# CRITICAL SUCCESS FACTOR ANALYSIS AND APPLICATION OF PROCESS CAPABILITY MEASUREMENT FOR IMPROVEMENT IN PRODUCTIVITY

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***Abstract—*** *Process capability is an important concept for industrial managers to understand. The challenge in today's competitive markets is to be on the leading edge of producing high quality products at minimum costs. This cannot be done without a systematic approach and such approach is contained within what has been called 'statistical quality control 'or' Industrial statistics'. The segment of statistical quality control discussed here is the process capability study. So why process capability so important? Because, it facilitates to manufacturer of a part are an important determination of a cost and quality of the resulting production. If the processing equipment selected is sufficiently accurate to meet quality target as established by tolerance reasonable costs and acceptable quality can be expected. If the processing equipment cannot consistently meet the quality target, high costs, scrap and reworked materials are inevitable outcomes.*

***Keywords— Process Capability; Machine; Product; Quality Control***

## 1. INTRODUCTION

In some companies, experienced manufacturing engineers, operators and foreman have learned from long experience that 'Machine 27' can handle the close turning work up to ± 0.002 inch and 'Machine 33' is better for the work from ± 0.003 to ± 0.006 inch. Since such knowledge about the performance capability of processing equipment is essential to the proper functioning of a quality control program. Many plants have made scientific investigation of these capabilities a keystone of their entire product and process control programme. It needs to develop techniques for this investigation, which were more effective for quality control purposes, the old rule of thumb techniques developed for this work is the process capability study.

In planning the quality aspects of operations, nothing is more important than advance assurance that the processes will meet the specifications. In recent decades, a concept of process capability has emerged to provide a quantified prediction of process adequacy. This ability to predict quantitatively has resulted in widespread adoption of the concept as a major element of quality planning. Process capability is the measured, inherent variation of the product turned out by a process. A process capability study is determination of total spread of the product as determine by measuring the product under controlled conditions. The process capability is independent of the specification but is determined by as follows

- Condition of the machine
- Operator skill
- Tooling
- Type of operations
- Raw materials used

## 2. OBJECTIVE

1. To prepare the control chart, so that speed of work enhances. As refer data this work was not carried outyet.
2. To improve productivity and quality of the product through process capability study.
3. All the observation and ideas related with the control charts will be verified and implemented by carrying out a case study in some organization.
4. In the view of social aspect by using this work, it will be tried to minimize the cost of finished product, so that it will help to the society

## 3. CASE STUDY

Tirupati conductors Pvt. Ltd, Jalgaon (M.S.) is one of the vendor of Bosch Chassis Systems India Ltd., Jalgaon (M.S.). It is started in 1992. The Director of company is Mr. S. M. Agrawal. From 1992 to 1997 company was manufacturing implements parts. Now from 1998 company is working on CNC machining. The Tirupati conductor Pvt. Ltd. is located in Mohadi shivar, Shirsoli road, nearly 8 km away from Jalgaon city. It is near to Bosch chassis systems India Ltd. Jalgaon. (M.S.) Tirupati Conductors Pvt. Ltd. also supplies various parts to Jain Irrigation Pvt. Ltd.; Supreme Pipes etc. The various parts produced by the TCPL are as follows.

- Control valve cylinder Head.
- Top link Crank
- TMC
- High tension Line Conductors
- Fuses

## A. Data Collection

Case No. 01
Operation No. 20
Part Name- C.V. Cylinder Head
Instrument Use – Dial Snap Guage.

TABLE 1 DATA COLLECTION OF CASE NO.01

| Sr. No. | 1 | 2 | 3 | 4 | 5 | $\overline{X}$ | R |
|---|---|---|---|---|---|---|---|
| 01 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.03 |
| 02 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.04 |
| 03 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.04 |
| 04 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.06 |
| 05 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.08 |
| 06 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.04 |
| 07 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.04 |
| 08 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.08 |
| 09 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.06 |
| 10 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.04 |

Mean of the Median = ∑ /n = 761.462/10 = 76.146
Mean of the Range = ∑R/n =0.056/1 = 0.0056Standard Deviation = σ = R/d2
Taking Statistical Constant for n=5; d2 = 2.32
σ = 0.0056/2.326
σ = 0.00267
For Statistical Constant for control chart, for sample size n=5; taking A2=0.577, D4=2.114 and D3 =0
U.C.L. = + A2 × R
= 76.146 + (0.577 × 0.0056)
U.C.L. = 76.150
L.C.L. = - A2. R
= 76.146-(0.577×0.0056)
L.C.L. = 76.143
U.C.L. R = R . D4
= 0.0056 × 2.114
U.C.L. R = 0.012238
L.C.L. R = R D3 = 0
Specification Width = Tolerance = S
S = 76.175 - 76.125
S = 0.05
Index, k = { 2×(D- )/S }
k = {2×(76.150 -76.146 )/0.05}
k = 0.16

$$Cp = \frac{\text{Specification Width}}{6.\sigma}$$

Cp = 0.05 / ( 6 × 0.00267)
Cp = 3.12
Cpk = (1- k) Cp
Cpk = (1- 0.16) 3.12
Cpk = 2.62
For Histogram
Number of Observation = n =50
Number of Classes = 6

$$\text{Interval} = \frac{\text{Maximum Value} - \text{Minimum Value}}{\text{No. of Classes}}$$

| Interval | Freq. | Cum Freq. |
|---|---|---|
| 76.140-76.142 | 2 | 2 |
| 76.142 – 76.144 | 5 | 7 |
| 76.144 – 76.146 | 31 | 38 |
| 76.146 – 76.148 | 7 | 45 |
| 76.148 – 76.150 | 0 | 45 |
| 76.150 – 76.152 | 2 | 47 |
| 76.152 – 76.154 | 3 | 50 |

Case No. 02
Operation No. 20
Part Name- C.V. Cylinder Head
Instrument Use- Dial Snap Guage.

TABLE 2 DATA COLLECTION OF CASE NO.02

| Sr. No. | 1 | 2 | 3 | 4 | 5 | $\overline{X}$ | R |
|---|---|---|---|---|---|---|---|
| 01 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.08 |
| 02 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.04 |
| 03 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.04 |
| 04 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.08 |
| 05 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.08 |
| 06 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.04 |
| 07 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.04 |
| 08 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.08 |
| 09 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 76.1 | 0.06 |
| 10 | 76.145 | 76.144 | 76.148 | 76.145 | 76.148 | 76.146 | 0.004 |

Mean of the Median = ∑ $\overline{X}$ /n = 761.462/10 = 76.146
Mean of the Range = ∑R/n = 0.056/10 = 0.0057
Standard Deviation = σ = $R/d_2$
Taking Statistical Constant for n=5; $d_2$ = 2.32
σ = 0.0057/2.326
σ = 0.00271
For Statistical Constant for control chart, for sample size n=5; taking $A_2$=0.577, $D_4$=2.114 and $D_3$ =0
U.C.L. $\overline{X}$ = $\overline{X}$ + $A_2$ × R
= 76.146 + (0.577 × 0.0057)
U.C.L. $\overline{X}$ = 76.150
L.C.L. $\overline{X}$ = $\overline{X}$ - $A_2$. R
= 76.146-(0.577×0.0057)
L.C.L. $\overline{X}$ = 76.143
U.C.L. $_R$ = R . $D_4$ = 0.0057 × 2.114
U.C.L. $_R$ = 0.0122
L.C.L. $_R$ = R . D3 = 0
Specification Width = Tolerance = S
S = 76.175 - 76.125
S = 0.05

Index, k = { 2×(D- $\overline{X}$ )/S }
k = {2×(76.150 -76.146 )/0.05}
k = 0.16

$$Cp = \frac{\text{Specification Width}}{6.\sigma}$$

Cp = 3.075

$C_{pk}$ = (1- k) Cp

$C_{pk}$ = (1- 0.16 ) 3.075

$C_{pk}$ = 2.583

For Histogram

Number of Observation = n =50

Number of Classes = 6

$$\text{Interval} = \frac{\text{Maximum Value} - \text{Minimum Value}}{\text{No. of Classes}}$$

$$= \frac{76.153 - 76.142}{6}$$

= 0.002

| Interval | Freq. | Cum Freq. |
|---|---|---|
| 76.141 -76.143 | 1 | 1 |
| 76.143 – 76.145 | 21 | 22 |
| 76.145 – 76.147 | 12 | 34 |
| 76.147 – 76.149 | 8 | 42 |
| 76.149 – 76.151 | 2 | 44 |
| 76.151 – 76.153 | 6 | 50 |

**Case No- 03**

Operation No. 20

Part Name- C.V. Cylinder Head

Instrument Use- Dial Snap Guage.

TABLE 3 DATA COLLECTION OF CASE NO.03

| Sr. No. | 1 | 2 | 3 | 4 | 5 | $\overline{X}$ | R |
|---|---|---|---|---|---|---|---|
| 01 | 76.14 | 76.14 | 76.14 | 76.14 | 76.146 | 76.14 | 0.04 |
| 02 | 76.14 | 76.14 | 76.14 | 76.15 | 76.15 | 76.14 | 0.07 |
| 03 | 76.14 | 76.14 | 76.14 | 76.14 | 76.14 | 76.14 | 0.04 |
| 04 | 76.14 | 76.14 | 76.14 | 76.15 | 76.14 | 76.14 | 0.08 |
| 05 | 76.14 | 76.14 | 76.14 | 76.15 | 76.15 | 76.14 | 0.08 |
| 06 | 76.14 | 76.14 | 76.14 | 76.14 | 76.14 | 76.14 | 0.04 |
| 07 | 76.14 | 76.14 | 76.14 | 76.15 | 76.15 | 76.14 | 0.08 |
| 08 | 76.14 | 76.14 | 76.14 | 76.14 | 76.14 | 706.14 | 0.06 |
| 09 | 76.14 | 76.14 | 76.14 | 76.14 | 76.14 | 76.14 | 0.08 |
| 10 | 76.14 | 76.1 | 76.1 | 76.14 | 76.14 | 76.14 | 0.03 |

Mean of the Median = $\sum \overline{X}$ /n = 76.1464

Mean of the Range = ∑R/n = 0.0053

Standard Deviation = σ = $R/d_2$

Taking Statistical Constant for n=5; $d_2$ = 2.32

σ = 0.0053/2.326

σ = 0.00256

For Statistical Constant for control chart, for sample size n=5; taking $A_2$=0.577, $D_4$=2.114 and $D_3$ =0

U.C.L. $\overline{X}$ = $\overline{X} + A_2 \times R$

= 76.1464 + (0.577 × 0.0053)

U.C.L. $\overline{X}$ = 76.150

L.C.L. $\overline{X}$ = $\overline{X} - A_2 . R$

= 76.1464 -(0.577×0.0053)

L.C.L. $\overline{X}$ = 76.143

U.C.L. $_R$ = R . $D_4$ = 0.0053 × 2.114

U.C.L. $_R$ = 0.01120

L.C.L. $_R$ = R . D3 = 0

Specification Width = Tolerance = S

S = 76.175 - 76.125

S = 0.05

Index, k = { 2×(D- $\overline{X}$ )/S }

k = {2×(76.150 -76.1464 )/0.05}

k = 0.144

$$Cp = \frac{\text{Specification Width}}{6.\sigma}$$

Cp = 3.2552

$C_{pk}$ = (1- k) Cp

$C_{pk}$ = (1- 0.144) 3.2552

$C_{pk}$ = 2.7865

For Histogram

Number of Observation = n =50

Number of Classes = 6

$$\text{Interval} = \frac{\text{Maximum Value} - \text{Minimum Value}}{\text{No. of Classes}}$$

$$= \frac{76.153 - 76.144}{6}$$

= 0.0019

| Interval | Freq. | Cum Freq. |
|---|---|---|
| 76.1430 -76.1449 | 3 | 3 |
| 76.1449 – 76.1468 | 28 | 31 |
| 76.1468 – 76.1487 | 12 | 43 |
| 76.1487 – 76.1506 | 1 | 44 |
| 76.1506 – 76.1525 | 3 | 47 |
| 76.1525 – 76.1544 | 3 | 50 |

**Analysis of Capability Indices and Process Cost**

The part under study, C.V. cylinder head has various cutting parameters affecting the operation such as vibration, speed; feed, depth of cut, nature of coolant, noise, temperature etc. But from the study point of view we have consider only three parameters as follows

(1) Speed of Machine

(2) Feed Rate

(3) Depth of cut

As per data analysis for Case 01; case 02 and Case 03 as follows

The values of capabilities indices are as follows

For Case -01

Cp = 3.12

$Cp_k$ = 2.62

*For Case -02*

Cp = 3.075

$Cp_k$ =2.583

*For Case -03*

Cp = 3.2552

$Cp_k$ = 2.7865

The above three case 01,02 and 03 the process are in statistical control, the operating conditions for above cases are as follows

Speed of Machine = 650 rpm

Feed Rate = 0.18 mm/rev

Depth of cut = 0.3mm

The production rate for above operating conditions was 80 parts / 8Hrs.(Shift). The process is in statistical control and there is scope for optimization of process costs by bringing the values of $Cp_k$ nearly equal to 1.67 ($Cp_k$ =1.67)

For decreasing the values of Cp and $Cp_k$, the following change, are to be done

Speed of machine= 750rpm.

Feed rate = 0.25mm/rev

Depth of cut = 0.6mm

By increasing all above three parameters on same machine (LTC-20 ) and same casting job; The capability indices obtained after data analysis for case No 04, Case No -05 and Case No -06 are as follows

For Case -04

Cp = 2.20

$Cp_k$ = 1.76

For Case -05

Cp = 2.142

$Cp_k$ = 1.798

For Case -06

Cp = 2.13

$Cp_k$ = 1.933

**<u>Process Cost Analysis</u>**

Cost analysis gives the details information of cost, which affect after the process capability measurement. For reduction of process cost through process capability measurement, it will be consider the following points for analysis of process cost.

(1) Tool Cost
(2) Inspection (Gauge) Cost
(3) Labour costs.

**(1) Tool Cost:** Tool is very important for any machining process operation. Tools cost plays a very important role in calculating a tool costs of production.

Before improvement:

For Case01, 02 and 03

Tool used was Carbide (HIP) Sandwich having a cost of Rs.200/Insert.

Tool cost = 200 Rs/Insert

Tool cost /edge =200/4=50 Rs/edge

Tool life =50Pieces/Insert

=50/4 Pieces/edge

=12.5 Pieces/edge

$$\text{Tool Cost} = \frac{\text{Cost / edge}}{\text{Pieces /edge}}$$

Tool cost = 4 Rs/Pieces

After Improvement:

After Changing a tool;

Net saving in cost of tool =(4.000-2.905)

Net saving in cost of tool =1.0945 Rs/Piece

**(2) Inspection (Gauge) Cost:**

For inspection of Op-20 Dial snap gauge is used having a cost of Rs.800.

Before improvement:

For case01, case02 and case03

The values of $Cp_k$ are as follows

Case-01; $Cp_k$ =2.62

Case-02; $Cp_k$ =2.583

Case-03; $Cp_k$ =2.7865

In this case the checking frequency was 100% because tolerance was ±0.025mm.

Total parts inspected =15000 parts/gauge

Cost of gauge = Rs. 800

Inspection Cost=800/15000

Inspection Cost = 0.0533 Rs/Part

After Improvement:

For case -04, Case-05 and Case-06

The values of $Cp_k$ are

Case-04; $Cp_k$ =1.76

Case-05; $Cp_k$ =1.79

Case-06; $Cp_k$ =1.933

Now we use sample inspection (i.e. 1:5) with the help of sample inspection wear and tear of gauges are decreased and life of dial snap gauge is increased.

Total parts Inspected = 15000 ×5

= 75000 parts

cost of gauge = Rs.800

Inspection(gauge) cost = 800 / 75000

= 0.01066 Rs./ Parts

Due to increase in dial snap gauge life ,

Net saving in gauge costs = 0.0533 - 0.01066

= 0.04264 Rs/part

Net saving in gauge cost = 0.04264 Rs. / Part

**(3) Labour Cost:**

For case 01,02 and 03,

$Cp_k$ = 2.62 (Case 01)

$Cp_k$ = 2.383 (Case 02)

$Cp_k$ =2.7865 (Case 03)

Required value of $Cp_k$ is 1.67, but above $Cp_k$ values, case 01,02 and03 these process are good but there is again scope to increase speed, feed and production rate can be increased.

Before Improvement:

(Considering 8 hrs shift)

Labour Salary = 13000 Rs/Month

=433.33 Rs/day

=18.05 Rs/hrs

Production Rate = 80 parts /shift

= 80/8

= 10 Parts / Hrs.

Labour Cost =18.05 /10

Labour Cost =1.80 Rs/Parts

After Improvement:

For case -04, Case-05, Case-06, we obtain,

The values of $Cp_k$ are

$Cp_k$ =1.76 (Case-04)

$Cp_k$ =1.798 (Case-05)

$Cp_k$ =1.933 (Case-06)
Labour Salary = 18.05 Rs/Hrs
Production Rates = 90 Parts / Shift
=11.25 Parts / Hrs.
Labour Cost = 18.05/11.25
Labour Cost = 1.60 Rs/part
Due to improvement in Cp and $Cp_k$ the production rate is increased from 80 to 90 parts per shift.
Net Saving in labour costs = 1.80-1.60
=0.20 Rs/parts
Net Saving in labour cost = 0.20 Rs/parts

As Cp and Cpk improves, the cycle time decrease means production rate per shift increases and other costs such as operator cost; electricity cost; manual compensation cost and inspection cost is saved. All above cost factors plays a very important role to decrease in total costs of production.

## 4. CONCLUSION

There are many industrial applications, which may important for reduction of process costs. Once of the benefits from the process is the capability of large area of processing, which can reduce production cost significantly. After considering the components supplied by the vendor Tirupati Conductors Pvt. Ltd., Jalgaon, out of them the most critical (C.V. Cylinder Head) component was selected for case study purposes. Process sheet and flow process chart studied in order to know the operations which was important for production for C.V. Cylinder Head with there specifications provided on the drawings.

After running process capability study for OP-20, values of $Cp_k$ found to be near to 2.6 but as per standard value of $Cp_k$ is 1.67. At present $Cp_k$ , process can be perform in good. So try to reduce the value of process capability indices. For reducing process capability indices, It may be try to increase the speed of machine, feed rate and depth of cut which is used in OP-20.

By increasing the speed, feed and depth of cut; the result is that process capability indices ($Cp_k$) reduced. (Near to 1.67) The effect of reducing process capability indices ($Cp_k$ nearly equal to 1.67), there is a saving in inspection costs, labour costs and tool costs. The overall effect is that large amount of saving in total production cost for mass production.

From the case study, it may conclude that it is not necessary to maintain high value of process capability indices, we can get high production rate if we maintain the value of Cpk nearly equal to 1.67.

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