Statistical control of machined high pressure die casting geometry by using of JM-SPC software

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Abstract

Usefulness of newest version of the JM-SPC computer program for a statistical analysis of production processes was examined. An analysis subject were results of measurements of 16 geometrical features of an Al-Si high-pressure die casting systematically controlled after machining on a coordinate-measuring machine. For analysis two criterion have been used: 1) Xave control chart and 2) a performance indicator of processes expressed by two commonly used indices: potential process capability index (Cp) and process capability index (Cpk).

Keywords: Statistical control, Variable valued data type, Histogram, Control chart, Cp and Cpk -index, Al-Si high pressure die casting

1. Introduction

In work [1] the investigations of the JM-SPC computer program usefulness for a statistical analysis of attribute valued data type have been presented. The analysed data - gained in LUMEL S.A from an Al-Si high-pressure die casting production processes - were referred to a casting produced in a multi-cavity die (four castings from each injection). Similar investigations for this casting, but for variable valued data type (after machining controlled casting dimensions), have been presented in [2]. The analysed casting machined in two identical* CNC-centers (Brother TCR 2A, signed in firma as: F92 and F98) is produced in a three-shift system. During each shift three or four at random chosen castings machined in chosen center are controlled on coordinate-measuring machine (Wenzel LH 65). By measurement procedure 16 tolerated geometrical features are controlled: 14 dimensions (11 hole diameters, signed as: d1-d11, 3 line dimensions, signed as: W1-W3), 2 plane features (parallelism, perpendicularity). Presented in [2] analyses referred to the castings machined in F92 CNC-centre have showed that:

- examined production process was stable in point of view of analysed control charts (Xave-S double control chart),
- examined production process was stable in point of view of Cp and Cpk indices,
- Cp and Cpk indices were different for all mould cavities,
- by diameter dimensions as well as by linear dimensions some trends in point of view of analysed control charts have been demonstrated,
- trends changes were probably with process rearranging connected,
- in few cases run lines of both control charts exceeded the control limit lines,
- in few cases the single values exceeded the specification limit lines,
- the lowest values of Cp and Cpk indices were for mould cavity no 3,
• data for holes diameters had mostly quasi normal distribution,
• one of linear dimension (signed as W3) had clearly two-modal distribution.

The obtained results are evidently representative only for production process realized in CNC-centre signed in foundry house as F92. In order to judge a total quality of production process the identical analysis for the data obtained during the same time period but in the second CNC-center has to be executed. Results of such analysis realized by using of the JM-SPC program are subject of this paper.

2. Analysis methodology and results

The analysis results, like in [2], have been presented below with a help of some diagrams generated by JM-SPC program.

The three mounts productions data for castings machined in F98 CNC-centre have been into JM-SPC program introduced.

Like in [2], the analysis data, as results of dimensional measurements of 16 casting dimensions read out direct from measurement protocol of the coordinate-measuring machine, have been into JM-SPC program by hand introduced.

Proceeding in the way described in [2] four data files have been created (each one for the castings issued from one of each of four (signed as: No 1, 2, 3, 4) mould cavities).

The all introduced data (all geometrical features of all machined in F98-centre castings) have been analysed. In order to analyse a chosen data set (chosen geometrical feature; for example: d1-diameter) it was sufficient to click an appropriate cell in a data grid (the data grid is partly visible in the left region of Figs. 2-4). The choice had to be finally accepted by clicking on cell in a data grid (the data grid is partly visible in the left region of form) was appeared with the analysis button. As an effect of clicking on cell in a data grid (adequately: above- and below GGS-, DGS-line) were also plotted in diagram of the measurement protocol of the coordinate-measuring machine. When the value of specification limit was behind of ordinate range, so the specification line has been plotted as limit line of coordinate system (GGS-line as upper line (edge) and DGS-line as bottom line (edge) of coordinate system). The values of specification limits have been displayed (Fig. 1-3) at the right side of the diagram (adequately: above- and below GGS, DGS-line). As a additional information, on the right edge of each Xave control chart diagram, a histogram of analysed data has been plotted.

As it has been shown in [2], the JM-SPC program allows to present simultaneously diagrams of two different control charts (double control chart technique). So, in order to obtain a subsidiary diagram, a right-clicking on the main control chart diagram is necessary. It allows to display a pop-up menu window containing a list of actual offered control charts (Fig. 1a). In Fig. 1a a S-control chart and in Fig. 1b X-chart have been chosen as subsidiary control chart. The X-chart presents the run line of all 178 single measurements.

Above the upper edge of each control chart diagram following information are visible: name of control chart type, signature of analysed dimension, time-period of analysis.

Because a correctness of all used here analytical techniques requires normality of analysed data distribution [3, 4, 5], in all cases it has been tested: 1) numerically (skewness and excess kurtosis - showed in results window) and 2) graphical (value-quantile plot or histogram with a calculated plot of normal distribution). The both mentioned graphical methods are available right-clicking on the results window, which allows to display a menu window (Fig. 1b) with pop-up menu containing necessary items. Clicking on the item Rysuj Histogram allows to display the histogram and on the Rysuj Test Rozk the value-quantile plot. The program version described in [2] allowed to display only one of the mentioned diagrams (one diagram direct over the results window (like in Fig. 1)). The newest program version allows to display simultaneously the both diagrams, but just when only the mean control chart (Xave) has been displayed (Figs. 2-4). Only in this case a graphical interpretation of Cpk-index is also possible to display (after clicking on Grafika Cmk item in pop-up menu showed in Fig. 1b).
Fig. 1. Analysis results for castings produced in mould cavity No 1 (F98 CNC centre): a) Xave-S double control chart and data histogram (controlled dimension: d2), b) Xave-X double control chart and normality test graph (controlled dimension: d3)
Fig. 2. Xave control chart, data histogram, normality test graph and graphical illustration of Cmk-index for castings produced in mould cavity No 1 (F98 CNC centre): a) controlled dimension: d4), b) controlled feature: parallelism)
Fig. 3. Xave control chart, data histogram, normality test graph and graphical illustration of Cmk-index for castings produced in mould cavity No 1 (F98 CNC centre): a) controlled dimension: W1), b) controlled dimension: W2)
Fig. 4. Xave control chart, data histogram, normality test graph and graphical illustration of Cmk-index for castings produced in mould cavity No 2 (F98 CNC centre): a) controlled dimension: W1, b) controlled dimension: W2
Fig. 5. Comparison of all statistical parameters calculated for all controlled dimensions of castings machined in F98 CNC centre and cast in: a) mould cavity No 1, b) mould cavity No 2, c) mould cavity No 3, d) mould cavity No 4.

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a b c d
In the diagram of graphical interpretation of Cmk-index the data histogram with a calculated plot of normal distribution are shown in the range of specification limits (marked by two most external vertical short-lines). Another two vertical short-lines, laying more central, show the GGI- and DGI – limits and both vertical long-lines (reaching to the upper edge of the diagram) show respectively: the target value (thicker) and the mean value.

Because, like in [2], a quantity of analysed data, was so large (16 analysed dimensions collected in four files (for each of four mould cavities), 13 analysed parameters for each dimension (see results window), one control chart for each controlled feature, distribution normality test, Cmk-plot), so it has been also decided to show only some exemplary diagrams for chosen geometrical features. On the contrary, all calculation results have been presented in tabular form in Fig. 5. In the table have been collected quantitative values (obtained from the results windows) calculated for each dimension (geometrical feature) and each mould cavity. Visible in Fig. 5, tables have been automatically created by JM-SPC program after analysis of all geometrical features. The results collected in this way JM-SPC program can treat as new data for next calculations. In this way the average values of Cmk-index have been calculated for each four mould cavities (see Fig. 5- results windows).

An analysis of Figs.1-4, allows to see that, like in [2]:

- by diameter dimensions (d2, d3, d4), as well as by linear dimensions (W1, W2), some trends have been presented,
- trends changes were probably with process rearranging connected,
- in view on analysed features the process was under control, but in few cases run lines of control charts exceeded the control limit lines,
- in few cases the single values exceeded the specification limit lines,
- in view on Cm and Cmk-indexes the process was under control, but only in two cases (Figs. 2b, 3a) good centred,
- all data had quasi normal distribution with some lesser (Figs. 1, 2, 3b) or bigger (Figs. 3a, 4) departures from the rule.

An analysis of values collected in tables shown in Fig. 5, allows to see that:

- in view on Cm and Cmk-indexes the process was under control, but seldom good centred (like in [2]: Cmk<Cm),
- the lowest values of Cm and Cmk-indexes have been established for both plane features (parallelism, perpendicularity), but it can be explained by distribution departures from normal distribution,
- in contrary to [2], the average values of Cmk-indexes were similar for all mould cavities, although – like in [2] – the lowest value have been obtained for mould cavity No. 3,
- in view on values the both normality indexes (skewness and excess kurtosis) all data had quasi normal distribution with some lesser or bigger departures from the rule.

3. Conclusion

The main conclusions of this work with regard on results presented in [2] are:

- examined production process was stable in view on analysed control charts,
- examined production process was stable in view on values of Cp and Cpk indices,
- the process capability was insensibly better in F98 CNC-center as in F92 (described in [2]),
- new feature of the JM-SPC introduced for variable valued data allowing to show the graphical interpretation of the Cpk-index has been appeared as very useful for results understanding.

References