Jurnal Dinamika Vokasional Teknik Mesin
Vol. 09, No. 2, October 2024, pp. 169-178
https://journal.uny.ac.id/index.php/dynamika/issue/view/77336
ISSN: 2548-7590, DOI: 10.21831/dinamika.v9i2.77336

In-Depth Investigation of Variations in Riser Quantity using Expendable Molds

Obaja Eden Sentosa Riyanto[1], Khansa Farrel J[2], Kyagus Ahmad I.Y.H[3], Wahyu Dwi E.[4], Rafi Akbar[5], Didin Zakariya Lubis[6*]
[1,2,3,4,5,6] Universitas Negeri Malang, Indonesia

Article Info

Article history:

Received Aug 27, 2024
Revised Oct 26, 2024
Accepted Oct 28, 2024
Published Oct 30. 2024

Keywords:

Aluminum
Riser
Sand Casting
Casting

Corresponding Author:

Didin Zakariya Lubis
Faculty of Vocational Studies
Universitas Negeri Malang
55281 Malang, Indonesia
Email: didin.zakariya.ft@um.ac.id

ABSTRACT

This study explores and investigates the impact of the riser quantity on shrinkage and surface quality of two cast products in the sandcasting process. The research was conducted in several stages: preparing the mold and equipment, performing the casting process, investigating shrinkage, and inspecting the products using a macro camera. Experimental results demonstrated that the number of risers significantly influences the final product quality. Specifically, the average shrinkage for molds with one riser was found to be 3.18% and 5.01% for the first and second products, respectively. In comparison to molds with two risers presented decreased shrinkage, with averages of 0.9% and 2.06% for the first and second product, respectively. Additionally, defects investigated and observed in the first product with a single riser mold underscore the importance of riser quantity alongside casting parameters. The findings of this research highlight that increasing the number of risers can enhance casting quality by minimizing shrinkage. improving surface finish. This research presented essential insights for optimizing riser design and quantity for expendable mold in sandcasting technology to achieve superior cast products quality.

INTRODUCTION

The growing industrial sector has a significant demand for repair damaged aluminum. This surge in demand leads to the need for aluminum recycling, enabling the reuse of damaged or scrap aluminum (Wong & Lavoie, 2019). Sand casting is a commonly used method employed to recycle metals, enabling for their subsequent reuse in various scope of application.

Casting, as one of the oldest metal forming methods, involves transforming raw materials into desired shapes (Khan et al., 2016). The quality of the casting products depends on the characteristic of the raw materials used in the casting process (K. Kumar et al., 2019). Therefore, chemical composition of the analysis is a crucial step in the casting process. Through this analysis, we can identify the content of elements that affect the mechanical, physical, and chemical properties of the material. The right composition of raw materials is the foundation for producing casting products with optimal quality and improved material properties (Pangestika, 2017).

One critical factor in producing high-quality casting parts is the meticulous design of the riser system. The overall quality of a casting is significantly affected by the gating system, encompassing the down sprue, runners, and poring conditions, as highlighted in previous research (Majidi & Beckermann, 2019). The riser system plays an essential role in ensuring adequate feeding of molten metal during the solidification process, thereby minimizing defects such as gas porosity, and shrinkage (Perez, 2020). Careful consideration like riser size, location, and cooling rate are essential to optimize the filling of the mold cavity and prevent the internal defects that might happen.

Riser is a critical component of gating system in the casting method, serving as a reservoir to accommodate the excession of molten metal, it also has a role as a feeder to supply additional molten metal to melt for shrinkage during solidification (R. Kumar et al., 2024). A well-designed riser can be effective to prevent defects like shrinkage cavities by directing molten metal to areas experiencing shrinkage. The effectiveness and efficiency of a riser depends on many factors from the casting process, including its size shape, and placement within the mold (Seo et al., 2018). For instance, a cylindrical riser is commonly preferred due to its favorable ratio between its height and diameter, which ensures to maintain a slower cooling rate into the casting (Creese, 2011). Additionally, the use of multiple risers might be necessary to achieve directional solidification, specifically in complex casting design.

Moreover, the design of the riser must account for the specific requirements and material properties of the casting process. For instance, materials with a large freezing range require different riser designs compared to those which have narrow freezing range (Martinez et al., 2023). Proper riser design not only enhances the mechanical properties of the casting, but it also improves overall efficiency of the casting process by reducing the post-casting repairs and additional rework (R. Kumar et al., 2024). Figure 1 illustrates sand-casting mold design with one riser.

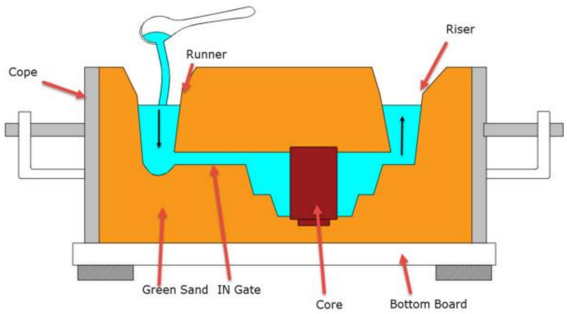

Figure 1. Illustration of sand-casting mold design (Kumar et al, 2024)

Focusing on expandable sand mold casting, this research investigates the effects of varying the number of risers on casting process with the aim of achieving optimal casting quality. By systematically altering the quantity of risers, we seek to identify the optimal configuration that minimizes defects such as porosity, shrinkage, and inclusions, while maximizing mechanical properties. This study will contribute to the development of innovative riser designs and optimized casting process especially for cylindrical parts in various applications.

METHOD

In this study, various tools and materials are used for the casting process. The cast products are analyzed for surface defects which will serve as the basis for conducting this research. The tools and material used in this research include a furnace for melting metal, specifically a crucible type designed for cast iron melting process, fueled by LPG gas. LPG (Liquified Petroleum Gas) consists of propane, an alkaline compound with three carbon atoms with the chemical formula C3H8, which is in a gaseous state under normal environment and conditions. Additionally, the flask is used as a frame or box that holds the sand in place during the mold making process. The top part is called the cope, and the bottom part is commonly called the drag. Flasks are usually created from wood or metal and can be rectangular, round, or hexagonal, depending on the requirements and specification. The geometry of the flask used in this research is 200 mm × 25 mm × 15 mm. The material used in the casting process is aluminum alloy. It is a widely available metal on Earth for its weight and corrosion resistance, therefore it is useful in many industrial applications. However, one of the drawbacks of aluminum is its characteristic which is low strength. Therefore, many studies focus on alloying aluminum with other materials to obtain the desired hardness (Yadav et al., 2024). The step of the casting process is presented on the figure 2 below:

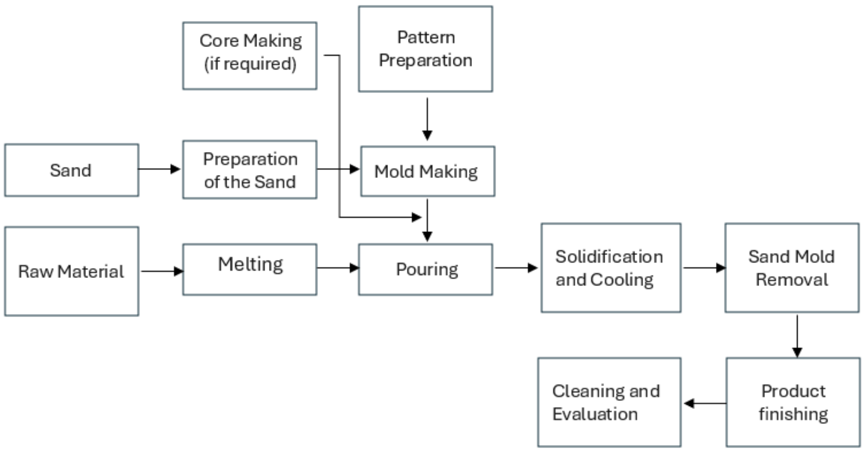

Figure 2. Research Design and Process

The sand-casting process begins with preparing the raw materials, including the sand mixture and the patterns, which are the shape used for this research. If the casting requires internal cavities, a core is made to form those areas. In this research internal cavity is not used. The sand is prepared by sieving, mixing it with binders, and controlling its moisture to ensure the mold will work well. A 15 kg sand mixture was composed of 80% silica sand and 20% bentonite, with the addition of a moisture content which is 600 ml water. The pattern was placed between the drag and cope halves of the mold, which were filled with the sand mixture. The cope half was equipped with a runner and riser system, and reinforcing agents such as carbon powder and lime were added to the sand. Once the sand is ready, it is packed around the pattern to create the cavity of the mold. This step is called mold making process which is done by hand using flask. After the mold is formed, it is inspected to catch any defects or flaws that might impact the product quality. Next, molten metal, heated to an elevated temperature up to 750°C, is poured into the cavity through runner using a preheated ladle to prevent thermal shock. Degassers were added to the furnace after the aluminum had melted completely, with variations of 0.3%, 0.4%, and 0.5%. After the previous step, the metal cools and hardens into the desired shape. Once it has been cooled enough, the expandable mold is broken away, revealing the new casting. The casting then goes through the finishing processes such as grinding and polishing to remove undesired extra material and achieved the desired surface finish. Finally, the casting is inspected based on the objective of this research which is in-depth study of various riser quantity. The details of the results are presented in thetable 1 and 2.

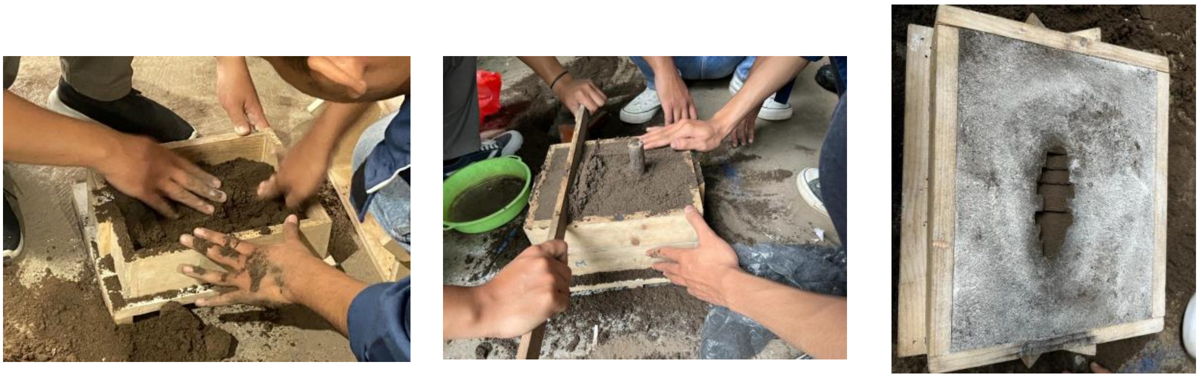

Figure 3. Mold Making Process

RESULTS AND DISCUSSION

This research investigae the role of riser quantity of influencing the product shrinkage through an expandable mold casting. By experimentally varying the number of risers employed in a controlled environment and condition, we sought to uncover the proper riser configuration to minimize and even prevent the casting defects, such as porosity, shrinkage, and hot tears. The previous research performed by Kumar et al showed that the geometry of the risers in casting affected the casting product quality. By performing Taguchi L9 orthogonal array design of experiments, the researchers used mathematical model to optimize riser design, balancing factors such as melting temperature, sand and vent holes. The study discovered that optimizing those parameters significantly improves the mechanical properties of the castings, leading to precise dimensional accuracy, higher production rates, and reduced solidification rate (R. Kumar et al., 2024). This study introduces a novel approach to optimize riser design in sand casting by focusing on the quantity of the risers rather than their geometric parameters. By methodically analyzing how different numbers of risers affect casting quality, material usage, and defect rates this research aims to provide new insight obtaining optimal casting performance. This approach diverges from traditional ways that adjust riser geometry, offering a fresh perspective to enhance the efficiency and effectiveness of the sand-casting process.

Shrinkage of the Casting Products

In this section, the impact of varying riser quantities on shrinkage in sand casting is investigated. Shrinkage is a critical factor in casting quality, as it can lead to defects such as voids and dimensional inaccuracies. By comparing the number of risers in the molds, we aim to identify the optimal configuration that minimizes shrinkage. The collected experimental data provides insights into how different riser quantities influence the solidification and the resultant shrinkage patterns. This analysis is critical to improve the efficiency of the casting and ensure the production of high-quality components. Two types of patterns were investigated which were ashtray pattern and shaft pattern. Figure 4 shows the geometry of the products.

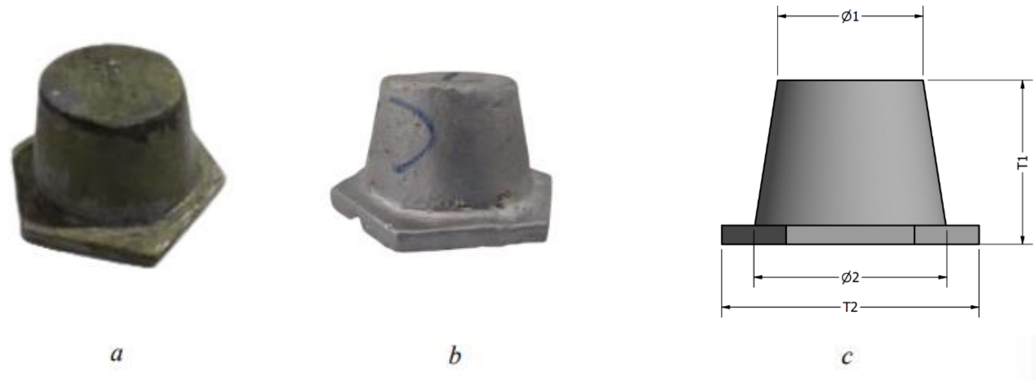

Figure 4. Ashtray pattern (a) Casting Product (b) CAD Design (c)

Table 1. Shrinkage for Ashtray Pattern

Specification	Pattern Dimension (mm)	Finished Cast Product (mm)	Number of Riser	(%) Shrinkage
Ø1	48	46	1	4,1
Ø2	53	52	1	1,8
T1	47	46	1	2,1
T2	63,5	60,5	1	4,7
Ø1	48	47,5	2	1,04
Ø2	53	52,5	2	0.9
T1	47	46,5	2	1,06
T2	63,5	62	2	2,3

Table 2 shows the results for the experimental work for ashtray pattern. The results from the table indicate that the number of risers significantly affects the shrinkage percentage in sand casting. For instance, the specification of Ø1 with a pattern dimension of 63.5 mm and one riser presents a shrinkage of 47% whereas the same specification with two risers shows a reduced shrinkage of 2.3%. This trend is consistent across other specifications, such as T1 and T2, where increasing the number of risers from one to two consistently lowers the shrinkage percentage. Additionally, the pattern dimensions and casting product dimensions reveal slight variations due to shrinkage, emphasizing the importance of the riser quantity to improve the casting quality. Overall, the data highlights that higher number of risers can effectively lower shrinkage and improve the dimensional precision of the cast product.

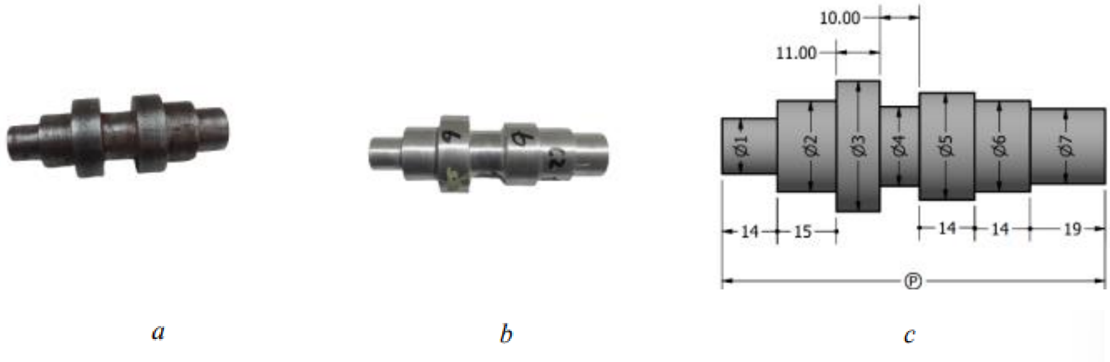

Figure 5. Shaft Pattern (a) Casting Product (b) CAD Design (c)

Table 2. Shrinkage for Shaft Pattern

Specification	Pattern Dimension (mm)	Finished Cast Product (mm)	Number of Riser	(%) Shrinkage
Ø1	17	16	1	5.8
Ø2	24	23	1	4.2
Ø3	37.5	36	1	4
Ø4	23	22.2	1	3.4
Ø5	37.5	33	1	12
Ø6	29	28	1	4
Ø7	21	20	1	4.7
P	100	98	1	2
Ø1	17	16.3	2	4.1
Ø2	24	23.5	2	2
Ø3	37.5	37	2	1.3
Ø4	23	22.5	2	2.1
Ø5	37.5	36.5	2	2.6
Ø6	29	28	2	3.4
Ø7	21	21	2	0
P	100	99	2	1

The presented data on the table shows a detailed comparison of experimental work for shaft patterns. It is observed that the one riser results in higher shrinkage percentages, ranging from 2% up to 12%, with the highest shrinkage occurred in the Ø5 geometry (37,5 mm to 33 mm). In contrast, adding the number of risers consistently reduces shrinkages, bringing it lower to a range of 0% to 4.1%. This significant reduction especially noticeable in smallest and biggest pattern dimension, shows that the use of additional risers enhances the solidification by ensuring better feed the molten metal distribution, thereby reducing defects such as shrinkage and porosity. Additionally, while the pattern dimensions remain constant in both processes, the finished cast product dimensions show slight enhancements in accuracy with two risers, suggesting that improved feeding and cooling rates contribute a promising dimensional stability. These findings highlight the importance of riser design in the casting industry to enhance product quality. Further analysis could be exploring material-specific effects to riser variations, leading to more tailored casting strategies in various industrial applications.

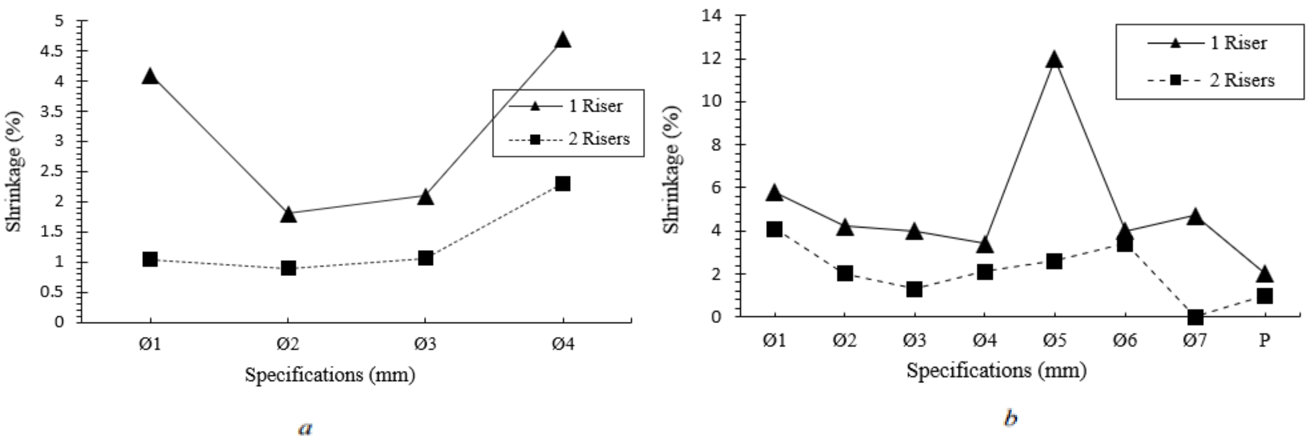

Figure 5. Shrinkage Comparison Graph : Ashtray Product (a) Shaft Product (b)

The figures above show the shrinkage comparison between ashtray product and shaft product. Both graphs consistently present that the design of two risers significantly reduces shrinkage compared to use the one rise. The average shrinkage of the ashtray product for one riser and two risers is 3.18% and 0.9% respectively. The average shrinkage of the shaft product for one riser and two risers is 5.01% and 2.06%, respectively. The trend is evident across different dimension specifications presented before, highlighting the importance of riser design in the sandcasting process. By optimizing the number of risers, manufacturers can get more precise and proper cast products, reducing the tendency of defects and improving overall production efficiency. The macro analysis is presented in the next section to know the surface quality of the cast products.

The quantity and design of risers play a crucial role in managing shrinkage, but they are not the sole factors affecting shrinkage. Other significant variables variable such as chemical composition of the molten metal, the cooling rate, and the overall design of the mold (Alagarsamy & Kumar, 2020). For instance, the gating system and the pouring temperature can significantly influence the effective temperature of the molten metal which in turn affects shrinkage. Additionally, the mold material and its thermal properties influence the solidification and the formation of shrinkage porosity (Liu et al., 2022). In this research, those parameters were determined resulting that the addition of the riser is an effective way to prevent shrinkage.

These insights align with findings from previous studies that the relationship between riser dimensions and shrinkage is crucial. The optimized riser design significantly reduces shrinkage porosity and void formation, ensuring the integrity of both iron and aluminum casting product (Upadhyaya et al., 2024). The number and geometry of riser sleeves significantly influence the shrinkage characteristics of the casting product (Herman et al., 2024). Comparing with the findings of this research, those emphasize the importance of riser in casting technology. By optimizing the design of riser or adding the number of risers could enhance the results. Further analysis could explore both cases by investigating optimum riser design, sleeve design, and the number of risers simultaneously.

Material Defects Study

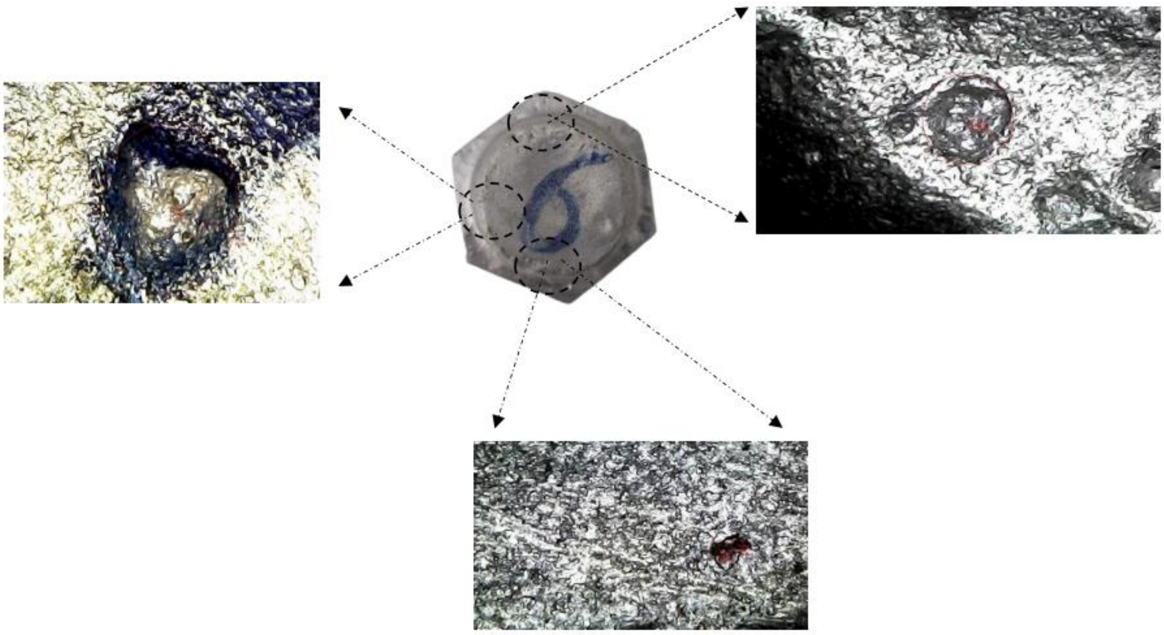

Figure 6. Macro Analysis for Defect in the Specimen

The surface testing using a macro camera was performed to analyze and identify some defects on the metal surface. The cast products quality is good, producing smooth surfaces after the finishing process and meeting the standards. However, in the variation with a single riser on the ashtray pattern product, some surface defects were observed and found. Figure 6 reveals the defects caused by loose sand and the mold pattern was concave and uneven. Figure 6 reveals the defects caused by loose sand and the mold pattern was concave and uneven. Most defects occurred in the bottom surface of the product. The common issues in sand casting are found to be due to several factors such as poor water content control, improper sand mixture, improper mold hardness control, and improper green compression strength (Sertucha & Lacaze, 2022). Based on the findings from Nandagopal et al., the solutions for preventing the defects successfully performed by ensuring the water content in the sand mixture is optimum, optimizing the green compression strength of the sand mold to withstand the forces during the process without breaking or deforming, and maintaining the mold hardness to ensure the mold retains its shape and surface quality (Nandagopal et al., 2021).

The defects occur due to several factors and the behavior depends on the metal material, casting parameters, and mold design and materials, it is possible to result in contrast for different cases. Previous research investigating riser quantity presented that the more quantity of riser increases the shrinkage although the hardness value was improved (Pangestika, 2017). It occurs because the design of the mold, sand mixture, and parameters are different. However, the surface quality is consistent when the number of risers is increased. It improves the product casting quality, good surface finish and improved material properties for the cast product.

CONCLUSION

Based on the experimental work conducted in this research, it can be stated and concluded that the number of risers in sand casting process significantly affects the shrinkage and surface quality of the finished cast products. The average shrinkage for one riser in the first and second product is 3.18% and 5.01% respectively. The average shrinkage for two risers in the first and second product is 0.9% and 2.06% respectively. The defects observed in the first product with one riser mold indicated that in addition to casting parameters, the number of risers also impacts the quality of finished cast products. Overall, increasing the number of risers can improve the casting quality by reducing the shrinkage and providing a high-quality surface finish.

ACKNOWLEDGMENT

This research was fully supported and funded by the faculty of vocational studies, Universitas Negeri Malang.

REFERENCES

Alagarsamy, A., & Kumar, S. (2020). Demystifying Shrinkage Porosity in Ductile Iron Castings. *International Journal of Metalcasting*, *14*(4), 1136–1151. https://doi.org/10.1007/s40962-020-00440-3

Creese, R. C. (2011). Metal Casting Cylindrical Riser Case Study. In R. C. Creese (Ed.), *Geometric Programming for Design and Cost Optimization: (with illustrative case study problems and solutions)* (pp. 27–31). Springer International Publishing. https://doi.org/10.1007/978-3-031-79330-1_7

Herman, A., Kubelková, I., Jarkovský, M., Kopanica, Z., Zeman, J., Břinčil, T., & Kolaříková, M. (2024). Improved Riser Material Efficiency of Massive Steel Casting by Using a New Type of Sleeve. *International Journal of Metalcasting*. https://doi.org/10.1007/s40962-024-01405-6

Khan, M. A. A., Sheikh, A. K., & Al-Shaer, B. S. (2017). Evolution of Metal Casting Technologies—A Historical Perspective. In M. A. A. Khan, A. K. Sheikh, & B. S. Al-Shaer (Eds.), *Evolution of Metal Casting Technologies : A Historical Perspective* (pp. 1–43). Springer International Publishing. https://doi.org/10.1007/978-3-319-46633-0_1

Kumar, K., Kalita, H., Zindani, D., & Davim, J. P. (2019). Casting. In K. Kumar, H. Kalita, D. Zindani, & J. P. Davim (Eds.), *Materials and Manufacturing Processes* (pp. 37–52). Springer International Publishing. https://doi.org/10.1007/978-3-030-21066-3_3

Kumar, R., Maurya, S. K., Choubey, M., Mishra, S. K., Jain, A. K., Sharma, A., Kumar, R., Kumar, I., Saxena, A., & Agrawal, M. (2024). Optimization and empirical studies of riser design in sand casting process using different mould properties. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *18*(5), 3473–3484. https://doi.org/10.1007/s12008-023-01725-7

Liu, Y., Peng, C., Li, W., Zhu, X., Shen, M., Liao, X., Liu, K., Wei, C., Yusuf, Y. A., Yang, J., & Cai, C. (2022). Effect of hollow insulation riser on shrinkage porosity and solidification structure of ingot. *Journal of Iron and Steel Research International*, *29*(12), 1951–1960. https://doi.org/10.1007/s42243-022-00790-8

Majidi, S. H., & Beckermann, C. (2019). Effect of Pouring Conditions and Gating System Design on Air Entrainment During Mold Filling. *International Journal of Metalcasting*, *13*(2), 255–272. https://doi.org/10.1007/s40962-018-0272-x

Martinez, D., King, P., Sama, S. R., Sim, J., Toykoc, H., & Manogharan, G. (2023). Effect of freezing range on reducing casting defects through 3D sand-printed mold designs. *The International Journal of Advanced Manufacturing Technology*, *126*(1), 569–581. https://doi.org/10.1007/s00170-023-11112-x

Nandagopal, M., Sivakumar, K., Sengottuvelan, M., & Velmurugan, S. (2021). Optimization of Process Parameters to Reduce the Green Sand Casting Defects. In G. Kumaresan, N. S. Shanmugam, & V. Dhinakaran (Eds.), *Advances in Materials Research* (pp. 655–661). Springer Nature Singapore.

Pangestika, O. W. (2017). *Pengaruh variasi jumlah riser pada pengecoran aluminium daur ulang dengan cetakan pasir terhadap cacat coran, kekerasan, dan struktur mikro.* Universitas Negeri Semarang.

Perez, N. (2020). Solidification Defects. In N. Perez (Ed.), *Phase Transformation in Metals: Mathematics, Theory and Practice* (pp. 461–518). Springer International Publishing. https://doi.org/10.1007/978-3-030-49168-0_10

Seo, H.-Y., Jin, C.-K., & Kang, C.-G. (2018). Design of a gate system and riser optimization for turbine housing and the experimentation and simulation of a sand casting process. *Advances in Mechanical Engineering*, *10*(8), 1687814018795045. https://doi.org/10.1177/1687814018795045

Sertucha, J., & Lacaze, J. (2022). Casting Defects in Sand-Mold Cast Irons—An Illustrated Review with Emphasis on Spheroidal Graphite Cast Irons. *Metals*, *12*(3). https://doi.org/10.3390/met12030504

Upadhyaya, R., Singh, K. K., Gautam, S. K., Kumar, R., Khandelwal, H., & Sharma, J. D. (2024). Investigation of the Quality of Flywheel SG Iron Sand Casting Using the Optimized Riser Dimensions: Numerical Simulation and Experimental Validation. *International Journal of Metalcasting*. https://doi.org/10.1007/s40962-024-01407-4

Wong, D. S., & Lavoie, P. (2019). Aluminum: Recycling and Environmental Footprint. *JOM*, *71*(9), 2926–2927. https://doi.org/10.1007/s11837-019-03656-9

Yadav, R., Dwivedi, V. K., & Dwivedi, S. P. (2024). Analysis of Mechanical Properties and Manufacturing Process of Aluminum Series. *Journal of The Institution of Engineers (India): Series D*. https://doi.org/10.1007/s40033-024-00750-4