EXPERIMENTAL ANALYSIS OF ALUMINIUM 7075 CASTING USING COMPUTER AIDED CASTINGS SIMULATION

A Project report submitted in partial fulfillment of the requirement for the award of the degree of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

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2018

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ACKNOWLEDGEMENT

We express immensely our deep sense of gratitude to **Mrs. B. KRISHNA PRAFULLA**, Assistant Professor, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences for his valuable guidance and encouragement at every stage of work for the successful fulfillment of students.

We were very thankful to **Prof.T.V.HanumanthaRao**, Principal and **Prof.B.Nagaraju,** Head of the Department, Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences for their valuable support and facilities.

We express our sincere thanks to **Mr.J.V.Bhanu Tej**, Assistant Professor, Department of Mechanical Engineering, Anil Neerukonda Institute of Technology & Sciences for his valuable suggestions throughout the project.

We express our sincere thanks to the non-teaching staff of Mechanical Engineering for their kind co-operation and support to carry on work.

Last but not the least, we like to convey our thanks to all who have contributed directly or indirectly for the completion of this project work.

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ABSTRACT

In the present days the manufacturers are facing the challenges in attaining the high productivity, quality and overall economy in the field of manufacturing by casting. Among all the casting processes available sand casting is a major and common casting technique and it used because it is an inexpensive and process is relatively simple. Sand casting is often utilized in industries to make parts that are comprised of iron, bronze, brass and at times Aluminium is used because of the cost effectiveness and it is good to recycle the used materials. However, flaws are common in sand cast parts and these flaws can affect the properties of the cast materials. In this thesis, we use click2cast simulation software to optimize the defects in sand casting. Click2cast helps users avoid typical casting defects such as air entrapment, porosity, cold shuts, etc. It is used to study of solidification behaviour and flow analysis in aluminium 7075 alloy castings in green sand mold. The solidification behavior analyzed experimentally by measuring temperature during solidification through riser cavity using infrared thermometer and results are analyzed and represented the process graphically. Based on the results simulation and necessary steps are taken to avoid defects like regulating pressure in mold cavity by providing vent holes and uniform pouring rate .

Keywords: Aluminium 7075, Solidification, Casting, Hardness, Microstucture, Filling, Mold, Defects.

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Chapter 1

INTRODUCTION

1.1 METAL CASTING

Metal casting is a versatile manufacturing process and one of the earliest metals shaping method known to human beings. It generally means pouring molten metal into a refractory mold with a cavity of the shape to be made and allowing it to solidify. When solidified, the desired metal object is taken out from the refractory mold either by breaking the mold or by taking apart. The solidified object is called casting. Fig 1.1 depicts casting process in foundry. Casting can produce products from few grams to several hundred tons and from simple shapes like watch cases to most complex parts like engine blocks. Almost any metal or alloy which can be easily melted is castable. Casting has many process variations depending upon the material, the type of pattern, mold and the pouring technique like sand casting, investment casting, die casting, squeeze casting and lost foam casting. Sand casting is the most widely used process which can be used to produce intricate parts in almost every metal that can be melted. According to worldwide census of casting production over 75 million metric tons of castings are produced annually. India is the fourth largest producer of castings. For successful production of castings one needs knowledge in preparation of molds and patterns, melting and pouring of liquefied metal, solidification and further cooling to room temperature, inspection and quality control. Because of the complex physics involved and the number of steps needed to produce a casting, the parameters which govern the quality of a casting are huge in number. The major sources of defects arise from inappropriate design of the part, feeding and gating system.

Fig 1.1 Metal casting process in foundry

1.2 SELECTION OF CASTING METHOD

With the development of industry techniques, the metal casting techniques also develop faster and faster,there is a lot of metal casting techniques appearance,but the standards,quality,accuracy,production cost and automation of metal castings are increasing, so to choose a suitable casting method is very important. The process of metal casting includes metal melting molds producing, pouring concretion and de-molds clearance, machining and so on. Sand metal casting is put to use as a priority. During metal casting producing, 60%-70% of metal castings are produced by sand metal casting method as the reasons are the low cost, the simple production process and the short production period, so the engine air cylinders, air cylinder lids and bent axis of automobiles are produced by green sand molds.

1.3 SAND CASTING

Sand casting is also known as sand molded casting, is a metal casting process characterized by using sand as the mold material. The term "sand casting" can also refer to an object produced via the sand casting process. Sand castings are produced in specialized factories called foundries. Over 70% of all metal castings are produced via a sand casting process.

Sand casting is relatively cheap and sufficiently refractory even for steel foundry use. In addition to the sand, a suitable bonding agent (usually clay) is mixed or occurs with the sand. The mixture is moistened, typically with water, but sometimes with other substances to develop strength and plasticity of the clay and to make the aggregate suitable for molding. The sand is typically contained in a system of frames or mold boxes known as flask. The mold cavities and gate system are created by compacting the sand around models, or patterns, or carved directly into the sand. Fig 1.2 depicts the sand casting process in foundry.

Fig 1.2 Sand casting process in foundry

Sand casting is one of the most popular and simplest types of casting and has been used for centuries. Sand casting used for smaller batches rather than permanent mold casting and at a very reasonable cost. Not only does this method allow manufacturers to create products at a low cost, but there are other benefits to sand casting, such as very small size operations. From castings that fit in the palm of your hand to train beds (one casting can create the entire bed for one rail car), it can all be done with sand casting. Sand casting also allows most metals to be cast depending on the type of sand used for the molds.

Sand casting requires a lead time of days, or even weeks sometimes, for production at high output rates and is unsurpassed for large part production. Green sand has almost no part weight limit, whereas dry sand has a practical part mass limit of 2300-2700 kg minimum part weight ranges from 0.0075-1 kg. The sand is bonded together using clays, chemical binders and polymerized oils. Sand can be recycled many times in most operations and requires little maintenance.

1.3.1 ADVANTAGES & DISADVANTAGES IN SAND CASTING

Advantages	Disadvantages
Ferrous and non - ferrous metals may be cast	Dimensional accuracy inferior to other processes.
Possible to cast very large parts.	Castings usually exceed calculated weight
Least expensive tooling	Poor material strength
Scrap can be recycled	High porosity possible
Short lead time possible	

Table 1.1 Advantages and disadvantages of sand casting

1.3.2 APPLICATIONS OF SAND CASTING

Sand casting is extensively used for cast iron and steel parts of medium and large size where surface smoothness and dimensional precision are the main concerns. Sand casting is also used to make large parts in material like bronze, brass, aluminium. Sand casting is used to produce a wide variety of metal components with complex geometries. These parts can vary greatly in size and weight, ranging from a couple ounces to several tons. Some smaller sand cast parts include components as gears, pulleys, crankshafts, connecting rods, and propellers as shown in fig 1.3. Larger applications include housings for large equipment and heavy machine bases. Sand casting is also common in producing automobile components, such as engine blocks, engine manifolds, cylinder heads, and transmission cases.

Fig 1.3 Applications of sand casting

1.4 TERMINOLOGY USED IN SAND CASTING

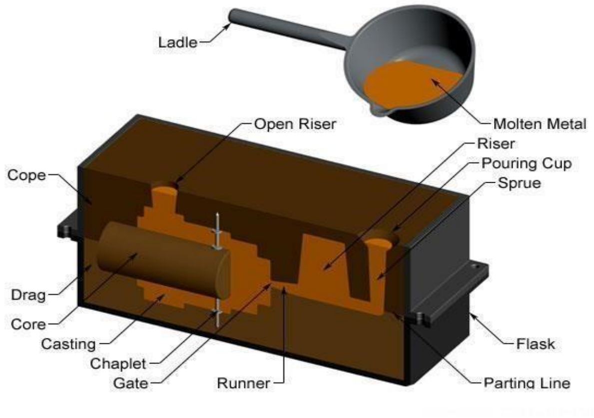


Fig 1.4 Overview of sand casting process

- **Flask**: A metal or wood frame, without fixed top or bottom, in which the mold is formed. Depending upon the position of the flask in the molding structure, it is referred to by various names such as **drag** – lower molding flask, **cope** – upper molding flask, **cheek** – intermediate molding flask used in three piece molding.
- **Pattern**: It is the replica of the final object to be made. The mold cavity is made with the help of pattern.
- **Parting line**: This is the dividing line between the two molding flasks that makes up the mold.
- **Molding sand**: Sand, which binds strongly without losing its permeability to air or gases. It is a mixture of silica sand, clay, and moisture in appropriate proportions.
- **Facing sand**: The small amount of carbonaceous material sprinkled on the inner surface of the mold cavity to give a better surface finish to the castings.
- **Core**: A separate part of the mold, made of sand and generally baked, which is used to create openings and various shaped cavities in the castings.
- **Pouring basin**: A small funnel shaped cavity at the top of the mold into which the molten metal is poured.
- **Sprue**: The passage through which the molten metal, from the pouring basin, reaches the mold cavity. In many cases it controls the flow of metal into the mold.
- **Runner**: The channel through which the molten metal is carried from the sprue to the gate.
- **Riser**: A column of molten metal placed in the mold to feed the castings as it shrinks and solidifies. Also known as "feed head".
- **Vent**: Small opening in the mold to facilitate escape of air and gases.
- **Chills**: Chills are metallic objects, which are placed in the mold to increase the cooling rate of castings, to provide uniform or desired cooling rate.

1.5 CASTING SIMULATION

Casting process simulation uses numerical methods to calculate cast component quality considering mold filling, solidification and cooling, and provides a quantitative prediction of casting mechanical properties, thermal stresses and distortion. Simulation accurately describes a cast component's quality up-front before production starts. The casting rigging can be designed with respect to the required component properties. This has benefits beyond a reduction in pre-production sampling, as the precise layout of the complete casting system also leads to energy, material, and tooling savings. The software supports the user in component design, the determination of melting practice and casting methoding through to pattern and mold making, heat treatment, and finishing. This saves costs along the entire casting manufacturing route.

Use of this casting simulation will keep casting producers competitive & profitable. In the sense they can provide precise& quick response to customer needs. Fig 1.5 depicts the sample simulation process.

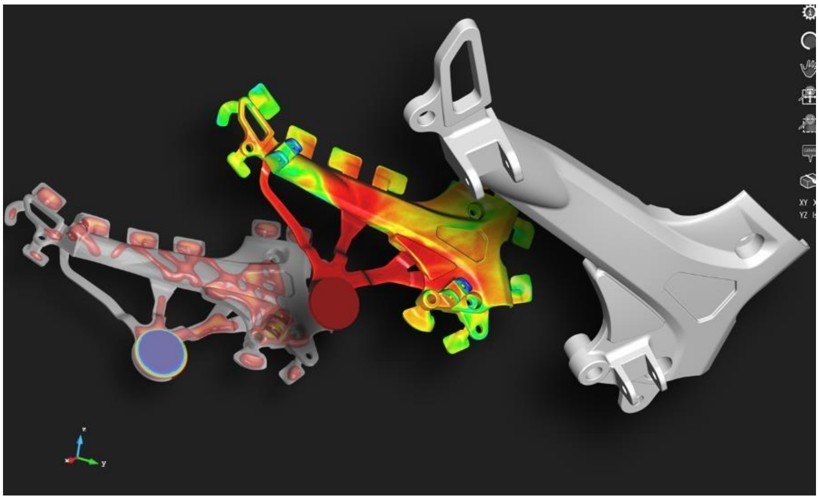


Fig 1.5 Overview of simulation process

1.5.1 BENEFITS OF CASTING SIMULATION

- Energy savings
- Improved product quality
- Shortened lead time
- First time right
- Prediction of metallurgy
- Increased production
- Less re-melting and refinishing

1.6 DESCRIPTION AND NECESSITY OF PROJECT

As we know foundry industry is main supplier to the various mechanical industries. Human being knows the casting technique from ancient time. From the ancient time there is continues knowledge addition in foundry technology. Still considering present market scenario as well as globalization and liberalization polices, it is big challenge to achieve sound casting with higher casing yield which is important to survive in market.

- ❑ The process of casting solidification is complex in nature and the simulation of such process is required in industry before it is actually undertaken. The defects like shrinkage cavity, porosity, and sink can be minimized by designing an appropriate feeding system to ensure directional solidification in the casting, leading to feeders.Major parameters of a feeding system include:feeder location, feeder shape and size and feed aids. By this project, an attempt has been made to carry out the entire methoding, simulation and optimization in CLICK2CAST software all the design parameters have been set properly in simulation software so that the results are obtained which visualizes the parameters and defects before experimental trials. This attempt has shown significant improvement in the quality of casting by optimizing the location and design of feeder for defect minimization. This project is carried out to get casting of a block which is preliminary associated with the various flow related defects. Defective casting is analyzed to get causes of defects. It is clear that defects are due to the improperly designed feeding system and gating system. Hence for complete elimination of these defects gating system and feeding system components are redesigned with the help of theoretical knowledge, feeding rule, past experiences and gating rules. Determining the solidification behaviour during casting processes is an important parameter for measuring the overall performance of process. It gives information about the properties of the metal being casted and its possible behaviour in the mold during casting process. Improper solidification, use of improper molding materials and casting conditions leads to defects such as mis runs, cold shuts, shrinkage, pin holes, air holes and porosity in final product.

- The scope of the work is limited to sand casting. This is because sand casting occupies the major share as close as 80% of castings produced by weight and the widely used metals in sand castings are Ferrous and Aluminium alloys. Our main aim is to study about the filling and solidification phenomenon through simulation and analyse the process experimentally to maximise the yield and enhance productivity and minimise the defects.
- Casting simulation helps visualize mold filling and casting solidification. It predicts related defects like shrinkage, porosity and hard spots and optimize the casting design to achieve the desired quality with high yield. Flow and solidification of molten metals is very complex difficult to simulate correctly by conventional techniques. For industrial application, we need an alternate approach that is fast, reliable and user friendly that is computer aided casting simulation.
- To minimise the various defects that occur in sand casting process like Mold erosion, metal penetration, run out, scabs, rattails, swell, pull down, cold shuts. Air entrapment, burn on to some extent by using the simulation software.
- Aluminium parts are routinely cast by every known process, offering a broad range of volume, productivity, quality, mechanization, and specialized capabilities. Most aluminium casting alloys display solidification characteristics compatible with foundry requirements for the production of quality parts. Many aluminium casting alloys display excellent fluidity for casting thin sections and fine detail. Aluminium casting alloys melt at relatively low temperatures. Aluminium casting processes can be highly automated. So aluminium is selected as the metal to be casted.

- Sand casting process is selected because it occupies the major share as close as 80% of castings produced by weight and the widely used metals in sand castings are Ferrous and Aluminium alloys.

1.7 ORGANIZATION OF REPORT

The report is organized in seven chapters. The first chapter contains the introduction about metal casting, mold design, mold construction, casting simulation and objectives and description of project. The second chapter covers the literature reviewed in the area of casting simulation and experimental analysis of casting. In the third chapter selection of casting material, pattern material and mold material are defined. The fourth chapter discusses the procedure in executing filling and solidification in casting using casting simulation software. The fifth chapter presents the procedure and carrying out experimental analysis of the casting and testing and inspection of the casting obtained and the sixth chapter contains the results and analysis of simulation process, experimental analysis and testing and inspection of casted object .The final chapter deals with summary of the work done, conclusions and future scope of the work.

Chapter 2

LITERATURE REVIEW

- **Ravi, B., Joshi, D., 2007. Feed ability analysis and optimization driven by casting simulation. Indian Foundry J. 53 (6),71—78.**

This article mainly focussed on design and optimization technique based on casting related defects and their research and outcomes. Ravi and Joshi worked on computer aided casting design and simulation of feeder and gating design of castings using Auto-CAST software and they describe how it assists in designing, modelling, simulating, analyzing and improving cast products. From their results it is concluded that the casting simulation helps visualize mold filling and casting solidification. It predicts related defects like shrinkage, porosity and hard spots and optimize the casting design to achieve the desired quality with high yield.

- **Hassan, I., Sheikh, A.K., Al-Yusuf, A., 2012. Mold design optimization for sand casting of complex geometries using advance simulation tools, material manufacturing Process.**

Hassan investigated the impeller shaped casting using MAGMASOFT Software. The effect of riser and gates on parameters, such as filling pattern, pressure and speed, cooling rate, solidification and related defects, was studied. The results of their studies shows that use of this casting simulation will keep casting producers competitive & profitable and with this simulation software the casting process from filling to solidification is simulated. Foundries relying on this simulation tool can have the advantage of the latest casting process design technology that calculates residual stresses, metallurgical prediction improves quality, reduces lead times and cost.

- **Choudhari, C.M.Padalkar, K.J., Duhamel, K.K.Narkhede, B.E.Mahajan, S.K., 2013. Defect free casting by using simulation software. Appl. Mechanical Matter.**

Choudhari suggested that by optimization method casting related defects can be improved. The proper location, size and design of gating and feeder system using simulation technology improved the shrinkage porosity and cracks in casting. From the results of their studies it is clear that the defects in casting process can be reduced to some extent using simulation software.

- **B. Ravi, “Casting Simulation and Optimisation: Benefits, Bottlenecks, and Best Practices,” Indian Foundry Journal, 54(1), 47-52,2008.**

From this literature B.Ravi concluded that the bottlenecks and non-value added time in casting development can be minimized by adopting CAD, Intelligent methoding and simulation technologies. These have been developed, successfully demonstrated on industrial castings, and now being used in several organizations. Several innovative algorithms, including VEM, geometric reasoning, and automatic solid modelling dramatically compressed the iteration time for methoding modification and simulation to less than one hour for even complex castings. Further, the simple and logical user interface greatly improved the learning curve for engineers, to just a few hours. As a result, even small foundries with little or no previous exposure to CAD/CAM software are able to effectively use the program to improve their casting quality, yield and productivity. It has also proven to be very useful for verifying the manufacturability of a casting and improving it by minor modifications to part geometry, before freezing the design. In future, it will be possible to offer automated methoding and simulation functionality over the Internet, enabling access to this technology to even SME foundries in remote areas. This study has been very helpful for understanding the best practices of simulation technology in manufacturing industry.

- **Ravi B, Metal Casting: Computer-Aided Design and Analysis, PHI, New Delhi, ISBN 81 203 2726 8, 4th print, 2008.**

B.Ravi concluded that in recent years, computer simulation of casting solidification has gained much ground, owing to the constant and painstaking efforts of researchers to make such software tools more reliable and easy to use. A significant number of real life case studies are also available in technical journals and proceedings of conferences related to casting. Still, only a handful of aluminium foundries are using these software tools today. This is owing to several challenges posed by first-time users. We first present an overview of computer-aided methods design. This is followed by the difficulties faced by foundry users, and how to overcome them through best practices gleaned from our experience with several simulation projects and consultants. From this he stated the need for integration of CAD with manufacturing industries for their rapid development.

2.1 RELATED STUDY - DEFECTS IN CASTING PROCESS

Casting is a process which carries risk of failure occurrence during all the process of accomplishment of the finished product. Hence necessary action should be taken while manufacturing of cast product so that defect free parts are obtained. Mostly casting defects are concerned with process parameters. Hence one has to control the process parameter to achieve zero defect parts. For controlling process parameter one must have knowledge about effect of process parameter on casting and their influence on defect. To obtain this all knowledge about casting defect, their causes, and defect remedies one has to be analyze casting defects. Casting defect analysis is the process of finding root causes of occurrence of defects in the rejection of casting and taking necessary step to reduce the defects and to improve the casting yield.

During the process of casting, there is always a chance where defect will occur. Minor defect can be adjusted easily but high rejected rates could lead to significant change at high cost. Therefore it is essential for die caster to have knowledge on the type of defect and be able to identify the exact root cause, and their remedies.

- Casting defects can be classified as follows

  - Filling related defect
  - Shape related defect
  - Thermal defect
  - Defect by appearance

2.1.1 FILLING RELATED DEFECTS

Blow holes

Blow hole is a kind of cavities defect, which is also divided into pinhole and subsurface blowhole. Pinhole is very tiny hole. Subsurface blowhole only can be seen after machining. Gases entrapped by solidifying metal on the surface of the casting as shown in fig 2.1, this result in a rounded or oval blowhole as a cavity and frequently associated with Slag or oxides. The defects are nearly always located in the cope part of the mold in poorly vented pockets and undercuts.

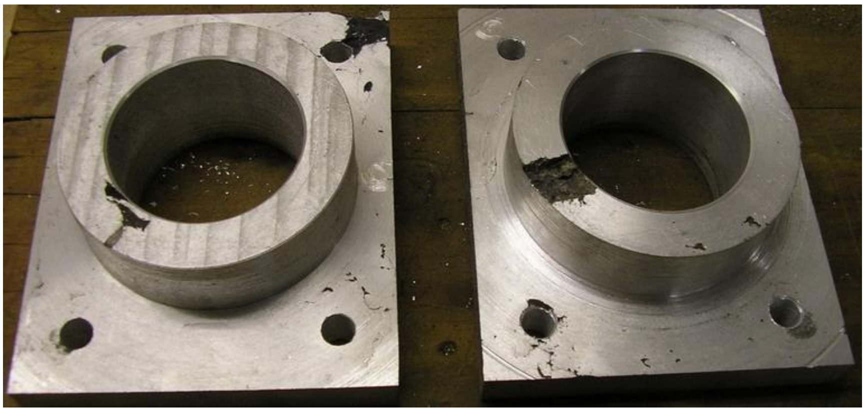


Fig 2.1 Blow holes in casting

Remedies

Reduce moisture content of sand. Improve conditioning of the sand. Reduce inert dust content. Improve gas permeability. Endeavour to use coarser sand. Reduce bentonite and carbon carrier content. Reduce sand temperature. Install a sand cooler if necessary. Increase sand quantity. Reduce bentonite content or use bentonite with a high specific binding capacity and good thermal stability.

❑ Sand burning

Burning-on defect is also called as sand burning, which includes chemical burn-on, and metal penetration, thin sand crusts firmly adhering to the casting. The defect occurs to a greater extent in the case of thick walled castings and at high temperatures. The high temperature to which the sand is subjected causes sintering of the bentonite and silicate components. In addition, the always present iron oxides combine with the low-melting-point silicates to form iron silicates, thereby further reducing the sinter point of the sand. Sintering and melting of the impurities in the molding sand enable the molten iron to penetrate even faster, these layers then frequently and firmly adhering to the casting surface.

Remedies

Even out incoming metal flow. Reduce pouring rate. Reduce liquid metal temperature

❑ Sand inclusion

Sand inclusion and slag inclusion are also called as scab or blacking scab. They are inclusion defects and looks like there is slag inside of metal castings. Irregularly formed sand inclusions, close to the casting surface, combined with metallic protuberances at other points as shown in fig 2.2. Sand inclusion is one of the most frequent causes of casting rejection. It is often difficult to diagnose, as these defects generally occur at widely varying positions and are therefore very difficult to attribute to a local cause. Areas of sand are often torn away by the metal stream and then float to the surface of the casting because they cannot be wetted by the molten metal. Sand inclusions frequently appear in association with CO blowholes and slag particles. Sand inclusions can also be trapped under the casting surface in combination with metal oxides and slag's, and only become visible during machining. If a loose section of sand is washed away from one part of the mold, metallic protuberances will occur here and have to be removed.

Fig 2.2 Sand inclusion defect

Remedies

Avoid high pouring rates and impact of metal stream against mold walls. Shorten pouring times, improve distribution of gates

❑ Cold lap or cold shut

Cold lap or also called as cold shut and is caused when two streams do not fuse together properly thus forming a discontinuity in casting as shown in fig 2.3. It is a crack with round edges. Cold lap is because of low melting temperature or poor gating system.

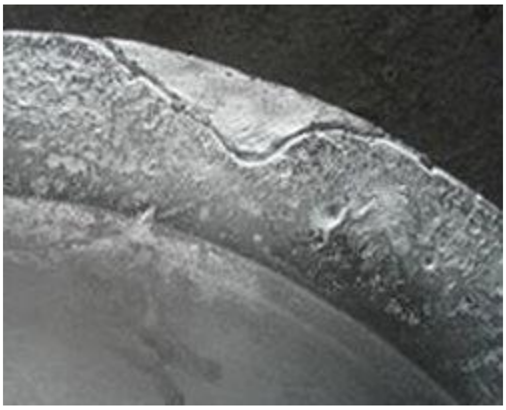


Fig 2.3 Cold shuts formed in casted object

Remedies

Adjust proper pouring temperature. Modify design of gating system

❑ Misrun

Misrun defect is a kind of incomplete casting defect, which causes the casting uncompleted. The edge of defect is round and smooth as shown in fig 2.4. When the metal is unable to fill the mold cavity completely and thus leaving unfilled portion called misrun.

Fig 2.4 Misrun defect in casting

Remedies

Adjust proper pouring temperature. Modify design of gating system.

- **Gas porosity**

The gas can be from trapped air, hydrogen dissolved in aluminium alloys, moisture from water based die lubricants or steam from cracked cooling lines. Air is present in the cavity before the shot. It can easily be trapped as the metal starts to fill the cavity. The air is then compressed as more and more metal streams into the cavity and the pressure rises. When the cavity is full it becomes dispersed as small spheres of high pressure air. Fig 2.5 depicts the gas porosity defect in casting.

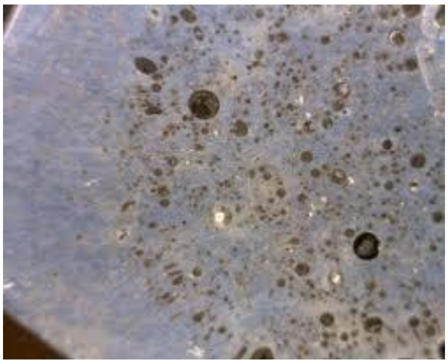


Fig 2.5 Gas porosity defect in casting

Remedies

Increase metal pouring temperature. Pour metal as rapidly as possible without interruption. Improve mold filling by modification to running and gating system. Reduce gas pressure in the mold by appropriate adjustment to molding material properties and ensuring Adequate venting of molds and cores.

2.1.2 SHAPE RELATED DEFECTS

- **Mismatch defect**

Mismatch in mold defect is because of the shifting molding flaks. It will cause the dislocation at the parting line. A mismatch is caused by the cope and drag parts of the mold not remaining in their proper position. This is caused by loose box pins, inaccurate pattern dowel pins or carelessness in placing the cope on the drag. Fig 2.6 shows mismatch defect in casting.

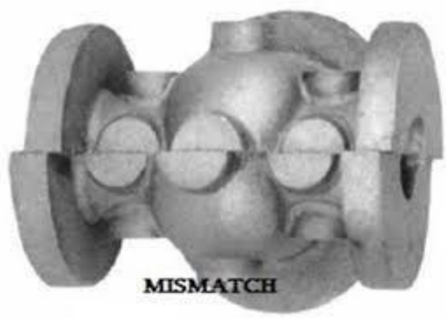


Fig 2.6 Mismatch defect in casting

Remedies

Proper molding box and closing pins should be used

- **Flash defect**

Flash can be described as any unwanted, excess metal which comes out and attached to the cavity or runner. Typically it forms a thin sheet of metal at the parting faces as shown in fig 2.7. There are a number of different causes of flash and the amount and severity can vary from a minor inconvenience to a major quality issue. At the very least, flash is waste material, which mainly turns into dross when re-melted, and therefore is a hidden cost to the business.

Fig 2.7 Flash defect in casting

Remedies

If your sprue is very tall and the casting covers a wide area of the mold face, it's very possible for the mold to actually be forced up by the hydrostatic pressure of the metal. Proper design of sprue helps as remedy.

2.1.3 THERMAL DEFECTS

- **Cracks or tears**

Cracks can appear in castings from a number of causes. Some cracks are very obvious and can easily be seen with the naked eye. Other cracks are very difficult to see without magnification. Excessive porosity in critical regions of the part may be the reason and fig 2.8 depicts the cracks formed during casting.

Fig 2.8 Cracks or tears formed during casting

Remedies

Reduce pouring temperature. Avoid superheating of metal. Use chills. Provide feeders Avoid early knockout and give sufficient cooling time. Reduce sharp corners in gating design.

- **Shrinkage**

Shrinkage defects occur when feed metal is not available to compensate for shrinkage as the metal solidifies. Shrinkage defects can be split into two different types: open shrinkage defects and closed shrinkage defects. Open shrinkage defects are open to the atmosphere, therefore as the shrinkage cavity forms air compensates. There are two types of open air defects: pipes and caved surfaces. Pipes form at the surface of the casting and burrow into the casting, while caved surfaces are shallow cavities that form across the surface of the casting. Closed shrinkage defects also known as shrinkage porosity, are defects that form within the casting. The isolated pools of liquid form inside solidified metal, which are called hot spots. The shrinkage defect usually forms at the top of the hot spots. They require nucleation point, so impurities and dissolved gas can induce closed shrinkage defects as shown in fig 2.9. The defects are broken up into macro porosity and micro porosity, where macro porosity can be seen by the naked eye and micro porosity cannot.

Fig 2.9 Shrinkage defect in casting process

Remedies

The general technique for eliminating shrinkage porosity is to ensure that liquid metal under pressure continues to flow into the voids as they form.

2.1.4 DEFECTS BY APPEARANCE

- **Cavities**

Blowholes, pinholes, Smooth-walled cavities, essentially spherical, often not contacting the external Casting surface (Blowholes). The defect can appear in all regions of the casting. Blowholes and pinholes are produced because of gas entrapped in the metal during the course of solidification

Remedies

Make adequate provision for evacuation of air and gas from the mold cavity, Increase permeability of mold and cores.

- **Incomplete casting**

Poured short and portion of the casting is missing. The edges adjacent to the missing section are slightly rounded and all other contours conform to the pattern. The sprue, risers and vents are filled only to the same height above the parting line, as is the casting. Insufficient quantity of liquid metal in the ladle and premature interruption of pouring due to workman's error may be the causes.

Remedies

Have sufficient metal in the ladle to fill the mold, Check the gating system. Instruct pouring crew and supervise pouring practice.

- **Defective surface**

Flow marks on the surfaces of castings. The defect appears as lines which trace the flow of the streams of liquid metal.

Remedies

Increase mold temperature. Lower the pouring temperature. Modification of gate size and location serves as remedy.

2.2 SUMMARY OF LITERATURE

With rapid development in computer hardware and software technologies, the usage of simulation tools in foundries has increased. casting process simulation is now a well established tool for the optimisation of casting design as well as process design .They have reached a point where the simulation tools have now become an integrated part of entire casting production process, from casting design to adjusting production parameters. There are many aspects of casting process that can be evaluated by using casting simulation process. As seen earlier, the casting process is extremely complex, and analytical procedures are very difficult to apply without using large number of assumptions many of the assumptions though simplify the calculation procedures, do not guarantee accurate results , this calls for some trial and error method to achieve sound casting which is time consuming and expensive.

Casting simulation utilises finite difference and finite element procedures depending upon the complexity of the problem. It provides large range of results of the complete behaviour of casting during filling as well as solidification. The simulation process allows establishing the appropriate casting design specific process parameters to control manufacturing process. Using the casting simulation as a virtual test in foundry it is possible to do a number of what-if scenarios to establish the optimum casting design and foundry process and very effective for obtaining good quality and defect free casting.

Chapter 3

MATERIAL SELECTION

3.1 MATERIAL SELECTION FOR CASTING

Aluminium plays a major role in the modern world through its innumerable applications, because of its intrinsic and versatile properties of lightness, strength to weight ratio, corrosion resistance, electrical and thermal conductivity, no toxicity etc. In the form of castings, either as cast or heat treated, aluminium is gradually replacing Gunmetal, bronze, stainless steel and many grey iron and malleable iron castings. Engine components like automobile and diesel pistons, automotive timing gear, gear boxes, crank cases, clutch housing, pump bodies, bracket, arms and hangers for different industries, components, fittings for chemical and marine uses, railways, storage tanks, flywheel housing and propellers, artificial limbs, ornamental hardware's, ashtrays, water jugs, art metal work, molding flasks, core. Drying plates and pattern castings, rotor of ceiling fans and many other components in different fields are made of A1-castings. Aluminium is a light, conductive, corrosion-resistant metal with a strong affinity for oxygen. This combination of properties has made it a widely used material, with applications in the aerospace, architectural construction and marine industries, as well as many domestic uses. Fig 3.1 shows various applications of aluminium.

Fig 3.1 Applications of aluminium metal in modern world

Aluminium has two main advantages when compared with other metals. Firstly, it has a low density about one-third that of iron and copper. Secondly, although it reacts rapidly with the oxygen in air, it forms a thin, tough and impervious oxide layer that resists further oxidation. This removes the need for surface-protection coatings such as those required with other metals, in particular with iron. All the indications are that the growth in the use of aluminium will likely accelerate. It is expected that in the near future the use of aluminium with specifically improved properties will grow in many applications, meeting the increased economic and ecological demands. Considering the entire life-cycle of an automobile, from the extraction of materials to the final disposal, including recycling and reuse applications, aluminium proves to be a potential alternative to steels in future automotive applications.

Aluminium casting is also a widely used method, due in large part of the superior versatility of the metal. As one of only a few materials able to undergo most metal casting processes, aluminium is a relatively adaptable substance to work with. Aluminium's corrosion resistance, high thermal and electrical conductivity, good mechanical properties and strength at high temperature make it an effective choice for sand casting. In aluminium alloys other elements are deliberately added to improve the properties in some way. Many alloys have been developed, the aim being to improve the strength while retaining the desirable properties of aluminium, most notably its lightness and corrosion resistance. In general though, while the addition of an alloying element increases the strength, it reduces the resistance to corrosion, making a compromise of the properties necessary.

3.1.1 ABOUT ALUMINIUM 7075 ALLOY

7075 aluminium alloy is an aluminium alloy, with zinc as the primary alloying material. It is strong, with strength comparable to many steels, and has good fatigue strength and average machinability. It has lower resistance to corrosion than many other aluminium alloys but has significantly better corrosion resistance than the 2000 alloys.

7075 aluminium alloy's composition roughly includes 5.6-6.1% zinc, 2.1- 2.5% magnesium, 1.2-1.6% copper and less than half percentage of silicon, iron, manganese, titanium, chromium and other metals. It is produced in many tempers, some of which are 7075-0, 7075-T6. 7075-T651.The mechanical properties of 7075 depend greatly on the tempering of the material.

- **7075-0**: Unheated treated 7075 have maximum tensile strength no more than 280MPa and maximum yield strength no more than 140MPa. The material has an elongation of 9-10%. As is the case for all 7075-aluminum alloys, 7075-0 is highly corrosion resistant combined with generally acceptable strength profile.

- **7075-T6**:T6 temper 7075 has an ultimate tensile strength of 510-540MPa and yield strength of at least 430-480MPa. It has a failure elongation of 6-11%. The T6 temper is usually achieved by homogenizing the cast 7075 at 450°C for several hours, quenching and then aging at 120°C. This yields the peak strength of the 7075 alloy. The strength is mainly derived from finely dispersed eta precipitates within grains and along grain boundaries.

- **7075-T651**:T651 temper 7075 has an ultimate strength of 570MPa and yield strength of 500MPa. It has a failure elongation of 3-9%. These properties can change depending on the form of material used. Thicker plate may exhibit lower strengths and elongation than the numbers listed above.

- **7075-T7**: T7 has an ultimate strength of 505MPa and yield strength of 435MPa. It has a failure elongation of 13%. T7 temper is achieved by over aging the material. This is often accomplished by aging at 100-120°C for several hours and then at 160-180°C for 24 hours. The T7 temper produces a micro structure of mostly eta particles. In contrast to the T6 temper, these eta particles are much larger and prefer growth along the grain boundaries.

- **7075-RRA**: The retrogression and reagent temper is a multi-stage heat treated temper. Starting with a sheet in the T6 temper it involves over aging past peak hardness to the T7 temper. A subsequent raging at 120°C for 24 hours returns the hardness and strength to T6 temper levels.

3.1.2 COMPOSITION OF ALUMINIUM 7075 ALLOY

ALLOYING ELEMENT	PERCENTAGE (%)
Zinc	5.10-6.10
Magnesium	2.10-2.90
Copper	1.20-2.00
Chromium	0.18-0.28
Iron	0.5
Silicon	0.4
Manganese	0.3
Titanium	0.2
Others	0.05
Aluminium	Remaining

Table 3.1 Composition of aluminium 7075 alloy

3.1.3 APLLICATIONS OF ALUMINIUM 7075 ALLOY

Due to their high strength to density ratio 7000 series alloys such as 7075 are often used in transport applications including marine automotive and aviation. These same properties lead to its use in rock climbing equipment, bicycle components are commonly made from 7075 aluminium alloy. Due to its high strength, low density, thermal properties and its ability to highly polished, 7075 is widely used in mold tool manufacturing and also used for Gears, shafts, aircraft parts, valve parts, low production plastic mold tools, blow molds for plastic bottles.

3.2 MATERIAL SELECTION FOR MOLD MAKING

Molding sand, also known as foundry sand, is a sand that when moisture and compressed or heated tends to pack well and holds its shape. It is used in the process of sand casting for preparing the mold cavity.

3.2.1 SELECTION OF GREEN SAND

Green sand is an aggregate of sand, bentonite, clay, pulverized clay and water. Its principle use is in making molds for metal casting. The largest portion of the aggregate is always sand, which can be either silica. There are many recipes for the proportion of clay, but they all strike different balances mold ability, surface finish and ability of the hot molten metal into degas. The coal typically referred to in as sea- coal, which is present at a ratio of less than 5%, partially combusts in the surface of the molten metal leading to off gassing of organic vapours.

- **COMPOSITION OF GREEN SAND**

ELEMENT USED	PERCENTAGE	REASON
Silica sand	70-85%	To provide refractoriness
Clay	10-20%	To act as binder, imparts tensile and shear strength to the mold
Water	3%	To activate clay and provide plasticity
Organic additives	1-6%	Enhance desired sand properties

Table 3.2 Composition of green sand

Sand casting is one of the earliest forms of casting practiced due to the simplicity of casting practiced due to the simplicity of materials involved. It still remains one of the cheapest ways to cast metals because of that same simplicity. Other methods of casting boast higher quality of surface finish but have higher cost. Green sand is usually housed in what casters referred to as flask, which is nothing more than boxes without a bottom or lid. The box is split into two halves which are stacked together in use. The halves are referred to as the top and bottom flask respectively. Not all green sand is green in colour but considered green as in the sense that it is used as wet state. The dry sand casting process results in a more rigid mold better suited to heavier castings. Fig 3.2 shows green sand.

Fig 3.2 Green sand

3.2.2 PROPERITIES OF GREEN SAND

The properties of green sand are adhesiveness, cohesiveness, collapsibility, flow ability, dry strength, green strength, permeability, refractoriness.

- **ADHESIVENESS:** Adhesiveness is a property of green sand to get the stick or adhere to foreign material such sticking of molding sand with the inner wall of molding box.

- **COHESIVENESS:** Cohesiveness is a property of molding sand by virtue of which the sand grain particles interact and attract each other within the molding sands. Thus, the binding capacity of the molding sand gets enhanced to increase the green, dry and hot strength property of molding and core

- **COLLAPSIBILITY:** After the molten metal in the mold gets solidified, the sand mold must be collapsible so that free contraction of the metal occurs and this would naturally avoid the tearing or cracking of the contracting metal. In absence of the collapsibility property the contraction of the metal is hindered by the mold and thus results in the cracks in the casting. This property is highly required in cores.

- **FLOWABILITY:** Flow ability is the ability of the sand to get compacted and to behave like a fluid. It will flow uniformly to all portions of pattern when rammed and distribute the ramming pressure evenly all around in all directions. Generally sand particles resist moving around corners or projections. In general, flow ability increases with decrease in green strength and vice versa. Flow ability increases with decrease in grain size of sand. The flow ability also varies with moisture and clay content in sand.

- **DRY STRENGTH:** As soon as the molten metal is poured into the mold, the moisture in the sand layer adjacent to the hot metal gets evaporated and this dry sand layer must have sufficient strength to its shape in order to avoid erosion in mold wall during the flow of molten metal. The dry strength also prevents the enlargement of mold cavity cause by the metallostatic pressure of the liquid metal.

- **GREEN STRENGTH:** The green sand after water has been mixed into it, must have sufficient strength and toughness to permit the making and handling of the mold. For this the sand grains must be adhesive i.e. they must be capable of attaching themselves to another body and therefore and sand grains having high adhesiveness will cling to the sides of the molding box. Also, the sand grains must have the property known as cohesiveness i.e., the ability of the sand grains to stick together. By virtue of this property the pattern can be taken out from the mold without breaking the mold and also erosion of mold wall does not occur during the flow of molten metal. The green strength also depends on the grain shape and size, amount and type of clay and the moisture content.

- **PERMEABILITY:** Permeability is also termed as porosity of the molding sand in order to allow the escape of any air, gases or moisture present or generated in the mold when the molten metal is poured into it. All these gases generated during pouring and solidification process must escape otherwise the casting becomes defective. Permeability is a function of grain size, grain shape and moisture and clay contents in the molding sand. The extent of ramming of the sand directly affects the permeability of the mold. Permeability of mold can be further increased by venting using vent rods.

- **REFRACTORINESS:** Refractoriness is defined as the ability of molding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting. It is a highly important characteristic of molding sands. Refractoriness can be increased to a limited extent. Molding sand with poor refractoriness may burn on the casting surface and no smooth casting surface can be obtained. The degree of refractoriness depends on the SiO2 content and the rougher the grain volumetric composition the higher is the refractoriness of the molding sand and core sand. Refractoriness is measured by the sinter point of the sand rather than its melting point.

Chapter 4

COMPUTER AIDED CASTING SIMULATION

4.1 SIMULATION

Computer aided casting simulation is essential tool for casting defects production and troubleshooting those defects and cast optimization. It helps to assure quality of casting and yield improvement without doing shop floor trails. Casting simulation helps visualize mold filling and casting solidification. It predicts related defects like shrinkage, porosity and hard spots and optimize the casting design to achieve the desired quality with high yield. Flow and solidification of molten metal is very complex difficult to simulate correctly by conventional techniques. Simulation is the process of imitating areal phenomenon using a set of mathematical equations implemented in a computer program. A complete and physically accurate simulation of metal casting process is very difficult. The important to develop a practically useful simulation program is the most important factor.

4.1.1 IMPORTANCE OF SIMULATION

The Casting Simulation may use by the engineers in foundry to assure quality of cast parts and yield optimization without charging out shop floor trails, it also helps engineers to analyzing and optimizing of feed ability of a casting during design phase. Casting simulation helps to visualize mold filling, solidification of casting and to predict the hot spot location where internal defects such as shrinking porosity. An internal defect occurs at the time of solidification, these internal defects can be eliminated by proper design of feed system. Yield is the ability of casting to manufacture acceptable casting in effective manner. Improved yield offers many benefits as material cost, better process control. By using computer casting simulation, an optimum gating and feeding system can be designed to improve yield, quality of casting and also eliminate internal defects.

4.1.2 CASTING SIMULATION SOFTWARE

There are number of casting simulation software are developed and are used in foundry worldwide. The application of casting simulation soft wares are also increasing day to day in Indian foundry as it essentially replaces or minimizes the shop floor trials to achieve the desired internal quality at the least possible time. Casting simulation technology become a powerful tool for casting defect troubleshoot in and method optimization. It will reduce the lead time for the sample casting and improved productivity and knowledge of software’s can be maintained for future use and for training new engineers in foundry.

4.1.3 LIST OF CASTING SIMULATION SOFTWARES

Complete and physically accurate simulation of metal casting process is very difficult. It is very important to develop a practically useful simulation program. Some of the well-known casting simulation software's which are used in foundry are mentioned below.

- SUTCAST
- PROCAST
- CLICK 2CAST
- MAGMASOFT
- FLOW3D
- OPTICAST
- SOLIDCAST
- QUICKCAST

4.2 SIMULATION SOFTWARE USED

Fig 4.1 Logo of click2cast software

Click2Cast is Finite Element based formulation. Typical challenges of meshing the domain are overcome by integrating with the Altair suite of meshing applications, bringing the accuracy of FEM to the world of casting flow and solidification computations. This provides an extremely accurate and fast solution for both fluid flow and solidification calculations. Click2Cast is a fast, easy, accurate and affordable casting simulation environment focused on creating high quality components with increased profitability through a highly intuitive user experience catering to beginners and experts alike. Users are able to avoid typical casting defects such as air entrapment, shrinkage porosity, cold shuts, mold degradation and more by using Click2Cast. It is one of the most powerful and user friendly tools for visualizing, modelling, analyzing, and optimizing every foundry process. The software simulates the molten metal of any casting alloy into sand or permanent molds. The software developed to accurately simulate the entire casting process and provide quick and reliable solutions to casting problems for any casting process and material needs. It provides mainly the Solidification Simulation and Mold Filling Simulation.

4.2.1 INPUTS FOR THE SIMULATION SOFTWARE

- The geometry of the mold cavity (3D model of the casting, feeders, and gating channels).
- Thermo physical properties (density, specific heat, and thermal conductivity of the cast metal as well as the mold material, as a function of temperature).
- Boundary conditions (i.e. the metal mold heat transfer coefficient, for normal mold as well as feed aids including chills, insulation and exothermic materials).
- Process parameters (such as pouring rate, time and temperature).

4.2.2 STEPS IN SIMULATION SOFTWARE

Fig 4.2 Steps in simulation by click2cast software

4.3 SIMULATION PROCEDURE

- Geometric modelling of mold
- Conversion of model to .stl file format
- Importing the geometry file to simulation software
- Ingate selection
- Meshing of model
- Material selection
- Run calculations
- Execute results

4.3.1 GEOMETRIC MODELLING OF THE MOLD

First step in framework is part solid modelling. To do cast simulation first a geometric model of part being casted has to be prepared and also feed system that is runner bar, in gate, riser also be prepared. These models saved into standard .STL format.

▣MODELLING USING CREO PARAMETRIC

Fig 4.3 Logo of creo parametric software

- ❑ Working on CREO means using both the CAD modeling approaches i.e. parametric and direct modeling. Hence you achieve two goals with single software. Designers can enjoy the control provides by parametric modeling on one hand and on the other hand, they can also enjoy the speed and flexibility of direct modeling. CREO can easily work on any CAD data source. Hence designers can save their lot of time and efforts while using CREO and operating on various platforms. It also eliminates the minor possibility of human errors while redesigning the same design. Thus it is helpful for both the designers and the organization.
- ❑ Firstly the dimensions of the model are considered and are tabulated as below.

Length and breadth of drag	24*24cm
Height of drag	6.5cm
Length and breadth of cope	24*24cm
Height of cope	6.5cm
Length of mold cavity	4.5cm
Breadth of mold cavity	4.5cm
Height of mold cavity	4.5cm
Diameter of sprue(top)	2cm
Diameter of sprue(bottom)	1cm
Length of runner	6cm
Diameter of runner	1cm
Diameter of riser(top)	1.6 cm
Diameter of riser (bottom)	0.8 cm

Table 4.1 Dimensions of the required mold

4.3.2 DESIGN OF MOLD:

Firstly using the creo software in part drawing the front view of the mold is drawn using the tools available creo parametric as per dimensions.

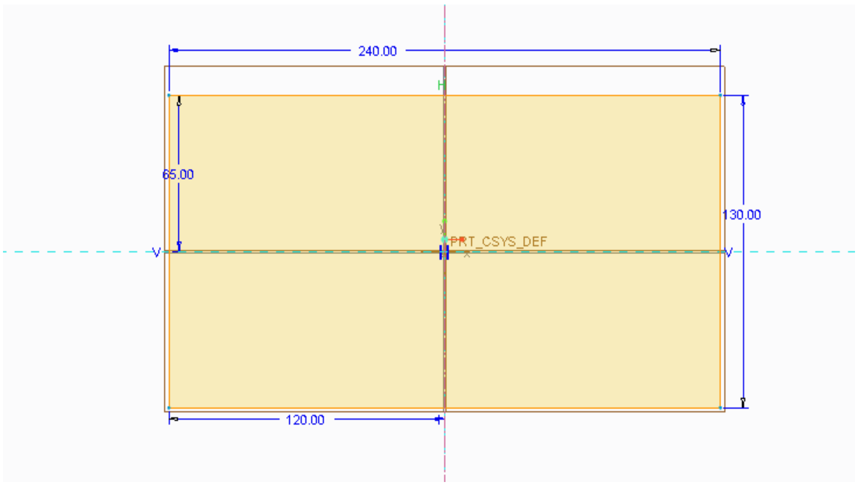


Fig 4.4 Front view of designed model of mold

- Now the sketched part is extruded and the complete outer part of the mold is modeled.

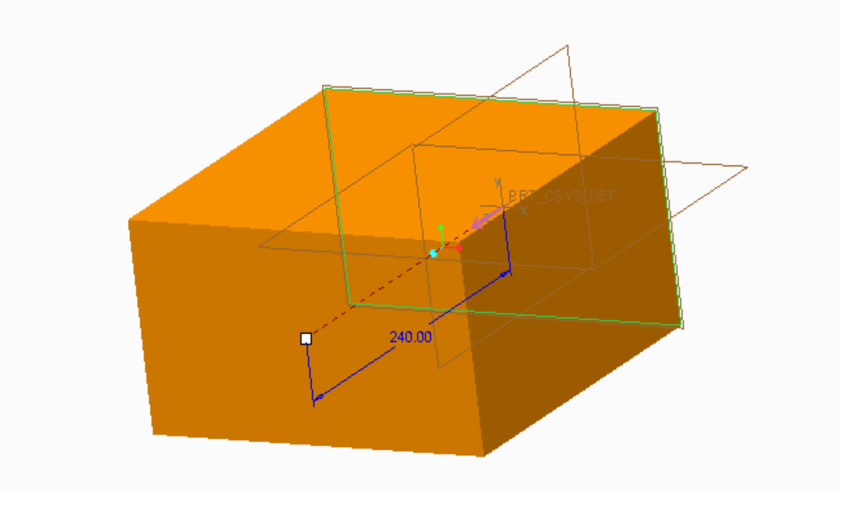


Fig 4.5 Extruded front view of designed mold

- Similarly on the mold front view is selected and the mold cavity, sprue hole, runner path, riser are sketched and extruded/revolved as per dimensions and requirement. By using the material removal option these extruded parts are removed as they are cavities inside the solid mold. The entire process of 3D mold design using creo parametric can be shown in step wise using model tree of designed model as shown in fig 4.6 and the final model designed shown in the figure4.7.

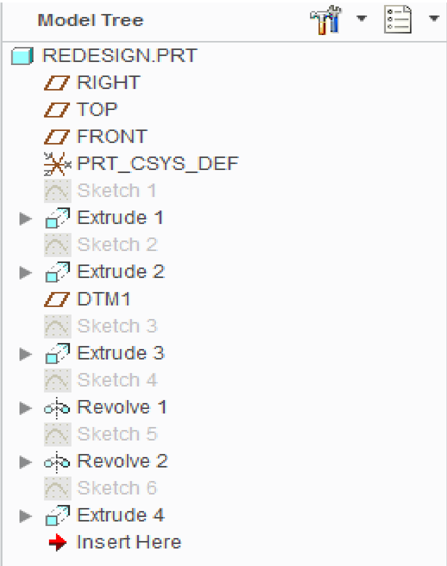


Fig 4.6 Model tree of design of mold using creo parametric

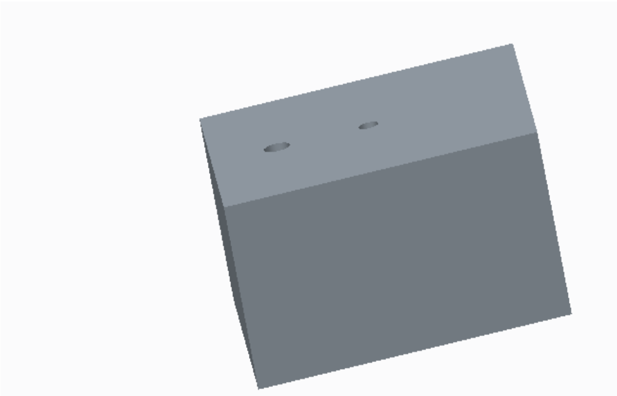


Fig 4.7 Required design of the mold modelled using creo parametric

- The cavities inside the mold are grouped together and are highlighted for better view of the internal feeding system and mold cavity in the modeled mold.

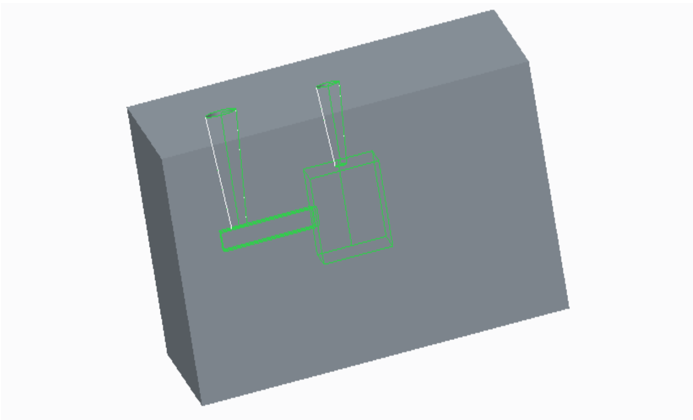


Fig 4.8 Grouping of cavities and highlighting for better view of inner features of mold

- The modelling of the mold is then completed and converted into standard .stl file format

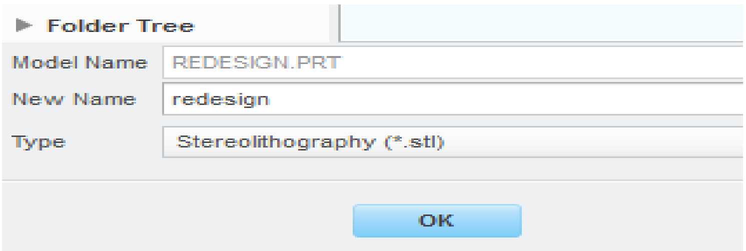
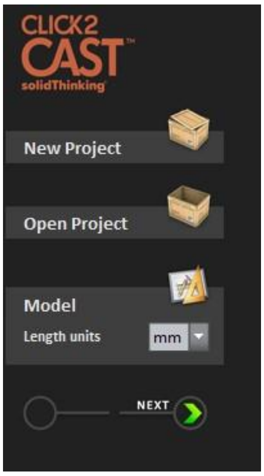


Fig 4.9 Conversion of creo model to .stl file format

4.4 SIMULATION USING CLICK 2CAST

4.4.1 IMPORTING THE GEOMETRY

After installing the click2cast software, open the application and select the new project from the tool bar and the .stl file of geometric model is imported to this simulation software and it is the basic step of the process as shown in fig 4.10. Stereo lithography is a file format native to the stereo lithography CAD created by 3D systems. This file format is supported by many other software packages, it is widely used for rapid prototyping, 3D printing, and computer aided manufacturing. STL files describe only the surface geometry of a three-dimensional object without any representation of color, texture or other common CAD model attributes. The software optimizes the design and shows the flow path that is cavity of the mold as shown in fig4.11.



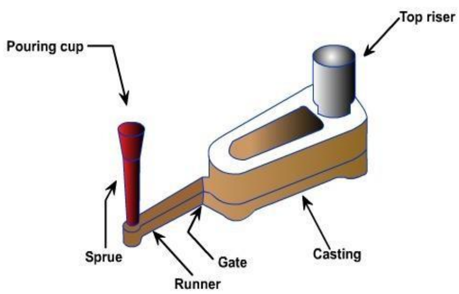


Fig 4.10 Importing the design Fig 4.11 Optimized design after importing

4.4.2 INGATE SELECTION

Ingate is basically where the casting material enters the actual mold cavity. It is a crucial element and all other factors of the metal casting's mold design are dependent on it. In the location next to the sprue base the cross-sectional area of the ingate is reduced. The cross-sectional reduction must be carefully calculated. The flow rate of casting material into the mold can be controlled accurately in this way. The flow rate of the casting metal must be high enough to avoid any premature solidification and thus ensure that the casting's gating system stays full of metal throughout the manufacturing process.

Fig 4.12 Selection of ingate

The ingate can be selected either by automatic or advanced options. Here we use the advanced option for the ingate. There are two types of ingates in which one of them is in rectangular shape and the other is in circular shape. As per the requirement of design we here select the circular shape and the radius has to be selected for the selected circular ingate that is at the sprue. The orientation XY is selected and using the option adds ingate and the ingate is given as shown in fig4.12.

4.4.3 MESHING

Mesh generation is the practice of generating a polygonal or polyhedral mesh that approximates a geometric domain. The term "grid generation" is often used interchangeably. Typical uses are for rendering to a computer screen or for physical simulation such as finite element analysis or computational fluid dynamics.

Three-dimensional meshes created for finite element analysis need to consist of tetrahedral, pyramids, prisms or hexahedra. Those used for the finite volume method can consist of arbitrary polyhedral. Those used for finite difference methods usually need to consist of piecewise structured arrays of hexahedra known as multi-block structured meshes. A mesh is otherwise a discretization of a domain existing in one, two or three dimensions. The mesh generated by the defining the element size and the clicking on create mesh as shown in fig 4.13 and mesh generated shown in fig4.14.

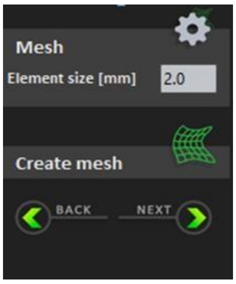


Fig 4.13 Defining element size and creating mesh

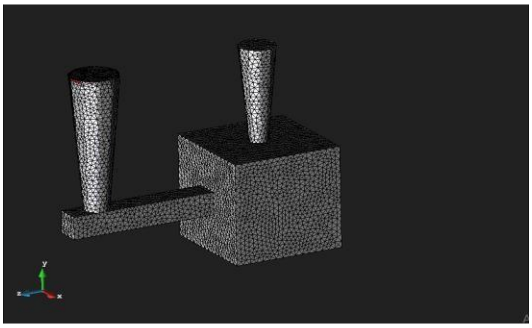


Fig 4.14 Meshed model using click 2 cast

- ❑ Mesh details can be displayed and shown below in fig 4.15 which gives properties of ingate and mesh properties in a detailed view.

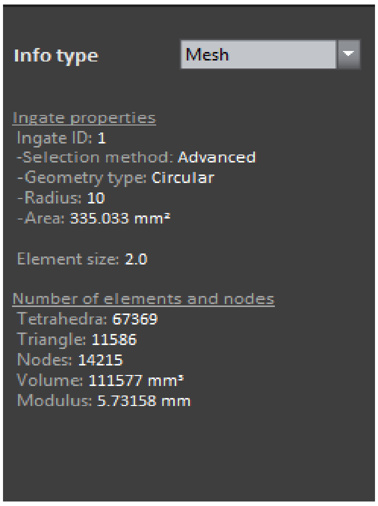


Fig 4.15 Details of meshed model

4.4.4 MATERIAL SELECTION

The required materials need to be selected in this section. As the material to be casted is selected in the part material group, here the aluminium group is selected and the type of aluminium alloy is also selected as A7075&The mold material 'Green Sand' is selected as per the requirement. Fig 4.16 depicts this process. In this software the properties of materials selected are auto generated and we need not provide any data additionally.

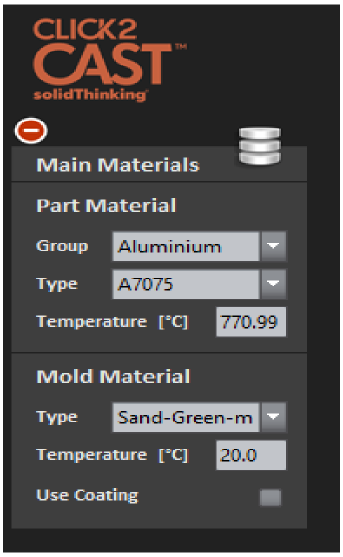


Fig 4.16 Selection of mold material and main material

4.4.5 DEFINE PROCESS PARAMETERS RUN CALCULATIONS

After material selection process parameters like specifying direction and results to be analyzed are selected and as we are intended to analyzed both filling and solidification results we need to select both and proceed to initiate the calculation process as shown in fig 4.17 and 4.18.

Fig 4.17 & 4.18 Defining process parameters and run calculations

- After completion of the calculations the following filling results and solidification results are obtained through the simulation software.

FILLING RESULTS	SOLIDIFACTION RESULTS
Flow front	Temperature
Temperature	Liquid fraction
Velocities	Solidification times
Air entrapment	Porosity percentage
Mold erosion	Porosity
Cold shuts	Solid modulus
Solid fraction	Riser designer
Pressure	Mold inner temperature

Table 4.2 Results that can be executed through simulation software

Chapter 5

EXPERIMENTAL ANALYSIS

5.1 THE PROCESS CYCLE FOR CASTING OF AA7075

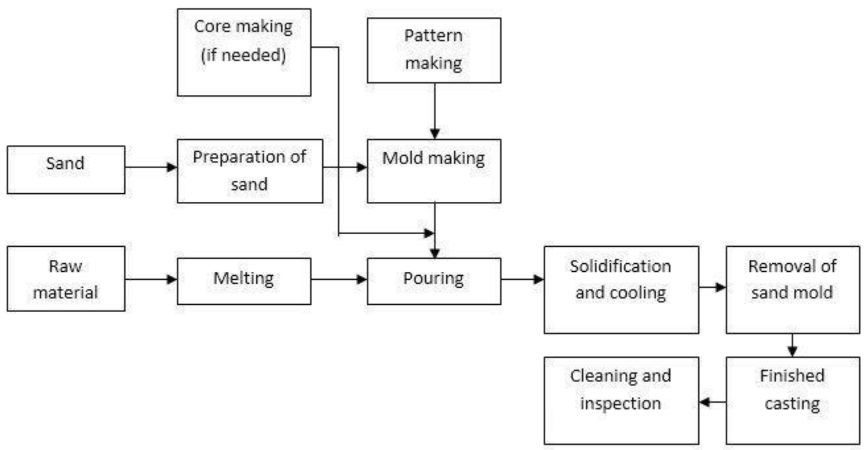


Fig 5.1 Flow chart showing process cycle of sand casting process

5.1.1 PATTERN PREPARATION

Pattern is the replica of required casting with addition of pattern allowances. The dimensions of the pattern are slightly different from the required casting due to addition of pattern allowances. The usual pattern materials are wood, metal and plastics. The most commonly used pattern is wood, the main reason being the easy availability and low weight. Also, it can be easily shaped and is relatively cheap. But the main disadvantage of wood is the absorption of moisture as a result of which distortions and dimensional change occur. A good construction may be able to reduce the war page to some extent. Hence, proper seasoning and upkeep of wood is almost a prerequisite for large scale of wood as a pattern material. The making of patterns is called pattern making, is a skilled trade that is related to the trades of tool and die making. Once the pattern is built the foundry does not want to change in shaping. The downside is that it wears out fast and is prone to moisture attack. Metal patterns are more long lasting, but they are heavier and difficult to repair once damaged.

❑ FUNCTIONS OF PATTERN

- ❑ A pattern prepares a mold cavity for the purpose of making a casting.
- ❑ A pattern may contain projections known as core prints if the casting requires a core and need to be made hollow.

- ❑ Runner, gates, and risers used for feeding molten metal in the mold cavity may form a part of the pattern.
- ❑ Patterns properly made and having finished and smooth surfaces reduce casting defects.
- ❑ A properly constructed pattern minimizes the overall cost of the castings.

❑ PATTERN ALLOWANCES

Pattern allowance is a vital feature as it affects the dimensional characteristics of the casting. Thus, when the pattern is produced, certain allowances must be given on the sizes specified in the finished component drawing so that a casting with the particular specification can be made. The selection of correct allowances greatly helps to reduce machining costs and avoid rejections. The allowances usually considered on patterns and core boxes are as follows

- ❑ Shrinkage or contraction allowance
- ❑ Draft or taper allowance
- ❑ Machining or finish allowance
- ❑ Distortion or camber allowance
- ❑ Rapping allowance

❑ Shrinkage or Contraction Allowance

All most all cast metals shrink or contract volumetrically on cooling. The metal shrinkage is of two types:

Liquid Shrinkage: It refers to the reduction in volume when the metal changes from liquid state to solid state at the solidus temperature. To account for this shrinkage riser, which feed the liquid metal to the casting, are provided in the mold.

Solid Shrinkage: It refers to the reduction in volume caused when metal loses temperature in solid state. To account for this, shrinkage allowance is provided on the patterns.

The rate of contraction with temperature is dependent on the material. For example steel contracts to a higher degree compared to aluminium.

❑ Draft or Taper Allowance

By draft is meant the taper provided by the pattern maker on all vertical surfaces of the pattern so that it can be removed from the sand without tearing away the sides of the sand mold and without excessive rapping by the molder.

- As per requirement we will mainly consider these two allowances for casting of aluminium 7075 alloy block of dimensions 45* 45* 45mm.
- As per the height of pattern surface in this particular experiment the standard allowances to be considered are as follows

Pattern material	**Height of pattern material (mm)**	**Draft allowances to provided for vertical faces in degrees**
Wood	21 -50	1.5(external) 2.5(internal)

Table 5.1 Draft allowances for aluminium castings

- As per standards the shrinkage allowance for aluminium alloys 13-16 mm/meter

- Dimensions of casting to be prepared 45*45*45mm

- Dimensions of pattern with allowances 46*46*46mm

- The sides of the pattern are finished by using emery papers so as to fulfill the draft allowances

5.1.2 MOLD PREPARATION

Fundamentally, a mold is produced by shaping a refractory material to form a cavity of a desired shape such that molten metal can be poured into the cavity. The mold cavity needs to retain its shape until the metal has solidified and the casting is removed. This sounds easy to accomplish, but depending on the choice of metal, certain characteristics are demanded of the mold. The most common method used to make metal castings is green sand molding. In this process, granular refractory sand is coated with a mixture of bentonite clay, water and, in some cases, other additives. The additives help to harden and hold the mold shape to withstand the pressures of the molten metal. The green sand mixture is compacted through mechanical force or by hand around a pattern to create a mold. The mechanical force can be induced by slinging, jolting, squeezing or by impact/impulse. The first step in the sand casting process is to create the mold for the casting. In an expendable mold process, this step must be performed for each casting as shown in fig 5.2 and 5.3.A sand mold is formed by packing sand into each half of the mold. The sand is packed around the pattern, which is a replica of the external shape of the casting. When the pattern is removed, the cavity that will form the casting remains. Any internal features of the casting that cannot be formed by the pattern are formed by separate cores which are made of sand prior to the formation of the mold. Further details on mold-making will be described in the next section. The mold-making time includes positioning the pattern, packing the sand, and removing the pattern as shown in fig 5.4. The mold- making time is affected by the size of the part, the number of cores, and the type of sand mold. If the mold type requires heating or baking time, the mold-making time is substantially increased. Also, lubrication is often applied to the surfaces of the mold cavity in order to facilitate removal of the casting. The use of a lubricant also improves the flow the metal and can improve the surface finish of the casting. The lubricant that is used is chosen based upon the sand and molten metal temperature.

Fig 5.2 and 5.3 Preparation of mold using green sand and single piece pattern

Fig 5.4 Prepared mold with gating system

5.1.3 CLAMPING

Once the mold has been made, it must be prepared for the molten metal to be poured. The surface of the mold cavity is first lubricated to facilitate the removal of the casting. Then, the cores are positioned and the mold halves are closed and securely clamped together as shown in fig 5.5. It is essential that the mold halves remain securely closed to prevent the loss of any material.

Fig 5.5 Clamping the prepared mold

5.1.3 MELTING AND POURING OF MOLTEN METAL

The molten metal is maintained at a set temperature in a furnace as shown in fig 5.6. After the mold has been clamped, the molten metal can be ladled from its holding container in the furnace and poured into the mold as shown in fig 5.7. The pouring can be performed manually or by an automated machine. Enough molten metal must be poured to fill the entire cavity and all channels in the mold. The filling time is very short in order to prevent early solidification of any one part of the metal.

Fig 5.6 Melting using melting furnace

Fig 5.7 Pouring of molten metal

- **MEASURING TEMPERATURE DURING SOLIDIFICATION PROCESS IN CASTING PROCESS USING INFRARED THERMOMETER**

  Using infrared thermometer temperature variations inside the mold cavity are measured at centre of cavity is observed during filling and solidification process during casting of AA7075. Following figure 5.8 and 5.9 shows measurement of temperature by using infrared thermometer by focusing the laser on to the required object. Infrared thermometer is focused through riser cavity at centre of mold cavity and temperature measured during solidification process and results are tabulated and curve is plotted.

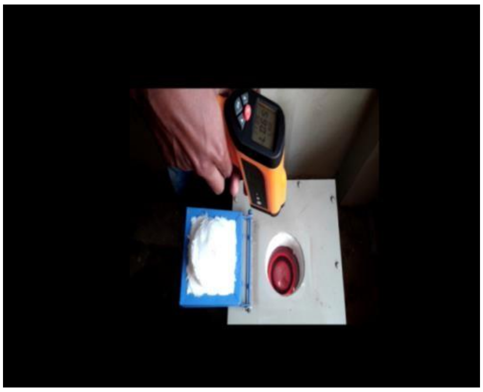


Fig 5.8 and 5.9 Temperature measurement using infrared thermometer

5.1.4 COOLING

The molten metal that is poured into the mold will begin to cool and solidify once it enters the cavity as shown in fig 5.12. When the entire cavity is filled and the molten metal solidifies, the final shape of the casting is formed. The mold cannot be opened until the cooling time has elapsed. The desired cooling time can be estimated based upon the wall thickness of the casting and the temperature of the metal. Most of the possible defects that can occur are a result of the solidification process. If some of the molten metal cools too quickly, the part may exhibit shrinkage, cracks, or incomplete sections. Preventative measures can be taken in designing both the part and the mold and will be explored in later sections.

Fig 5.10 Cooling of mold after pouring the molten metal

5.1.5 FETTLING AND TRIMMING

After the predetermined solidification time has passed, the sand mold can simply be broken, and the casting removed. This step, sometimes called shakeout, is typically performed by a vibrating machine that shakes the sand and casting out of the flask. Once removed, the casting will likely have some sand and oxide layers adhered to the surface. Shot blasting is sometimes used to remove any remaining sand, especially from internal surfaces, and reduce the surface roughness. During cooling, the material from the channels in the mold solidifies attached to the part. This excess material must be trimmed from the casting either manually via cutting or sawing, or using a trimming press. The time required to trim the excess material can be estimated from the size of the casting's envelope. A larger casting will require a longer trimming time. The scrap material that results from this trimming is either discarded or reused in the sand casting process. However, the scrap material may need to be reconditioned to the proper chemical composition before it can be combined with non-recycled metal and reused. The fig 5.11 and 5.12 shows the trimming of casted metal and fettling of mold to remove casted metal.

Fig 5.11 Fettling of the mold

Fig 5.12 Trimming of unwanted material

5.2 TESTING AND INSPECTION OF CASTED METAL

5.2.1 CASTING QUALITY TEST METHODS

Inspection and testing of castings encompasses five main categories: casting finishing, dimensional accuracy, mechanical properties, chemical composition and casting soundness.

- **Casting Finish**

The surface finish of a metal casting can be influenced by the type of pattern or molding sand, mold coating, and method of cleaning. So far, instrumentation for measuring surface roughness has not provided a useful evaluation, so it is performed largely through simple visual comparison using a series of test panels with increasing surface roughness.

- **Dimensional Accuracy**

Variation in the dimensions of a casting can be the result of mold cavity expansion caused by the heat and head pressure of molten metal, the contraction of the metal as it cools and heat treatment. These expansions and contractions are predicted by the patternmaker who will compensate for the variations in the pattern's design. For large volumes of castings, casting facilities may measure the critical dimensions of the castings more often to check for possible drift, particularly drift due to pattern wear. If a casting requires tight tolerances that are critical to the part's application, those tolerances should be specified by the customer. Casting customers should check how their casting supplier will verify the dimensions of the parts they produce. The accuracy of the measuring tools is just as important as the dimensional accuracy of the castings. In many instances, the gauges or fixtures needed to routinely check the dimension are supplied to the casting facility by the customer. Expecting exact dimensions over the course of a production run will result in frustration. The dimensions of each casting will vary slightly, so castings are specified by setting a range of values that the dimensions can fall within. The range between the lower tolerance limit and upper tolerance limit can be set by the supplier, but the narrower the range, the more difficult to produce and test and therefore more costly the casting will be.

- **Mechanical Properties**

Mechanical testing gives an evaluation of the metal and the casting to determine whether the properties are in compliance with the specified mechanical requirements. Following are common mechanical tests used in metal casting facilities.

- **Hardness testing**

The most commonly used procedure for mechanical property testing, it provides a numerical value and is non-destructive. Hardness values generally relate to an alloy's mach inability and wear resistance. The Brinell hardness test uses a 10-mm diameter carbide ball to indent a 3,000-kg load. The impressions are large enough to provide a dependable average hardness. Rockwell hardness tests make smaller indented impressions, which also can be satisfactory if the median of several values is used.

- **Tensile and impact testing**

Conducted on test specimens of standardized dimensions, the two most common types are tensile and charpy impact. Tensile testing provides ultimate tensile strength, yield strength, elongation and reduction of area data. Charpy impact testing determines the amount of energy absorbed during fracture and is used to gauge ductility and strength.

- **Service load testing**

Usually conducted on the entire casting to evaluate its properties, it can be conducted in a number of ways. Castings that must carry a structural load can have a load applied in a fixture while the deflection and the load are measured. Pressure-containing parts can be hydraulically tested to a proof load or destruction. Rotating parts can be spin tested. These types of tests check the soundness of the casting, as well as its properties.

❑ Chemical Composition

The chemical composition of an alloy has a significant bearing on its performance properties. Chemical composition can be further affected by minor alloying elements added to the material. Casting alloys are typically specified accorded to ASTM, SAE and AMS alloy specifications.

5.2.2 HARDNESS TEST

Hardness test experiments are efficient way of measuring hardness of an engineering material. Hardness is a measure of a material's resistance to localized plastic deformation. Hardness of a material describes how hard it is to deform that particular material. Quantitative hardness techniques involve a small indenter, where the indenter is forced on to a surface of a material to be tested. The force and the rate of load application are controlled by the Universal Hardness Tester. The reason why hardness tests are widely and frequently used are: they are simple and inexpensive, the test is non-destructive and the process is very quick. The hardness data is very helpful information for any engineering material as this data can be used to estimate different mechanical properties. Fig 5.13 shows shaping of casted object to test for hardness.

Fig 5.13 Shaping of casted metal

Fig 5.14 Rockwell hardness

testing machine

Rockwell hardness testing machine shown in fig 5.14 was chosen for finding the hardness of both base and deformed base. Constant load of 100 kgf was maintained during evaluation of hardness and sufficient dwell period about 15 seconds was allowed. Reported hardness data was based on the average of 5 readings and obtained one was rounded off to nearest whole number. Indentations were made on flat surface material. Fig 5.15 depicts the Rockwell hardness testing machine for finding the hardness using diamond intender. As the base metal is being steel family B-scale has been adopted.

5.2.3 MICROSTRUCTURE EXAMINATION

Microscopic examinations could satisfy many purposes and one of the key persistence of it in materials engineering is examining defects in materials. Defects in a material determine important properties and performing microstructure examinations helps to develop relations between the microstructure of the material and its properties. Defects and imperfections are crucial factors and there are many types of defects. The purpose of the experiment was to inspect the microstructure, the shape and size of the grains for different samples. The experiment was performed with optical microscope which is not as precise as electronic microscopes but is very easy to use and the results can be achieved much faster.

❑ Mounting

Mounting is chosen for supporting the specimens, which includes the process of compressing and heating Bakelite powder around a work specimen in order to form a solid disk or puck that can be used to handle the sample easier. Fig 5.15 depicts the mounting machine for supporting the specimens in order to view the microstructure of the specimen properly and fig 5.16 shows the prepared specimens after mounting.

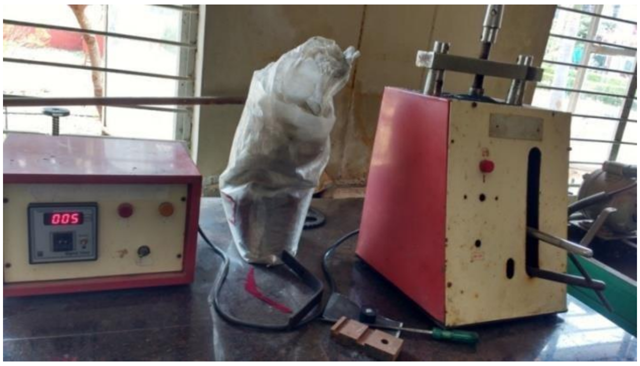


Fig 5.15 Specimen mounting press

Fig 5.16 Specimens mounted using mounting machine

- **Surface finishing operation**

Any topographical irregularities present on the surface are made flatten by using belt grinder and it is used to finish the work pieces that much show high surface quality and high accuracy of shape and dimension. Belt grinding is a versatile process suitable for all kind of applications, including finishing, de burring, and stock removal. Fig 5.17 depicts the belt grinder machine for removing the sharp edges of different samples.

Fig 5.17 Belt grinder for surface finishing operation

- **Optical microscopy**

Specimens were cut from casted metal (AA7075 aluminium alloy) and formed specimens were subjected to standard metallographic practice to obtain scratch free surface. Metallographic examination was carried out to understand the distribution of precipitates in the matrix of base Keller's reagent (95% H_2O, 2.5% HNO_3, 1.5% HCl,1% HF) was used as etchant to reveal the microstructure Polished and etched samples were examined under inverted trinocular metallurgical microscope shown in fig 5.18 (make: Dewinter India, New Delhi) under magnification of100x.

Fig 5.18 Observation of micro structures using inverted trinocular microscope

Chapter 6

RESULTS AND ANALYSIS

6.1 RESULTS & ANALYSIS OF CASTING SIMULATION

▣DURING FILLING

The gating design has driven by the ideal mold filling time, which depends on the cast metal, casting weight and minimum wall thickness. Fast filling leads to turbulence related defects (such as mold erosion, air aspiration and inclusions). On the other hand, slow filling may cause defects related to premature solidification (such as cold shuts and miss runs). To optimize the gating design, the program simulates the mold filling and computes the total fill Time.

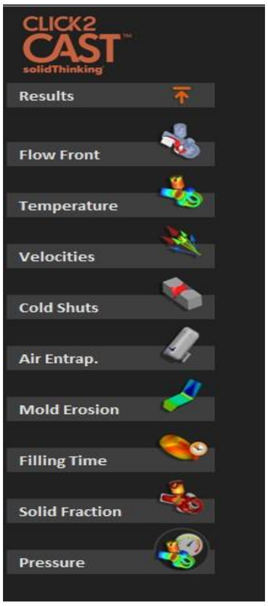


Fig 6.1 Filling results that can be obtained by simulation using click2cast

6.1.1 VARIATION OF VELOCITY DURING FILLING

The Optimal Filling Time depends on the speed of flow that is of the molten metal. This mostly varies within the gating channels and the mold openings. The metal will be hot and fast at these locations and thus it leads to huge damage if the flow is not maintained properly. The speed of the molten metal depends on two factors. The metallostatic head and the ratio of cross-sections of sprue exit, runner and ingates. Fig 6.2, 6.3, 6.4, 6.5 shows the results of rate of flow of velocity in mold cavity at various filling rates using simulation software. Velocity variations will also shows volumetric rate in which the liquid metal is introduced into the mold. Pouring velocity needs to be carefully controlled during the metal casting operation, since it has certain effects on the manufacture of the part. If the pouring velocity is too fast, then turbulence can result. If it is too slow, the metal may begin to solidify before filling the mold.

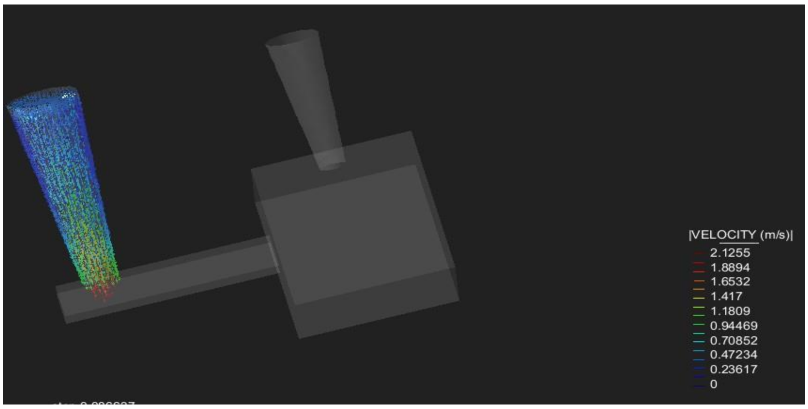


Fig 6.2 Velocity variations after 25% filling of mold

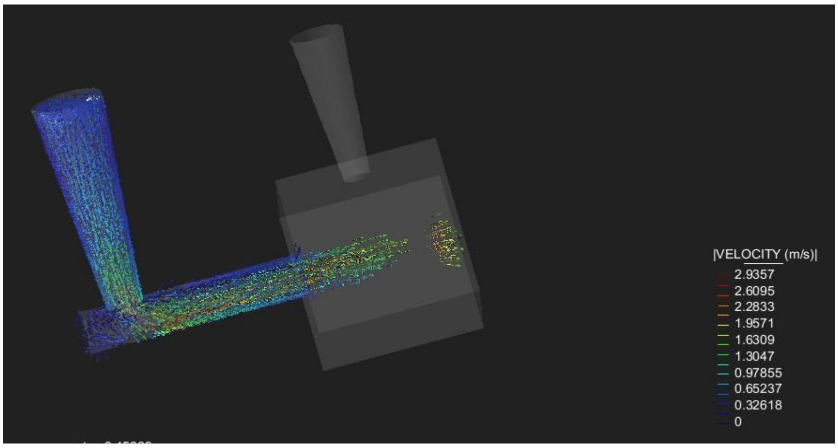


Fig 6.3 Velocity variations after 50% filling of mold

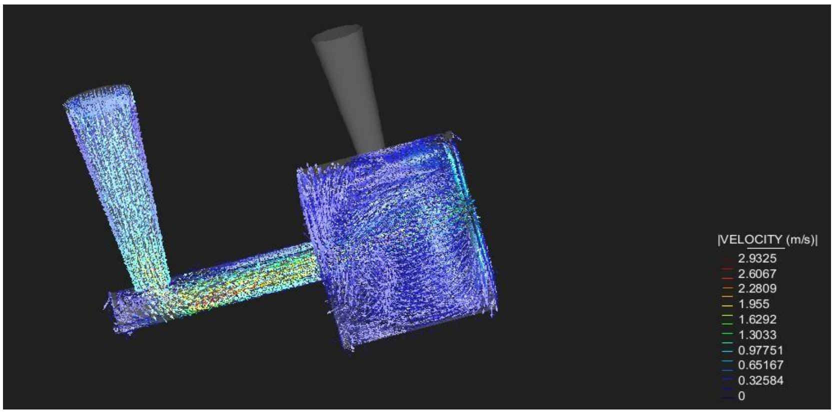


Fig 6.4 Velocity variations after 75% filling of mold

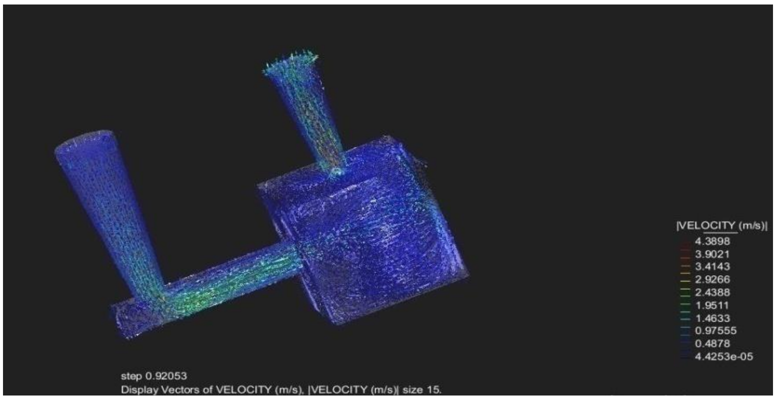


Fig 6.5 Velocity variations after complete filling of mold

- From the results of velocity it is clear that the filling velocity is being increased as shown in fig 6.2 due to effect of gravity as well as the tapering of the sprue which avoids air aspiration effect and molten metal flows into the mold cavity and also there is no sudden changes observed in the velocity variations from fig 6.5 which shows there is no defect in gating system.

6.1.2 VARIATION OF TEMPERATURE DURING FILLING

Pouring temperature refers to the initial temperature of the molten metal used for the casting as it is poured into the mold. This temperature will obviously be higher than the solidification temperature of the metal. The difference between the solidification temperature and the pouring temperature of the metal is called the superheat. Fig 6.6 shows the variation of temperature in mold during filling process

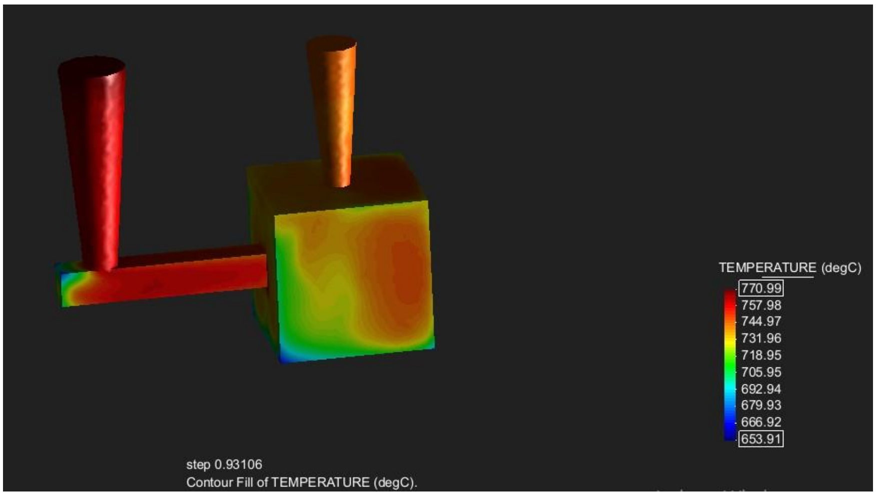


Fig 6.6 Variation temperature of mold during filling process

- From the fig 6.6 which shows the results of temperature during filling and from the results it is clear that temperature at sprue area as well as sprue base is more due to continuous travel of molten metal which is at high temperature and as the metal enters mold cavity and comes out through riser and the bottom part of mold cavity will not experience much temperature than other parts of gating system and variation of temperature during filling depends upon the temperature of molten metal.

6.1.3 VARIATION OF PRESSURE DURING FILLING

Pressure is expressed as ℓ*g* h where ℓ is metal density and h is height of liquid metal column above the filling point. Fluidity, a technological feature, reflects the ability of liquid metal to flow continuously even as it solidifies via a given mold passage, filling it to reproduce the detailed design. When the molten metal rises in the mold, filling can be hindered due to the backpressure created by compressed air in the cavity thereby reducing the metallostatic pressure. Venting enables to regulate the back pressure.

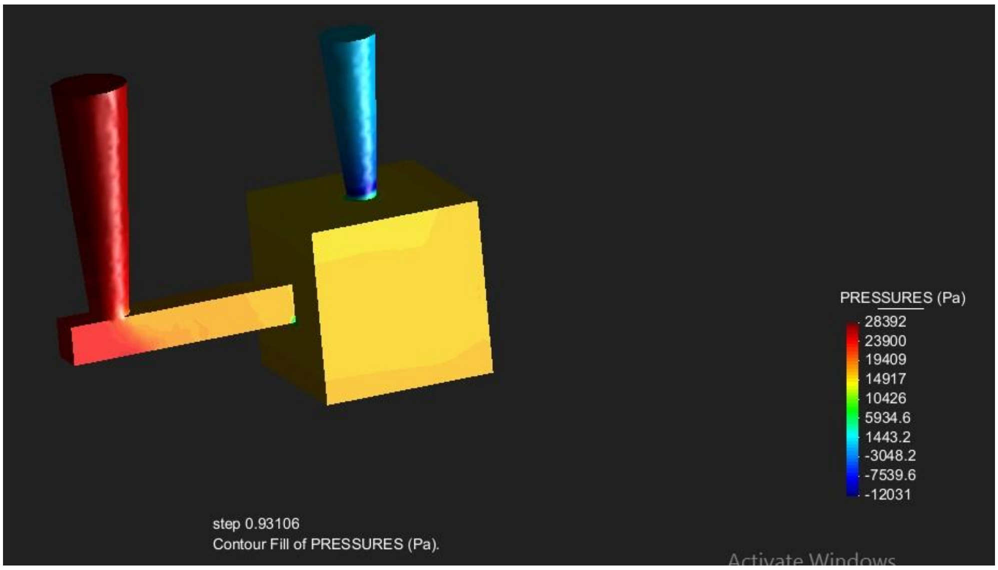


Fig 6.7 Variation of pressure in mold during filling process

- From the fig 6.7 it is clear that pressure concentration will be greater at sprue and sprue base due to continuous pouring of molten metal which is at higher temperature and remaining areas like riser will have less pressure as venting enables to regulate the pressure. If the pressure concentration is more at sprue , runner , pouring basin is high there will be no effect on the casted object as they are trimmed and scrapped later but if the pressure concentration is high at mould cavity necessary measures should be taken and design need to be modified. From this particular analysis as shown in fig 6.7 variations at mold cavity are not so high and these can be controlled by providing vent holes while experimentation to regulate pressure and to eliminate defects.

6.1.4 COLD SHUTS FORMED DURING FILLING

Poor fluidity of molten metal gives rise to cold shut or misrun. Cold shut occurs when streams of molten metal arising from opposite direction fail to fuse completely. Fig 6.8 shows results of cold shuts formed in casting during filling process.

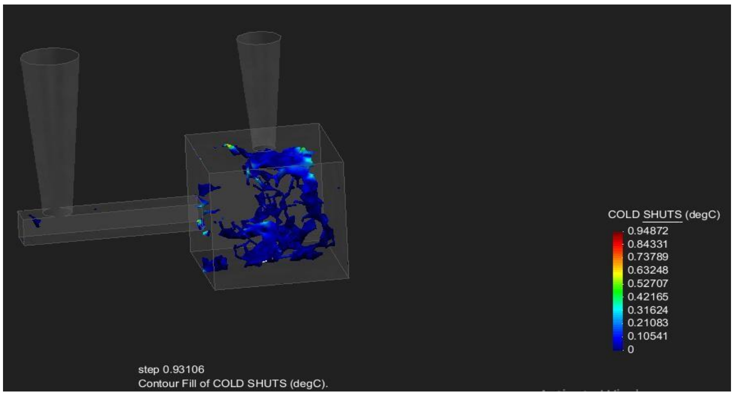


Fig 6.8 Cold shuts formation during filling process

- From the fig 6.8 it is observed that cold shuts formed at mold cavity and riser areas which are minor but it is very common as the metal enters the runner path and there on into the mold cavity the streams of molten metal arise from opposite direction may not fuse properly. From fig 6.8 it is clear from the profile of shuts formed shows that they are not major defect if it is major then the gating system design has to be modified.

6.1.5 AIR ENTRAPED DURING FILLING

Air entrapment shows the amount of entrained air occurring in metal casting systems, such as gravity-poured casting processes. It is based on simple physical mechanisms, which means it can also be used to estimate the amount of entrained air occurring in other metal casting systems. Recent additions of even more physical details in the model allow entrained air, which is assumed to be in the form of bubbles, to be modelled as rising in the surrounding liquid metal because of buoyancy forces and even leaving the liquid if it reaches a free surface.

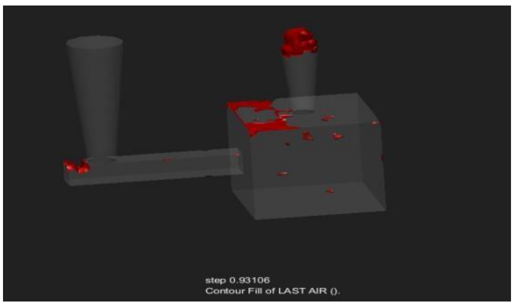


Fig 6.9 Air entrapped during filling process

- From the fig 6.9 it is clear that the air entrapped majorly at riser cavity and upper portion of mold cavity as the filling starts from the sprue area, the air inside the cavity at riser will be entrapped and bubbles are formed as the filling is continuous and time taken for filling is very fast.

▣ DURING SOLIDIFICATION

The solidification of liquid metal in the mold cavity takes place immediately after entering into the cavity Solidification is a result of heat transfer from internal casting to external environment and the rate of solidification is not uniform throughout the casting. The solidification of liquid metal in the mold cavity starts from the edges of the casting and it progress towards the centre of the casting. The solidification front directed from the thinnest section towards the thickest section and the thinner section solidifies quicker comparison to the thickest section.fig 6.10 shows the solidification results that can be executed using simulation software.

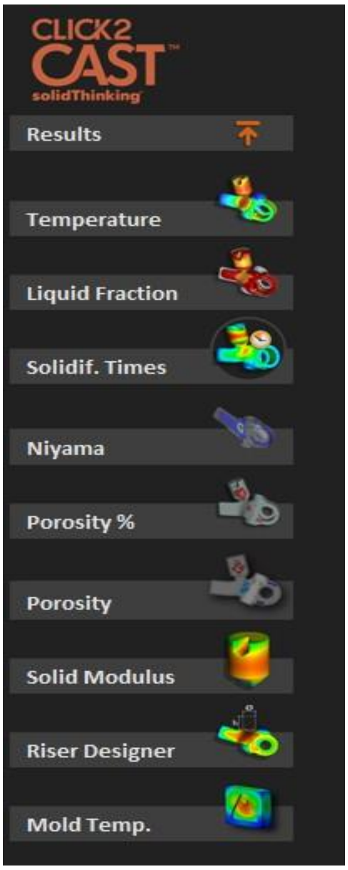


Fig 6.10 Solidification results that can be executed through simulation software

6.1.6 SOLIDIFICATION TIME

The parameters like casting geometry, material and process of casting determine the solidification time of a casting.

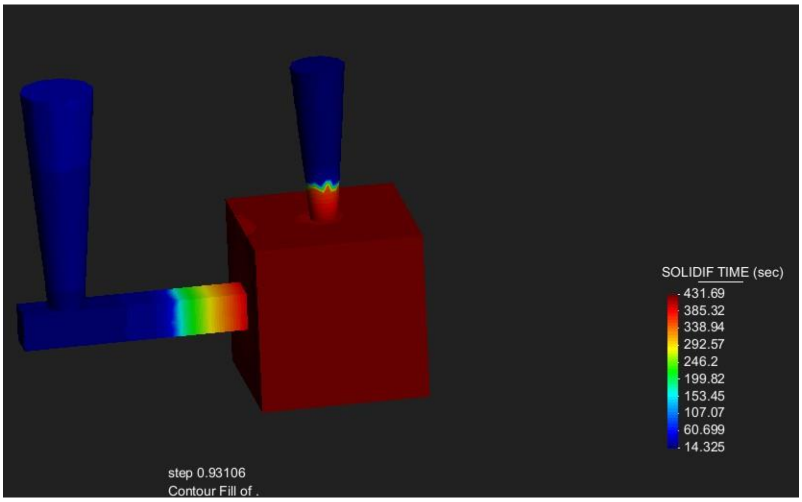


Fig 6.11 Solidification time for casting

- From the results it is clear that time taken for solidification at mold cavity will be more when compared to remaining parts of gating system due to ventilation at sprue and riser and due to absence of air at mold cavity as shown in fig 6.11 it takes more time for solidification. Solidification time also depends upon the mold material, surface area. The solidification time will not be uniform throughout the casting. The solidification of liquid metal in the mold cavity starts from the edges of the casting and it progress towards the centre of the casting so the time taken at the centre of cavity will be greater obviously.

6.1.7 POROSITY (%) OBSERVED DURING SOLIDIFICATION

The casting voids most often referred to as porosity can be caused by gas formation, solidification shrinkage, or non-metallic compound formation, all while the metal is liquid. Large gas-related voids caused by trapped mold or core gases in the molten metal are called blows or blowholes.

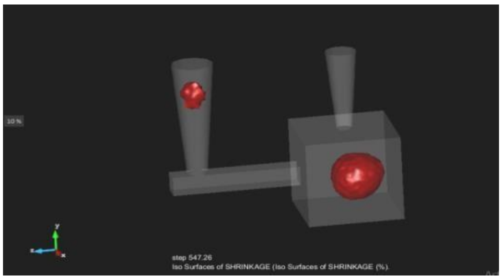


Fig 6.12 Porosity (%) during solidification process

- From the results of porosity observed that the porosity at inner part of mold cavity is high due to gas formation and during solidification it is very common that the mold cavity cools slowly and inner most part of the casting may not solidify properly as shown in fig 6.12 and there is also increase in porosity at centre due to continuous flow of molten metal.

6.1.8 MACRO POROSITY OBSERVED

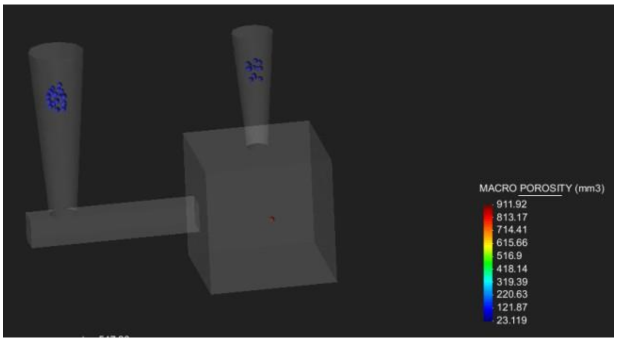


Fig 6.13 Macro Porosity during solidification process

- ❑ From the results of micro porosity it is clear that the solidification shrinkage at sprue and riser will have less effect as shown in fig 6.13 and as the gating system is scraped later it will not influence the properties of casted metal

6.1.9 SOLIDIFICATION MODULUS

In the field of foundry technology, modulus is defined as the ratio between volume and heat-emitting surface. Calculation of the modulus is used to determine and approximately calculate the solidification time of a casting approximately.

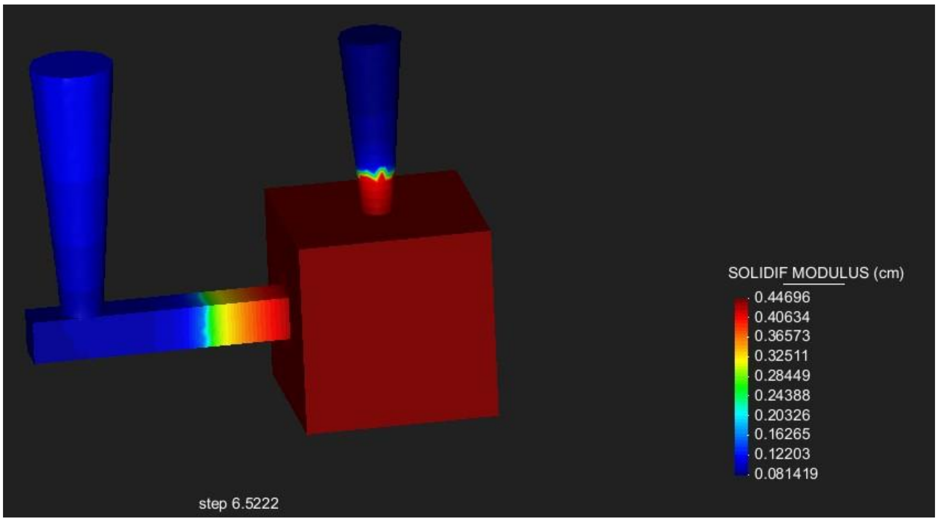


Fig 6.14 Solidification modulus during solidification process

- ❑ The modulus has such specificity that during process of casting formation, it is not a constant but its initial value decreases with the solidification progress because the remaining melt volume can decrease faster than its cooling surface. From the figure 6.14 it is clear that the modulus at mold cavity will be more due to more surface area.

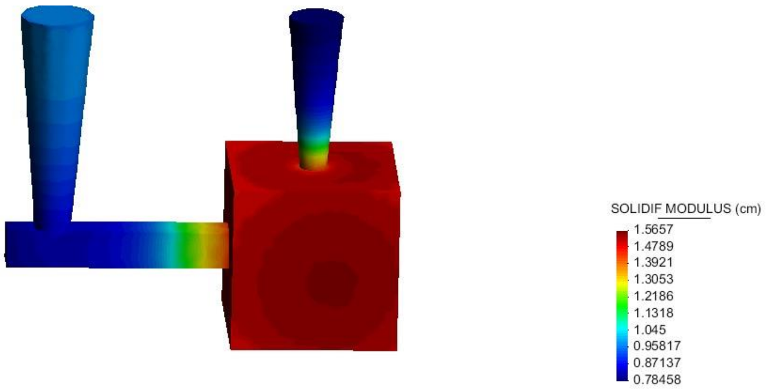


Fig 6.15 Solidification modulus during solidification process in ceramic mold

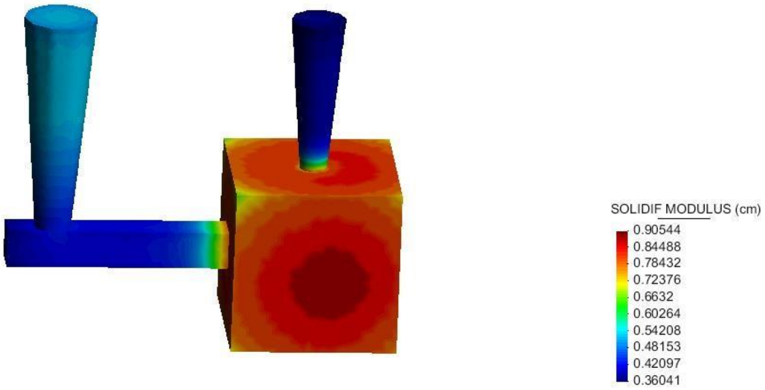


Fig 6.16 Solidification modulus during solidification process in H13 steel mold

- Fig 6.15 and 6.16 depicts the solidification modulus analysis of aluminium 7075 castings using grey cast iron and h13 steel molds respectively and these results shows that the solidification modulus will also depends upon the mold material. From the results it is clear that the solidification modulus varies and it is directly proportional to rate of solidification.

6.1.10 SOLIDIFICATION TEMPERATURE ANALYSIS

The solidification of liquid metal in the mold cavity takes place immediately after entering into the cavity Solidification is a result of heat transfer from internal casting to external environment and the rate of solidification is not uniform throughout the casting. The solidification of liquid metal in the mold cavity starts from the edges of the casting and it progress towards the centre of the casting. The solidification front directed from the thinnest section towards the thickest section and the thinner section solidifies quicker comparison to the thickest section.

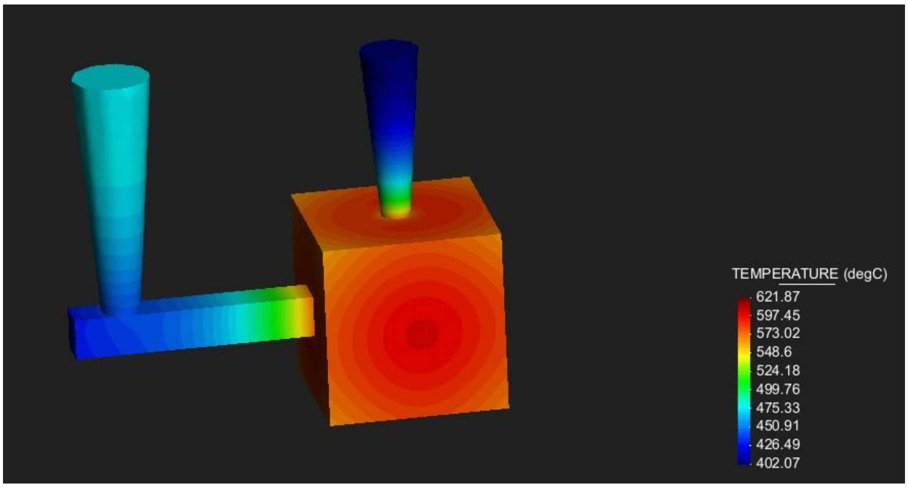


Fig 6.17 Solidification temperature variation at 25% solidification process

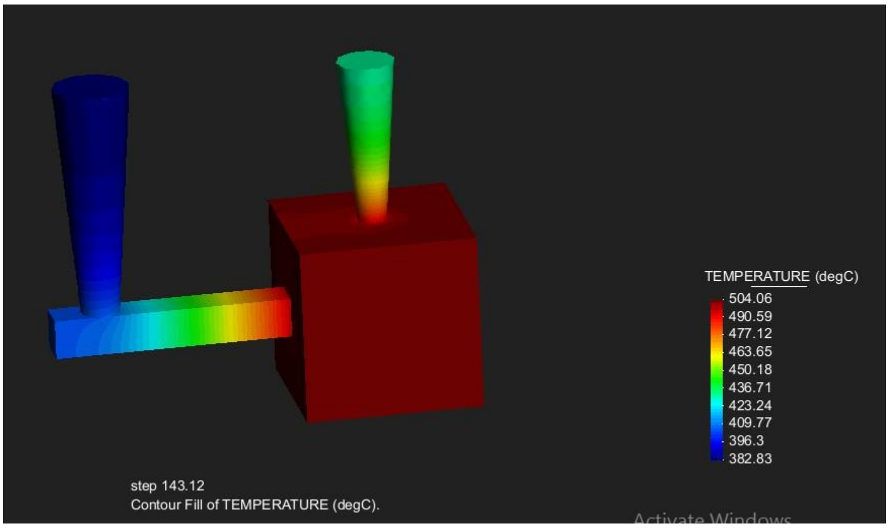


Fig 6.18 Solidification temperature variation at 50% solidification process

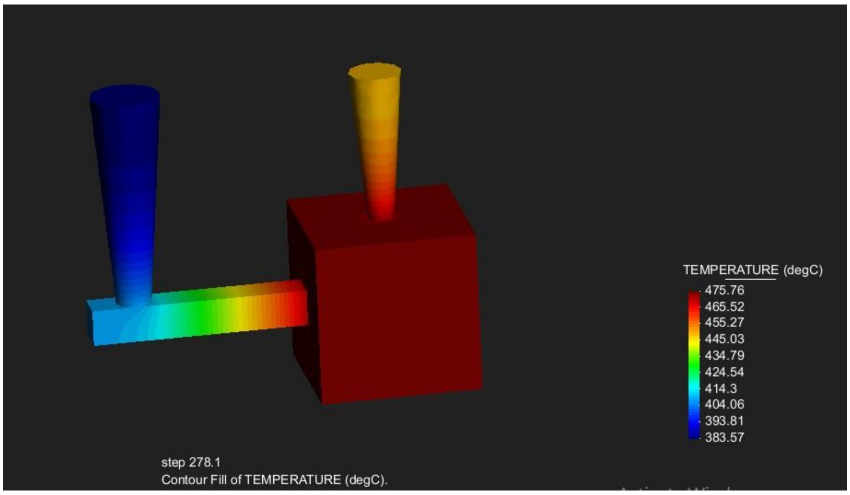


Fig 6.19 Solidification temperature variation at 75% solidification process

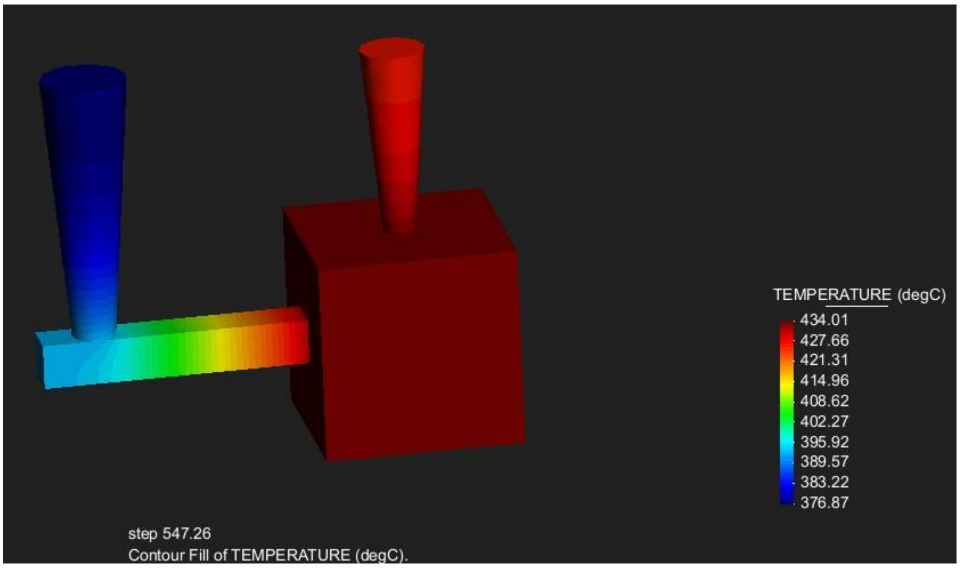


Fig 6.20 Solidification temperature variation at 100% solidification process

- From the results it is clear that solidification temperature will be more at the mold cavity due to no proper ventilation or absence of air and solidification time for mold cavity will be more when compared to remaining parts of gating system due to ventilation at sprue and riser and due to absence of air at mold cavity as shown in fig 6.20.solidification time will be less at sprue and riser. Solidification temperature depends upon the surface area of the mold material, rate of heat transfer and temperature of liquid metal and properties of mold material.
- As solidification process is the most important process in casting process it is important to study about the variation of temperature during solidification process. So by using the simulation software solidification temperature for other mold material with same casting material is analysed to understand the solidification process as shown in fig6.21.

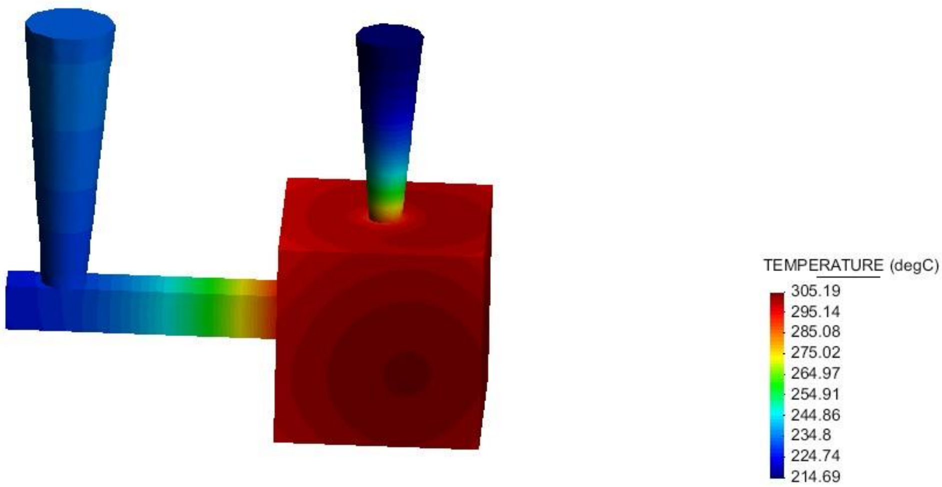


Fig 6.21 Variation of temperature at 100% solidification process for grey cast iron mold

- From the fig 6.20 and 6.21 the material used for casting used in both the cases is aluminium 7075 alloy but the solidification temperature varies because of the mold material. The solidification for gray cast iron mold will be fast due to faster heat transfer rate that is due to high thermal conductivity and specific heat capacity of grey cast iron.

6.1.11 MOLD INNER TEMPERATURE ANALYSIS

Mold material should have ability of the molding material to resist the temperature of the liquid metal to be poured so that it does not get fused with the metal. During pouring and subsequent solidification of a casting, a large amount of gases and steam is generated. These gases are those that have been absorbed by the metal during melting, air absorbed from the atmosphere and the steam generated by the molding and core sand. If these gases are not allowed to escape from the mold, they would be entrapped inside the casting and cause casting defects. To overcome this problem the molding material must be porous. Proper venting of the mold also helps in escaping the gases that are generated inside the mold cavity.

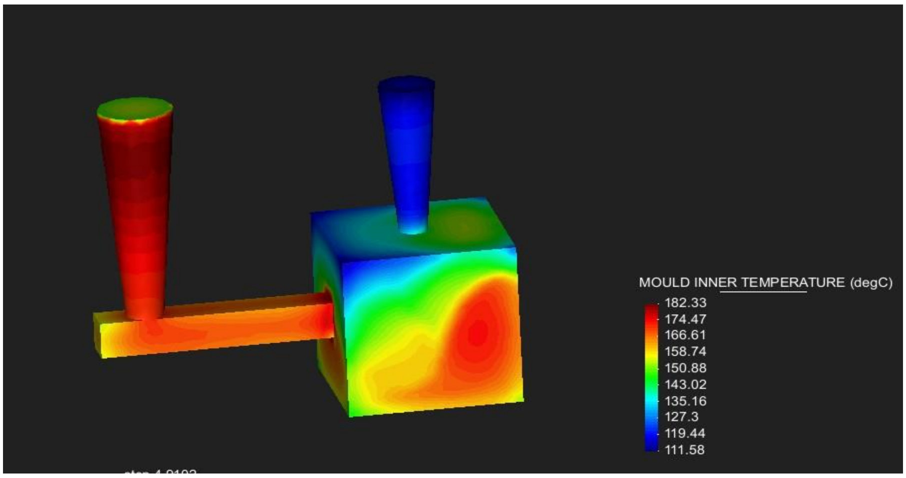


Fig 6.22 Mold inner temperature variation at 25% solidification process

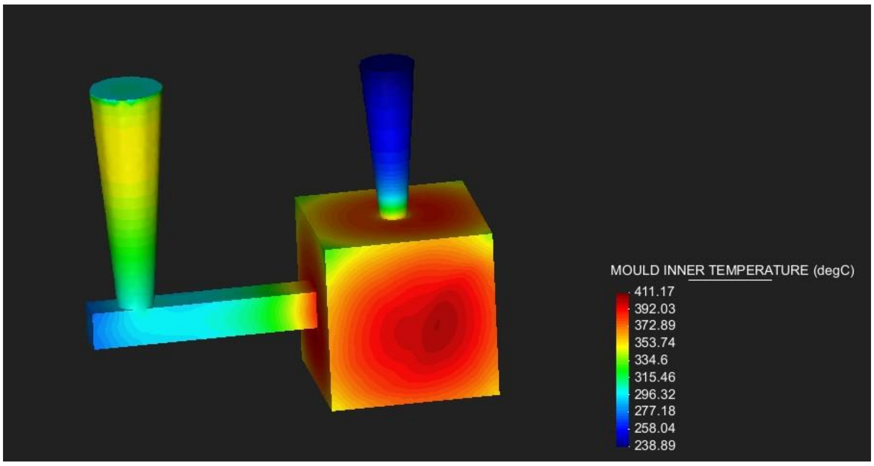


Fig 6.23 Mold inner temperature variation at 50% solidification process

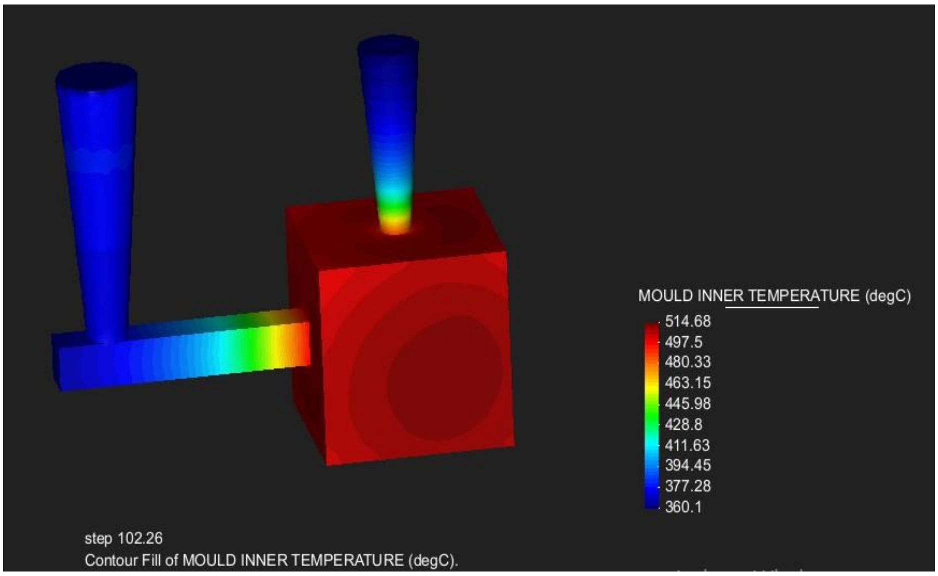


Fig 6.24 Mold inner temperature variation at 75% solidification process

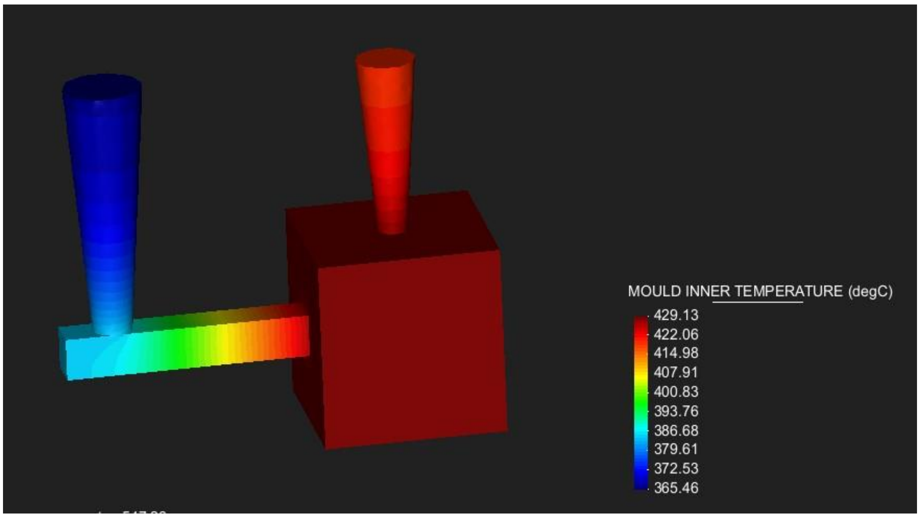


Fig 6.25 Mold inner temperature variation at 100% solidification process.

- Mold material should have ability of the molding material to resist the temperature of the liquid metal to be poured so that it does not get fused with the metal. During pouring and subsequent solidification of a casting, a large amount of gases and steam is generated. These gases are those that have been absorbed by the metal during melting, air absorbed from the atmosphere and the steam generated by the molding and core sand. Mold inner temperature at mold cavity will be more as shown in fig 6.25 and as the solidification progresses mold inner temperature at mold cavity increases and at remaining parts of gating system mold inner temperature decreases.

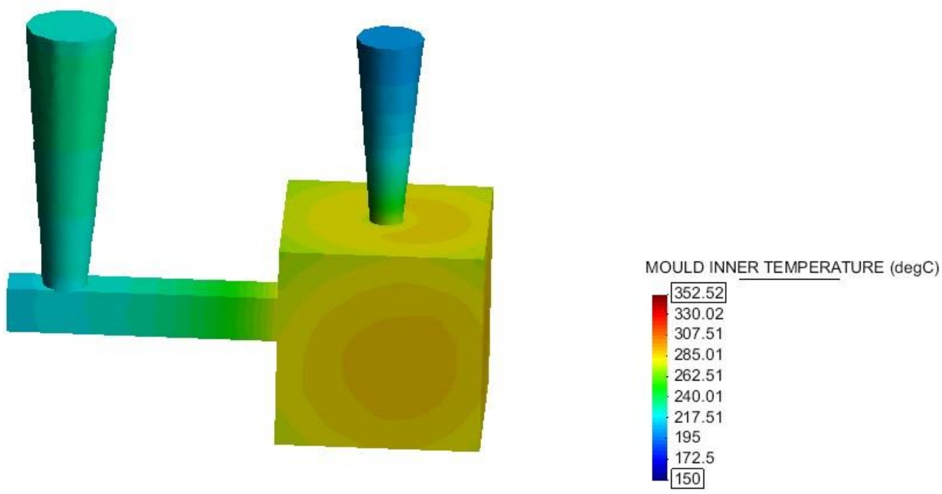


Fig 6.26 Mold inner temperature at 100% solidification in grey cast iron mold

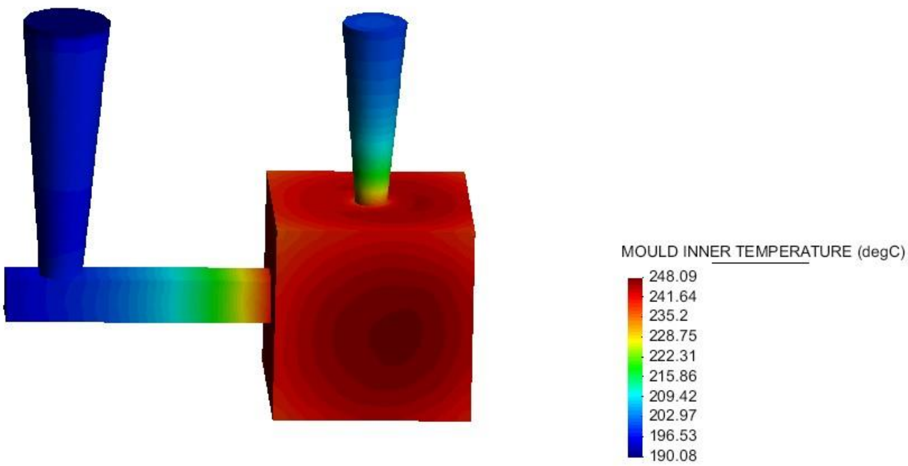


Fig 6.27 Mold inner temperature at 100% solidification in ceramic mold

- Fig 6.26 and 6.27 shows the analysis of mold inner temperature in casting of aluminium 7075 alloy using grey cast iron and ceramic molds respectively. From the results it is concluded that the variation of mold inner temperature depends upon the thermal conductivity and specific heat capacity of mold material.

6.2 RESULTS & ANALYSIS OF CASTING EXPERIMENTATION

- **MEASURING TEMPERATURE AT CENTRE OF MOLD CAVITY DURING SOLIDIFICATION OF CASTING PROCESS USING INFRARED THERMOMETER**

An infrared thermometer is a thermometer which infers temperature from a portion of thermal radiations emitted by object being measured. It is also called as laser thermometer as the laser is used to help aim the thermometer. It is a non contact type thermometer and just by amount of infrared energy emitted by the surface of object and this serves as alternative where thermocouples are used.

Using infrared thermometer temperature variations inside the mold cavity are measured at centre of cavity is observed during solidification process during casting of AA7075. Following table shows measurement of temperature by using infrared thermometer by focusing the laser on to the required object. Infrared thermometer is focused through riser cavity at centre of mold cavity and temperature measured during solidification process and results are tabulated and curve is plotted temperature versus time.

Time (in sec)	Temperature(in deg .centigrade)
Initial	**619**
10	**594**
30	**578**
50	**561**
70	**546**
90	**527**
110	**509**
130	**483**
150	**469**
170	**445**
190	**413**
210	**392**
230	**384**
250	**376**
270	**365**
290	**310**
310	**296**
330	**273**
350	**245**
370	**239**
400	**224**

Table 6.1 Results of experimental analysis of solidification process

- Graph plotted using results obtained during solidification process shown in fig6.23.

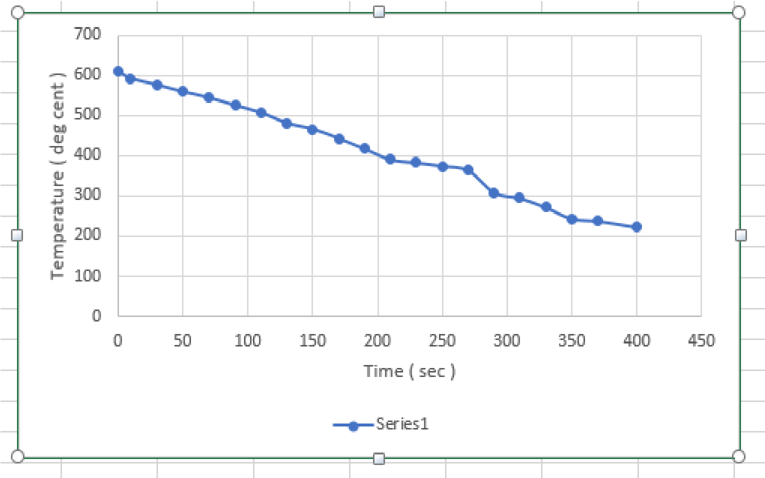


Fig 6.28 Time vs Temperature graph during solidification process

- From the results obtained as shown in table 6.1, during the solidification process experimentally and it is clear that the variations in temperature are gradual and the results of experiment are in good agreement with the simulation results.
- Fig 6.28 depicts the cooling curve of this sand casting process and the cooling curve is a line graph that represents the change of phase of matter from liquid to solid. The initial point is the pouring temperature and from there gradual cooling during solidification is observed and plotted as shown in 6.28. This curve helps in comparison of simulation results obtained for the same casting process.

6.3 COMPARISON OF THE SOLIDIFICATION TEMPERATURE VARIATIONS DURING SIMULATION AND EXPERIMENTAL ANALYSIS OF CASTING PROCESS

- From the results obtained in simulation process for solidification temperature variations and the results obtained in experimental analysis of solidification temperature variations a comparison is made to analyse the agreement of the simulation results with the experimental results. As the solidification process is the most important step in casting process and also determination of parameters during experimental analysis is very limited and the solidification temperature analysis is the only parameter that can be measured effectively during solidification process.

- From the figures 6.17, 6.18, 6.19, 6.20 the temperature variations observed and the graph is plotted from the simulation results.

❑

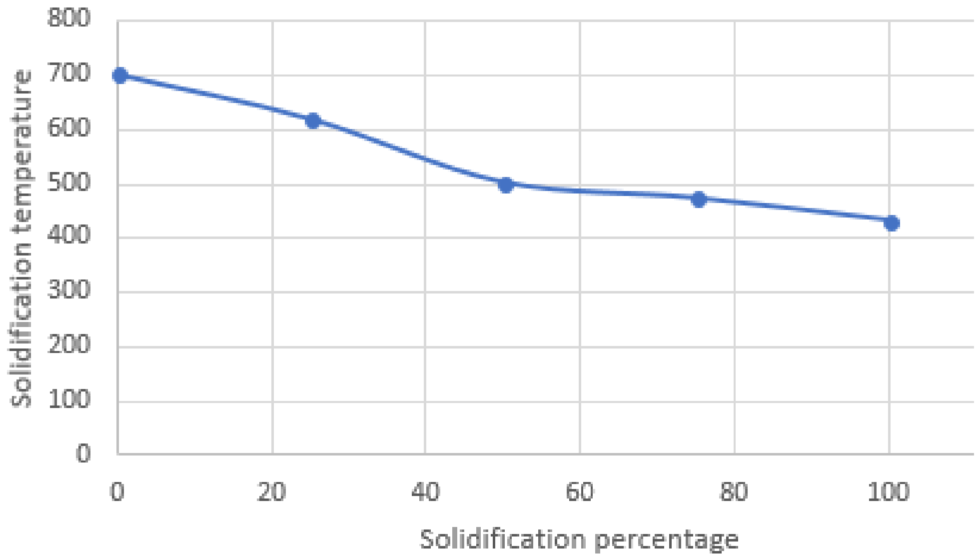


Fig 6.29 Graph showing the variation solidification temperature from simulation Results

❑

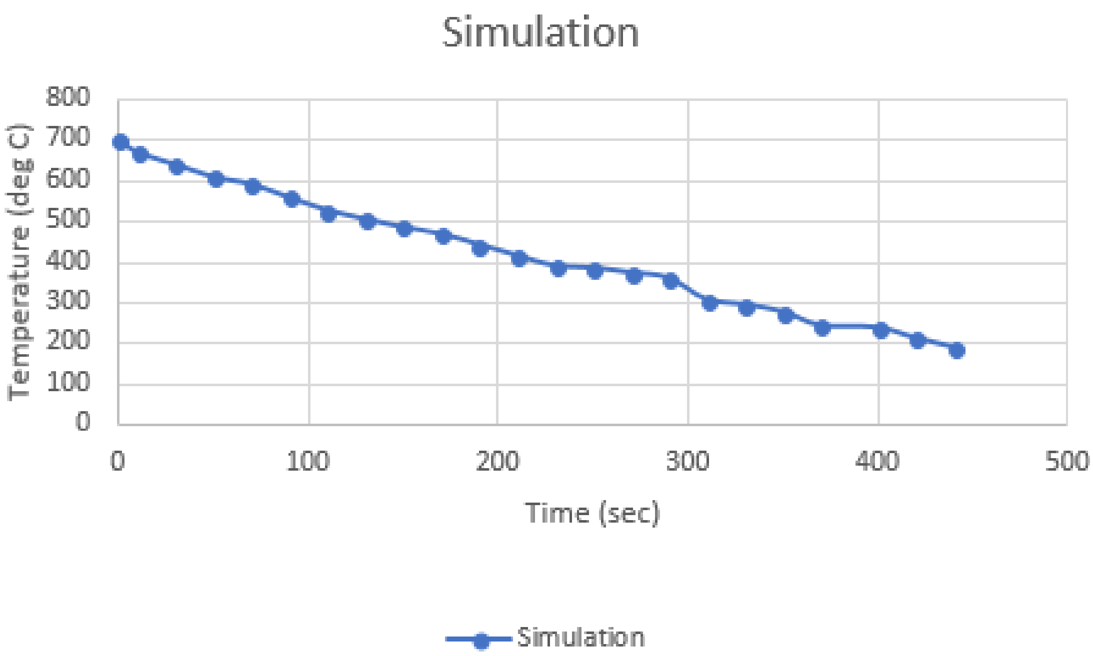


Fig 6.30 Time Vs Temperature graph showing solidification results during solidification process

⊡COMPARISON OF SIMULATION AND EXPERIMENTAL RESULTS OF SOLIDIFICATION PROCESS

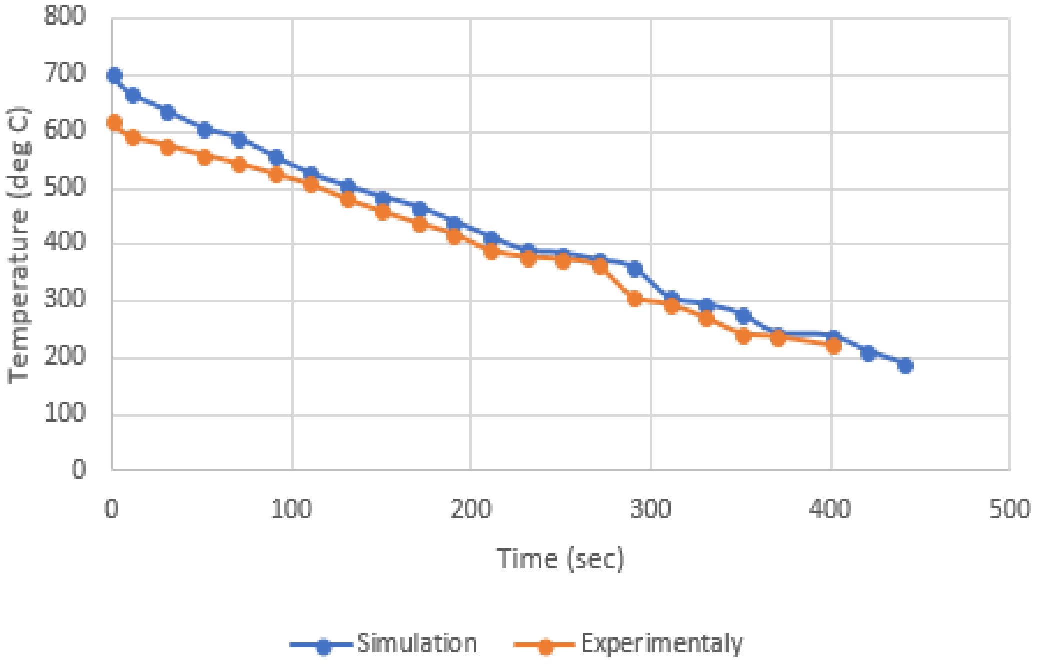


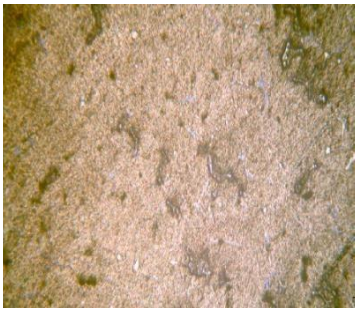
Fig 6.31 Graph showing the simulation and experimental results of solidification process

- From the fig 6.31 which shows the comparison of solidification temperature during casting process and the comparison shows that the experimental results are in good agreement with the simulation results and the variations may be due to atmospheric conditions where casting process is performed and errors occurred while measuring with the infrared thermometer.

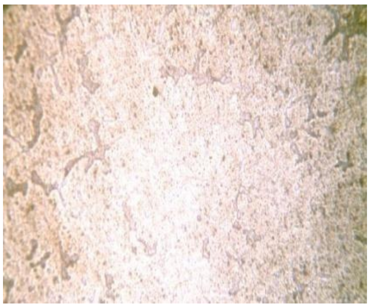
6.4 MICROSCOPIC EXAMINATION OF CASTED OBJECT

After the fettling and trimming the casted object three samples were collected from three faces and subjected to microscopic examination. Following figures show the results obtained microstructures examined under metallurgical microscope under magnification of 100x.

Microscopic examinations could satisfy many purposes and one of the key persistence of it in materials engineering is examining defects in materials. Defects in a material determine important properties and performing microstructure examinations helps to develop relations between the microstructure of the material and its properties. Defects and imperfections are crucial factors and there are many types of defects. The purpose of the experiment was to inspect the microstructure, the shape and size of the grains for different samples.



BOTTOM FACESAMPLE



TOPFACESAMPLE

SIDE FACE SAMPLE

Fig 6.32 Microstructures observed for all samples

- From the results it is clear that the grains in side face sample are fine grains and bottom face sample has coarse grains the reason for grain size variation may be due to effect of heat transfer during the solidification process. As the solidification progresses the improper heat transfer rate at bottom face of casted object may be the reason for coarse grains and ramming of sand tightly at the cavity may reduce this effect. Top face and side face grains are all most fine grains but the reason for difference in grain size may be the top face exposed to little ventilation and connected to riser and the solidification at the connections of gating system may not be proper due to variation in geometry at the boundaries.

6.5 RESULTS & ANALYSIS OF HARDNESS TEST

From the results of microscopic examination on the casted object different grain sizes are observed for the different faces of casted object. So in order to investigate the parameters hardness test is carried out on the three faces of casted object

POSITION OF INDENTATION	TOP FACE OF CASTED OBJECT	SIDE FACE OF CASTED OBJECT	BOTTOM FACE OF CASTED OBJECT
8 mm away from centre to left	90	75	31
4mm away from centre to left	58	92	36
At centre of object	59	93	33
4mm away from centre to right	61	96	32
8 mm away from centre to right	50	77	41
AVERAGE HARDNESS VALUE	63.6	86.4	34.6

Table 6.2 Results of hardness test

❑ RESULTS OF HARDNESS TEST

- Standard hardness (Rockwell B) 87
- Top face of casted object (series1) 63.6
- Side face of casted object (series2) 86.4
- Bottom face of casted object (series3) 34.6

❑ GRAPHICAL REPRESENTATION OF HARDESS

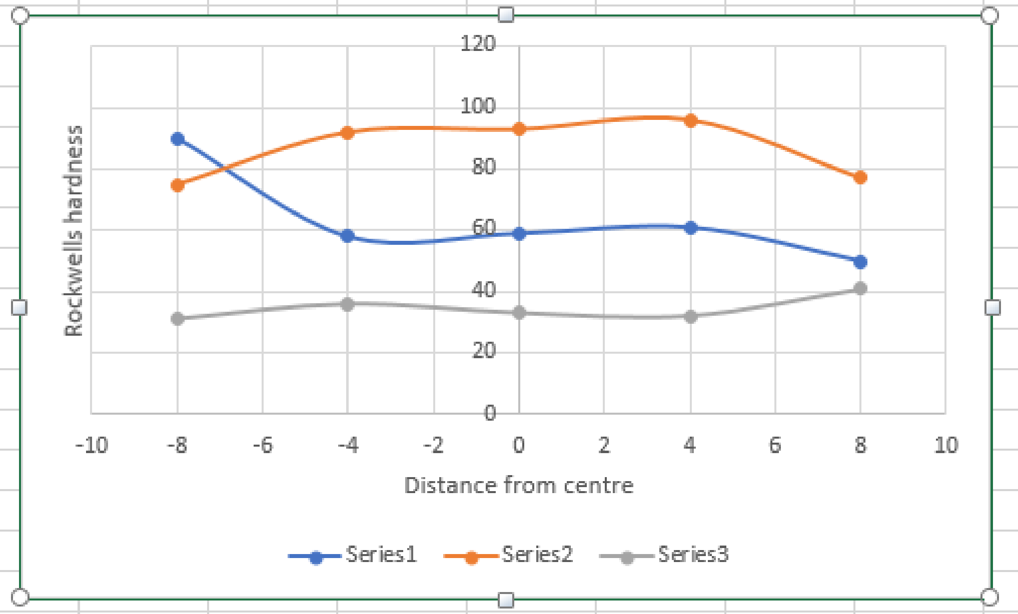


Fig 6.33 Graphical representation of hardness values

- Hardness test experiments are efficient way of measuring hardness of an engineering material. Hardness is a measure of a material's resistance to localized plastic deformation. Hardness of a material describes how hard it is to deform that particular material. From the results of hardness it is clear that the bottom face of casted object exhibits less hardness the reason may be sand inclusion. Due to sand inclusion the hardness value on bottom face of casted metal will be less and the variation of hardness can be observed from the fig6.33.The top face of casted metal has hardness slightly less than standard hardness due to improper solidification.

Chapter 7

CONCLUSIONS

- It can be concluded that the application of computer aided casting simulation is the powerful tool for prediction of casting defects. The application of computer aided casting simulation technologies in foundries can able to minimize the non value added time in casting development, as it reduces the number of trial casting required on the shop floor.

- The casting simulation software Click 2 cast which is based on finite element method is used in study of solidification behaviour and flow analysis in aluminium 7075 alloy castings in green sand mold. This helped in visualising the mold filling and casting solidification. It predicts related defects like shrinkage, porosity, cold shuts, and air entrapment. These results obtained are very useful to achieve the desired quality with high yield. Flow and solidification of molten metal is very complex difficult to simulate correctly by conventional techniques. Simulation is the process of imitating areal phenomenon using a set of mathematical equations implemented in a computer program and hence by using the simulation software various parameters and their effect on the casting process is analysed.

- Experimental analysis of casting process is carried out based on the results of simulation and necessary steps are taken to avoid defects like regulating pressure in mold cavity by providing vent holes and uniform pouring rate etc,. The solidification behavior analysed experimentally by measuring temperature during solidification through riser cavity using infrared thermometer and the results are analysed and represented the process graphically. The casted product is inspected and the microscopic examination and hardness tests are carried out to analyse the defects and properties.

- Solidification process in simulation process and experimental analysis are compared by using both the results of solidification results and represented graphically as shown in 6.31 and the results are satisfactory. The application of casting simulation software based on finite element method and shows good results and similar with the experimental results.

- The casted object is inspected by carrying out the microscopic examination at different faces of casted object and from the results of microscopic examination on the casted object different grain sizes are observed for the different faces of casted object. So in order to investigate the parameters hardness test is carried out on the three faces of casted object and the variations of hardness are observed.

- From the study it is concluded that production of reliable, economical, high accuracy cast component can be prepared by application of simulation software in casting process.

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