CCET JOURNAL OF SCIENCE AND ENGINEERING EDUCATION

ISSN(Print):2582-0680 ;ISSN(Online):2455-5061 *Vol. –6, Page-28-33 Year-2022*

# USE OF SIMULATION TECHNIQUES IN ENHANCEMENT OF THE QUALITY AND PRODUCTIVITY OF DUCTILE IRON CASTINGS

**Sumit Mathur*, Srinivasa Rao Pulivarti**, R H Gajghat*****

**Mechanical Engineer, Quality check Department, RITES Limited, C.G, India,* ***matsumit@gmail.com***
*****Professor, Mechanical Engineering, CCET, Chhattisgarh, India,* ***srinivas.indore@gmail.com***
*******Professor, Mechanical Engineering, CCET, C.G, India,* ***radhegaj@gmail.com***

**Abstract**

*Production of sound casting, on the other hand, necessitates a full understanding of the entire casting process. However, faults and casting rejections continue to be commonplace because, in most cases, the designer lacks domain knowledge about casting processes and does not have a technique for determining the parameters that result in sound casting. Casting simulation software simulates the way casting engineers make decisions about the casting process in a virtual environment. It also analyses each decision to identify design modifications that can be made to improve the quality of the casting while also reducing lead time, tooling, and manufacturing costs, among other benefits. Because of the use of simulation software, we can confidently state, "Get it right the first time and every time." Simulation software can be extremely useful in calculating time-consuming formulas, constructing solid models that will be useful in visualising the actual situation such as core/mould assembly, gating and feeding arrangements with the main casting before going into actual practise, and calculating the results of test. A number of different methods of casting simulation are used, including the finite element method (FEM), the finite difference method (FDM), and the finite volume method (FVM). Using the finite difference method (FDM) and the finite volume method (FVM), an attempt has been made to review simulate casting solidification and optimise the casting gating system in order to achieve the highest possible yield in this research article.*

***Index Terms:*** *Ductile iron, Casting modelling, Simulation, Optimization of gating system, Yield optimization.*

## 1. INTRODUCTION

Foundries play an important role in the manufacture of crucial automobile components. These foundries are currently suffering from low quality and productivity as a result of a variety of elements in the manufacturing process. The quality of the cast is determined by the process of solidification that occurs after the pouring. Construction and improvement of equipment, as well as the use of computerised casting modelling and solidification simulation, are becoming increasingly popular among foundries in order to better design the casting process for the production of castings before castings are prepared or before equipment is constructed or improved [1]. The primary goal of employing computerised casting modelling and solidification simulation is to improve the quality of the casting formed, both in already produced castings and in first-time castings, while simultaneously lowering the cost of the casting manufactured. Casting solidification simulation may be used to minimise the number of shop floor trials while also ensuring that no defects are present in the castings [2].

### 1.1 Background

The first metal that was melted by main was copper and then bronze, an alloy of copper. No definite period can be given for the advent of copper age, which overlapped with that of the stone age of human pre-history. The period between 8000 and 3000 B.C. is called the Mesolithic period of history and was marked by events that greatly stimulated human progress [3]. Bronze, which has greatly superior strength properties in the as-cast condition, generally replaced copper around 3000 B.C, and the age is known as bronze age Which lasted up to 1200 B.C. and then the age of iron began. Cast iron began to be melted around 200 B.C. but at that stage it was regarded as a gem and mainly used for ornaments.

### 1.2History of Foundry

History of iron making in India is still obscure and no definite data are still available. While wrought iron worked by hammering was known well before 1000 B.C. the evidence of use of iron casting is only available from 1000 B.C. Thus, iron castings came into regular use only after Alexander's invasion of India around 300 B.C. Well known Iron Pillar near Qutab Minar in Delhi is made from wrought iron which was given shape by forging. In India iron casting age may be said to have started around 200 B.C.

### The Ductile Iron

It was originally known as spheroidal-graphite (SG) cast iron or nodular iron, but it is now referred to as ductile iron, which is the worldwide nomenclature for the material [4]. It is a kind of cast iron in which graphite is observed in the microstructure as spheres (nodules). During solidification of the ductile iron, eutectic graphite segregates from the molten iron in a manner that is comparable to the method in which eutectic graphite segregates from grey cast iron. Although the graphite develops as spheres in preference to as flakes or any other form characteristic of grey iron, this is due to the addition of chemicals to the molten iron prior to casting. Compared to grey iron or malleable iron, spheroidal graphite-containing cast iron is significantly stronger and has more elongation [5]. It may be thought of as a natural composite in which the spheroidal graphite lends unique features to ductile iron, with the ductile iron serving as the matrix.

The invention of Ductile Iron was first documented in 1948. Due to a decade of active research and development in the 1950s, ductile iron had a tremendous surge in use as an engineering material throughout the 1960s, and the quick increase in commercial application has continued to this day. Ductile iron has been used as a technologically valuable material for a number of years and is still in use today [6]. However, although many researchers have evaluated its mechanical performance under a variety of settings, others have sought to understand its solidification behaviour and the several variables that must be considered in order to produce a product that is acceptable. We are still at a loss to explain how a flake-like graphite form evolves into the spheroidal morphology that gives ductile iron its better qualities, even after more than a decade of research. Because the graphite in ductile iron occurs as spheroids rather than flakes, as it does in grey iron, an uncommon mix of qualities may be achieved by using it. It is possible to achieve this kind of solidification by adding a very small but specified quantity of Mg or Ce or both to molten iron with the appropriate composition [7]. The base iron is closely regulated in the amount of certain minor components that can interfere with the production of graphite spheroid that can be present in the base iron. The magnesium that has been added interacts with the Sulphur and oxygen in the molten iron, altering the way graphite is produced. Control techniques have been created in order to improve the efficiency with which ductile iron is processed. Because of the high carbon and silicon content of ductile iron, the casting method has a number of advantages, although the graphite spheroids have only a little impact on the metal's mechanical qualities. Malleable iron has a linear stress-strain relationship and a wide range of yield strengths, making it a versatile material [8].

## 2. COMPUTER-AIDED CASTING METHOD DESIGN

Cast irons are essentially alloys of iron and carbon, similar to steels, but with a higher percentage of carbon content. Carbon content varies between 2.67 percent and 6.67 percent in cast iron. The presence of high carbon content in cast iron makes it brittle, and the majority of commercially made varieties contain between 2.5 and 4% carbon by weight. Cast iron has a low ductility and is therefore difficult to work with. They are easy to work with and can be cast into a variety of shapes. Because casting is the only procedure that can be used to apply these alloys, they are referred to as cast irons. The qualities of any form of cast iron can be adjusted over a wide range by using adequate alloying, efficient foundry control, and appropriate heat treatment. The shape distribution of the free carbon particles in the cast iron will have a significant impact on the physical qualities of the cast iron. Cast irons are brittle and have lesser strength qualities than steels, but they can be cast more quickly than most steels and are therefore more widely used. Cast irons are classified into several types, including white cast iron, malleable cast iron, grey cast iron, nodular cast iron, and alloyed cast iron [10].

### 2.1 Simulation in Casting Process

Simulation is the process of simulating a real-world phenomenon through the application of mathematical equations. Metal casting is a manufacturing method in which molten metal is poured into a mould cavity that has been designed and built to the desired shape and size before being allowed to solidify. Naturally, metal casting simulation is a very complex phenomenon that involves the flow of fluid, the transfer of heat between the mould and the molten metal, and many other variables and processes. When it comes to the development of precise simulation software, it is sometimes remarked that it is a 'rocket science for rocket scientists'. The manufacturing process of metal casting involves a large number of variables that must be controlled in order for it to be successful. As a result, the key to developing a realistic and useful casting simulation programme is to identify the most critical parameters that are associated with it. Several researchers have been working diligently for several decades to discover the same thing. Geometry, material, and procedure are three of the most important influencing elements in the process of casting metal.

AutoCAST, MAGMASoft, ProCAST, SOLIDCast, CAP/WRAFTS, CastCAE, Cast flow, Castherm, JSCast, MAVIS, Nova-Solid/Flow, PAM-CAST, RAPID/CAST, and SIMTEC are some of the prominent casting simulation software packages accessible to foundry engineers. For the purpose of solving the corresponding differential equations, this simulation software typically employs one of the numerical techniques listed below: Finite Differences Method (FDM), Finite Volumes Method (FVM), Finite Element Method (FEM), and Vector Element Method (VEM), among others. SOLID CAST, OPTI CAST and FLOW CAST are based on the FEM technique, whereas QuikCAST is built on the FDM technique and AutoCAST is built on the VEM technique. ProCAST, SOLID CAST, OPTI CAST and FLOW CAST are based on the FDM technique. When the input parameters are close to the real-world values as it is possible, it is easy to see why the simulation software will work well if and only if these parameters are used. The thermo-physical properties of the cast metal and the mould, as well as the interface boundary conditions, are the most significant input variables for this type of simulation programme. These numbers, on the other hand, are temperature dependant. As a result, obtaining values

CCET JOURNAL OF SCIENCE AND ENGINEERING EDUCATION
ISSN(Print):2582-0680;ISSN(Online):2455-5061 *Vol. – 6, Page-28-33, Year-2022*

for various metal-mould-process combinations is a time-consuming and complex endeavour. As a result, the results of simulation software may differ from what is observed in real life.

### 2.2 A brief discussion on previous work

As previously stated, if the CAD model, FEM mesh, material properties, and boundary conditions are all perfect, simulation software produces dependable and precise results (otherwise: garbage in, garbage out). Most of the time, material characteristics and boundary conditions data must be determined and fine-tuned through experimental investigation. As a result, this process could take several weeks, which is far beyond the capabilities of most enterprises. Engineering students and graduates with advanced degrees, CAD/CAM experience, and casting design skills are required to participate in simulation programmes and interpret the results correctly.

Figure 1 depicts a schematic representation of the preparation mechanism employed by a manufacturing company for the preparation of several wedge blocks. The product that is currently being manufactured using the existing method design has a defect caused by shrinkage. The outcome of the simulation confirms this as well. Figure. 2 depicts the shrinkage defect and the simulation result that was obtained as a result of it. For this reason, as illustrated in Figure 3, stack moulding is used to eradicate the flaw while also improving the entire process involved with the creation of the product. The techno-economic analysis of wedge casting per tonne demonstrates that using a stack moulding strategy, the cost per piece decreases while the productivity increases.

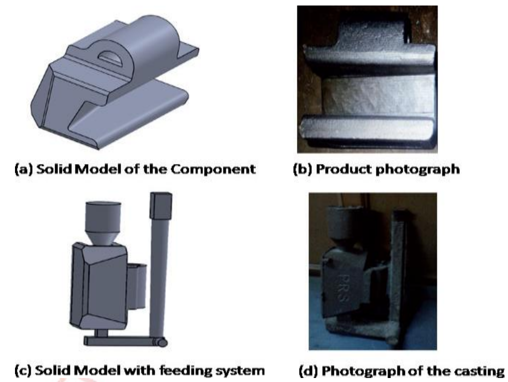


**Fig-1:Scheme of wedge block preparation**

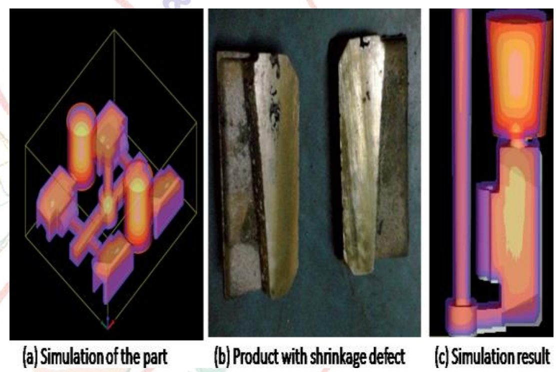


**Fig.-2: Product with shrinkage defect and linked simulation**

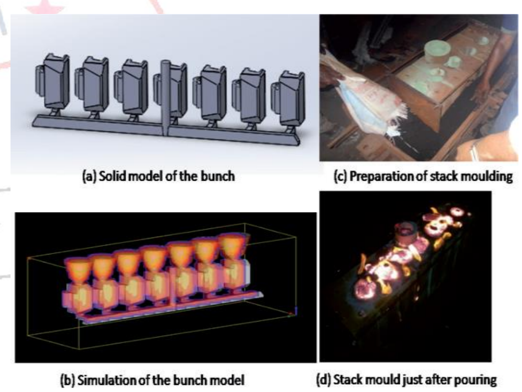


**Fig.-3: Scheme to indicate the modification done**

A train is formed by the joining of coaches through the use of couplings. Screw couplings were commonly utilised in the past. Screw coupling has some intrinsic restrictions, such as the inability to haul longer trains in freight, the inability to ascend coaches in wrecks and derailments, the risk to the life of shunting personnel, and the demand for a larger number of maintenance personnel. On the other hand, central buffer coupling (CBC) has several advantages, including the fact that the coupling is safe for shunting staff, that less time is required due to the possibility of quick detachment, that less staff is required for uncoupling, and that the coaches do not climb on each other during an accident, thereby preventing damage to life and property.

The CBC is made up of three major parts: the knuckle, the coupler body, and the yoke. The CBC is a result of a casting process. In this case study, the application of casting simulation software to a CBC product is presented using real-world data. The simulation software is capable of identifying the loopholes in the existing design, and the caveats can be ironed out through the use of appropriate methodology. Final simulation results reveal that there are very few deleterious defects in the cast part, resulting in a significant reduction in the amount of money spent on trial and error.

The solid modelling software is used to build the 3D CAD model, which is then translated to the .STL format. The Z-CAST simulation programme reads the .STL file that was imported. Pouring temperature is assumed to be 1610 °C, and pouring time is assumed to be 30 seconds. Exothermic sleeves are employed in this instance, and the mould temperature is assumed to be 30°C before to the pouring of molten metal into the mould. The material's shrinkage tolerance is also taken into consideration, and it is 3.5 percent.

## 3. CONCLUSION

The method layout of a casting is an important aspect of tooling development. It involves decisions regarding part orientation in mold, parting line, cores, cavity layout, feeders, feed aids and gating system. An improper method layout leads to either poor quality or low yield, affecting manufacturing costs and productivity.

Casting simulation can overcome the above problems: virtual trials do not involve wastage of material, energy and labour, and do not hold up regular production. However, most of the simulation programs available today are not easy-to-use, take as much time as real trials, and their accuracy is affected by material properties and boundary conditions specified by the user. The biggest problem is the preparation of 3D model of the casting along with mold, cores, feeders, gating, etc., which requires CAD skills and takes considerable time for even simple castings

.

## ACKNOWLEDGEMENT

The authors acknowledge the support of CCET Bhilai.

## REFERENCES

[1]. J. O. Choi, J. Y. Kim, C. O. Choi, J. K. Kim, and P. K. Rohatgi, "Effect of rar earth element on microstructure formation and mechanical properties of thin wall ductile iron castings," Mater. Sci. Eng. A, vol. 383, no. 2, pp. 323–333, 2004, doi: 10.1016/j.msea.2004.04.060.

[2]. W. Xu, M. Ferry, and Y. Wang, "Influence of alloying elements on as-cast microstructure and strength of

gray iron," Mater. Sci. Eng. A, vol. 390, no. 1–2, pp. 326–333, 2005, doi: 10.1016/j.msea.2004.08.030.

[3]. K. M. Pedersen and N. S. Tiedje, "Graphite nodule count and size distribution in thin-walled ductile cast iron," Mater. Charact., vol. 59, no. 8, pp. 1111–1121, 2008, doi: 10.1016/j.matchar.2007.09.001.

[4]. K. Herfurth and S. Scharf, "Casting," Springer Handbooks, pp. 325–356, 2021, doi: 10.1007/978-3-030-47035-7_10.

[5]. T. Willidal, W. Bauer, and P. Schumacher, "Stress/strain behaviour and fatigue limit of grey cast iron," Mater. Sci. Eng. A, vol. 413–414, pp. 578–582, 2005, doi: 10.1016/j.msea.2005.08.200.

[6]. R. Salazar F., M. Herrera-Trejo, M. Castro, J. Méndez N., J. Torres T., and M. Méndez N., "Effect of nodule count and cooling rate on as-cast matrix of a Cu-Mo spheroidal graphite," J. Mater. Eng. Perform., vol. 8, no. 3, pp. 325–329, 1999, doi: 10.1361/105994999770346873.

[7]. T. Skaland, "Developments in Cast Iron Metallurgical Treatments," pp. 1–29, 2001.

[8]. D. White, "Avoiding Shrinkage Defects and Maximizing Yield in Ductile Iron," Trans. Am. Foundry Soc., vol. 120, no. 12–081, pp. 389–398, 2012.

[9]. Z. IGNASZAK, "The Risk of Ductile Iron Post-inoculation for Heavy Section Castings," Mater. Sci., vol. 9, no. 3, pp. 245–249, 2003.

[10]. S. Bočkus, A. Venckunas, and G. Žaldarys, "Relation between section thickness, microstructure and mechanical properties of ductile iron castings," Medziagotyra, vol. 14, no. 2, pp. 115–118, 2008.