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ENHANCEMENT OF QUALITY OF THE PROCESSES USING STATISTICAL TOOLS- A REVIEW

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Abstract

Process enhancement can be achieved only through proper monitoring of a specific process and by taking necessary steps of actions toward the eliminations of variations or defects associated with it. Once a deviation from the prescribed values of a process are said to occur, it is mandatory to take action to eliminate the causes, which are responsible for the process abnormality, for the continuous improvement throughout the organization. This paper reviews the history of Statistical tools such as Control charts, Histogram, Cause and Effect diagram combined with both Statistical Process Control and Process capability Indices and how these are helpful in enhancing the process by continuous monitoring through inspection of the samples. Statistical tools for process enhancement are carried out using the Statistical approach, which is nowadays a widely used technique for implementing the Total Quality Management in a firm. But still, some managements of small and medium sized company arescared of implementing these techniques due to the cost and time constraints involved in it. This paper gives a pureidea of the usage of statistical tools according to the situations exhibiting in a firm, collected from various research works on different types of processes. If these valuable tools are used with apt knowledge, attaining through proper training and motivation, then one firm can establish its market by enhancing its quality and productivity of the process, in this competitive world.

Index terms: *Process enhancement, Quality improvement, Statistical Tools, Process Capability Indices.*

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1. INTRODUCTION

Statistical Quality Control (SQC) tools are the major valuable tools for performing the task of finding out the deviations and defects of finished components of each process in a statistical way. This kind of approach washed out the traditional approach, where the components are examined after the whole process accompanied with a single product, is completed. The traditional method pays a way of wasting huge amount of money invested in a product, when a defect is found on a product, because it doesn't support to observe the defects at the initial stage. Hence, a statistical method is introduced for the simple usage and rapid results regarding the deviation within the process. Statistical Quality Control methods apply statistical principles and techniques at every stage of design, manufacturing and servicing, AbdulkadirGullu[1].

2. METHODS AND MATERIALS

2.1. Concept of Statistical Quality Control

SQC tools uses the process values to determine, whether the process is in control or out of control. If the process is found out to be in control as specified by the customers or engineers, the process need not to be disturbed. But, by theory of manufacturing, no two products manufactured in same conditions and same parameters are identical. The variations are inevitable. If the deviations are too high, i.e., if the process is out of control, then some measures are to be carried out to make the process, back into the form. For continuous improvement of the process, monitoring every process is essential in case of mass production. This can be made easy by using the Statistical tools such as Control chart and Histogram principles

P.R Drake [2] studied the tools of SQC which give an alarm when any values falls out of control and to make attention towards the process for rectification purpose. The major reason for the falling of values out of control is due to assignable cause. The assignable causes are time bound one and hence can be easily traced and detected. But the impact of assignable cause on the process variation is more than the chance cause.

2.2 Control Chart

Control charts are the one of the most important and effective statistical tools for determining the process stability and variability [2]. These charts contain the upper control limit and lower control limit (Statistical condition of the process) with control limits imposed on the center of it, for effective measuring of the quality characteristics.

2.3.Histogram

Based on the frequency of distributed values, one can come to a conclusion whether the values falls within the specified values and gives a normal distribution curve out of it. This can be achieved through Histogram, where the values are plotted against the sample size, to see where the product variations are more, either near the lower specification limit or near the upper specification limit(functional requirement). If the variations are due to chance causes alone, the observations will follow a normal curve. This represents the under controlled process. If the process is out of the control, then there must be a presence of assignable causes and it will not follow the normal curve.

2.4 Cause and Effect diagram

To examine the assignable causes, Cause and Effect diagram is made to bring into picture. This diagram analysis the four major elements (4 M's) for the variations to occur, they are namely; Men, Machine, Method, Material [2]. This diagram takes an end effect and analyses the causes related to it. These tools, Control chart, Histogram and Cause and Effect diagram are used to enhance the process by combination of Statistical Process Control and Process Capability Indices are discussed.

2.5 Concept of Statistical Process Control

The Statistical Process Control (SPC) technique is an integral to implement the Statistical Quality Control, WincoW.C.Yung [3]. SPC is not only associated with the plotting of values on the graph, but it also deals with the checking of attribute and variable quantities. This graphical approach also helps to show a real time data to the operator and helps for continuous monitoring of the data. SPC is one of thetool to clearly indicate whether engineering assistance is required to solve an out of control condition [3].

2.6 Concept of Process Capability Studies

The Process Capability Studies (PCS) are used to monitoring the capability of the process, Mats Deleryd [4]. It is based on some sort of values which are collected to examine the process using Control chart or some other tools. This study is mainly done by statistical method by using formula:**$Cp = USL – LSL / 6\sigma$**, whereUSL is the Upper specification Limit and LSL is lower specification limit.

The Process Capability index is Cpk is used to provide an indication of the variability associated with the process has conformed to its specifications, BharathwajRamakrishnan et al., [5]. This can be calculated by:

$$C_{pk} = \text{Min}\ (USL - \mu,\ \mu - LSL) / 3\sigma$$

where it measure the distance between the expected value of the studied characteristics μ, and the nearest specification limit and related this distance to the half of the natural process spread, 3σ [4].

Capability analysis helps to determine the ability for manufacturing the products within the tolerance limits and engineering values [1]. Hence, this approach is used in companies nowadays.

When properly applied, these statistical tools along with the SPC and PCS are the effective ways for improving the process quality, Laura M.M. Ribeiro et al., [6]. Due to this, a high quality products can be manufactured which provides some advantages such as reduces scrap, or reprocessing and increased market share [1].

The success is not achieved only by the implementation of these Statistical tools along with SPC and PCS, but the management' scooperation is also needed for its effective implementation.

3. LITERATURE REVIEW

The Statistical tools are recommended for all the processes, it may be of mechanical, electrical, computer and its application, and it doesn't stop with this. The scope of using these Statistical tools is more than the above specified and the followings are described detailed below. Here various practical applications are demonstrated and the how these tools along with SPC and PCS are used in a right way to get required results.

3.1 Application to machine tools

The Statistical tools can be applied to a machine tool for measuring its performance and to eliminate the quality problems. AbdulkadirGullu [1], stated in his research that, by using statistical tools such as Control chart of X-R, and by using machine capability Cp,along with process capability Cpk, problems such as undesirable tolerance and the ovality during machining process can be eliminated by examining the machine tools.

In the research, attempts are made for experimentation in a medium sized company on a machining process of castings and found out some deviations from the design and attained tolerance of the workpiece [1]. Due to this instabilty in process, investigations are made in the causes responsible for the deviations to occur in many perspectives. He reevaluated the whole process because of some problems occurred in the assembly area of the company. Hence, the workpiece was decided to analysis thoroughly, right from the first process to the last process, up to which it has undergone. Initially the study concentrates on the Turning operation of the casting and observed that some values went wrong from the specified values of tolerance and the ovality. So, it was decided to move to the initial process, where the cast was made out of foundry.

The actual sizes of the casting, after turning operation are 62.500-62.250, 56.410-56.490 and 63.512-63.550. But, some defects were found and some castings tolerances were moved out of control. So, by using a lot acceptance sampling plan, the casting products are examined by using the Control chart of X-R and those results were plotted on histogram for the process capability analysis. On analyzing, the size variation of one part affects the product in all the five production line. Hence, statistical work, normal distribution diagram and histogram are carried out in the study for the investigation.

In the production line 1, all the processes are within the tolerance level which can be inferred from the histogram (Fig 1). But the Cpk value for the two sizes (56.410 – 56.490 and 63.512 – 63.550) was less than 2, while Cp is greater than 2. Hence, the process is reevaluated and noticed from the whole production line, Cp and Cpk value of the two sizes other than 62.500 – 62.250 were accomplished.

The histogram for the whole process reveals that high frequency size of 62.500-62.250 being manufactured near the lower tolerance level (Fig 2). This shows the product is experiencing some problem in any one of the production line, while the other two processes are normal.

When X-R chart was plotted, some production lines were moved out of control for all the three sizes (Fig 3). Hence these out of control process were to be controlled.

So, the process parameters were made to change for achieving the process within the control limits. Some parameters were changed as follows:

- First, the structure of the workpiece material was examined. It was noticed that, the castings were taken out of the furnace before the predetermined time.
- To prevent the ovality, the center line of the chuck and tail stock of the CNC machine was readjusted.
- The speed, feed rates and the cutting depth of the machining parameters were examined and adjusted.

As a result of these changes, made onto the machine, the parts were manufactured within the tolerance limits and ovality and surface roughness problems were eliminated.

3.2 Application to Modern manufacturing

SQC tools can be applied to today's modern manufacturing process for the effective process monitoring. In the research paper of Laura M.M Ribeior [6], he made a case study on the casting process and described a situation where the traditional SPC tools are not recommended.

In his paper, he observed the ferrous casting process of both small and large sized, have some variations due to the improper pouring and melting temperature of the metal, depending on the weight of the casting. For small sized castings, higher temperature is desired and for large sized castings, lower temperature is desired. He considered the both temperatures as dominant variables because the temperature is a function of weight of the cast in the casting process.

Previously the variables were plotted in the control chart and viewed the results. Due to change in the weight of the casting, the dominant variable also varies, which results in the shifting of values to upper and lower control limits (Fig 4). So, control charts are not meant for controlling and improving the process variation in this case [6].

For this purpose, he proposed an approach for small sized casting, by making the casting weight as a determined factor for the production planning. It is not possible to establish a temperature specification for each casting. The weight class of the casting to be poured should be adjusted by the worker. This is possible by the adoption of Delta chart (Fig 5) described in Sower et al [7] for minimizing the internal scrap due to excessive variation in the pouring temperature. This chart should be used as a descriptive statistical tool to help the operator for adjusting the pouring temperature according to the change in the weight of the casting [6] (Fig 6).

In the same way an approach was proposed for the large sized castings, where the temperature of the holding and melting furnace is continuously varying to the moulding line. For this a Cumulative SUM chart was introduced (CUSUM) (Fig 7). The statistics used in this chart was the cumulative sum of the absolute deviations of the temperature from the reference value, k. This reference value is the target temperature for the respective weight class [6]. The cumulative sum value should be reset once the change in weight requires.

3.3 Application to Production process

SQC tools can also be applied to the existing production process for continuous improvement. In the research paper of M. Dukey-Burlikowski [8], he presented the modern quality monitoring and quality control of a metallurgical industry, by using Control chart of type X-R and Quality capability of process Cp, Cpk were considered.

The research was carried out in a metallurgical industry and created the control chart to visualize whether it permits the decrease of production cost accompanying by elimination of existing problems. Samples were collected in time span over the month on a random temporary distance. The sample values were plotted in the control chart of X-R type for viewing the average and range over the time span (Fig 8). It has been described that after receiving 20 samples and inscription of this to a suitable form, then counting of limits control for average value and range value, then the process is stable [8]. The quality index capability value Cp is calculated from the obtained value. The result from this research revealed that the SPC techniques are used for the prediction of what will occur in the future. Control chart along with process capability determines the quality level and gives an alarm signal.

3.4 Applicability of techniques

In the research work of Werner A.J. Schippers [9], describes how the statistical tools are used according to the situations and how the success or failure attained by the way of using it. The various situations were mentioned with corresponding techniques are described below.

Failure of SPC tool is due to wrong usage of SPC techniques according to specific techniques and also due to lack of management commitment. Beside the application of right SPC techniques, the worker should have some basic knowledge of how to use it.Some techniques are failed to implement because it may not fit for the condition to be controlled.

The Q1 companies apply the control chart to some characteristics of produced part [9], because the control charts application make the level of scrap to get reduced. But at the same time, application of control chart to large variety of products involves too costly and it is best recommended to the small variety of products. This research paper differentiated the applicability of SPC techniques based on the constraints vs stimuli. Both relate the possible and desirable ways of applying the Process Control techniques (PCT) into a process. Many factors determine the usage of right tool such as process and product on one hand and people, procedures and management on other hand. The paper clearly says that all the SPC techniques are statistical. Hence, mostly the control chart were used for the Process control, which was introduced by Shewhart in 1920. This makes a conclusion on the taken samples, by separating the good batches from the bad ones..It gives quick response to the worker, once the deviation occurs. This was the first improvement in SQC and the second improvement was the origin of Pareto analysis with Fishbone diagram (Cause and Effect diagram) [9].

The paper also includes the aim of SPC, which clearly mention that prime reason for using the SPC is to control the process and not the products [9] and it is purely output oriented which doesn't integrate with the technical details. So, another way for preventing failure during production is introduced by dividing the production into three phases: trial production, process definition, product definition.

In first phase, i.e., trial phase, the checking of process is done to verify the capability of a specific process to produce the product. This is often done by Capability studies and by Design of Experiments. The next phase, i.e, process definition, deals with the clarification of the fits on process by using Quality Function Deployment (QFD). The final phase describes, the robustness of the process using Taguchi process.

The paper also presents a framework which gives an overview of the situations and phases in which activities that contribute to the process control is performed. In this framework, major elements of the process control is defined such as execution phase, where the process is controlled on the regular basis by using product definition, process definition, process control and product assurance.

When a new product has been introduced, then definition phase has to describe the process control methodology. But this phase doesn't give full details of process control because of lack in technical details. Hence, a new phase has been introduced called, improvement and correction phase. These phases uses the technical details, on three layers like Improvement activities on execution phase, Improvement activities on used definition**,** and Improvement activation definition activities. These phases and layers are defined for the better utilization of the Process Control Techniques (PCT).

These SPC techniques are suitable according to the situations and the need of best practice approach.

3.5 Application to Electronic Circuits

A research paper proposed by Winco K.C Yung [3], made the simple techniques on SPC and the seven quality improvement tools to improve both the product and process quality and productivity of printed circuit board. The research also integrates KAIZEN and TQM with the SQC tools by integrating the management commitment also.

The paper takes the problem of declamation / resin void on the printed circuit boards. The reason for the declamation / resin void is found out by using Cause and Effect diagram (Fig 9). Next the Pareto analysis is used to prioritize the root cause for the declamation/ resin voids problem (Fig 10). The related area for the improvement is once again falls into the category of 4 M's and the actions were carried out in these areas [3].

Some main actions are:
Men: Proper training to the personnel and recording of vaccum reading for every press cycle.
Method: Improving the cooling efficiency of the caul plate.
Machine: Maintenance of the vaccum pump seal on regular basis.
Material: Assuring the incoming quality of the products and improving the storage area of the incoming products.

By implementing these actions onto the process, a significant improvement on the process is observed on the basis of first pass yield. After the implementation, process capability was calculated and some observations on the value are detected (Fig 11).

Due to these actions, more of tangible and intangible benefits are noticed, such ascontinuous improvement on quality, better customer satisfaction, lower inventory level are achieved.

4. SCOPE OF THE WORK

SPC cannot be implemented to production in such a manner that in which one begins exploitation by measuring new devices [8].

The scope of this review paper is for the better understanding of the Statistical tools along with the Total Quality Management tools such as Statistical Process Control and Process Capability Studies and the integration of all these tools for a better result (Fig 12). This better understanding pays a way of better usage of the tools as per the required situation to save the time and cost, which the management isspending towards it and for continuous improvement.

5. RESULTS & DISCUSSION

It was noted that the productions process was not in normal condition before these techniques are implemented into the process. After the techniques were built into the process, the management and the employee had understood the cost wastage due to the rejection of the work piece and motivation among them were developed.

As seen from these studies, statistical process control and statistical quality control were effective in improving a process, irrespective of its application. It need not to be the production or manufacturing oriented process, it can also be related to environmental issues or medical issues or construction based.

CONCLUSION

The implementation of the Statistical Tools along with the SPC and Process Capability Studies, decline the process capability, unless it is used in a right way. It gains the workers enthusiasm in participating in this program, without making much resistance to the employee or the management. Because of its ultimate goal of improving the quality and the productivity of the process, the management of small and medium sized company gains more profit. Hence, they can come forward to put forth these techniques, irrespective of the cost incurred for the implementation.

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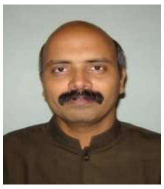
BIOGRAPHY



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Mr. J. Praveen Kumar, has completed B.Tech in Mechanical Engineering at SASTRA University. He had been selected by Larsen &Toubro as Executive Engineer.

Mr. B. Indhirajith, has completed B.Tech in Mechanical Engineering at SASTRA University. He had been selected by Turbo Energy Limited (TEL), a group of TVS.

FIGURES:

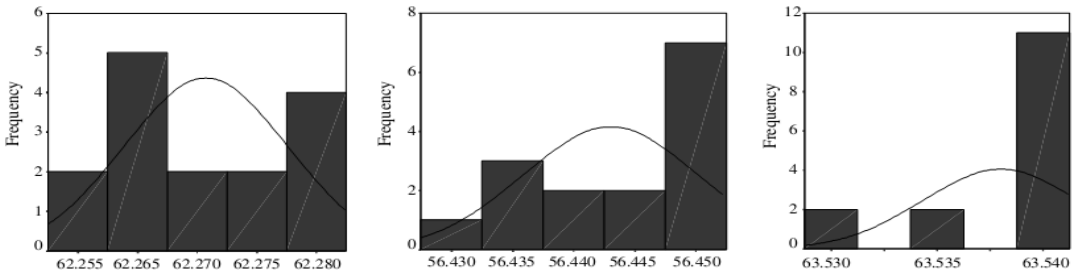

Fig. 3. For the production line 1, histograms of 62.500–62.250, 56.410–56.490 and 63.512–63.550 sizes.

Fig 1: Histogram for the production line 1 for all three sizes (Ref 1)

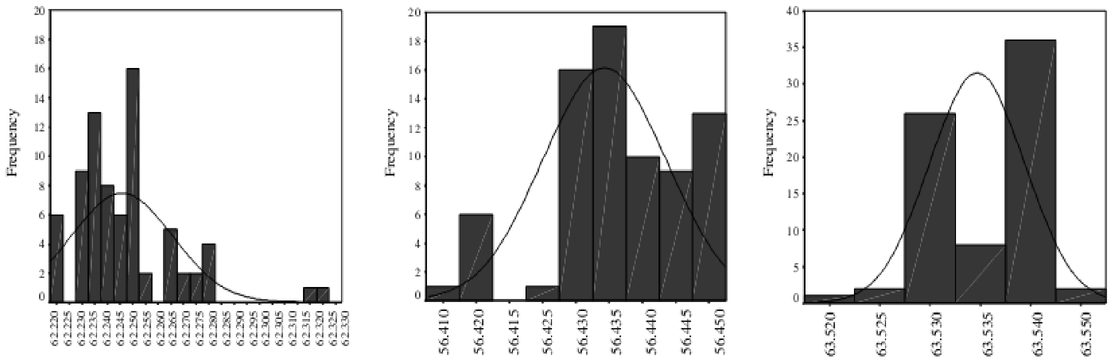

Fig. 4. The histograms of 62.500–62. 250, 56.410–56.490 and 63.512–63.550 sizes for the whole process.

Fig 2: Histogram for the whole production line (Ref 1).

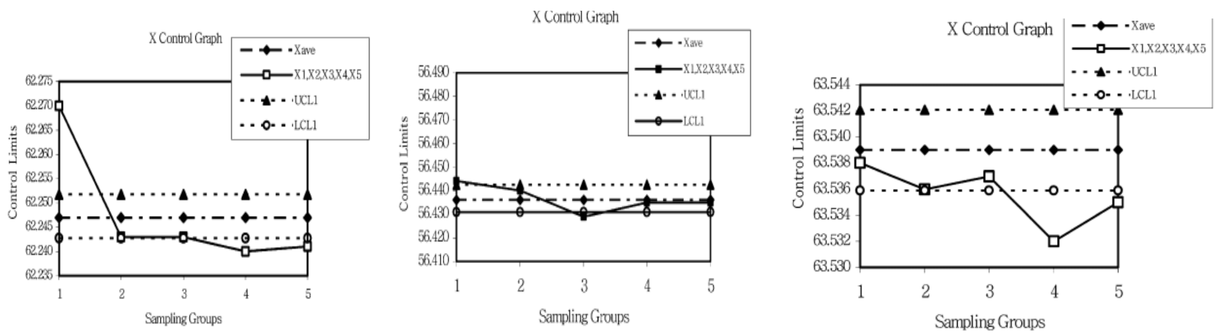

Fig 3: Control chart show the out of control values of some production lines (Ref 1).

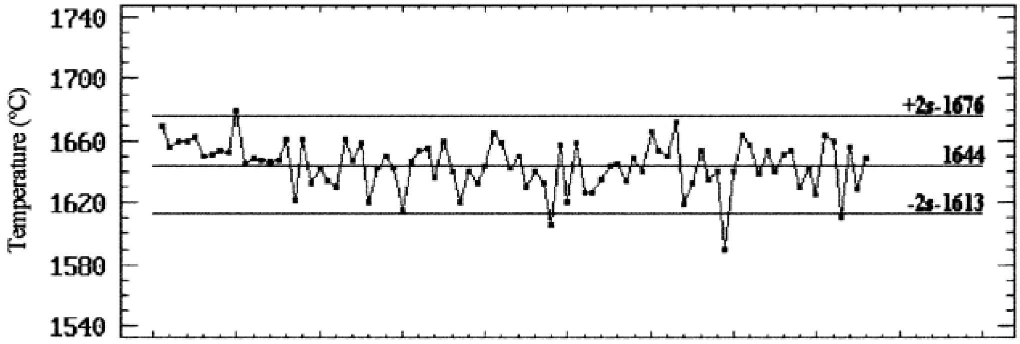

Fig 4: Control chart shows the variations in melting temperature of the casting (Ref 6)

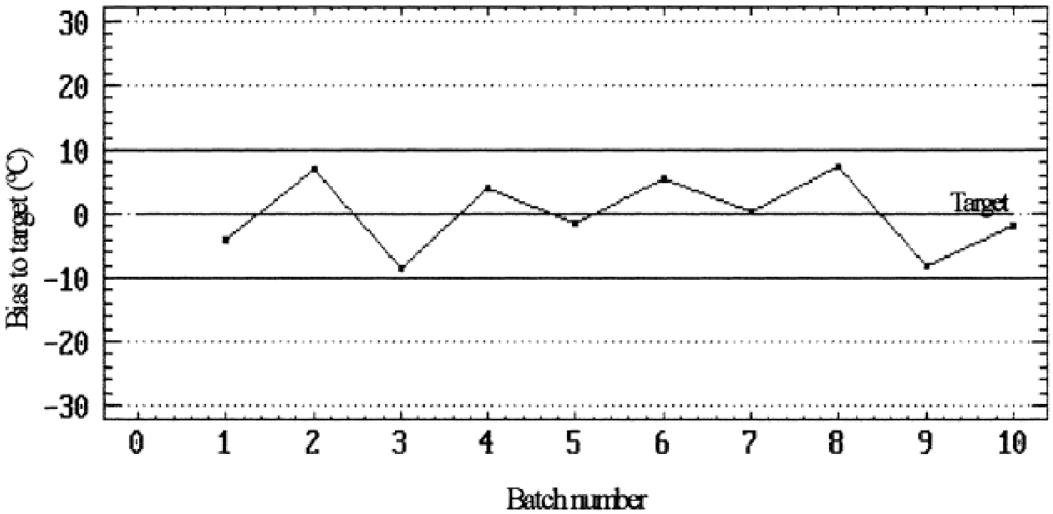

Fig 5: Control of melting temperature using Delta Chart (Ref 6).

	Operating Limits: ± 10°C					
Class (weight)	A	B	C	D	E	F
Target (temp.)	T_A	T_B	T_C	T_D	T_E	T_F

Fig 6: Specified values of Temperature of different weights (Ref 6)

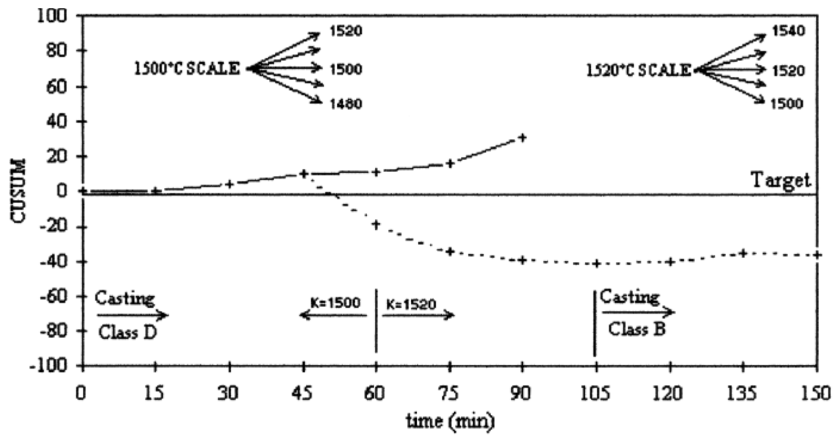

Fig 7: CUSUM chart for the large castings due to change in temperature (Ref 6).

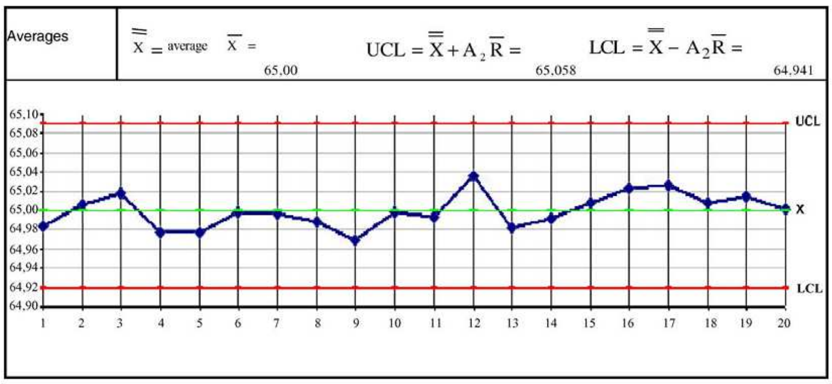

Fig 8: Control chart of type X-R for the obtained values (Ref 8).

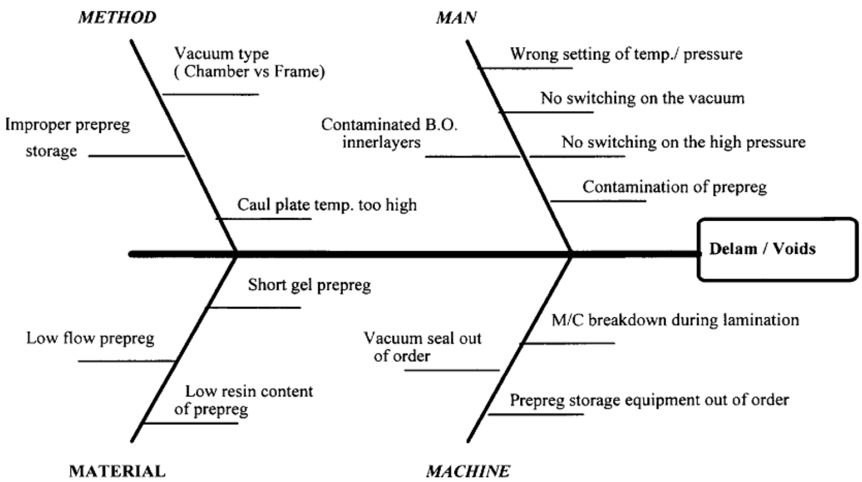

Fig 9: Cause and Effect diagram to find the defect in PCB (Ref 3).

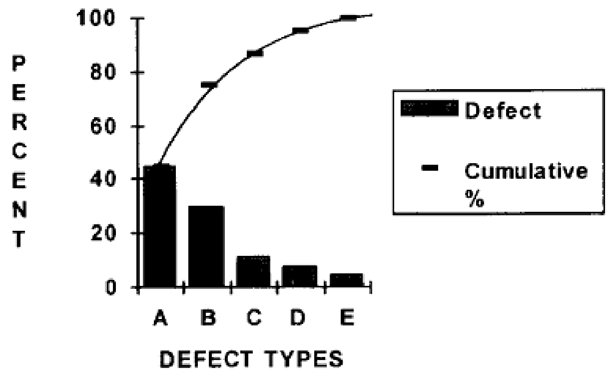

Fig 10: Pareto analysis for prioritizing the defect (Ref 3).

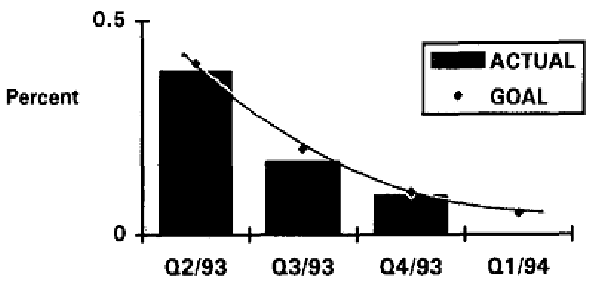

Fig 11: Improvement in the resin void defects (Ref 3).

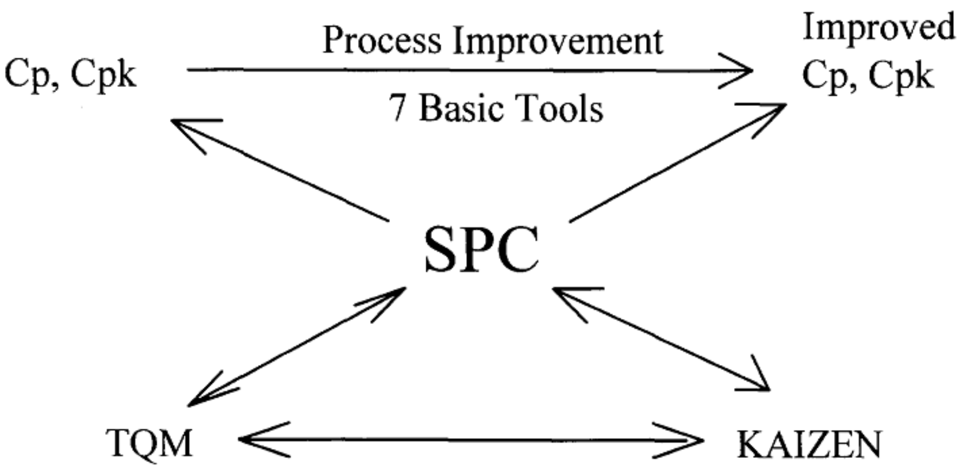

Fig 12: Integration of quality tools for the improvement in a process (Ref 3).