African Journal of Applied Research
Vol. 11, No. 1 (2025), pp.871-891
http://www.ajaronline.com
https://doi.org/10.26437/ajar.v11i1.
Received: July 7, 2024
Peer reviewed: September 25, 2024
Revised: November 2, 2024
Published: January 2025

EMPIRICAL EXPLORATION OF OPTIMAL GATING SYSTEM DESIGN FOR SAND CASTING PROCESS

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ABSTRACT

Purpose: This paper aims to analyse and optimise the gating system used in the sand casting process to produce drainage doors at Deepshikha Casting in Nagpur. It focuses on understanding how gate design impacts productivity and the quality of the cast, drawing attention to common defects and the role of gravity casting techniques.

Design/Methodology/Approach: This paper discusses the present gating system of Deepshikha Casting in detail to identify defects, such as sand inclusions, blow holes, pinholes, gas holes, shrinkage, and misruns. The present gating ratio and system weight assessment are thus used to suggest changes in the design to improve the process efficiency and quality of the product.

Findings: The research indicates that the existing gating system has an inappropriate gating ratio, resulting in a high rate of faults and reduced productivity. The system also weighs a lot, which deters efficiency. Improving the gating design reduces flaws, increases the quality of castings, and enhances molten metal flow.

Research Limitation: The output of the present work is limited to Deepshikha Casting alone, which is used for drainage door casting. Further research must be conducted on different casting products and technologies for a broad application.

Practical Implication: This sector of sand casting can benefit from optimising the gating system, maximising productivity and minimising casting defects, thus reducing costs and improving efficiency.

Social Implication: The environment will also benefit from efficient casting because of reduced use of resources, reduced waste, and fewer consumables. Better procedures also translate to increased production of safer products.

Originality/Value: This paper provides practical, applied solutions for optimising the gating system of sand casting. Its insights are particularly informative for a foundry working with fragile metals and using gravity casting.

Keywords: *Casting. gating scheme. gravity. mould cavity. productivity*

ISSN: 2408-7920

Arca Academic Publisher

Received: July 7, 2024
Peer reviewed: September 25, 2024
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INTRODUCTION

A Gating System (GS) is the fundamental design required to create a casting that fills the mould cavity properly and smoothly without any gaps, cavities, or solid inclusions. A sound gating system directs pure molten metal to flow via a ladle to the cavity to ensure correct and smooth filling of the casting cavity. This is also based on the design of the gating channels, including the placement and orientation of the runner, sprue, and ingate (Beckermann, 2003).

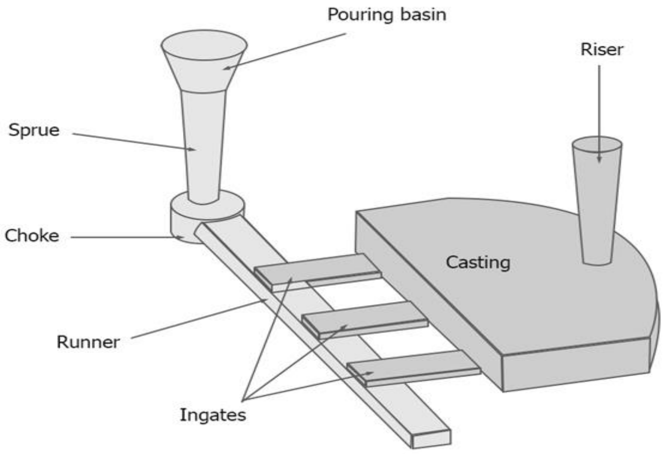

Figure 1: Gating System

Clean molten metal is one of the four basic needs that enable an effective gating system. The gating system aims to smoothly clean molten metal poured into the casting cavity. The chamber of the casting gets evenly filled. The whole cavity of the casting is being filled. To minimise surface instability, a fresh metal that blocks the entry of slag and impurities must be packed into the mould hole. A solid filling in the mould minimises bulk turbulence. If the filling is constant, it means the casting fill is being made under control. When the hollow is filled, the metal thins and has the minimum resistance at the ends. Features of each gating system element Pouring basin: The pouring basin has a funnel-like top-mounted aperture (Seo et al., 2018)The pouring basin's primary function is to regulate molten metal flow from the dipper through the sprue.

A vertical tube called a sprue connects the pouring basin to the runner or gate. It is often constructed tapering downward to prevent air aspiration. The sprue's cross-section can be rectangular, square, or round.

Sprue Well

It is located near the base of the sprue. It curves the molten metal toward the runner, preventing it from falling freely through the sprue.

Runner

A long, horizontal channel carries and distributes the molten metal to the ingates. This ensures that there is enough molten metal in the cavity to ensure proper filling.

Gate

These are small openings connecting the mould and runner chambers. The number of gates used can vary depending on the casting size.

Functions of Gating System Filling up the mould cavity with proper gating mechanisms should be easy and efficient. Minimum turbulence is needed when the melted metal decants into the mould cavity. It should arrest the growth of the mould. There must be an adequate temperature gradient in the casting. In one direction, it must be encouraging solidification. It must regulate the rate of metal filling of the mould chamber. The gating system design must meet these basic requirements. Gating should be designed so that it does not cause damage to the mould or core due to the decrease of metal speed inside the chamber and its direct impingement on the divisions or centres of the mould (Edlabadkar & Chaudhari, 2023).

In the same regard, too much turbulence would increase the ambition of mould gases, which would then cause erosion in the metal in the mould; hence, the metal should flow within the mould cavity with as little turbulence as it can muster. This brings down the defects in casting, such as inclusions in sand, porosity, decline, gas holes, and blow holes, among others. Also, the gating system should be simple enough to mould easily, mainly when mechanical techniques require minimal fettling and cast yield as high as possible. There are some incongruences among these duties and constraints. Compromising all these factors will be attempted so that casting fabrication may be fault-free.

LITERATURE REVIEW

Determining the best casting process variables to employ in various ways to improve casting quality has made significant progress in recent years. It is acknowledged that one of the crucial parameters in casting eminence is the aim of the factors of the sand-casting method. Several journal publications, conference proceedings, and studies by professional associations and institutes have optimised green sand casting factors (Shilpa et al., 2021; Aloni, 2019; Samaraweera et al., 2017). A few of them are summarised here. Section sensitivity is supposed to apply to all cast metals. The solidification rate reduces as the segment size cultivates, accompanied by a rise in grain size and a consequent decline in workable strength.

Different moulding methods create castings made of grey iron. Several factors significantly affect the construction and features of the concluding casting. The casting design significantly impacts the decision of which procedure to choose, among other things (Krause & Shaw, 1969). The fluctuation in parameters causes various casting faults, significantly reducing castings' production while raising the price of their manufacture. Sympathetic to the root causes of flaws is vital for their eradication. The process parameters will be optimised utilising the process window technique to decrease the flywheel fault refusal percentage of the green sand casting method (PWA). This work examines how dissimilar method factors touch flaws that arise during sand casting (Kumaravadivel & Natarajan, 2013).

According to a study reported in (Saikaew & Wiengwiset, 2012), foundry makers in iron moulding manufacturing depend on the superiority of the sand mould to create first-class iron mouldings. This study aimed to minimise the amount of Bentonite and liquid supplied to a used sand mould to reduce the waste produced during iron casting. The approaches used include a combination of response surface methodology, error propagation, and experimental design. The study arrived at the ideal ratio for adding bentonite and water to remove sand mould (Saikaew & Wiengwiset, 2012).The study concludes that using computer-assisted methods, solid modelling, and casting simulation technologies can reduce bottlenecks with non-value-added time in the progress of castings. In this instance, the flywheel-molding model is transferred to MAGMA-5 software to simulate the model and create the design. To avoid foundry flaws and lower manufacturing costs (Ramu et al., 2012).

Every year, the information is acquired via a questionnaire given to attendees of a 3-day certificate course for working professionals on "Casting Design and Simulation" held every year in September or October. The survey offers helpful information on the penetration, advantages, and drawbacks of using IT for metal casting. According to (Ravi et al., 2005), a paper published in Foundry journal (2012) based on this survey for the reported period of 2002 to 2010, even though CAD/CAM and simulation aid in faster development and a reduction in the percentage of rejections, the Indian foundry industry still has a long way to go before catching up to other nations in terms of value addition, quality, and productivity. Major new fields that require substantially more technological engagement include aerospace and military. According to Jakubski and Dobosz, (2010) revealed that a substantial amount of data created is typically not immediately checked and recorded. Computer-assisted quality control and optimisation do not employ the measured and gathered data. To gain access to more considerable quantities of probability data, the proper measuring equipment must be purchased, and new personnel must be hired. Artificial neural networks are one of the current production optimisation techniques.

The Indian Institute of Foundry initiated research to develop a vision plan for the foundry sector for 2020 and advised the necessary steps to accomplish that goal. The report on vision was given during the Foundry Congress 2012. They were forced to thoroughly examine the business due to the significant disparity between China and India and the foundry industry's incapacity to supply the number and quality required locally.

The next is an overview of key results related to this goal. Superiority levels must transition from percent to PPM levels. Demand for clusters must be gathered by constructing shared infrastructure. The analysis of the literature found in the aforementioned research papers and reports, as well as some other research papers and reports, reveals that the Indian foundry industry needs to pay closer attention to technological advancement for solid modelling, tool growth, and optimisation of related factors (Edlabadkar et al., 2023).

Design optimisation of the gating system allows for a soft filling of the mould without air setup or material flow blockage. In order to build a mould that is perfect while avoiding pricey hit-and-miss predictable mould aim and expansion practices in the foundry sector, the essay underlines the usefulness of simulation. It also highlights the significance of simulations in accelerating the creation of casting patterns and generating cast goods of excellent quality (Iqbal et al., 2012). Several assessments are conducted to create a compelling offer exercise design. The goal is to speed up the process while maintaining quality.

Although several specific work phases in the exercise of bids were examined in-depth, not all foundry-specific considerations were considered. Further research will examine if the results are typical of similar businesses. The analyses will extend to the usage of permanent moulds independent of this study (Krötzsch et al., 2001). The comparisons demonstrate that when appropriate thermal expansion parameters for the steel, mould, and core materials are included in the calculations, the pattern allowances (PA)s are frequently anticipated with reasonable accuracy.

The fundamental flaws in the stress simulations consistently lead to discrepancies with the observations. One is that the model does not account for the silica sand's irreversible growth. This is particularly crucial for tiny cores or other mould components that exceed 1,200 o C in temperature. The stress model's inability to take into consideration the development of an air gap between the casting and the mould is its second drawback (Beckermann, 2003).

Trial-and-error techniques are still used by foundries to fix casting issues. A more methodical approach to defining, identifying, and locating the underlying cause of a fault has advantages. The classification of the faults using worldwide standard defect codes is demonstrated. Experiments are designed to detect and regulate the variables using potent approaches like defect mapping, questioning to find the fundamental causes and experiment design. A real-world case study of shrinking porosity is detailed to demonstrate how these strategies may be applied in practice (Alagarsamy, 2003).The procedure is obsessed with product variables related to quality (surface polish, tolerance, maximum void size), manufacturing, and geometry.

The casting model and shape complexity, which is significant in process planning, have been measured. The AHP, which enables pair-wise comparison and consistency testing of judgments, has been used to calculate the weights assigned to characteristics (Chougule & Ravi, 2005). It will take the full cooperation of the government, researchers, professional organisations, user foundries, consultants and their OEM clients to complete the ambitious project of the virtual foundry (Edlabadkar & Chaudhari, 2023). The casting procedure was optimised using numerical mould filling and solidification simulations for large cylinder liners. Simulations were utilised to forecast and improve the casting conditions. The cooling was much enhanced by removing chill blocks, particularly the indirect chill blocks in the core. The mechanical and productivity qualities improved (Yoo et al., 2008).
The technology for casting simulation has sufficiently advanced to become a crucial tool for identifying casting defects and improving procedures (Ravi, 2008). In large-scale casting, the

gating and riser system design is crucial for both quality and cost, and it is anticipated to accomplish numerous goals at once. However, the design of gating and riser systems is still the product of a protracted trial-and-error optimum process because of the conflicting aims, even with commercial simulation tools.

It has been suggested that several evolutionary algorithms (EAs) might help choose the geometrical dimensions of gating and riser systems. This work designed a route using a multi-objective EA and a single-objective optimisation method to design the gating and riser systems. This path was taken in an actual situation and validated using expensive simulation software (He et al., 2022). When used to the gating and riser design of a sand casting, it produces positive results and offers the ability to make decisions with more freedom (Kor et al., 2009).

The casting technique produces many important forms and is employed in large-scale manufacturing. The parts have essential shapes that are very small and very big. The most crucial component of the casting process is the gate system. The proper gating is crucial for a sound, defect-free casting process and improved yield. Even in a well-regulated process, casting errors can still be discovered, making it difficult to identify their root causes (Ravi, 2010). The initial outcomes of computer modelling of normal and optimal gating systems are presented. The advanced in cast steel casting foundries today were contrasted with numerous optimisation suggestions (Jezierski et al., 2018).

Casting simulation is a crucial and effective technique for determining where the gating system and riser should be placed to minimise defects. When the gating system is simulated using the Auto Cast programme, it is discovered that the hotspot is precisely in the middle of the cast component. The scheme is then modified, and utilising cold, the hotspot is projected into the riser in the following simulation (Ambekar & Jaju, 2014).The production of high-quality die castings depends on a well-designed runner and gating system that guarantees a consistent mould filling pattern. To assess the cavity-filling process visually, a flow study of the component is done.

A Commutator End (CE) bracket from a cold chamber die-cast product was used in this investigation. Several faults, including Cold closes, Misrun, Shrinkage porosity, and Gas porosity, were discovered after the component was cast. This ultimately caused several components to be rejected. The previous flat gate gating system was replaced with a modified spoon-fed gate to increase the casted quality (Ramnath et al., 2014). The properties of the cast TWDI component, as well as the pressure and speed of the advancing metal front and mould filling, are directly impacted by this parameter. The sprue height of 50 mm is insufficient to effectively force melt through the gating channels, resulting in a poor run and inadequate filling of the mould chamber, as opposed to heights of 100 to 350 mm, which produced moulds that were adequately filled (Ghuge et al., 2018).

The possibility of turbulent flow and metal splashes, which can result in oxide pollution and problems with molten metal filtering, is greatly influenced by the design of the sprue base.

Nevertheless, sprue significantly impacts the gating system's ability to generate oxide. Connecting the erroneous sprue to the correct sprue base will probably only result in a slight reduction of oxide inclusions, while the exact decrease amount is hard to predict. The best type of sprue base is one that has a chamfered notch in both the drag and the cope (Siodmok et al., 2018).

It was discovered that conventional steel casting processes that employ the commonly used assembly of prepared refractory tubes behaved unfavourably. Devices that could give filling behaviour with extreme control were demonstrated. The most recent systems used a naturally pressurised filling system, filters flush mounted on top of the runner acting as bubble diverters, terminal spin traps, and (2) naturally pressurised filters. These innovative filling techniques showed exceptional performance in simulation, correlating with real experience of the capacity to consistently create defect-free castings for the first time in the history of casting (the trident gate in particular) (Dojka et al., 2018). In this study, the ideal gating system for fabricating turbine housing is devised, and the riser is given a heater as a heat source to minimise its size.

A symmetrical gating system is used when the runner is split into two branches to generate the two products in a single operation (Duan et al., 2023). Additionally, the sprue, runner, gate ratio are adjusted to 1:0.9:0.6 to construct the cross-sectional forms of the sprue, runner, and gate. The impacts of the riser's shape, the sleeve's material, the heater's temperature, and the presence of insulating material at the riser's top are next investigated using a casting analysis (Seo et al., 2018).

Many manufacturing process characteristics must be considered to produce a sound casting of at least an acceptable grade. A casting design that emphasises the gating system is among the most crucial. It is well-known that the better the gating system, the higher the casting quality.

However, designing and constructing the gating system following all theoretical and practical guidelines is frequently challenging, if not impossible. As a result, the topic of gating system optimisations is still intriguing from both a scientific and practical standpoint (Jezierski et al., 2016)While significant work has recently been done to identify and improve the parameters that lead to casting defects in the sand-casting process, very little research has been done on the systematic identification of the various parameters related to molten metal flow, which depends upon ASPE and the gating system and is crucial to improving casting acceptability.

The literature that is now available pays very little attention to yield, ambition effect, and losses through the gating system, all of which affect overall costs and productivity. Of all the possible defects, some are more difficult to understand and avoid when conducting a qualitative analysis of sand casting. In complex geometrical conditions, porosity is frequently challenging to guess. Current studies on the physical sand mould casting process cannot depict the turbulences and metal flow that occur when molten metal is dispensed into the mould cavity. Consequently, these flaws result in a high percentage of casting rejection and a notable decrease in output.

MATERIALS AND METHODS

The research design focuses on analysing and optimising the gating system in steel casting to reduce defects and rejection rates, as observed at Deepshikha Industries, Nagpur. It involves applied and experimental research using primary data from industrial observations and quality inspection reports, complemented by secondary data from existing literature. The methodology includes statistical analysis of defect patterns, root cause analysis, and Computational Fluid Dynamics (CFD) simulations to evaluate and improve the gating system. The study aims to identify significant flaws, propose optimised solutions, and significantly reduce the current rejection rate of 20–24%, enhancing casting quality and efficiency.

A visit to Deepshikha Industries in Nagpur revealed that various steel casting works are made there. Shrinkage, Pin Holes, Blow Holes, Sand Inclusion, Misrun, Gas Holes, and other common casting flaws are noticeable. It was discovered that the industrial sector was struggling with rejection, especially for steel castings utilised as dead weight for machinery.

Figure 2: Drainage Cover produced at Deepshikha Industries Nagpur

Table I: The inspection report for the quality desk's

Job Qty	shrinkage	Blow and gas holes	Sand inclusion	Misrun	Total	% of rejection
25	2	2	1	1	6	24%
25	3	1	-------	1	5	20%
25	3	1	-------	1	5	20%
25	3	1	1	1	6	24%
25	1	1	1	2	5	20%
25	2	------	2	1	5	20%
The average percentage of rejection is around 20% to 24%						

It was apparent to track the actual casting manufacturing process relative to the used gating system in order to reduce the fraction of casting faults and rejections after reviewing the inspection report and speaking with GM production about the proportion of rejected parts and various casting flaws discovered during the production of the drainage door used as a dead mass for the drainage door. It was unambiguous to look into and analyse the current industry-wide gating system.

Examining and evaluating the current gate system

It is observed how Deepshikha Industries in Nagpur makes dead weight for ginning. It is checked that both the way they do it now and the new way they might use it. Then, it is decided whether the new way would work better. The main goal of this lesson is to use a common way of making things with liquid metal, along with a regular way of pouring the metal, based on what the researcher studies. After discussing casting problems and the percentage of rejected components utilised as dead weight with GM production, it was learned that the aforementioned flaws might be considerably minimised by utilising an appropriate gating system. It is, therefore, believed that the primary goal of research should be to optimise the gating mechanism.

Design and Dimension of Existing Gating System

By discussing casting faults and the percentage of rejected dead weight with GM production, it was learned that the aforementioned problems may be considerably minimised by using a suitable gating system. Therefore, it is believed that the primary goal of research should be to optimise the gating mechanism. It was decided to thoroughly examine and analyse the present gating system to eliminate casting errors.
Overall volume of gating = 6.57 × 10- 4 m3

The overall weight of gating = Overall volume of gating × density

= 6.57×104 ×7.2×103 = 4.73kg

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Calculating the gating ratio for the current gating system

Common casting faults were found using the industry-standard gating system, which raised the rejection rate and decreased productivity. In demand to reduce the proportion of refusal, it was absolute to use foundry technology that complies with the ISO 28238:2010 standard gating ratio. Ratio of gates: How rapidly melted pewter flows over the sprue is influenced by the cross sections of the racers, gates, and sprue. There are suggestions for a wide range of gating ratios in the literature from various theoreticians. The typical way to express the dimension aspects of every gating system is in gating ratio terms.

Table 2: Gating area and dimensions for the current gating scheme.

Sr. No.	Part	Existing GS Dimensions (mm)	Existing Gating Area (mm2)
1	SPRUE	D1= 25, D2=20	500
2	Runner	L=60 H=65 T=23	910
3	In Gates	L=30 H=15, W=40, L=15, H=5 W=40	1060

The gating ratio converts to 1:1.87:2.13

Nonetheless, apiece the recommended normal gating ratio for grey cast iron (i.e. 1:2:1, 1:2:0.5, 1:4:1, 2:7:1). As a result, according to experts in foundry technology, the produced gating ratio does not meet the normal gating ratio.

Proposed Gating System

Bottomless research and investigation of the current gating system revealed that the industry had used the wrong method. The calculations and analysis of the current gating system yielded a reasonably typical result: a gating ratio of 1:1.87:2.13, which does not correspond to the conventional gating ratio as determined by the researcher's study of foundry technology. The additional finding from the computation of the current gating system is that it weighs around 4.75 Kg, which is excessive and has to be reduced significantly.

This calculation revealed that the flow form of the current Gating System is laminar.

Table 3: Gating area and dimensions for Planned gating scheme.

Area	Current	Current	Planned	Planned
Sprue	4.91X10 -5 mm3	301.681X10 -3kg	4.91 X10 -5 mm3	301.68X10 -3 kg
Runner	6.712 X10 -5 mm3	483.262X10 -3 kg	7.2956X10 - 5 mm3	0.6135 kg
In gates	72 X10 -6 mm3	517.41X10 -3 kg	14.4X10 -6 mm3	103.68X10 -3 kg
Riser	5 X10 -4 mm3	3.67 kg	2.034 X10 -4 mm3	1.3646 kg
Total		4.75 kg		2.39 kg

Gating system computation and ratio for the suggested gating system

The following designs are conducted in the direction of continuing the standard gating ratio based on variations in the sizes of the current gating system. These calculations will result in a gating ratio for the suggested gating system.

Table 4: Current Dimension of Existing Gating System

Cross-sectional Area	In mm2
Sprue	490
Runner	1100
Gates	510

Therefore, the gating Ratio will be 490: 1000: 510 = 1: 2.24: 1.04

Table 5: The area for the current and planned Gating Systems.

Sr. No	Current Gating Area (mm^2)	Planned Gating Area (mm)
1	491	490
2	920	1100
3	1050	510

Hence, according to Lan et al. (2022) and Raza et al. (2021) findings in foundry technology, the proposed gating ratio, which is (1: 2.24: 1.04), matches the standard gating ratio, which is 1:2:1. This flow pattern analysis is crucial for producing Ginning Dead Weight since it helps decrease different casting flaws by employing the current gating system.

RESULTS AND DISCUSSION

At Deepshikha Industry in Nagpur, trials have been conducted employing the suggested gating mechanism. The outcomes of the experiment are highly sound and beneficial. It was discovered that by using the ISO 28238:2010 gating ratio, the overall weight of the GS was reduced from 4.75 kg to 2.4 kg, the total percentage of refusal was decreased from 20% to 24% to 6.5% to 8%, the yield increased from 87% to 93%, the productivity increased from 40% to 72%, and the flow was maintained laminar through all of the GS sections, which is crucial for reducing casting defects.

Inspection report

Table 6: Inspection Report Using Proposed Gating System

Job Qty	shrinkage	Blow holes & gas holes	Sand inclusion	Misrun	Total	% of defects
25	0	0	1	1	2	8
25	0	0	1	0	1	4
25	0	0	0	1	1	4
25	0	0	1	1	2	8
25	0	0	1	0	1	4
25	0	0	0	1	1	4
The average proportion of refusal is around 4% to 8%						

The actual weight of the planned and current gating systems

Table 7: Real weight assessment of the current and planned gating systems.

Section	Current)	Current	Planned	Planned
Sprue	4.91X10 -5 m3	301.681X10 -3 kg	4.91 X10 -5 m3	301.68X10 -3 kg
Runner	6.712 X10 -5 m3	483.262X10 -3 kg	7.2956X10 - 5 m3	0.6135 kg
In gates	72 X10 -6 m3	517.41X10 -3 kg	14.4X10 -6 m3	103.68X10 -3 kg
Riser	5 X10 -4 m3	3.67 kg	2.034 X10 -4 m3	1.3646 kg
Total		4.75 kg		2.39 kg

The suggested gating ratio was the same as the conventional gating ratio. As a result of the necessary modifications to the current gating system's design and size, the overall weight of the GS decreased from 4.75 kg to 2.39 kg. Any industrial industry engaged in mass production might choose this because it is the most economical alternative.

Analysis of Bunch Weight for the Suggested Gating System

Table 8: The results of experiments with the suggested gating scheme.

Sr. No	Batch No.	Bunch	Casting	Gating	% yield
1	DDR/2023/03	40.25kg	37.93 kg	2.32 kg	0.94236
2	DDR/2023/03	40.32 kg	37.98 kg	2.34 kg	0.941964
3	DDR/2023/03	40.38 kg	38.01 kg	2.37 kg	0.941308
4	DDR/2023/03	40.65 kg	38.27 kg	2.38 kg	0.941451
5	DDR/2023/03	40.65 kg	38.26 kg	2.39 kg	0.941205
6	DDR/2023/03	40.7 kg	38.3 kg	2.4 kg	0.941032
7	DDR/2023/03	40.75 kg	38.34 kg	2.41 kg	0.940859
8	DDR/2023/03	40.8 kg	38.38 kg	2.42 kg	0.940686
9	DDR/2023/03	40.85 kg	38.42 kg	2.43 kg	0.940514
10	DDR/2023/03	40.95 kg	38.5 kg	2.45 kg	0.940171
Average		40.63 kg	38.239 kg	2.391 kg	94.1155

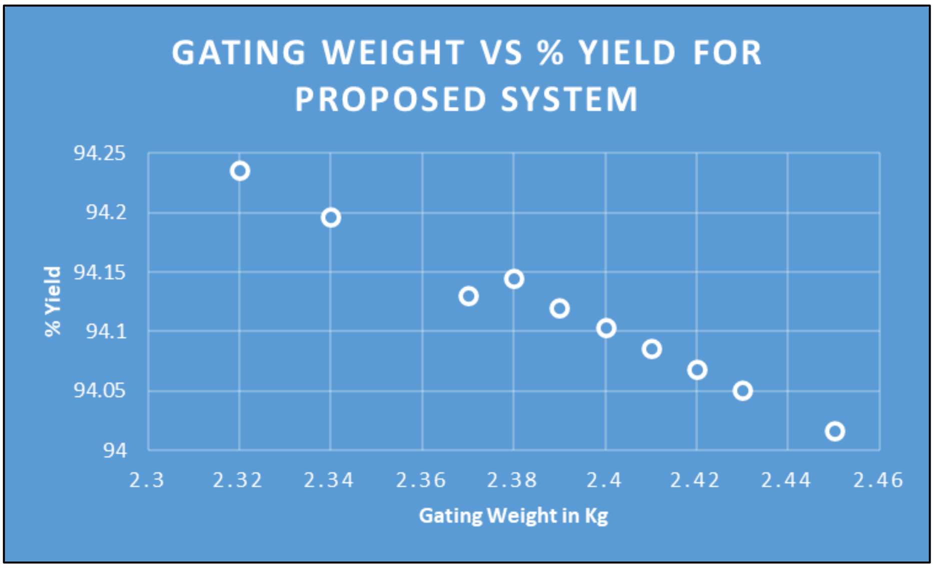

Figure 3: Proposed Gating Weight in Kg Vs % Yield for proposed system

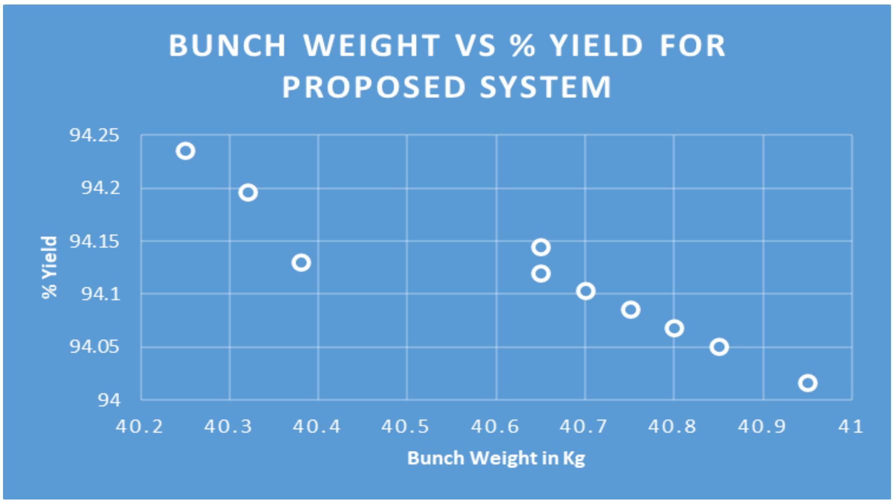

Figure 4: Bunch Weight in Kg Vs % Yield for proposed system

Using the suggested gating system, the bunch weight study provided an average weight of casting discovered of 38.239 kg, an average bunch weight of casting found of 40.63, and an average yield percentage of 94.11% with an average weight of the present gating system of 2.391 kg.

Table 9: Bunch Weight Analysis for the Current Gating System

Sr. No	**Batch No.**	**Bunch**	**Casting**	**Gating**	**% yield**
1	DDR/2022/11	43.75 kg	39.12 kg	4.63 kg	0.894171
2	DDR/2022/11	43.8 kg kg	39.15 kg	4.65 kg	0.893836
3	DDR/2022/11	43.85 kg	39.18 kg	4.67 kg	0.893501
4	DDR/2022/11	43.9 kg	39.22 kg	4.68 kg	0.893394
5	DDR/2022/11	43.95 kg	39.25 kg	4.7 kg	0.89306
6	DDR/2022/11	43.98 kg	39.26 kg	4.72 kg	0.892678
7	DDR/2022/11	44 kg	39.25 kg	4.75 kg	0.892045
8	DDR/2022/11	44.05 kg	39.2 kg	4.85 kg	0.889898
9	DDR/2022/11	44.08 kg	39.2 kg	4.88 kg	0.889292
10	DDR/2022/11	44.15 kg	39.22 kg	4.93 kg	0.888335
Average		43.951 kg	39.205 kg	4.74 kg	89.20201

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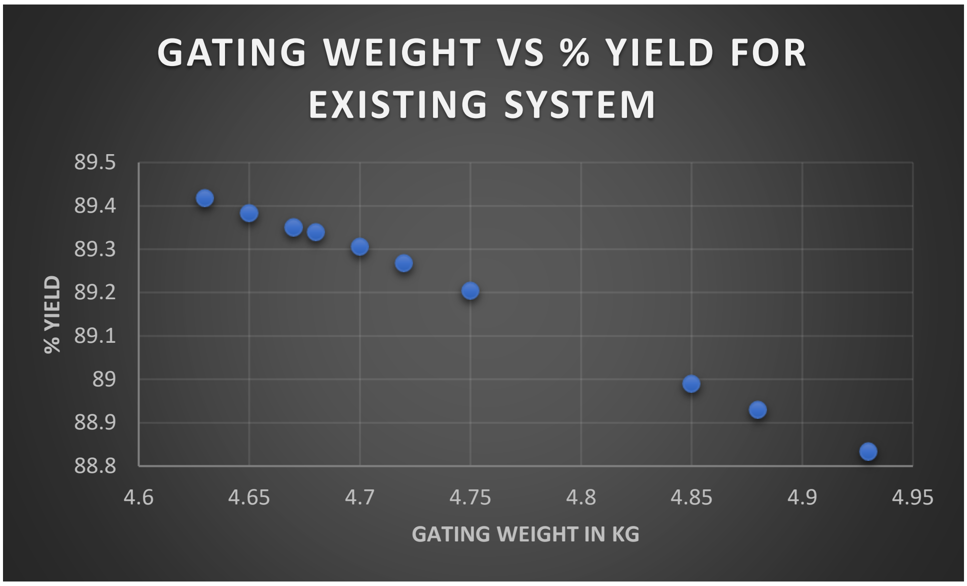

Figure 4: Existing Gating Weight in Kg Vs % Yield for proposed system

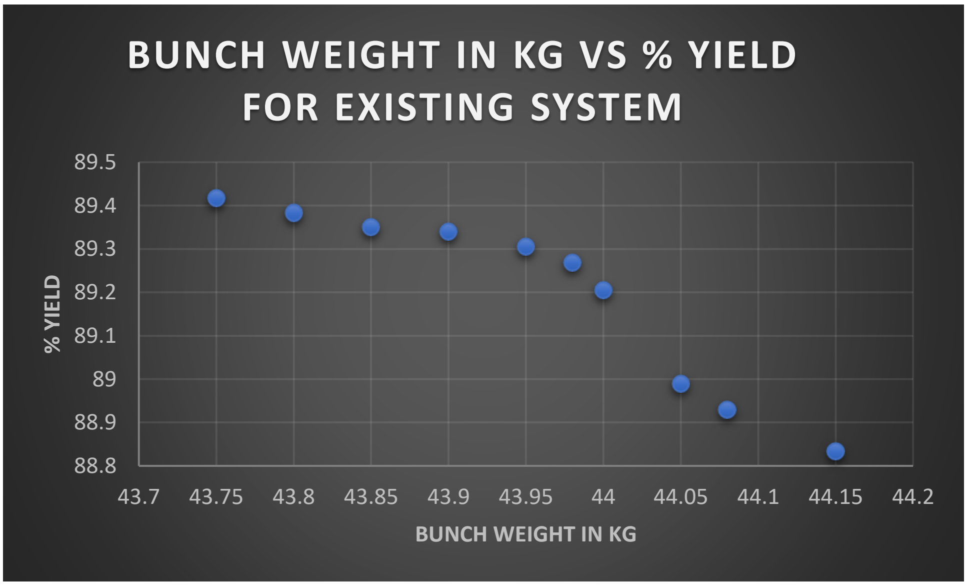

Figure 5: Existing Bunch Weight in Kg Vs % Yield for the proposed system

The average bunch weight of the casting discovered was 43.953 kg, while the average weight of the current gating system was 39.207 kg, producing an average yield percentage of 89%. The average bunch weight comparison of the proposed and existing gating systems revealed an improvement in yield percentage of 89% to 94%, which is most cost-effective for the industrial sector.

Discussion

The goal of this investigation is to pinpoint the issue with the gating method utilised to produce the dead weight that Deepshikha Industries in Nagpur uses in its machinery. After careful observation, examination, and study of every aspect of the gating system, it was discovered that even a slight modification in the system's size significantly impacted the manufacturing price. With the current gating system, the typical overall percentage of rejection ranges from 20% to 24% of the total casting produced. On average, 4% to 8% of the total casting is rejected under the suggested gating method. This significant shift in the typical rejection rate impacts manufacturing costs. The finding aligns with Maniar and Patel (2023), who revealed that an appropriate gating system might significantly eliminate all of the aforementioned faults; it was discovered after carefully examining the casting process. Thus, the primary research focus is on optimising the gating mechanism.

A wide range of variables influences the gating design. However, one of these criteria stands out as crucial among the rest. Extensive investigation and analysis led to the decision to adhere to the ISO 28238:2010 standard of gating ratio that several casting researchers had previously advised. It was discovered that the prior gating ratio was erroneous and must be maintained in order to preserve standard. After calculating the system's weight, it was discovered that it has to be significantly lighter overall. After thorough observation and evaluation, it was determined that the gating system's design and dimensions should be modified as needed.

Trials have been conducted at Deepshikha Industries in Nagpur using the suggested gating mechanism. The outcomes of the experiment are highly sound and beneficial. It was discovered that using the ISO 28238:2010 standard of gating ratio increased overall productivity. Additionally, the entire weight of the GS decreased from 4.75kg to 2.39kg, the total percentage of refusal decreased from 20% to 24% to 4% to 8%, and the yield increased from 89% to 94%.

The present study's findings concerning Deepshikha Industries' optimisation of the gating system, cost reduction, and minimisation of defects in the casting process are similar to those of the other research. As for the optimistic results of the study using ISO 28238:2010 gating standards, generally, the literature supports the concept that an optimum gating design has a profound effect on lowering the rejection rate, cutting the cost of production, and improving yield (Khan et al., 2022; Bhatt et al., 2021; Rajkumar et al., 2021).

Gating System Effect on Casting Quality: According to published research, gating design—specifically, gating ratio is a crucial component of casting process quality and economic efficiency. According to studies by (Ravi, 2008) and (Hu et al., 2022), poor gating can result in flaws, including porosity, shrinkage, and turbulent flow, all of which raise rejection rates to high levels like the 20%–24% rate that was first discovered in the casting output of Deepshikha Industries. It has been demonstrated that gating ratio optimisation to recommended standards considerably reduces these flaws, which aligns with the findings of Bhatt et al. (2021), which results in a lower rejection rate of 4%–8%. Gate Optimization Can Yield Lower Production Cost Some studies have even revealed that slight changes in weight distribution and gate sizes result in drastic cost savings (He et al., 2022; Ghuge et al., 2018). Deepshikha achieved material waste reduction, which these studies term a reduction in manufacturing costs and better material usage efficiency.

Industries when the company cut down the weight of the gating system to 2.39 kg from an initial 4.75 kg. Research by Kumaravadivel and Natarajan (2013) indicates that traditional gating ratios increase casting yield besides reducing rejections.

For instance, Kumar's work indicates that an optimised gating system implementation results in a yield increase consistent with the increase from 89% to 94% in your case. This yield increase is consistent with notions in the literature about how reduced turbulence and controlled metal flow improve casting productivity.

International Standards and Best Practices

The literature stream always supports standardising gating procedures as proposed by ISO 28238:2010. The evidence in the real world shows that such standards lead to better product performance and productivity. Deepshikha Industries' adoption of ISO 28238:2010-based gating ratios and the resultant productivity increase and defect reduction showcase a trend that aligns with the research findings of the industry's researchers, Chandra and Balaji (2019). International Standards and Best Practices: The body of research continuously supports using standardised gating procedures, such as those suggested by ISO 28238:2010.

Empirical evidence shows that these standards improve product performance and consistency. Deepshikha Industries' use of ISO 28238:2010 -based gating ratios and the ensuing productivity and defect reduction improvements are consistent with findings from industry researchers such as Chandra and Balaji (2019). The study appears to support Deepshikha Industries' findings that gate size optimisation and maintaining standardised ratios can significantly increase yield, minimise rejections, and save on manufacturing costs.

The ISO 28238:2010 standard seems broadly applicable for general casting applications, consistent with this study's successful outcome. However, some specific gating applications seem worth exploring in particular situations.

CONCLUSION

Typical modifications to the gating system's design and dimensions are essential during the casting product's production. After careful observation, examination, and scrutiny of every aspect of the GS, it was discovered that even a slight modification in the system's size significantly impacted the manufacturing price. The goal or slogan of the project is to maximise productivity, which is crucial for any manufacturing business, by reducing casting defects, reject rates, and gating system weight.

The outcomes of the experiment are highly comprehensive and beneficial. By expanding a standard gating ratio according to the research, it was discovered that the overall efficiency increased. This was accomplished by dropping the total proportion of refusal from 20% to 24% to 4% to 8% and increasing the yield from 89% to 94%. A standard gating ratio is critical when designing a gating system for steel casting. Casting flaws and rejection rates must be reduced; hence, standard optimisation techniques must be used. The ideal weight of the gating system must be developed while designing its usual components. Flow pattern analysis is crucial for determining whether the flow pattern of molten metal during casting is laminar or turbulent to decrease different casting flaws. Increased yield and productivity percentages are required to enhance the steel-casting gating system.

The study presents significant practical and social implications by optimising the gating system design for steel casting. It reduces the rejection rate from 20–24% to 4–8%, thereby lowering manufacturing costs, minimising material waste, and enhancing overall productivity with an increased yield from 89% to 94%. Improved casting quality ensures reliable components that meet industry standards, while the standardised gating ratio and weight optimisation techniques provide scalable solutions for similar industries.

Socially, these advancements contribute to economic growth through cost-effective and efficient production processes, ensure job security by stabilising industrial operations, and enhance customer satisfaction with higher-quality products at potentially lower prices. Additionally, reducing waste supports sustainable manufacturing practices and addresses environmental concerns.

The study's novelty lies in introducing a standardised gating ratio designed explicitly for steel casting, achieving a rare combination of reduced defects and increased yield. The comprehensive flow analysis ensures laminar molten metal flow, minimising turbulence-related defects, while the dual focus on optimising gating system weight and enhancing productivity highlights its innovative approach. Furthermore, the findings are adaptable to other casting industries, making this research valuable to manufacturing practices.

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