APPLICATION OF SIX SIGMA METHODOLOGY FOR REDUCING REJECTION RATE OF ENGINE VALVE

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Abstract:

Quality is an approach to understand exactly what customers require and consistency deliver accurate solutions within budget on time and with the minimum lose to the company. In recent days quality is just regarding meeting the expectation of customer, no matter what the cost is. Therefore all the companies strive hard to increase the quality of the products and create customer delight. Various methodologies are available for quality improvement. These involves six sigma, lean management, lean six sigma, agile management, re-engineering, total quality management, just in time, kaizen, poka yoke, etc. All these methods tend to achieve a very similar goal. The DMAIC method is used in this project, where DMAIC stand for D-Define, M-Measure, A-Analysis, I-Improvement, C-Control.

The objective of the project is "Quality Improvement in Centre less Grinding Process Using DMAIC Approach". Centre less grinding of round metal rods was identified as the cell,

Creating maximum number of rejections. The problem was defined and analyzed using basic quality tool like Pareto diagram. Brainstorming session was done using cause and effect diagram. The improvements were analyzed and documented. The standard operating practices were created and operation trainings were imparted to the operators.

***Key words**:* Quality, DMAIC, Centre less grinding, Six Sigma,Design of experiments.

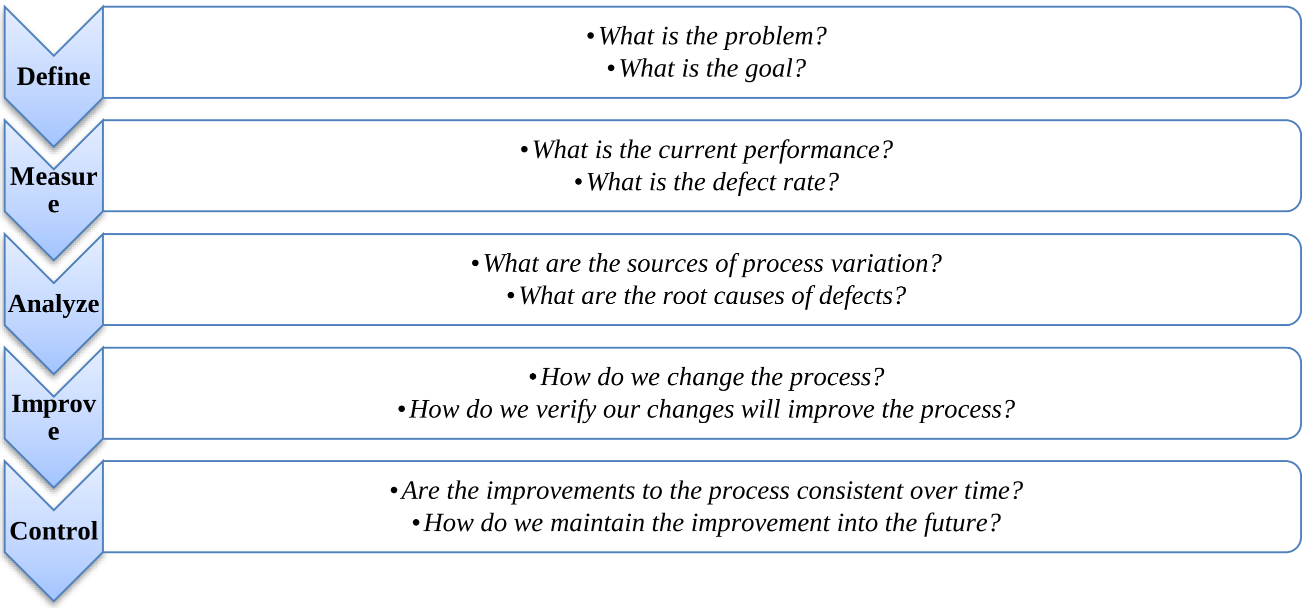
1. Introduction

The rapid growth of industrial competition throughout the world has bought about the needs to stay in focus on how best a company can be producing to the customer's requirement at a minimum cost. According to industrial point of view lean manufacturing is an integrated socio-technical system whose main objective is to eliminate waste by concurrently reducing supplier, customer, and internal variability. Small scale manufacturing organizations have been contributing significantly to the growth of the country. The entrepreneurs are using the bottom work force physically but not intellectually. There is a missing feeling of responsibility in small scale industries because there is no housekeeping, no management information, and no store management and there is no production planning and control system.

Motivation: In the current scenario markets require good quality products at low cost. Such products can be produced by using lean manufacturing approach. Small and medium enterprises (SMEs) have played a vital role in India's economic growth. With over 30 million units, SMEs accounted for 17 per cent of the country's GDP in 2011. SME units currently employ 60 million people. A survey suggests that Small scale industry's field agents have limited knowledge of lean manufacturing methods and tools, and that only about 10% of agents are having lean manufacturing assistance, but they have all the resources to implement lean methods. Literature survey reveals that there is a scope to study the application of Lean tools in small scale industries.

1.1 Six Sigma:

Six-Sigma is a set of techniques and tools for process improvement. It is a management philosophy focused on eliminating mistakes, waste and rework and it aims to reduce the number of mistakes/defects to as low as 3.4 occasions per million opportunities. It establishes a measurable status to achieve and embodies a strategic problem-solving method to increase customer Satisfaction and dramatically reduce cost and increase profits. Six-Sigma gives chastisement, building, and a groundwork for solid decision making based on simple statistics. The real power of Six Sigma is simple because it combines people power with process power. The Six Sigma is a financial improvement strategy for an organization and now a day it is being used in many industries. Basically it is a quality improving process of final product by reducing the defects; minimize the variation and improve capability in the manufacturing process. The objective of Six Sigma is to increase the profit margin, improve financial condition through minimizing the defects rate of product. It increases the customer satisfaction, retention and produces the best class product from the best process performance. DMAIC and DFSS methods are the two most common methodologies to implement Six Sigma. DMAIC is a problem-solving method which aims at process improvement (Pande et al., 2005); DFSS refers to the new product development. The DMAIC methodology uses a process-step structure. Steps generally are sequential; however, some activities from various steps may occur concurrently or may be iterative. Deliverables for a given step must be completed prior to formal gate review approval.



D DEFINE the problem and scope the work effort of the project team.

M MEASURE the current process or performance.

A ANALYZE the current performance to isolate the problem

I IMPROVE the problem by selecting a solution

C CONTROL the improved process or product performance to ensure the target(s) are met.

2. METHODOLOGY

2.1 Define phase

The purpose of this step is to clearly articulate the business problem, goal, potential resources, project scope, and high-level project timeline. This information is typically captured within project charter document. Write down what you currently know. Seek to clarify facts, set objectives, and form the project team.

Define the following:

a. A problem

b. The customer(s)

c. Voice of the customer (VOC) and Critical to Quality (CTQs) — what are the critical process outputs?

d. The target process subject to DMAIC and other related business processes

e. Project targets or goal

f. Project boundaries or scope

A project charter is often created and agreed upon during the Define step

. **CURRENT SIGMA LEVEL OF PROCESS.**

1. Number of units = 1000
2. Opportunities per unit =5
3. Number of defects = 137
4. Total number of opportunities = No. of units × Opportunities per unit = 1000*5=5000
5. Percentage defective = (137 / Total no. of opportunities) × 100 = (137/ 5000) × 100 =2.74
6. Percentage yield = 100 – Percentage defective = 100 – 2.74 = 97.26
7. DPMO (Defects per Million Opportunities) = (Number of defects / Total number of opportunities) × 10^6 = 27400
8. Sigma level =3.4 (from Table)

Rejection percentage

1. Average total production = 1000
2. Average total rejection = 137
3. Rejection percentage = (Average total rejection / Average total production) × 100

= (137 / 1000) × 100 = 13.7 %

The sigma level which is to be achieved at the end of the project is 3.7

A SIPOC diagram gives the fair idea of the total process.

Table -1: SIPOC diagram

Supplier	Input	Process	Output	Customer
Rane engine valves ltd.	Raw material	Cutting process	Shaft	Dimension checking
Dimension checking	Shaft	Checking dimension	Initial shaft	Friction welding
Friction welding	Initial shaft	welding	welded shaft	Upset Forging
Upset Forging	welded shaft	Upset Forging	Forged shaft	Turning
Turning	Forged shaft	Turning	Turned valve	Grinding
Grinding	Turned valve	Grinding	Grinded valve	Thread rolling
Thread rolling	Grinded valve	Thread rolling	Final part	Inspection
Inspection	Final valve	Inspection	Engine valve	Package and supply to customer

To study the manufacturing process of engine valve since there was a rejection during manufacturing due to some defects. For that we decided that we should start to observe 6 different processes from raw material cutting to the final dispatch of final part. The 6 different processes are cutting process, Checking dimension, Friction welding, Upset Forging, Turning, Grinding, Thread rolling A SIPOC diagram is a tool which gives a fair idea of the total process hence we used it to get the idea about process of manufacturing. A SIPOC diagram is as shown above.

2.2 Measure phase:

To brainstorm the entire process after visiting the shop floor to identify the problem in the process.

We visited the shop floor for observing how grinding process takes place, what are the different kinds of parts they manufactured, identified who are their customers and who are their material suppliers. Some of the customers are CARCLO Technical Plastics Pvt Ltd, Doddaballapur, Rane Engine Valve Ltd, Tumakuru, Titan Industries Limited, Hosur, Tafe, Doddaballapur, Indo US MIM Tech, Doddaballapur /Hoskote, Turbo India, Bangalore, Kashi Precision Components, Bangalore.

In Chinthala industry, spare parts were manufactured and supplied to various customers. We found that Shaft 'MK0035' had consistent rejection in long period of time, so we had taken Shaft 'MK0035' for our project to study and try to decrease its rejection percentage.

The 5 different types of defects which are causing high rejection of the shafts are:

- **Poor Surface finish:** There are many factors that can affect the surface finish generated in a grinding operation. Because of the difference in wear mechanisms, their factors can be different or have a significantly greater impact. Some of the factors include grinding wheel speed, grit size, depth of cut, machine conditions and grinding parameters.
- **Improper dimension:** If the dimension of the work piece is not proper then there will be difficulty in controlling the dimensional accuracy. Due this there will be more rejections at the end of the process.
- **Defective raw material:** Sometimes the raw materials can be defective if they are contaminated or have the wrong formulation. They must meet regulatory requirements (safe and legal for the intended use) and specifications (contribute to the functionality and quality of the process and product).
- **Overcut:** It refers to excessive cutting of the metal piece which leads maximum rejections.
- **Corrosion:** It is a natural process which converts refined metal to a more chemically stable form, such as its oxide. It is mainly caused due the quantity, direction and speed of the coolant.

Detailed process map: A detailed process map helps us to identify the steps in the process which are creating defects.

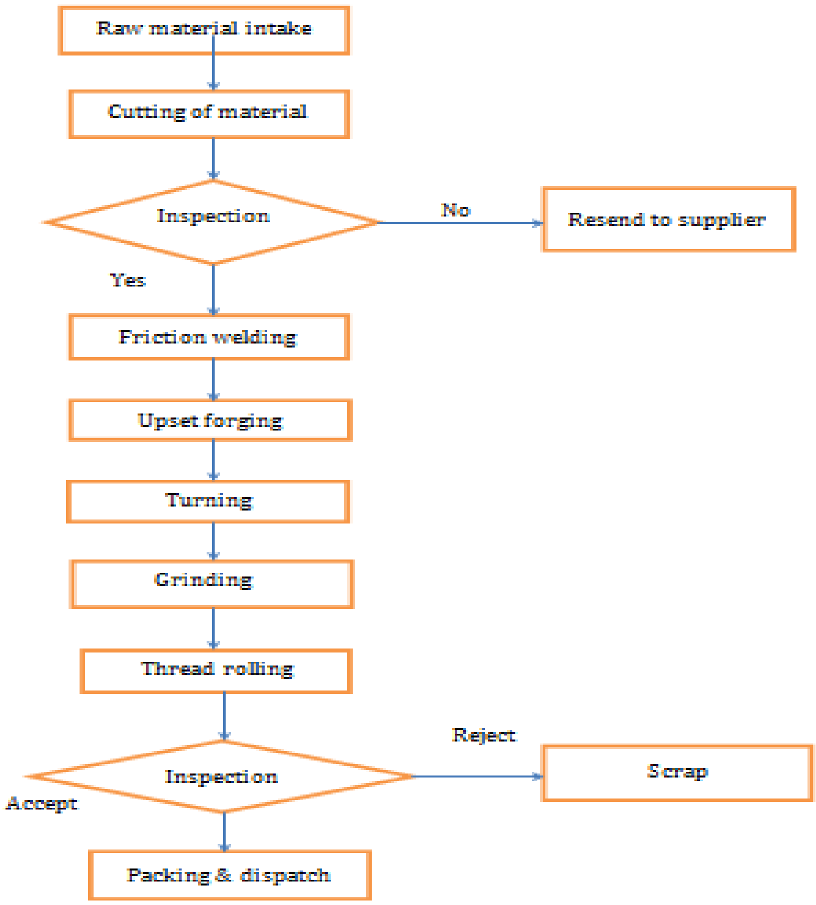


Fig -1: detailed process map

❖ **Data collection:**

For conducting the study, we decided to collect information on rejection percentage of shaft for 3 weeks by visual inspection to identify defects in each and every part.

There were no practices of data collection for rejection of parts. No records were maintained. Firstly a format to read out the rejection data was created.Now the rejection data was collected for each operation in the process of manufacturing. In the lot size of 1000 pieces at start 863 pieces were accepted.

We collected the data for 9 lots manufactured during the month of January (2017) which was based on daily check sheet which includes quantity output of number of rejection in different operations as shown in the table 6.3.

In first week, the lot size was 1000, rejection quantity was 137. Out of 137 defects, poor surface finish defects was 51, Improper dimension was 38, Defective raw material was 20, Overcut was 10, inspection was 9, corrosion was 7 and other defects was 2.

In second week, the lot size was 850, rejection quantity was 136. Out of 136 defects, poor surface finish defects was 52, Improper dimension was 36, Defective raw material was 19, Overcut was 9, inspection was 11, corrosion was 6 and other defects was 3.

In third week, the lot size was 900, rejection quantity was 136. Out of 136 defects, poor surface finish defects was 50, Improper dimension was 35, Defective raw material was 20, Overcut was 11, inspection was 9, corrosion was 8 and other defects was 3.

Table -2: data of rejected engine valve

Week	Lot size	Poor Surface finish	Improper dimension	Defective raw material	Overcut	Inspection	corrosion	others	Percentage
1	1000	51	38	20	10	9	7	2	13.7
2	850	52	36	19	9	11	6	3	13.6
3	900	50	35	20	11	9	8	3	13.6

2.3 Data Analyze phase:

- **Pareto analysis:**

Table -3: 1table of different types of defects

Reasons for rejection	**Counts**	**Percentage rejection**	**cum.Percentage rejection**
Poor Surface finish	51	37.226277	37.226277
Improper dimension	38	27.737226	64.963504
Defective raw material	20	14.59854	79.562044
Overcut	10	7.2992701	86.861314
Inspection	9	6.5693431	93.430657
Corrosion	7	5.1094891	98.540146
others	2	1.459854	100

The above table shows the data of defects that are caused in the grinding operation, for the above observed dat we need to plot the pareto chart to analysis the major cause for the bad surface finish. And further we should do brainstorming session to find the rout causes for the rejection and poor surface finish of the engine valve.

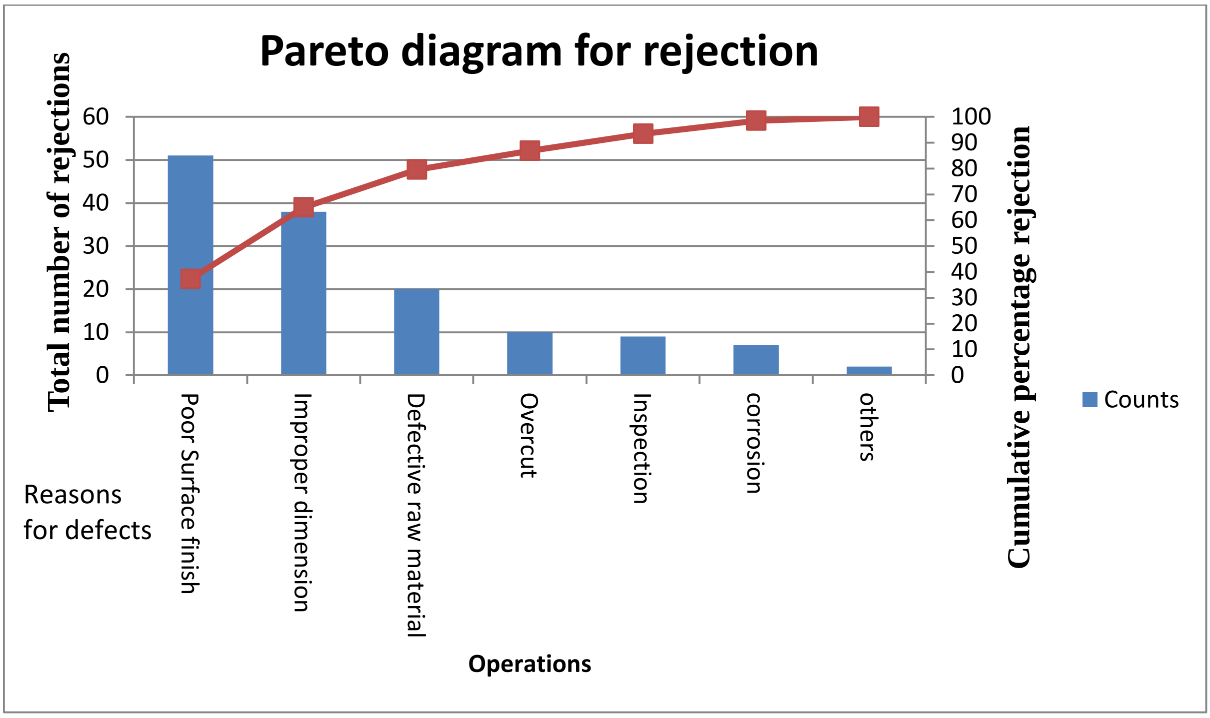


Chart -1: pareto chart

Pareto principle states that 20% of defects causes 80% of rejections hence we used Pareto analysis to prioritize the defects. To arrive at 20% of defects we calculated the percentage rejection of each defect and cumulative percentage. Then we plotted Pareto chart by taking types of defects along x-axis and total rejections along y-axis. Draw bar chart and cumulative line. Draw the line parallel to x-axis at 80% of cumulative axis and again draw the line perpendicular to x-axis from the point of intersection of cumulative line and line drawn parallel to x-axis which will give us 20% of the causes. From the chart we can say that 1st significant is surface finish and 2nd significant reason for defect is improper dimension. From this plot we came to know that surface finish and improper dimension are identified as 20% reasons of defects causing 80% of rejections.

❖ Cause and effect diagram:

Table -4: list of causes for the rejection of engine valves through brainstorming

Categories	Causes
Man	Lack of experience, Improper training, Operator skill
Material	Inherent property of material, Impurities, Storage conditions
Machine	Coolant, Improper tools used, Machine conditions

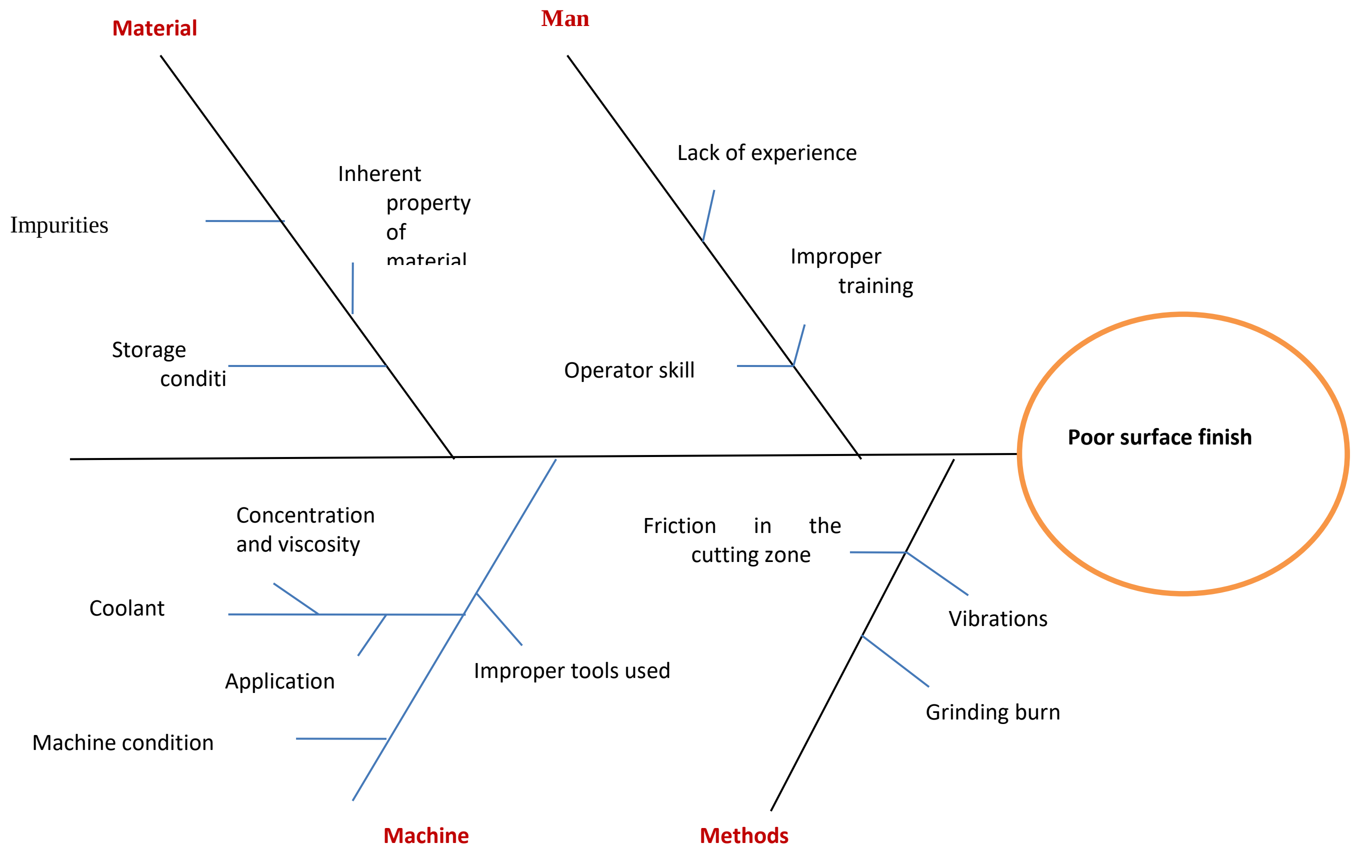


Chart -2: cause and effect diagram

In rejection of engine valveswith respect to man we had identified the causes such as Operator skill, improper training and Lack of experience. With respect to material some of the causes identified are Inherent property of material, Impurities and Storage condition. With respect to method some of the causes identified are Friction in the cutting zone, vibrations, grinding burn. With respect to machine we had identified the causes such as Coolant, Machine condition, improper tools used.

2.4 Improve phase:

The purpose of this step is to identify, test, and implement a solution to the problem; in part or in whole. Identify creative solutions to eliminate the key root causes in order to fix and prevent process problems. Use brainstorming or techniques like Six Thinking Hats and Random Word. Some projects can utilize complex analysis tools like DOE but try to focus on obvious solutions if these are apparent.

- Create innovative solutions
- Focus on the simplest and easiest solutions
- Test solutions using PDCA cycle
- Based on PDCA results, attempt to anticipate any avoidable risks associated with the "improvement" using FMEA
- Create a detailed implementation plan
- Deploy improvements

Tools to be used are

- Brainstorming
- Mistake Proofing
- Design of Experiments
- Pugh Matrix
- QFD/House of Quality
- Failure Modes and Effects Analysis (FMEA)
- Simulation Software

Improve phase:

- We decided to carry out design of experiment to find out solution to the identified causes for one of the major defect among two major defects from the multi-voting.
- We took 3 levels i.e. high, medium and low for the two process variables to find out solution for one of the major defect among two major defects.
- We analyzed the result of the DOE and found the solution to suggest improvements for reducing rejection percentage of rocker arm.
- We concentrated on reducing one of the major defects among two major defects and for another defect we gave the suggestions.
- We calculated the amount of cost will be saved after the improvements applied.
- We calculated the sigma level which will be achieved after improvements applied.

Tools used:

- **Design of experiments:**

DOE is a statistical technique used in quality control for planning, controlling, analyzing and interpreting sets of experiments aimed at making sound decision without incurring a too high cost or taking too much time.

DOE involves around the understanding of the effects of different variables on other variables. The objective is to establish a cause and effect relationship between a number of independent variables and dependent variables of interest. The dependent variable, in the contest of DOE, is called the response and the independent variables are called factors. Experiments are run at different factor values, called levels. Each run of an experiment involves a combination of the level of the investigated factors. Each of the combinations in a single factor is referred to treatment.

In many factors, each combination of the level of the factor is referred to as a treatment. When the same number of response observations is taken for each of the treatment of an experiment, the DOE is said to be balanced. Repeated observations at a given treatment are called replicates. The number of treatments of an experiment is determined on the basis of the number of factor levels being investigated in the experiment.

Table -5: measurements of surface finish under three levels

Speed (rpm)	**Depth of cut (mm)**	**Grit (microns)**	**Surface finish(Ra)**
800	0.1	120	1.4
800	0.1	240	1.9
800	0.05	60	0.82
800	0.05	120	1.5
800	0.05	240	1.8
800	0.01	60	0.6
800	0.01	120	1
800	0.01	240	1.5
1200	0.1	60	0.5
1200	0.1	120	0.7
1200	0.1	240	1
1200	0.05	60	0.52
1200	0.05	120	0.75
1200	0.05	240	1.1
1200	0.01	60	0.9
1200	0.01	120	1.6
1200	0.01	240	1.8
1500	0.1	60	0.45
1500	0.1	120	0.6
1500	0.1	240	1.1
1500	0.05	60	0.62
1500	0.05	120	0.85
1500	0.05	240	1.2
1500	0.01	60	0.91
1500	0.01	120	1.65
1500	0.01	240	1.85

The above table shows the variations in the dimensions and surface finish with respect to the variation the the RPM, depth of cut and grit size. We varied three trials for each with three leves of variation in the attributes. each trial gave us different surface finish and dimensions, all the obtained data are to be evaluated by plotting the data in the pareto chat so that we can conclude the which among the variation is suitable to control the surface finish and we can obtain good dimension stability in the future work also.

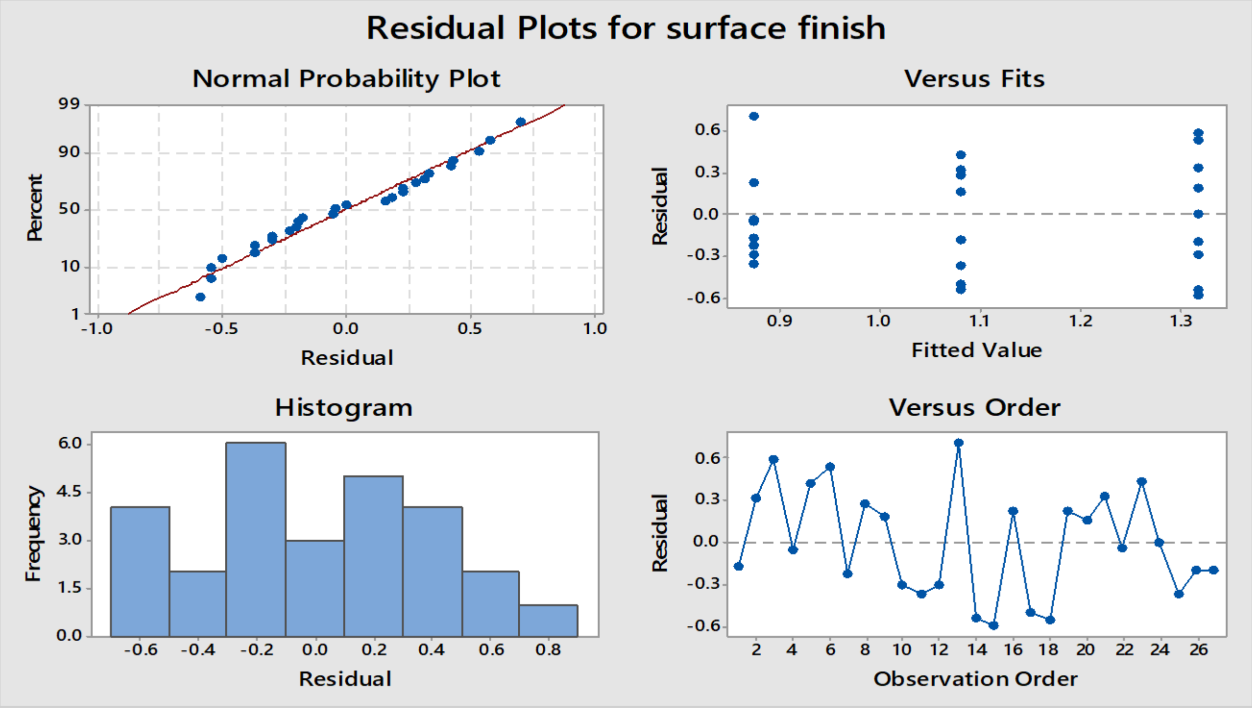


Chart -3: graphical view of surface finish data

2.5 Control phase:

In this phase the improvements that are suggested to be followed and maintained are included, improvement suggested for reducing rejection by poor surface finish are as follows From the design of experiment we found that fine surface finish can be obtained by applying grit size of 120 microns or 60 microns and depth of cut of 0.05mm, hence we suggested the company to follow the above combination of grit size and depth of cut Provide classroom training with help of ppt and case studies, focus more on job training for employees so that they can understand the changes well Train the maintenance operator to do preventive maintenance as per the planned schedule to keep machine in good condition Automate the setting process

3.0 Conclusion:

The main objective of this project is to improve the surface finish of the engine valve and also to improve the dimension stability. After collecting the data and plotted in the pareto chart, we can conclude the to get good surface finish the operator should use the grinding wheel with grit size of 60 or 120 and also he should give a minimum depth of cut of 0.05mm, increase in the speed of the rotating wheel will also improve the quality of surface finish.

4.0 Scope for future work:

Focus on other major causes for rejection:

Improper dimension was found be the second major cause for rejection of shaft. So we try to concentrate on dimensional accuracy for our further study in order to reduce the rejection percentage of engine valve. Improper dimensions are due to improper tool setting. That is dimensions mainly depend on operator skill. We have to concentrate more on training the machine operator in order to reduce the rejection percentage.

JIT implementation:

The implementation of JIT reduces scrap rework, setup time and total inventory. There was also a positive correlation between setup time, total inventory, scrap and rework when companies converted to JIT. It reduces WIP accumulation. JIT emphasizes the preventative measures. Firms often discover that when they invest in preventative measures, it reduce4s the other quality costs by more than the increase in the preventative costs

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