

# Numerical Simulation To Forecast Cast Defects In Pulley During Sandcasting Process

A.SUNANDA<sup>1</sup>, Dr. M. V. JAGANNADHA RAJU<sup>2</sup>

1. Reaserch scholar, Mechanical Engineering, AU College of Engineering, Visakhapatnam & Assistant professor, Mechanical engineering, Sreenidhi Institute of Science and Technology, Hyderabad, Telangana, India.  
email: sunandasathish14@gmail.com .
2. Associate Professor, Mechanical Engineering, AU College of Engineering, Visakhapatnam, Andhra Pradesh, India.  
email: rajumvj@gmail.com .  
DOI: 10.47750/pnr.2023.14.02.106

## Abstract

Casting is one of the most important processes in manufacturing, as it allows for the production of complex parts with intricate shapes. It involves creating intricate patterns and shapes using sand as a medium. Sandcasting has been used to create beautiful artwork, jewelry, and architectural elements. It is a unique way to express creativity and can be used to make stunning pieces of art. The critical issue with the sand casting process is casting defects and unstable casting quality. The pulley's quality characteristics have been affected by casting defects, which leads to a large number of shop floor trails, a high rejection rate, and poor casting performance. Knowledge of casting defects and causes is essential for quality control. Various researchers have stated that 90% of casting defects are obtained only because of the inadequate design of the gating and feeding systems. In this work, creo software was used to create the Solid model of a pulley and the gating system. Using Procast Simulation software, mold filling, and solidification analysis was performed. Medium carbon steel was chosen for its wide variety of automotive applications. The Sand mold was chosen as a mold material, and prediction analysis has been carried out using computer-aided simulation software.

**Key words:** casting defects, simulation, filling analysis, solidification analysis.

## INTRODUCTION

Medium-carbon steels are extensively used for the production of railway tracks, train wheels, crankshafts, gears, and machinery parts due to their extraordinary properties such as higher strength, resistance to wear, and toughness.

Casting is a critical process in manufacturing as it enables the production of complex and intricate parts. It is a process that involves pouring molten metal into a mold or die, which then solidifies and takes the shape of the desired part. Casting has been an integral part of manufacturing for centuries, but with advancements in technology, it is now possible to produce parts with greater accuracy and precision. Casting plays an important role in many industries such as aerospace, automotive, medical, and consumer goods. By using casting methods, manufacturers are able to create components that are more durable and efficient than ever before. Furthermore, casting can be used for both large-scale production runs and small-scale prototyping. This makes it an incredibly versatile tool for any manufacturer looking to improve their products or processes. Most of the defects will occur during the casting process. Identifying the root cause and reduction of these defects is an essential task for the foundries to survive in this competitive environment. Regulated parameters like alloy composition, melting and pouring temperature, gating system, molding, and solidification rate are the only way of zero-defect possibility. In order to suit recent trends, Industries and Foundries need a method to evaluate the process that provides all the details without experimentation. In this work simulation is carried out for the manufacturing of medium carbon steel pulley. Simulation is an effective way for the metal casters to predict various defects and to produce reliable results in a limited period of time. Various casting simulation software such as Procast, Click2Cast, Auto

CAST, ADSTEFAN, and MAGMASOFT, etc. can predict many defects (Shrinkage porosity, Blowholes, Cold-shut, etc.) Casting technology can be optimized based on the simulation results, and the errors can be reduced. One of the sources for casting rejection is shrinkage defect. The effect of metal shrinkage significantly impacts casting efficiency. There is a need for a skilled operator to run the simulation software, and it consists of many processes such as creating the 3D object according to customer requirements using design software, applying boundary conditions, simulation using software, results verification, redesigning the gating system, production. The cost of the material which we used for this process is very low, and the process of sand casting is highly versatile. The role of a skilled operator is to predict the defects and to reduce the defects. If the defects are more, the skilled person redesigns the gating system, and this procedure continues up to the defect vanishes.

## MATERIAL AND METHODOLOGY

The main object of this paper is to simulate the solidification process of the pulley component based on cad and analyze the results and to optimize the gating and risering parameters in order to achieve better sand casting properties. The most important parameter in casting simulation is data collection and to draw the necessary component. The 3D model of the pulley with necessary gating system elements such as riser, runner, and sprue is created using creo modeling software on which five risers are provided. The STL file of the pulley is imported in procast software. After importing it into simulation software to analyze mold filling and solidification first, we have to define processing parameters such as casting material, type of molding method, pouring temperature, pouring time. Medium carbon steel is chosen as a material for pulley casting. The pouring temperature for the molten metal is 1550 °C. Sand molding is used as a molding method. The molding material used for this process is silica sand. The furnace used for melting purposes is an induction furnace having a capacity of 300 kg. The shrinkage defect has occurred after the completion of the simulation process. In order to achieve sound casting, the 3D model of the pulley is modified by increasing the size of the riser, sprue and gating system. Once the simulation process is over, the results can be post-processed to view mold, filling, solidification color-coded temperature profiles. Input parameters for procast simulation is shown in table 1 and the filling parameters is shown in table 2. The procedure to enhance cast design is shown in fig 1. The creo model and the pulley pattern is shown in fig 2 and fig 3. The pouring system and mold was shown in fig 4 & 5. The results of cast defect analysis was shown from fig 6-12.

TABLE 1 INPUT PARAMETERS FOR PROCAST SIMULATION

parameter	Type of mould	condition
material	Green sand mould	Medium carbon steel(1040)
Density	1.5gm/cm <sup>3</sup>	7.845 g/cc
Initial temperature	270C	1550
Liquidus temperature	-----	1498
Solidus temperature	-----	1429

TABLE 2 FILLING PARAMETERS

	Option1	Option2
Fill time	40sec	40 sec
No of risers	5	5
Riser size	62.5*157.5(bottom risers)	75*180(bottom risers)
	62.5*124.5(top riser)	75*147(top riser)
Sprue size	50*170	75*192.5
Pouring type	Gravity pouring	Gravity pouring
Output files	Fluid flow Temperature distribution Solidification Hot spots shrinkage porosity	Fluid flow Temperature distribution Solidification Hot spots shrinkage porosity
Riser type	open	open

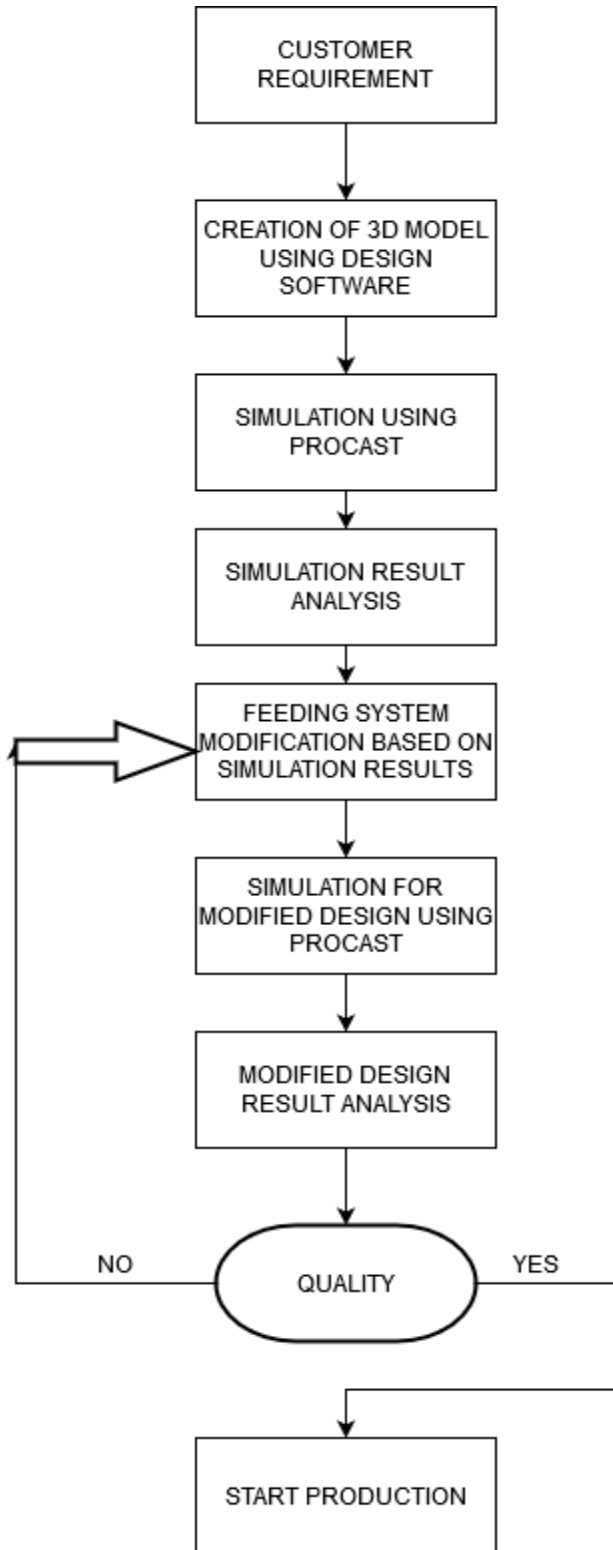


Fig 1: procedure to enhance cast design



Fig 2 : The 3D creo model of pulley



Fig 3 : pulley pattern

A. Simulation using procast software: procast is a casting simulation software developed by the ESI group, France. This was used to simulate fluid flow, solidification of the sand casting of the pulley. In order to predict the molten metal behavior within the mould, casting simulation and result analysis were carried out.

The sequence of steps involved in the simulation process is preprocessing, main processing, and post- processing.

Preprocessing: Importing the cad geometry into simulation software, the program reads cad geometry and generates the mesh. AISI 1040 material is applied for the pulley. The cad geometry with the pouring system is shown in the below fig.

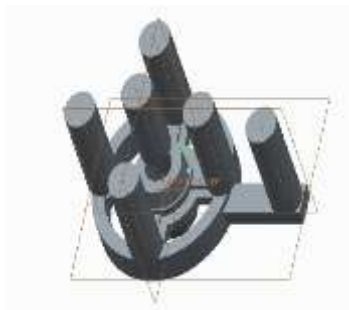


Fig 4 : The pouring system of pulley

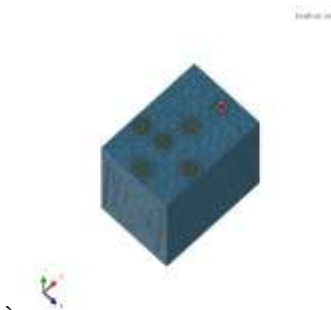


Fig 5 : mold of the pulley

Main processing: The next step after preprocessing is the main processing. Main processing includes the addition of boundary conditions and material data, filling, and temperature calculations. In this stage, initially, the mesh size is defined as 5. Processing time depends on so many variables such as mesh size, dimensions of casting and mold, the configuration of the computer, and processing time.

Post- processing: presentation and evaluation come under the category of post- processing. The results are post-processed to judge the color-coded temperature profiles of mold, filling, and solidification, velocity vectors or residual stresses.

B. Defect analysis: Analysis of casting defects is the method of determining the root cause of the Incidence of defects in casting rejection and taking the necessary steps to reduce the defects. There are several parameters in casting processes that operate at different levels that can cause casting defects. Several causes have been identified under different categories for each form of defect, such as design, molding, and parameters related to pouring/melting.

## RESULTS AND DISCUSSIONS

The method of casting molding involves the process of cast filling and the process of cast solidification. The cast filling method is one in which a more-temperature fluid fills a casting cavity through the gate gradually. Cast Solidification is a heat exchange

process that is very important to prevent defects due to shrinkage. The solidification process begins when the molten metal is poured in the sand mold. Three successive stages are involved in the process first stage is cooling the liquid metal, the second stage is solidification, and finally, the third stage is cooling the solid metal. The cast temperature field during solidification is shown in the below diagram. The solidification, temperature field, hot spots and shrinkage porosity of the pulley is shown in the below figure . The temperature in the central region is 1346 to 1448 0 C, which is very high after solidification. The higher temperature region is largely found in the central portion of the pulley. Hot spots are formed more in the central region of the pulley. Shrinkage porosity at various locations of the component is reduced by increasing the diameters and height of the risers and sprue and ingate. Imperfections formed during the casting process are closely associated with the factors of molten metal pouring and gating system design. Shrinkage of the metal is one more reason for the formation of those imperfections.



Fig 6: Temperature contour of pulley in option1



Fig 7: Temperature contour of a pulley in option2



Fig 8 : solid- phase change in option1



Fig 9 : solid- phase change in option2



Fig 10 :Hotspots formed in option1

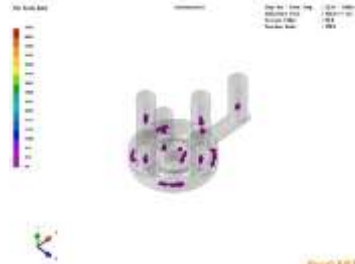


Fig 11 :Hotspots formed in option2



Fig 12 : shrinkage porosity in option1

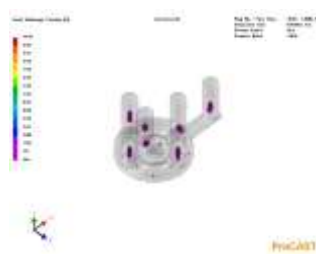


Fig 13 : shrinkage porosity in option2

## CONCLUSIONS

Computer-aided casting and simulation packages, which involve virtual processes, can replace trial and error-based experimental casting procedures. The simulation tool has the flexibility to evaluate and visualize mold filling and solidification processes in a color bar, to identify critical positions, and to identify casting defects such as micro porosities and shrinkage porosities. Through numerical simulation, the sand mould casting process of the pulley with a complex structure is deeply analyzed. The following conclusions can be made.

1. The defects caused at the center of the casting are due to air entrapment, insufficient feeding, and non-sequential solidification.
2. The simulation of casting solidification can be used effectively to reduce casting defects.
3. The casting shrinkage can be predicted exactly with the use of simulation software.

## REFERENCES

- [1]. Barot, R. P., & Ayar, V. S. (2020). Casting simulation and defect identification of geometry varied plates with experimental validation. *Materials Today: Proceedings*, 26, 2754–2762. <https://doi.org/10.1016/j.matpr.2020.02.575>
- [2]. Dou, K., Lordan, E., Zhang, Y. J., Jacot, A., & Fan, Z. Y. (2019). Numerical simulation of fluid flow, solidification and defects in high pressure die casting (HPDC) process. *IOP Conference Series: Materials Science and Engineering*, 529, 012058. <https://doi.org/10.1088/1757-899x/529/1/012058>
- [3]. Dubey, S., & Swain, S. R. (2019). Numerical investigation on solidification in casting using ProCAST. *IOP Conference Series: Materials Science and Engineering*, 561, 012049. <https://doi.org/10.1088/1757-899x/561/1/012049>
- [4]. Gao, Y., Sun, S., & Jin, H. (2019). Casting simulation of cast steel joint based on Pro-CAST. *IOP Conference Series: Materials Science and Engineering*, 592, 012086. <https://doi.org/10.1088/1757-899x/592/1/012086>
- [5]. Guo, E. J., Zhao, S. C., Wang, L. P., Wu, T., Xin, B. P., Tan, J. J., & Jia, H. L. (2016). Numerical simulation of casting process to assist in defects reduction in complex steel tidal power component. *IOP Conference Series: Materials Science and Engineering*, 117, 012037. <https://doi.org/10.1088/1757-899x/117/1/012037>
- [6]. Kabnure, B. B., Shinde, V. D., & Patil, D. C. (2020). Quality and yield improvement of ductile iron casting by simulation technique. *Materials Today: Proceedings*, 27, 111–116. <https://doi.org/10.1016/j.matpr.2019.09.022>
- [7]. Liu, J.-, Yang, L., Fang, X.-, Li, B., Yang, Y.-, Fang, L.-, & Hu, Z.-. (2020a). Numerical simulation and optimization of shell mould casting process for leaf spring bracket. *China Foundry*, 17(1), 35–41. <https://doi.org/10.1007/s41230-020-9089-3>
- [8]. Malik, I., Anwar Sani, A., & Medi, A. (2020). Study on using Casting Simulation Software for Design and Analysis of Riser Shapes in a Solidifying Casting Component. *Journal of Physics: Conference Series*, 1500, 012036. <https://doi.org/10.1088/1742-6596/1500/1/012036>
- [9]. Nimbalkar, S. L., & Dalu, R. S. (2016). Design optimization of gating and feeding system through simulation technique for sand casting of wear plate. *Perspectives in Science*, 8, 39–42. <https://doi.org/10.1016/j.pisc.2016.03.001>
- [10]. Xiong, J. J., Meng, F. L., Liang, Q. J., & Cao, C. (2019). Casting Process Design and Simulation of Large Cast Steel Bracket. *Key Engineering Materials*, 815, 125–130. <https://doi.org/10.4028/www.scientific.net/kem.815.125>