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SPC (Statistical Process Control): A Quality Control Technique for Confirmation to Ability of process

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Abstract-*Variability in process performance often results in waste and rework. For improvement in quality and productivity process variation needs to be reduced. Many techniques are available for quality improvement. Statistical Process Control (SPC) is one such TQM technique which is widely accepted for analyzing quality problems and improving the performance of the production process. Statistical Process Control (SPC) is methodology using control charts for assisting operators, supervisors, and managers to monitor the output from a process to identify and to eliminate the cause of variations. SPC is a proven technique for determining the process capability and predicting the yield from a process. In industry, suppliers are required to provide evidence of statistical process control to their customers. Survivors in highly competitive markets will be those firms that can demonstrate their quality capability. In this paper need of SPC, types & procedure of plotting control charts and process capability confirmation by SPC as a quality control tool is discussed.*

Keywords: UCL, LCL, SPC, Cp, Cpk, Cpl, DMAIC

1. INTRODUCTION:

1.1 Need of Process Control:-

Variation is fact of life it is everywhere & it is unavoidable. Attaining consistent product quality requires understanding, monitoring & controlling variations. Attaining optimal product quality requires a never ending commitment to reducing variations. Where does variation come from ?

Walter Shewhart, founder of SPC recognized that variations has two broad causes

1. Common causes also called chance ,random or unknown
2. Special causes also called assignable causes.

Common causes are inherent in the process and can be thought of as "natural rhythm of the process". Common causes are evidenced by a stable, repeating pattern of variation. Real quality improvement requires a continual focus on reducing the common cause variation.

Special causes of variation are a signal that something has changed in process. Special causes are evidenced by a disruption of the stable, repeating pattern of variation Special causes of variation result in unpredictable performance and must therefore be identified and remove before taking other steps to improve quality.

A process is called "under control" when deviation in output is the result of chance variations. When the pattern of output does not follow the distribution expected from chance causes, the process is considered "out of control" and the cause is probably assignable.

Here is the answer of the above: SPC (Statistical Process Control)

Typical questions that are answered by statistical process capability study are: -

- Where the process centered?
- How much variability exists in the process?
- Is the performance acceptable?
- Is the process stable?
- What factors contribute to variability?

Many reasons exist for conducting the process capability study. Manufacturing may wish to determine a performance base line for a process, to prioritize projects for quality improvements, or to provide statistical evidence of quality for customer. Purchasing may conduct a study at a supplier plant to evaluate a new piece of equipment or to compare different suppliers.

1.2 Statistical Process Control

Statistical process control made form three words & they are stand for

Statistical: We collect large amounts of data about our memory products from experiments. We study that data to learn how our actions affect the performance of our products.

Process: The method of doing something.

Control : We use the data to adjust the process to achieve the desired results. Those results are dependent on customer requirements, efficiency, quality, and reliability.

So SPC is a technique which is based on collection of data and used for attaining the desired result in the process.

Statistical Process Control (SPC) is a powerful collection of problem-solving tools useful in achieving manufacturing process stability and improving capability through the reduction of variability . It may be used when a large number of similar items is being produced. The underlying assumption is that good items are produced when processes are in control with respect to target values. The main objective of SPC is to give a signal when the process changes, i.e. its mean moves away from the target value and/or its variability increases.

1.3 Process Capability:

Process capability is the range over which the natural variation of the process occurs as determined by the system of common causes. It is the ability of the combination of people, machine, methods, material and measurement to produce a product that will consistently meet design specifications. The proportion of output that can be produced within design specifications measures process capability; in other words it is measure of uniformity of process. Process capability can be measured if all special causes have been eliminated and the process is in the state of statistical control. Process capability is important to both product designer and manufacturing engineer. A process capability study allows one to predict, quantitatively, how well a process will meet designed to yield specific information about the performance of the process under specified operating conditions.

The six steps involved in the process capability study are: -

1. Choose the representative machine or segment of the process.
2. Define the process conditions.
3. Select a representative operation.
4. Provide materials that are of standard grade with sufficient amount for uninterrupted study.
5. Specify the gauging or measurement method to be used.
6. Provide a method of recording measurements and conditions, in order, on the unit procedure.

Process capability index

The importance of process capability is in assessing the relationship between the natural variation of the process and the design specifications. This is often quantified by a measure known as the **Process capability index**. The process capability index CP is defined as the ratio of specification in a single quantitative measure.

$$CP = \frac{UCL-LCL}{6\sigma}$$

UCL = Upper control limit
LCL = Lower control limit
σ = Standard deviation of process

Two important facts about the CP index should be pointed out. One relates to the process conditions and others relates to the interpretation of the values that have been calculated. First, the calculation of CP has no meaning if the process is not under statistical control. The natural spread 6 sigma should be calculated using a sufficient large sample to get a meaningful estimate of the population standard deviation "sigma". Second, a CP of 1.00 would require that the process be perfectly centered on the mean of the tolerance spread to prevent some units from being produced outside the limits with a CP of 1.33, and still easier with a CP of 2.00. Clearly, the value of CP does not depend upon the mean of the process. To include the information on the process centering, one-sided indexes are often used. One-sided process capability indexes are as follows: -

$$Cp = \frac{UTL-LTL}{6\sigma}$$

UTL = Upper tolerance limit
LTL = Lower tolerance l limit
σ = Standard deviation of process

$$Cpu = \frac{UTL - X\ BAR}{3\sigma}$$

$$Cpl = \frac{X\ BAR - LTL}{3\sigma}$$

CPk = min (CPu; CPl)

Two statistical techniques are used to establish process capability. One is the frequency distribution histogram & other is the control chart. Control Charts are the main statistical technique used to conduct process capability

1.4 Theory Of Control Charts:

Control chart is a graphic aid to detect quality variation in output from a production process. As

opposed to the aim of acceptance sampling (to accept or reject products already produced), control chart help produce a better product. The charts have three main applications: (1) to determine the actual capability of production process (2) to guide modifications for improving the output quality of process, and (3) to monitor the output. The monitoring function shows the current status of output quality and provides an early warning of deviation from quality goals.

1.4.1 Types of control charts:

Control charts have two principle divisions: attributes and variables. Attribute control can be further divided into charts for percentage defectives and chart for the number of defects per unit. The main interest in the variables is control over changes in the average and the range of measurements. Control chart for all these considerations follows the same basic format of mean value bounded by upper and lower control limits. It is the calculation of the control limits that distinguishes the type of chart.

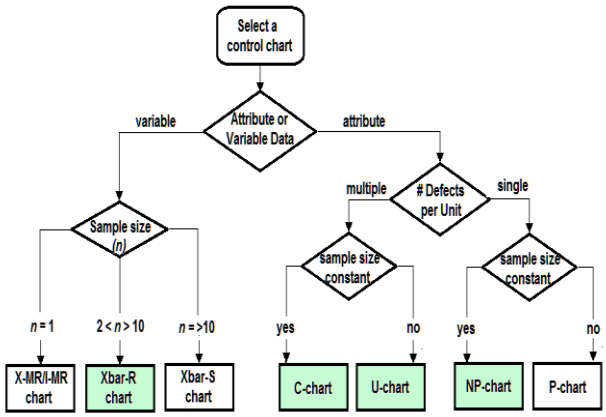

Fig-1: Shows the selection criteria of control charts on the basis of data available (variables or attributes) with sample size or subgroup size.

Mean and range chart (X Bar and Rbar/R Chart)

The chart most commonly used for variable data are the **X bar chart**, and the **R chart** (range chart). The **X bar** charts are used to monitor the centering of process, and the **R chart** is used to monitor the variation in process. These charts are used together for the analysis of variable data. The range is used as a measure of variation simply for convenience, particularly when the workers on the factory floor perform control chart calculations by hand. If the data is large and computer programs analyze the data, it is better to use the standard deviation as a measure of variability.

Values of constants:

σ = Rbar /d2

UCL XBAR = X bar + A2 * Rbar

LCL XBAR = XDbar + A2 * R bar

UCL r = D3 * Rbar

LCL r = D4 * Rbar

σ	= estimated standard deviation
R bar	= Mean of ranges
X bar	= Mean of means of individuals
UCL XBAR	= Upper control limit for means
LCL XBAR	= Lower control limit for means
UCL r	= Upper control limit for ranges
LCL r	= Lower control limit for ranges
D4,D3,A2,d2	=Values of constants

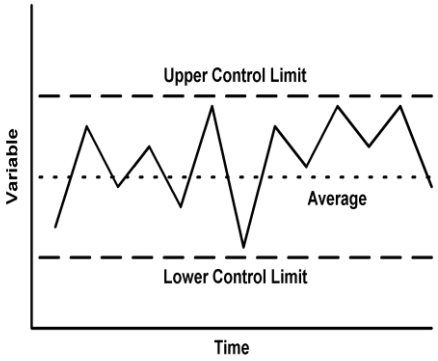

Chart -1: Show the Control Chart Sample

2. PROCEDURE FOR CONFIRMATION OF PROCESS CABALITY

2.1 Plotting Of Control Chart

The procedure followed to plot and to find out the Control limits for all the charts are almost same. So we will discuss the procedure to plot and to find out control limits for Xbar as mean chart and R bar as range chart.

X bar chart

1. Take samples.
2. Record measurements along process changes occurred during the study in the format for data collection.
3. Calculate the sum and then average (X1, X2 , X3.....) of each sub group
4. Calculate the sum and then average (X bar) of all sub groups.
5. X bar = (X1 + X2+ X3 + X4 + X5)/5

6. Calculate the control limit UCL_x Upper Control limit and LCL_x Lower Control limit for X Bar chart i.e.
7. UCL_x = Xbar + A2 * Rbar
8. LCL_x = Xbar – A2 * Rbar
9. Where A2 = 0.58 for n = 5 A2 = 1.02 for n = 3
10. Draw the average (Xbar), UCL_x and LCL_x as solid lines on the "control chart". Compare all the sub group averages (X1, X2, X3.....) against the UCL_x and LCL_x.
11. Check the data for stability.
12. If any sub group goes out of control limits, then it is sign of presence of special causes.
13. Initially for establishing the control limits and carrying out capability study, calculate the control limits to exclude the effect of out control periods. Exclude all sub groups affected by the special cause, examine the remaining sub group for homogeneity by repeating steps 5-11 till range chart shows control, but there should not be too many exclusions.

Rbar chart

1. Take samples.
2. Record measurements along process changes occurred during the study in the format for data collection.
3. Calculate the range (R) of each sub group,
   R= X (highest) – X (lowest)
4. Calculate the average range (R) of all sub groups
   Rbar = (R1 + R2 + R3 + ----------Rn) /n
5. Calculate UCL_r (Upper Control Limit) and LCL_r (Lower Control Limit) for showing the range of sub group.
   UCL_r = D_4 * Rbar
   LCL_r = D_3 * Rbar
   Value of D_4 and D_3

For n = 5	For n = 3
D_4 = 2.11	D_4 = 2.51
D_3 = 0	D_3 = 0

6. Draw the average (R), UCL_r and LCL_r as solid line on the "control chart" on range chart. Compare all the sub groups against the UCL_r and LCL_r.
7. If any sub group goes out of control limits, then it is sign of presence of special causes.
8. For establishing the control limits and carrying out capability study, calculate the control limits to exclude the effect of out control periods. Exclude all sub groups affected by the special cause, examine the remaining sub group for homogeneity by repeating steps 3-7 till range chart shows control, but there should not be too many exclusions

2.2 Calcualting The Process Capability Index (Cp,Cpk)

i. Estimate the process standard deviation (σ) by the following method

$$\sigma = Rbar/d_2$$

where d_2 = 2.33 for n = 5

where Rbar is the average of sub group ranges.

ii. Calculate the process capability as given below:

Process Capability Cp = (USL – LSL)/ 6σ

= tolerance / 6σ

Process Capability Index C_{pk} = Minimum of Cpl, Cpu

Cpl = (Xbar – LSL)/ 6σ

Cpu= (USL – Xbar)/3σ

σ = Standard Deviation

X bar = Mean find in the X bar chart

USL =Upper specification Limit

LSL= Lower Specification Limit

2.3 Process Capability Index (Cp,Cpk)

For the process in control satisfactorily Cp and Cpk ≥ 1By convention, when a process has a Cp value less than 1.0, it is considered potentially incapable of meeting specification requirements. Conversely, when a process Cp is greater than or equal to 1.0, the process has the potential of being capable. By convention, when the Cpk is less than one, the process is referred to as incapable. When the Cpk is greater than or equal to one, the process is considered capable of producing a product within specification limits. In a Six Sigma process, the Cpk equals 2.0. Ideally, the Cp should be as high as possible. The higher the Cp, the lower the variability with respect to the specification limits. In a process qualified as a Six Sigma process (i.e., one that allows plus or minus six standard deviations within the specifications limits), the Cp is greater than or equal to 2.0.

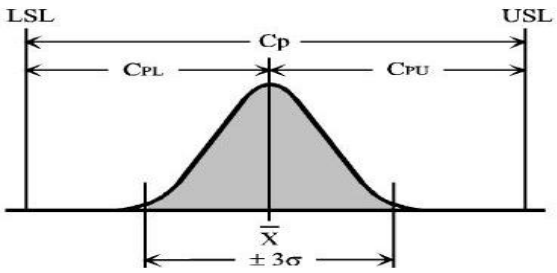

Fig-2: Shows the Relationship between Cp and Cpk

3. REVIEW OF RELATED LITERATURE

Number of researchers has published research papers on the topic of SPC. The literature that deals on SPC for effectively optimizing a process is quite vast. Some of the are given below

Héctor Ramírez and Eloy Mendoza [1] (2015) investigated how the augmented reality (AR) can help to the SPC, to guarantee the quality of the products by reducing the times of training, or showing instructions on real-time of how the staff need to measure this values correctly.Today companies invest on statistical process control (SPC), where they seek to measure key values in the manufacturing processes, to maintain the quality in the products. The problem is that the measurement of these values can be affected by the expertise of the staff because of poor training, a high staff turnover, or because the complexity of the process.For this experiment two groups of young engineers were given a set of instructions to do a quality process measuring. On one team a manual instructions was provided and on the other team an application of augmented reality where the subject can watch on site the instructions on real time of the process. With the analysis of the results it was determined that the group with the augmented does the process up to 30% faster

Amir Azizi [2] (2015) integrated the Statistical Process Control (SPC), Overall Equipment Efficiency (OEE), and Autonomous Maintenance (AM) to achieve continuous improvement in the production capability. This integration enhanced the productivity performance, evaluate production productivity by continuously improve the equipment efficiency and process control in tiles manufacturing industry. OEE is indicator to measure the equipment efficiency. Analysis and efficiency improvement are carried out using Define, Measure, Analyze, Improve and Control (DMAIC). SPC is suggested as monitor function for evaluating the process quality performance and the seven basic tools are used to tackle the manufacturing process variations. AM is applied in the glazing line to improve the machine efficiency by giving more responsibility and authority to the operators to do more improvement and preventative actions to their own machines. Result of the implementation of AM has successfully reduced 8.49% of the defect rates of glazing line from 14.61% to 6.12%. Machine breakdown time has been decreased from 2502 minutes to 1161 minutes whereas the OEE has been improved 6.49% from 22.12% to 28.61%.

Pavol Gejdos [3] (2015) studied the tools of statistical process control, through which we can achieve continuous quality improvement. The advantage of these tools is that they can identify the effects of the processes that cause unnatural variability in processes that result of errors and poor quality. He concluded that SPC as a very effective tool in ensuring process stability and benefits of the use of SPC with DMAIC (*Define, Measure, Analyze, Improve and Control)* improvement model. This combination of tools is very suitable for achieving the desired objectives of quality improvement and efficient manner can help solve all tasks and problems of the process of quality improvement.

Pranay S. Parmar, Vivek A. Deshpande [4] (2014) concluded from case studies that the SPC techniques can give the significance improvement to the quality. These tools and techniques are simple to implement and it needs the top management involvement and employee support. In this paper it has found that the SPC tools can be applied to different product for reducing the defect and are used globally to improve quality. SPC seems to be a collection of statistically based problem-solving tools.

Sarina Abdul Halim Lim and Jiju Anton [5] (2014) investigate SPC is applied in the food industry with huge benefits in the business to diverse stakeholders .SPC implementation in the food industry is beneficial and guidelines relating to SPC implementation in the food industry has resulted in a slow adoption. Although there are limitations and barriers impeding the implementation, if the implementation wasdone correctly and greatly facilitated, SPC can be a versatile technique for managing quality improvement in the food industry and sustaining the quality of food products.

Dr. D. R. Prajapati [6] (2012) found that statistical process control (SPC) techniques in the automotive industry is offering customers the widest and latest range of sealing solutions. SPC analysis may easily help in improving the efficiency of the manufacturing process thus decreasing the number of defective products, thus saving a lot of re-work cost and valuable time. For each specific product the suggested preventions can considerably decrease the loss to the industry in terms of both money and time. Although, improvement in rejection level of all the other products of the industry is noticed, shocker seals were the main concern because the rejection level of this product was more than 9.1%. After implementing the required suggestions /recommendations for shocker seals, it is found that process capability is improved and it is greater than required.

B.P. Mahesh & M.S. Prabhuswamy [7] (2010) illustrates the step by step procedure adopted at a soap manufacturing company to improve the Quality by reducing process variability using Statistical Process Control. Span of one year, many easily executable Remedies were implemented. Then the entire study was

repeated again for the production lines. Post implementation study revealed that defects rate drastically came down thus reducing the process variability. improvements in Cp and Cpk values were obtained

Bimal Mishra and G.S. Dangayach [8] (2009) found on their research that Statistical Process Control (SPC) is an effective statistical tool used to prevent defects on a cigarette-manufacturing company in Nepal. The research was carried out on three cigarette-making machines, i.e., 01, 02 (plain makers) and 09 (filter cigarettes with premium brands), which have high variability in circumference. The initial data were taken on all three machines, and then special causes were eliminated. After eliminating special causes, the CP (process capability indices) was increased for Maker-02 from 0.343 to 0.709 and for Maker-09 from 0.521 to 1.044. Thereafter, several common causes were identified and eliminated, which resulted in an increase in CP (process capability indices) for Maker-02 up to 1.0567 from 0.343 and for Maker-01, up to 1.0372 from 0.717. Other recommendations and suggestions for preventive as well as corrective action were also made based on Failure Mode and Effect Analysis (FMEA).

Bharatendra K. Rai [9] (2008) concluded that using SPC & control charts, out-of control situations are reduced from over 66% to about 4%. When a major quality problem faced by tea packaging units is control of weight variation in the tea packets. When the weight variation in tea packets is high, it is likely that buyers get under weight packets in some segments of the market and overweight packets in some other segments. Although an average consumer may not notice the difference, packet weight below certain limit may require the company to pay a substantial amount as fine to the government regulating agencies that conduct such audits. At the same time over weight packets constitute an additional loss to the company. Although SPC & control charts are well suited to help control such weight variation, their successful implementation at the machine requires a user-friendly approach for the operators who need to maintain it on a daily basis.

Chandandeep Grewal and A.D. Gupta [10](2006) found that Statistical Process Control is an effective means for controlling and improving the process quality & with the application of variable control charts, significant improvement has been experienced in terms of process capability indices and defective parts per million. PPM level in each case has reduced drastically which is a step to achieve the six sigma level. The company is a leading manufacturer of mechanical locking systems, door handles and security systems for automotive .The company is accredited with ISO 9001 and QS 9000 quality standards. The company has more than 200 employees and it is located in NOIDA. Major customers of the company in four wheeler segments are Ford, Telco, Fiat, Maruti, General Motors etc., and in two wheeler segments are Bajaj Auto, Kinetic Motors, LML, Yamaha, Hero Motors etc. The company has separate quality assurance department. Four critical variables i.e centre distance, hole location, groove location and diameter were selected on the basis of rejections due to them.

4. CONCLUSION

From the above we concluded that SPC is a effective tool of quality and process control in all type of industry not only manufacturing industry where quality and customer satisfaction is the major concern. The power of SPC lies in the ability to examine a process and the sources of variation in that process, using tools that give weightage to objective analysis over subjective opinions and that allow the strength of each source to be determined numerically.

A high Cp value doesn't guarantee a production process falls within specification limits because the Cp value doesn't imply that the actual spread coincides with the allowable spread (i.e., the specification limits). This is why the Cp is called the process potential. The process capability index Cpk, measures a process's ability to create product within specification limits. The higher the Cpk, the narrower the process distribution as compared with the specification limits, and the more uniform the product. As the standard deviation increases, the Cpk index decreases. At the same time, the potential to create product outside the specification limits increases.

The Cpk index can never be greater than the Cp, only equal to it. This happens when the actual process average falls in the middle of the specification limits.

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