

The effect of equipment efficiency on occurrence of non-conforming products in die casting

S. Borkowski ^{a,*}, A. Czajkowska ^b

^{a,b} Institute of Production Engineering, University of Technology, Armii Krajowej 19B, 42-200 Częstochowa, Poland

* Contact for correspondence: e-mail: bork@zim.pcz.czest.pl

Received: 26.02.2010; accepted in revised form: 30.03.2010

Abstract

This study focuses on determination of the relationships between equipment efficiency in casting machines and the level of quality. The determination was made based on coefficients of Total Productive Maintenance and r correlation coefficient. The degree at which breakdowns and downtime affect the occurrence of non-conforming products was also evaluated. The goal of further investigations is to determine the structure of downtime and finding which downtime types have greatest impact on the quality of die-casting products.

Keywords: quality, die casting, equipment efficiency in casting machines, correlations

1. Introduction

Foundries today, in order to execute technological processes connected with casting, are equipped in a number of machines and equipment which are often partially or fully automated. Regardless of the equipment automation level, it is always necessary to incur expenses on repairs and maintenance, which, in consequences, impacts on the quality of the manufactured castings. The focus of quality-related activities [1] should not be on the detection of the finest non-conformities but rather on prevention of the previously detected non-conformities whose causes are already known. Knowledge of them makes it easier to search for enhanced design solutions for castings and dies [2] as well as for the processes. The goal of this study was to investigate the impact of equipment efficiency [3] on the quality of die castings made of AlSi alloys, and, in consequence, to point to opportunities of limitation of the number of non-conforming products through focus on proper maintenance. The paper presents the analysis of efficiency for two cold chamber die casting machines: semi-automatic IDRA machine with 700 t clamping force, manufactured in 2007 and Buhler machine from the seventies with clamping force of 660 t. The machines were marked M1 and M2, respectively.

2. Effect of the Efficiency of Die Casting Machinery Operation on the Quality of the Manufactured Products

Evaluation of equipment efficiency was made on the basis of TPM (Total Productive Maintenance) coefficient. TPM is typically defined as maintenance of the equipment implemented throughout the whole enterprise. TPM is a rather broader concept than conventional maintenance, which involves the necessity of scheduling and performing overhaul works, certification of instruments and devices, repairs of machines and equipment. The following TPM coefficients were employed for the analysis: operation coefficient (WE), operation rate coefficient (WPD), loading coefficient (WW) and effective time coefficient (UCD), given by the following formulae (1), (2), (3), (4) [4].

$$WE = ((TZ - TP) / TZ) * 100 \quad (1)$$

$$WW = WPD * UCD * WJ * 100 \quad (2)$$

$$WPD = (ICJ / RCJ) * 100 \quad (3)$$

$$UCD = ((P * RCJ) / (TZ - TP)) * 100 \quad (4)$$

Machine operators were asked to record the times connected with:

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

In order to determine if and how TPM coefficients and individual downtime impact on the quality of casting, correlation coefficient r was used [5]. Correlation coefficient was calculated from the formula (5):

$$r = \frac{\text{COV}(x, y)}{\delta x * \delta y} \quad (5)$$

δx - standard deviation of x variable,

δy - standard deviation of y variable,

In order to confirm the significance of r coefficient for each pair of variables, the significance level p was calculated. P value was calculated based on the set value of t-Student variable (x) and the values of parameters. Then, the significance of the relationship between X variables (non-conformity level – PN) and Y (coefficients such as: operation coefficient (WE) and loading coefficient (WW); times: breakdown time (TA), downtime (TP), die breakdown time (TA_d), machine breakdown time (TA_m)) was verified.

3. Analysis of Correlations Between TPM Coefficients and the Quality Level

Analysis of correlations (at the level of significance of 0.05) between the non-conformity level (PN) TA, TP, WE, WPD, WW and UCD for the machine No. 1 and No. 2 are presented in Figures 1 and 2, respectively. The correlations were calculated in total for 27 weeks in 2008 for both analysed machines. As results from the analysis of the Fig. 1 and 2, a strong positive correlation between the non-conformity level and breakdown time can be observed for both machine No. 1 and machine No. 2. This correlation is slightly stronger in the case of the machine No. 2 ($r=0,71$). As results from this analysis, rise in breakdown time (TA) occurs with the rise in the number of non-conforming products. The relationships between breakdown time and the quality level for the machine No. 1 are similar to those for the machine No. 2. In both analysed machines there is a significant [5] negative relationship between the operation coefficient and the non-conformity level.

As results from the analysis, loading coefficient impacts more on the level of non-conforming products in the case of the machine No. 2, reaching the value of $r = -0.549$. Operation rate coefficient also plays a more significant role in the case of the machine No. 2. However, effective time impacts significantly on the quality only in the case of the machine No. 2. Effective time coefficient in the case of the machine No. 1 does not significantly contribute to the occurrence of non-conforming products. This results from the fact that nominal unit time (ICJ) and real unit time (RCJ) are similar in the new, semi-automatic machine.

In the case of the machine No. 2, lack of automated casting spoon or the manipulator impacts on the rise in the number of manual operations necessary to be performed by an operator, which causes that USD reaches lower value than in the case of the machine No. 1 and, as results from Fig. 3, determines the occurrence of non-conforming products (22%).

Assessment of the level at which TP, TA, WE, WW, WPD, UCD explain the occurrence of non-conforming products was performed by means of the coefficient of determination R^2 , treated as the fraction of variance of the dependent variable (PN, represented by the level of non-conforming products) explained by the independent variable. The level of the coefficient for M1 and M2 is presented in Fig. 3. Analysis of Fig. 3 reveals that occurrence of non-conforming products is considerably determined by TP, TA, WE (above 45%).

Figure 3 also proves that effective time of operation impacts significantly on the quality only in the case of the machine No. 2. This coefficient reaches value of -0.4761 , which means that the number of non-conforming products decreases with the rise in this coefficient. Operation rate coefficient plays also more important role in the case of the machine No. 2, where occurrence of non-conforming products is explained in 45.5%, as compared to the machine No. 1 ($R^2=18.9\%$).

4. Conclusions

Analysis of the investigations reveals, in both cases, that the downtime (TP) breakdown time (TA), operation coefficient (WE), capacity coefficient (WW) and operation rate coefficient (WPD) considerably determine the quality of castings. A strong positive correlation between the level of non-conforming products and downtime and breakdown times can also be observed in both analysed machines. Other coefficients depend on the level of modernity of the studied machines. Effective operation time significantly affects the quality only in the case of the machine No. 2, which is caused by huge differences between nominal and real time of manufacturing of one piece of casting. In the case of the machine No. 1, which is more modern and more automated, more impact on the quality can be observed from downtime (TP) breakdown time (TA) and operation coefficient (WE) whereas in the case of the machine No. 2, essential effect is from WW, WPD and UCD coefficients. In the case of the machine No. 1, UCD coefficient does not significantly impact on occurrence of non-conforming products.

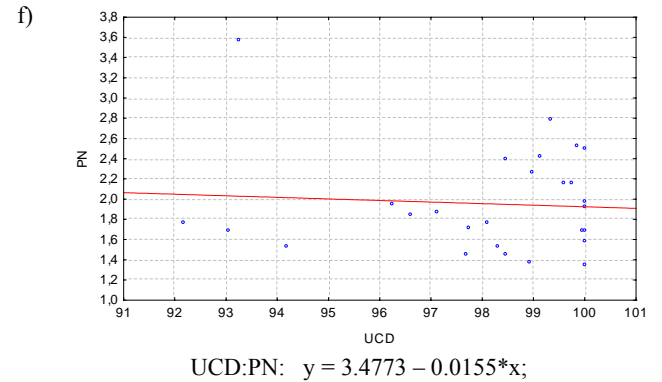
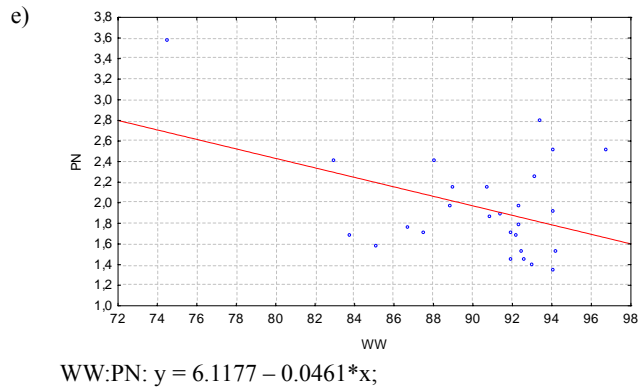
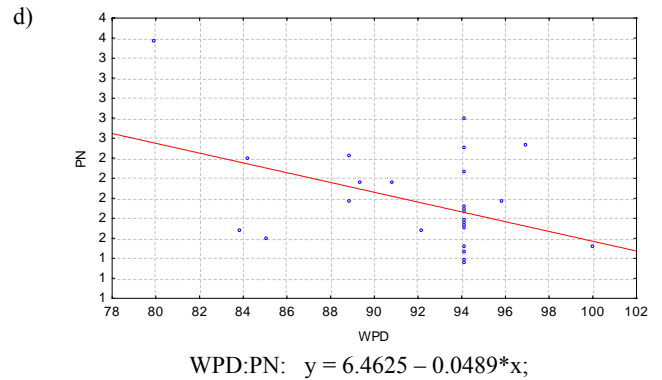
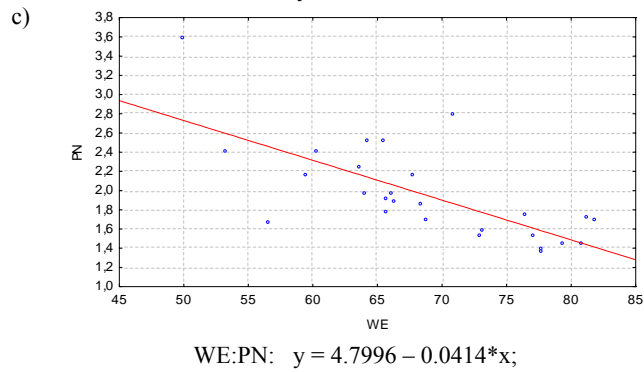
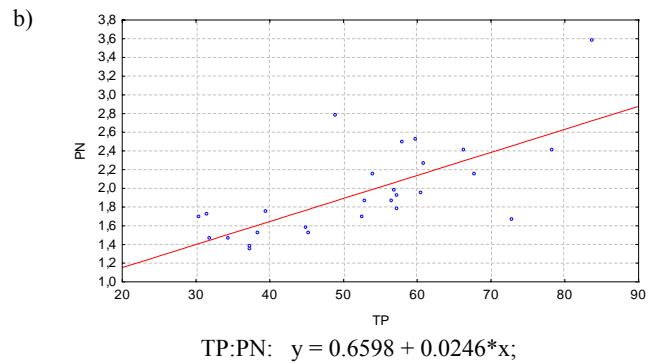
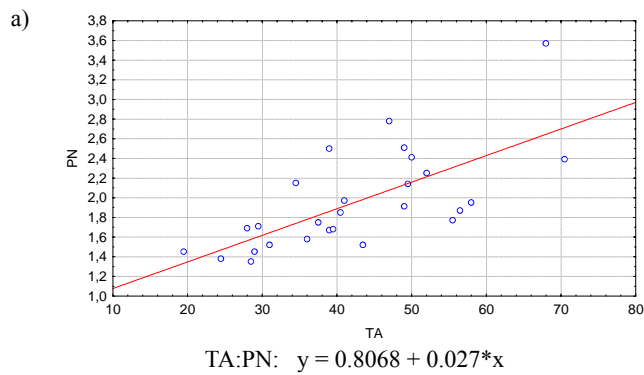
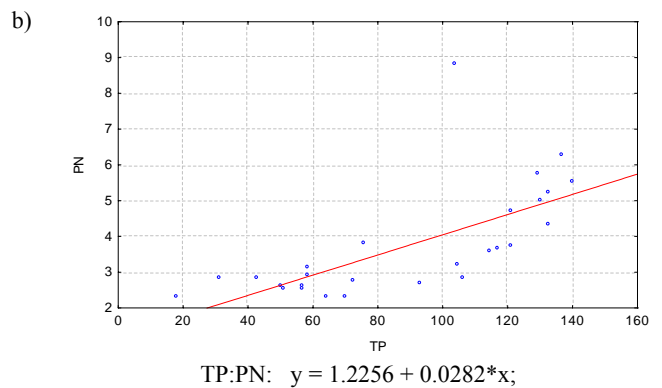
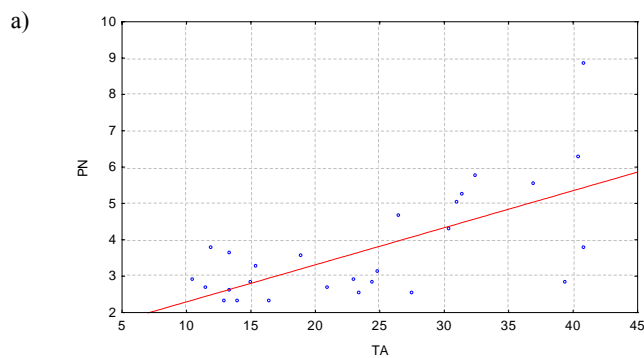


Fig. 1. Scatter between non-conformance level (PN) and the times and TPM coefficients calculated for the machine No. 1 (IDRA): a) TA, b) TP, c) WE, d) WPD, e) WW, f) UCD.



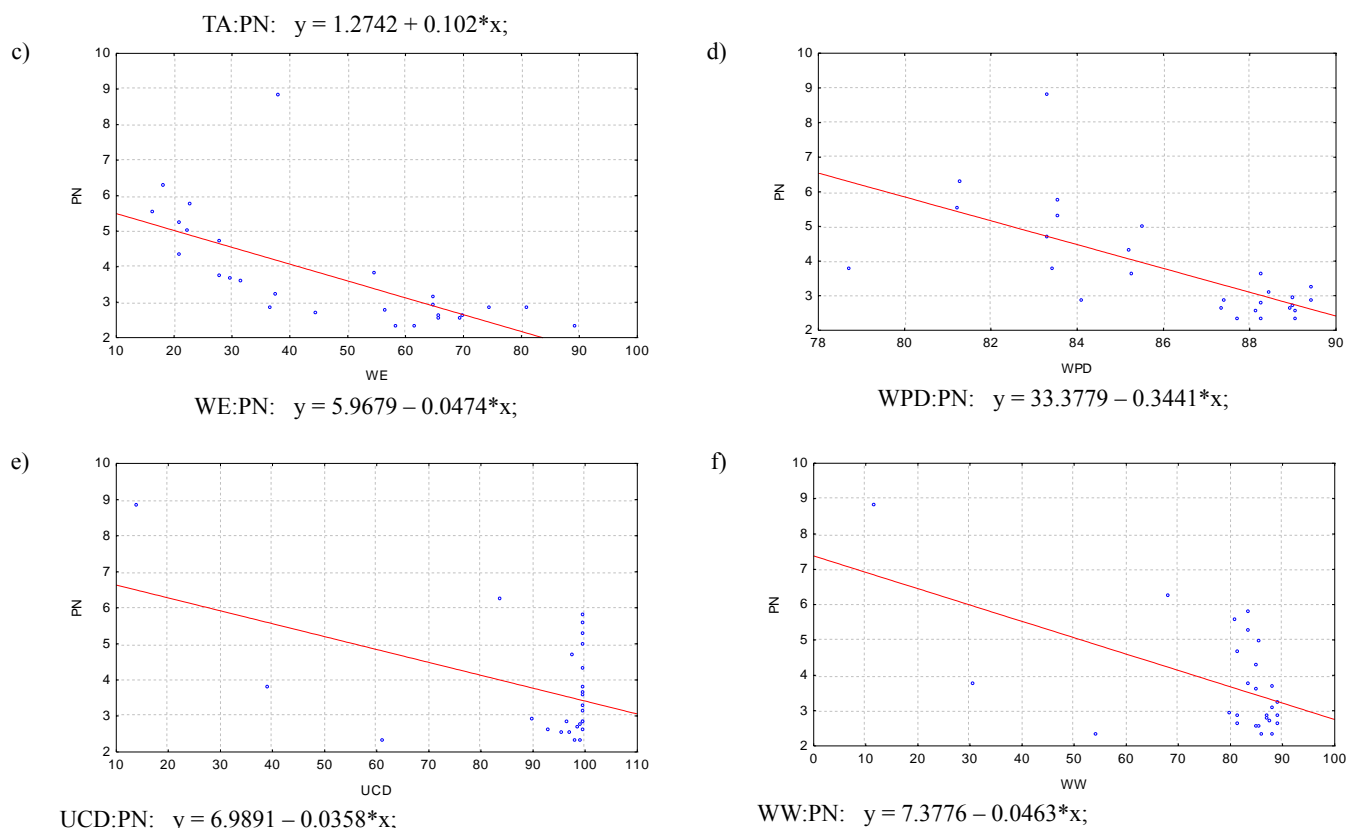


Fig. 2. Scatter between non-conformance level (PN) and the times and TPM coefficients calculated for the machine No. 2: a) TA, b) TP, c) WE, d) WPD, e) UCD, f) WW

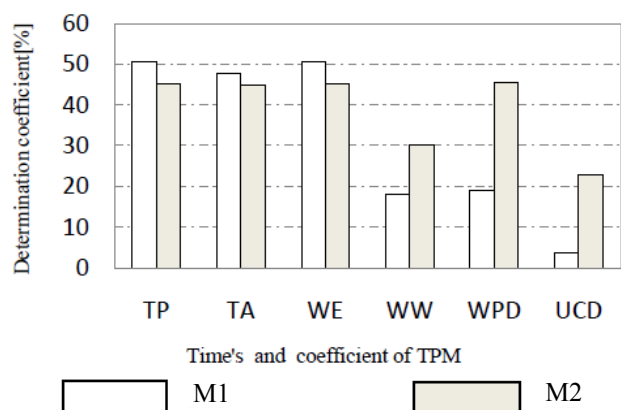


Fig. 3. Level of determination of the quality of castings by TP, TA, WE, WW, WPD, UCD for M1 and M2 (27 weeks in 2008).

Acknowledgments

Scientific elaboration finance from scientific funds in 2008 – 2010 years as a research Project N N 507 457334

References

- [1] W. Orłowicz, M. Mróz, Quality rating of Al-Si casts. Archives of Foundry vol. 4, No. 14, 2004, pp. 363-368.
- [2] E. Majchrzak, J. Mendakiewicz, Optimum location of sensors used for mould parameters estimation, Archives of Foundry Engineering, vol. 10, No 1 (2010) 97 – 100 (in Polish).
- [3] S. Borkowski, L. Jeziorski, A. Rychter, Managing the working time of machines by TPM. WSZiM Sosnowiec. Management and Marketing No. 6 (2/2004) (in Polish).
- [4] S. Borkowski, J. Selejdak, S. Salamon, Effectiveness of machines and devices use, Publishing by Technical University of Częstochowa, Częstochowa 2006 (in Polish).
- [5] S. Ostasiewicz, Z. Rusnak, U. Siedlecka, Statistics. Elements of the theory and tasks. Publishing by University of Economics, Wrocław, 2006, p. 333 (in Polish).