Modification of Die Design to Improve Productivity and Reduce Scrap in Manufacturing

Likith M[1], Arshad[2], Hemanth A N[3], Kushal S[4], Srinivas S[5],

1,2,3,4 -Student, School of Mechanical Engineering, REVA University, Bengaluru, Karnataka, India
5-Assistant Professor, School of Mechanical Engineering, REVA University, Bengaluru, Karnataka, India

ABSTRACT

In the present work, the components used included a cast iron pattern, cast iron die body, cast iron bottom flange, and a mild steel location plate. The mould was prepared using resin-coated sand as the moulding material. The assembly was carried out with precise alignment to ensure dimensional accuracy during casting. The mould was preheated to a temperature range of 180°C to 250°C to facilitate proper curing of the resin. Molten metal was poured at a temperature between 1350°C and 1450°C, depending on the alloy used, ensuring optimal fluidity and defect-free filling. Other process parameters such as mould dwell time (5–8 minutes), pouring rate (controlled to prevent turbulence), and ambient humidity (maintained below 60%) were carefully monitored and controlled. All procedures were conducted in accordance with standard casting practices to achieve consistent and high-quality results. From the above work it was concluded that the product dimensions. i.e length is reduced from 613mm to 535mm due to this decrease in mass from 38.74kg to 33.81kg which has shown higher productivity rate of 12% and lesser scrap rejection rate of 5 to 10%.

1.Introduction

The aim is to improve the casting process by reducing defects and increasing overall efficiency. The existing manual casting method often results in variations in mould thickness, inconsistent metal flow, and uncontrolled cooling rates. These issues lead to high rejection rates and significant material wastage, affecting productivity and cost-effectiveness.To overcome these challenges, a 4-die design was introduced, bringing greater consistency and repeatability to the process. This improvement minimized human error and common casting defects such as porosity and shrinkage, resulting in more reliable output.Key process parameters—such as pouring temperature, cooling time,were studied in detail to understand their impact on productivity and quality. Based on this analysis, practical adjustments were recommended to streamline production and enhance performance. The ultimate goal is to establish a simple, efficient, and low-cost casting method that can be easily adopted by other foundries. By implementing these changes, it's possible to achieve higher quality castings, reduced scrap rates, and better use of resources, supporting more sustainable and cost-effective manufacturing.

2.Literature Review

Kazumi chi Shimizu et al [1] presented paper on "Mechanical Properties of Spheroidal Graphite Cast Iron Made by Reduced Pressure Frozen Mold Casting Process". This paper explains a new, environment-friendly casting method called Reduced Pressure Frozen Mold (RPFM), where molds are frozen at –40°C using just water and silica sand. This method avoids harmful chemicals and reduces dust, noise, and waste. It's a cleaner, more efficient alternative to traditional casting processes with better environmental and performance benefits.

Gaurav S. Biraje and Aamir M. Shaikh [2] presented paper on “A Review on Analysis and Optimization of Parameters for Spheroidal Graphite (SG) Iron Casting” This paper reviews how to improve SG iron quality by focusing on key casting steps like nodulation (adding 0.03–0.05% magnesium) and inoculation (adding FeSi). These steps help form round graphite nodules. Image processing is used to study the structure, and tools like the Taguchi method help optimize casting settings. In one case, SG iron castings achieved 658 MPa strength, 2.5% elongation, and 264 BHN. The paper shows how small changes in ingredients and process settings can lead to better cast iron products.

Fragassa et al [3] presented paper on “Comparison of Mechanical Properties in Compacted and Spheroidal Graphite Irons” This study compares Spheroidal Graphite Iron (SGI) and Compacted Graphite Iron (CGI), both made under the same conditions. SGI turned out to be stronger of 549 MPa and harder to 310 BHN, while CGI was more stretchable of 18% elongation but softer to 170 BHN. SGI is better for parts that need strength and durability, while CGI is better for parts that need some flexibility. This comparison helps decide which material to use based on how the part will be used.

Franco Zanardi et al [4] presented paper on “Reclassification of Spheroidal Graphite Ductile Cast Irons Grades According to Design Needs” This paper talks about a smarter way to group SG (Spheroidal Graphite) iron grades based on real design needs like yield strength of 220–480 MPa, elongation, and the strength ratio (UTS/YS). It highlights how changing silicon content from 2% to 4.2% can make the material either stronger or more flexible. A new "Material Quality Index" (MQI) is introduced to help ensure quality and consistency. This reclassification helps engineers pick the right SG iron grade for the right job whether it needs strength, ductility, or easier machining.

Doru M. Stefanescu et al [5] presented paper on “Recent Developments in Understanding Nucleation and Crystallization of Spheroidal Graphite in Iron- Carbon-Silicon Alloys” This paper focuses on the recent developments in understanding the nucleation and crystallization of spheroidal graphite (SG) in Fe-C-Si alloys, with about 15% dedicated to graphite's crystal structure and bonding, including lattice types and anisotropic growth behaviours. Around 20% discusses growth mechanisms such as platelet formation, 2D nucleation, spiral growth, and defects. Another 15% analyses different graphite morphologies like foliated, dendritic, and hopper structures, with parallels drawn from analogous materials. Approximately 10% covers the asymmetric coupled zone in the Fe-C-Si diagram and its effect on undercooling and solidification behaviour. The role of melt impurities and minor elements in influencing graphite nucleation and degeneration is discussed in about 15% of the paper, while another 15% focuses on nucleation mechanisms and the identification of effective nucleates using advanced microscopy and crystallographic theories. Finally, about 10% provides historical context and industrial relevance, especially highlighting SG iron’s growth in applications like wind turbine castings.

Jon Sertucha et al [6] presented paper on “Chunky Graphite in Low and High Silicon Spheroidal Graphite Cast Irons–Occurrence, Control and Effect on Mechanical Properties” This paper explores the formation and control of chunky graphite in spheroidal graphite cast irons, with 25% covering the experimental setup and methodology. Around 20% focuses on the effects of silicon and rare earths, showing higher Si which promotes formation of chunky graphite while controlled rare earths reduces it. About 15% each is dedicated to the roles of antimony and tin both suppress chunky graphite but may cause spiky graphite. Microstructural classification and analysis methods make up 10%, mechanical property impacts another 10%, and the remaining 5% discusses prior studies and industrial relevance.

7. Jin-Su Ha et al [7] presented paper on “The Effect of Boron and Copper on the Microstructure and Graphite Morphology of Spheroidal Graphite Cast Iron” This paper examines the effects of trace boron (B) and copper (Cu) on spheroidal graphite cast iron, with 20% on experimental setup, 25% on microstructural changes showing B increases ferrite and graphite surface area, and 15% on thermal analysis revealing B alters phase transformation enthalpies. About 20% covers mechanical properties, noting B reduces strength but enhances elongation and ductility, while 15% involves SEM/EDS-based elemental analysis. The final 5% highlights sustainability potential using Bcontaining scrap in casting.

3.Problem Identification

The manual casting process has been leading to significant inconsistencies in mould thickness, metal flow, and cooling rates. These variations result in high defect rates, including porosity, shrinkage, and incomplete filling, which contribute to increased material wastage and reduced productivity. The lack of process standardization also causes difficulties in maintaining consistent quality across batches. There is a need for a more reliable, cost-effective, and scalable casting approach that minimizes defects, enhances efficiency, and ensures better resource utilization.

4. Objectives

- To improve productivity and reduce the cost of material
- Modifying the existing die design and reducing the scrap rate by improving the average production rate up to 12% .

5.Methodology

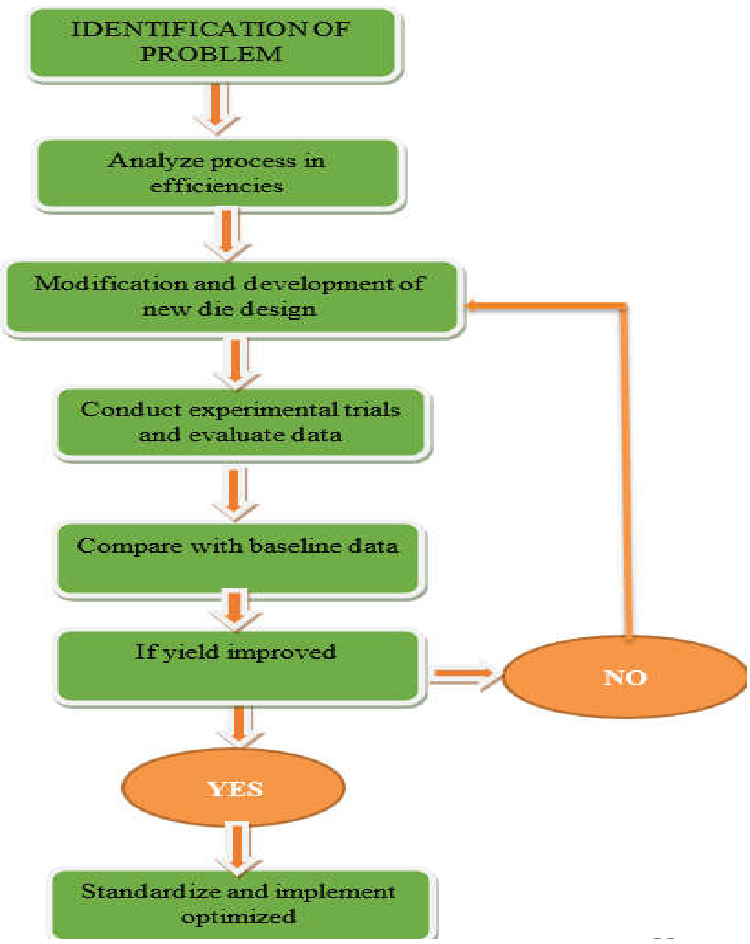

Figure 1:Methodology Flow Chart

5. Calculation for reduction of cost

Data obtained from drawing are :

- ➢ Length : 535 mm
- ➢ Dia : 105 mm

W.K.T Volume: (□x d2)/4 x L mm3
Calculation of mass based on given by company
Volume (v0) = (□x d2)/4 x L0
Where,
V0 = volume in mm3
d = diameter in mm
L0 = length in mm
V0 = (□ x 1052)/4 x 613
V0 = 5307976.043 mm3
Mass (m0) = density (□) x volume (v0)
Where,
m0 = mass in kg
□ = density in kg/mm3
V0 = volume in mm3
m0 = 7.3x10-6 x 5307976.043
m0 = 38.74 kg

calculation based on modified design

Volume (v1) = (□ x d2)/4 x L1
Where,
V1 = volume in mm3
d = diameter in mm
L1 = length in mm
V1= (□ x 1052)/4 x 535
V1 = 4632572.892 mm3
m1 = 7.3x10-6 x 4632572.892
m1 = 33.81 kg
By above calculation it is clearly seam that since length is reduced the mass of the raw material and hence production cost is also reduced.
M = (m0-m1)/m1 x 100
M = (38.74-33.81)38.74 x 100
M = 12.72%
This above calculation clearly shows the reduction in mass of the product and increase in productivity of manufacturing the component.
The above calculation was repeated for remaining product and the average increase in productivity was found to be 12%.

6.RESULT AND DISSCUSSION

As part of the casting process optimization, the component's length was reduced from 613 mm to 535 mm, resulting in a more compact and efficient design. This dimensional change led to a significant reduction in mass from 38.74 kg to 33.81 kg, saving approximately 4.93 kg of material per component. The decrease in weight not only contributed to lower raw material consumption but also enhanced overall productivity, as lighter castings are quicker to handle, cool, and finish. This optimization enabled faster cycle times, reduced energy usage during processing, and lowered transportation costs—ultimately improving the efficiency and cost-effectiveness of the entire manufacturing process.

7.CONCLUSION

The reduction in raw material consumption played a key role in improving the overall efficiency of the casting process. By minimizing the mass of each component, less metal was required per casting, which directly lowered material costs and reduced dependency on excess inventory. This optimization also led to shorter lead times, as lighter components required less time for melting, pouring, cooling, and finishing. As a result, more components could be produced in less time without compromising quality. Additionally, the streamlined process helped bring down the overall manufacturing cost, making production more economical and scalable, while supporting higher throughput and better resource utilization .

8. REFERENCES

1. Kazumichi Shimizu, Yaer Xinba, Masahito Tanaka and Hideki Shudai “Mechanical Properties of Spheroidal Graphite Cast Iron Made by Reduced Pressure Frozen Mold Casting Process” Materials Transactions, Vol. 50, No. 5 (2009)

2. Gaurav S. Biraje, Aamir M. Shaikh, “A Review on Analysis and Optimization of Parameters for Spheroidal Graphite (SG) Iron Casting” Production of IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 11, (2016)

3. C. Fragassa , N. Radovic , A. Pavlovic , G. Minak ,“Comparison of Mechanical Properties in Compacted and Spheroidal Graphite Irons” Vol. 38, No. 1 (2016)

4. Franco Zanardi and Carlo Mapelli and Silvia Barella “reclassification of spheroidal graphite ductile cast irons grades according to design needs” Copyright (2020)

5. Doru M.Stefanescu , Gorka Alonso and Ramon Suarez “Recent Developments in Understanding Nucleation and Crystallization of Spheroidal Graphite in Iron-Carbon Silicon Alloys” MDPI Published on (5 February 2020).

6. Jon Sertucha, Garikoitz Artola, Urko de La Torre and Jacques Lacaze, “Chunky Graphite in Low and High Silicon Spheroidal Graphite Cast Irons–Occurrence, Control and E ect on Mechanical Properties” MDPI Published on (27 November 2020).

7. Jin-Su Ha, Ji-Woo Hong, Ji-Wook Kim, Soo-Bin Han, Chang-Young Choi, Hye Jin Song, Jin-Seok Jang, Dong-Yul Kim, Dae-Cheol Ko, Seong-Hoon Yi, and Yong Jae Cho, “The Effect of Boron (B) and Copper (Cu) on the Microstructure and Graphite Morphology of Spheroidal Graphite Cast Iron” MDPI Published on (7 June 2023).