IMPORTANCE OF PROCESS CAPABILITY AND PROCESS PERFORMANCE INDICES IN MACHINE TOOL

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ABSTRACT

A process is a unique combination of machines, tools, methods and personnel engaged in providing a product or service. Process capability indices have been used in the manufacturing industry to provide quantitative measures on process potential and performance. The output of a process can be product characteristic or process output parameter. Process capability indices (Cp, Cpk,) provide a common metric to evaluate and predict the performance of processes. In this study, at the first the process capability indices are presented Then machine capability indices are discussed Finally, process performance indices Pp, Ppk, and difference between Cpk and Ppk are presented

***Keywords**: Process Control Process Capability, Machine Capability, Process Performance, Indices.*

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1. INTRODUCTION

High quality production provides some advantages such as reduced scrap or remachining and increased market share. For this purpose there are some requirements to be met. First of all the organization should be cooperative and the quality should come first. On the other hand, in order to meet quality requirements of final product, quality should be achieved at every stage of production [1]. Another way of achieving good quality during production is to use the statistical period techniques at every stage of production. If the production is statistically under control the process can continue and there is no need for a change in the process. However, if it is not statistically under control, the assignable causes should be discovered and removed from the process. Statistical quality control methods apply statistical principles and techniques at every stage of design, manufacturing, and servicing. Statistical quality control methods are quite different from traditional methods and they have made great contribution to improvements in companies dealing with mass production.

The process needs to be in control before it assess its capability, if it is not then it will get incorrect estimates of process capability. A process is a unique combination of machines, tools, methods and personnel engaged in providing a product or service. The output of a process can be product characteristic or process output parameter. Process capability indices provide a common metric to evaluate and predict the performance of processes. It can assess process capability graphically by drawing capability histograms and capability plots. These graphics help us assess the distribution of the data and verify that the process is in control. It can also calculate capability indices, which are ratios of the specification tolerance to the natural process variation. Capability indices, or statistics, are a simple way of assessing process capability. Because they are unitless, it can use capability statistics to compare the capability of one process to another.

Process capability compares the output of an in-control process to the specification limits by using capability indices. The comparison is made by forming the ratio of the spread between the process specifications (the specification "width") to the spread of the process values, as measured by 6 process standard deviation units (the process "width"). Process capability attempts to answer the question that can be consistently meet customer requirements. The number one limitation of process capability indices is that they are meaningless if the data is not from a controlled process. The reason is simple: process capability is a prediction and you can only predict something that is stable.

Process capability indices, as a process performance measure, have become very popular in

assessing the capability of manufacturing processes in practice during the past decade. More and more efforts have been devoted to studies and applications of process capability indices. For example, Rado (1989) demonstrated how imprimis technology, Inc. used the process capability

indices for program planning and growth to enhance product development. The Cp and Cpk indices have been used in Japan and in the US automotive industry such as Ford Motor Company (Kane, 1986a, b). For more information on Process capability indices (Kotz and Johnson, 1993;, Kotz *et a/.,* 1993).

Because the sample mean and the sample variance are not unitless, they can be cumbersome as summary statistics for the process location and variance, respectively. This is particularly true in a manufacturing process with many characteristics to be examined. Capability indices are unitless and associate the process location and variance with one-sided or two-sided specifications, with or without a target value for the process mean. These indices provide an effective means for communicating assessments of the process capability. The capability indices relate the manufacturer's specifications to the natural tolerance of six standard deviations used in US quality control literature.

In this study, at the first, a process capability indices (Cp, Cpk,) are presented Then machine capability indices are discussed. Finally, process performance indices Pp, Ppk, are presented. Also, differences between process capability and process performance indices are explained.

2. PROCESS CAPABILITY INDICES

Process capability studies are used for monitoring the capability of a process. This implies that it has to be based on some sort of collection of data from the process. In order to get a fair picture of the capability of the process, it has to be stable when the data is collected After the collection of data from a stable process, the data may be assessed in several ways. One way to do the assessment is to use process capability indices, which provide numerical measures of the capability.

Capability Requirement:

The statistical properties of the two estimator CPU, and CPL are exactly the same. For convenience of presentation, let CI be either CPU or CPL. In current practice, a process is called ``inadequate'' if CI < 1.00; it indicates that the process is not adequate with respect to the production tolerances specifications, either process variation needs to be reduced or process mean needs to be shifted closer to the target value T. A process is called capable if $1.00 \leq CI \leq 1.33$; it indicates that caution needs to be taken regarding process distribution,

some process control is required. A process is called satisfactory if $1.33 \leq CI \leq 1.50$; it indicates that process quality is satisfactory, material substitution may be allowed, and no stringent quality control is required. A process is called excellent if $1.50 \leq CI \leq 2.00$; it indicates that process quality exceeds ``satisfactory'' and a process is called ``super'' if CI >2.0. Table I summarizes the five conditions and the corresponding CI values (W.L Pearn and K.S. Chen2002)

Quality condition	C_I values
Inadequate	$C_I < 1.00$
Capable	$1.00 \leq C_I \leq 1.33$
Satisfactory	$1.33 \leq C_I \leq 1.50$
Excellent	$1.50 \leq C_I \leq 2.00$
Super	$2.00 < Ci$

Process capability Cp: The process capability Cp is defined to be:

$$Cp = 6\,\sigma$$

A process is said to be capable if the value of Cp is 1, Cp is used to determine the system location in tolerance limits. The size of deviations from the average value of process dimensions will indicate how well the production is. If the system is not at the center of specification values, the trend of Cp is progressing faultily.

Process capability index Cpk: It is used to determine the average so that the system will works better in the specification limits. If the value of Cpk is 1 it shows that the manufacturing is going on in the system specification limits staying at 99.73% level (+3σ limits). If the system centralized at the target value, Cp and Cpk values will be equal. When the values of Cp and Cpk is 1, this is considered, as the minimum requirement of the system for some companies. Cpk is defined to be:

$$Cpk = \min (USL - \mu / 3\sigma ,\ \mu - LSL / 3\sigma)$$

After studying process capability, process capability index, it is seen that only Cp relates tolerance interval to the process 6 σ where as Cpk relates to target value.For satisfactory results Cp and Cpk should be higher than 1.33. If the average right on target Cp and Cpk are same as shown in fig no. 1. The more of target value, the bigger the difference between Cp and Cpk.Cpk can never be higher than Cp.

	Bad Cp Good	
Bad CpK Good	Process not capable Change tool or adjust for good accuracy	Process capable But average needs to be adjusted
	not possible	Process capable and well adjusted

Fig. no.1 relation between Cp and Cpk

3. MACHINE CAPABILITY

Process capability is calculated over a long period of time and is influenced by manufacturing environment. Machine capability is calculated within a short period .The impact of all the materials and parts must be eliminated this is used for to audit the quality behavior of the single machine. The calculations are same for Cm, Cmk as Cp, Cpk respectively. Cm and Cmk determine whether the machine tool is capable or not. Fig no. 2 shows the different parameters which causes the variation in the process. Each of these parameters contribute some degree of variability to the process.

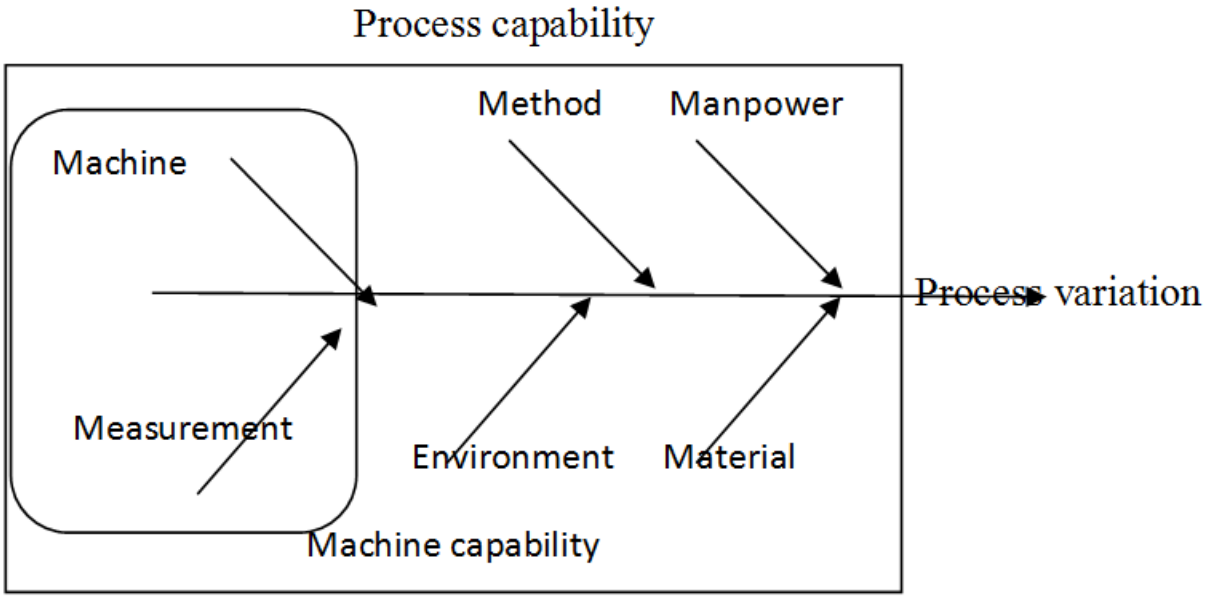

Fig.no.2 Fish bone diagram

4. PROCESS PERFORMANCE INDICES

Process performance index basically tries to verify if the sample that have generated from the process is capable to meet customer requirement. It differs from process capability in that

process performance only applies to specific batch of material. Process performance is only used when process control can not be evaluated .

Process performance index(Pp)-The ratio of tolerance to the variation in sample .when value of Pp is 1 ,it indicates the sample variation exactly equals to the tolerance. Under normal distribution Pp is given by

$$P_p = \frac{\text{HighSpec} - \text{LowSpec}}{6\sigma_X}$$

Process performance index(PpK)-This gives measure of both process dispersion and its centering about average.

$P_{pk} = \text{Min}[\text{Ppl}, \text{Ppu}]$ where

$$P_{pl} = -\frac{Z_L}{3},\ P_{pu} = -\frac{Z_U}{3}$$

Under normal distribution PpK is given by

$$Z_L = \frac{\bar{\bar{X}} - \text{LowSpec}}{\sigma_X}, Z_U = \frac{\text{HighSpec} - \bar{\bar{X}}}{\sigma_X}$$

5. DIFFERENCE IN PROCESS CAPABILITY INDEX AND (CPK) AND PROCESS PERFORMANCE INDEX(PPK)

Cpk is a shorter term and Ppk is a broader term. If you want to know how much variation the process exhibits a Ppk measurement is useful. If you want to know how that process affect the ability of process to meet customer requirement Cpk is useful. Cpk gives us the idea about the process capability of the machine which can be used in the future. But the Ppk gives the idea about what you have done in the past. "Ppk produces an index number (like 1.33) for the process variation. Cpk references the variation to your specification limits. If you just want to know how much variation the process exhibits, a Ppk measurement is fine. If you want to know how that variation will affect the ability of your process to meet customer requirements (CTQ's), you should use Cpk." Michael Whaley

"It could be argued that the use of Ppk and Cpk (with sufficient sample size) are far more valid estimates of long and short term capability of processes since the 1.5 sigma shift has a shaky statistical foundation." Eoin

"Cpk tells us what the process is capable of doing in future, assuming it remains in a state of statistical control. Ppk tells you how the process has performed in the past. You cannot use it predict the future, like with Cpk, because the process is not in a state of control. The values

for Cpk and Ppk will converge to almost the same value when the process is in statistical control. that is because Sigma and the sample standard deviation will be identical (at least as can be distinguished by an F-test). When out of control, the values will be distinctly different, perhaps by a very wide margin."

6. CONCLUSION

Capability analysis helps to determine the ability for manufacturing between tolerance limits and engineering specifications. Capability analysis can be applied not only to production period but also to a machine or machine tool. Capability analysis gives the information about changes and tendencies of the system during production. It is used to determine the system tendencies between tolerance limits.

As it can be seen from the study accomplished, the process control and capability method is more effective for determining the quality problems and solving them in small and medium sized companies that manufacture parts by machining and develop more efficient processes in order to survive in the competitive market. Thereby, correct understanding of the components of variables, definition of factors causing variations and keeping them under control is all important for small sized companies.

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