ALUMINIUM CASTING TECHNOLOGY MANAGEMENT ANALYSIS

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Abstract

The turbulent manufacturing market, and in particular the metallurgical industry, determines continuous improvement in the level of production efficiency and product quality. The aim of the study was to create a universal model enabling an assessment to be made of the impact of the modernity of aluminium casting machining technology on the quality of the final product and occupational safety in the company under study. The research methodology included the determination of the degree of modernity of machines, identification of the impact of the degree of modernity of machines on the quality and safety of the process, as well as the analysis of relations that occur between critical nonconformities and technological factors and accidents and near misses. The method presented in the study can be useful for the effective management of casting treatment technology in manufacturing companies, in order to select an appropriate development strategy and ensure safe working conditions.

Keywords: Mechanical engineering, management and quality, foundry, aluminium alloy

1. INTRODUCTION

The production system is an integral part of manufacturing enterprises that enables the execution of production processes. The main objective of the production system is to ensure an adequate level of quality, reliability, productivity, efficiency and modernity [1,2]. The level of modernity of technical resources and the entire production system is an important component of enterprise development [3]. Modernity is the result of progressive development in the field of science and technology, whereby the phrase new object is not always equated with modern [4]. With regard to technical systems, modernity can be defined as a higher degree of fulfilment of expectations, together with the application of the latest experience and trends in: design, construction, manufacture and operation [5]. Modernity is linked and identified with the term quality, as modern equipment is most often associated with high quality workmanship. Therefore, it is important to assess the level of modernity of a company's production resources, which is often the starting point for activities to improve the level of competitiveness in the market [6]. The level of efficiency of the means of production is one of the components of the productivity of the production system, as well as controlling analyses of the manufacturing process. Efficiency most often indicates the relationship that exists between the expected results and the actual production volume. Therefore, it is important to carry out productivity analyses of the entire production process and its components, i.e. individual workstations and production operations. The effectiveness of these studies is influenced by the identification of resource constraints (bottlenecks) and the consideration of organisation-specific critical resources [7].Due to the increase in demand for aluminium alloy parts and components and the increase in demands placed on these components in the metallurgical industry, analyses are being carried out on the progress and achievements in the shaping of aluminium alloys [8], on the improvement of manufacturing technology [9] or on the improvement of casting quality - the microstructure and properties of castings [10]. The literature on the subject also identifies critical parameters affecting each casting process and which significantly determine the quality characteristics of metal castings [11]. Comparative analyses of casting techniques [12] and reviews of new process technologies [13] developed to identify the most favourable solution to help foundry men make the optimum decision on the choice of technique taking into account the assurance of a high level of quality, environmental friendliness, favourable cost implications and taking into account occupational safety are being carried out. However, the issue of assessing the modernity of aluminium casting processing technology remains unresolved. The proper implementation of management-related analyses makes it possible to restructure and improve foundries, and thus to manage machining technology effectively. Therefore, the aim of this study was to create a universal model to perform an assessment of the impact of the modernity of aluminium casting machining technology on the quality of the final product and occupational safety in the company under study. The possibility of influencing the quality of aluminium products is of great importance, e.g. in the electronics industry [14,15], in shaping [16] as well as in construction [17] and military applications [18] as well as in further development of analytical methods [19,20].

2. METHOD OF RESEARCH

In terms of ensuring the desired level of product quality, a management model for casting technology was developed (**Figure 1**).

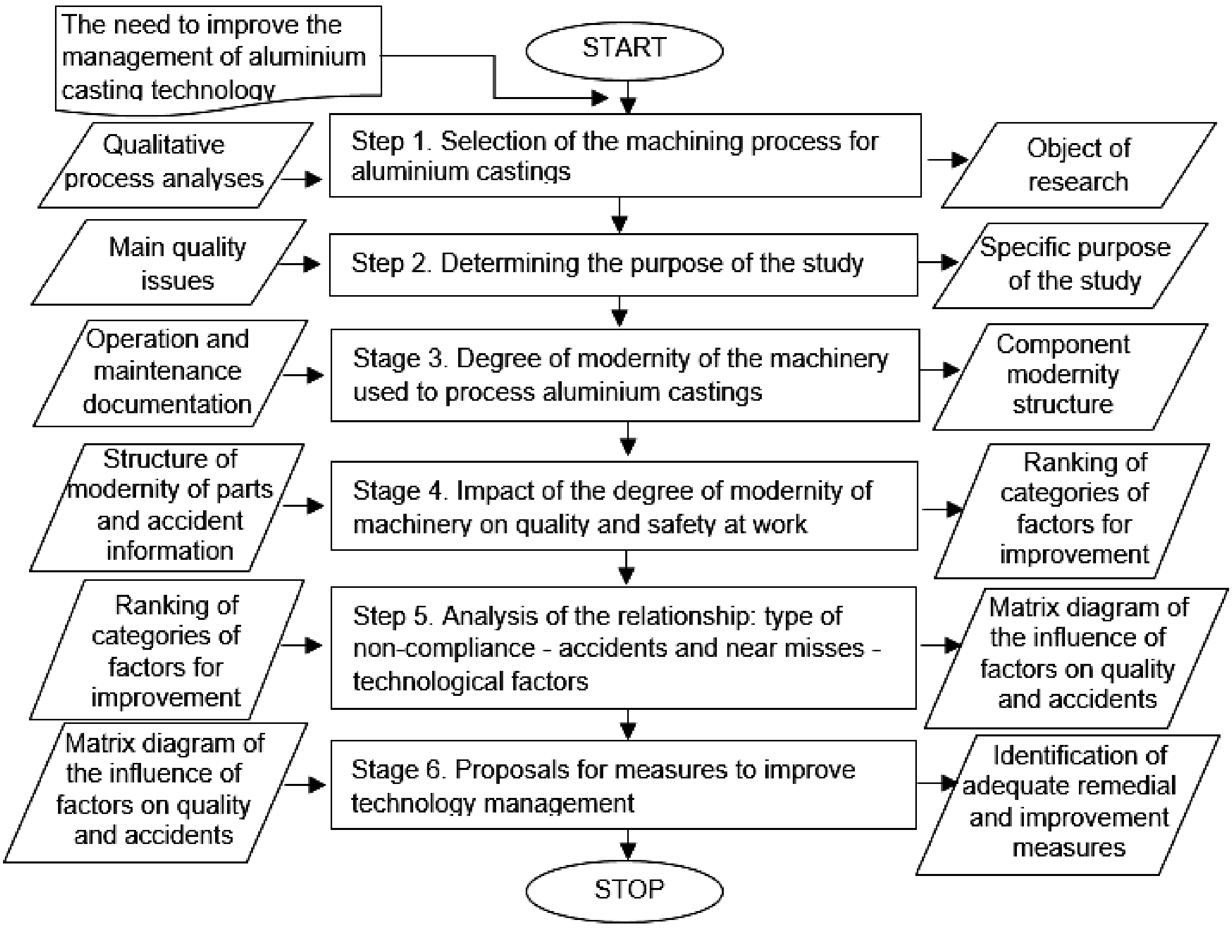

Figure 1 Concept of a management model for aluminium casting processing technology

Step 1. Selection of the aluminium casting machining process (research subject): the selection of the object of research should concern the aluminium casting machining process, which should be diagnosed with a view to identifying the key factors affecting the decline in the quality of the safety level. **Step 2.** Defining the research objective: the objective of applying the model should be to improve the aluminium casting machining process in terms of the quality of the products produced and to ensure occupational safety. In addition, the objective should address the variables that characterise the subject of the research. **Stage 3.** Degree of modernity of the machinery used for aluminium casting machining: the identification of strategic components is carried out by analysing the operation and maintenance documentation, and classifying them into categories A, B and C (ABC technology method). A Pareto-Lorenz diagram is used to visualise the results of the classification. The degree of modernity is assessed using Parker's five-level scale, whereby: level 1 - simple parts (can be manufactured using craft techniques), level 2 - parts manufactured using techniques that have been known and unchanged for years, level 3 - parts manufactured using technology based on technical knowledge, level 4 - parts manufactured using modern technology, level 5 - parts manufactured using the latest technology (patented, found only in this device). **Stage 4.** Impact of the degree of modernity of the machinery on the quality and safety of the process: as part of the implementation of Stage 4, a brainstorming session should be conducted during which experts present information on the level of quality of the machining processes carried out and on quality problems within the investigated workstation. Recorded accidents within the analysed workstation and potential causes (related to the state of the analysed workstation) of the situation should also be presented. The responses are grouped into 5M categories and an Ishikawa diagram is created**. Stage 5.** Analysis of the relationship: type of nonconformity - accidents and near-misses - technological factors: using a matrix diagram, the relationship between the identified product nonconformities and accidents and near misses (vertical view of variables) and the categories of factors generating the negative events is presented. The diagram also considers the degree of importance from the customer perspective and the company perspective on a five-point importance scale. **Step 6** Suggestions for improvement actions in the context of improving quality and occupational safety: the expert team identifies improvement measures for the aluminium casting machining station under the categories man, material, machine, method, management.

3. RESULTS

Stage 1 Selection of the machining process for aluminium castings (subject of the study): The rough machining process of oil sump castings used in light vehicles was investigated. Pre-treatment is carried out on a numerically controlled lathe. The basic parameters characterising the lathe used are shown in **Table 1**. Due to the competitive nature of the data, the exact name of the lathe is not indicated. The decrease in the level of quality of the technological operations carried out within the designated machining station and the increase in the number of complaints determined the choice of research subject. **Stage 2** Defining the research objective: The aim of the research is to improve the machining process of aluminium oil sump castings in the context of increasing the quality of manufactured products and ensuring occupational safety. **Stage 3** Degree of modernity of the machines used for machining aluminium castings: The components of the sum-controlled lathe were identified from the operation and maintenance records. The components were classified into categories A, B and C and rated using Parker's five-degree scale, as illustrated in **Table** 2. The main assemblies of the lathe that have a significant impact on the outcome of the technological operations were mostly rated at level 4, as well as levels 5 and 3. This distribution in segment A indicates that the parts of the lathe manufactured using the latest technology based on technical knowledge. Based on the analysis of the modernity of the workstation, the results were analysed using a Pareto-Lorenz diagram (**Figure 2**) to graphically present the results of the modernity assessment according to Parker's scale. The Pareto-Lorenz chart presented shows that the numerically controlled lathe was mainly rated at the third level of modernity (54% of the components). After analysing the components of the workstation under study, it can be concluded that out of the 13 main components of the lathe, only one was assigned the fifth level of modernity according to Parker's scale. **Stage 4** Influence of the degree of modernity of the machines on quality and process safety: Current quality problems caused by the condition of the analysed lathe were attached and data on work accidents and their causes related to the analysed site were collected. After a brainstorming session involving the production manager, quality control manager and foundry department manager, the employees' responses were grouped into 5M categories and visualised in the form of Ishikawa diagrams (**Figure 2**). The analysis of the factors shows that in the area of 'machine', the experts saw the main problems related to its poor maintenance and inadequate condition. On the 'methods' side of work and production, problematic issues were also identified (lack of job documentation). The analyses carried out indicate that the causes of work accidents or near misses are mainly technology-related elements (machine, human).

Table 1 Features of the numerically controlled lathe under analysis

Features of the lathe	Parameter
Maximum workpiece diameter	1000 mm
maximum workpiece height	700 mm
maximum turning diameter	1500 mm
main motor power	45 kW
maximum workpiece weight	1800 kg
number of tool locations	12
year of manufacture	2002

Table 2 Assessment of the state-of-the-art of numerically controlled lathe components

No	The segment	Components of the lathe	Evaluation
1.	A - main components which largely determine the result	Control panel	4
2.		Program	5
3.		Control system	4
4.		Tool used	3
1.	B - sub-assemblies that support the operation of the machine	Hydraulic system	3
2.		Drive system	3
3.		Slide	2
4.		Manipulator	3
1.	C - parts of the machine safety sub-assembly	Machine base	3
2.		Machine structure	3
3.		Lubrication system	2
4.		Cooling system	3
5.		Chip transport	2

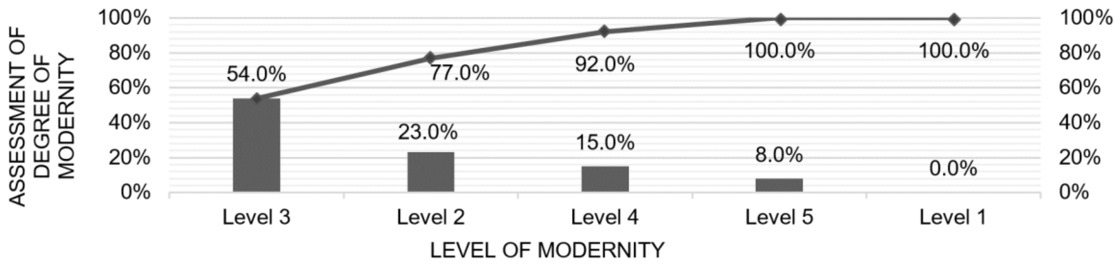

Figure 2 Generalized assessment of the level of modernity of the workstation

Table 3 Analysis of the causes of poor casting pretreatment quality and accident and potential accident situations

Poor quality of pretreatment of casting	
Category	**Potential cause**
Material	poor casting properties, inadequate casting dimensions, lack of repeatability
Machine	Poor maintenance of the lathe, inadequate technical condition of the lathe, inadequate accessories, poor setting of the lathe
Man	lack of knowledge, lack of responsibility, poor communication, low qualifications, lack of care for the workplace
Method	lengthy process, lack of work instructions, lack of procedures, outdated technology
Management	poor organisation of work, work at too fast a pace, frequent retooling of the lathe, poor quality control, staff turnover, lack of supervision
Accident and near-accident situations	
Material	poor arrangement and storage of work items (products)
Machine	inadequate securing of the machine, worn-out machine parts, inadequate repair and overhaul, breakdown of the machine
Man	arbitrary behaviour of the employee, ignoring the danger, poor concentration of the employee, poor behaviour of the employee
Method	poor work organisation, lack of work instructions, lack of procedures, lengthy process, lack of training
Management	lack of supervision, poor communication with management, poor communication between employees, poor work organisation

Poor technical condition of the machine and inadequate behaviour of employees or failure to comply with health and safety rules are common causes of risky events. Stage 5 Analysis of the relationship: type of non-conformity - accidents and near-misses - technological factors: The result of the analysis of the relationship between product nonconformities and accidents and near-misses and the categories of factors causing them is presented in the form of a matrix diagram (**Table 4**). The analysis used a scale of 1-5 for the importance of nonconformities to the customer and the importance of accidents and near-misses to the business owner. Based on the strength of the relationship, a ranking of factor categories (5M) was drawn up for the improvement of the aluminium casting machining process. The analysis of the strength of the relationship shows that the factors in the "machine" and "human" categories have the greatest influence on the occurrence of critical nonconformities, while the factors in the "human" group have the greatest influence on accidents and near misses, followed by "machine" and "management". Step 6 Suggestions for improvement in the context of improving quality and safety at work: Within the 5M category, the expert team proposed that in the areas with the greatest impact (human, machine), periodic training should be implemented, job instructions should be developed, and constant inspection and maintenance, provision of appropriate tooling and improvement of lathe settings should be carried out. Additional measures to define a control system, ensure constant supervision of workers.

Table 4 Analysis of the influence of factors on the occurrence of non-conformities related to casting pretreatment and failures and near misses

Discrepancies	Materiality level	Man	Machine	Method	Management	Material	Modernity of the lathe	Technology (total)
Dimensional irregularities	4	5	5	3	3	2	3	3
Defects	5	5	5	4	3	2	3	3
Burrs	4	4	5	3	4	2	3	3
Inadequate surface roughness	4	4	5	5	4	2	3	3
Incomplete machined product	4	5	5	2	4	2	3	3
Sum of products	-	232	250	170	184	101	-	-
Ranking	-	II	I	IV	III	V	-	-
Accidents and near misses	5	5	4	4	4	1	4	4
Total	-	9	4	0	1	1	5	5
Ranking	-	I	II	IV	III	V	-	-

4. CONCLUSION

The implementation of research related to the management of aluminium casting machining processes allows restructuring and improvement measures to be carried out within the foundry. The aim of the study was to create a universal model enabling an assessment to be made of the impact of modernity of aluminium casting machining technology on the quality of the final product and on work safety in the company under study. The effect of the analyses carried out was to identify the critical parts of the numerically controlled lathe and to identify the key factors that therefore influence the quality of the machining process of aluminium castings and occupational safety. The steps identified allowed the determination of the relationship that exists between groups of factors and key casting nonconformities and accidents and near misses. The method presented in the study may be useful for the effective management of casting processing technology in production companies, in order to adopt an adequate development strategy and ensure safe working conditions.

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