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Quality and productivity improvement in gear manufacturing process by using quality control chart and capability analysis including sampling

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ABSTRACT

Increasing productivity and profitability are main objectives of any organization. Many tools and techniques are used to reduce rejections and defects of product. Most of the rejections and defects are occurred due to improper control of quality of product. So use of 7 Quality control tools is best way to reduce rejections and defects of product after analysing of manufacturing process. Another advantage is increasing customer satisfaction by use of 7 Quality control tools in today competitive market. Based on application of these tools will increase the level of standard products which they require as vision of an organization. The purpose of this work is to discuss the effect of implementation of Total Quality Management (TQM) in manufacturing industry (Press Com Industries Pvt Ltd.). Very few service companies have been able to reap full benefits of TQM. One major reason for its inadequate success is that of trying to implement in service companies techniques that have been successful in manufacturing. In manufacturing, emphasis of TQM is on "zero defects". Control charts and sampling are the major tools of quality control. However, in services, emphasis is on "zero defections". Focus is on customer satisfaction and team approach. TQM can boost profits and improve customer satisfaction by reducing defects.

Keywords: *Defect reduction, Pareto chart, Quality tools, TQM, gear Manufacturing, Sampling, Control chart*

1. INTRODUCTION

The art of meeting customer specifications, which today is termed as "quality". Quality is the symbol of human civilization, and with the progress of human civilization, quality control will play an incomparable role in the business. It can be said that if there is no quality control, there is no economic benefit. In the current world of continually increasing global competition it is imperative for all manufacturing and service organizations to improve the quality of their products.

Construction projects are an extremely complex process, involving a wide range. There are plenty of factors affecting the quality of construction, such as design, materials, machinery, construction technology, methods of operation, technical measures, management systems, and so on. Because of the fixed project location, large volume and different location of different projects, the poor control of these factors may produce quality problems. During controlling the whole process of construction, only accord with the required quality standards and user promising requirements, fulfilling quality, time, cost, etc., construction companies could get the best economic effects. Construction companies must adhere to the principle of quality first, and insist on quality standards, with the core of artificial control and prevention, to provide more high quality, safe, suitable, and economic composite products.

2. PROBLEM STATEMENT

Present study was done at Press Com Industries Pvt Ltd, Govindpura, Bhopal on application of 7 quality tools and Selection of tools and techniques for problem solving, because of its high rejection rate.

The present company is facing a rejection due to some defect, after observing data of the company most frequently rejected part identified is undersized hole. Undersized hole is identified as most severely affected quality, hence it was considered for detailed investigation.

Fig. 1: Spur gear with under sized hole

3. PROBLEM DEFINITION

The present case study deals with reduction of rejection rate of spur gear defects at Press Com Industries Pvt Ltd, Govindpura, Bhopal. The company faces rejection of 15.50 % which resulted into reduced quality and productivity.

4. DATA COLLECTION

In this phase we collect the data. Therefore it becomes very important to secure a correct measuring system before the project. So a list of problems better to say opportunities for improvements were identified, following problems were listed down in their operations.

Table 4.1: Name of defects

S.No	Type of defect
1	Undersized hole
2	Nicks
3	Teeth alignment
4	Oversized hole
5	Porosity

The check sheet is a simple document that is used for collecting data in real-time and at the location where the data is generated. Rejection check sheets are generally large data sheets showing the total information about rejected items. The defects such as undersized hole, nicks, teeth alignment, oversized hole and porosity have been identified (Table 1) and data of each part was collected (for a specified time span) from the company which shows the production and rejection status of individual part.

Table 4.2: Data for Pareto analysis

S. No	Type of defect	Quantity
1	Undersized hole	186
2	Nicks	124
3	Teeth alignment	46
4	Oversized hole	8
5	Porosity	38

It is apparent that from this short list that under sized a holes are the main problem. However, real applications typically have many defects categories and many parts, all of which monitored over time.

5. CAUSE AND EFFECT DIAGRAM

Once a defect, error, or problem has been identified and isolated for further study, we must begin to analyze potential causes of this undesirable effect. In situation where causes are not obvious, the cause and effect diagram is a formal tool frequently useful in unlayering potential causes. The cause and effect diagram constructed to identify potential problem areas in the spur gear manufacturing process mentioned in the following figure:

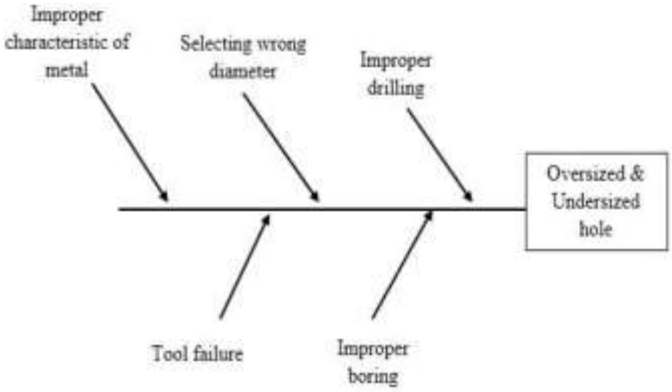


Fig. 2: Cause and effect diagram of spur gear defect problem for oversized and undersized hole

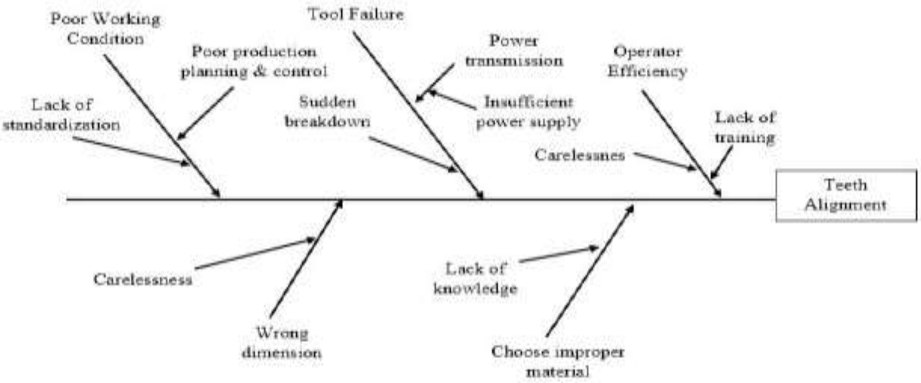


Fig. 3: Cause and effect diagram of spur gear defect problem for teeth alignment

In analysing the spur gear defect problem, we elected to lay out the major categories of spur gear defects as man, machine, material, methods, measurement and environment. We got some effect such as teeth alignment, nicks and porosity, undersized and oversized hole and their causes. A brainstorming session ensured to identify the various sub-causes in each of these major categories and to prepare the diagram in Figure 3.

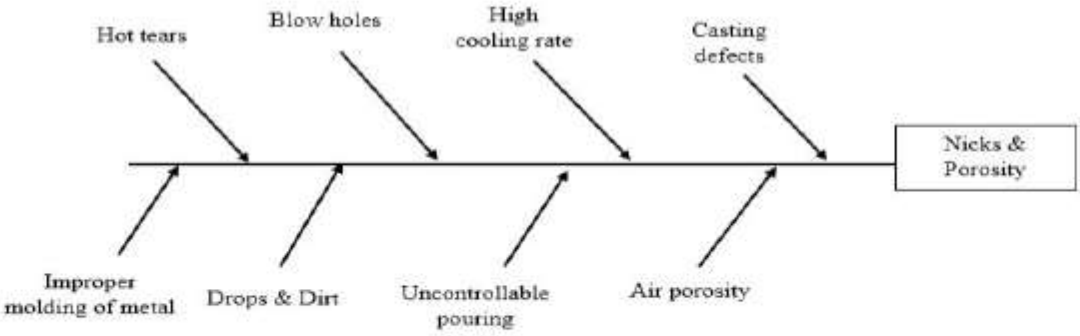


Fig. 4: Cause and effect diagram of spur gear defect problem for nicks & porosity

5.1 Pareto chart

The Pareto principle states that it is possible for much performance measure, such as scarp, machine failure, vendor's problems, and inventory cost and product development time, to separate the vital few causes resulting in unacceptable performance from the trivial many causes. Historically, this concept has also known as the 80/20 rule, which states that the performance measure can be improved 80% by eliminating only 20% of the causes of unacceptable performance.

Table 4.3 Pareto analysis worksheet

S. No	Type of defect	Quantity	Percentage	Cumulative %
1	Undersized hole	186	186/402 = 46	46
2	Nicks	124	30	76
3	Teeth alignment	46	11	87
4	Oversized hole	8	2	89
	Total	364		

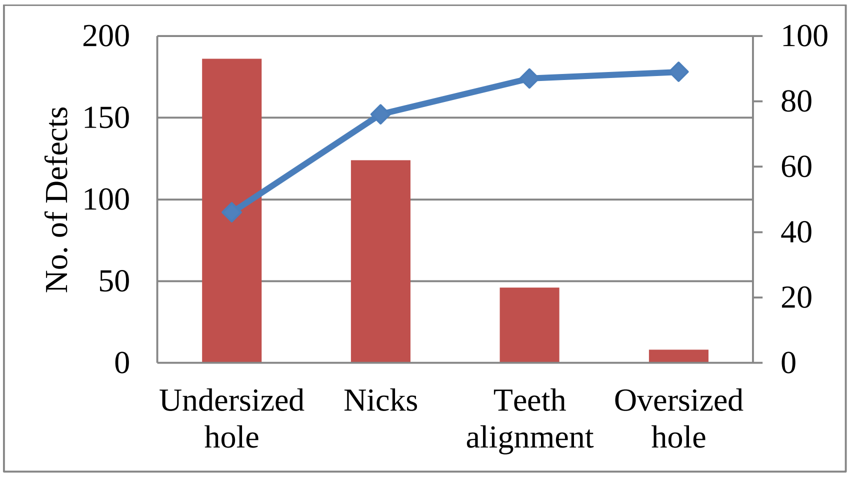


Fig. 5: Pareto chart of bearing hub for last four months

It is apparent that from this short list that under sized a holes are the main problem. However, real applications typically have many defects categories and many parts, all of which monitored over time. It is convenient to represent these data graphically as in (Figure 5). This graph has been prepared using the work sheet in (Table 2). The defects are arranged in rank order in column-1. The number of defects appears in column-2. The percentages that each defects represents of the total number of defects appears in column-3. The cumulative percentage of column-3 appears in column-4. One difficulty in collecting data by such categories as under size, nicks and oversize is that a particular part or item being evaluated may fit into several categories. In this case the preferred approach is to mark each defects. In (Figure 6) all defects are shown graphically to find out a most effective defect over these defects.

6. HISTOGRAM

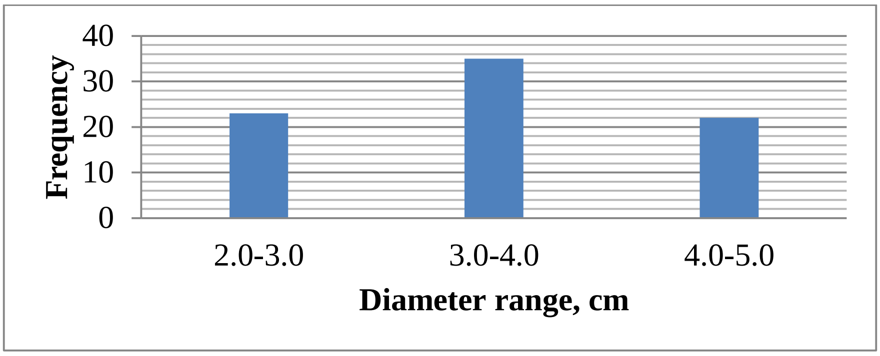


Fig. 6: Histogram for spur gear diameter data

A graph of the observed frequencies versus the spur gear diameter is shown in Figure 6. This display is called histogram. The height of each bar in figure 6 is equal to the frequency of occurrence of spur gear diameter.

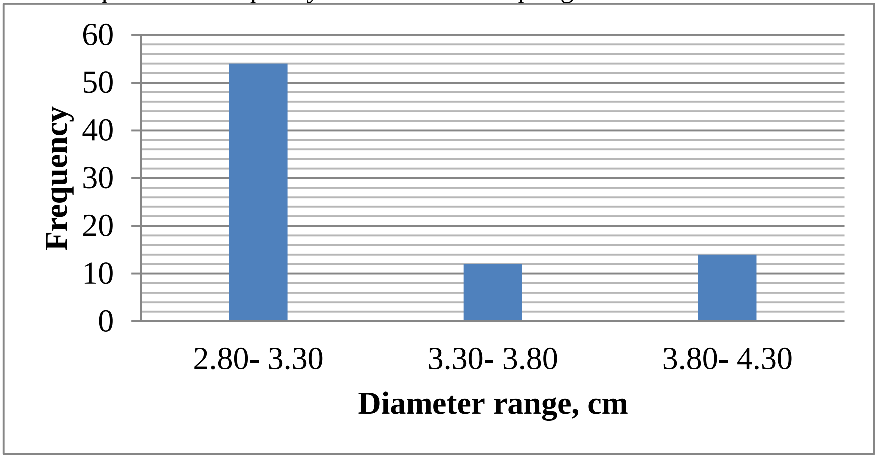


Fig. 7: Histogram for spur gear diameter data for oversized hole

A graph of the observed frequencies versus the spur gear diameter is shown in Figure 7. This display is called histogram. The height of each bar in figure 7 is equal to the frequency of occurrence of spur gear diameter.

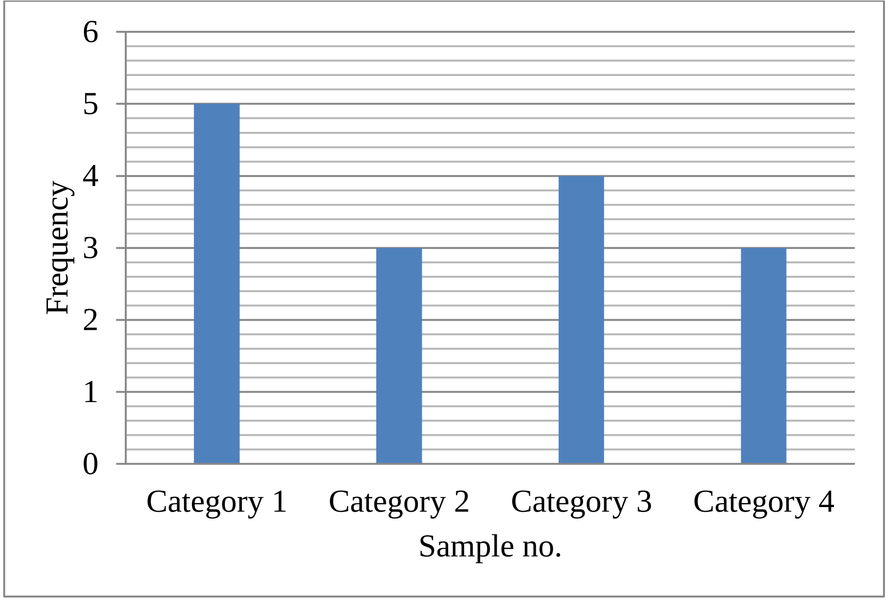


Fig. 8: Histogram for spur gear data for nicks

A graph of the observed frequencies versus the sample number is shown in Figure 8. This display is called histogram. The height of each bar in figure 8 is equal to the frequency of occurrence of nicks in spur gear.

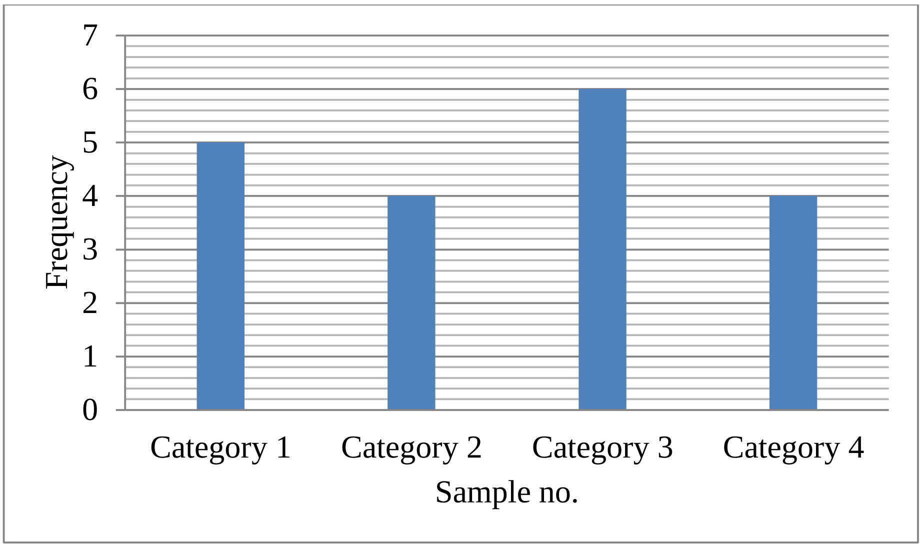


Fig. 9: Histogram for spur gear data for misalignment

A graph of the observed frequencies versus the sample number is shown in Figure 9. This display is called histogram. The height of each bar in figure 9 is equal to the frequency of occurrence of nicks in spur gear.

7. CONTROL CHART

7.1 Variable chart

Variable data are measured on a continuous scale in variable chart. For example: time, weight, distance or temperature can be measured in fraction or decimals. The possibility of measuring to greater precision defines variable data.

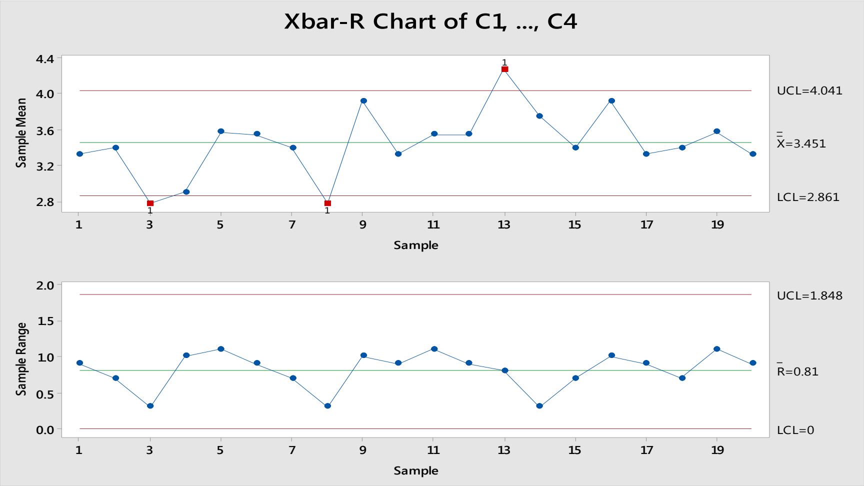


Fig. 10: Control chart for spur gear diameter

7.2 Attribute chart

This type of control chart is applicable equally to manufacturing and service organizations. In a manufacturing organization, manufacturing time and quality may be accepted as good or bad. Attributed data are counted and cannot have fractions or decimals. Attributed data arise when to determine only the presence or absence of something, success or failure, accept or reject, correct or not correct.

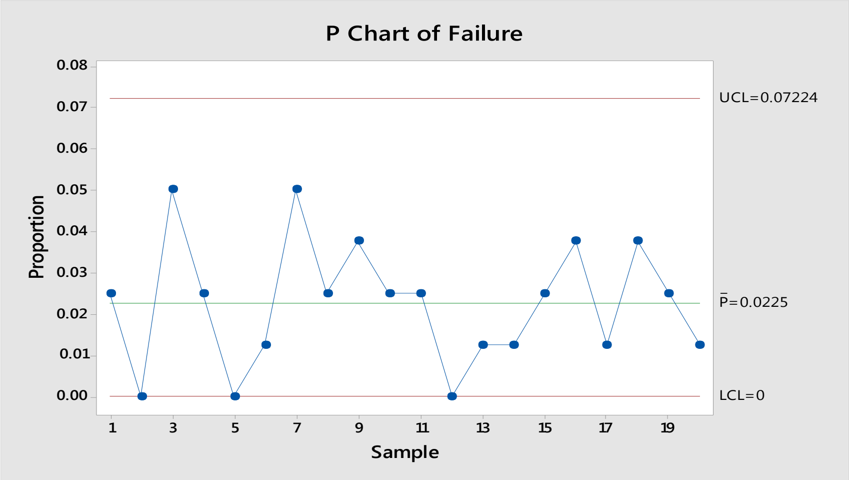


Fig. 11: Control chart (p-type) for the data set for undersized hole

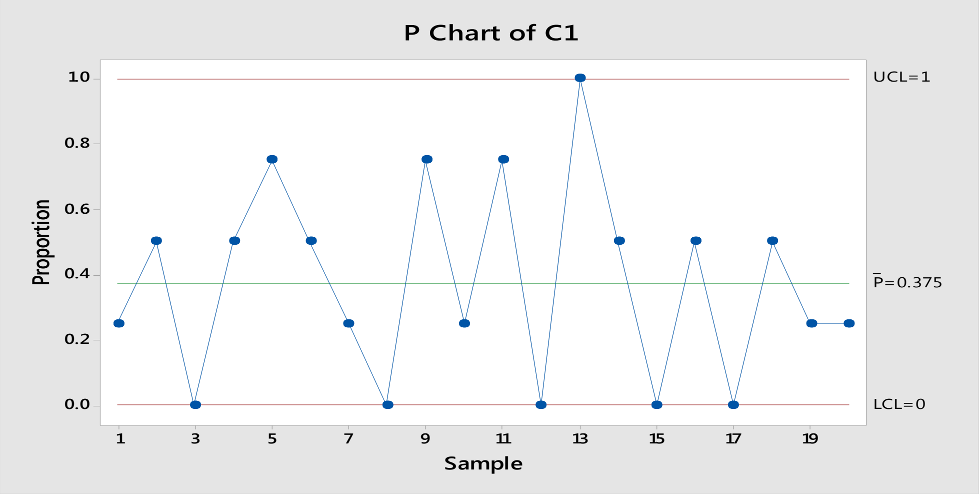


Fig. 12: Control chart (p-type) for the data set for oversized hole

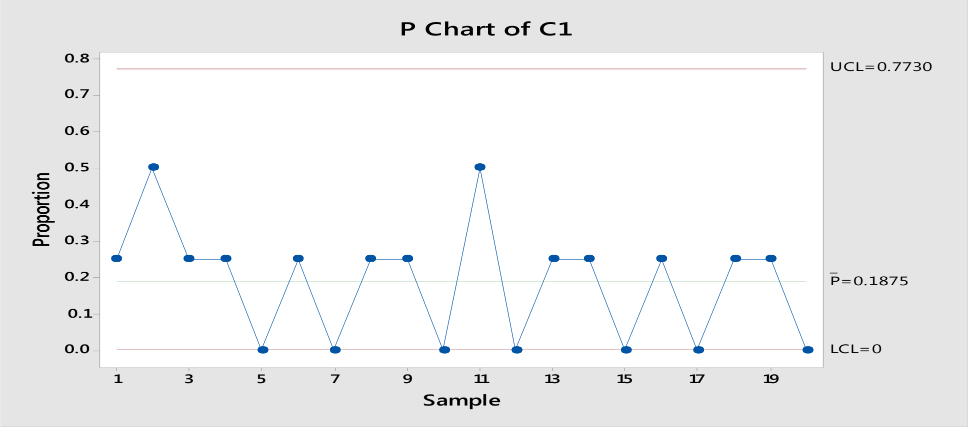


Fig. 13: Control chart (p-type) for the data set for nicks

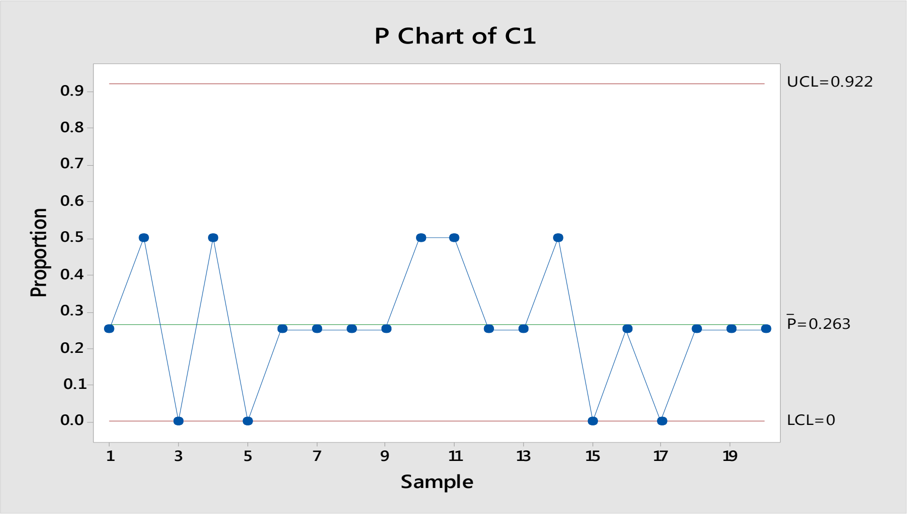


Fig. 14: Control chart (p-type) for the data set for misalignment

8. PROCESS CAPABILITY ANALYSIS

8.1 Data collection for process capability analysis

A manufacturing company wants to monitor the diameter of the spur gear. During the base period 20 samples are observed the sample size is 4. If USL = 3.25 cm and LSL= 2.98 cm and the measurements of individual diameter are as follows:

From Table

Range value, R = 0.745

Now $\sigma = R/d_2 = 0.745/\ 2.059 = 0.3618$

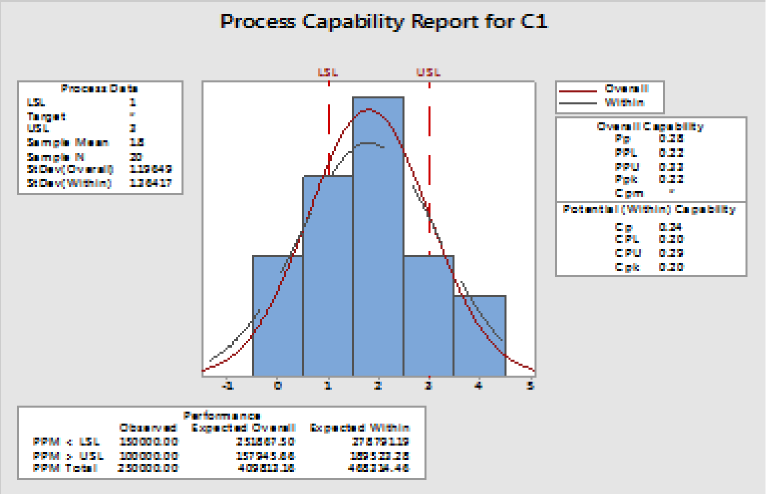
$m = (USL + LSL)/2 = (3.25 + 2.98)\ /2 = 3.115$

$K = 2(m\text{-}X)/\ USL - LSL = 2(3.454\text{-}\ 3.115)/0.27 = 0.251$

$Cp = USL - LSL/\ 6\ \sigma = 0.27/\ 6 \text{ x } 0.3618 = 0.124$

$C_{PK} = Cp\ (1\text{-}K) = 0.124\ (1\text{-}\ 0.251) = 0.94$

Since the process is within the specification limit and $C_P > 1$, hence the process is capable. And C_P may not be equal to zero and C_{PK} is always less than or equal to C_P.



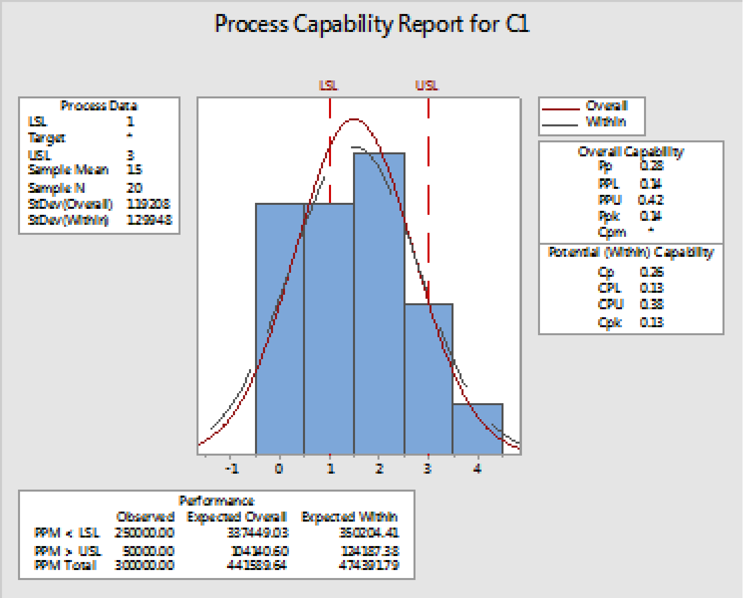
Process Data	
LSL	1
Target	*
USL	3
Sample Mean	18
Sample N	20
StDev(Overall)	119649
StDev(Within)	136417

Overall Capability	
Pp	0.28
PPL	0.22
PPU	0.33
Ppk	0.22
Cpm	*

Potential (Within) Capability	
Cp	0.24
CPL	0.20
CPU	0.29
Cpk	0.20

Performance	Observed	Expected Overall	Expected Within
PPM < LSL	150000.00	251867.50	27879119
PPM > USL	100000.00	157945.66	189523.28
PPM Total	250000.00	409813.16	468314.46

Fig. 15: Process capability report for undersized hole



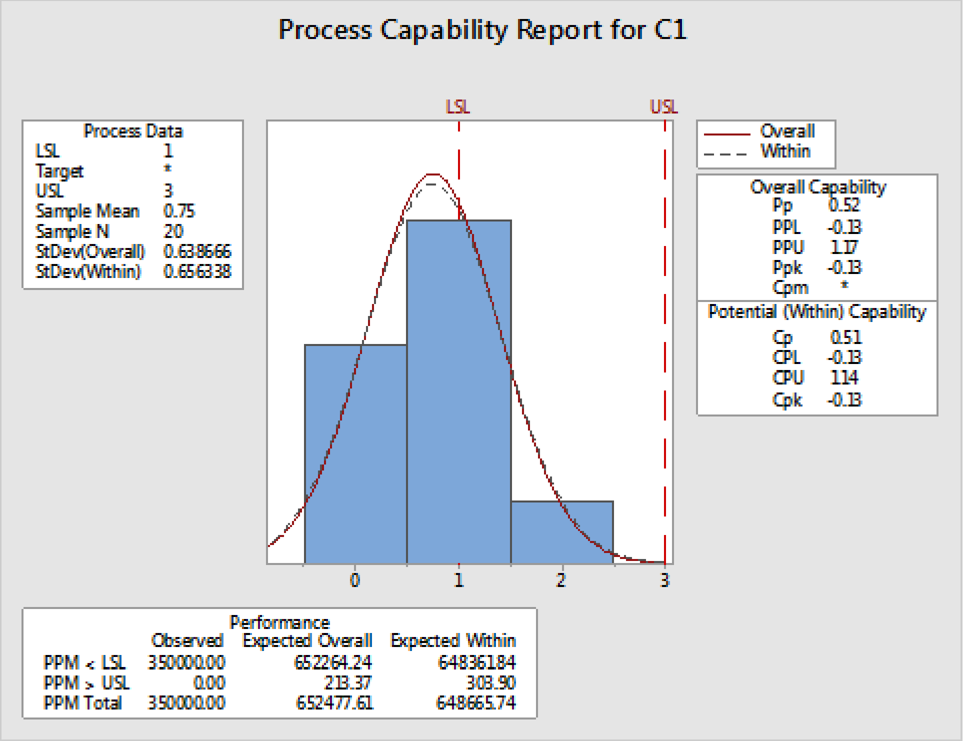
Process Data	
LSL	1
Target	*
USL	3
Sample Mean	15
Sample N	20
StDev(Overall)	119208
StDev(Within)	129948

Overall Capability	
Pp	0.28
PPL	0.14
PPU	0.42
Ppk	0.14
Cpm	*

Potential (Within) Capability	
Cp	0.26
CPL	0.13
CPU	0.38
Cpk	0.13

Performance	Observed	Expected Overall	Expected Within
PPM < LSL	250000.00	337449.03	350204.41
PPM > USL	50000.00	104140.60	124187.38
PPM Total	300000.00	441589.64	47439179

Fig. 16: Process capability report for oversized hole



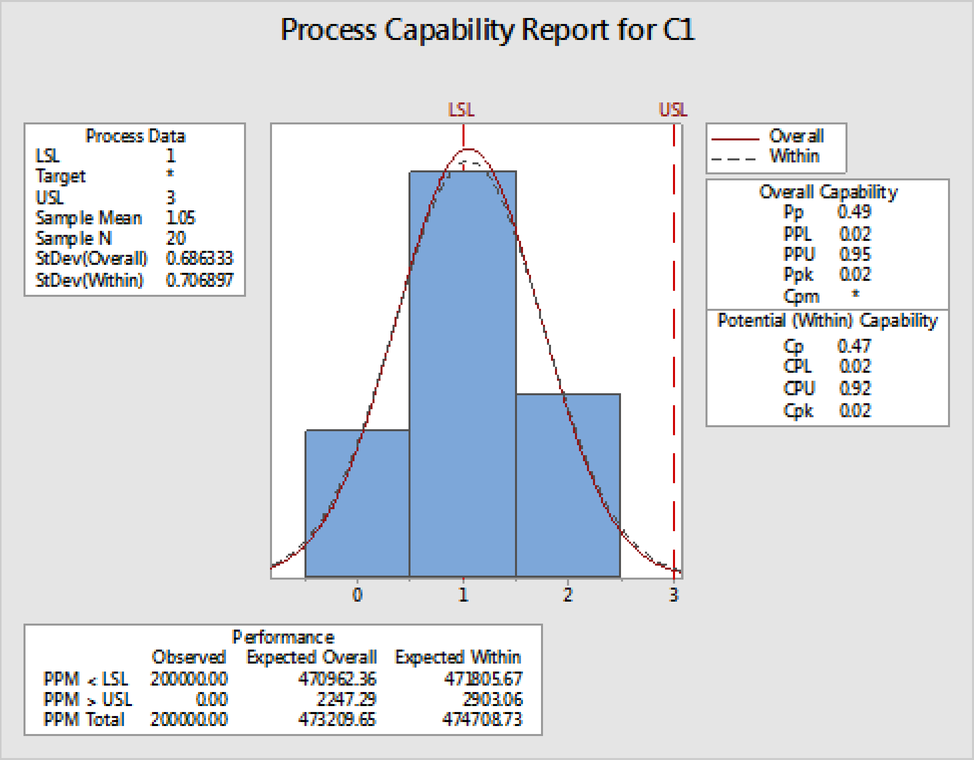
Process Data	
LSL	1
Target	*
USL	3
Sample Mean	0.75
Sample N	20
StDev(Overall)	0.638666
StDev(Within)	0.656338

Overall Capability	
Pp	0.52
PPL	-0.13
PPU	1.17
Ppk	-0.13
Cpm	*

Potential (Within) Capability	
Cp	0.51
CPL	-0.13
CPU	1.14
Cpk	-0.13

Performance	Observed	Expected Overall	Expected Within
PPM < LSL	350000.00	652264.24	64836184
PPM > USL	0.00	213.37	303.90
PPM Total	350000.00	652477.61	648665.74

Fig. 17: Process capability report for nicks



Process Data	
LSL	1
Target	*
USL	3
Sample Mean	1.05
Sample N	20
StDev(Overall)	0.686333
StDev(Within)	0.706897

Overall Capability	
Pp	0.49
PPL	0.02
PPU	0.95
Ppk	0.02
Cpm	*

Potential (Within) Capability	
Cp	0.47
CPL	0.02
CPU	0.92
Cpk	0.02

Performance

	Observed	Expected Overall	Expected Within
PPM < LSL	200000.00	470962.36	471805.67
PPM > USL	0.00	2247.29	2903.06
PPM Total	200000.00	473209.65	474708.73

Fig. 18: Process capability report for misalignment

9. ACCEPTANCE SAMPLING

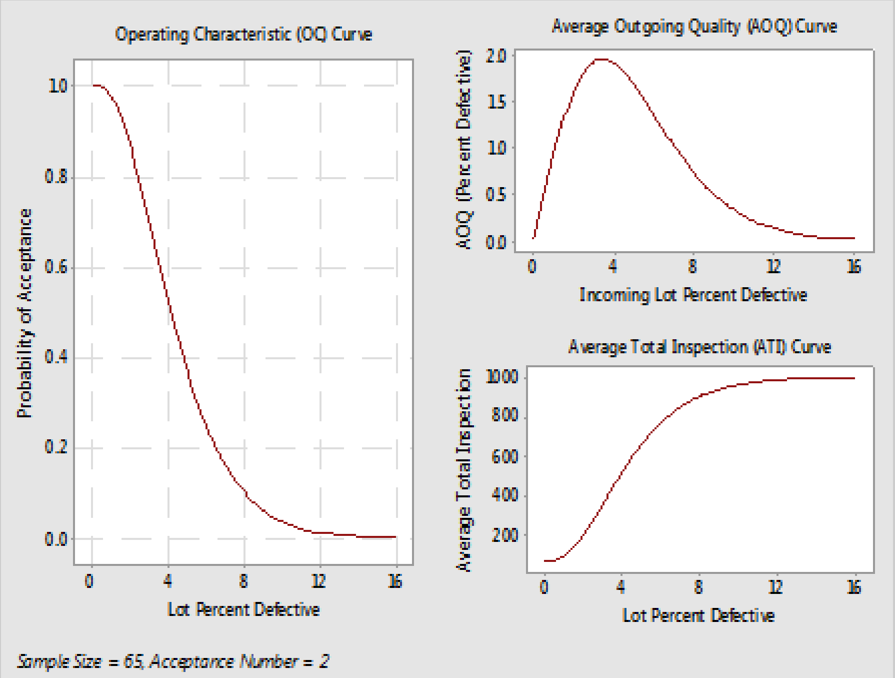
9.1 Data collection for acceptance sampling

A batch of 1000 products is manufactured by a spur gear manufacturing company. An agreement between the producer and the customer specified by the following:

Batch size, N = 1000 where sample size, n = 40. Acceptance number, c = 2 (from Nomo-graph).

9.1.1 Generated plan for undersized hole

For each lot of 1,000 gears, you need to randomly select and inspect 65. If you find more than 2 defectives among these 65 gears, you should reject the entire lot. If you find 2 or fewer defective items, accept the entire lot.



Sample Size = 65, Acceptance Number = 2

Fig. 19: Acceptance sampling plan for undersized hole

Above fig. shows the probability of accepting lots at various incoming quality levels. In this case, the probability of acceptance at the AQL (1%) is 0.972, and the probability of rejecting is 0.028. When the sampling plan was set up, company and supplier agreed that lots of 1% defective would be accepted approximately 95% of the time to protect the producer.

Sample Size	65
Acceptance Number	2

Accept lot if defective items in 65 sampled ≤ 2; Otherwise reject.

Percent Defective	Probability Accepting	Probability Rejecting	AOQ	ATI
1	0.972	0.028	0.909	90.8
8	0.099	0.901	0.741	907.3

Average Outgoing Quality Limit(s) (AOQL)

AOQL	At Percent Defective
1.968	3.450

9.1.2 Generated plan for overersized hole

For each lot of 1,000 gears, you need to randomly select and inspect 65. If you find more than 2 defectives among these 65 gears, you should reject the entire lot. If you find 2 or fewer defective items, accept the entire lot.

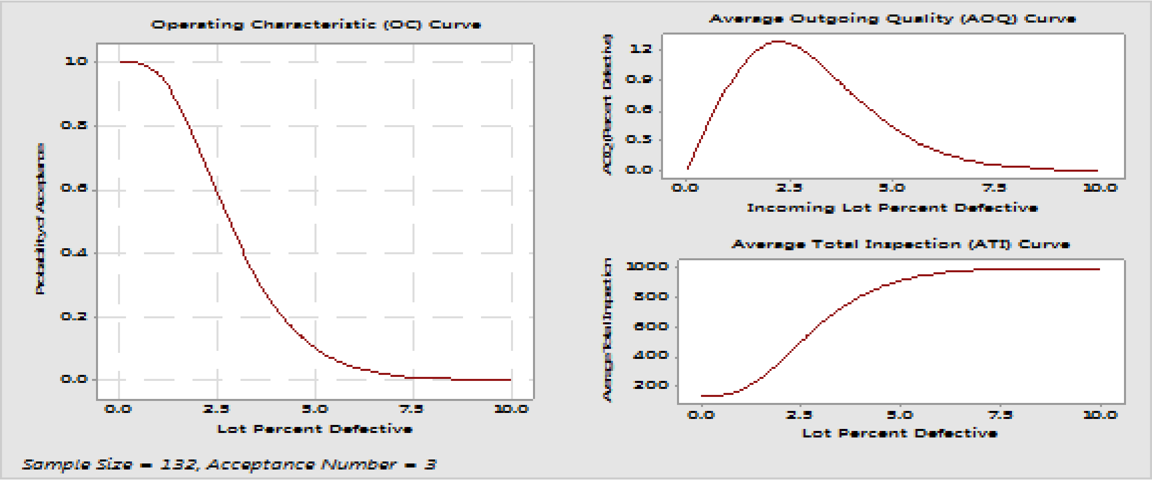


Fig. 20: Acceptance sampling plan for oversized hole

Above fig. shows the probability of accepting lots at various incoming quality levels. In this case, the probability of acceptance at the AQL (2.5%) is 0.546, and the probability of rejecting is 0.9. When the sampling plan was set up, company and supplier agreed that lots of 2.5 % defective would be accepted approximately 95% of the time to protect the producer.

Sample Size	132
Acceptance Number	3

Accept lot if defective items in 132 sampled ≤ 3; Otherwise reject.

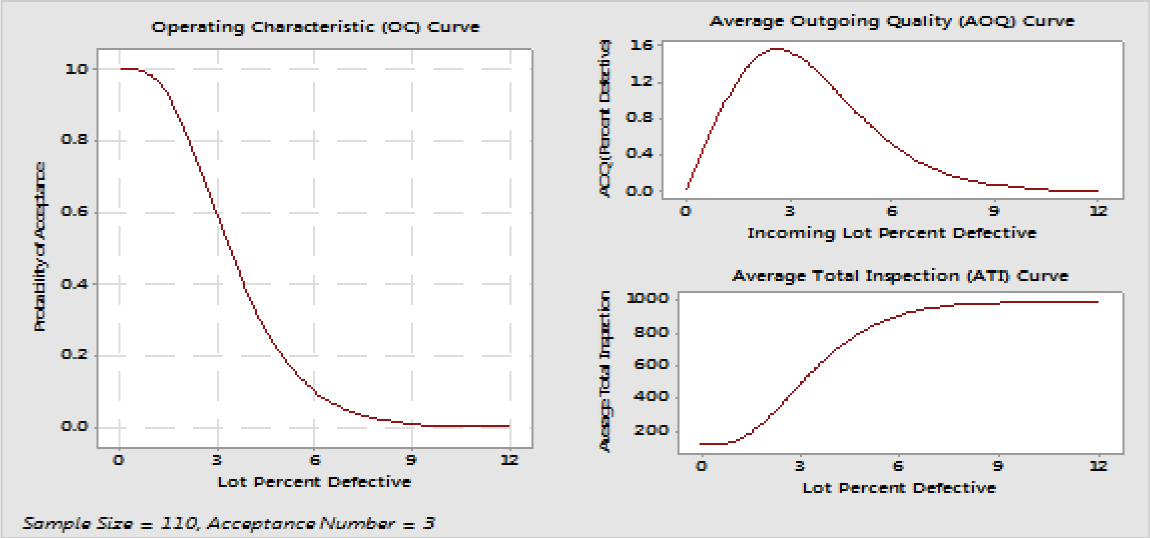
Percent Defective	Probability Accepting	Probability Rejecting	AOQ	ATI
1	0.956	0.044	0.830	170.4
5	0.099	0.901	0.431	913.9

Average Outgoing Quality Limit(s) (AOQL)

AOQL	At Percent Defective
1.278	2.220

9.1.3 GENERATED PLAN FOR NICKS

For each lot of 1,000 gears, you need to randomly select and inspect 65. If you find more than 2 defectives among these 65 gears, you should reject the entire lot. If you find 2 or fewer defective items, accept the entire lot.



Sample Size = 110, Acceptance Number = 3

Fig. 21: Acceptance sampling plan for nicks

Above fig. shows the probability of accepting lots at various incoming quality levels. In this case, the probability of acceptance at the AQL (3 %) is 0.546, and the probability of rejecting is 0.6. When the sampling plan was set up, company and supplier agreed that lots of 3 % defective would be accepted approximately 97 % of the time to protect the producer.

Sample Size 110

Acceptance Number 3
Accept lot if defective items in 110 sampled ≤ 3; Otherwise reject.

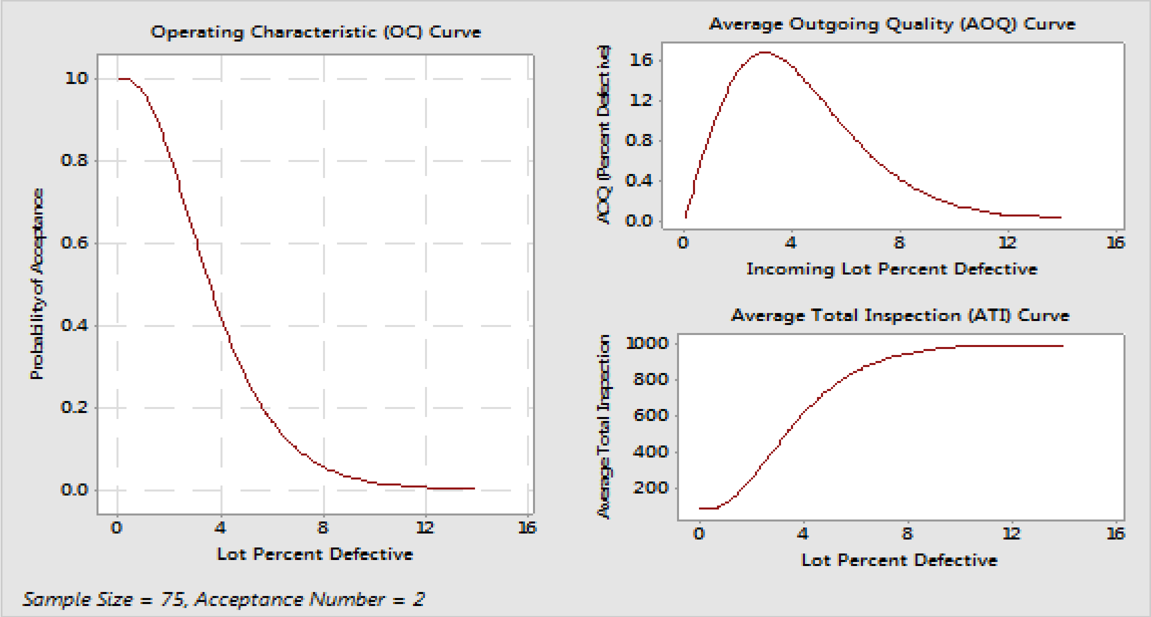
Percent Defective	Probability Accepting	Probability Rejecting	AOQ	ATI
1	0.975	0.025	0.868	132.3
6	0.098	0.902	0.523	912.8

Average Outgoing Quality Limit(s) (AOQL)

AOQL	At Percent Defective
1.572	2.661

9.1.4 Generated plan for misalignment

For each lot of 1,000 gears, you need to randomly select and inspect 65. If you find more than 2 defectives among these 65 gears, you should reject the entire lot. If you find 2 or fewer defective items, accept the entire lot.



Sample Size = 75, Acceptance Number = 2

Fig. 22: Acceptance sampling plan for misalignment

Above fig. shows the probability of accepting lots at various incoming quality levels. In this case, the probability of acceptance at the AQL (4 %) is 0.4, and the probability of rejecting is 1.6. When the sampling plan was set up, company and supplier agreed that lots of 4% defective would be accepted approximately 96 % of the time to protect the producer.

Sample Size	75
Acceptance Number	2

Accept lot if defective items in 75 sampled ≤ 2; Otherwise reject.

Percent Defective	Probability Accepting	Probability Rejecting	AOQ	ATI
1	0.960	0.040	0.888	111.7
7	0.097	0.903	0.627	910.5

Average Outgoing Quality Limit(s) (AOQL)

AOQL	At Percent Defective
1.688	2.995

10. CONCLUSIONS

For spur gear manufacturing problem, after observing all the data and analysis we find that its production quality is very close to the six sigma limits. Some variation occurs due to natural causes which can be eliminated. Type-I error occurred. So, if the spur gear manufacturing company continuing their quality research, it will help them to acquire a best product quality and make a highest position in the market.

In this thesis, the most effective way of quality control and productivity improvement has tried to find by experimenting on a manufacturing company. Using all quality tools and sampling plan is an expensive procedure. For any industry, using the control chart is the best way for quality testing. Cause and effect diagram, histogram are used to determine the causes and effects of production process. Acceptance sampling is used to determine the errors in control chart.

Statistical process control is a powerful tool to achieve sig sigma level. The following improved tools used in spur gear manufacturing can be used in any industry to achieve their desired level of quality and productivity.

There are several approaches to choose from when the goal is to increase the quality and productivity of a spur gear manufacturing company. The techniques used in this thesis have been limited due to insufficient time and resources. In this paper only the quality tools have been used and tried to find the most effective way of quality testing and improving productivity. These have given a better solution. But if any one uses other technique of industrial engineering then he will get more benefit than this thesis. If it is decided to use the data in future studies it would be interesting. By this way it may be possible to specify high quality and productivity. The quest for higher quality and productivity will never stop and the project extreme spur gear manufacturing will proceed. An important suggestion for future work is to test if the findings are applicable to other products and machines within the factory. A deeper understanding could possibly make the conclusions from this study more understandable and easier to apply to other products.

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