Management of the activity of quality assurance of cast iron castings in foundries

A Josan, E Ardelean, M Ardelean and V Puțan
Politehnica University of Timisoara, Department of Engineering and Management, 5 Revolution Street, Hunedoara, 331128, Romania
E-mail: ana.josan@fih.upt.ro

Abstract. In Romania, at present, the process of casting the parts is used under different methods. Thus, castings have different configurations and are used in various fields of technology, such as for the automotive industry, motorcycles and engines, electrical and electronics, space, computing and office equipment, agricultural machinery, aeronautics, woodworking or household industry. There is also a wide variety of materials used in casting these types of castings. The quality of the castings is found in the final product and, therefore, a special importance is attributed to the management activity to ensure the proper management of all processes in the foundry. For this, methods, techniques and management tools are used and applied so as to continuously optimize processes and activities and to be in accordance with the objectives of the system, respectively the continuous quality assurance and customer satisfaction. The paper presents the possibility of obtaining the quality of vermicular graphite cast iron castings, of the gate valve type.

1. Introduction
If a foundry is analyzed as a global system mainly through the prism of the manager, the quality of the castings directly influences the manufacturing costs as well as the production volume, by the fact that rejects and defects that need remediation affect manufacturing costs and production volume is dictated by demand market, which depends on the quality of the products or services [1].

Consequently the quality, which in the conditions of the competitive economy is a primary factor for the viability of the company, must be in the center of attention of the foundry manager. Thus, the control and assurance of the quality must occupy the central position of the organization's management. Moreover, the continuous growth and improvement of an organization's performance depends, to a large extent, on how proper management is ensured within the organization. The activities carried out within the organization have as main purpose the achievement of the established objectives, through the optimal use of resources. Thus, the quality management system of an organization carries out activities of planning, organization, the control and quality assurance, in the context of measurable objectives established and stated in the policy defined at the level of the organization, according to ISO 9001: 2015 standards [2].

In a foundry, it is necessary to implement a quality management system due to economic factors (reducing non-quality costs, reducing complaints, increasing sales volume, etc.) but also competitive factors (increasing confidence that products will satisfy quality requirements mentioned in the specifications) [3].
Quality is a key indicator of any organization. The arguments in favor of this statement are related to the fact that the quality level of the products is influenced by all the departments of an organization, but it also influences them. In this context, it is possible to talk in foundries about conformity / non-conformity for a cast part.

According to [4], conformity represents the fulfillment of a customer's requirement and its antonym, respectively non-conformity, represents the non-fulfillment of a requirement. Requirement means “need or expectation that is declared, generally implicit or mandatory” [4]. Thus, one of the main purposes of a quality management system is to act as a tool for prevention. The concept of preventive action in this standard is expressed through the use of risk-based thinking in formulating the requirements of the quality management system [2].

The management system of a foundry involves monitoring and evaluating each process, respectively the application of the PDCA cycle for each process carried out within the organization. For each process it is necessary to establish a working procedure (instructions) and apply corrective / preventive measures where appropriate, in order for the proper functioning of the organization [3].

2. The technological process of obtaining the casting
Currently, there is a growing global demand for castings in most areas, especially in the automotive and space industries. In Romania, at present, the process of casting the parts is used under different methods. Thus, castings have different configurations and are used in various fields of technology, such as for the automotive industry, motorcycles and engines, electrical and electronics, space, computing and office equipment, agricultural machinery, aeronautics, woodworking or household industry [5].

Due to the wide range of fields in which castings are used, the methods and technologies applied to obtain them are also particularly important.

Thus, technology has (regardless of the operation or phase to which it refers) special importance, marked by its percentage in the production process both technically and economically. Technology must always find the best solutions from a technical point of view (which will place the product in the required technical conditions) but also economically. The correlation between them is reflected in the cost of the product, which must be competitive or, in the absence of competition, be economical, profitable.

In order to obtain some parts by casting, it is necessary to go through well-defined stages that are grouped by activity sectors. Usually, a foundry specializes in casting ferrous / non-ferrous alloys, equipped with induction furnaces or electric arc furnaces for elaborating (processing, mainly, own metal waste), mechanized and manual line for obtaining moulds and cores etc. The main sectors of a foundry are [6]:

- Preparation of raw materials and auxiliary materials for moulds and cores;
- Moulding practice;
- Core moulding;
- Preparation of raw and auxiliary materials for the elaboration of the alloy;
- Elaboration of liquid alloy;
- Casting of liquid alloy;
- Cooling and solidification of casting;
- Shake-out of moulds;
- Cleaning of castings;
- Technical quality control.

Figure 1 systematically presents the component elements of a foundry system as well as the interaction between subsystems [6].
Figure 1. The components of a foundry system: SPMM - Sector for the preparation of moulding mixture; SPCM - Sector for the preparation of core mixture; SPEM – Sector for preparation of elaboration materials; E – Elaboration of liquid alloy; M – Moulding; CM - Core moulding; Ca - Casting; Co – Cooling; S - Shake-out; Cl – Cleaning; TQC - Technical quality control

For the analysis of the activities necessary for the elaborating of the manufacturing technology of the cast iron part, a Wedge Gate Valve is studied. This type of castings are used in hot/cold installations or other fluids (exclusively acidic or flammable); its work at the nominal pressure $P_n = 25$ bar and has the nominal diameter $D_n = 150$ mm (Figure 2) [7].

Figure 2. The drawing of the finished piece – Wedge Gate Valve

The studied part ($WGV$) is cast in grey cast iron with vermicular graphite ($GJV 350$), elaborating in induction furnace. The characteristics of the elaborated vermicular graphite cast iron, $GJV 350$, are presented in Table 1 [8].

Table 1. The chemical composition and mechanical properties of cast iron $GJV 350$

| Chemical composition (%) | Mechanical characteristics |
|--------------------------|---------------------------|
| C  Si  Mn  P  S  Rm  Rp0.2  A  E  HB |
| 3,4-3,8  2,0-3,0  0,8-1,2  Max.0,08  0,03  ≥350  Min 240  1,5  140-160x10⁵  160-220 |
In foundry, the technology of obtaining the finished product places special emphasis on the technology of moulding-casting, which has an essential role in obtaining the quality of the casting. In this sense, first of all, the quality management of the organization emphasizes, regarding the realization of the castings, that it is necessary to plan the realization of the product and then identify the processes related to the relationship with the customer. Thus, the organization plans and develops all the processes necessary to make the finished product, starting from the supply of raw materials to the performance of technical quality control. All the activities necessary to carry out the activities within the organization are described in the procedures and are provided: equipment, competent employees for the execution of special procedures that take place within the organization but also the necessary resources.[3]

Thus, based on the drawing of the finished piece (Figure 1), the technological design is made (Figure 3). It has a very important role due to the fact that the castings have different configurations and different degrees of complexity. It is necessary to take into account all stages and aspects of the process, respectively: the casting position of the part, the establishment of shrinkage, processing and technological allowances, as well as constructional inclinations. All these elements are presented on the technological design (Figure 3) with different hatches and colors, established according to standards and industrial practice[9].

![Figure 3. Technological design](image)

The studied casting has a configuration that is suitable for mechanized moulding. For this it is necessary to make a metal pattern, preferably made of aluminum. The pattern of the piece is made of two equal parts, separated according to the separation plane of the piece (Figure 4), so that two mould parts will be needed. The negative of the casting will be obtained, both in the lower mould part and in the upper mould part; the runner heads and the gate runner will be mounted in the upper mould part[9].
Figure 4. The pattern of casting (metallic pattern)

The metal pattern, being composed of two pieces separated by the separation plane, is positioned on the moulding boards and fixed in screws (for the lower mould part the lower part of the pattern is mounted and for the upper mould part: the upper part of the pattern, together with the runner heads and pouring gate) [9].

The two moulding boards are mounted on the frame on the molding machine then, with the help of some rolling paths, from the moulding area are brought the mould jacket, which are placed over the moulding board.

In order to obtain the core (made according to the technological design) a core box will be made (the separation plane of the core box will be identical to the separation plane of the casting).

The casting is performed from two ladles containing modified and postmodified liquid cast iron, during 15 sec / mold. After casting the liquid alloy the mould reaches the cooling area of the molding-casting installation. Until the mould reaches the end of installation the casting solidifies and the shake-out process can take place (there is a shaking table at the end of cooling area) [9].

The mould reaches the shaker grill where the shake-out takes place and the raw casting is transported by means of a metal conveyor to the cutting area of the runner heads and the pouring gates. The removal of the pouring gates is done by hitting with the hammer and of the runner heads by cutting with abrasive disc.

In the situation where, following the shake-out operation performed on the shaker, a moulder mixture remained on the casting, it is transported to the area of the sandblasting chambers, to be cleaned. After this preliminary cleaning, the casting is transported to the pendulum grinders for a complete finishing [9].

After cleaning and finishing operations, a normalized heat treatment is applied to the casting (heating to a temperature of 900°C, maintaining at this temperature about 1.5h, then cooling in air), to obtain a fine perlitic structure and a homogenization of the structure.

After performing the technical quality control, the casing is transported to the priming sector, then to the scalping sector and, finally, it is delivered to the beneficiaries.

The moulding mixture required to make the molds will be of the AFC2 type (pattern mixture and filler mixture). The cores will be made of AMS3 type mixture using wooden core boxes. Instructions for the preparation of raw forming mixtures for the moulding of the casting are contained in the technical documentation of the organization [10].

Following the use of the unique moulding mixture for raw moulds (AFC-2), a series of rejects were registered in practice due to the use of this type of moulding mixture.
3. Quality assurance of the technological process
The quality assurance standards of the castings require the control of the production, respectively the monitoring, evaluation and application of corrective / preventive measures for all the processes applied in the foundry [11]. The processes that take place within the organization are documented in work instructions and procedures (previously reviewed and approved) and refer to:
- Elaborating and casting of the cast iron;
- Mechanical processing applied to castings;
- Application of heat treatments to castings;
- Monitoring and evaluation of all production processes;
- Application of corrective measures in case of identification of process / product non-conformities;
- Application of risk-based thinking, respectively application of preventive controls to minimize the negative effects that appeared during the technological process.

Thus, for the analyzed casting, the industrial practice indicates the occurrence of product non-conformities, due to the moulding mixtures used (such as raw moulding mixtures): out of 42 castings, 9 were rejected (showing surface defects) which represents approx. 22% (Figure 5).

![Figure 5. The situation of the castings](image)

Following the audit process, the causes that determine the appearance of these surface defects were identified, causes due to the moulding mixtures. These are the following:
- the appearance of the moisture condensation zone (this being an area with low resistance), followed by the formation of a layer of dry moulding mixture whose expansion is prevented by the walls of the mould dilatation;
- the deep penetration of the liquid alloy through the intergranular spaces of the moulding mixture;
- insufficient refractoriness of the moulding mixtures;
- use of improperly moulding mixtures.

To prevent the occurrence of these defects, in technological practice, it is necessary:
- ensuring a minimum humidity in the moulding mixture
- increasing the strength of the moulding mixture, by increasing the amount of binder used
- increasing the refractoriness and permeability of moulding mixtures by using appropriate moulding mixtures
- the use of both core mixtures and pattern / filler mixtures corresponding to the technologies adopted.

Due to the high percentage of registered rejects (22%), the experimentation of the use of combinations of moulding mixtures was carried out, in order to optimize the recipes used and to reduce the number of castings rejects.
In order to analyze the influence of moulding mixtures on the quality of castings, several types of mixtures (pattern, filler and core) were studied. Thus, three types of pattern mixtures were used, in addition to the filler mixture and three types of core mixtures. Their use led to a decrease in surface defects by 16% (Figure 6), (Figure 7).

![Figure 6. Analysis of castings using the three types of mixtures recipes](image)

![Figure 7. Share of defects registered in the use of the three types of mixtures](image)

4. Conclusions

The use of advanced materials to obtain parts used in various industries (automotive, machine building, energy, civil and industrial construction, etc.) is an important step in the development of technological processes. In this context, an important role is played by research and innovation processes in order to use different unconventional materials and determine their characteristics [12], [13].

In particular, in a foundry, the road to success begins with the development of a new casting by establishing a partnership between the foundry and its customers. By applying the know-how of the moulding-casting technology in the design phase, the economic implementation of the technology in the subsequent production process is ensured. With the help of methods, techniques and tools applied in each stage of the technological process, castings are obtained that comply with customer requirements and quality assurance standards. Thus, a very important role at the management level is the establishment, application and fulfillment of strategies to ensure the quality of castings in foundries.

The organization's management must adopt a policy of continuous improvement of all aspects of the foundry which will pursue the following aspects: Human Resources, Production / Performance, Process, Productivity (Efficiency) [14].

In a modern foundry, all stages of the process of obtaining the castings must be controlled, from the raw materials and auxiliary materials to the conditions of delivery and packaging of the castings. It must be established which operation is controlled, with which it is controlled (classic or special equipment) and in what volume.

Thus, following the analysis performed in industrial practice, it is found that the implementation of the quality management system in foundries leads to a decrease in the percentage of rejects by 4-5%, which is reflected in the company's costs and the company's image on the market.

References

[1] Bejan M and Rusu T 2004 Efectele implementării standardului ISO 9000, în contextul integrării României în spaţiul economic European, Buletinul AGIR IX(3) 19
[2] ***2015 ISO 9001 Quality management systems – Requirements
[3] Josan A 2007 Quality management, Publishing Polytechnic, Timișoara
[4] ***2015 ISO 9000 Quality management systems – Fundamentals and vocabulary
[5] Rășină M C 2011 Creșterea competitivității sistemelor de producție orientate spre realizarea matrițelor pentru forjare și turnare, Brașov, Doctoral Thesis
[6] Avram S E 2009 Implicațiile implementării unui sistem integrat într-o organizație, Simpozionul
 „Impactul Aquis-ului comunitar asupra echipamentelor și tehno
giilor de mediu”, Agigea, Romania, 26-28 aug

[7] ***https://rominservvalves.kmginternational.com/upload/files/rom
inserv_valves_produse_catal
og_romana_final_edit_rev1_1479.pdf*** - JV060006 – Cast Iron Gate Valve to DIN 3202-F4

[8] ***2012 EN 16079 Fonding - Compated (vermicular) graphite cast irons. General technical
quality conditions

[9] Josan A 2012 *Casting and moulding technologies of metal parts – the project guide-book*,
Publishing Polytechnic, Timișoara

[10] Ștefănescu C and all 1985 *Technology designer's guide in foundries*, Technical Publishing,
Bucharest

[11] ***http://ghidcertificare.ro/articole/derularea-actiuni-corective-preventive-cerinta-baza-
standardului-iso-9001.html***

[12] Crăciun A L, Pinca-Bretotean C, Uțu D and Josan A 2016 Tribological properties of
nonasbestos brake pad material by using coconut fiber, *IOP Conf. Ser.: Mater. Sci. Eng.* 163
0124014

[13] Pinca-Bretotean C, Craciun A L, Josan A and Ardelean M Friction and wear characteristics
of organic brake pads material *IOP Conf. Ser.: Mater. Sci. Eng.* 477 012009

[14] Iliș L 2003 *Managementul calității totale*, Cluj-Napoca, Ed Dacia, pp 90/107