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A Review on Casting Defect Minimization Through Simulation

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Abstract— The objective of this paper is to find defects in casting process. Causes for shrinkage defects are discussed and remedies for the shrinkage defect would help to improve the quality of casting product. By proper casting technique, improving feeding design, proper location of ingates and risers will reduce the shrinkage defect. Simulation in software SOFTCAST helps to detect shrinkage defect and using discussed remedies help to reduce rejection rate.

Key words: Casting, Casting Defect, Shrinkage, Simulation

I. INTRODUCTION

Casting is a process which carries risk of failure occurrence during all the process of accomplishment of the finished product. Hence necessary action should be taken while manufacturing of cast product so that defect free parts are obtained. Mostly casting defects are concerned with process parameters. Hence one has to control the process parameter to achieve zero defect parts. For controlling process parameter one must have knowledge about effect of process parameter on casting and their influence on defect.

A well designed feeding system is very important to ensure the better quality of castings. Design of feeding system also involves the decision about correct location of risers and number of risers to be used. For new castings or the castings having very high rejection rates, modification of feeding system design is of prime importance. These modifications are done manually which involves huge time, cost and other resources. Casting simulation can effectively overcome these difficulties and provide powerful tool for prediction of the process growth. Simulation of existing feeding system provides the locations of the points where chances of defects are high. This information can be used to modify the feeding system design. Feeding systems are modified and simulated unless satisfactory results are obtained.

II. CASTING DEFECTS

A. Shrinkage

Shrinkage defects occur when feed metal is not available to compensate for shrinkage as the metal solidifies. Shrinkage defects can be split into two different types: open shrinkage defects and closed shrinkage defects. Open shrinkage defects are open to the atmosphere, therefore as the shrinkage cavity forms air compensates. There are two types of open air defects: pipes and caved surfaces. Pipes form at the surface of the casting and burrow into the casting, while caved surfaces are shallow cavities that form across the surface of the casting.

Closed shrinkage defects, also known as shrinkage porosity, are defects that form within the casting.

Isolated pools of liquid form inside solidified metal, which are called hot spots. The shrinkage defect usually forms at the top of the hot spots. They require a nucleation point, so impurities and dissolved gas can induce closed shrinkage defects.

1) Possible Causes

The density of a die casting alloy in the molten state is less than its density in the solid state. Therefore, when an alloy changes phase from the molten state to the solid state, it always shrinks in size. This shrinkage takes place when the casting is solidifying inside a die casting die. At the centre of thick sections of a casting, this shrinkage can end up as many small voids known as ‘shrinkage porosity’.

If the shrinkage porosity is small in diameter and confined to the very centre of thick sections it will usually cause no problems.

However, if it is larger in size, or joined together, it can severely weaken a casting. It is also a particular problem for castings which need to be gas tight or water tight.

2) Remedies

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

III. BLOWHOLE

Blowhole is a kind of cavities defect, which is also divided into pinhole and subsurface blowhole. Pinhole is very tiny hole. Subsurface blowhole only can be seen after machining. Gases entrapped by solidifying metal on the surface of the casting, which results in a rounded or oval blowhole as a cavity. Frequently associated with slag’s or oxides. The defects are nearly always located in the cope part of the mould in poorly vented pockets and undercuts.

1) Possible Causes

- Inadequate core venting
- Excessive release of gas from core
- Excessive moisture absorption by the cores
- Low gas permeability of the core sand

2) Remedies

- Improve core venting, provide venting channels, and ensure core prints are free of dressing
- Reduce amounts of gas. Use slow-reacting binder.
- Reduce quantity of binder. Use coarser sand if necessary.
- Apply dressing to cores, thus slowing down the rate of heating and reducing gas pressure.
- Dry out cores and store dry, thus reducing absorption of water and reducing gas pressure.

B. Sand Burning

Burning-on defect is also called as sand burning, which includes chemical burn-on, and metal penetration.

The defect occurs to a greater extent in the case of thick walled castings and at high temperatures.

The high temperature to which the sand is subjected causes sintering of the bentonite and silicate components.

In addition, the always present iron oxides combine with the low-melting-point silicates to form iron silicates, thereby further reducing the sinter point of the sand. Sintering and melting of the impurities in the molding sand enable the molten iron to penetrate even faster, these layers then frequently and firmly adhering to the casting surface.

1) Possible Causes

- Lustrous carbon content too low
- Proportion of low-melting-point substances too high
- Uneven mould compaction Gating and pouring practice
- Uneven distribution of inflowing metal with resultant over-heating
- Temperature of liquid metal too high

2) Remedies

- Increase proportion of lustrous carbon producer.
- This in-creases the amount of coke as well as the amount of lustrous carbon, which then results in positive separation between mould and metal.
- Use purer silica sands or, if necessary, add new sand. Reduce dust content. If necessary, reduce the amount of bentonite.
- Even out incoming metal flow
- Reduce pouring rate

C. Sand Inclusion

Sand inclusion and slag inclusion are also called as scab or blacking scab. They are inclusion defects. Looks like there are slag's inside of metal castings.

1) Possible Causes

- Low core strength
- Excessive core mismatching
- Pouring rate too high, with heavy impact against mould wall surface resulting in erosion
- Ladle too far above pouring basin
- Pouring time too long

2) Remedies

- Increase the strength of the cores. Use greater proportion of binder.
- Compact cores more evenly and effectively and, if necessary, inject gas more evenly
- Avoid core mismatching.

D. Cold Lap Or Cold Shut

Cold lap or also called as cold shut. It is a crack with round edges. Cold lap is because of low melting temperature or poor gating system.

When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called mis-run. A cold shunt is called when two metal streams do not fuse together properly.

1) Possible Causes

- Lack of fluidity in molten metal
- Faulty design
- Faulty gating

2) Remedies

- Adjust proper pouring temperature
- Modify design
- Modify gating system

E. Misrun

Misrun defect is a kind of incomplete casting defect, which causes the casting uncompleted. The edge of defect is round and smooth.

When the metal is unable to fill the mould cavity completely and thus leaving unfilled portion called misrun. A cold shunt is called when two metal streams do not fuse together properly.

1) Possible Causes

- Lack of fluidity in molten metal
- Faulty design
- Faulty gating

2) Remedies

- Adjust proper pouring temperature
- Modify design
- Modify gating system

F. Gas Porosity

The gas can be from trapped air, hydrogen dissolved in aluminum alloys, moisture from water based die lubricants or steam from cracked cooling lines.

1) Possible Causes

- Metal pouring temperature too low.
- Insufficient metal fluidity e.g. carbon equivalent too low.
- Pouring too slow.
- Slag on the metal surface.
- Interruption to pouring during filling of the mould.
- High gas pressure in the mould arising from molding material having high moisture and or volatile content and/or low permeability.
- Lustrous carbon from the molding process.
- Metal section too thin.
- Inadequately pre-heated metallic moulds.

2) Remedies

- Increase metal pouring temperature.
- Modify metal composition to improve fluidity.
- Pour metal as rapidly as possible without interruption. Improve mould filling by modification to running and gating system.
- Remove slag from metal surface.
- Reduce gas pressure in the mould by appropriate adjustment to molding material properties and ensuring
- Adequate venting of moulds and cores.
- Eliminate lustrous carbon where applicable.
- If possible, modify casting design to avoid thin sections.
- Ensure metal moulds are adequately pre-heated and use insulating coatings.

G. Mismatch Defect

Mismatch in mold defect is because of the shifting molding flashes. It will cause the dislocation at the parting line.

1) Possible Causes

- A mismatch is caused by the cope and drag parts of the mould not remaining in their proper position.
- This is caused by loose box pins, inaccurate pattern dowel pins or carelessness in placing the cope on the drag.

2) Remedies

- Check pattern mounting on match plate and
- Rectify, correct dowels.
- Use proper molding box and closing pins.

H. Cracks Or Tears

Cracks can appear in die castings from a number of causes. Some cracks are very obvious and can easily be seen with the naked eye. Other cracks are very difficult to see without magnification.

1) Possible Causes

- Shrinkage of the casting within the die
- Undercuts or damage in die cavities
- Uneven, or excessive, ejection forces
- Thermal imbalance in the die
- Insufficient draft in sections of the die
- Excessive porosity in critical regions of the part
- Product design not matched to the process
- Inadequate die design

2) Remedies

- Reduce dry strength; add saw dust, coal dust
- Reduce pouring temperature
- Avoid superheating of metal
- Use chills
- Provide feeders
- Avoid early knockout. Give sufficient cooling time.
- Correct composition
- Reduce sharp corners

I. Incomplete Casting

Poured short, the upper portion of the casting is missing. The edges adjacent to the missing section are slightly rounded; all other contours conform to the pattern. The spree, risers and lateral vents are filled only to the same height above the parting line, as is the casting.

1) Possible Causes

- Insufficient quantity of liquid metal in the ladle.
- Premature interruption of pouring due to workman's error.

2) Remedies

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

IV. LITERATURE REVIEW

A. Harshil Bhatta, Rakesh Barota, Kamlesh Bhatta, Hardik Beravalaa, Jay Shah

In this paper, authors have attempted to modify the existing feeding system design of a component coded EP20 which is being cast by the Grey Cast Iron foundry FINE CAST PVT. LTD., V.U. Nagar. The component, as shown in Fig.1, is casing of gear box and is made of Cast Iron having 240 kg weight. Foundry has problems such as shrinkage, cold shut, mismatch and crack for this casting, as shown in Fig.2. It is clearly seen that shrinkage is the most frequently occurring defect out of all the three. In this paper, solution for shrinkage defect has been developed.

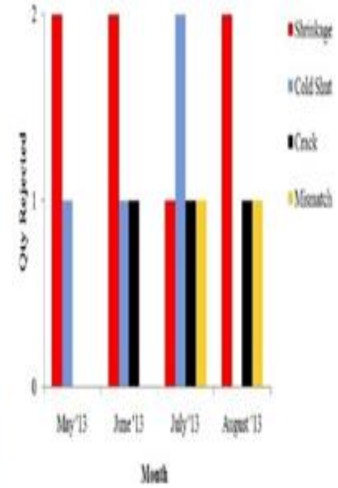

Fig. 1: Actual casting EP20 Fig. 2: Monthly rejection rate of EP 20

1) Modeling And Simulation

Solid model of the casting which was simulated is shown in Fig. 3. During uploading of the part, parameters such as molding sand material and its mesh size are also specified. Fig. 4 shows simulation result of the casting

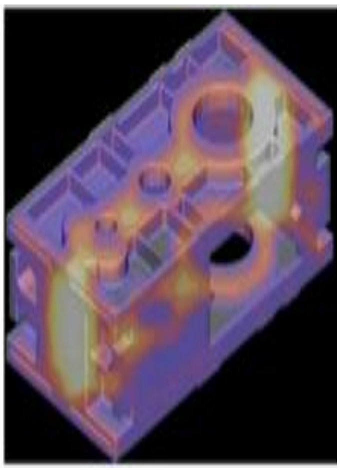

Fig. 3: Solid Model of Casting EP20 Fig. 4: Simulation Result of the Casting EP 20.

B. C. M. Choudhari, B. E. Narkhede, S. K. Mahajan

The objectives of this study is to represents stepped plate casting design and its numerical simulation using Auto-CAST-X software of square shaped (at top) plate having three perforations with diminishing height (at bottom)followed by experimental validation.

It has thick 208 x 208 mm square shape with a thickness of 21mm and then the perforations of diminishing height begins from left to right as 24mm (thickest section), 19 mm (thicker section), and14 mm (thick section), respectively for the entire width of square shape.

The simulation is based on Gradient Vector Method (GVM), which computes temperature gradients (feed metal paths) inside the casting, and follows them in reverse manner to identify the location and extent of shrinkage porosity. This is a new method that is found to be much faster than finite element or finite volume method, and usually more accurate too. The simulation costs are a fraction of the costs of foundry trials, while providing better and faster insight for casting optimization.

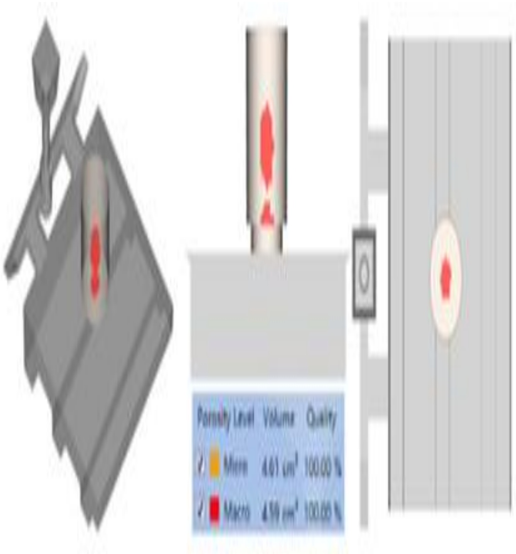

Fig. 5: Shrinkage porosity (macro-red, micro-orange).

The shrinkage porosity was computed from the temperature gradients using metal-specific process characteristics, which can be adjusted to calibrate the results with respect to the observed location of shrinkage porosity. Shrinkage porosity can be obtained in the solidification function under feed module by clicking on Shrinkage tab. It will be displayed as dots inside the casting: red for macro-porosity and orange for micro-porosity (Fig. 5).

C. Dr. B Ravi, Durgesh Joshi

This paper focuses on feedability analysis and optimisation driven by solidification simulation (Fig. 6). It starts with the user importing the CAD model of the as-cast part. The feeder design is carried out by identifying a suitable location to connect the feeder, computing its dimensions, creating its solid model and attaching to the part model. Then feedability analysis is carried out by solidification simulation followed by checking for the presence of hot spots inside the casting as well as connections between the feed paths. If internal defects are predicted, then feeder design is modified. If it is not possible to improve the quality by feeder design alone, then the part design is modified. Finally, yield is computed and compared with the yield obtained by other layouts with acceptable quality, and the one giving the highest yield is selected for implementation. The steps are described in detail next.

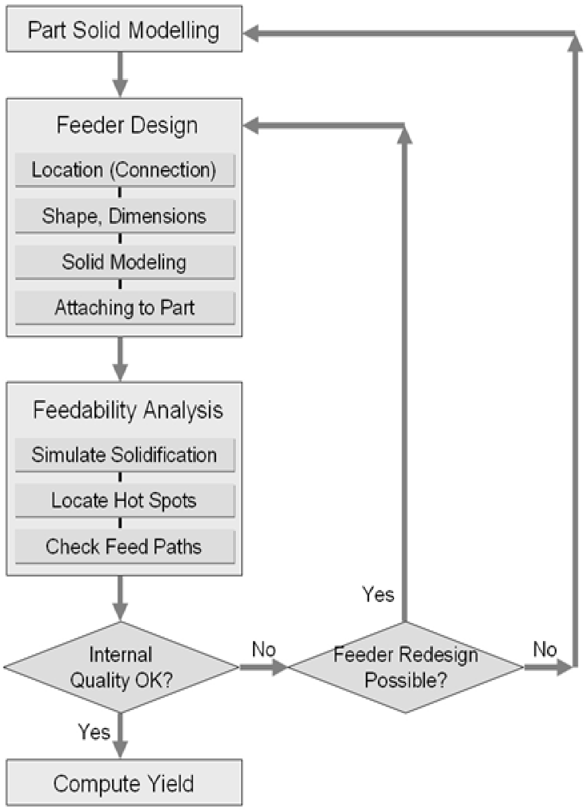

Fig. 6: Framework for feeder design and optimisation

D. Mayur Sutaria, Vinesh H. Gada, Atul Sharma, B. Ravi

The aim of this research paper is to compute feed-paths and hot-spots by combining level-set-method based sharp interface and feed-path model. The model is based on the solution of energy and level-set equations in solid and liquid, with Stefan condition on the interface. The energy and level-set equation are discretized using finite-volume and finite-difference method, respectively. Feed-path is computed by tracking mass-less particles along the liquid–solid interface during solidification using combined Eulerian–Lagrangian framework. The proposed model is benchmarked on six test cases, where temperature contours and solidification time are compared with a finite-element-method based commercial software. The capability to predict the temporal evolution of interface and to identify multiple hotspots is validated with an industrial aluminum-alloy lug casting. The numerical as well as experimental validations demonstrate the effectiveness of level-set-method for feed-path calculation.

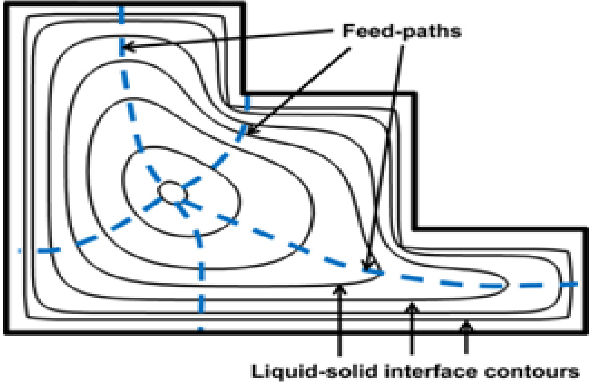

Fig. 7: Liquid–solid interface (solid lines) and feed-paths (dotted lines) inside stepped casting.

Computation of the feed-path is proposed, using several mass-less particles defined the interface. These particles are advected along with the interface at each time step using interfacial velocity components computed by level-set-method, which is essentially in the opposite direction of the maximum temperature gradients. Based on the shape of the mold cavity and thermal condition on the boundary, the movement of mass-less particles will be different. Thus, the feed-paths can be generated by tracking the position of several mass-less particles on the interface. Accurate location of the hot-spot can be obtained as the point at which the mass-less particles converge. The feed-paths are always normal to the liquid-solid interface contours as shown in fig. 7. The solid lines indicate liquid-solid interface contours and dotted lines indicate feed-paths.

E. X. Sua,G.Wang, Y.T. Zhang, J.F.Li, Y.M.Rong

In this paper, the simulation of whole manufacturing processes and manufacturing chains can be realized using Finite Element Techniques. Casting can change the dimensions of the model obviously, the deformation considering casting was about 10times larger than that of the ideal case. The stress generated by casting can quicken the austenitizing during the heat up process. The stress has little influence on organization transformation. The stress generated during casting is low, and during the heat up process much higher stress is brought in. Comparing figure 8 (a) with figure 8 (b) in separately, the stress generated during casting cannot change the nature of the organization transformation. Furthermore, the distribution trends of the two cases have little difference. The stress generated by casting cannot influence the organization transformation obviously

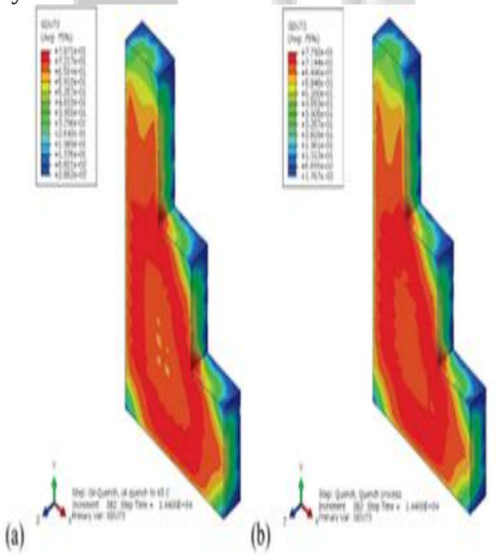

Fig. 8: Distribution of Lower Bainite (volume fraction) (a) ideal case; (b) the case considering the results of casting.

F. E. Anglada, A. Meléndez, L.Maestro, I. Domiguez

This paper presents the adjustment process of a simulation model to improve the correlation between simulation results and parts industrially manufactured. It includes the data registration at foundry plant, the preliminary set-up of the model and the later adjustment process to reach a correlation level according to the industrial necessities. The adjustment has been performed by means of inverse modelling. This technique uses thermal histories experimentally registered as base, and modifies the material properties and boundary conditions used in simulation until reaching a good correlation between numerical simulated cooling curves and they registered experimentally. The adjustment has been also focused on the shrinkage defects.

The simulation model is a FEM model developed in commercial software specifically focused on metal casting simulation. The case of study is an investment casting process, vacuum poured, of a nickel base super alloy designated Hastelloy X. Usual in the manufacture of components for aeronautical turbines.

G. F. J. Bradley, M. Samonds

This paper concerns the numerical simulation of solidification of near eutectic ductile iron alloys, which is somewhat more difficult than simulation of freezing range alloys from a number of standpoints, particularly in the case of graphitic cast irons, which may solidify according to the stable austenite-graphite system or the metastable austenite-carbide system. Commercial near eutectic ductile irons are often of slightly hypereutectic composition.

For such irons the start of solidification temperature is difficult to determine from thermal analysis data, since the evolution of latent heat associated with graphite precipitation in the primary solidification range is generally insufficient to produce a distinct arrest in the cooling curve. Similarly, the end of solidification temperature is difficult to precisely determine because of segregation effects. While most solidification takes place over a narrow temperature range associated with the eutectic plateau, ductile iron may in fact freeze over quite a wide range of temperature.

V. CONCLUSION

Defects like shrinkage, blow holes, sand burning, sand inclusion, cold shut, mis-run were identified during casting process. Among all, shrinkage defect was major cause for rejection rate. It is suggested that simulation to be carried out in FEM based software SOFTCAST where shrinkage defect is identified and during simulation an optimum feeding design is to be found out and at that feeding design there is no shrinkage defect found. And the experiment can be carried out to validate the simulation.

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