Journal of Production and Industrial Engineering
Volume 4, Issue 1, June 2023, pp 36 - 41
https://doi.org/10.26706/jpie.4.1.icramen202308

Literature Review on Optimization Techniques Used for Minimization of Casting

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Abstract: During the past several decades, significant progress has been achieved in establishing the proper values of casting process variables to enhance casting quality utilising a variety of methodologies. One of the most important factors in casting quality is the design of the sand-casting process variables. The optimization of green sand-casting factors has been studied and analyzed in several journal and conference papers, as well as research by professional associations and institutions; a few of them are summarized below.

Keywords: Gray Cast Iron, Casting, Yield percentage, aspiration effect.

Mini Review – Peer Reviewed
Received: 15 April 2023
Accepted: 25 May 2023
Published: 28 June 2023

Cite this article: Ajinkya P. Edlabadkar, S. S. Chaudhari, "Literature Review on Optimization Techniques Used for Minimization of Casting", *Journal of Production and Industrial Engineering*, RAME Publishers, vol. 4, issue 1, pp. 36-41, 2023.
https://doi.org/10.26706/jpie.4.1.icramen202308

1. Introduction

One of the oldest cast iron products is grey iron. Grey iron is still utilised in instances where its qualities have shown it to be the best material available, despite competition from newer materials and advertising. Grey iron is the most adaptable metal used in foundries out of all the others. The high carbon content makes foundry melting, casting, and subsequent machining possible. It is the most fluid and can be cast into complicated shapes because it has the lowest pouring temperature of any ferrous metal. Cast components made from ductile cast iron are becoming increasingly used for a variety of technological applications, including the automotive sector [1-5].

Castings made of grey and ductile iron may be made using almost any typical foundry method. Several molding processes are used to create grey iron castings. A few of them significantly impact the finished casting's structure and qualities. The most important component, the casting's design, influences the choice of a method, among many others. Sand casting is one of the most widely used metal casting methods due to the low cost of raw materials, the ability to create a wide range of castings in terms of size and composition, and the potential for reusing molding sand. Sand-casting is the process of pouring hot metal into a mold and allowing it to cool [6-10].

There are many different compositions of grey and ductile iron available commercially. The nature of the castings produced and the availability of cheaper raw materials locally may allow foundries that adhere to the same requirements to utilise different compositions. As a result, chemical composition is not taken into account when choosing castings unless it is absolutely necessary for the purpose [11-13].

Grey iron castings include a total of 2.75 to 4.00 percent carbon, 0.75 to 3.00 percent silicon, 0.25 to 1.50 percent manganese, 0.02 to 0.20 percent sulphur, and 0.02 to 0.75 percent phosphorus. Some of the alloying components that could be present in different ratios are molybdenum, copper, nickel, vanadium, titanium, tin, antimony, and chromium. Typically, nitrogen concentrations range from 20 to 92 parts per million. The concentrations of some elements may be greater than those shown above, although the ranges are often narrower [14-16].

A serious issue is the prevalence of flaws in the production of grey and ductile iron castings. While some problems are entirely ornamental, others might negatively affect how well the component works. The goal of this research is to get a better understanding of the foundry process in order to remove or at the very least decrease casting faults, which are mostly caused by the gating system. A parametric analysis of all pertinent gating system or methoding features can be used to achieve this [17-20].

The Indian Foundry Industry has been identified as one of the key thrust areas where technology transfer and absorption is a priority, especially in light of the industry's significant potential (India is currently ranked second in the world behind China) as well as the fact that the Indian foundry industry is unable to meet local demand in terms of both quantity and quality [21-23].

Around 80% of India's 4600 foundry businesses serve low-volume markets, with the bulk of them being small and medium-sized businesses. Some medium-sized foundries have been successful in modernising their technology; the quality of their output is comparable to that of foundries abroad; however, their volume of production, productivity, yield percentage, and most importantly, the percentage of total defect free (OK) castings, remain comparatively lower when compared to part per million (PPM) basis for rejection in foundries abroad [24-26].

By using non-gradient based optimization techniques for the key parameters that parametric analysis has discovered, CAE fields can decrease foundry rejection, significantly cut waste, and preserve foundry profitability. Moreover, effective methoding techniques paired with casting simulation techniques will increase molten metal yield. Reduced energy needs for remelting scrap will result from increased output of molten metal (Approximately 1KWh is required to melt 1Kg of ferrous metal). It's crucial to remember that the price of 1 KWh of power saved is significantly greater than the price of 1 KWh of electricity generated [27-32].

Because to the quick advancements in computing technology, solidification, segregation, and even microstructure evolution in the casting process may now be effectively replicated.

2. Review of Literature

D.E. Krause, Executive Director,1940-1973 mentioned that section sensitivity is a feature intended for all cast metals. The rate of solidification slows down as the section size grows, which is followed by an expansion of the grain size and a reduction in the tensile strength. Compared to other cast metals, grey iron is more vulnerable to the effects of freezing rate on strength and hardness. This was created through the method of solidification. Grey iron castings are produced using a variety of moulding techniques. A few of them have a significant impact on the final casting's structure and characteristics. One of several factors that influences the process selection is the casting's design [6].

A. Kumarvadivel, U. Natrajan, demonstrated that the quality of a green sand casting is the result of several distinct parameters, according to a study published in the International Journal of Advanced Manufacturing Technology (2013).
A change in the parameters causes a variety of casting flaws, which lowers the total yield and raises the cost of production. Understanding the origins of these errors is crucial for fixing them. This study's objective is to ascertain how various process variables impact flaws that develop throughout the sand-casting process. In order to reduce the proportion of flywheel faults that are rejected during the green sand-casting process, the process window approach (PWA) will be employed to optimize the process parameters [11].
According to Charnnarong Saikaew, Searmsak Wiiengwiest, the sand mould's quality is crucial for foundry makers to produce high-quality iron castings (2012). In order to reduce waste from iron casting, this study set out to find the best bentonite-to-water ratio to use in a recycled sand mould. The approaches involve combining experimental design, response surface technology, and error propagation. The properties of moulding sand were tested by adding varying amounts of bentonite and water to a recycled sand mould. It was determined how hard the iron castings' surfaces were using a stereo microscope and a Rockwell hardness tester. According to the study, the suggested bentonite addition ratio is the ideal one [22].
T. Ramu, Dr. M.L.S. Deva Kumar, B.K.C. Ganesh carried out the research which proposes that utilising computer-aided methoding, solid modelling, and casting simulation technologies might decrease bottlenecks and non-value-added time in casting development. It was published in the International Journal of Materials and Biomaterials Applications (2012). In this instance, in order to save manufacturing costs and eliminate foundry errors, the PRO-E model of the flywheel casting is uploaded to the MAGMA-5 programme for simulation and pattern generation [23].
Dr. B. Ravi and Dr. D. Joshi in an annual study of information technology (IT) applications in the Indian foundry sector is carried out by IIT Bombay. The data is gathered via a questionnaire distributed to participants in a three-day certificate course on "Casting Design and Simulation" for working professionals, which is offered every year in September or October. The survey provides useful data on the penetration, advantages, and problems of IT in metal casting. According to a study based on this survey, the Indian foundry sector is still far behind other nations in terms of value addition, quality, and productivity, even if CAD/CAM and simulation help with faster development and reduced rejection rates [20].
J. Jakubski, St.M. Dobosz. argues that a significant quantity of data produced in casting operations is rarely monitored and documented directly, especially not automatically. The study was published in Poland's J Archives of Foundry Engineering (2010). Yet not even the data that is measured and gathered is used for computer-assisted quality control or optimization. Higher amounts of probability data require both the acquisition of appropriate measurement tools and the hire of new personnel. Nowadays, artificial neural networks are used to optimize manufacturing [29].
In a report on vision is given in Foundry Congress 2012's proceedings, in 2020 suggest the required actions to realize that vision, the Indian Institute of Foundry started a research. They have been forced to perform an in-depth analysis of the industry due to the stark differences between India and China as well as the foundry sector's inability to meet local demand in terms of quantity and quality. The following are a few significant interpretations of this vision [30].
• Quality Issues: The focus has to change from quantity to quality. It is necessary to convert quality levels from percent to PPM.
• Machinery and mechanization: There are no facilities for casting simulation, design, patternmaking, finishing, or testing because of high costs and poor individual utilization. While establishing shared facilities, cluster demand must be pooled.

The Indian foundry industry should put more effort into technological development, especially in the areas of CAD/CAM and CAE for solid modeling, tooling development, and optimization of variables associated with the green sand-casting process, in order to produce defect-free castings with quicker development, according to the review of literature published in the aforementioned research papers and reports.
In 2012 Advance Simulation Tools Taylor and Francis Publication mentioned that with no air entrapment or material flow blockage, the gating system's smooth mould filling is made possible by design optimization. In order to produce an ideal mould design while avoiding the pricey hit-or-miss method utilised in traditional mould design and development in the foundry sector, this article emphasizes the usefulness of simulation. It also shows how simulations might expedite the process of developing a casting pattern and generating an effective cast [33].

3. Conclusion

Certain problems in qualitative analysis of Sand Casting are more challenging to comprehend and prevent than others. For instance, it is often difficult to estimate porosity in circumstances with complicated geometrical structures. Inside the casting, this kind of fault might create a three-dimensional network. Porosity significantly affects a casting's mechanical properties as well as its overall integrity. Porosity can impair component performance in addition to lowering productivity and increasing costs when making crucial engine components like cylinder heads and cylinder blocks.
Faults that frequently occur in grey iron cast components are hard to describe. Upon machining, certain defects are visible in the cross section. Physical sand mould casting does not give a clear picture of the metal flow and turbulences that happen when molten metal is poured into the mould cavity, which causes a variety of defects to appear, increasing the likelihood that the casting will be rejected and causing a sizable loss in productivity.
Following is the research gap from the mentioned literature review.

- Much work has been done, in recent years, to analyze and optimize the parameters that cause defects in castings produced in sand casting process, but researcher has given very less attention on systematic identification of various parameters that are associated with flow of molten metal(Which depends on ASPE) and gating system which plays an important role to increase acceptability of castings.
- In available literature very negligible focus given on yield, aspiration effect and losses through gating system which affects in overall productivity and costing involved.
- For qualitative analysis of Sand Casting, among the several possible defects, some defects are more challenging to understand and avoid. For example, the prediction of porosity in complex geometrical situation is not straight forward in general.
- Existing investigation about Physical Sand mould Casting process does not give a clear idea about the metal flow and turbulences occurring during the pouring of molten metal into the Mould Cavity, which in turn cause the occurrences of various defects that leads into higher percentage of casting rejection and huge loss of productivity.
- The objectives of the proposed research work will be :
    1. To determine the optimal level of various essential parameters associated with gating system and flow of molten metal through gating system in Sand Casting.
    2. Investigation of yield, aspiration effect and losses through gating system which affects in overall productivity and costing involved in sand casting process.

3. Design of optimal gating system for improvement in quality of cast components as well as yield percentage.(2 Case Studies)
4. Determining empirical relationship between involved parameters and development of mathematical model .

- In this research the prime focus will be minimizing the defect developed in castings and improvement in quality as well as yield percentage. In this research work more emphasis will be given on verification of model proposed by experimental validation for optimal design of the gating system.

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