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Analysis of the causes of control panel inconsistencies in the gravitational casting process by means of quality management instruments

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Abstract

All castings can have defects caused by, for example, deviations in material characteristics, structure or properties, but the skillful use of available technologies and quality management tools allows for the detection and elimination of casting incompatibilities as well as the prevention of their recurrence in the future. The aim of the article was to analyse the types of defects in castings, locate the areas with the most frequent occurrence of defects and identify the reasons for the presence of defects in castings of the control panel and its cover. The paper presents the usefulness of a combination of quality management instruments for diagnosing material discontinuities in the analyzed castings.

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1. Introduction

One of the most important goals of running a company is to achieve the highest possible profit, which is mainly dependent on the number of realized orders. Contemporary companies are looking for ways to provide them with sustainable succession on the market, while at the same time creating a lasting existence and prestige (Talib et al., 2013). Availability of goods and services on the market makes the level of quality of products the main factor of competitiveness. The competitiveness of any national economy is based on the competitiveness of its enterprises, which are the elements that take account of its characteristics in order to be able to capture the components of competition (Mazur et al., 2010; Pietras, 2017).

Castings, the quality of which is determined by the technical conditions of their acceptance, are essential for every branch of industry (Kasliwal et al., 2017; Hsu et al., 2014). The production of casting, and, thus, maintaining the high quality of the finished product, is related to a number of technological parameters that may affect the quality of the finished product. The problem occurring during the casting production process is the inability to simultaneously control all the factors of the technological process (Ulewicz and Novy 2013). One and the most important option affecting the quality and competitiveness of a casting is to confirm that the casting is free from defects. (Humphreys et al., 2013, Ling et al., 2017). A defect or defects of castings shall be deemed to be any deviation of structural, material, physicochemical or mechanical properties from the applicable requirements. (Kim et al., 1995). A large variety of defects occurring in castings results from the very essence of the casting production technology, consisting of technological operations involving the design and manufacture of a casting mould and the technology of melting liquid metal. The qualifications of foundry employees, the nature of production, technical equipment of the foundry, etc., are also important (Arunkumar et al., 2008; Vergnano et al., 2019). When producing castings, it is impossible to ensure that there are no defects in every piece of manufactured art. The use of appropriate control and measurement equipment and instruments influencing the quality of production processes and products at all stages of their life cycle leads to actions aimed at minimizing losses. (Broucaret et al., 2001). Once a casting is found to be free from defects, it is considered to be of good quality. (Kasliwal et al., 2017a). Therefore, it is justified and necessary to select appropriate technological parameters not only to stabilize the process, but also to select appropriate quality management instruments contributing to the achievement of the desired level of quality and at the same time measurable organisational and financial benefits. The instruments used in the study (Pareto Lorenzo's diagram, brainstorming method, Ishikawa's diagram) are characterized by a planned, repeatable way of proceeding with the implementation of quality management tasks in production systems at different levels of management and stages of development of modern enterprises.

2. Experimental

The aim of the conducted research was to diagnose in between operational, quality control of castings condition of the control panel with its cover and to identify the reasons for the occurrence of inconsistencies in castings, in relation to which appropriate preventive and corrective actions could contribute to reducing the number of non-compliant castings.

The conducted research concerned the batch of products made in the 1st quarter of 2019 in one of the production companies located in the southern part of Poland. The scope of the casting inspection included verification of the casting surface and determination of the place of non-compliance and precise determination of the type of identified non-compliance. The quality control also included verification of the correctness of the casting marking. Quality control was performed in accordance with the internal procedure of the company according to each production order..

The 3D model of the control panel with its cover is shown in Figure 1.

Fig. 1. The subject of the research - model 3D of the control panel along with the lid

The subject of the research is cast gravitational in EN alloy AC-AlSi 12 (Cu) (EN AC-47000). Table 1 shows the chemical composition of used alloy.

Table 1. The chemical composition of EN AC-AlSi12(Cu) alloy

Element	Value (%)	
	min	max
Cu	-	1
Sn	-	0.1
Ti	-	0.15
Si	10.5	13.5
Mg	-	0.3
Cr	-	0.1
Mn	0.1	0.5
Ni	-	0.2
Fe	-	0.8
Zn	-	0.5
Pb	-	0.2
other pollutants (everyone individually)	-	0.5
other pollutants total)	-	0.15
Al - remainder		

Source: own study based on: http://ctntw.prz.edu.pl

Mechanical properties of casting EN alloy AC-AlSi 12 (Cu) Table 2 is showing.

Table 2. Mechanical properties of EN AC-AlSi12(Cu) alloy

Name of the property	Value (%)		Unit of measurement
	min	max	
Yield point (R0,2)	80	100	MPa
Resistance to stretching (Rm)	150	210	MPa
Extending (A5)	1	4	%
Brinella hardness	50	65	HB

Source: own study based on: http://ctntw.prz.edu.pl

3. Results and discussion

Currently, in the analyzed company, each casting of the control panel is subjected to a visual quality control performed after the completion of each production operation. In order to minimise the number of castings verified as non-compliant, the analysis of the reasons for discards has been undertaken. The first step of the analysis was to determine the areas in the casting of the control panel (Figure 2) in which the most frequent irregularities occur and to determine the type of these defects.

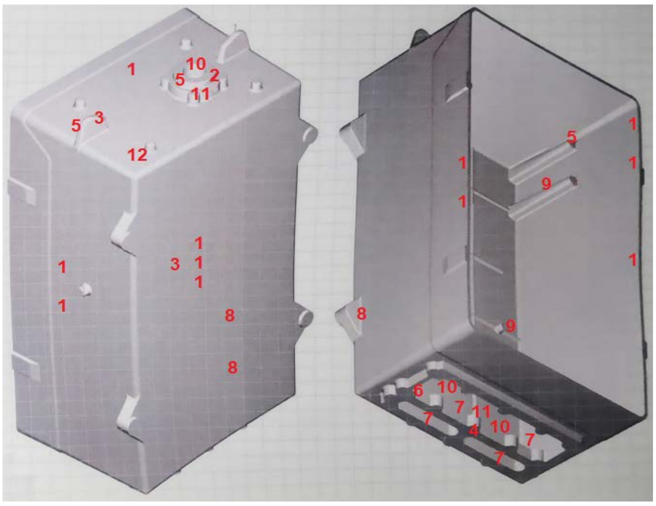


Fig. 2. Cast of the control panel with marking out areas in which incompatibilities most often appear (1 - disagreement of the thickness of the partition wall; 2 - systolic hollow; 3 - dirtying with sand; 4 - misrun; 5 - gas bladders; 6 - moving the core of the form; 7 - disagreement of the surface roughness; 8 - removing; 9 - of interjecting sand; 10 - mechanical damage; 11 - sanding; 12 - I am going pale or illegible marking the cast)

Preliminary analysis identified 12 types of non-compliances in the control panel casting. An integral part of the control panel is its cover, which has also been subjected to preliminary analysis (Figure 3).

The proposed instrument for an in-depth analysis of casting defectiveness was the Pareto-Lorenz analysis to identify the most significant inconsistencies from the point of view of the number of their occurrence (Fig. 4). In the Pareto Lorenzo diagram, the non-conformities have been highlighted as shown in Figures 2 and 3.

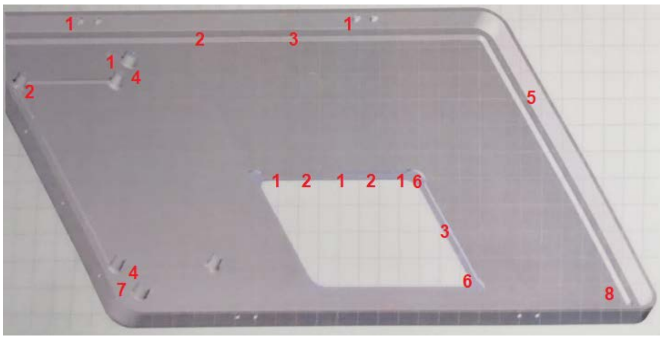
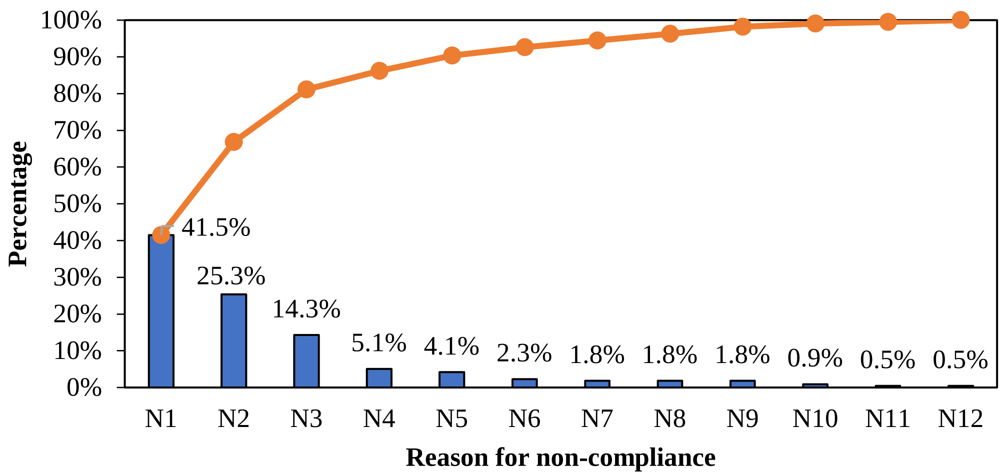


Fig. 3. Cast of the lid of the control panel with marking out areas in which incompatibilities most often appear (1 - misrun, 2 - systolic hollow; 3 - porosity; 4 - of interjecting strange material; 5 - mechanical damage; 6 - sanding; 7 - gas bladders; 8 - incorrect or illegible marking the cast)

Analysis of the cast of the control panel conducted by means of Pareto-Lorenzo ddemonstrated that the following disagreements were the most important ones: N1 - disagreement of the thickness of the partition wall (41.5%), systolic hollow (25.3%) and dirtying with sand (14.3%). Specified defects contribute to the creation of the 81.1% of all the gaps following the process of pouring the detail out. Whereas Lorenzo's Pareto analysis performed for the lid of the control panel specified the most substantial defects concerning the disagreement: N1 - misrun (45.7%), N2 - of systolic hollows (17.2%) and N3 - porosity of the cast (15.5%). As a result of the presence of specified disagreements, 78.4% of all the gaps occurred after the process of pouring the detail out.

In order to reduce costs and make the right decision regarding the handling of non-compliant products, defects should be disclosed at the earliest possible stage of the production process, because then they generate lower costs than detection at the time of final inspection. Additionally, the disclosure of a defect in the place where it occurs enables the application of effective corrective and improvement actions, which in the future may eliminate it.

a)



b)

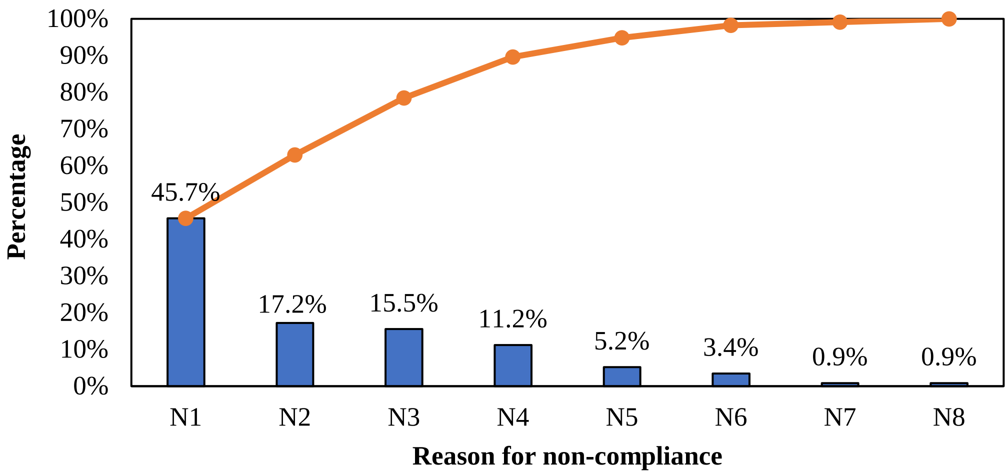


Fig. 4. Graph of Pareto-Lorenzo: a) of the cast of the control panel, b) of the lid of the control panel

Data on the type of quality control in which the most inconsistencies with a particular type of defect are detected and decisions on handling the non-compliant product are presented in Table 3.

Table 3. Percentage of the decision to deal with the incompatible production

Cast of the control panel				
Kind of the defect	Quality check	Decision		
		Recycling	Repair	They allowed
disagreement of the thickness of the partition wall	control between operating	88%	10%	2%
systolic hollow	control between operating	69.3%	28.1%	2.6%
dirtying with sand	preliminary control	77%	22 %	1%
Cast of the lid of the control panel				
misrun	preliminary control	66%	34%	0%
shrinkage cavity	control between operating	61.1 %	37.1%	1.8%
porosity	control between operating	87.3%	12%	0.7%

To identify the causes of the most severe quantitative inconsistencies (control panel casting - incompatibility of casting wall thickness; control panel cover casting - under casting) in the analyzed castings, it was decided to use a combination of quality management instruments, i. e. the brainstorming method and the Ishikawa diagram.

The brainstorming method has been used to search for all possible causes of product incompatibilities and their hierarchy. The causes identified during the brainstorming session are presented in the Ishikawa diagram showing the mutual relationships of causes causing specific problems (Figure 5). Due to volume limitations, the article contains a part of Ishikawa diagrams containing the key causes of the discrepancies.

4. Summary and conclusion

Continuous monitoring of the production process and improvement of the quality of manufactured products is the key to the success of every company. The presented proposal for a detailed analysis of the types of occurring incompatibilities in castings, identification of areas in which defects are most frequently located and identification of the causes of the presence of defects in castings contributes to their elimination and implementation of effective measures to prevent the occurrence of incompatibilities in the future. The key reason for the most significant flaw in the control panel (incompatibility of wall thickness) was that the metal temperature was too low during casting, while in the case of lid casting, insufficient permeability of moulding sand contributed to the most severe flaw - misrum of casting.

Further research will be related to the implication of the proposed sequence of casting defect analysis, which is an effective way of solving quality problems within the production of other products offered by the company.

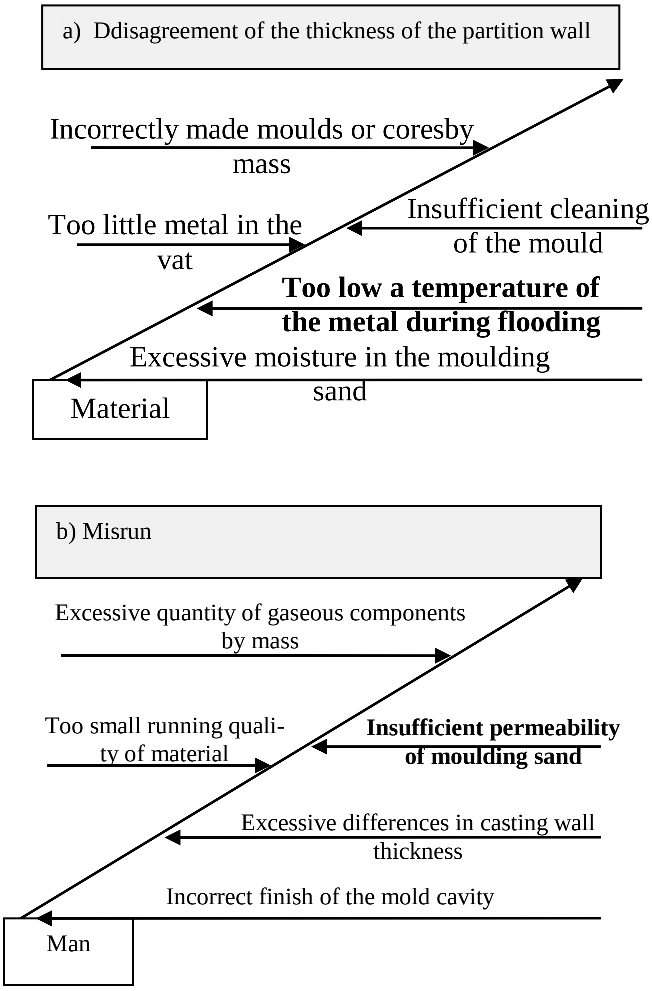


Fig. 5. Fragment presenting the diagram of Ishikawa information from the area of appearing of crucial causes problem quality: a) cast of the control panel b) cast of the lid of the control panel

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利用质量管理手段分析重力铸造过程中控制面板不一致的原因

關鍵詞
帕累托-洛伦茨图
头脑风暴
石川图
优质工具

摘要
所有铸件都可能由于例如材料特性，结构或性能的偏差而导致缺陷，但是熟练使用可用技术和质量管理工具可以检测和消除铸件不兼容并防止其在铸件中再次出现。未来。本文的目的是分析铸件中的缺陷类型，找出缺陷最频繁出现的区域，并确定控制面板及其盖板铸件中存在缺陷的原因。本文介绍了结合使用质量管理工具来诊断所分析铸件中材料间断的有用性。