Assessment of performance quality of moulding machines

A. Fedoryszyn
AGH University of Science and Technology, Faculty of Foundry Engineering, Reymonta St. 23, 30-059 Krakow, Poland
Corresponding author. E-mail address: alfa@agh.edu.pl
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Abstract
The methodology is given to assess the performance quality of moulding machines whereby the potential performance and capability of the process are determined accordingly. This method is most useful in assessing the machines and manufacturing processes to find out if the machine or processes perform in statistically regulated condition, which is documented in the quality certificate.

Keywords: Moulding machines, Quality performance, The potential performance, The machine capability

1. Introduction
Quality of casting products depends on the applied moulding method and machines. Presently, moulds are made from synthetic mix with bentonite using the jet and impulse moulding machines. These machines deliver good performance when the operating conditions are adequate. It is worthwhile to mention that castings are now available that are made with higher levels of precision than by previously used moulding machines. The dimensional precision of castings made in sand moulds is associated chiefly with the pattern equipment (inclination) and moulding errors, mainly due to the applied compaction technique [6].

To provide a full characteristic of moulding machines it is required that the efficiency data and their performance quality indices should be known. These indices include the potential performance of the process representing its variability, and its capability showing its position and critical capability in relation to the tolerance field.

2. Characteristics of performance of the jet-squeeze moulding machine
The advantages of sand compaction by the airflow moulding technology (the process SEIATSU) include the high dimensioning precision of manufactured castings. While controlling the dimensions of an exemplary casting (Fig 1), the deviations are derived and the range of its mass variability. For the sake of comparison, the variability range of the casting dimensions and mass are given for the same castings manufactured using the jolt-squeeze moulding machine (Fig 2).

Fig. 1. Dimensions of a casting [5]
3. Performance of an impulse-squeeze moulding machine

Performance of an impulse-squeeze moulding machine can be assessed by checking the variability range of mass and dimensions of castings. This assessment is facilitated when we apply the performance quality indices that characterise the potential performance of the process and its capability [1-4].

The potential performance of the is determined by the machine capability, involving the performance of the moulding machine. The potential performance of the process represents the potential capability of the moulding machine to manufacture the given feature in an unchangeable manner within the given specification limits. This index is defined as the ratio of the tolerance interval to the natural process spread and is used to assess the efficiency and quality of mould manufacturing processes.

Assuming the process variability range to be ±3σ, the value of this index is derived from the formula:

\[ C_m = \frac{(GGS - DGS)}{6s}, \]

where: \( CGS, DGS \) - upper and lower limit of specification, \( s \) - standard deviation.

This relationship reveals what fraction of the normal distribution curve is contained within the pre-determined specification limits. Assuming the variability range to be ±3σ, then for \( C_m = 1 \) the average number of castings outside the specification limits is 0.27 (assuming that the process is centred with respect to the tolerance field) and the number of non-conforming products per million (ppm) will be 2700.

Standard deviation \( s \), being the basic measure of spread, is obtained from the formula:

\[ s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n}(x_i - \bar{x})^2}, \]

Performance and quality are also evaluated basing on the critical machine capability \( C_{m\text{crit}} \). This index shows the position with respect to the tolerance limits. Its upper and lower values are derived from the formulas:

\[ C_{mk,u} = \frac{GGS - \bar{x}}{3s}; \quad C_{mk,l} = \frac{\bar{x} - DGS}{3s}, \]

Evaluation of the process uses the critical value, i.e. the smaller of the two. For the ideal state of the process, where the mean value should coincide with the normative value, \( C_m = C_{m\text{crit}} \).

Characteristics of moulding machines obtained by this methodology are given as plots of variability of mass of the casting products (Fig 3) manufactured using an impulse moulding machine FT 65 (PPP Technical) [7]. For comparison, we provide the dimensions of the same castings (Fig 4) formed in moulds made by the jolt-squeeze moulding machines FKT 65 [7].
Table 1.
Potential performance of the process and quality performance

<table>
<thead>
<tr>
<th></th>
<th>Impulse-squeeze moulding machine</th>
<th>Jolt-squeeze moulding machine</th>
</tr>
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<tbody>
<tr>
<td>$\bar{x}$</td>
<td>7.96</td>
<td>8.03</td>
</tr>
<tr>
<td>$s$</td>
<td>0.109</td>
<td>0.204</td>
</tr>
<tr>
<td>$C_m$</td>
<td>3.04</td>
<td>1.64</td>
</tr>
<tr>
<td>$C_{mk, u}$</td>
<td>2.54</td>
<td>1.32</td>
</tr>
<tr>
<td>$C_{mk, l}$</td>
<td>2.32</td>
<td>1.19</td>
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</tbody>
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The performance and capability indices suggest that better results are achieved when moulds are made by the impulse-squeeze method, using the moulding machine FT 65. That seems to corroborate the data given in manufacturers’ leaflets advertising novel techniques of compacting sand with bentonite.

4. Conclusions

Machine and process capability studies involve the assessment based on the process performance. Quality performance is analysed to find if the given production task is being completed with the required precision and in the specified time limits. This methodology of characterising moulding machines allows for assessing the capability and quality of casting processes. This qualification is required when new machines are commissioned, after major repairs and in basic analyses of machines and processes [2]. This methodology enables us to describe the machines and equipment precisely enough whilst the implemented processes are being incessantly verified.

References