International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 06, June - 2017

Development of DCDC Bottom Cover Casting using Autocast XI

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***Abstract*— Metal casting is one of the oldest methods of manufacturing. It has played a vital role in the development and advancement of human civilizations. Metal casting process is very simple to understand but still it involves many variables which make it very complex to design and run. For good quality design of casting, knowledge of three fundamental fields is required which are Fluid mechanics, Heat transfer and Metallurgy. Defects like shrinkage cavity, porosity, and sink can be avoided by proper designing of feeding system. For designing purpose many software are available in the market which uses different algorithm for solving solidification and filling problems in casting. In present work, AUTOCAST XI (based on Gradient Vector Method) casting simulation software has used for design and simulation of casting. The proposed approach overcomes the difficulty of controlling process parameters in foundries (mainly due to manual processes and unskilled labors), by making the design more robust (less sensitive) with respect to process parameters.**

Keywords—AUTOCAST, casting simulation, casting, gravity die casting, casting development.

I. INTRODUCTION

Metal casting is one of the oldest methods of manufacturing of components. It has played a vital role in the development and advancement of human civilizations. After 5000 years since its birth, still metal casting is very important in everyday life.

Metal casting process is very simple to understand but still it involves many variables which make it very complex to design and run. For good quality design of casting, knowledge of three fundamental fields is required which are Fluid mechanics, Heat transfer and Metallurgy.

Casting is a process of obtaining desired shape by pouring molten metal in cavity (having reversed shape that has to be produce) and allowing it to solidify. Prior to casting, melt has to be prepared. Great care must be taken while preparing a melt as many defects like blow holes, gas porosity, etc., are because of bad quality of melt.

Any casting process is starts with melting of metal. It is first and very important as final properties of casting after solidification are mainly depends on quality of melt. Many defects in casting are due to bad quality of melt hence it is very important to treat melt before pouring. For example, at high temperature, hydrogen solubility is increase in aluminium alloys, which then cause gas porosity in casting after solidification [9]. To prevent this degassing methods are used. There are two types of degassing methods Mechanical and Chemical. In chemical method, degassing tablets are added in melt while melting.

Next step after the melt preparation is Mould making in sand casting or die design in die casting. It is very complex yet very vital for good quality of casting. Defects like shrinkage cavity, porosity, and sink can be avoided by proper designing of feeding system. For designing purpose many software are available in the market which uses different algorithm for solving solidification and filling problems in casting. In present work, AUTOCAST XI (based on Gradient Vector Method) casting simulation software is going to be used for design and simulation of casting. According to B. Ravi, [1] GVM method is found to be more accurate and computationally faster than other process. Filling of mould is essential part in casting process as it affect heat transfer and solidification process. Solidification rate of casting is depends on interfacial heat transfer coefficient (IHTC) and hence for accurate simulation of the casting process IHTC is necessary [2].

II. LITERATURE REVIEW

From existing literature it is found that casting is very complex process and it is affected by many different parameters. Lubos palak investigated effect of different filling condition on the quality of cast of aluminium cylinder in gravity die casting process [8]. Investigation involves use of three different gating systems and its individual effect on quality of cast. Three gating system are top gating system, bottom gating system and tilting gating system.

Top gating system is very useful for better cooling of casting but very complex for filling by gravity as it causes a lot of turbulence. 80% of casting defects are caused by turbulence [9]. J. Campbell stated ten rules of casting in which he suggested critical velocity of melt as 0.5 m/s. velocity greater than critical velocity at any point in casting should be avoided for good quality of melt. If the speed of liquid exceeds critical velocity its surface film is folded in bulk of liquid. Author gives a name to this folded film as ‘bifilms’. These bifilms after solidification in casting reduces fatigue resistance and strength. Bifilms may create leak path and causes leakage failure.

According nayama criterion, last region to solidify is most probable location of shrinkage porosity. So, main aim of any simulation software is to shift last solidifying region away from part i.e. in feeder. Reis et al. (2008) modeled the shrinkage defects during solidification of long and short freezing materials. The shrinkage defects in short freezing materials tends to be internal, in the form of porosity, while in long freezing materials these defects tend to be external in the form of surface depressions.

B. Ravi proposed gradient vector method (GVM) to visualize feed path and to design feeding system in casting [1]. GVM method is computationally faster and more accurate than other process. It involves computation of solid liquid interfacial heat flux vector using analytically derived solution to phase change heat transport equation. For no shrinkage porosity, feed path must originate from feeder and not from part. Feeder must be able to compensate all liquid shrinkage in casting at the same time it should be position within feeding distance to the hot spot.

B. Ravi investigated different methods to analyze solidification shrinkage in casting and found out the following result [1].

TABLE I. COMPARISON BETWEEN DIFFERENT NUMERICAL TECHNIQUES FOR CASTING SIMULATION

Mode	Relative distance between computed hot-spot and centroid of shrinkage (%)	Computation time (min)
Experiment (centroid of shrinkage)	-	-
FVM	1	85
MVM	7	7.2
LSM	1	85
GVM	1.4	8

AUTOCAST XI is based on GVM which is computationally faster and accurate. Chaudhary et al. (2014) investigated the validity of AUTOCAST X by conducting experimental trial of casting and comparing it with its simulation result.

Mirbagheri [12] investigated the effect of wall roughness on melt flow. He concluded that, roughness in sand mould increases the amount of erosion in sand as a vortex flow can be produce due to roughness. Roughness is also important for design of feeding system as flow pattern in casting is affected by the roughness and which is responsible for temperature distribution in casting.

III. STEPS INVOLVE IN CASTING DEVELOPMENT

A. Solid modelling
B. Castability Analysis
C. Tooling and Methoding
D. Process Simulation
E. Production and Quality planning
F. Actual Casting
G. Casting Inspection

Casting development is starts with initial design of product to be casted. In computer aided casting development solid modeling is a starting point as it gives better visualization of product without being actually produced. Product details are required to perform the castability analysis on product. Castability is ease with which the component/ product can be casted using a particular casting process. For example, Gravity casting is suitable for product having minimum thickness greater than 3 mm and total production quantity must be greater than 10000 units to justify its initial investment. In other words, suitability of a product to a particular casting process can be found out by using a castability analysis.

After castability analysis, the tooling and methoding is now decided. Hence, the data gather for the process simulation is based on tooling and methoding. That data include, mould material, mould temperature, pouring rate, pouring temperature, etc. In present work, both castability analysis and numerical simulation can be performed using AUTOCAST XI software. In AUTOCAST XI, part process compatibility is checked using three parameters viz. Part weight, Part size and minimum thickness. By performing simulation, proper gating system can be determined from AUTOCAST XI.

In this step, actual production is carried out. In gravity die casting, a die a made having cavity in shape of casting to be produced with a proper gating system. After casting production, casting is inspected against the various casting defects. Inspection process includes visual inspection, X- ray radiography, and ultrasonic testing. Corrective action is then taken based on the causes of casting defects.

IV. NUMERICAL SIMULATION USING AUTOCAST XI

Simulation using Autocast XI is a very good way to design the molding cavity i.e. part with gating system. Simulation using Autocast do not produces waste, it does not consume any time for lots of actual trial before final design.

A. Actual Model

The following 3D model is given by the customers. From fig.1, Minimum dimensions is greater than 4 mm , so it is possible to produce this part using GDC. But the small holes on the top are difficult to produce during GDC. So, Instead of producing holes during casting, we can drill those holes after casting using machining process. Though this approach reduce yield but it also helps to reduce rejection rate means it improves quality.

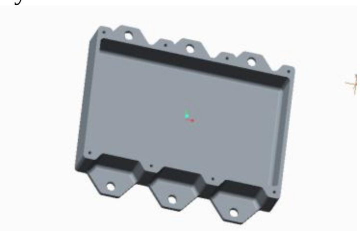

Fig.1. Final size and shape required of DCDC Bottom cover

B. Model with Casting Allowances

Before going toward solidification simulation, necessary changes have to be made on part dimensions to improve the process compatibility for the given part. Various allowances have to be provided on part. First, 3 mm machining allowance has to be provided on critical surface, and then 2^0 draft allowances is to be provided surface perpendicular to parting surface. Parting surface is decided based on easy

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 6 Issue 06, June - 2017

removal of part from casting die. And last 3.7% shrinkage allowance by volume is provided. After providing all these allowances, final dimensions of the cavity are shown in fig. 2.

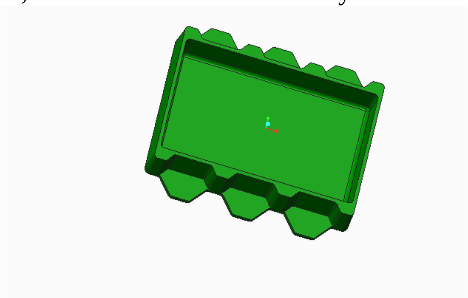

Fig.2. DCDC bottom cover with various casting allowances

C. Mold Dimension and Other Properties

Pouring Temperature = 670 °c and 720 °c.
Die Temperature = 200 °c.
Die (mold) size = 330mm x 200mm x 160mm.
Casting Metal = AlSi12.
Die Material = Mild steel.
Part weight = 408.7 gm.

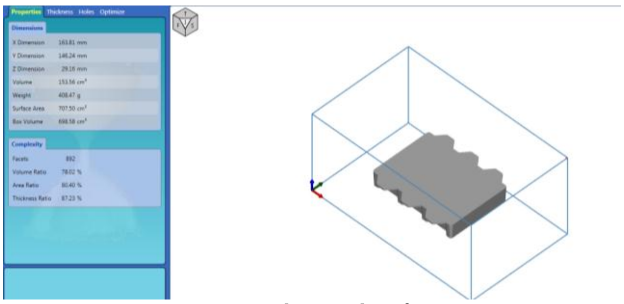

Fig.3. Complexity index of part

For this software, model is required in .stl format.

Volume ratio, Area ratio and thickness ratio are the measures of complexity of shape of castings. High value of these ratios indicates complexity of shape of casting.

Here, Volume ratio = 1 - (volume of part/ volume of mold box) = 78.02 %

Area ratio = 1 - (Area of sphere of equal volume / Area of part) = 80.40 %

Thickness ratio = 1 – (minimum thickness of part / maximum thickness of part) = 87.23 %

Using thickness module in part function, we can also checked the thickness at different location in part.

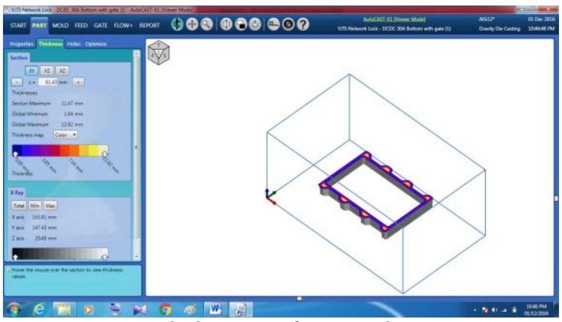

Fig.4. Part Thickness map for DCDC bottom cover

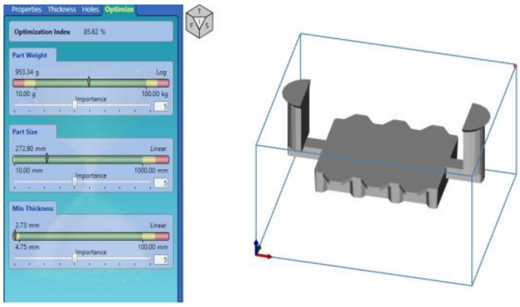

Fig.5. Part and Process compatibility

The compatibility of product requirement and process capability is measured using optimization index which is checked from three parameters part weight, part size and min. thickness.

D. Feeder design

Before going toward feeder design, orientation has to be selected. Here, horizontal orientation is selected as it would allow better flow with relatively less filling time than vertical orientation. Parting plane is selected at top of flat surface of part as it allows easy ejection of casting.

Feeder is a part of gating system which provided the material to compensate the liquid shrinkage in the casting during solidification. The purpose of feeder is justify only if, it has sufficient amount of material to compensate liquid shrinkage and it should be able to supply that material to the location where shrinkage porosity is likely to occur. Hence, Feeder must be connected to close portion having hotspots.

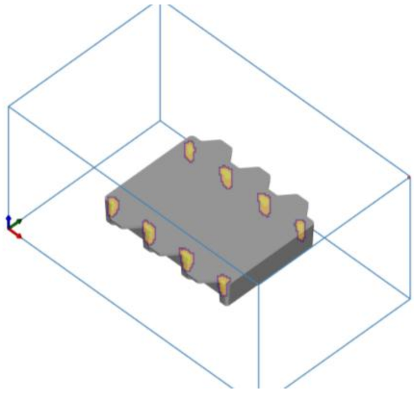

Fig.6. Hotspot in DCDC bottom cover

Hotspots are the last solidifying region probable to get shrinkage porosity. Fig.6. showing the locations of hotspots that are likely to be occurred in the part if no gating system is attached.

First, side feeder (half cylindrical) having dia. 25mm and height 70 mm had attached through neck size 20 mm x 15 mm x 15 mm. but it was unable to prevent shrinkage porosity.

Hence, I have increased the diameter from 25 mm to 30mm.

Fig.7. shows the locations of hotspots that are likely to be occurred after attaching the gating system to part. In general, shrinkage porosity is inevitable but we can shift it to the feeder so that no shrinkage porosity would present in part. Hence, main objective of attaching feeder is to shift shrinkage porosity from part to feeder.

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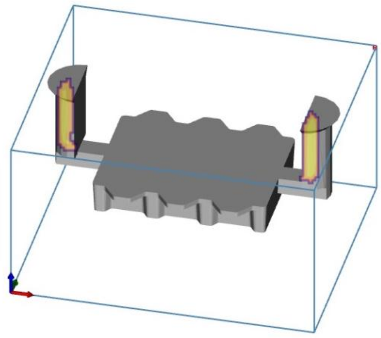

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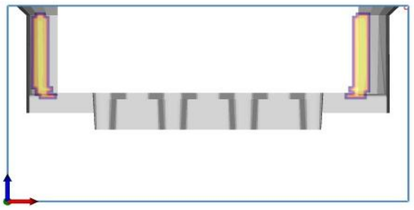

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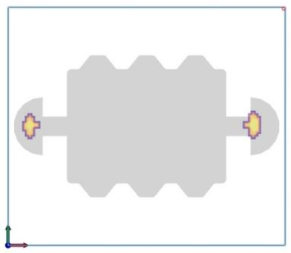


(c)

a. Isometric view b. Front View c. Top view

Fig.7.. Shifting of hotspots from main cavity to Sprue and feeder

Software is also able to give visualization of feeding path. It enables to visualize direction solidification of casting. It connects the point in the casting that solidifies later to the point that solidifies earlier. Ideally, feedpath should end in feeder for good quality casting.

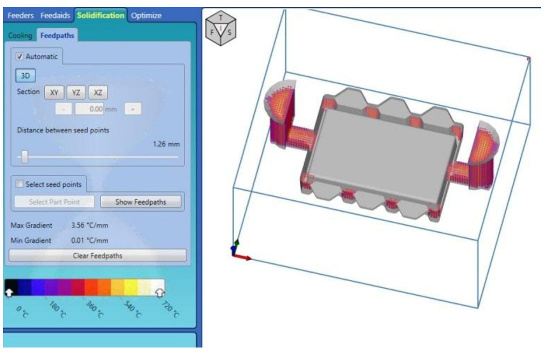


Fig.8.. Feed path visualization

E. Gating design

Many defects in casting can only be preventing by proper designing of gating system. For e.g. Cold shut, air porosity, mis-run etc.

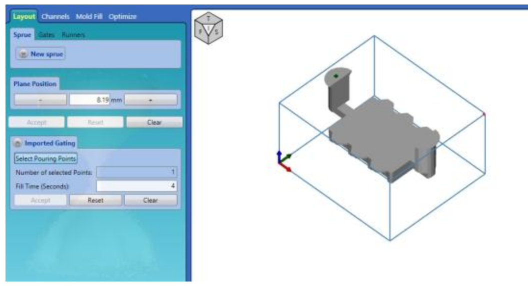


Fig.9. Pouring point located at top of sprue in imported gating system

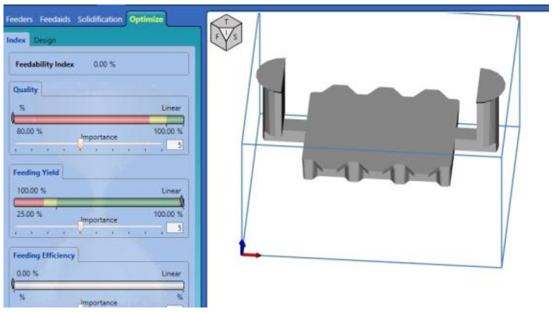
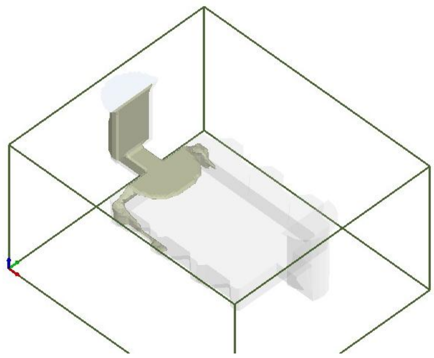


Fig.10. Feeding optimization index

Software has one optimize function through which it automatically select dimensions as per required fill time. But as the gating system is imported with the part this function not activated instead we can decide the fill time depends on molten metal pouring rate in casting cavity. Here, as gating system directly imported with model instead of creating it in software, feedability index 0% is showing.

F. Filling and solidification Simulation

As permanent die has very low porosity, filling visualization helps to detect possible location for air vents. The below figures showing visualization of metal filling in the cavity of casting die.



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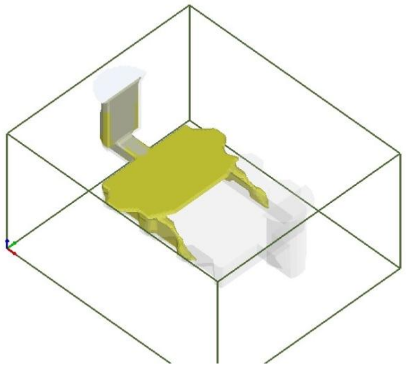

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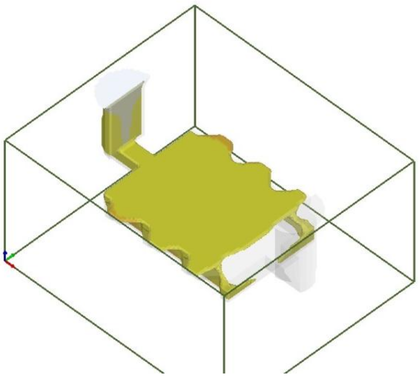

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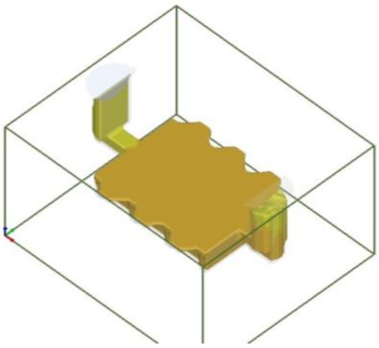


(d)

Fig.11. Metal filling simulation visualization

G. Shrinkage Porosity

Shrinkage porosity is form at a last solidifying region in the casting and it is a casting defect. Shrinkage porosity can only be preventing by proper design of gating system.

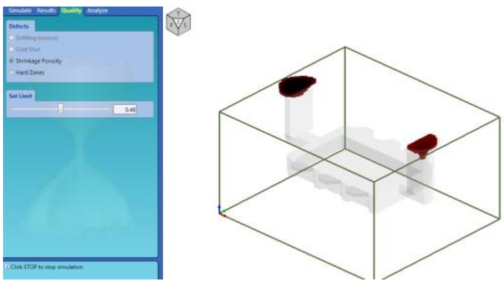


Fig.12. Shrinkage porosity in sprue and feeder

V. DIE DESIGN

After deciding the dimensions of gating system with part, the cavity formation in die can be started. A special care have to be taken for easy removal of casting from die cavity and hence parting line and location of ejector pins position is very important for casting die design.

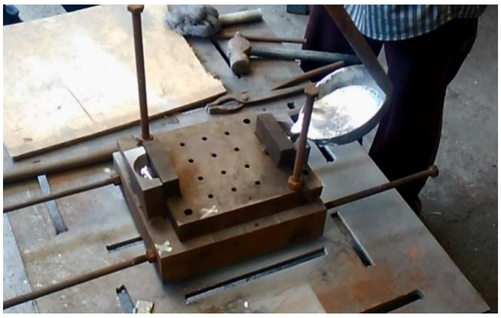
Fig.13. Exploded view of Die assembly

Cavity in die is made using CNC machine and gating systems can be form on die using vertical milling machine. Cavity has to be polished after machining.

Fig.14. Die for Gravity die casting

VI. EXPERIMENTAL VALIDATION

For experimental validation, molten metal was poured in die cavity and allow solidifying at room temperature. Casting produced was free form all defects. From manual inspection it is proved that casting was free from surface defects. And by cutting part in different halves it is proved that no shrinkage porosity was present.



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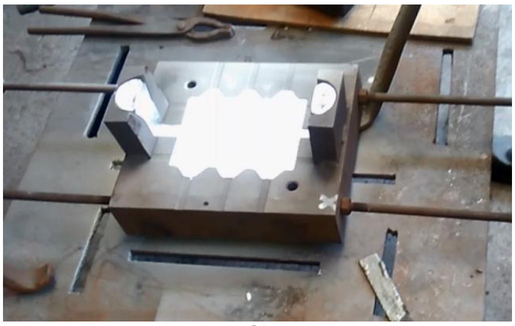

(b)

Fig.15. Casting of DCDC Bottom cover

Fig.16. Part safter casting

VII. CONCLUSION

Casting is very complex process and producing a defect free casting is very difficult task as quality of casting is depends on both design and process parameter. The lead time of sample delivery in casting involves lot of trial production until the desired quality of casting produces.

But all that difficulty can be reduced by using simulation software that can give accurate result regarding probable casting defect. Casting simulation software can all gives robust design by giving best design to casting such that defect can be eliminated without changing any process parameters.

Simulation software also reduces lead time in casting by reducing numbers of trial that has to be performed before the actual production. Simulation software also provide optimum yield to casting and thus it reduces cost of casting at the same time it increases production rate. Ultimately, higher productivity can be obtained using simulation software in casting fields.

ACKNOWLEDGMENT

This work is carried out in VJTI, Mumbai and Sonakshi founders, Vasai. Authors gratefully acknowledge the support given by Prof. P. M. Ravanan, Production Department, VJTI, Mumbai and Ankush Gajbhiye, Ph.D. scholar, Production Department, VJTI, Mumbai in casting simulation. Authors also acknowledge the support given by Nimesh Dodiya and Divyesh Bakrania from Sonakshi Founders, vasai in conducting casting trials.

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