Analysis and Optimization of Gating System for TVS SATELITE

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***Abstract*-Defect free Casting is the main aim for foundry industry. To achieve this; foundry does number of shop trials to eliminate defect.This takes lot of time to design proper system. For better casting; gating system plays an important role. Casting simulation software's have eased the designing of proper gating system. In this work AUTOCAST X software has been used which is an easy to use program, based on vector element method for simulation to predict shrinkages and gas porosity easily. A well-designed runner and gating system is very important to produce good quality die castings by providing a homogenous mould filling pattern. Flow analysis of the component is done in order to visibly analyze the cavity filling process. In this study, a TVS SATELITE, product was chosen.The objective of this work is to represent TVS SATELITE casting design and its simulation using AUTOCAST-X software. Initially when the component was casted numerous defects such as Cold shuts, Misrun, Shrinkage porosity and Gas porosity were found. This in turn led to rejection of number of components. In order to improve the quality of the castings produced, the gating system design was changed from the existing gate to modified gate. The component was designed using AUTOCAST Software. The process parameters like metal temperature, fill velocity and filling time are considered for optimizing the process.**

Keywords : TVS SATELITE, AUTOCAST Software, Shrinkage.

I. INTRODUCTION

In automobile industries many parts used are of different shapes and they are difficult to manufacture so the casting process is always used in the manufacturing of the automobile products. Casting is a very versatile process and capable of being used in mass production. Foundry is mother industry. In casting process lots of research has been carried out in foundry technology, but yet trial and error method used for designing the gating system, it is time consuming and costly process, so the material utilization, energy utilization, and other resources utilization is very difficult in foundry industries[7]. Many critical shapes are manufactured in foundry by casting process, because of critical shapes present many defects arise in casting while directional solidification. Even in a completely controlled process, defects are found out. So for the good directional solidification proper designing of gating system is very important to provide metal in liquid form to the casting cavity. The defects like shrinkage, porosity can be minimized by designing proper feeding system [1].The location and extent of shrinkage porosity can be predicted by identifying regions of high temperature (hot spots) and low gradients [2]. These defects also can be minimized by an intelligent methoding and simulation casting software [4]. Casting defect analysis is the process of finding the root cause of occurrence of defects in the rejection of casting and taking necessary steps to reduce the defects [5]. The gating system should be designed properly because oversized gating system leads to lower yield of the casting. The various gating system are designed for the casting and 3D CAD models of this designs are made and simulated using AUTOCAST-X flow plus [6].

In casting process, gating system plays an important role to produce a high quality casting. A poorly designed gating system results in casting defects. A gating system controls mould filling process. The main function of gating system is to lead clean molten metal from ladle to the casting cavity ensuring smooth, uniform and complete filling. Hence to design a good gating system one must know the behavior of fluid flow during mould filling process. Mould filling is a complex phenomenon, influencing both internal and external quality. The flow of molten metal after being poured is a transient phenomena accompanied by turbulence, separation of the flow from the boundaries, dividing and combined flow at the junction, simultaneous heat transfer during the flow and onset of solidification. Moreover melt properties like density, viscosity and surface tension are continuously changing during the flow. All this together makes the filling analysis quite complex. Mainly arising defects in casting are shrinkage porosity, hot spots, etc. Then by using casting simulation software these defects can be minimized. Hence casting solidification simulation enables preventing potential problems before solidification of product. The objective of this work is carried out simulation of casting under software to minimize the above motioned defects.

NOMENCLATURE
G:Liquid metal per mould (kg)

T:Pouring time (sec)
ξ:Velocity Factor
hst:Ferrostatic Head (cm)
σ:Density of liquid metal (kg / $cm^{3})$
hsp:Height of sprue above ingate (cm)
b:Height of casting above ingate (cm)
c:Total height of casting(cm)

At initial stage we design a gating system for the object TVS satelite and simulation solidification has been carried out for the same. The obtained simulation result shows casting with some defects. Hence there is a need to redesign the gating in order to remove defects from the casting.

1.1 Casting Defects in the Existing Model

Flow Mark

Flow mark is the occurrence of visible metal flow marks on the casting surface. It can be removed by proper polishing of the mould cavity. The main causes for this defect is Non parallelism between platens of die, less draft provided and worn out Tie bar guide bushes [3]

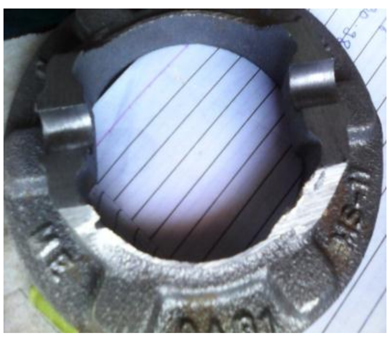


Fig 1.1.Flow Mark

Blow Holes

Blowholes are smooth, round holes. Blow-holes are produced because of gas entrapped in the metal during the course of solidification. The main causes for this defect is low velocity and pressure and excess machining stock and bad Chill vent design. And Excess moisture in the molding sand.

Gas Porosity

Gas porosity is the formation of bubbles within the casting after it has cooled which shown in figure 1.2. The main causes for this defect is low velocity and pressure of molten metal, excess machining stock and bad Chill and vent design [3]

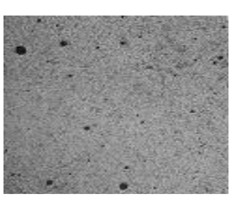


Fig.1.2 Gas Porosity

Shrinkage

Metals shrink as they solidify; if this shrinkage is not compensated by providing risers, etc., voids will occur on the surface i.e. surface shrinkage or inside i.e. internal shrinkage the casting. The shrinkage defect is caused due by molding, core making, gating, etc.

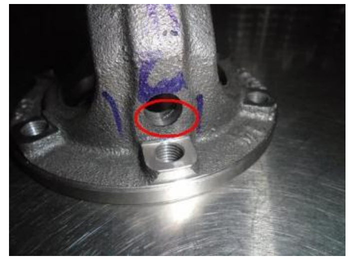


Fig.1.3 Major Shrinkage Fig.1.4 Minor Shrinkage

II. LITERATURE REVIEW

Following literature review is carried out for the basic study regarding gating system design before doing actual gating design for a product TVS SATELITE.

C. M. Choudhari , B. E. Narkhede, S. K. Mahajan, In this study, they showingcomponenthaving shrinkage porosity defect leading to failure. Also due to sudden variation in thickness it was subjected to incomplete filling. Then they redesign and redevelop the component by providing sufficient draft and radius at the junction of Component geometry. Their work has been made to carry out the entire methoding, simulation and optimization in AutoCAST X software which is based on Vector Gradient Method (VGM). Then it is observed thatentire shrinkage porosity should get shifted in the feeder by setting all the design parameters in numerical simulation software. This gives significant improvement in the quality of casting. When they compared their workwith the experimental trial simulation, the results were found in good agreement. [1]

Dr. B. Ravi,His study gives "Computer-aided Casting Design and Simulation Computer-aided casting". His Design and simulation gives a much better and faster insight for optimizing the feeder and gating design of castings. The Key inputs, steps and results are discussed in his work. Casting simulation however, poses several challenges: technical as well as non-technical (resources) for industrial users. Hehighlights the best practices based on his experience with several casting simulation projects, and directions for further research in this area to make casting simulation more easy, accessible and economical for industrial users. And he conclude 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 modeling 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.[2]

B. VijayaRamnatha, C.Elanchezhiana, Vishal Chandrasekhar, A. Arun Kumar, S. Mohamed Asif, G. Riyaz Mohamed, D. VinodhRaj ,C .Suresh Kumar, In this study, a Commutator End (CE) bracket, a cold chamber die casted product was chosen. Initially when the component was casted they analyzed various defects such as Cold shuts, Misrun, Shrinkage porosity and Gas porosity. The results of their design give rejection of number of components. Then they changed the gating system from the existing flat gate to modified spoon fed gate in order to improve the quality of the castings produced. They designed component using Pro- Engineer and flow analysis was carried out using Rotork Flow 3D Software. They consider process parameters like metal temperature; fill velocity and filling time for optimizing the process. Quality assessment for the die casting parts was made by microstructure analysis. [3].

C. M. Choudhari, B. E. Narkhede, S. K. Mahajan, Inthis paper, theyredesign and develop a casting free from defects, in particular, shrinkage defect. Theytakencomponent for simulation study was subjected to shrinkage defects. And which was the major cause for the rejection in the foundry. The component under their study consists of square shaped (at top) plate having three perforations with diminishing height (at bottom) and subjected to multiple hot spot. When they carried out various simulation trialsoptimum location of feeder has been identified. Proper feeding has helped in shifting the hot spot completely inside the feeder. And hence improvement of the feedability index which represents yield of feeders and quality of casting. Then they compare simulationresults with the experimental trial and the comparison was found to be correct.[4]

Uday A. Dabade and Rahul C. Bhedasgaonkar, In this paper they combined design of experiments and computer assisted casting simulation techniques. That combination was made to analyze the sand related defects in green sand casting. They selected ductile iron cast component and an attempt has been made to obtain the optimal settings of the molding sand and mould related process parameters of green sand casting process. They considered green sand related process parameters like moisture content, compression strength, and permeability of molding sand and mould hardness. In first part of this paper Taguchi based L18 orthogonal array was used for the experimental purpose and analysis was carried out using Minitab software for analysis of variance (ANOVA) and analysis of mean (AOM) plot. ANOVA results indicate that the selected process parameters significantly affect the casting defects and rejection percentage. Then in the second part, they performed shrinkage porosity analysis using casting simulation technique by introduction of a new gating system designed, solid model developed for four cavities mould. Then they take number of iterations using casting simulation software for mould filling and solidification analysis to reduce the level and intensities of shrinkage porosities in cast component. The result shows reduction in shrinkage porosity (about 15%) and improvement in yield (about 5%) with new gating and feeding system design. [5]

Utkarsh S. Khadeand Suresh M. Sawan, In this paper they analyzed and studied casting of brake disc. This work has been made to solve the problem of lower casting yield due to over designed gating system components. To overcome this problem they redesigned gating system which is based on gating rules, gating design procedure, theoretical knowledge, casting simulation and practical considerations. Theymade various 3D CAD models of that designs and designed gating systems for the casting and simulated using simulation program Autocast-X flow plus. After analyzing the simulation results, they get results which are not agreed, then they made changes in that design and 3D CAD model and simulated again, theyrepeated thatprocedure until the desired results are obtained so as it will give the sound quality casting with the higher casting yield, profit and productivity.[6].

Swaroop S. Magdum, Baliram R. Jadhav, In this work they shows the development of the casting processes simulation techniques used in the AutoCAST simulation software. In the simulation technique they designed gating systemnumerically and by that dimensions theydrawn 3D model of the gating and cavity, that model is used for virtual casting in that process by that simulation technique trial and error method, the optimized gating system was finalized. After that they implementedfinalized designed gating system on the pattern for simulation process and taken the sample casting to validate the result of the simulation technique. So they overcome wastage caused due to trail and error by using this technique and optimization of quality implies lower production cost and higher yield.[7]

M. Di Foggiaa, D.M. D'Addona, This paper is focused on the description of investment casting process and its key parameters in order to give a quite detailed knowledge of the main indicators of this manufacture method, for its nature prone to have high costs of rework or scrap. It provides a brief description of EuropeaMicrofusioniAerospaziali and a simple, schematic flow of the main processes; afterwards the main processes are discussed in more detailed manner with their manufacturing methods and product specifications. These are indispensable preconditions to introduce the discussion on the critical parameters for investment casting process. [8]

Literature study helps in designing the proper gating system. All the papers give information related to gating design and various trends and innovations in foundry industry.

III. DESIGN OF GATING SYSTEM

Gating system

The gate is the most restrictive orifice in the total fluid flow concept of the filling operation in the die-casting die. It is the point at which the metal enters into the die cavity. There exists a geometrical & mathematical relationship for the dimensioning of the gating of die casting dies. Most of the casting defects such as bad surface, improper filling, flow marks, cold shuts, soldering and thermal imbalance are caused due to improper gating. The location, size, and type of gate are 3 important factors in gating.

Runner Design

Runners should be shaped in such a way to minimize the surface area to volume ratio. Various types of runner are shown in figure 3.1

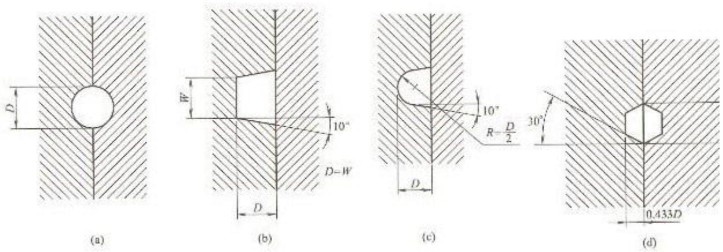


Fig.3.1 Runner profiles (a)fully round (b)trapezoidal (c)modified trapezoidal (d) hexagon

The criterion of efficient runner design is that the runner should provide a maximum cross sectional area from the standpoint of pressure transfer and a minimum contact on the periphery from heat transfer.

Existing Gating System

It is the initial design of gating in which casting defect like shrinkage has been accrued in the top of riser provided. It is a type of gating where the metal flows perpendicularly to the side walls of the casting. In this type, when the metal flows into the cavity it is directly met with an obstruction thereby reducing the flow velocity and causing turbulent flow into the cavity.

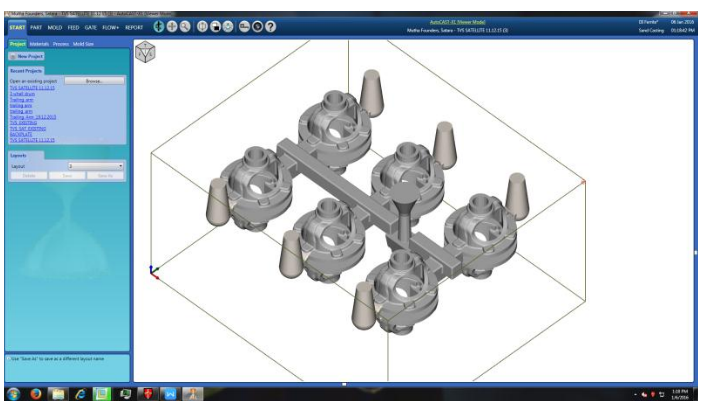


Fig.3.2Existing gating system

Design Calculations

Casting: TVS SATELITE
Weight of casting = 1.20 kg / pc
No. of castings / mould = 12 Nos
Total weight of casting = 1.2 × 12 = 14.40 kg

Gating Design:-

1) Liquid metal per mould (G) = 1.5 × Total casting weight
= 1.5 × 14.4
= 21.60 kg
2) Pouring time (t) = 0.9 × √2 × G
= 0.9 × √ 2 × 21.6
= 5.92 Sec   Say 6 Sec.

3) Velocity Factor (ξ) = 0.40 assumed

4) Ferrostatic Head $hst = hsp - \frac{b^2}{2c}$
Where,
hsp = height of sprue above ingate = 17.78cm
b = height of casting above ingate = 7.30 cm
c = Total height of casting = 7.30 cm
$hst = 17.78 - \frac{7.30^2}{2 \times 7.30}$
=14.13cm
5) Density of liquid metal (σ) = 6.8 kg / cm^3
6) Total ingate area =
$= \frac{22.6 \times G}{\sigma \times t \times \xi \times \sqrt{hst}}$
= 80.712 cm^2
Down sprue area = 807.12 mm^2
Taking Gating Ratio = <u>1:1.2:2</u> we get,

807.12:968.54:1614.24

Down sprue area = 807.12 mm^2
Runner Area = 968.54 mm^2
Ingate Area = 1614.24 mm^2
(Gate Velocity must be 40.50m/s)
7) Length of the gate
Gate length = Gate Area/ Gate thickness = 1614.24/4.5
= 358.72mm

Thumb rule is that if Gate Area is equal to ¼ of the component mass then we will get a good filled casting.
Component Mass = 1200 gm
Therefore minimum gate area required = 1200/ 4 = 300 mm^2

Riser Calculations:-

Casting Weight = 14.4 kg
1) Feed metal requirement = 0.04 × weight of casting
= 0.576 kg
2) Form table of Height : diameter Ratio
Top Diameter of Riser = 30 mm
Feed Metal (gm) = 576 gm
H:D Ratio = 5:1
3) Riser Diameter = 4 × M_s + Riser Top Diameter
= 50 mm
4) Riser Height = H:D Ratio × Riser Top Diameter
= 150 mm

Modified Gating Design:-

Here upto step no 3 calculations are same then by changing hsp = height of sprue above ingate = 12.70 cm
Then,
$hst = 12.70 - \frac{7.3^2}{2 \times 7.3}$
= 9.05 cm
1) Total ingate area =
$= \frac{22.6 \times G}{\sigma \times t \times \xi \times \sqrt{hst}}$
= 10085.2cm^2
Down sprue area = 1008.52 mm^2
Taking Gating Ratio = <u>1:1:2</u> we get,

1008.52:1008.52:2017.04

Down sprue area = 1008.52 mm^2

Runner Area = 1008.52 mm^2

Ingate Area = 2017.04 mm^2

(Gate Velocity must be 40.50m/s)

2) Length of the gate

Gate length = Gate Area/ Gate thickness = 2017.04 /4.5

= 448.23mm

3) Area of the runner

Runner area = 2×gate area = 2 × 2017.04

= 4034.08 mm2

4) Width of the runner

Runner width = √ (2× runner area) = √ (2 ×4034.08)

= 89.82mm

5) Depth of the runner

Runner depth = Runner width/2 = 89.82/2

= 44.91mm

By using this modified design we can totally minimize the defects occurred while using existing design. Hence the casting produced will be defect free. And quality of production is maintained and production should be increased.

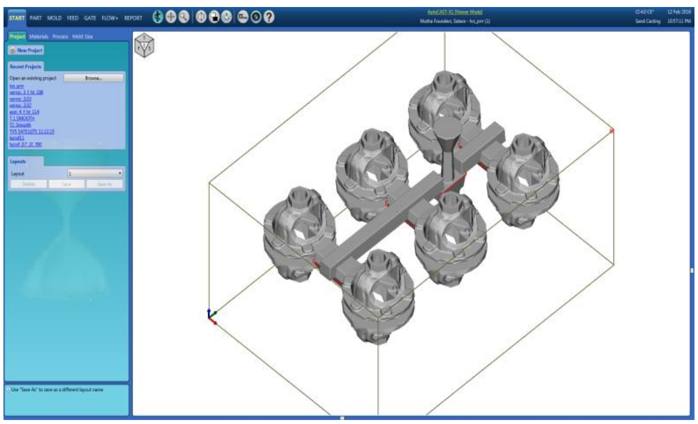


Fig.3.3.Modified gating system

IV. RESULTS AND DISCUSSION

The main initial step of this software is to create 2D model of object in design software and save it in standard .stl file and import it in AUTOCAST X.

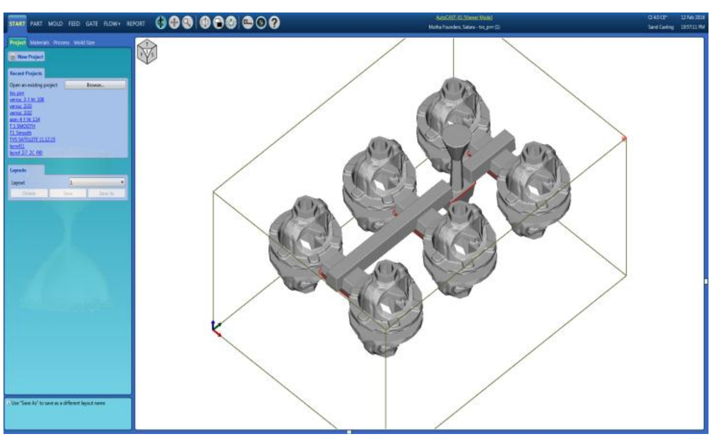


Fig.4.1. Modified gating with mold box

As per the foundry requirement thefig shows mould box of dimensions 388 mm X 540 mm X 274.2 mm. Green sand has been used as a mold material. The casting process used is sand casting. There are XII numbers of cavities present in the mold box. And hence gating is designed in such a way to fill all mold cavities continuously without any delay in the filling.

The result filling of molten metal in all the cavities in shown as..

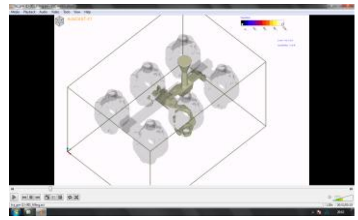


Fig.(a) 5% of Filling

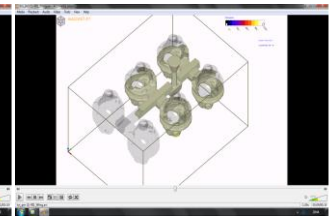


Fig.(b) 50% of Filling

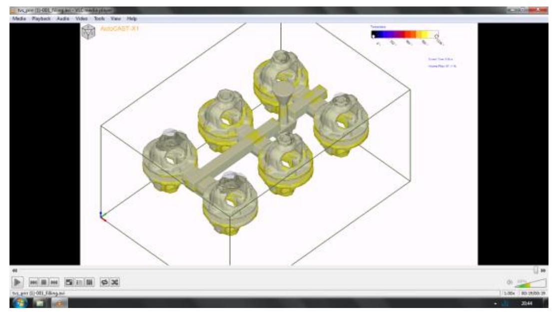


Fig.(c) 99% of Filling

Fig.4.2. % of filling in cavities

The results of filling of molten metal in the all the cavities shows that the filling is continues in all the cavities while no any turbulence in the flow. This gives defect free casting after solidification.

In the initial gating design the hot spots has been occurred in the top of feeder. Which gives the casting with defect like shrinkage as explained in the problem definition.

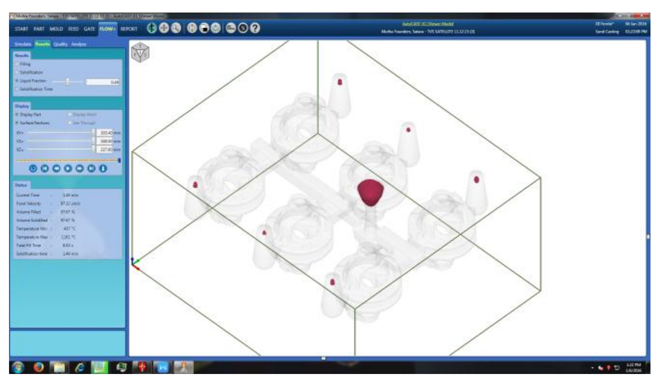


Fig.4.3. Hotspot region in existing gating design

This results in wastage of material also it becomes time consuming. Then we decided to remove that hot spot region by doing modification in existing gating design.

We do changes in the ingate area and feeder. We replace existing rectangular cross section of ingate with the ingate with draft at both sides. While taking simulation trail we can observe that there is no any shrinkage in casting after complete solidification and removing the feeder doesn't matter on the quality of casting.The changes made in the design are removal of feeder and change in cross section of ingate i.e. area increased from1614.24 mm^2 to 2017.04 mm^2.

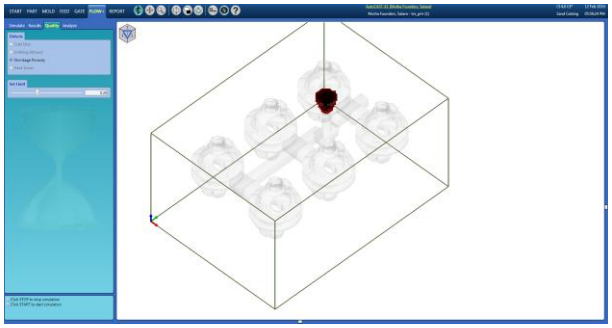
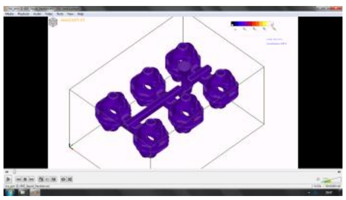


Fig.4.4. Modified design with no shrinkage porosity

The results of liquid fraction and air fraction are shown in following fig. Ranging from high to low value



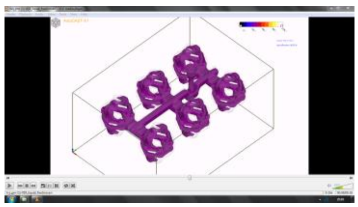


Fig.(a)97.87% of Liquid Fraction Fig(b).50% of Liquid fraction

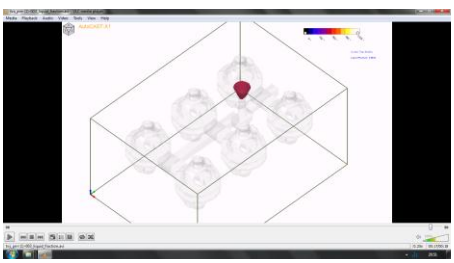


Fig.(c) 0.95% of liquid fraction

Fig.4.5 % of Liquid Fraction

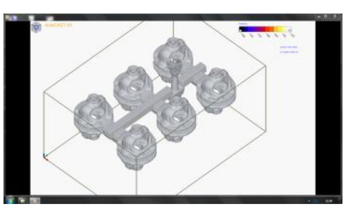


Fig.(a)99% of Air Fraction Fig.(b)50% of Air Fraction

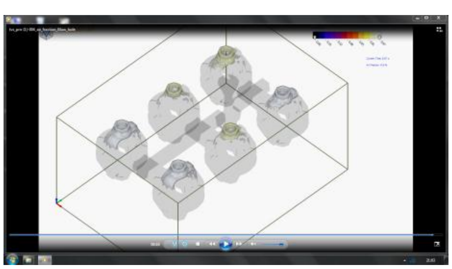
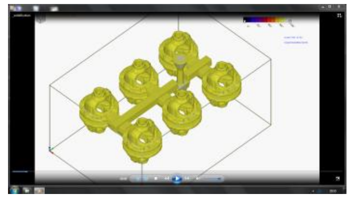


Fig.(c)5% of Air Fraction

Fig.4.6. % of Air Fraction

The liquid fraction and air fraction gives the result of occurrence ofblow holes in the casting simulated. All results done with modified design are okay.
The final solidification results also shows defect free and sound casting



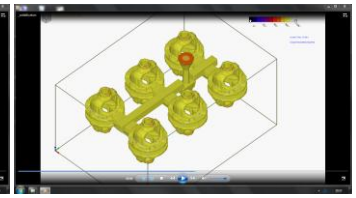


Fig.(a) 5% of Solidification Fig.(b) 50% of Solidification

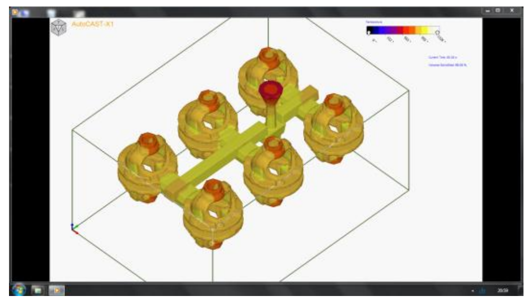


Fig.(c) 99% of Solidification

Fig.4.7. Solidification

V.CONCLUSION

The paper dealt with simulation and design of gating system due to which various casting defects are reduced and that was our objective. Initially component TVS Satelite was selected. When component was tested shrinkage defects was analyzed. This was due to improper gating system. It led to uneven and turbulent filling in the die cavities. And this results in reduction in quality and increase in rejection rates. A new gating was designed and by replacing initial gating with modified gating the molten metal flows into the die cavity with uniform filling and within less time. Hence it results in less time working with minimizing all casting defects with increase in production without any loss of material, machine and man power. The proposed yield in existing design of gating system is around 45%. And with modified gating system yield becomes 60 to 70%.

VI. FUTURE SCOPE

In the company that TVS Satelite is in continues production. We an again made some modification in the gating system which is suitable for foundry and this gives increase in rate of production. We can do optimization of gating system for better result.

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