NATIONAL CONFERENCE ON INNOVATIVE TRENDS IN ENGINEERING & TECHNOLOGY – NITET-19
15-16th March 2019
NOVATEUR PUBLICATIONS
International Journal Of Innovations in Engineering Research And Technology [IJIERT]
ISSN: 2394-3696

A REVIEW OF OPTIMIZATION OF DEFECTS IN CASTING COMPONENTS BY USING SIMULATION TECHNOLOGY

Mrs. Chandanshive S.A
M.Tech Scholar, Manufacturing Process Engineering, AGPIT, Solapur, Maharashtra, India

Prof. G.R. Deshpande
Assoc. Professor, Manufacturing Process Engineering, AGPIT, Solapur, Maharashtra, India

Abstract:
Casting is one of the most economical processes which are used to get complicated metal shapes which then require little or almost no machining. Major defects found in casting, such as the shrinkage cavity, porosity and hot tears etc. are obtained results of solidification process of molten metal. Minimization of these defects is possible by making appropriate changes in the feeding parameters, such as location of feeder, size of feeder and shape etc. By choosing correct set of parameters we can achieve the desired quality and yield that are difficult to achieve. This is why a need has felt for the computer aided optimal feeder design united with the solidification simulation to condense the number of trials on shop floor and to obtain enhanced yield with high quality, in nominal possible time. This paper describes and gives the information about research carried out in the past, to foretell the location of the shrinkage porosity and various techniques used to minimize the shrinkage porosity, by stressing the important conclusions and results.

Keywords - Casting, feeder design, shrinkage cavity, solidification, simulation.

Introduction:

Casting of the metal is one of the oldest of all manufacturing processes used to manufacture the complex shape objects. The solidification rate affects the microstructure of the casting material which again influences the properties such as hardness, strength etc. The position of the riser plays a very important role in casting of metals and mainly relies upon the form and size of casting used. Placement of the riser also depends upon thermal properties and mold design of casting material. Shrinkage is a foremost defect in sand casting and habitually responsible for rejections of casting parts. Shrinkage may be defined as "reduction in the size of a casting during its evolution from a liquid to a solid state."

The Aluminum and its alloys (Al-alloys) are more prone to defects, like shrinkage-one of the persistent problems, that impact on quality of the castings. Shrinkage distinctiveness is useful for enhancing mechanical properties of castings. Predicting the liquid-metal all through solidification has been imperative to consider the different modes of shrinkages and trace the development of the liquid-metal free surfaces. Simulation can be a powerful tool of analyzing various material phenomena occurred during casting process.

Simulation is a tool that gives idea about methods of filling and solidification process of casting component. It also helps in dipping the time required to manufacture a new casting by removing numbers of foundry trails. There are amount of casting simulation software's available today in market such as Auto-CAST, Solid-CAST, Magma-soft, Pro-CAST, that are developed by different companies. Some simulation software's are based on different numerical techniques such as Vector Element Method, Finite Element Method, Finite Difference Method, Vector Gradient Method Finite Volume Method, etc. and are accessible to find defects and minimize them.

2. Approach to Shrinkage Porosity

2.1 Classification of the shrinkage porosity:

When the casting is solidifying remote pools of liquid appear inside the solidified metal that is called hotspots. The shrinkage porosity usually gets formed at the top of hotspots. Shrinkage is defined as the reduction in volume of casting when metal is cooling or solidifying or it may also define as defect which is round in shape, which is isolated and distributed over some portion of casting [2].
Shrinkage porosity can be classified into two types:

(i) Macro porosity
(ii) Micro porosity [1, 3].

Macro porosity occurs inside of casting near hotspot and can be seen by naked eye whereas micro porosity forms uneven shapes with dendrites and minute cavities which cannot be seen with bare eye.

2.2 Formation of Shrinkage porosity:

From casting point of view, the problem of porosity formation is complex and most interesting. Irrespective of these things, effort is being and has been made to supply information concerning the shrinkage porosity formation. Research shows that defects related to shrinkage results from the interaction of several phenomenons such as

1. Heat transfer through solidification,
2. feeding current and its free surfaces [3],
3. warp of the solidified layers
4. The occurrence of dissolved gases.

It is supposed that defects occurring in the castings due to shrinkage porosity are strongly prejudiced by the time-changing temperature profile inside the solidifying casting [4]. Solidifying region of casting part gives idea about having sufficient amount of feed of metal at higher temperature is determined by the temperature gradient within part. Shrinkage pores will appear in regions experiencing amount reduction due to phase transform with no admission to feed metal. With reference to above research P. D. Lee [1] showed that porosity configuration in the aluminum alloys have two primary causes:

(i) volumetric shrinkage and
(ii) evolution of hydrogen gas

Volumetric shrinkage passes on to the density distinction between the solid and liquid phases of alloy. As solidification profits, the volume diminish and surrounding liquid flow in to compensate. Depending upon the quantity and distribution of solid, the fluid flow impeded or even entirely blocked. When sufficient liquid is not there to flow in cavity, voids (pores) gets formed. This type shrinkage porosity can be in the form of many smaller distributed pores or one huge void.

2.3 Factors Affecting Shrinkage Porosity:

Campbell and Gunasegaram [4] showed that rates of heat transfer at the casting or molding interface plays a important role in deciding the temperature gradient in solidifying casting in the permanent molds. Temperature gradients are the function of geometry of casting and that of runner [4]. As thinner sections would solidify earlier than thicker areas, a temperature gradient exists from thinner to the thicker section. The solidification pattern or melt flow pattern as inside casting and time required fill the casting is important in determining temperature gradients [4].

More the flow length inside the cavity more and more heat loss would take place and which results in unfilled cavity or unsolidified cavity. As solution to this the notion of directional solidification was introduce which allows a constant temperature gradient between feed metal and solidifying region.

2.4 Modeling of the Shrinkage Porosity:

Once the porosity forms, these pores will breed until they have reached balance between all forces acting upon them including pressure and interfacial energy.

There are 3 modeling methods for modeling of the shrinkage cavities:

1. Direct Shape Method (DSM),
2. Material Property Reduction Method (MPRM) and
3. Shape Simplification Method (SSM) [16].

DSM generates the finite element mesh directly from original shape of shrinkage cavity in the casting parts. This method is simple to use but involves large number of elements to symbolize the shapes of shrinkage cavities, thus lead to elevated cost of analysis and results in many numerical errors.

The conception of MPRM is based upon modulus of elasticity of materials in lowest range of porosity derived from assumption that voids do not interact. SSM models the shrinkage cavities defects in to shape of hollow spheroid [16]. It involves making spheroid that encloses STL (Stereo lithography) format of shrinkage cavity. To predict the location of macro shrinkage cavity a 3D model was developed [5], by solving heat transfer & mass preservation models. It shows that when an region will be completely disconnect from sources of the liquid metal (risers) where a empty space will form. Similarly a model of shrinkage for long and short freezing metals is developed by taking into consideration that volume shortfall due to shrinkage can only be remunerated by two phenomena one is dejection of the outside surface or by creating interior pores [3].

2.5 Casting Solidification Simulation:

Nowadays CSS- Casting Simulation software's has become an influential tool to know the growth of casting process for predicting internal defects and solidification analysis. Casting simulation tool should be used for quality enhancement [14], yield improvement and speedy development of new casting reducing quantity of foundry trails. Simulation includes Mold filling visualization, Solidification analysis and predicts location of interior defects such as shrinkage porosity, misrun etc. The study made on simulation of the mould filling and the solidification of the casting that is green sand ductile iron concluded that the use of simulation software for casting like Pro-CAST is capable to get rid of the defects like shrinkage and porosity etc. in casting [13].

It also assists in improving the yield of casting and at the same time the optimization of gating system is completed. Similarly shrinkage cavities and supplementary defects may be dogged by pattern of solidification inside the casting [12, 13]. M. Sutaria et.al and others [9, 10, and 11] worked upon a novel idea where optimization of casting feeding is completed with the assistance of feed paths.

The calculation of feed-paths is finished by method known as the Vector Element Method (VEM). By using this method it is probable to be familiar with the direction of feed metal from a given point can be identified. It clearly denotes where the shrinkage porosity may expand by showing the supply paths converging at various points in the casting. And the rest of the work is ended by the FEM based simulation software for visualizing casting feed paths in a improved way. This technique is used for standard Al-alloy casting wherever feeder optimization is finished with the aid of VEM based software. A narrative investment casting process was developed for production of ingot of TiAl alloys by forming a minute vertical temperature gradient lying on the mold.

The main benefit of this process is that it allows solidification of casting beginning from bottom to the top sequentially. The arithmetical simulation and experimental results analysis showed that shrinkage porosity of the Ti-47Al-2Cr-2Nb alloy was considerably improved by applying a small vertical temperature gradient of three degree Celsius/mm on mold [15], but there is no effect of pressure and pouring temperature on the metal alloys and had not apparent consequence on the reduction of shrinkage porosity. The decisive value of the Niyama criterion that can dependably predict the shrinkage porosity in Ti-47Al-2Cr-2Nb alloy was recognized by the comparison of investigational and simulated results. Design of the experiments and the computer assisted casting simulation methods are combined to investigate the sand related & methoding related defects in green sand casting. In first method Taguchi supported L18 orthogonal array was utilized for the experimental reason and analysis was conceded out using 'Minitab' software for examination of variance (ANOVA) and analysis of mean (AOM).ANOVA results designate that the selected procedure parameters significantly influence the casting defects and refusal percentage. In the second method, shrinkage porosity analysis is finished by introducing a novel gating system to solid model planned in CAD consisting of four cavity molds. To obtain the shrinkage porosity to optimize stage in casting part there be number of iterations performed by means of casting simulation software. As consequence of new gating and feeding structure there was reduction in shrinkage porosity (about 15%) and improvement in yield (about 5%) was observed [12]. From a research it indicates that when combination of advanced simulation techniques and basic simulation are used in big foundries and cloud simulation techniques is used in small scale industry or SME, things run smoothly with well-organized utilization of available resources. As for example in foundry quality of casting of aluminum wheels were predicted by shrinkage index, [13] in Pro- CAST software. Similarly when applied to the engineering field, that too in production field it reduces wastage of resources by saving cost [14]. With the assistance of Auto-CAST software hotspots in the casting were positioned and also optimum location for placing feeder in the casting was recommended. Application of exothermic sleeve was as well studied as feed aids. The simulation learning has shown the development in feeding, yield and quality of the casting. Another grey cast iron foundry FINE CAST PVT, LTD. was facing a problem of high rejection rate for shrinkage defect developed in part. By the use of the simulation software Auto-CAST which use hybrid technique for the computation reason the rejection rate were reduced to halved [14]. The technique is computationally much quicker than other methods like FEM, FVM, FDM, etc. [14]. This method too gives reliable results in conditions of Interfacial Heat Transfer Coefficient (IHTC) than other methods. [3]

Conclusion

1) In casting design procedure, mostly shrinkage defects occur in part. Nowadays with casting simulation software we can predict the location of shrinkage porosity and can be eliminated within no time, saving lot of foundry trials and cost.

2) Such as Pro-CAST software which relies on FEM method is used for solidification analysis of casting part & software has stand up to marks to eliminate in shrinkage porosity in casting also software has reduced the rejection pace of particular casting to a lower level. In Pro- CAST software geometric elements are displayed in terms of tetragonal and hexagonal entities.

3) Similar software is Magma-soft which is FVM based which uses cubic or the brick shaped

elements. This simulation method is most competent and accurate than the previous one (Pro-

CAST). It reduces the lead time and increase the yield of casting without carrying any actual trails on foundry.

4) Auto-CAST is casting simulation software which is becoming popular day by day because of its simplicity, computational capabilities and simple to use user interface. This software based on VEM method by which feed paths are computed and converging of these feed paths in casting at particular point gives position of shrinkage porosity and defect is eliminated by placing feeder at that location. The results provided by Auto-CAST software exactly matches with experimental validation. The time required for making computation is very less than other software's available.

References

[1] P.D.Lee, A.Chirazi, D. See. "Modeling microporosity in aluminium-silicon alloys: a review, "Journal of Light Metals, 1, 2001 pp. 15-30.

[2] A S Sabau and S Visvanathan,"Microporosity Prediction in Aluminum Alloy Castings" Metallurgical and Materials Transcations B, 33B, 2002 pp. 243-255.

[3] A. Reis, Y. Houbaert, Zhian Xu, Rob Van Tol, A.D.Santos, J.F.Duarte, A.B. Magalhaes ,"Modeling of shrinkage defects during solidification of long and short freezing materials," Journal of Materials Processing Technology, 202, 2008 pp. 428–434.

[4] D.R.Gunasegaram, D.J. Farnsworth,1, T.T. Nguyen,"Identification of critical factors affecting shrinkage porosity in permanent mold casting using numerical simulations based on design of experiments" Journal of Materials Processing Technology, 209, 2009 pp.1209–1219.

[5] Vishwanathan, "Modeling of Microporosity, Macroporosity and Pipe Shrinkage Formation during the Solidification of Alloys Using a Mushy-Zone Refinement Method: Applications to Aluminum Alloys," Metallurgical and Material Transactions A, 33A, 2002, pp. 2095-2106

[6] T.R.Vijayaram,"Numerical simulation of casting solidification in permanent metallic molds," Journal of Materials Processing Technology, 178, 2006, pp. 29–33.

[7] P.Prabhakara rao, G.Chakaraverthi "application

[8] Maria Jos Marques, "CAE Techniques For Casting optimization"„ INEGI, 2006, pp. 4465-4591

[9] Sutaria, M., "Casting Simulation Case Study: Shaft Pin (Cast Iron- Green Sand Casting)," Indian Foundry Journal, 56(12), 2010, pp. 53.

[10] Jagdishwar, M., "Casting Simulation Case Study: Pulley Casting (Ductile Iron- Sand Casting)," Indian Foundry Journal, 56(11), 2010, pp. 49.

[11] Joshi, D., Ravi, B., "Classification and Simulation Based Design of 3D Junctions in Castings," AFS Transactions, 117, 2009, pp. 7-22.

[12] Rahul Bhedasgaonkar, Uday A. Dabade, "Analysis of Casting Defects by Design of Experiments", Proceedings of 27th National Convention of Production Engineers and National Seminar on Advancements in Manufacturing VISION 2020, 2012

[13] Yeh-Liang Hsu, Chia-Chieh Yu, Computer Simulation Of Casting Process Of Aluminium Wheels – A Case Study, J. Engineering Manufacture, Vol. 220, Part B, 2006, pp. 203-211.

[14] B.Ravi, "Casting Simulation- Best Practices", Transactions of 58th Indian Foundry Congress, Ahmadabad, 2010, pp.1-6.

[15] Li Y G., "Progress towards the production of high quality y-TiAl castings", Proceedings of the third international symposium intermetallics (ISSI-3), TMS, 2001, pp.181-189.

[16] Kwak S Y, Cheng J, Kim J T and Choi J K. Structural analysis considering shrinkage defect of casting part. "Int'l J. of Cast Metal Research", 21 (1-3), 2008, pp. 419-423.