21.946	21.945	21.943	21.945
	21.941	21.942	21.946	21.945	21.943	21.943	21.945
	21.941	21.943	21.945	21.945	21.944	21.943	21.945
	21.941	21.942	21.946	21.945	21.943	21.943	21.945

CONCLUSION :

PRODUCTION INCHARGE :

TQM HEAD SIGN :

OPERATOR SIGN :

## **ANNEXURE - V, CALIBRATION SCHEDULE**

Even though, they are doing calibration in the instruments used in the machine shop areas, assembly areas testing areas etc., But they are not sending these instruments in time. To avoid this, In the TQM implementation programme, calibration schedule was introduced for sent the instrument in time. And also responsibilities for sent the instruments used in the each area of the company are allocated to the TQM members. The introduced calibration schedule in this programme is shown in the Table 15.

