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IMPLEMENTATION OF SPC TOOLS FOR PROCESS IMPROVEMENT: A CASE STUDY

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Abstract
The main objective of this paper is to draw Pareto chart and cause and effect diagram for automotive components; using statistical process control and their tools. The Pareto chart gives us the percentage of different product defects. The quality and productivity of products may be improved by applying various quality tools. Over last decade; the level of significance on SPC analysis has been considerably increased but the literature findings reveal the importance of understanding the concepts, critical assumptions and methodologies; while implementing in various manufacturing process. It is found that the defects in crank shaft bearings are a very serious issue which leads to the wastage of money and time of industry.

Keywords: Pareto chart, Quality tools Cause & Effect diagram Automotive anufacturing industry.

1. Introduction

Statistical quality control is a term which is used to describe the set of statistical tools used by quality professionals. Statistical process control is an industry-based methodology for measuring and controlling quality during the manufacturing process. Quality data in the form of product or process measurement is obtained in real-time during manufacturing. This data is then plotted on a graph with pre-determined control limits are determined by the capability of the process, whereas specification limits are determined by the client' need.

Data that falls within the control limits indicates that everything is operating as expected. Any variation within the control limits is likely due to common cause, the natural variation that is expected as part of the process. If data falls outside of the control limits, this indicates that an assignable cause is likely the source of the product variation and something within the process should be changed to fix the issue before defects occur.

1.1 The need for Statistical process control

Dedication to constant improvement in quality and productivity is needed to prosper in today's economic climate. Yesterday's standards are not good enough. A company's product has competition from companies throughout the world because modern communication and transportation have created a world marketplace. The quality of a product has to be world class, as good as the best in the world, in order to compete. Consumers are looking for the best combination of price and quality before they buy. Today each company employee must be committed to the use of effective methods to achieve optimum efficiency, productivity, and quality to produce competitive goods.

When a company produces a product or service, it utilizes many interrelated processes and each process involves several to many steps to accomplish a specific task. These may be several sources of data available as the task is undertaken and measurements that have to be within specified limits or outcomes to be judged acceptable or not acceptable. All the different processes are combined to yield the final product or service.

Statistical process control (SPC) is a procedure in which data is collected, organized, analysed, and interpreted so that a process can be maintained at its present level of quality or improved to a higher level of quality.Collection of data: the measurement data from a process is usually collected in small samples. Large samples are generally used to determine the proportion of nonconforming items or to analyse shipments from supplier.

SPC can be applied wherever work is being done. Initially it was applied to just production processes, but it has evolved to the point where it is applied to any work situation where data can be gathered. As companies work toward a total quality goal, SPC is used in more diverse situations. SPC involves the use of statistical signals to identify sources of variation, to improve performance, and to maintain control of processes at higher quality levels. The statistical concepts that are applied in SPC are very basic and can be learned by everyone in the organisation. All workers must know how SPC applies to their specific jobs and how it can be used to improve their output. Supervisors must be aware of the ways SPC can be used in their sections. They must create and maintain a management style that emphasizes communication and cooperation between levels and between departments.

1.2 SPC Goals

The following are the primary goals of Statistical process control:

(i) To minimize production costs. This is accomplished with a “make it right the first time” program. This type of program can eliminate costs associated with making, finding, and repairing or scrapping substandard products.

(ii) To attain a consistency of products and services that will meet production specifications and customer expectations. Reduce product variability to a level that is well within specifications so the process output will match the desired design quality. This consistency leads to process predictability, which benefits the company by helping management meet quality targets.

(iii) To create opportunities for all members of the organisation to contribute to quality improvement.

(iv) To help both management and employees make economically sound decisions about actions affecting the process.

Basic tools used for statistical process control (SPC) are:(i) Flowchart (ii) Pareto chart (iii) Check sheet (iv) Cause and effect diagram (v) Histogram (vi) Scatter diagram and vii) Control charts.

SPC involves the use of statistical signals to identify sources of variation, to improve performance, and to maintain control of processes at higher quality levels. The statistical concepts that are applied in SPC are very basic and can be learned by everyone in the organisation. All workers must know how SPC applies to their specific jobs and how it can be used to improve their output. Supervisors must be aware of the ways SPC can be used in their sections. They must create and maintain a management style that emphasizes communication and cooperation between levels and between departments. Gaafar and Keats [1] focused on the Statistical Process Control (SPC) implementation phase in an effort to underline that SPC is not just control charts, and that many steps have to be accomplished before these charts are used. In addition, they highlighted the role of training and presented it as an on-going process which involves everyone in the organization. These SPC implementation steps are not meant to be a checklist; they provide guidelines that can be modified in accordance with organizational-specific requirements. Cheikh and McGoldrick [2] discussed the work, which has been carried out in the area of tolerances with cost, function and process capability the main parameters in mind. So that the resulting functional variables of the assembly can meet their respective functional tolerances requirement and cost of manufacturing all the components to their respective functional tolerances is minimized. It shows that, when manufacturing cost information and process capability information are available, functionally correct design at minimum cost can be achieved. Furthermore, they showed how statistical analyses of the manufacturing processes involved can lead to the relaxation in requirement at the same time, maintaining the desired levels of product quality and reliability.

1.3 Literature review

Chaudhry and Higbie [3] examined the implementation and use of statistical process control in a chemical and plastic firm. They studied the factors which are associated with the practical implementation of statistical process control, and discussed their effects on the output. They discussed the important components of SPC process in context of their achievements at a manufacturing facility. They also discussed the benefits achieved from the successful implementation of SPC. Goh [4] outlined the functions of statistical tools and examined the steps in which they are adopted by non-statisticians in industry. A “seven S” approach is explained, highlighting a strategy for the effective deployment of statistical quality engineering. In a manufactured product attainment of superior quality and reliability depends upon the existence of a framework integrating an organisation’s capabilities in management, technology and information utilization. With respect to information utilization, statistical tools are particularly essential for optimizing product and process performance.

Ribeiro et al. [5] presented a new procedure for quality control and quality assurance in scenarios where several variables and attributes have to be monitored. The proposed procedure, named integrated process control, begins with the definition of control stations on the production line, where a single chart that aggregates several variables and attributes is used. This procedure is complemented by using Pareto charts, which determine the quality characteristics contributing the most to the number of defectives. The integrated process control also uses traditional control charts; however, these are used selectively following the indication of the Pareto charts. The joint use of these tools facilitates the identification and solution of quality problems, allowing the improvement actions to be taken at the right time and place. The key advantages of the proposed procedure are: the ability to handle variables and attributes on a single integrated chart, the statistical approach, providing a solid basis for decision making, and the strong managerial appeal provided by the integrated charts. MacCarthy and Wasusri [6] reviewed non-standard applications of statistical process control (SPC) charts reported in the literature from the period 1989 to 2000, inclusive. Non-standard applications are analysed with respect to application domain, data sources used and control chart techniques employed. The principal application domain for statistical process control (SPC) charts has been for process control and improvement in manufacturing businesses. Salehi et al. [7] proposed that advanced automatic data acquisition is now widely adopted in manufacturing industries and it is common to monitor several correlated quality variables simultaneously. Most of multivariate quality control charts are effective in detecting out-of-control signals based upon an overall statistics in multivariate manufacturing processes. Balamurali [8] considered that capability index Cpmk and confidence limits are estimated using the bootstrap technique. They conducted a simulation using three distributions (one normal and two non-normal) and a made a comparison to show the performances of the three bootstrap confidence intervals. Das and Sachan [9] discussed the importance of control charts in detecting the assignable cause of variation. They discussed the assumption under which these charts are developed. They proposed some alternatives control charts for controlling location parameters based on some robust estimators, because the present charts are not used with assumption in real situations. They also showed the performance of proposed control charts and compared them with some existed robust control chart. Amiri et al. [10] discussed the limitations of MEWMA control chart in spite of its ability to detect small shifts in the process with multiple quality characteristics due to its high cost of implementation. They applied and optimized two multi-objective approaches, an aggregative and a non-aggregative approach using a genetic algorithm. They evaluated the proposed approaches through a numerical example from the literature and the efficiency of the multi-objective approaches are verified in comparison with the previous methods. Debnath and Shankar [11] demonstrated impact of statistical process control (SPC) and Taguchi parameter design to monitor the academic process of the institution and finding an optimum condition of the various parameters involved with the process, which would maximize customer satisfaction across the institution. They suggested that this approach may add more value to both academics and practitioners. Prajapati [12] presented the economic design of modified X^{-} chart for auto correlated data and comparison with the economic design of Shewhart's X^{-} chart. He attempted to counter autocorrelation by designing the modified X^{-} chart; as the cost of operating a process control system is an important element in the economic design of control charts. The economic designs of both modified and Shewhart X^{-} charts for auto correlated observations are presented; using Lorenzen -Vance cost model. The modified X^{-} chart is based upon sum of chi-squares and has simplicity like Shewhart X^{-} chart but more efficient than standard chart.

1.4 Products and Industry

This industry is an automotive parts manufacturing company. This company is established in 1985.This is one of the largest integrated component manufacturers in India with a strong global presence. It has also become one of the world's largest global forging and integrated machining companies. The Group has operations across Forging, Iron and Aluminium Casting, Machining and Sub-Assemblies. It has world-class facilities across India, Japan, Thailand, Germany, Hungary, Italy, Romania, UK, Brazil, Mexico and US. This Group is comprised of corporate entities Amtek Auto, JMT Auto, Global Technologies and other subsidiaries and associates. With the infrastructure and technology platform developed over 25 years, the Group is well positioned in the Indian Auto and Non-Auto component markets.

1.5 Products Manufactured by the Company

There are many products are manufactured by industry like connecting rod , drive shaft , crank shaft, cylinder block, flywheel, cam shaft, steering etc. But in our study we have taken four main products namely connecting rod, drive shaft, crank shaft, cylinder block. These manufacturing processes of these products are discussed below.

1.6 Crank shaft manufacturing process:

The specifications of crank shaft are as under:

1. Major diameter - 17.2+0.2 in mm
2. Minor diameter - 15.2-0.2 in mm
3. Parallelism 0.04mm in 100 mm
4. Reaming 6.25+0.22 in mm
5. Hardness 45-60 hrc
6. Bearing Diameter 22mm+(.034mm/.044mm)

Figure 1 shows the sample of crank shaft.

Figure 1 Crank shaft

Various steps of manufacturing process of crank shaft are discussed below:

➢ **Hardening & Tempering:** The piece is heated above its critical point and then quenched in water. This improves the strength & hardness of the drive shaft but induced residual stress and surface cracks, to remove these tempering is done, in which the piece is heated below its critical temperature and then cooled down in oil (very slow cooling). This process also improves the toughness of the piece.

- **Grinding:** Grinding is an abrasive machining process that uses a grinding wheel as the cutting tool. A wide variety of machines are used for grinding.

- **Face Milling:** It is the machining process of using rotary cutters to remove material from a work-piece by advancing (or feeding) in a direction at an angle with the axis of the tool

- **Fine boring:** In machining, boring is the process of enlarging a hole that has already been drilled (or cast), by means of a single-point cutting tool.

- **Gun drilling:** Gun drilling is a process that produces deep, straight holes in a variety of materials. A gun drill tool differs from a conventional twist drill by its unique head geometry; a standard gun drill has a single effective cutting edge.

- **Thread rolling:** Thread rolling is a cold forging process that can be performed on any ductile metal. The forming process can be used to produce other special forms, such as knurls.

- **Hole drilling:** Drilling is a cutting process that uses a drill bit to cut a hole of circular cross-section in solid materials. The drill bit is usually a rotary cutting tool, often multipoint. The bit is pressed against the work-piece and rotated at rates from hundreds to thousands of revolutions per minute.

- **Reaming:** A reamer is a type of rotary cutting tool used in metalworking. Precision reamers are designed to enlarge the size of a previously formed hole by a small amount but with a high degree of accuracy to leave smooth sides.

- **Final inspection:** Final inspection is done and the product is sent for packaging.

Manufacturing process of Crank shaft is shown in Figure 2.

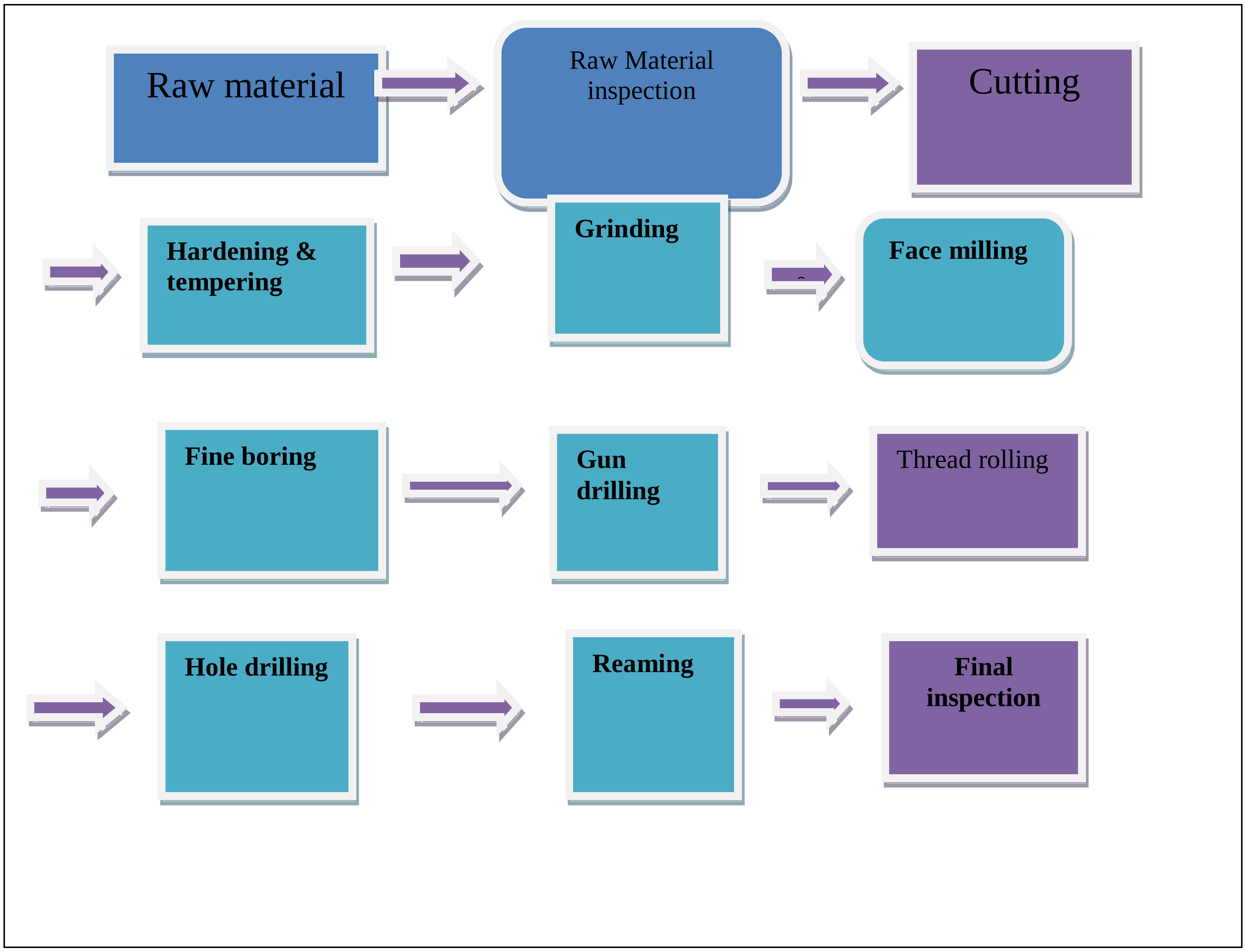

Figure 2 Flow diagram of crank shaft manufacturing process

2. Research Method

After the thorough analysis of the rejection quantity, it is concluded that four products namely Drive Shaft, cylinder block depth, crank shaft bearing diameter and connecting rod (big end) diameter in the Company. Pareto chart is used for the analysis of the defects in the manufacturing processes.

Pareto analysis a statistical technique in decision making, used for selection of limited number of tasks that produce significant overall effect. It uses the Pareto principle

“Few cause accounts for most of effects”. The Pareto chart, a bar graph that ranks problems in decreasing order of frequency, was adapted to quality control by Joseph M. Juran, a noted authority and leader in the resurgence of quality in U.S. industry. Pareto discovered that 80% of the wealth in his country in the early 1900s was concentrated in 20% of the population. Dr.Juran discovered that 80-20% split also occurs in quality control. Eighty percent of the scrap is caused by 20% of the problems, and 80% of the dollar loss caused by poor quality is concentrated in 20% of the quality problem.Figure 2 shows the flow diagram of manufacturing process of crank shaft.

This technique helps to identify the top 20% of causes that need to be addressed to resolve 80% of the problems. Once the top 20% of the causes are identified, then tools like Ishikawa diagram or Fish-bone analysis can be used to identify the root causes of the problems. The Pareto chart is named after Vilfredo Pareto, an economist and sociologist who lived from 1848 to 1923. Originally trained as an engineer he became the managing director of a group of coalmines. Later he took chair of economics at Lausanne University, ultimately becoming a recluse. Mussolini made him senator in 1922 but by his death in 1923 he was already at odds with the regime. Pareto was an elitist believing that the concept of the vital few and the trivial many extended to human beings. The phrase of the 'the vital few and the trivial many' deserves a place in every manager's thinking. It is itself one of the most vital concepts in modern management. The results of thinking along Pareto lines are immense.

Following procedure is used to draw the Pareto chart:

Step 1 Form an explicit table listing the causes and their frequency as a percentage.

Step 2 Arrange the rows in the decreasing order of importance of the causes (i.e. the most important cause first)

Step 3 Add a cumulative percentage column to the table.

Step 4 Plot with causes on x- axis and cumulative on y-axis

Step 5 Join the above points to form a curve

Step 6 Plot (on the same graph) a bar graph with causes on x-axis and percent frequency on y-axis.

Step 7 Draw line at 80% on y-axis parallel to x-axis. Then drop the line at the point of intersection with the curve on x-axis. This point on the x-axis separates the important causes (on the left) and trivial causes (on the right)

Step 8 Explicitly review the chart to ensure that at least 80% of the causes are captured.

2.1 Pareto Diagram for finding major problem in Amtek Auto Pvt. Ltd.

The data collected for the month of February 2016 is shown in the Table 1

Table 1 percentage of defects of various components

S. No.	Name of Defect	Number of defects	Cumulative no. of defects	Percentage of defects	Cumulative percentage of defects
1	Drive shaft run out (in mm)	463	463	33.75%	33.75%
2	Crank shaft bearing diameter undersize & oversize (in mm)	225	688	14.61%	48.36%
3	Under size of cylinder block depth (in mm)	219	907	13.28%	61.64%
4	Undersize & Oversize of connecting rod diameter (big end) (in mm)	192	1099	12.26%	73.9%
5	drive shaft length oversize (in mm)	96	1195	5.54%	79.44%
6	drive shaft length undersize (in mm)	72	1267	4.53%	83.97%
7	Connecting rod oval diameter (in mm)	67	1334	4.1%	88.07%
8	Crank shaft parallelism (in mm)	57	1391	3.89%	91.96%
9	Undersize of cylinder block drill diameter (in mm)	48	1439	3.6%	95.56%
10	Undersize of cylinder bore diameter (in mm)	36	1475	2.54%	98.1%
11	Finishing/Reaming in Crank shaft (in mm)	18	1493	1.2%	99.3%
12	Cylindricity in Connecting rod (in mm)	16	1509	0.7%	100%

The graphical representation of Pareto chart is shown in Figure 3

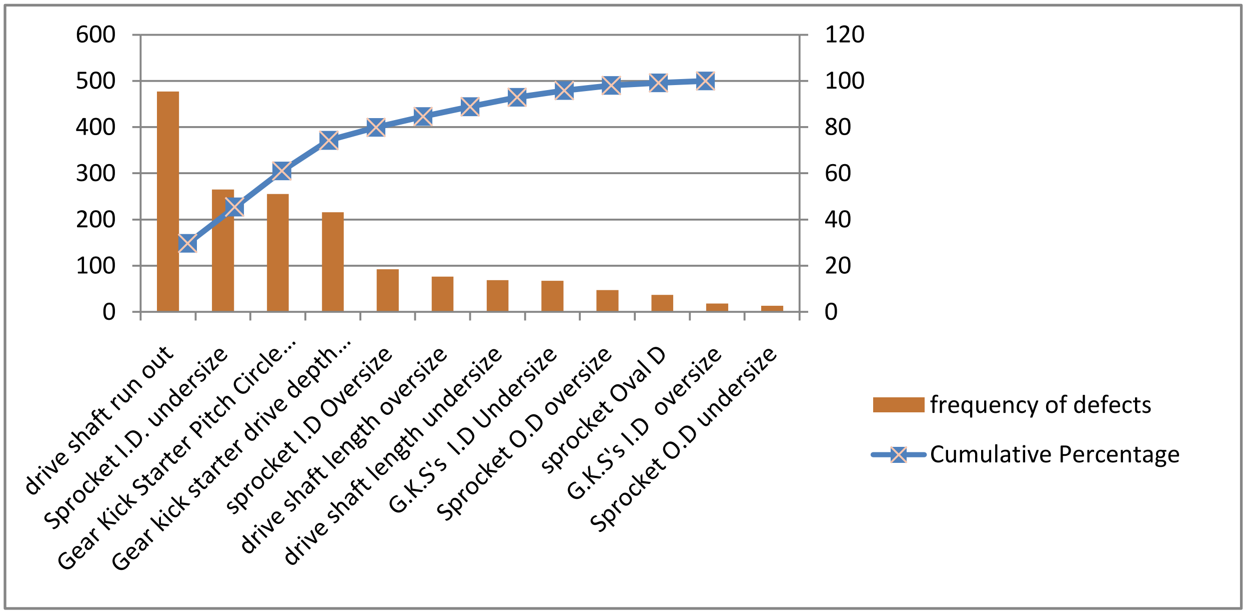

Figure 3 Pareto diagram for problem analysis in Amtek Auto

3. Results and Analysis

It is observed from the Pareto analyses that there are five main major defects which contribute maximum rejection level of the industry and these are

1. Drive shaft run-outs (33.75%)
2. Crank shaft bearing diameter undersize & oversize (14.61%)
3. Under size of cylinder block depth (13.28%)
4. Undersize & Oversize of connecting rod diameter (big end) (12.26%)
5. Drive shaft length oversize (5.54%)

All above five defects contribute to more than 75% of the total defects occurring in the industry. With the help of Pareto analysis main defects affecting the company are identified.

3.1 Cause & effect diagram for crank shaft bearing diameter

Figure 4 shows cause and effect diagram for crank shaft bearing diameter

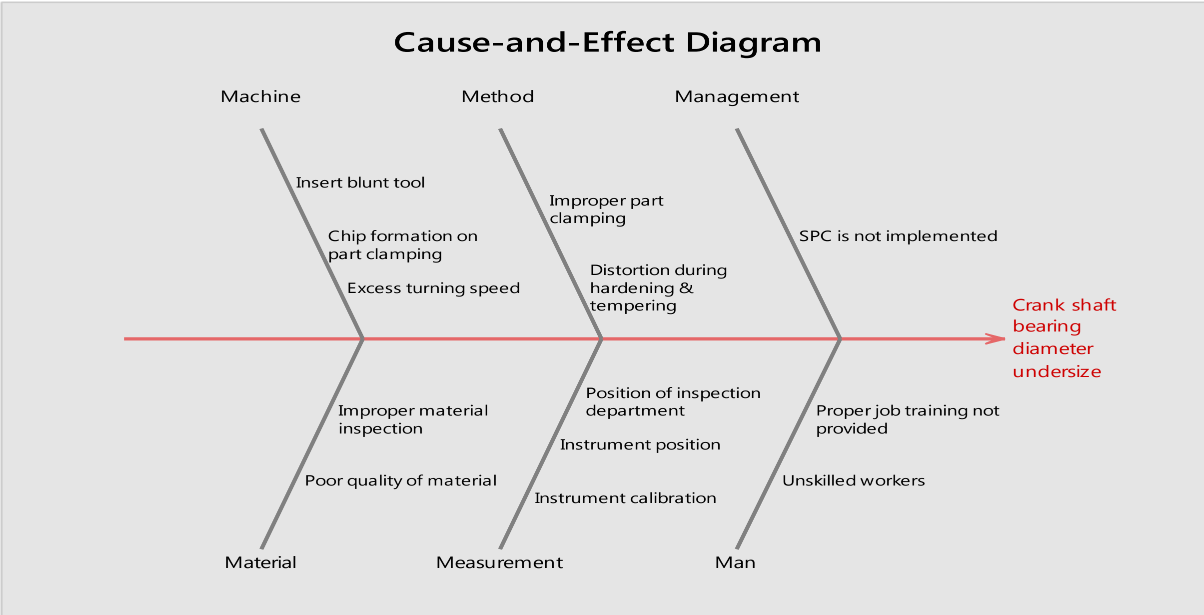

Figure 4 cause and effect diagram for crank shaft bearing diameter undersize

3.2 Recommendations to minimize the defects:

(i) In-process inspection is must for each manufacturing operation.

(ii) Cutting speed should be optimum.

(iii) Inspection should be done carefully.

(iv) Blunt tools should be replaced with new tools.

(v) Jaw and chucks should be installed carefully.

(vi) Revolving center should be replaced periodically.

(vii) Workers should be imparted proper job training

(viii) The materials should be inspected carefully before issuing for products.

4. Conclusion (10pt)

Both management and employees in the service sector can take advantage of SPC techniques to analyse processes and procedures. Processes may be streamlined to save employee hours. Procedures that lead to mistakes may be changed so that the incidence of mistakes is reduced or eliminated. Employee involvement in the use of charts and check sheets can lead to valuable input in improving the service.

It is found from the Pareto analysis that maximum percentage of rejection (33.75%) is due to drive shaft run-outs defects. Other two important causes are Crank shaft bearing diameter undersize & oversize (14.61%) and under size of cylinder block depth (13.28%) respectively.

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