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ABOUT MANUFACTURING PROCESSES CAPABILITY ANALYSIS.

II. CASE STUDY

BY

CĂTĂLIN UNGUREANU* and RADU IBĂNESCU

“Gheorghe Asachi” Technical University of Iaşi,
Faculty of Machine Manufacturing and Industrial Management

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Abstract. The capability analysis of manufacturing processes is a complicated task. It is necessary to go through some steps to verify the distribution of values for the quality feature tracked. Then the percentage of products outside specified limits can be estimated. The paper presents such a case study.

Key words: quality management, statistical process control, process capability.

1. Introduction

As a quantitative measure, process capability indices are widely used to determine whether a process is capable of producing items within designer specification limits. The objective of these statistical measures is to estimate process variability relative to process specifications. Furthermore, a process capability index provides a common standard of product quality to suppliers and customers (Jeang & Chung, 2009).

*Corresponding author; *e-mail:* cungurea@zahoo.com

In order to estimate the percentage of process capability and potential non-compliant products will go through several stages. At first it will check the homogeneity of the data collected using the iterations method. It has two variants, depending on the parameter tested: the total number of iterations or the maximum length of iteration. In the second phase will verify the normality of the distribution frequency characteristic values as followed. For this Kolmogorov Smirnov test are used. Then if empirical distribution approaches to a Gaussian normal one, we can move on to estimate the percentage of not conform output from the process.

2. Processes Capability Coefficients

As is known, for each process it is prescribed target value and specification boundaries. After how they relate target value and upper specification limit (USL) and lower (LSL) to process the average and standard deviation can be defined following situations (Montgomery, 2001):

-stable process as accuracy and precision
($x_0 = \bar{x}$, $T = USL - LSL \rangle 6\sigma$),
-unstable process as accuracy and stable as precision
($x_0 \neq \bar{x}$, $T = USL - LSL \rangle 6\sigma$),
-stable process as accuracy and unstable as precision
($x_0 = \bar{x}$, $T = USL - LSL \langle 6\sigma$),
-unstable process as accuracy and precision
($x_0 \neq \bar{x}$, $T = USL - LSL \langle 6\sigma$).

Similarly, capability coefficients of the process will be defined (Rujnić-Sokele *et al*., 2010) Cp (1), Cpk_u (2) and Cpk_l (3).

$$Cp = \frac{USL - LSL}{6\sigma} = \frac{T}{6\sigma} \tag{1}$$

$$Cpk_u = \frac{USL - \bar{x}}{3\sigma} \tag{2}$$

$$Cpk_l = \frac{\bar{x} - LSL}{3\sigma} \tag{3}$$

Overall Cpk index is the lowest value of Cpk_u and Cpk_l . Index Cpk values represent the level of confidence in the capability of a process:

- Cpk <1 - the manufacturer is not able and there is inevitably improper output from the process.

- *Cpk* = 1 - the manufacturer is not really able, since any change in the process will result in improper output, sometimes undetected.
- *Cpk* = 1.33 - still far from acceptable situation because noncompliance is not likely to be detected by the process control charts.
- *Cpk* = 1.5 - still unsatisfactory because inconsistent production will take place and the chances of being detected are not yet high enough.
- *Cpk* = 1.67 - promising, improper exit will occur, but there is a very good chance to be detected.
- *Cpk* = 2 - high level of confidence in the manufacturer, provided that the control files are used regularly (Oakland, 2003).

3. Case Study

To illustrate the methodology previously presented was study a process of machining for some pieces whose quality specification is $N = 89^{+0,05}_{-0,05}\,mm$. There are extracted in order of 100 units of product processed, the values of which are shown in Table 1.

Table 1
Values of Processed Products

88.99	88.99	89.00	88.98	89.03	88.97	89.00	88.99	88.99	88.98
88.98	88.96	88.98	88.97	89.02	89.00	89.01	89.02	88.96	88.99
89.00	89.01	89.02	88.99	89.01	89.03	89.02	88.98	88.98	89.00
88.97	89.02	89.01	89.00	89.01	89.00	88.97	89.02	89.00	88.98
89.01	89.01	89.00	88.97	89.03	89.02	89.01	89.01	88.99	89.00
89.03	89.00	89.01	88.98	89.03	88.99	88.99	88.99	89.00	89.02
88.99	89.04	89.00	88.99	89.04	89.02	89.04	89.00	89.01	89.01
89.00	89.02	89.04	89.03	89.00	88.98	88.99	89.01	89.00	89.02
89.01	88.98	88.99	88.98	89.01	89.00	89.00	89.02	89.01	89.01
89.03	89.00	88.96	89.00	88.99	88.99	89.00	89.01	88.99	89.00

For these values arithmetic mean (1), standard deviation (2) and median (3) were calculated.

Then the homogeneity of data using iterations is tested. To determine the total number of iterations, using the data in Table 1 are marked with symbol (a) quality characteristic values lower than the median, with another symbol (b) higher than the median and the third symbol (m) equal to the median. Then to determine the number and length of iterations is easy. The results are shown in Table 2.

$$\bar{x} = 89.00151mm \quad (1)$$

$$\sigma = 0.018676mm \quad (2)$$

$$M = 89.00mm \quad (3)$$

Table 2

Iteration Method Aplication

Crt Nr.	Value	Simb.	Iter. Nr.	Iter. Len.	Crt Nr.	Value	Simb.	Iter. Nr.	Iter. Len.
1	88,99	a	1	2	51	88.97	a		
2	88.98	a			52	89.00	m	30	1
3	89.00	m	2	1	53	89.03	b	31	1
4	88.97	a	3	1	54	89.00	m	32	1
5	89.01	b	4	2	55	89.02	b	33	1
6	89.03	b			56	88.99	a	34	1
7	88.99	a	5	1	57	89.02	b	35	1
8	89.00	m	6	1	58	88.98	a	36	1
9	89.01	b	7	2	59	89.00	m	37	1
10	89.03	b			60	88.99	a	38	1
11	88.99	a	8	2	61	89.00	m	39	1
12	88.96	a			62	89.01	b	40	2
13	89.01	b	9	3	63	89.02	b		
14	89.02	b			64	88.97	a	41	1
15	89.01	b			65	89.01	b	42	1
16	89.00	m	10	1	66	88.99	a	43	1
17	89.04	b	11	2	67	89.04	b	44	1
18	89.02	b			68	88.99	a	45	1
19	88.98	a	12	1	69	89.00	m	46	2
20	89.00	m	13	2	70	89.00	m		
21	89.00	m			71	88.99	a	47	1
22	88.98	a	14	1	72	89.02	b	48	1
23	89.02	b	15	2	73	88.98	a	49	1
24	89.01	b			74	89.02	b	50	2
25	89.00	m	16	1	75	89.01	b		
26	89.01	b	17	1	76	88.99	a	51	1
27	89.00	m	18	1	77	89.00	m	52	1
28	89.04	b	19	1	78	89.01	b	53	3
29	88.99	a	20	5	79	89.02	b		
30	88.96	a			80	89.01	b		
31	89.98	a			81	88.99	a	54	3
32	88.97	a			82	88.96	a		

33	88.99	a			83	89.98	a		
34	89.00	m	21	1	84	89.00	m	55	1
35	88.97	a	22	3	85	88.99	a	56	1
36	88.98	a			86	89.00	m	57	1
37	88.99	a			87	89.01	b	58	1
38	89.03	b	23	1	88	89.00	m	59	1
39	88.98	a	24	1	89	89.01	b	60	1
40	89.00	m	25	1	90	88.99	a	61	3
41	89.03	b	26	7	91	88.98	a		
42	89.02	b			92	88.99	a		
43	89.01	b			93	89.00	m	62	1
44	89.01	b			94	88.98	a	63	1
45	89.03	b			95	89.00	m	64	1
46	89.03	b			96	89.02	b	65	4
47	89.04	b			97	89.01	b		
48	89.00	m	27	1	98	89.02	b		
49	89.01	b	28	1	99	89.01	b		
50	88.99	a	29	2	100	89.00	m	66	1

From Table 2 it appears that the total number of iterations I = 66, in which Ia = 22, Ib = 23, Im = 21. Then normal variable z is calculated with (4), where n is the number of observations.

$$z = \frac{\left| I + \frac{1}{2} - \left(\frac{n}{2} + 1 \right) \right|}{\sqrt{\frac{n-1}{4}}} \tag{4}$$

For this example z = 3.19. Depending on the value of z, the Laplace function value Φ (z) is chosen from tables (Oakland, 2003). In this case, Φ (z) = 0.499. For a significance level of α = 0.05, which provides a confidence level of 95%, vas determined the minimum allowable number of iterations $I_\alpha = 42$. The inequality $I > I_\alpha$ is checked (66 > 42). The length iterations test is checked too, $K_{min} > K$ ($K_{min} \cong 10$, K=7).

The Kolmogorov-Smirnov test is applied to check the normality of the experimental distribution. For this Matlab Statistical Toolbox was used.

Kolmogorov-Smirnov test `kstest(x)` performs a comparison between the values in the data vector `x` to a standard normal distribution. Graphical representation of this comparison is shown in Fig. 1.

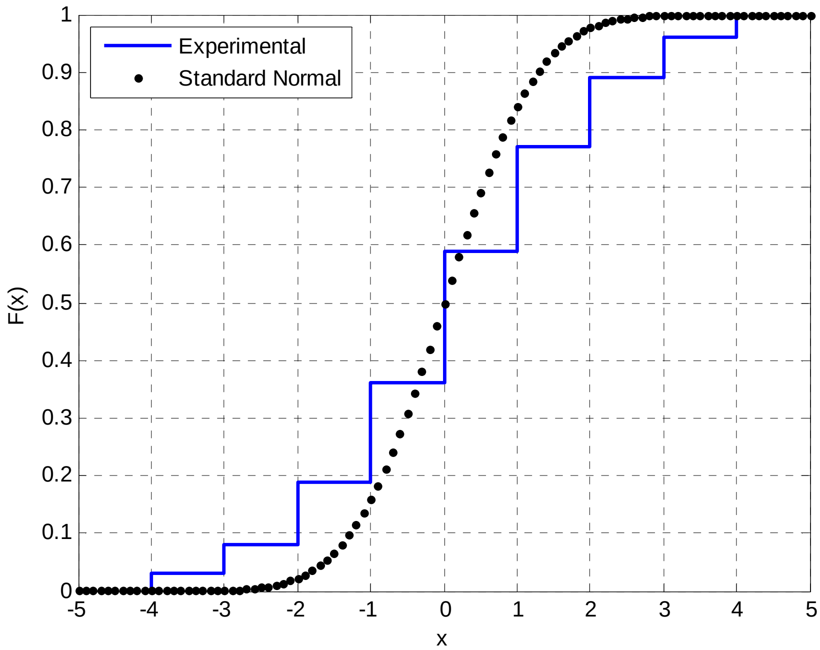

Fig. 1 − Graphical representation of Kolmogorov-Smirnov test.

So, the experimental distribution may be assimilated to a normal one (h=1). Graphical representation of absolute frequency histogram and normal distribution curve has been made with Matlab function `histfit` and it is presented in Fig.2.

Using eqs. (1) – (3) the capability coefficients are determined: $Cp = 0.892$; $Cpk_u = 0.865$ and $Cpk_l = 0.919$. So, $Cpk = 0.865$.

As seen, the manufacturing process is not able to fit into the prescribed quality specifications. This will result in not conform output from the process. Percentage of these results beyond the limits of tolerance is determined by eqs. (5) and (6) and the tabulated values of Laplace function.

$$Z_u = \frac{USL - \overline{x}}{\sigma} = 2.5963 \quad (5)$$

$$Z_l = \frac{\overline{X} - LSL}{\sigma} = 2.7581 \quad (6)$$

Our estimation is that 0.49% of products will be above the upper specification limit, and 0.3% below lower specification limit.

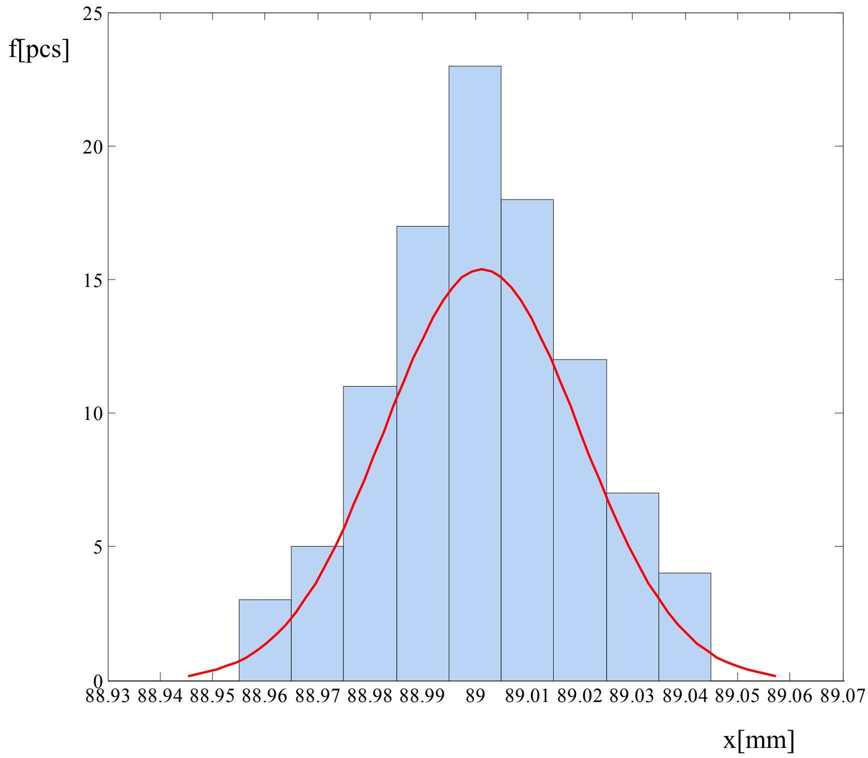

Fig. 2 − Experimentals data histogram and distribution curve.

4. Conclusions

The presented method of analysis allows processes capability determination and potential irregular output estimation. After taking a sample of experimental data, it is necessary to check that it is only under the influence of the common causes of variation, special causes being removed. For these iterations method and Kolmogorov Smirnov test are used. If these tests are passed, researched empirical distribution can be assimilated to a normal one. One can then determine the process capability and the percentage of scrap. It is for the management to decide if things continue in this manner or human and financial efforts are needed to improve quality.

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ASUPRA ANALIZEI CAPABILITĂŢII PROCESELOR DE FABRICAŢIE. II. STUDIU DE CAZ

(Rezumat)

Metoda de analiză prezentată permite determinarea capabilităţii proceselor şi estimarea eventualelor ieşiri neconforme. După ce se prelevează un esantion de date experimentale, se verifică dacă procesul este numai sub influenţa cauzelor comune de variatie, influenţa cauzele speciale fiind înlăturată. Pentru aceasta se foloseste metoda iteraţiilor şi testul Kolmogorov Smirnov. Dacă aceste teste sunt trecute, distribuţia empirică cercetată poate fi asimilată unei distribuţii normale. Se poate apoi determina capabilitatea procesului şi procentul de rebut. Revine managementului sarcina de a decide dacă lucrurile pot continua în acest mod sau sunt necesare eforturi umane şi financiare pentru ameliorarea calităţii.