International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972

Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

INTERNATIONAL JOURNAL OF INNOVATION AND INDUSTRIAL REVOLUTION (IJIREV)
www.ijirev.com

GLOBAL ACADEMIC EXCELLENCE

DESIGN AND ANALYSIS OF THE GATING AND RISERING SYSTEM FOR STEEL SAND CASTING

Amir Hidayat [1], Alias Mohd Saman [2*], Norliana Mohd Abbas [3]

[1] School of Mechanical Engineering, Universiti Teknologi Mara (UiTM), Malaysia
Email: 2023437668@student.uitm.edu.my
[2] School of Mechanical Engineering, Universiti Teknologi Mara (UiTM), Malaysia
Email: aliasms@uitm.edu.my
[3] School of Mechanical Engineering, Universiti Teknologi Mara (UiTM), Malaysia
Email: norliana@uitm.edu.my
[*] Corresponding Author

Article Info:

Article history:
Received date: 28.07.2024
Revised date: 13.08.2024
Accepted date: 12.09.2024
Published date: 24.09.2024

To cite this document:

Hidayat, A., Saman, A. M., & Abbas, N. M. (2024). Design And Analysis Of The Gating And Risering System For Steel Sand Casting. *International Journal of Innovation and Industrial Revolution*, *6* (18), 75-87.

DOI: 10.35631/ IJIREV.618006

Abstract:

Steel sand casting involves complex processes that significantly impact the quality and integrity of the final product. Among these processes, the design of the gating and risering systems plays a crucial role in ensuring defect-free castings. This research focuses on optimizing the gating and risering system design for steel sand casting with the aim of improving casting quality and minimizing defects. Through a detailed case study, the study seeks to develop a robust gating and risering system specifically tailored for steel casting applications. Computational applications using CATIA software for 3D modelling and Altair Inspire Cast for process simulation and analysis was employed to rigorously evaluate and validate the effectiveness of the proposed design. The study aims to meet performance criteria and enhance casting integrity. The ultimate goal is to propose an optimal gating and risering system configuration that not only addresses the challenges identified in the case study but also serves as a practical guideline for improving the overall efficiency and quality of steel casting processes. Key findings from the study highlight velocity, solid fraction, and porosity as significant parameters during the filling and solidification process, providing benchmarks for improving the casting process. Ultimately, an improved model with a yield improvement of 17.65% and an enhanced casting process was achieved. The findings underscore the importance of an optimized gating and risering system in enhancing the casting process, reducing defects, and producing high-quality steel products through detailed filling and solidification analysis, ultimately improving casting yield.

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

Keywords:

Casting Simulations, Casting Yield, Gating And Risering Systems, Globe Valve

Introduction

Steel Sand Casting

Steel is a versatile engineering material, used widely in sectors such as automotive, oil and gas, transportation, aerospace, and heavy machinery. Its history in steel casting dates back to 645 BCE in China, and it remains important today due to its cost-effectiveness and adaptability (L. Pandey, 2015).

Steel casting involves pouring molten steel into a mould to create products such as valves, crane hooks, impellers, and pressure vessels. These castings are valued for their strength and durability. However, producing high-quality castings requires careful management of gating and risering systems, which control the flow and solidification of the molten metal. Defects in these systems, such as porosity, trapped air, and shrinkage, account for 90% of casting rejections and can lead to lower productivity and higher costs (Nazma et al., 2018; P. Desai et al., 2019; Shankar Kamble et al., 2016). Thus, optimizing these systems is crucial to enhance casting quality, reduce material waste, and improve overall manufacturing efficiency. Despite comprising only 10% of foundry industry sales, steel castings are indispensable for their ability to produce complex and robust components (Blair & Steven, 1995).

In the context of valve manufacturing in Malaysia, the industry faces significant challenges. One of the major issues is the country's reliance on imported valves due to the domestic industry's inability to meet quality and production demands. Malaysia imports more valves than it exports, with MYR 404 million in imports compared to MYR 288 million in exports (Observatory of Economic Complexity (OEC), 2024). This dependence on imports not only affects the trade balance but also highlights the underlying inefficiencies in local manufacturing practices. Local foundries struggle with casting defects, particularly in the gating and risering systems, which lead to increased scrap rates and compromised product integrity. These issues underscore the urgent need to design and analyse effective gating and risering systems that can produce defect-free castings, thereby increasing the competitiveness of Malaysia's valve manufacturing sector.

Gating and Risering Systems

Gating and risering systems are fundamental in the casting process, providing pathways for molten metal and reservoirs for excess metal. These systems significantly influence mould filling efficiency and defect mitigation. Figure 1 illustrates the components in the sand mould.

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
IJIREV
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

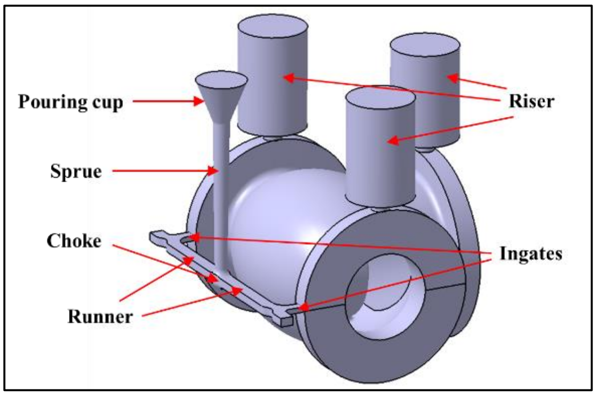


Figure 1: Components in the Sand Mould

In the casting procedure, molten metal is poured into a pouring cup, travels through a sprue, and then through a choke that controls its flow speed. The runner directs the metal to the ingates, guiding it into the mould cavity, where it respects to the desired shape. Risers act as reservoirs to prevent shrinkage defects. Once solidified, the casting is removed from the mould and undergoes finishing processes such as trimming and surface treatments. The effectiveness of the final product heavily depends on the design of the gating and risering systems, which must follow specific rules apart from trial and error. Some of the rules are the pattern allowance, gate branching, and the riser size and placement. These criteria ensure an effective filling and solidification pattern to produce high-quality product. Once developed, a design verification is needed to ensure the system is suitable for the case study.

Casting Simulation Tools

Casting simulation tools are vital for evaluating the efficiency of gating and risering systems, predicting flow behaviour, and detecting potential casting defects before production. These tools are particularly important in developing new products, often requiring multiple trial-and-error cycles in the foundry. Simulation tools can significantly reduce the product development process at a time when demand is increasing for new product variations. A well-known computer-aided engineering (CAE) software for casting simulations such as Click2Cast, AutoCAST, MAGMASOFT, and Inspire Cast are some of the powerful tools in analysing the casting process. These tools are user-friendly, reliable, and provide predictable results. For example, a study using Altair Inspire Cast identified defect levels with over 80% probability as a benchmark to analyse the results and recognized any possible improvement on the casting (Yekane & Amar S, 2021).

Although the gating and risering systems have been simulated to overcome the casting defects, the design needs to be modified, ideally, to reduce material usage. The modification of the channel systems is broad and flexible; every adjustment made to the components of the gating and risering systems can affect the casting process significantly. Thus, a modification with the aim of eliminating casting defects is the main goal in optimizing the gating and risering systems.

Casting Yield

Casting yield is a way to determine the optimization level of the gating and risering systems in producing a product (P. Desai et al., 2019). It is calculated using the weights of the casting, gating, and risering systems. The formula for casting yield is:

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

$$yield\ (\%) = \frac{W_{casting}}{W_{casting} + W_{Gating} + W_{Riser}} \times 100 \quad (1)$$

Where $W_{Casting}$ is the weight of the casting, W_{Gating} is the weight of the gating system, and W_{Riser} is the weight of the risering system. High-quality castings with excessively designed gating and risering systems may reduce casting yield. Improving casting yield is crucial to reduce trials, material waste, and enhance customer satisfaction. Optimal casting yield can be achieved by reducing the volume of gating and risering systems while minimizing defects. A yield value is typically within 60% to 80% (P. Desai et al., 2019; Shankar Kamble et al., 2016). An optimized casting yield is achieved when the casting process is improved concurrently. For instance, a case study on car brake drums showed that refining the gating system design, such as adjusting choke areas, sprue shape, ingates, and runners, increased yield from 66.57% to 81.68% (P. Desai et al., 2019). Additionally, employing design of experiments techniques yielded a further 2.72% improvement (Yekane & Amar S, 2021). Even small enhancements in casting yield can significantly reduce defects, ensuring superior casting quality and efficient material utilization.

This study aims to design and analyse the suitable gating and risering systems for body globe valve used in steam transportation by simulating the casting process and improve casting yield.

Methodology

The study began with the selection of a suitable case study for the casting product. This was followed by designing the casting model, along with the gating and risering systems, based on theoretical calculations. The research scope excluded mould and patternmaking, casting accessories such as chillers and sleeves, and the heat treatment process, concentrating solely on the gating and risering design.

The initial design was then imported into simulation software for a thorough process evaluation. Identifying issues in filling and solidification prompted a redesign of the gating and risering systems to create an improved design. Subsequently, the improved design underwent further simulation to evaluate and validate the results. A comprehensive comparison between the initial and improved designs highlights the enhancements in casting performance and yield, with each phase detailed in the subsequent sections. This methodology integrates case study selection, gating and risering systems design, simulation, qualitative analysis, and iterative refinement to optimize the casting process for the chosen case study.

Selection of Case Study

A body globe valve was chosen as the case study for this project due to its extensive use in regulating fluids in industrial pipelines, particularly in Malaysia's oil and gas (O&G) sector. This choice aligns with the government’s Twelfth Malaysia Plan (RMK-12), which emphasizes increasing domestic contributions to the energy sector’s sustainability (Malaysian Investment Development Authority (MIDA), 2022). Additionally, the Malaysia Industrial Valves Market saw a -10.48% compound annual growth rate (CAGR) in 2021, highlighting limited local production (6Wresearch, 2023). Focusing on the body globe valve can provide valuable insights into improving gating and risering system design for local foundries, potentially boosting productivity and reducing reliance on imports.

International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
IJIREV
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

The body globe valve, illustrated in Figure 2, is made of carbon steel, which is suitable for high-pressure and high-temperature operations (Blair & Steven, 1995). It weighs 46.58 kg and measures 356.0 x 276.0 x 297.5 mm. Table 1 details the material properties of carbon steel, emphasizing its cost-effectiveness and robustness across various industries.

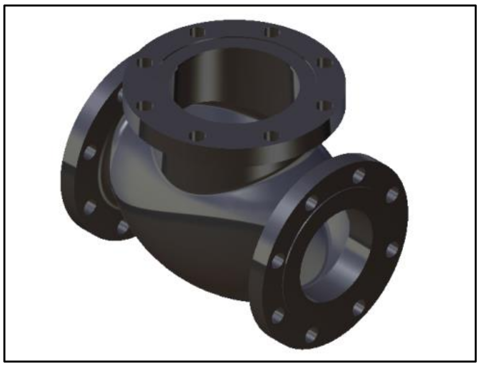


Figure 2: Body Globe Valve

Table 1: Chemical Composition of ASTM A216 WCB Carbon Steel, %

C	Mn	P	S	Si	Cu	Ni	Cr	Mo	V
0.35	1.0	0.035	0.035	0.6	0.3	0.5	0.5	0.3	0.03

Choosing the right material is crucial for producing high-quality castings, as properties like strength, hardness, and corrosion resistance vary. A216-WCB, a common cast carbon steel, is often used for valve bodies, fittings, and flanges due to its strength and toughness. Its carbon content balances strength and ductility, making it suitable for high-pressure and high-temperature applications (Qin, Lv, Li, & Li, 2021). Understanding material characteristics is essential for selecting the appropriate material and organizing the casting process. It helps in designing the size of gating and risering systems and estimating pouring times based on material parameters.

Design Modelling of Globe Valve Model and Casting Model

The globe valve model's geometry was created using CATIA software, with dimensions reflecting the final product after casting and finishing, as shown in Figure 3. In sand casting, it is crucial to consider “pattern allowance” before conducting the casting simulation (P. L. Jain, 2003). Pattern allowance includes machining, draft, and contraction allowances, ensuring the component model's sizes meet the required specifications.

The casting model of the globe valve, shown in Figure 4, incorporates a machining allowance, eliminating holes, thickening flange surfaces by 3 mm, and simplifying small sharp edges. This ensures the casting will undergo necessary machining processes to meet design requirements. A draft allowance of 0.5 degrees was applied to the flanges on both halves to facilitate easy removal from the mould.

The contraction allowance accounts for shrinkage during solidification, making the casting slightly larger than the final product. For carbon steel, the contraction rate is 20 mm per meter, so the model was scaled up by 1.02% along each axis using CATIA’s ratio feature. This careful

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006
consideration of allowances ensures the casting model meets final product specifications after all necessary machining and solidification processes.

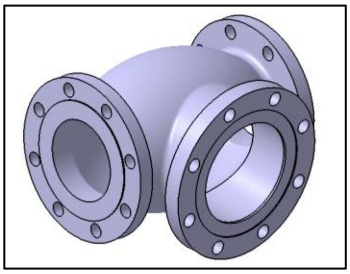


Figure 3: Globe Valve Model

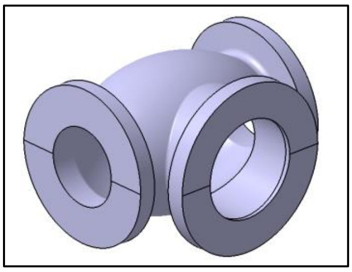


Figure 4: Casting Model

Initial Design of Casting Model

Establishment of The Gating System

The gating system is essential for ensuring the proper flow of molten metal into a casting cavity, necessitating calculations to determine the sizes of the sprue, runner, ingates, and riser. These parameters must be designed considering the metal being cast, the geometry, and the casting properties to achieve high-quality results. This study employed an empirical method, compiling formulas from previous studies and reliable sources to design the gating system. The process began with identifying the casting weight (W), pouring time (t), and choke area (A). A gating ratio of 2:1.75:1.5 was used to determine the dimensions of the sprue and runner, while the riser size was calculated using Caine's method.

Formula involves:

Pouring time, t	$t = K(1.41 + \frac{B}{14.59})\sqrt{W}$	(2)
Choke area, A_C	$A_c = \frac{W}{dtc\sqrt{2gH}}$	(3)
Gating ratio (A_s:A_r:A_g)	2:1:75:1:5	
Effective sprue height, H	$H = h - \frac{P}{2a}$	(4)
Sprue diameter, D (top and bottom)	$\frac{\pi D^2}{4} = A_c$	(5)
Cup height	$2.5(D)$	(6)
Runner and Ingates dimension	$A_{r/g} = \frac{4A_c}{2}$	(7)
Riser	$X = \frac{(\frac{V}{SA})casting}{(\frac{V}{SA})riser}$	(8)
	$X = \frac{L}{Y-B} + C$	(9)

Terms:

W – Weight of casting
K – Material composition factor
B – Average thickness of casting product
d – Material density
c – Coefficient of friction
g – Gravity
h – Sprue height
P – Cavity height from the parting line
a – Total cavity height
V/SA – Volume/surface area
Y – Volume of riser/volume of casting
L, B, C – Constant

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

Once all the values have been obtained, the gating system's theoretical design can be simplified as illustrated in Table 2. The gating system's ideal dimensions are represented by these values. Nonetheless, in order to examine the design and identify any flaws, a simulation tool is required. In comparison to the globe valve model in Figure 3, the size and casting weight are raised by considering all the pattern's allowances. The updated measurements are 369.0 x 281.5 x 306.5 mm with a weight of 53.89 kg.

Table 2: Calculation Results of Gating and Risering System Components

No.	Gating System Components	Values
1	Casting model dimensions, $(W \times L \times H)$	369.0 x 281.5 x 306.5 mm
2	Casting weight, W_C	53.89 kg
3	Pouring time, t	14 sec
4	Choke area, A	254.05 mm^2
5	Sprue height, H	300 mm
6	Tapered sprue diameter, D	18 mm (bottom) 25 mm (top)
7	Cup height	62.5 mm
8	Runner $(W \times H)$	(20 x 13) mm
9	Ingates $(W \times H)$	(16 x 8) mm
10	Riser diameter	100 mm
11	Riser height	150 mm

Design Assembly and Simulation Setup

The design assembly which is called the initial model can be seen in Figure 1. The design and placement of components followed the rules and guidelines of the gating system (P. L. Jain, 2003). Based on the calculations in Table 2, the molten metal's pouring time into the pouring cup was set at 14 seconds. The sprue height is 300 mm, slightly higher for a similar mould size, with a choke area of 254.05 mm^2 located below the sprue. The gating ratio is 2:1.75:1.5, resulting in a total runner cross-sectional area of 1063.3 mm^2, divided into two runners with dimensions of 20×13 mm. The ingates have a total area divided into four channels, each with a cross-sectional area of 127.03 mm^2, and dimensions of 16×8 mm. A top open riser is used for the initial design, which the risers were exposed to open atmospheric pressure.

The process continued with the evaluation stage by setting up the simulation using the Altair Inspire Cast software. The software provides essential tool to perform the casting simulation. In performing the simulation, five steps need to be completed and simplified in Table 3.

Table 3: Five Steps in Altair Inspire Cast

No.	Steps	Description	Remarks
1	Cast part	Material Pouring temperature	Carbon steel (A216-WCB) 1550 ℃
2	Gate	Filling entrance Designated filling system	Top of the sprue Runner and ingates
3	Components	Core/mould Riser	Mould/core material: Furan sand Mould size: 551 × 554 × 518 mm
4	Basic Setup	Calculated filling time	14 seconds
5	Run	Mesh size & Run	8.5 mm

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

Figure 5 illustrates the simulation setup. The model was assigned the "cast part" of carbon steel (A216-WCB) with a pouring temperature of 1550 °C. The "filling entrance" was set at the top of the sprue, and the runner and riser systems were allocated to the "designated filling system". The mould used Furan sand and had dimensions of 551×554×518 mm. The pouring time was set to 14 seconds, and the mesh size was 8.5 mm. This setup ensures accurate simulation and analysis of the casting process for the globe valve model.

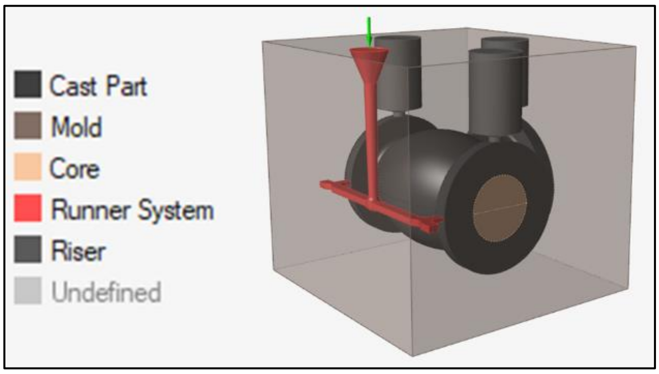


Figure 5: Simulation Setup

Improved Design of the Casting Model

The improved design for the globe valve casting was developed based on the initial simulation results. The initial design faced issues such as high velocity, isolated molten metal, and porosity, which compromised the casting's structural integrity and performance. Modifications to the gating and risering systems were made, and repeated simulations helped refine the casting process and improve yield. Figure 6 shows the differences between the initial and improved designs.

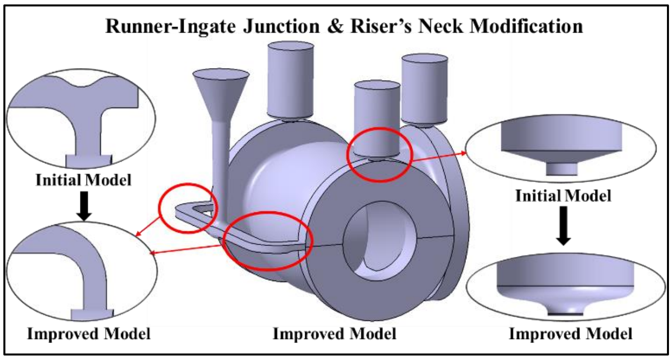


Figure 6: Differences Between the Initial and Improved Designs

Based on Figure 6, the gating system has been redesigned for improved casting flow. The runner-to-ingate branching now provides a direct path to the casting. The riser neck has been altered from a chamfered to a curved transition, enhancing flow and preventing bottlenecks during solidification. The riser's volume has been reduced by optimizing the Caine's curve to cut material usage. The pressurised system has been modified to give more area to the runner, and the sprue height is shorter due to the reduced riser height for an open riser. These changes are detailed in Table 4.

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

Table 4: Design Comparison between Initial and Improved Designs

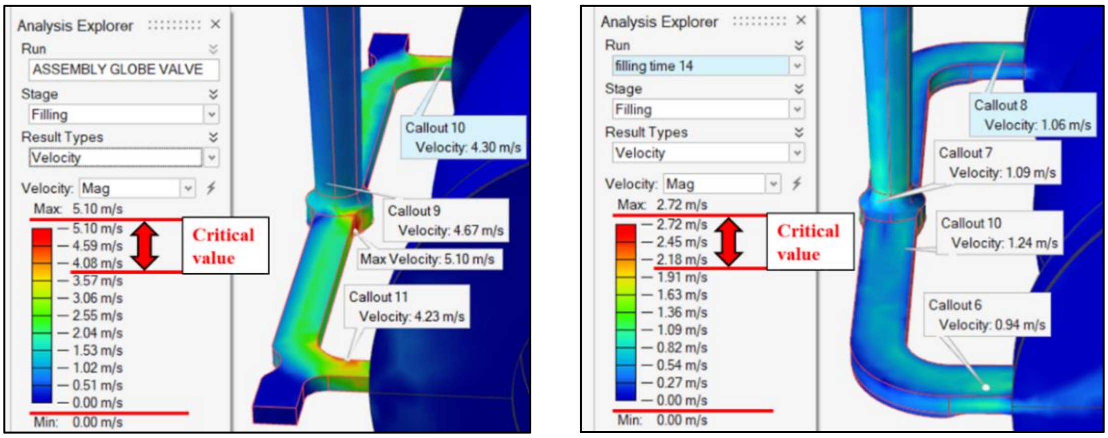
Components	Initial	Improved
Gating ratio	2:1.75:1.5	1:2:1.5
Sprue height	300	250
Riser height (mm)	150	110
Riser diameter (mm)	100	73
Riser volume (mm^3)	3.57×10^6	1.41×10^6

Result & Discussion

Simulation offers detailed insights into mould cavity filling from sprue to riser. This study compares the improved and initial designs by examining velocity during filling, solid fraction during solidification, and porosity. A qualitative analysis is also conducted to evaluate flow behaviour, defect formation, and overall mould performance. Yield values for both models are assessed to quantify efficiency. These comparisons validate the optimal gating and risering system for the case study, ensuring comprehensive improvement over the initial design.

Velocity during Filling Stage

During the filling stage, the velocity of the molten metal is crucial for ensuring smooth fluid flow. High velocity can cause issues such as flow turbulence, mould erosion and incomplete mould filling (Sama, Macdonald, Voigt, & Manogharan, 2019). The gating system, consisting of junctions, significantly influences the velocity profile during the filling stage. The results show the velocity profile at the gating system with several plots highlighting velocity. The colour map in the legend represents the velocity range within the casting, with 80% and above indicating the critical velocity threshold (Yekane & Amar S, 2021).



(a) **(b)**

Figure 7: Velocity Analysis for (a) Initial Model and (b) Improved Model

As shown in Figure 7(a), certain areas of the gating system, specifically the runners and ingates, experience high velocity, with the bottom of the sprue reaching a maximum velocity of 5.1 m/s. Three callouts in the red region indicate that all values exceed the critical velocity value of 4.08 m/s. This suggests that the gating system is poorly designed, particularly the branching from the runner to the ingate, and that the gating ratio is unsuitable for this case study.

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

In the Improved model shown in Figure 7(b), the transition between the runner and ingate is smoother, and the gating ratio has been adjusted from 2:1.75:1.5 to 1:2:1.5. This modification increases the total ingate area relative to the sprue area, reducing the velocity and providing uniform metal flow in the gating system. The callout plot locations remain the same, and all values are now below the critical threshold. Additionally, no red regions are present, indicating that the velocity is sufficiently reduced to prevent turbulence, providing uniform metal flow in the gating system and minimizing erosion.

Solid Fraction during Solidification Stage

Solid fraction refers to the proportion of solidified material within the casting, which helps identify the areas that solidify last. These areas are at risk of developing porosity, especially at the flanges, if the risering system is improperly designed (Manjabacas & Miguel, 2023). Figure 8 shows the progression of solidification of the solid fraction. Directional solidification is the goal, with the riser being the last to solidify. In the figure, coloured regions indicate liquid material, while transparent regions indicate solidified material.

The first two images for both the initial and improved models are taken at the same time point which is at the start and at 98 seconds, to show the progress. The third image for each design was taken when the liquid in the casting isolated from the riser. The middle flange is the earliest area to solidify because it is the last area to receive molten metal, causing the temperature to drop further and the molten metal to solidify first. The last image shows the isolation for the left and right flanges, helping to identify the isolated metal in the casting. The red circle in the image shows the isolated metal within the casting.

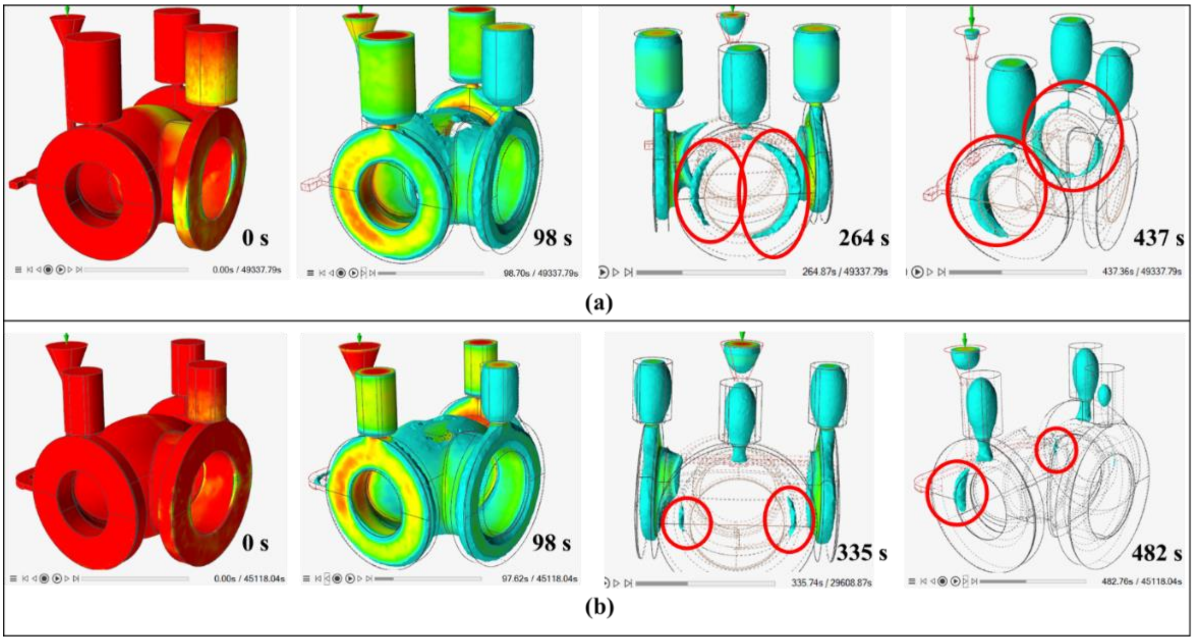


Figure 8: Solid Fraction for the (a) Initial Model and (b) Improved Model

The result shows that the initial model failed to achieve directional solidification. The model experienced a bottleneck at the riser neck, preventing the riser from feeding the casting. Consequently, all three flanges in the initial model remained mostly in a liquid state and became

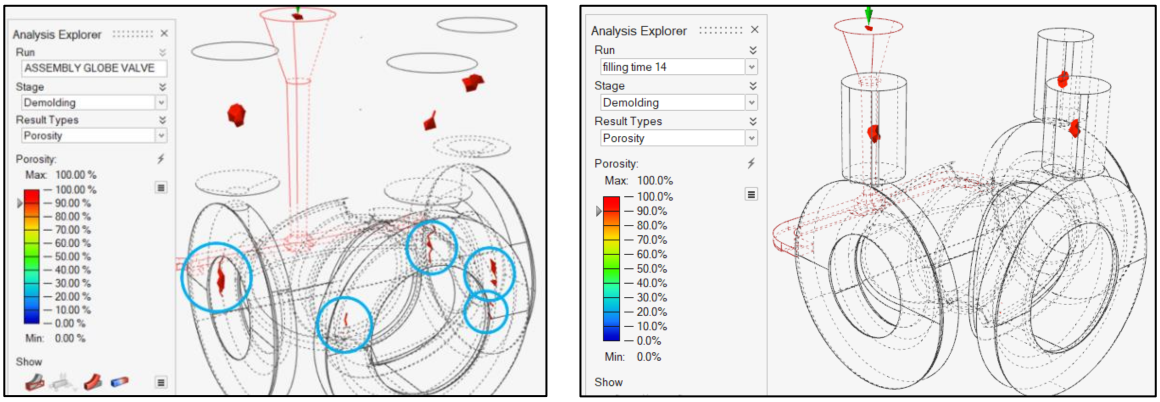
International Journal of Innovation and Industrial Revolution
EISSN: 2637-0972
IJIREV
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006

isolated. As the metal cools and shrinks, if the casting cannot receive additional molten metal from the riser, porosity can develop, leading to defects in the casting (Yekane & Amar S, 2021). In comparison, while the improved design in Figure 8(b) also encounters a bottleneck, the volume of isolated metal in the casting is significantly reduced, lowering the risk of porosity.

The time taken for the liquid in the casting to be isolated from the riser also increased from 264 to 335 seconds for the middle flange, 437 to 482 seconds for the left and right flanges. This allowed the molten metal to solidify in directional order. This improvement is due to the smooth curve established between the riser and the neck, ensuring proper directional solidification. This finding is evidenced by the porosity analysis.

Porosity Analysis

Porosity is a small void or gas presence within the casting. The occurrence is due to the improper solidification pattern, as leaving the high volumes of isolated metals within the casting can produce carbon monoxide gases (Blair & Steven, 1995). In the simulation results, the percentage shown on the legend indicates the probability of a defect occurring. The higher the percentage, the higher the chances of porosity occurring in that coloured region (Altair Inspire Cast, 2023). Figure 9 shows the porosity of the initial design and the improved design. The porosity indicator for both simulations was set at 90% for comparison.



(a) **(b)**

Figure 9: Porosity Analysis for the (a) Initial Model and (b) Improved Model

Based on the initial model in Figure 9(a), it is shown that porosity issues were notable at the flanges and within the riser of the body globe valve casting. These voids are not just minor defects; they have the potential to severely compromise the mechanical properties and structural integrity of the casting (Landage, 2020). By modifying the gating and risering systems, the velocity during the filling stage has been reduced for minimizing turbulence and preventing air entrapment. Additionally, the riser's design should be altered to promote directional solidification, ensuring that the metal solidifies in a controlled manner that minimizes the formation of voids. The effectiveness of these modifications is demonstrated in the improved design shown in Figure 9(b), where the occurrence of porosity has been successfully mitigated. This not only enhances the quality and reliability of the casting but also ensures that the final product meets the standards required for its application.

Casting Yield Comparison

Despite the effectiveness of the gating and risering systems in producing high-quality castings, it is crucial to design them optimally to reduce material usage and increase productivity. Based

International Journal of Innovation and Industrial Revolution
IJIREV
EISSN: 2637-0972
Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006
on equation (1), reducing the volume of the gating or risering system can increase casting yield. Table 5 shows the yield values for the initial and improved models.

Table 5: Casting Yield Comparison between the Initial and Improved Model

Components	Initial	Improved
Casting model	53.89 kg	
Gating system	4.67 kg	3.83 kg
Riser	30.50 kg	11.29 kg
Casting yield	60.43%	78.08%

Based on these values, the casting yield for the improved model has increased by 17.65% compared to the initial model. The gating system weight has decreased by 0.84 kg due to the reduction in sprue height, while the riser weight has decreased drastically by 19.21 kg, which is approximately 62% of the original size. This significant weight reduction is valid as the improved design does not exhibit porosity or other defects, as shown in the simulation results. Therefore, the improved model effectively reduces material usage while eliminating casting defects.

Conclusion

In summary, this study successfully simulated and enhanced the casting process using a globe valve as a case study and selecting a suitable casting material. By designing the gating and risering systems based on detailed calculations and guidelines, the study ensured effective and defect-free operation. Two gating system designs were proposed: an initial empirical model and a improved model refined through simulation. The casting simulation tool identified potential defects and optimized the process, resulting in several modifications and reducing defects. Consequently, the casting yield improved from 60.43% to 78.08%, a 17.65% increase. This improvement reduces material waste, boosts productivity, and lowers costs, benefiting the manufacturing industry and enhancing customer satisfaction.

Acknowledgement

The authors would like to express their sincere gratitude to Universiti Teknologi MARA (UiTM) for funding the publication of this project.

References

6Wresearch. (2023, June). Malaysia Industrial Valves Market. Retrieved 31 January 2024, from https://www.6wresearch.com/industry-report/malaysia-industrial-valves-market-2020-2026

Altair Inspire Cast. (2023, December 12). Result Types. Retrieved 29 December 2023, from https://help.altair.com/cast/en_us/topics/cast/analysis/result_types_r.htm

Blair, M., & Steven, T. (Eds.). (1995). *Steel Castings Handbook* (Sixth). ASM International.

L. Pandey. (2015). Sand Casting – A Basic Review. *International Journal of Innovative Research in Technology*, *2*(7), 477–483.

Landage, U. S. (2020). Porosity Analysis and Optimization of Casting Process Parameters using Simulation Software for Sand Casting. *International Journal for Research in Applied Science and Engineering Technology*, *8*(11), 182–193. doi:10.22214/ijraset.2020.32101

Volume 6 Issue 18 (September 2024) PP. 75-87
DOI 10.35631/IJIREV.618006
Malaysian Investment Development Authority (MIDA). (2022). Malaysia: Building an Agile, Sustainable and Competitive Oil and Gas Hub. Retrieved 2 July 2024, from https://www.mida.gov.my/wp-content/uploads/2020/12/5.-Oil-_-Gas-SIB-2022-2023.pdf

Manjabacas, M. C., & Miguel, V. (2023). A Methodology to Define the Niyama Criterion Reinforced with the Solid Fraction Analysis: Application to Sand Casting of Steel Bars. *Metals*, *13*(10). doi:10.3390/met13101777

Nazma Sultana, Md. Rafiquzzaman, Younosur Rahman, & Apurba Das. (2018). Solidification and Filling Related Defects Analysis Using Casting Simulation Technique with Experimental Validation. *International Journal of Mechanical Engineering and Applications*, *6*(6), 150–160. doi:10.11648/j.ijmea.20180606.12

Observatory of Economic Complexity (OEC). (2024). Valves in Malaysia. Retrieved 31 January 2024, from https://oec.world/en/profile/bilateral-product/valves/reporter/mys?redirect=true

P. Desai, J. Sohan, L. Vishal, K. Rajat, G. Prasad, & K. Amol. (2019). Use of Casting Simulation for Yield Improvement. *International Research Journal of Engineering and Technology*, *6*(3), 7704–7707.

P. L. Jain. (2003). *Principles of Foundry Technology* (4th ed.). West Patel Nagar, New Delhi: Tata McGraw-Hill.

Qin, S., Lv, P., Li, S., & Li, Y. (2021). *Casting process of gate valve steel based on ProCAST simulation*. In *Journal of Physics: Conference Series* (Vol. 1798). IOP Publishing Ltd. doi:10.1088/1742-6596/1798/1/012013

Sama, S. R., Macdonald, E., Voigt, R., & Manogharan, G. (2019). Measurement of metal velocity in sand casting during mold filling. *Metals*, *9*(10). doi:10.3390/met9101079

Shankar Kamble, B., Mahadik, S., Raosaheb Dhaware, G., Ganesh Mehta, K., & Gundap, D. (2016). Optimization & Experimental Validation of Feeding System for Steel Casting Using Traditional and Simulation Technique-A Case Study. *International Research Journal of Engineering and Technology*, *3*(6), 1684–1689. Retrieved from www.irjet.net

Yekane, & Amar S. (2021). *Casting Yield Improvement Using Modelling and Simulation Technique*. In *Proceedings of I-4AM 2019* (Vol. 1, pp. 89–98). Springer. doi:10.1007/978-981-15-5689-0_9