ARCHIVES of FOUNDRY ENGINEERING

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

ISSN (1897-3310)
Volume 10
Issue 4/2010

13 – 16

3/4

Modernity of parts in casting machines and coefficients of total productive maintenance

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Received 28.06.2010; accepted in revised form 16.07.2010

Abstract

The goal of this study is to investigate the impact of equipment efficiency in casting machines on the quality of die castings made of Al-Si alloys in consideration of their modernity. Analysis focused on two cold-chamber die-casting machines. The assessment of modernity of the equipment was made based on ABC analysis of technology and Parker's scale. Then, the coefficients of total productive maintenance (TPM) were employed for assessment of the efficiency of both machines. Using correlation coefficients r allowed authors to demonstrate the relationships between individual TPM coefficients and the number of non-conforming products. The finding of the study is pointing to the differences between the factors which determine the quality of castings resulting from the level of modernity of machines.

Keywords: Die casting, ABC analysis, Parker's scale, Total productive maintenance (TPM), Correlation coefficients R.

1. Introduction

Contemporary foundries, in order to perform technological processes connected with manufacturing die castings, are equipped in a number of machines and equipment, frequently partially or fully automated. Regardless of the degree of automation of machine stock, it is necessary to incur expenditures on maintenance and repairs, which, in consequence, is connected with the quality of manufactured castings.

It is generally accepted that properly selected and properly used parts of subassemblies contribute to improvement in the quality of manufactured products. The goal of this chapter is to investigate the impact of equipment maintenance effectiveness [1] on the quality of die castings made of Al-Si [2]. Additional element is taking the modernity level into consideration. In order to achieve this, the machines with completely different modernity level were assessed.

2. Characteristics of the Studied Subject

Assessment covered Idra machine with clamping force of 700 tonnes manufactured in 2007 and Bühler − 660 machine manufactured in 1972. For simplicity, the analysed machines were marked M1 (Idra 700) and M2 (Bühler 660). Machine operators recorded times connected with:

- equipment availability (breakdown, readjustments, regulation),
- equipment loading (semi-automatic operation, lack of stoppages),
- quality loss (non-conformances, technological trial runs).

3. Application of ABC Technology Method for Assessment of Modernity of Casting Machines and Equipment

Modernity of machine parts and equipment can be classified by means of ABC technology. Categorization of subassemblies under A, B or C groups is connected with the role performed by the given subassembly during manufacturing of the casting, which is connected with machine cycle. Machine cycle in die-casting machine is presented in Fig. 1.

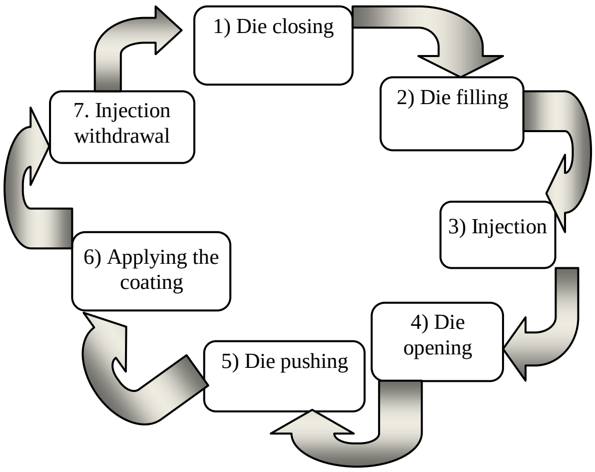


Fig. 1. Die casting cycle in IDRA 7000

Parts of A category (basis subassembly) take active part in formation of the features of a casting and determine its quality. Parts of the subassembly of category C do not contribute to gaining competitive edge (utilized in machines from many sectors). Individual subassemblies used in the machine were assessed on a Parker's scale of 1 to 5 (level 1- simple parts, level 5 – parts manufactured using the most modern technologies).

Table 1 presents the subassemblies of casting machines which were subject to assessment according to ABC technology method.

Table 1.
The assessed subassemblies in the studied machines

No.	Subassembly	M1	M2
A1	Filling system	4	2
A2	Central pushing system	4	2
A3	Manipulator	4	1
A4	Cooling system	3	3
A5	Filling system	4	1
A6	Sprinkler	4	1
B1	Battery system	4	2
B2	Closing system	4	2
B3	Core system	4	2
B4	Hydraulic system	4	2
B5	Pump system	3	2
B6	Cooling system	4	2
B7	Lubrication system	4	3
B8	Control panel	4	2
B9	Safety devices	4	2
C1	Machine base	3	1
C2	Injection system base	3	1
C3	Electrical wiring	3	2

Not all the subassemblies equally affect the quality of castings. In the case of die castings, the crucial effect is from: injection system, cooling system, level of automation of filling system, mechanism of removal of castings from the die and the mechanism of application of dividing means. Figure 2 presents shares of individual assessments according to Parker's scale (1-5 points) for subassemblies in both machines.

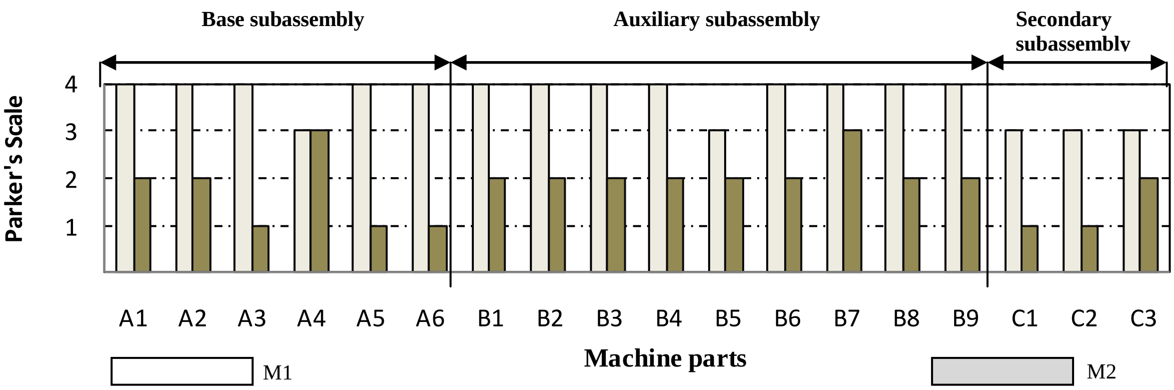


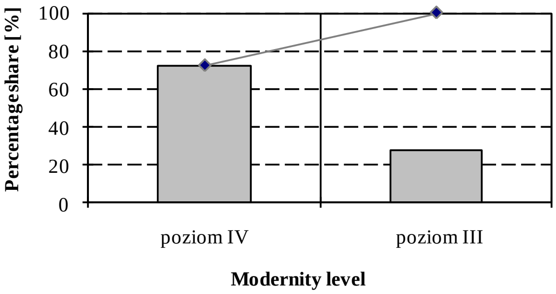
Fig. 2. Modernity level in M1 and M2 machine parts

Figure 3 presents Pareto-Lorenz diagrams for modernity of parts in both machines.

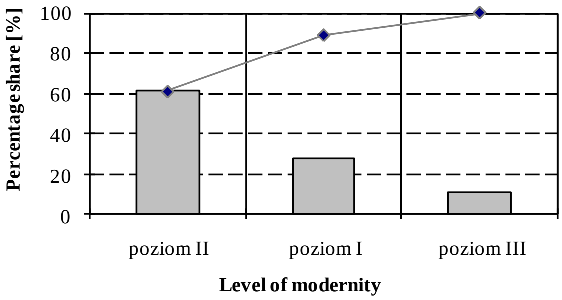
As results from the analysis, parts used in M1 machine, which add products special attributes (base subassembly – A) are in 70% at 4th level of modernity. Similarly, in the subassembly which supported only one part, it was assessed at the level 3 (pump system). This means that in most of cases the level of modernity was high.

Analysis of Figure 3 also reveals that over 27% of all the part installed in machine M1 demonstrate level 3 of modernity (secondary subassembly).

To sum up, one can conclude that the subassembly in the analysed machine (M1) show quite high level of modernity at the level of 4 (Fig. 3a). In the case of machine M2, slightly over 60% of parts are maintained at the level 2 of modernity, 27% of parts at the level 1 and 11% of parts at the level 3 (Fig. 3b). Parts in base subassembly in machine No. 2 were assessed in 50% at the level 1 of modernity.



a)



b)

Fig. 3. Pareto-Lorenz diagram for modernity of parts: a) machine M1, b) machine M2

Parts in machine M2 assessed at the level 1 of modernity include A3 – collector, A5 – filling system and A6 – sprinkler. Level of automation of these parts is essential from the standpoint of automation of the process of casting, level of difficulty of the performed activities and, in consequence, level of non-conformity. All the parts in auxiliary subassembly (M2) were assessed at the level 2 of modernity, whereas the machine base C1 and injection system base were assessed at the level 1. As results from the analyses, machine M2 demonstrates low level of modernity.

Mechanization improves work efficiency and stabilizes the process, which is conducive to increasing the quality of casting and reduction in the level of non-conformity. As results from the analysis, machine M1 is much more automated compared to the machine M2. It is not fully automated, however, most of its subassemblies are at high (4th) level of modernity.

4. Analysis of the Level of Utilization and Types of Stoppages in the Studied M1 and M2 Machines

Based on time of machine work, the following coefficients of total productive maintenance (TPM) were evaluated: operation coefficient (WE), operation rate coefficient (WPD), effective time coefficient (UCD) and loading coefficient (WW).

Table 2 presents the values of correlation coefficient r [3] and significance level *p* for both machines. The correlation was calculated in total for 27 weeks in the year 2008 for both studied machines.

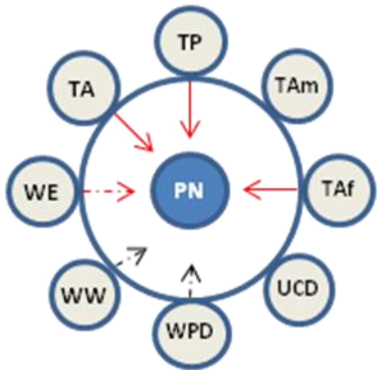
Table 2.
Correlation coefficient r and significance level p for M1 and M2

M	*r* *p*	TP	TA	WE	WPD	UCD	WW
1	*r*	0.710	0.691	-0.711	-0.435	-0.193*	-0.424
	p	0.000	0.000	0.000	0.024	0.335*	0.028
2	*r*	0.672	0.670	-0.674	-0.674	-0.4761	-0.549
	p	0.000	0.000	0.000	0.000	0.0121	0.003

* statistically insignificant coefficient

The effect of individual TPM coefficients: breakdown time (TA), downtime (TP), operation coefficient (WE), loading coefficient (WW), operation rate coefficient (WPD), effective time coefficient (UCD), die breakdown time (TA_f) and machine breakdown time (TA_m) on quality level (PN – represented by the level of non-conforming products) is presented in the form of correlation graphs (Fig. 4)

a)



b)

Fig. 4. Graphs for interrelations between the level of non-conformance (PN) and variables TP, TA, WE, WW, WPD, UCD, TA_f, TA_m: a) M1, b) M2

Graph radius equals 1, i.e. maximal value of *r*. Length of the section (arrow) from the external to internal circle provides information about correlation strength [3].

⟶ positive correlation,

– · → negative correlation.

Lack of arrow means lack of correlation between the variables.

Comparison of the effect of individual factors of TPM on the level of quality in both studied machines are presented in Fig. 5.

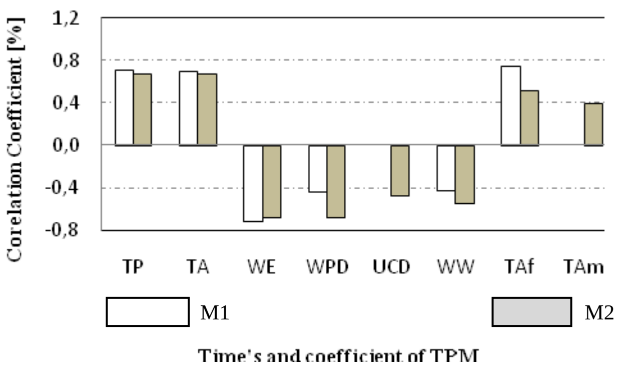


Fig. 5. Comparison of the effect of TPM factors in both studied machines

As results from the analysis of Figure 5, the following correlations can be observed in both studied machines:

- positive significant correlation between downtime (TP), breakdown time (TA), die breakdown time (TA_f) and the level of non-conformities (PN),
- negative significant correlation between operation coefficient (WE), operation rate coefficient (WPD), loading coefficient (WW) and the level of non-conformities (PN)

Analysis of the investigations also reveals that in the case of machine M1, effective time coefficient (UCD) and time of other machine breakdowns (TAm) do not significantly affect quality level, which is caused by small differences between ideal and real time of manufacturing of one piece of castings (new).

5. Conclusions

Analysis of the investigations reveals that downtime (TP), breakdown time (TA), operation coefficient (WE), die breakdown time (TA_f) are of highest impact on quality level in the case of the machine with higher level of modernity (M1), whereas operation rate coefficient (WPD), effective time coefficient (UCD) and loading coefficient (WW) considerably affect the quality in the case of the machine M2.

In the case of the machine with higher level of automation (M1) higher loss results from switch-offs (breakdowns, downtime, readjustment) compared to reduced operation rate, which is observed in the case of machines with lower level of modernity and requires from operators to repeat a high number of activities.

In the case of both analysed machines, highest loss results from die breakdown rather than other types of machine breakdown.

Acknowledgements

Scientific study financed from scientific funds in 2008 – 2010 as a research Project N N 507 457334

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