3rd Research/Expert Conference with International Participations
"QUALITY" 2003, Zenica, B&H, 13 and 14 November, 2003.

STUDY ABOUT THE CAPABILITY OF THE FURNACE OF THE ALLOYS ELABORATION

Micle Valer
Technical University
Cluj-Napoca
Romania

Rusu Tiberiu
Technical University
Cluj-Napoca
Romania

Avram E.Simona
Technical University
Cluj-Napoca
Romania

Riti-Mihoc Emil
Technical University
Cluj-Napoca
Romania

Keywords: capability, furnace, alloys

ABSTRACT

The paper presents the aspects concerning the importance of the capability calculation of the metallurgical processes. The calculation method (the necessary relations) of the two indexes Cp and Cpk, as well as the way of interpreting them, are presented. The paper presents an analysis of the use of the capability indices Cp and Cpk in the control of the metallurgic processes for steel elaboration.

1. INTRODUCTION

Within the metallurgical processes, it is aimed at obtaining some products having characteristics within the limits of the admitted tolerances. In order to quantize the quality of a process, it is necessary to know its capability.
Capability is the result of the ratio between the real performance of an installation or process and the required/prescribed efficiency.
The study of the capability of the metallurgical processes is made by determining the equipment and installations performances of achieving a framing of the spreading field over the specified tolerance field. The capability of a process may be evaluated using C_p and C_{pk} indexes. C_p characterizes the capacity of the process to produce products within the fixed tolerance limits. C_{pk} takes into consideration both the extending of the spreading field and the centring process (adjustment).
The knowing of these indexes facilitates the establishment of the causes of the deficiencies in the process development, and simplifies the dialogue on the quality both between the specialists and the clients and suppliers.
The determination of the capability indexes is based on the statistical data processing. The analysis of a process capability is achieved by going through the following stages: a precursory analysis of the manufacturing process collecting data for analyzing the capability; data analysis; interpretation of the results; conclusions.

2. THE DETERMINATION OF C_P AND C_{PK} CAPABILITY INDEXES AND THE EVALUATION OF THE PROCESS CAPABILITY

C_p index characterizes the ability of the process to achieve products having characteristics within the limits of fixed tolerances (Figure 1) [2]. If L_{sup} is the superior limit stipulated by norms and L_{inf} is the inferior limit, the capability index C_p can be determined by the relation:

$$C_p = \frac{L_{\sup} - L_{\inf}}{6\sigma} \tag{1}$$

in which **σ** is the standard deviation.
Knowing only the capability index C_p proved to be not sufficient to evaluate the capability of a process.
Thus, the second index C_{pk} has been introduced which takes into consideration both spreading and the centring of the process. The centring index C_{pk} can be determined by using the following relation.($\overline{x}$ is the overage of the performed measurements):

$$C_{pk} = \min\left[\frac{L_{\sup} - \overline{x}}{3\sigma}, \frac{\overline{x} - L_{\inf}}{3\sigma} \right] \tag{2}$$

By choosing the minimum between the two values, the process capability in the most unfavourable case, is known.
The evaluation of the capability of the processes is made according to the value of the indexes C_p and C_{pk}. Thus, if C_p is smaller than 1, the process is not adapted: a part of the obtained products will have characteristics beyond the admitted tolerances (Figure 1, a). In these conditions there must be acted upon the process, by modifying or changing the means of fabrication.

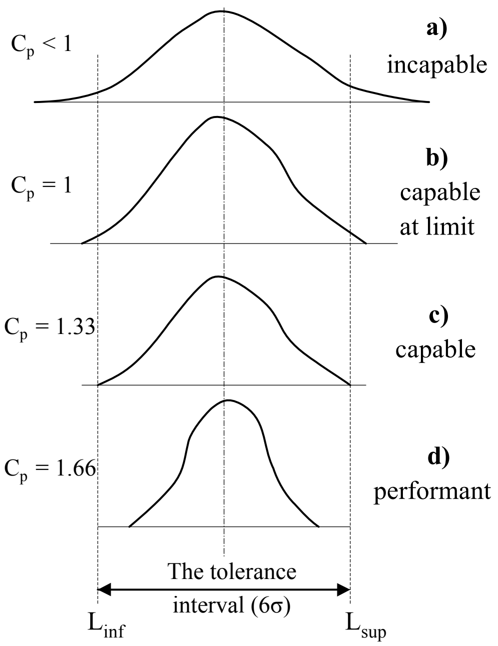

FIGURE 1. EVALUATION OF THE PROCESS CAPABILITY DEPENDING ON THE VALUE OF THE C_P INDEX

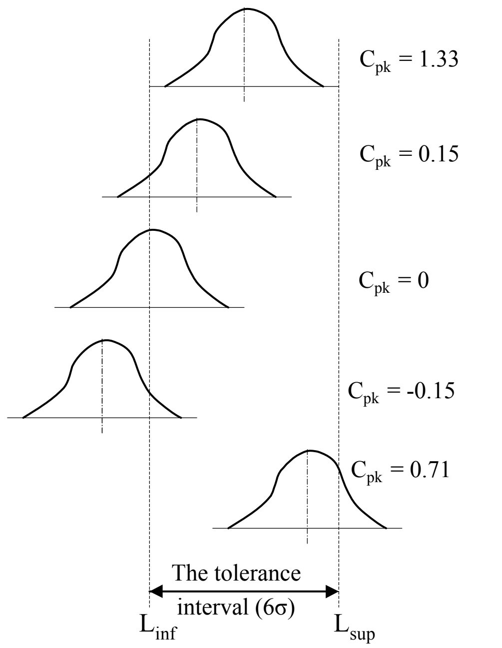

FIGURE 2. EVALUATION OF THE PROCESS CAPABILITY DEPENDING ON THE VALUE OF THE C_{PK} INDEX

If C_p is equal to 1, the process is capable just on the line in order to respect the tolerances: 99.73 % from the products are good (Figure 1, b).
If C_p is bigger than 1, the process is "capable": over 99.73 % of the products are good (Figure 1, c). A value often mentioned in the literature of speciality which gives a certainty upon the process capability is C_p = 1.33. It is said that if C_p is comprised between 1 and 1.33 the process is acceptable but its behaviour is not totally mastered. The explanation for this value is very simple and it is given by the fact the mathematical expression for determination of C_p, 6σ is at denominator. Thus, if the tolerance interval is equal to 6σ, the process does not permit to manufacture 100 % good products but "only"99.73 % good products.
The second index of capability C_{pk} permits the characterization mainly of the mode of the process centring (Figure 2) [2]. The 1 value of C_{pk} indicates the fact that 99.73 % of the products will have the characteristics within the fixed tolerances. If C_{pk} = 1.33 then 99.994 % of the products will be at the tolerance limits.
If $C_{pk} < 1$ it means that a part of the products have their characteristics beyond the tolerance interval (the less C_{pk} the more refuses).
If $C_{pk} > 1.33$ the products will have their characteristics within the pre-defined tolerance limits and the bigger C_{pk} is the better they will be. Finally, if $C_{pk} < 0$, it means that the measurement overage is beyond the tolerance interval.
Therefore, for a correct evaluation of the capability of a process it is necessary to know both indexes. The condition of a process capability is that C_p and $C_{pk} \geq 1$, but in order to have c certainly on the process capability it is preferable that the value of the two indexes to be at least 1.33.

3. USE OF THE CAPABILITY INDICES C_P AND C_{PK} IN THE CONTROL OF THE METALLURGIC PROCESSES FOR STEEL ELABORATION

This paper aims to analyze an electrical oven for the elaboration of a steel having the following composition (imposed by standards): 0,42 – 0,49 % C; 0,90 – 1,25 % Mn; 0,15 – 0,35 % Si; max. 0,025 % S, P; 0,95 - 1,35 % Cr; 0,20 - 0,35 % Mo; max. 0,25 % Ni; max. 0,3 % Cu.
For the capability analysis of the oven, the chemical compositions of 35 charges have been recorded and processed statistically. In order to obtain the most relevant information regarding the oven, the C_P and C_{PK} indices have been analyzed for nine elements of the alloy (C, Mn, S, P, Si, Cr, Ni, Cu, Mo).
Experimental results:
Carbon analysis. Carbon is a chemical element with a great importance for steels. Figure 3 shows the variation of the carbon concentration with respect to the charge, as well as the maximum values allowed by the standard [3].
The values C_P = 1.22 and C_{PK} = 1 for carbon satisfy the capability condition of a process ($C_P \geq 1$, $C_{PK} \geq 1$) [2], but do not satisfy the certainty condition which imposes that C_P and C_{PK} be at least 1.33.
Manganese analysis. Manganese is an accompanying element in cast iron and steel. Its analysis is made in the same manner as in the case of carbon. The variation of the manganese concentration with respect to the charge is shown in Figure 4 [3].
The values C_P = 0.20 and C_{PK} = 0.16 for manganese do not satisfy the capability condition of a process ($C_P \geq 1$, $C_{PK} \geq 1$).
Sulfur analysis. Sulfur is a bad chemical element producing red shortness of steels. The values C_P = 5.29 and C_{PK} = 5.26 for sulfur satisfy the capability condition of a process ($C_P \geq 1$, $C_{PK} \geq 1$), as well as the certainty condition which imposes that C_P and C_{PK} be at least 1.33.

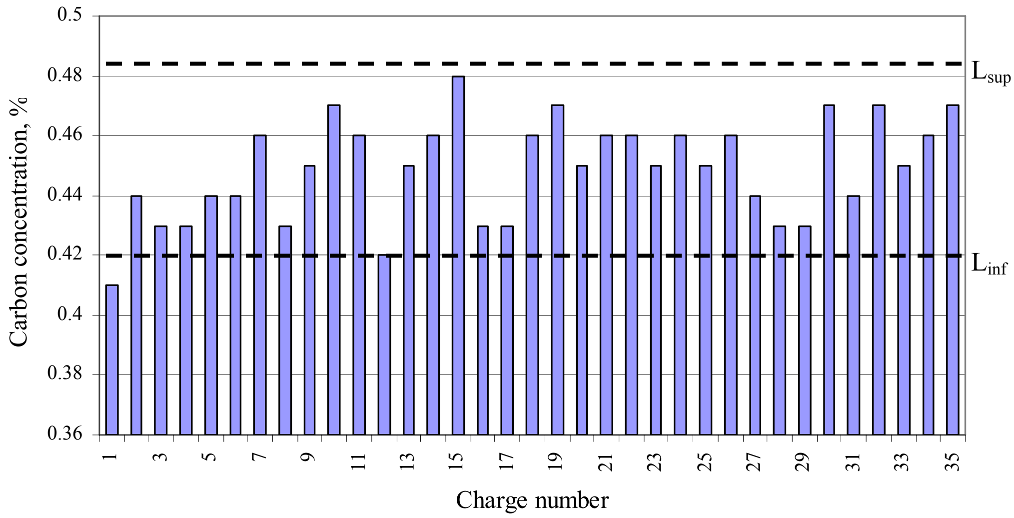

FIGURE 3. VARIATION.OF THE CARBON CONCENTRATION WITH RESPECT TO THE CHARGE NUMBER

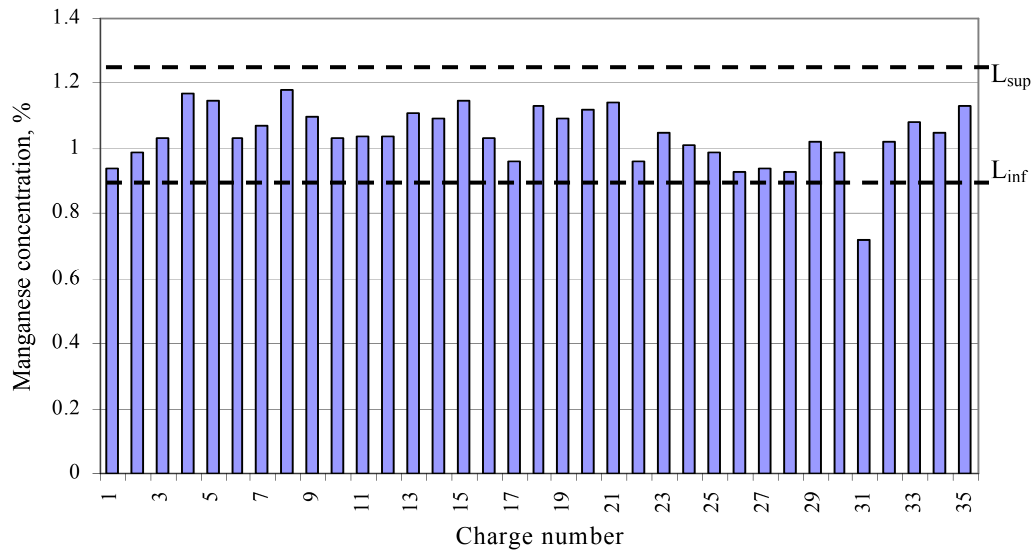

FIGURE 4. VARIATION. OF THE MANGANESE CONCENTRATION WITH RESPECT TO THE CHARGE NUMBER

Phosphorus analysis. Phosphorus is a bad chemical element producing blue shortness of steels.

The values $C_P = 5.73$ and $C_{PK} = 4.13$ for phosphorus satisfy the capability condition of a process ($C_P \geq 1$, $C_{PK} \geq 1$), as well as the certainty condition which imposes that C_P and C_{PK} be at least 1.33.

Silicon analysis. Silicon is an accompanying element in cast iron and steel. Its analysis is made in the same manner as in the case of carbon. The variation of the silicon concentration with respect to the charge is shown in Figure 5 [3].

The values $C_P = 0.46$ and $C_{PK} = 0.22$ for silicon do not satisfy the capability condition of a process ($C_P \geq 1$, $C_{PK} \geq 1$).

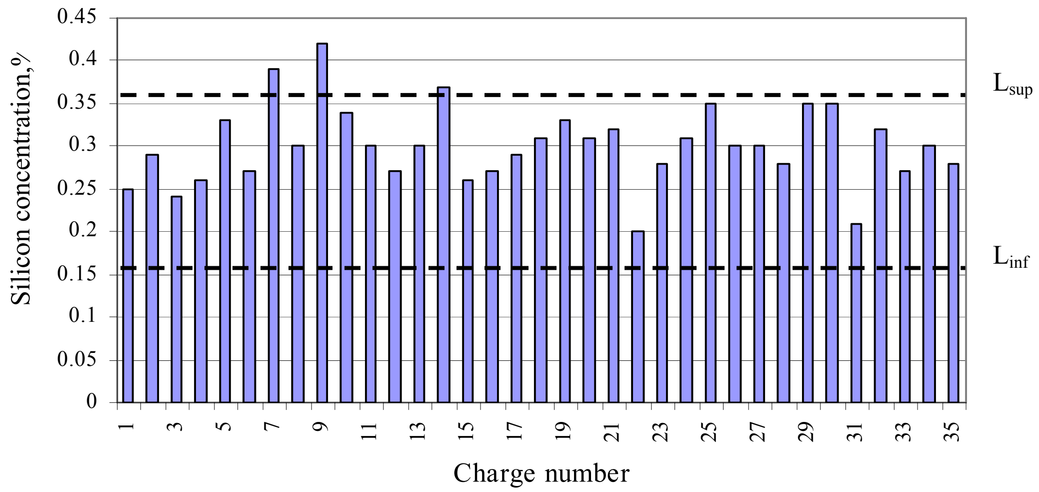

FIGURE 5. VARIATION OF THE SILICON CONCENTRATION WITH RESPECT TO THE CHARGE NUMBER

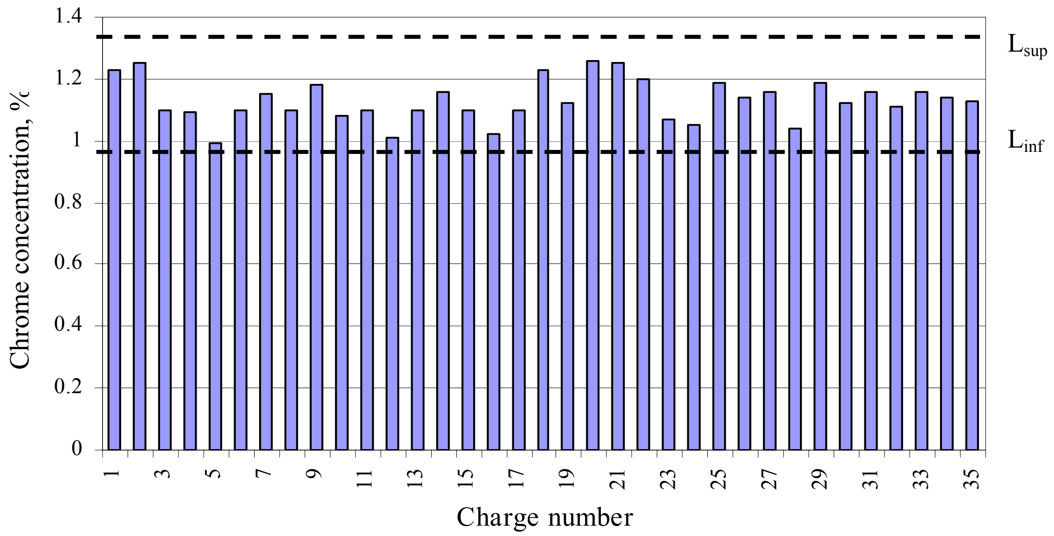

FIGURE 6. VARIATION OF THE CHROME CONCENTRATION WITH RESPECT TO THE CHARGE NUMBER

Chrome analysis. Chrome is an accompanying or alloying element in steel. The variation of the chrome concentration with respect to the charge is shown in Figure 6 [3]. The values C_P = 0.41 and C_{PK} = 0.37 for chrome
do not satisfy the capability condition of a process ($C_P \geq 1$, $C_{PK} \geq 1$).
Nickel analysis. The values Cp = 0,15 and Cpk=-0,03 for nickel not satisfy the cabability condition of the process (Cp ≥1, Cpk ≥1).
Molybdenum analysis. The values C_P = 3.7 (greater than 1) and C_{PK} =0.7 for molybdenum do not satisfy the capability condition of a process ($C_P \geq 1$, $C_{PK} \geq 1$).
Copper analysis. The values C_P = 1.07 (greater than 1) and C_{PK} = 0.23 for copper do not satisfy the capability condition of a process ($C_P \geq 1$, $C_{PK} \geq 1$).
Table 1 represents a general presentation of the results concerning the indices C_p and C_{pk}

determined for the nine elements of the steel (C, Mn, S, P, Si, Cr, Ni, Cu, Mo).

TABLE 1. THE INDICES C_P AND C_{PK} DETERMINED TO CONTROL THE METALLURGIC PROCESSES OF STEEL ELABORATION

Capability indices	Acceptable value	The indices C_p and C_{pk} determined for the following elements								
		C	Mn	S	P	Si	Cr	Ni	Cu	Mo
C_p	≥ 1	1.22	***0.2***	5.29	5.73	***0.46***	***0.41***	***0.15***	1.07	3.7
C_{pk}	≥ 1	1	***0.16***	5.26	4.13	***0.22***	***0.37***	***- 0.03***	***0.23***	***0.7***

4. CONCLUSIONS

The calculation of the alloys elaboration process capability is a little known.
The two indexes of capability C_p and C_{pk}, through a correct interpretation can be an important factor for evaluating the quality of a process.
The determination of the process capability can be made periodically by using the technical calculation, this contributing to the improvement of the resulted products quality.
The knowing these indexes facilitates the establishment of the causes of the deficiencies in the process development, and simplifies the dialogue on the quality both between the specialists and the clients and suppliers.
Taking into account the data presented above, the furnace obeys the conditions regarding the capability indices only for three elements (C, S, and P).
The indexes C_p and C_{pk} calculated for the other elements (Mn, Si, Cr, Ni, Cu, Mo) do not respect the capability condition of the elaboration process. Starting from this unsuitable indexes we have to find solutions which will contribute at the chemical composition improvement of the elaborated alloy.

5. REFERENCES

[1] Pillet, M.: SPC, les mesures de capabilité, Revue Pratique de Controle Industriel, no.171, nov.1991.,

[2] Peyrucat, J.-F: Les outils de la qualité. La capabilité des processus, Mesures 662, Fevrier 1994.,

[3] Avram, S.E., Micle, V. – Use of the capability indices C_p and C_{pk} for evaluating the capacity of the ovens to elaborate iron alloys according to the standards prescriptions, National Conference on Metallutgy and Materials Science, Buckarest, 20-21 sept.2001.