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Enhancement of Design of Gating System of Tie Plate Lower (C-1401-018) to Reduce Rejection

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Abstract:- In order to scale back the process development time and maintain profit alongside increasing consistency of the system, it's become obligatory for foundry engineers to optimize gating system and so forestall defects before the production of casting starts.

Investment casting method is producing method to form advanced geometrical components of metal materials in mass production. However again and again completely different defects arise like shrinkage, porosity, cracks etc. These defects are decreased by acceptable changes in gating parameters, like location, form and size. Improving the investment casting gating system supported style of gating system and simulation with the aim of rising casting quality.

The simulation techniques are used to reduce shop floor time. Design of gating system is very important in any molding or casting process, in order to get defect free components. In this paper, task is accomplished through SoftCast software, which is entirely used for casting process.

Keywords:- *Investment Casting, Hotspots, Softcast.*

I. INTRODUCTION

Investment casting is a method conjointly referred to as the lost-wax method, or precision casting. During this method a wax pattern should be created for each casting and gating system; i.e., the pattern is expandable.

A number of variants of the process exist, however they need following points in common:

- Disposable or expandable patterns are used.
- Molding is completed with a fluid combination or slurry.
- The aggregate is hardened in touch with the pattern, providing precise reproduction of the pattern.
- The mixture is secured with an inorganic ceramic binder.
- The mould is heated to drive out all gases.
- Pouring is performed with the mould preheated to a controlled temperature so as to pour thin sections which might not otherwise fill out.

The steps in the process are as follows:

- A die for casting the wax patterns is made.
- Wax patterns and gating systems are made from metal dies by injection. Patterns and gating system should be assembled if cast singly. They can join by heating the surfaces to be attached in case of waxing or moisturizing them with a solvent, carbon tetrachloride, in case of polystyrene patterns.
- Precoating: The wax assembly is immersed into slurry of a refractory coating material. Typical slurry consists of 325-mesh silica flour suspended in ethyl silicate solution of appropriate viscousness to provide a regular coating once drying. After dipping, the assembly is coated by sprinkling it with 40 to 50 AFS silica sand and allowed to dry.
- The coated-wax is next invested within the mold. This is done by inverting the wax assembly on the table; close it with a paper-lined steel flask, and pouring the investment-molding mixture around the pattern. The mold material settles by gravity and utterly surrounds the pattern because the work table is vibrated. The molds are then allowed to air-set.
- Dewaxing and preheating: Wax is molten out of the hardened mold by heating it in an inverted position at 200 to 300 F. For burnout and preheating, the molds are heated at the rate of 100 to 160F per hour from regarding 300F to 1600 to 1900 F for ferrous alloys and 120F for aluminium alloys.
- Pouring: When the mold is at temperature, the metal is gravity-poured into the sprue. Atmospheric pressure might then be applied to the sprue to force-fill the mold cavity.

The solidification characteristics of metals and alloys and the way these were influenced by composition and external variables, of these factors should be accounted for in planning a gating system for a casting. A lot of specifically, the shrinkage behavior and crystal growth morphology should be recognized if the gating sting is to be effective. In considering cooling characteristics, the usual growth from the outside to the inside of casting was discovered. Gating system must control progressive solidification in such the way that no a part of casting is isolated from active feed channels throughout the complete cooling cycle. This can be cited as directional solidification.

The Gating and Risering Committee of the American Foundrymen's Society has done much toward standardizing the nomenclature in connection with the feeding of castings.

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Therefore the definitions evolved by these groups serve as a useful reference for this purpose.

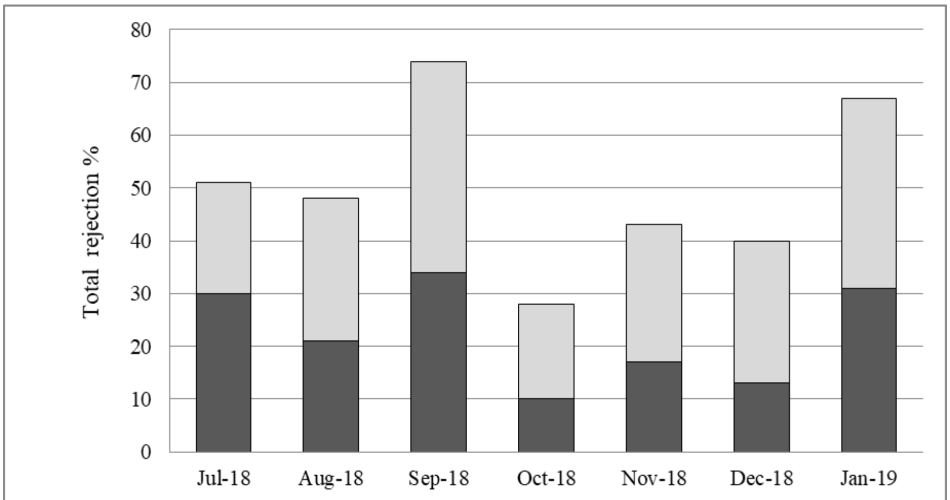
Investment casting gating system design is completely different from ordinary sand casting, as a result of it's not solely guide the liquid metal into the cavity of the channel, however additionally act as a bearing function on the wax module and shell and therefore the channel guiding pattern material in and out of the cavity. Thus it's very vital to design investment casting gating system. If the design isn't affordable, it'll not solely have an effect on the quality of module assembly and demoulding, and can directly have an effect on the quality of cast iron castings, to cause the casting defects like shrinkage cavity, porosity, slag inclusion, cracks, etc.

II. PROBLEM IDENTIFICATION AND DEFINITION

As per discussion with company experts, I came to know that the rejection percentage is more than 50% on an average and this is harmful for economy of company.

From previous data of rejection obtained by company records the defect which is repeatedly observed is shrinkage defect and which is more than other casting defects. It is showed in following graph.

From fig.1 we obtained the percentage of shrinkage defect in the total rejection of Tie Plate Lower. Other defects consist of leak, knocking damage, cracks, flow lines, excess polishing, swelling, shell breakage, bend, chemical, wax pattern, porosity. As compare to other defects the percentage of shrinkage is higher.



	Jul-18	Aug-18	Sep-18	Oct-18	Nov-18	Dec-18	Jan-19
Other defects	21	27	40	18	26	27	36
Shrinkage	30	21	34	10	17	13	31

Fig 1:- Shrinkage Defect in Total Rejection of Tie Plate Lower (C-1401-018)

III. OBJECTIVES

In tune with identified problem, the objectives of proposed work are

- Study and analysis of existing gating system of Tie lower plate (C-1401-018).
- Optimize design of gating system of Tie lower plate (C-1401-018)
- Reduce the shrinkage percentage of Tie lower plate (C-1401-018)

IV. LITERATURE REVIEW

A.A. Chalekar and et.al.[1] In this article they minimized the defects which will be caused because of faulty design of gating system and master die by using CATIA V5 and simulation. Here the case study of piston is taken for analysis which is producing in foundry for first time. Instead of redesigning the mould many times in trial and-error fashion, the gating and risering was designed with the help of computer modeling.

The use of computer aided producing helps plenty in saving the time and financial resources. The defects will be well decreased by exploitation specialized software for casting simulation.

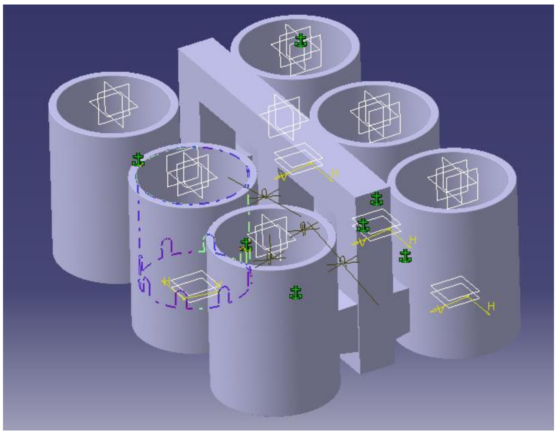


Fig 2:- 3D Model of Cluster

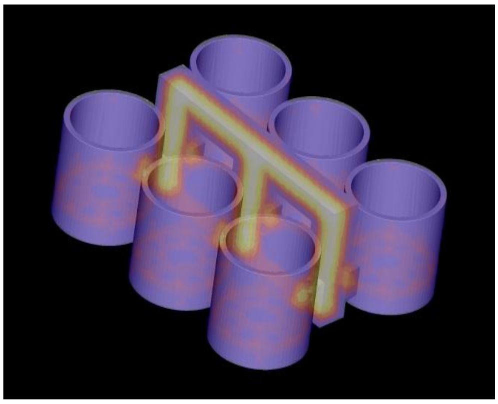


Fig 3:- Simulation Result of Cluster

Rajesh Rajkolhe and et.al.[2] It is essential for die caster to possess information on the sort of defect and be ready to determine the precise root cause, and their remedies. To get this all information regarding casting defect, their causes, and defect remedies one has got to be analyze casting defects. Casting defect analysis is that the process of finding root causes of prevalence of defects within the rejection of casting and taking necessary step to cut back the defects and to boost the casting yield.

A.A. Chalekar and et.al.[3] In this paper they explained step by step guide to design a gating system for spacer (lantern bush) which may be more generalized for the other part. the tactic used for orientating of feeding parts utilized in this case study comes from the principles that are developed supported the initial ideas by Chvorinov and after elaborated by Wlodawer. This method is called as 'Modulus method'.

Geometrical approach for designing can replace the normal manner of trial and error ordinarily utilized in industries nowadays. This can cause reduction in time between the concept and producing phase by a major quantity. Also, the value of process and redesign is eliminated increasing profit of industry.

Sagar M Bechara and et.al.[4] In this paper explained regarding lost-wax casting method could be a manufacturing method to create advanced geometrical components of metal materials in mass production. However again and again completely different defect happens like shrinkage cavity, blow holes, porosity, etc. These defects may be reduced by acceptable changes in gating parameters, like gating system location, form and size. Up the casting gating systems based on design principle of gating system and casting simulation with the goal of improving casting quality like reducing casting defects and increasing yield.

Jenn-Kun Kuo and et.al.[5] This analysis is of mold flow analysis to the design of gating systems for 17-4PH stainless steel embedded impellers. The target is to eliminate shrinkage and porous defects common in investment casting. They adopted numerous bottom, side, and prime pouring systems with completely different pouring parameters to look at the behaviour of the liquefied metal flow and solidification within the mold cavity. Here they designed a pressurized gating system with specific gating quantitative relation to attain a stable flow rate at ingates.

The likelihood of shrinkage defect formation was assessed using the preserved soften modulus (RMM) and also the Niyama criterion. Experiments and non-destructive inspections show that optimizing the design of the gating system prevented surface shrinkage and interior defects.

Atul A. Bhujugade and et.al.[6] They explained in this paper concerning the computer simulation technique and design of experiment used for casting defects analysis. Here by using simulation software to attain optimum design range of iterations are performed. With new gating system reduction in shrinkage by (about 2.85%) and yield improvement by (about 9.85%) is discovered. within the second part design of experiment used for casting defects analysis therefore sand related and running practices connected parameters thought-about are moisture content, sand particle size, mould hardness and pouring temperature.

V. METHODOLOGY

Methodology is often represented as a framework that contains the elements of the work based on the objectives and scope of the project. a good framework will present the view of the project and be used to organize or extract the information simply. This includes the assorted steps concerned like literature study, design, testing part, etc.

- **Identification of problem:** Very first step is to identify and define the problem. For this, data collection regarding that specific work area is important. After identifying problem the definition and statement of problem is necessary which can clear the concept.
- **Objective of project:** Project objective describes the status that should be achieved at the end of project. It represents a data management in step with the 3 dimensions of magic triangle (quality, time and cost).
- **Literature survey:** A literature survey or review during a project report is that section that shows the assorted analyses and research created within the field of your interest and therefore the result is revealed, taking under consideration the various parameters of the project and therefore the extent of the project.
- **Identification of process parameters:** The parameters regarding casting process such as moisture content, mould hardness, pouring temperature, surface finish are considered. The identification of these parameters plays vital role for understanding of process.
- **Trial runs to established range of parameters:** For controlling the quality in established range of parameters trial runs are mandatory.
- **Design optimization:** Design improvement is an engineering design methodology using a mathematical formulation of a design drawback to support choice of the design style among several alternatives.
- **Design & simulation by using software:** Simulation software system relies on method if modeling a true development with set of mathematical formulas.

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- **Production of Casting:** Casting is a manufacturing method during which a liquid material is typically poured into the mould that contains hollow cavity of desired form, then allowed to solidify.
- **Result analysis:** The casting defect is an unwanted irregularity during a metal casting process. If the rejection percentage is more then again design rectification is done on that and the new design is checked by taking trials.

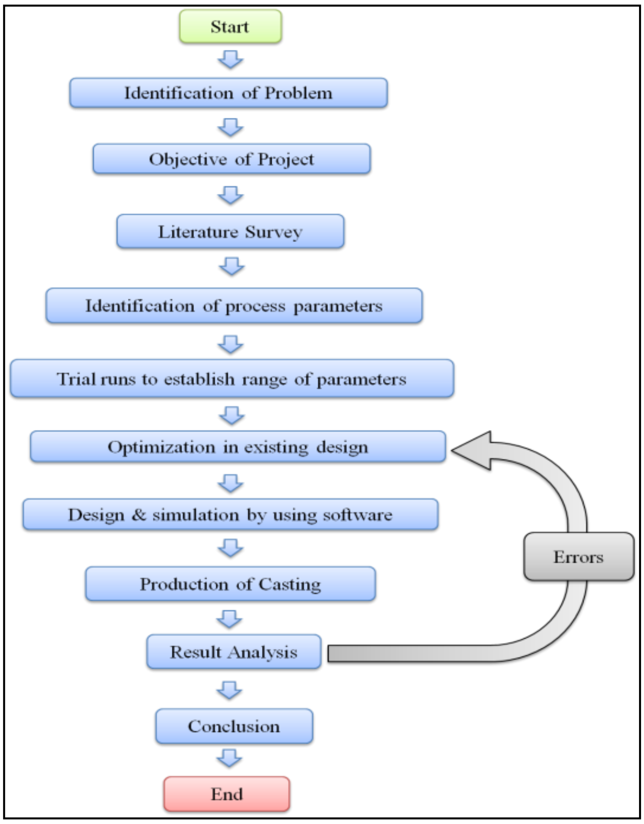

Fig 4:- Methoology

VI. IDENTIFICATION OF PROCESS PARAMETERS

The parameters concerning casting process such as moisture content, mould hardness, pouring temperature, surface finish are considered.

Fluidity: Fluidity is defined as the ability of liquefied metal to flow through and to fill mould cavity before solidification happens. It governs the filling of moulds and also the sharpness of cast details. The issues involved with fluid flow and laws of governing fluids will be studied usefully to boost any design.

Pouring temperature: Pouring is the method by which liquified metal is transferred to solid for cooling and solidification and so be converted into final product. Pouring temperature is that the temperature to which the liquified metal has got to be raised to before being poured into casts for cooling and setting.

Sand and ceramic material has terribly high ability to face up to high temperatures of liquified metals while not undergoing an amendment in their properties. Therefore, they are used as coating material for moulds within which alloys with high temperatures got to be poured for cooling.

Filling time: The optimum pouring time is nothing but the time needed to solid or mould a product. The potency of the casting is generally affected by two situations.

- Slow filling: If the rate of the fill the velocity low, it results in cold shuts and misruns.
- Fast filling: The quick filling is governed by the onset of surface instability. The optimal filling time lies in between this quick and slow filling.

For steel castings,
Pouring time in seconds, $t = (2.4335-0.3953 \log W) \sqrt{W}$

Shell material: Ceramic moulds as used in investment casting have enjoyed the reputation of being the foremost correct of all numerous mould varieties on the market. This can be a curious perception which can be the results of method being for several years restricted to production of rather small castings wherever dimensional issues were naturally too small to be of concern.

Shell moulds have been used with some success, but there is tendency to form surface defects. These can be eliminated by use of chill type shell moulds. Ceramic moulds are also feasible. These permit pouring thinner sections than with conventional sand moulds.

VII. DESIGN OF EXISTING GATING SYSTEM

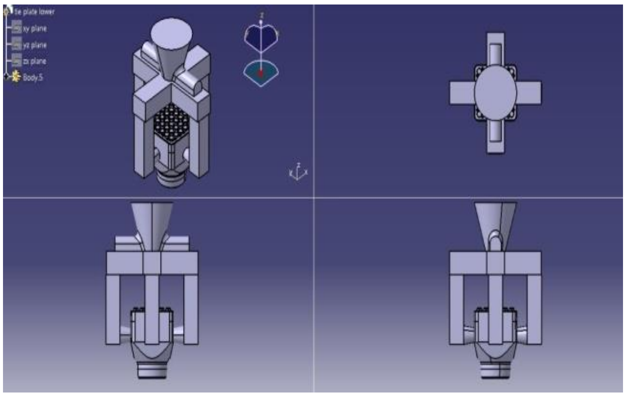

Fig 5:- Gating system of Tie Plate Lower (C-1401-018)

Existing design of Tie Plate Lower (C-1401-018)			
Mass	***Volume***	***Area***	***Density***
24.29 kg	0.003 m^3	0.363 m^2	7860 kg/m^3

Table 1:- Design Characteristics of Tie Plate Lower (C-1401-018) for Existing Model

Component modeling: The Tie Plate Lower (C-1401-018) was modeled using the conventional 3-D modeling software CATIA and SoftCAST.

Simulation: Once the component modeling was completed, it was subjected to simulation and the "Hot Spot" was identified. As soon as the "Hot spot" was identified, a proper gating system was designed. This is known as first iteration. Simulation using SoftCAST software includes four modules or stages known as

- Data Conversion: The data of the model was converted into STL format which is supported by the SoftCAST software. SoftCAST follows the strategy of slicing 3D structures into several number or 2D layers by inserting horizontal cutting planes.
- Mesh Generation: Mesh generation is the first and foremost task of any finite element analysis and generating FEM mesh is decisive for the success of the casting simulation program.
- Temperature Field Calculation: The temperature field calculations include mesh details, time scan detail, material definition, execution.
- Result Representation: The spots with smaller cross sections cool faster and the spots with bigger cross sections take longer time for solidification.

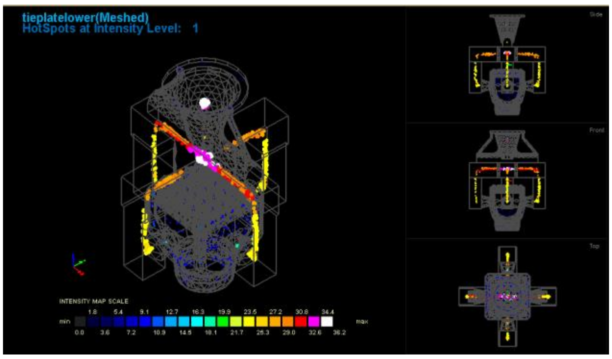

Fig 6:- Tie Plate Lower (C-1401-018)– Intensity of Hotspot

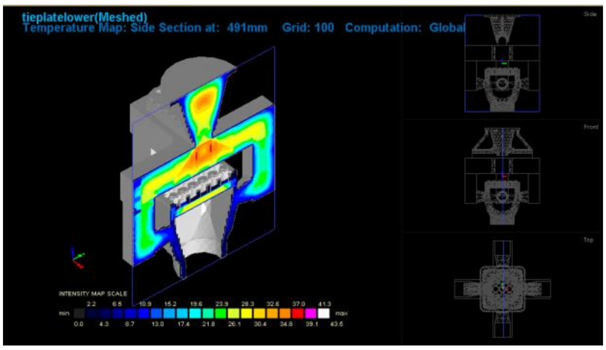

Fig 7:- Tie Plate Lower (C-1401-018)– Temperature Distribution

From temperature distribution the critical places of solidification of cast can be found. The higher is the heat capacity of molten metal the higher is the time required for cooling. The cooling rate is also depends on the surface area.

Results: From above software analysis the castings are manufactured but after testing we got shrinkage defects on the outer surface. As per the simulation software the temperature distribution required for this particular component is unbalanced. So the rectification in design of gating system is essential.

A. Design Changes for trial -1

Ingate opening- Shifted from vertical surface to slant surface.

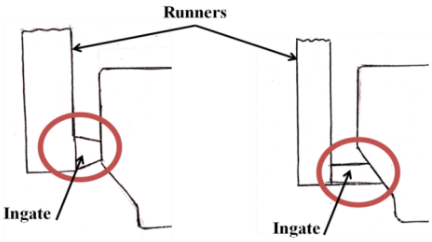

Fig 8:- Ingate Opening

Dimensions of ingate- Reduction in diameter from 30mm to 20mm.

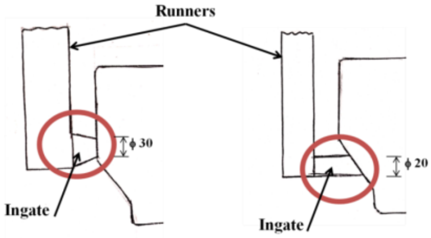

Fig 9:- Dimensions of Ingate

Runner bar- Drafted shape is provided to reduce turbulence.

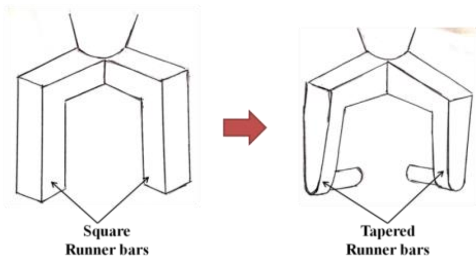

Fig 10:- Drafted Runner Bar

Metal temperature is reduced from 1550°C to 1520° - 1536°C.

VIII. DESIGN OF GATING SYSTEM (TRIAL-1)

Due to troubles in existing gating system the alteration in design became essential, so here the design of gating system is changed as shown in following figure.

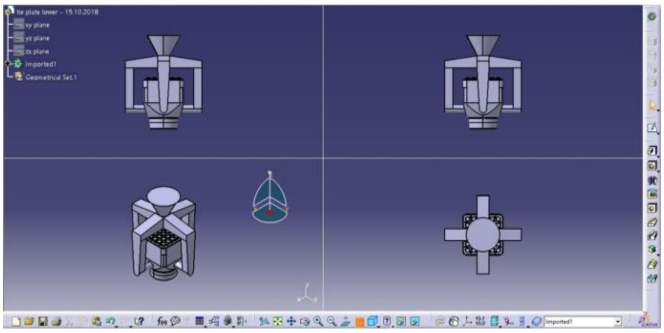
Fig 11:- Gating system of Tie Plate Lower (C-1401-018)

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Trial -1 design of Tie Plate Lower (C-1401-018)			
Mass	***Volume***	***Area***	***Density***
13.44 kg	0.002m^3	0.283 m^2	7860 kg/m^3

Table 2:- Design characteristics of Tie Plate Lower (C-1401-018) for 1st Trial Model

Component modeling: Here single ingate with drafted runner is provided for sufficient pouring. Due to the drafted runner bars the losses in flow can be reduced.

As soon as the "Hot spot" was identified, a proper gating system was designed. This is known as first iteration. Simulation using SoftCAST software includes four modules or stages known as

- Data Conversion
- Mesh Generation
- Temperature Field Calculation
- Result Representation

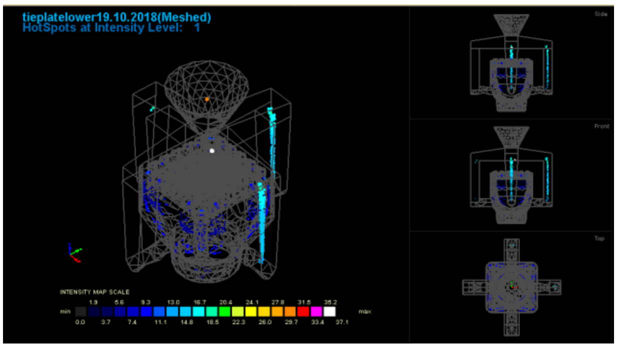

Fig 12:- Tie Plate Lower – Intensity of Hotspot

The intensity of hotspots changes by the cross section of model. The cross section of runner bars is bulky than the actual model. So the intensity of hotspot is greater in runner bars and it is shown by color coding.

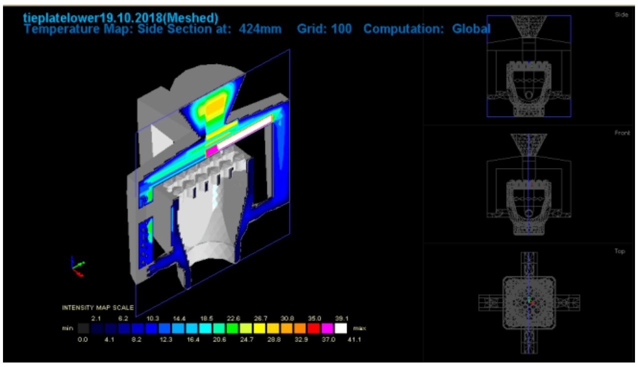

Fig 13:- Tie Plate Lower – Temperature Distribution

From temperature distribution the critical places of solidification of cast can be found. The higher is the heat capacity of molten metal the higher is the time required for cooling. The cooling rate is also depends on the surface area.

Results: From above software analysis the castings are manufactured but after inspection and testing we got shrinkage defects at the opening of ingate. As per the simulation software the temperature distribution required for this particular component is unbalanced due to sharp corners. So the modification in design of gating system is necessary.

B. Design Changes for Trial -2

Gating system- Double gating is provided with different sizes on different faces.

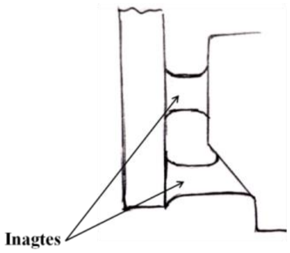

Fig 14:- Double Gating System

Cross bar: size is increased i.e. 40mm.
Runner bars: made drafted to avoid turbulence in flow.

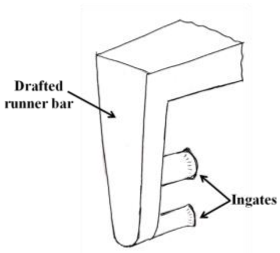

Fig 15:- Drafted Runner Bar

Fillets are provided to avoid shrinkage at ingates.

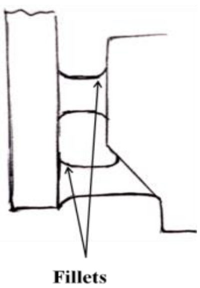

Fig 16:- Fillets on Ends of Ingates

IX. DESIGN OF GATING SYSTEM (TRIAL-2)

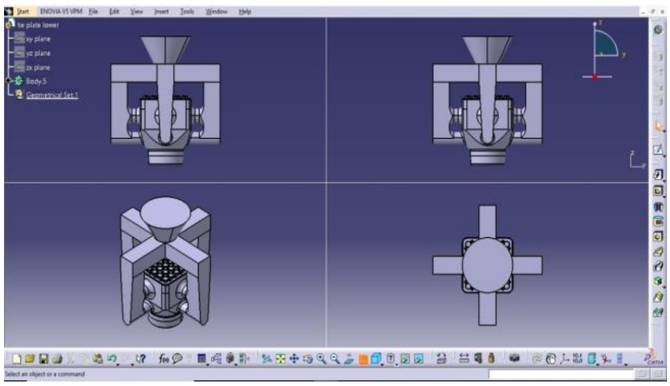

Fig 17:- Gating system of Tie Plate Lower (C-1401-018)

Trial -2 design of Tie Plate Lower (C-1401-018)			
Mass	***Volume***	***Area***	***Density***
20.42 kg	0.003m^3	0.335 m^2	7860 kg/m^3

Table 3:- Design characteristics of Tie Plate Lower (C-1401-018) for 2nd Trial Model

Component modeling: Here double ingates with drafted runner are provided for sufficient pouring. Due to the drafted runner bars the losses in flow can be reduced.

Once the component modeling was completed, it was subjected to simulation and the "Hot Spot" was identified. As soon as the "Hot spot" was identified, a proper gating system was designed. This is known as first iteration. Simulation using SoftCAST software includes four modules or stages known as

- Data Conversion
- Mesh Generation
- Temperature Field Calculation
- Result Representation

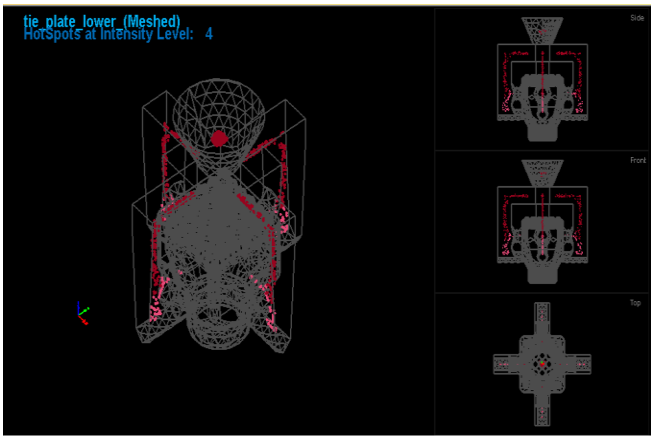

Fig 18:- Tie Plate Lower (C-1401-018)– Intensity of Hotspot

Figure shows the intensity of hotspots, the spots with smaller cross sections cool faster and the spots with bigger cross sections take longer time for solidification.

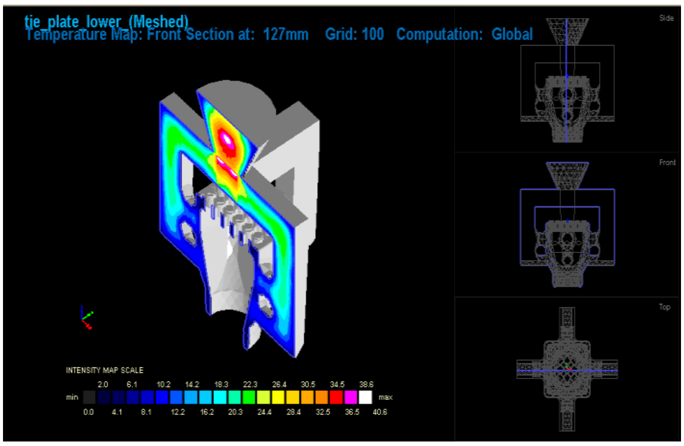

Fig 19:- Tie Plate Lower (C-1401-018)– Temperature Distribution

Fig.19 represents the plotting of temperature distribution in entire casting during the process. The temperature is highest at center of pouring cup and at center of cross bars. The cross sectional area of gating system is larger than casting product hence the cooling rate is higher at casting than gating system.

Results: The gating system has better performance regarding the temperature distribution than 1st trial. From the simulation of this model we can say that the casting trial will be non-defective.

X. CONCLUSION

	Density	***Area***	***Volume***	***Mass***
Existing model	7860 kg/m^3	0.363 m^2	0.003 m^3	24.29 kg
1st trial	7860 kg/m^3	0.283 m^2	0.002 m^3	13.44 kg
2nd trial	7860 kg/m^3	0.335 m^2	0.003 m^3	20.42 kg

Table 4:- Comparison of design characteristics of Tie Plate Lower (C-1401-018)

Total weight reduction is 3.87 kg
Total cost of casting is Rs. 20000/-
Cost of basic raw material is approximate 45% of total cost.

The material cost is kept 45% of total cost of casting and remaining is processing cost. From this percentage we can calculate material cost of single casting i.e. Rs.9000/- for existing model.

So, Cast steel cost per kg is near about Rs.371/-
Here we reduced 3.87 kg per piece
Hence total cost saving is 3.87*371 = Rs. 1435.77/-
Average production per month=21 pieces
Cost saving on average production per month= Rs. 30151/-
Cost saving per year = Rs. 3,61,812/-

REFERENCES

[1]. Minimization of Investment Casting Defects by Using Computer Simulation - A Case Study, A. A. Chalekar, S. A. Daphal, A. A. Somatkar, S. S. Chinchanikar, Journal of Mechanical Engineering and Automation, 2015.

[2]. Defects, Causes and Their Remedies in Casting Process: A Review, Rajesh Rajkolhe, J. G. Khan, International Journal of Research in Advent Technology, Vol.2, No.3, March 2014.

[3]. Designing of Feeding System for Investment Casting Process - A Case Study, A.A. Chalekar, A.A. Somatkar, S.S. Chinchanikar, Journal of Mechanical Engineering and Automation 2015

[4]. Optimization of Gating System and Minimization of Casting Defect based on Casting Simulation: A Review, Sagar M Bechara, Dilbagsingh Mondloe, International Journal for Scientific Research & Development Vol. 2, Issue 10, 2014.

[5]. Optimal gating system design for investment casting of 17-4PH stainless steel enclosed impeller by numerical simulation and experimental verification, Jenn-Kun Kuo, Pei-Hsing Huang, Hsin-Yi Lai &Jian-Rong Chen, International Journal of Advanced Manufacturing Technology, March 2017
[6]. Minimization of Casting Defects Using Casting Simulation Technique and Casting Defects Analysis Using Design of Experiment, Atul A. Bhujugade, Vijay B. Sabnis, International Journal for Research in Applied Science & Engineering Technology Volume 3 Issue VI, June, 2015.
[7]. Design and analysis of gating system for pump casing, N.Jayakumar, Dr.S.Mohanamurugan, Dr.R.Rajavel, International Journal of Engineering and Technology (IJET), Vol.6 No 5 Oct-Nov 2014.