Simulation of sand casting to predict porosity for Ductile Iron

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Abstract:- The final casting parts are the greatly influenced life of cast parts and mechanical performance by the presence of porosity. The progress way to predict the presence of porosity is the reduced or eliminate in shop floor with help of the computer simulation program. The main aim of experiments performed to verify possibilities of the simulation software how much meshing results in simulation and experimental to predict presence of the porosity of casting process, shrinkage porosity it's very difficult and challenge to eliminate porosity but is the transfer to unimportant area can't be affects mechanical performance. So there are requirements of shrinkage porosity prediction with help of the simulation software namely click2cast software is made Altair Software Company. The porosity prediction before the production start of foundry its advantage of the industry I was performed for simulation and experimental work was be done Spheroidal Graphite Iron material solidification module in click2cast simulation software. Temperature and time calculation takes into basic phenomena at the origin of the micro and macro porosity .for the experiments purposes have used a pattern made of the maximum T shape cover at pattern its take into mold with a shape and size of mold. Material have used done Spheroidal Graphite Iron it's were not loaded from the software databased but manual loaded material specification is available to load material data but result of simulation and actual works little bit distorted by deviation because of the chemical composition of metal. The important phase of the casting is the solidification which effects of the porosity formation, such as nodular iron pore growth undercooling of the liquidus point and solidus point have be create cooling curve with help of the temperature and solidification time derivate. These data were then included to the database of simulation software and used in the simulation process.

***Key Words*:** Design, Simulation, Thermal analysis, Spheroidal Graphite Iron, Predict shrinkage porosity

1. INTRODUCTION

Most frequently occurring defects during casting are associated with porosity and sand inclusion of Spheroidal Graphite Iron, in this type material porosity forms during solidification, in the function of parts, where is two mechanisms take place first is the gas porosity and second during solidification of metal shrinkage porosity of the micro/macro porosity formation is take place because of the insufficient feeding of the material and local pressure drop in casting permeability problem mass inerratic by Darcy's law [3]. The accurate in the prediction of the shrinkage porosity it's mainly depended on the important of the thermal properties and physical parameter of the material as well as mold cavity properties also accurate input parameter of the boundary condition and load condition that will define system work presents the data utilized in the simulation programs will be optimized to make it representative for a sand casting process, in order to be able to predict location and character of porosity. The simulation of the metal temperature distribution, metal cooling curves and niyama value for will be analyzed and compared with experimental values as well as porosity in real castings.

2. LITERATURE

Study of related this works same paper literature of shows below to progress works important helps research paper

Marek Bruna et al done an advance calculation for the prediction of porosity formation for aluminum alloy by advance porosity module included in ProCAST software. In the experiment, he used thermal analysis to get accurate data about used alloy [marekbruna, 2017[1].

Zhao et al the works on the riser size of the aluminum alloys is optimized by using a conventional method and Auto CAST simulation software. Work on fluid flow interdendritic driven on shrinkage and gas porosity help of the chills place on a plate at end of chills effect, center chills effect identify solidification time of casting [Zhao and Liu, 2007] [2].

NielsSkat et al the simulation technology have sufficient to a prediction of the porosity formation. This paperwork on the mold filling simulation of casting process porosity formation and comparisons of feeding on risers with and without insulating sleeves. The metal in the riser without sleeves shows piping, whereas the metal in the riser containing an insulating sleeve does not show piping. The liquid in the insulating sleeve moves down horizontally and has a large influence on lowering the total level of micro-porosity in the casting [NielsSkat et al., 2013][3].

Kulkarni et al., 2011, find out the heat transfer during solidification of commercial yavailableAl-4.5% Cu alloy casting CO2-sand mold was assessed using an inverse analysis technique. The casting/mold interfacial heat flux and the peak heat flux represented the maximum heat transfer from the casting toCO2-sand mold. The time of occurrence of the peak heat flux transients was nearly five seconds after pouring. During this processing, porosity formation can be minimized [4].

3. EXPERIMENT

the experimental work was being done based on location of shrinkage porosity can be predicted with of the click2cast simulation software and niyama criterion which is depending on thermal parameter like maximum temperature gradient, cooling rate of material also other thermal data obtained using the simulation solidification event, finite element method (FEM) will be used to predict the location of the porosity in casting with the help of solidification simulation. The prediction of the shrinkage porosity it's mainly depended on the important of the thermal properties and physical parameter of the material as well as mold cavity properties also accurate input parameter of the boundary condition and load condition that will define system work presents the data utilized in the simulation programs will be optimized to make it representative for a sand casting process, in order to be able to predict location and character of porosity. The simulation of the metal temperature distribution, metal cooling curves and niyama value for will be analyzed and compared with experimental values as well as porosity in real castings.

3.1. Used alloy and its properties

The Spheroidal Graphite Iron was used in the in experimental it's a chemical composition listed in table1. Airkings Industry, GIDC Rajkot, which helped us with casting and material provided, uses mentioned metal in their production and they have a nearest to exact composition of every batch, so it was possible for us to make identical metal for simulation purposes.

Table1.Chemical composition Spheroidal Graphite Iron

Material	Fe	C	Si	Mn	P	S	Cr	Mo	Cu	Al
%	93.6	3.26	2.30	.283	0.0228	0.0186	0.0465	0.0574	0.177	0.0089

3.2. Mold material

Design of mold and shape of casting is chosen with respects to T junction by different size of length and wide is the cover by one mold cavity as shown in figure2. The shrinkage porosity obtain during solidification the main aims of how much porosity of junction, sprue based on design of diameter (H= 1.5D) with trapper angle connected with 3 gates part through a narrowed area (which will solidify first and additional feeding will not be possible for the formation of internal micro and macroporosity in the gating system of casting as shown in figure 1.

Figure1. Mold Shape of different size of T junction

3.3. Thermal analysis

In experimental work, thermal analysis was being depending mainly to found helpful data for click2cast simulation software. As will be simulation software main advantages is the possibility of presence porosity or other defects was be arise in simulation software is eliminated at shop floor without any trail and the obtain high quality of the casting. If the properly simulation create in order to several metallurgical parameters is required like boundary condition and load condition, which is the material properties as well as mechanical properties is required if interdendritic liquid such as chemical composition, specific heat, density of cooling rate is input parameter, mainly aims of this solidification of metal is between two points liquidus and solidus porosity mechanism formation. The liquidus points temperature of Spheroidal Graphite Iron is the 1211 °C which the start to convert the material solid to a liquid stage and up to heating pouring temperature at 1520 °C it was Spheroidal Graphite Iron and a solid point of this material is the 1115 °C. Between two points solidification event take place it also affects the of formation of porosity within junction area these parameters vary with time and temperature as well as one junction location to another junction location. Simulation solution of the create graph and experimental setup with a place of the thermosensor probe at every T junction it measures the casting temperature of solidification events as shown in figure2.

Figure2. Mold with thermosensors probe

Four thermosensors probe were placed into T junction, rest of the were directly in various places at the mold. For recording temperature data during experiments was used generic thermometer and Temperature vs. time cooling curve for sample 1,2 and 3 poured at a temperature 1480°C 1500°C and 1520°C respectively at the graph is presented in figure3. This obtains simulation time vs temperature curve recorded. At graph, numbers show at 2062, 6721, 3080, and 3489 at recorded T junction.

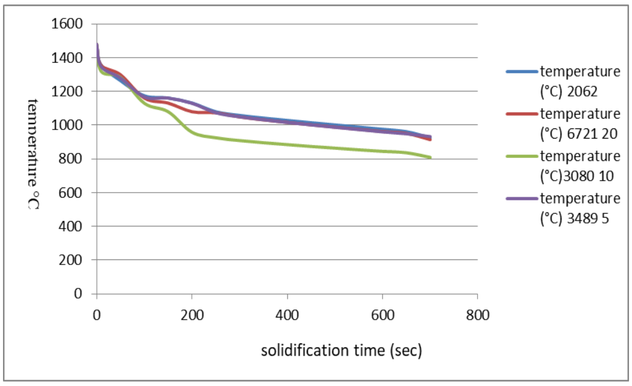

Figure3. Temperature vs. Time Cooling curve of SGI.

Solidus point

The solidus point is the take place at temperature 1115°C at which point's material has been solid after this points metal is fully mechanically rigid and solid contraction will start, beyond this condition feeding is the very difficult or impossible it can possible only at applied positive mechanical pressure, In SGI this occurred at approximately 80-90 % at solid fraction value is .77 -1 show in table2 solid – temperature 1115 °C.

Liquidus point

At a low fraction of the solids (0-20%) is at with respect to temperature 0-0.068 solid fraction value was been obtain simulation software shown in table2. There is usually no difficulty feeding the solidification shrinkage as the dendritic network is not yet liquidus point beyond this temperature liquid contraction is take place and liquid feeding of molten metal or mass feeding of dendritic grains is easily accomplished. The fraction solid at which this occurs is called the dendrite liquidus point. In SGI the dendrite liquidus point occurs at 17.43% solid – temperature 1194 °C.

Table2. The solid fraction with respect temperature

Temperature	Solid fraction
1195	000
1194	0.02
1180	0.068
1170	0.77
1160	0.99
1115	1
1114	1

In order to make effective and accurate simulation model, another required information needs to be filled into click2cast database - fraction solid curve. Fraction solid is defined as the percentage of solid phases formed at any point in time during solidification also shown figure solidification event at figure5. Accurate information concerning the fraction solid is necessary to characterize the solidification process and make predictions as well as perform computer simulation on feeding. Click2cast simulation model uses fraction solid curve to predict macro porosity formation in examined ductile iron. Corresponding numerical values for liquidus and solidus are T_{liq} (1195°C) and T_{sol} (1115°C) and fraction solid curve was filled into click2cast database. Same metal and alloy but only standard value can put us material data mentioned above were filled into click2cast, which allowed us to make relatively precise simulation model, in addition, also data from thermocouples placed in mold were filled into a database.

4. SIMULATION

The methodology for the location-based porosity formation and prediction in Spheroidal Graphite Iron with help of the flowchart in the simulation software clicIk2cast, it directly obtain niyama value finite element method but the only mechanism is shown due to shrinkage porosity formation can't obtain gas porosity is casting parts is removed by permeability calculation and same thermal parameter is affected by porosity formation like 1) heat transfer of metal to mold, 2) cooling rate of material 3) fluid flow which feeds the solidification shrinkage and 4) Pressure drop index based on Darcy's law within the interdendritic liquid. The simulations were made using software click2cast. This software solves the mass conservation equations using the finite element method. The mesh employed in the solution of the system is with meshing size 3 mm, triangle shape of mesh number of mesh 6790 and volume 124087 mm^3

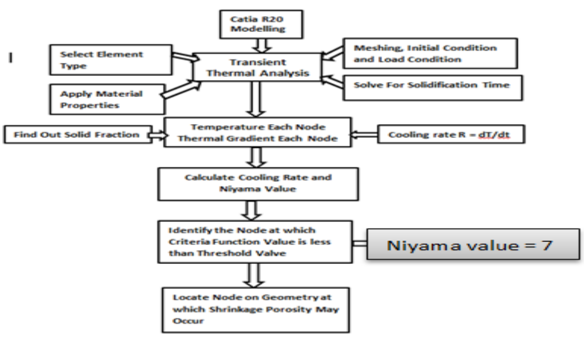

Figure4. Flowcharts simulation

Where it seen that casting was created with small size elements so calculation time is take more is an accurate and real condition. Mold elements cant seen at simulation software but see mold temperature in result it considers was mold temperature analysis, Clilck2cast simulation is finite elements method apply and mass conservation equation of Darcy and a related result of the solidification time at which used in the analysis can obtain solidification time of metal show figure5.

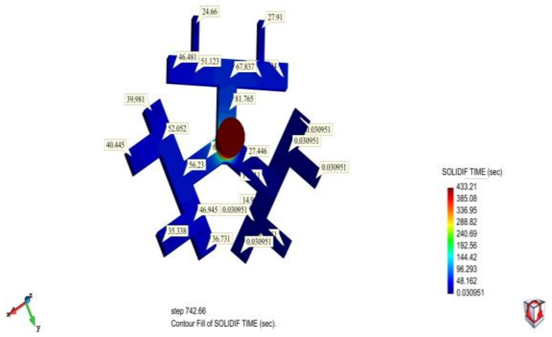

Figure5. Solidification time T junction node

The simulation includes specific heat, thermal conductivity, density, latent heat, and solidus and liquidus temperatures. Most of these data were obtained by thermal analysis from real ductile iron, as was described above. The effort was to obtain most of the data from real conditions and use a minimal amount of data from present databases of click2cast, so the simulation results correspond with reality. Regarding the process conditions, the initial temperature of the silica sand mold was assigned at 20 °C and the pouring temperature was varying according to Table3. Heat taking from the mold was set to air cooling boundary condition. Interface conditions between melt and mold were set with respect to the type of mold material and metal cooling curve and solidification time at different area of location is shown figure5.

Table3. Pouring Temperatures

Seriously no.	Temperature °C
1	1520
2	1500
3	1480

The experiments performed at different temperature at mentioned table3 and measured at T junction temperature in experiments than average of the all it shown figure6 t1, t2, t3 and t4 it all are experiments average result compares the cooling curve monitored by the simulation results with the click2cast simulation it mention at figure6 2062, 672, 3080 and 3489 are the simulation cooling rate result. The calculated profile is in very good agreement with the experimental, what we have achieved by gradual modifying heat transfer conditions and also molds properties. From the graph can be also seen, that initial temperature which was set in click2cast was slightly lower than the temperature from a real thermosensor. The reason for this increase was chemical composition is slightly different at simulation, that thermosensor probe wasn't preheated and during measurements thermosensor probe , itself a particular amount of heat from the melt and it was necessary to consider this deviation Fig5.

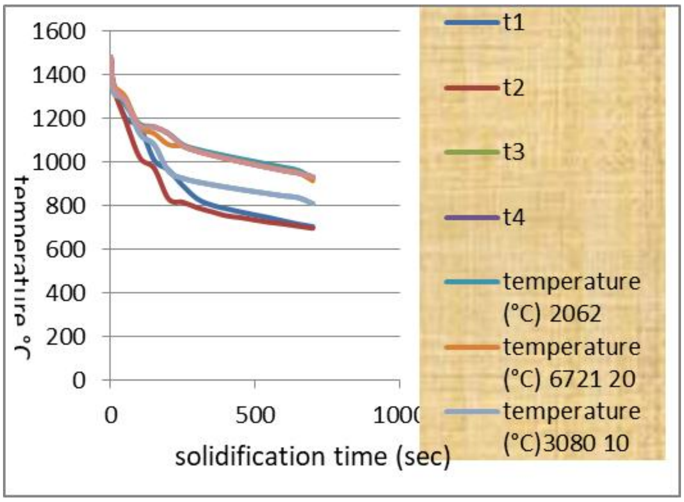

Figure6. Cooling curves comparison experiment and simulation

After all the thermo-physical data, boundary conditions, simulation parameters and heat transfer coefficients are determined, simulation can proceed with calculations. Microporosity was characterized within an area of the whole sample and compared with simulations results. As can be seen in Figure6, the dark colour cluster which is assumed to be gas porosity defects are found in the middle of the samples casts poured at 1480 °C and1500 °C fewer porosity defects in centre area can be observed at higher pouring temperature as shown in Figure6.

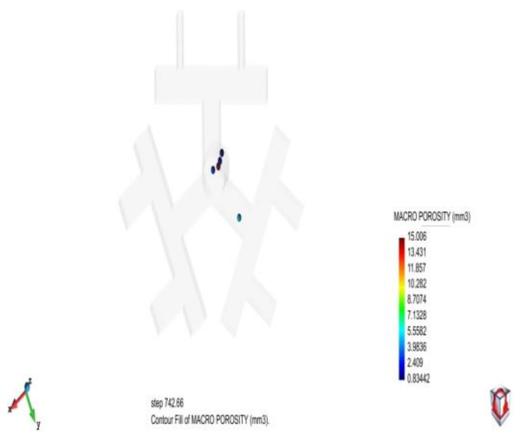

Figure7. A porosity of click2cast simulation

Above picture simulation software through the centre of the casting, as is simulation porosity size with colour spectrum represents of the location and size of total porosity prediction in the given area. Spectrum was set to all simulations on the same value of the experiments with test of the radiography image ISO standard certified lab so results may be compared and evaluation is meaningful. Samples 1, 2 and 3 show exact area of the location lower amount of total porosity obtains, but has increased the probability of porosity presence in centre area at pouring gate area, as can be confirmed also at a real sample test though radiography test at all three sample, RT (radiography test) sample 2 and simulation we can find common features, gas porosity is concentrated in the whole part, while shrinkage porosity is closer to the near to T Junction. One big cluster of internal shrinkage porosity from insufficient feeding is near the top of sprue at the last stage of the cooling and temperature is below solidus, more detailed explanation and analysis will be discussed in the near future. Above mentioned results represent just first steps of extensive works going underway, RT tasting is the same result of simulation but experiments already show a promising method for porosity prediction.

5. CONCLUSION

A work was been done to increase the accuracy of simulation to predict macro porosity in ductile iron casting and improvement the quality of casting parts in industry to minimum loss under the defective rejection of casting. The ductile iron casting is produced as the industry material composition and silica sand was used and molten metal is ductile iron, thermal analysis is proved like helpful method to find out a wide range of the solidification event actual casting have consider was simulation software, used to simulation software same fundamental parameter is direct affected to shrinkage porosity like temperature and time variation graphs cooling rate condition as well as mechanical parameter also affect like design of sprue, gate and runner which ultimately effects of the porosity, the percentage of shrinkage porosity increase with decreasing of the cooling rate when the junction is more compare with other area is definitely slow in last cooling stage there and gas porosity is interfere of casting micro porosity is evolution, so we can with certainty recognize gas porosity, shrinkage porosity and blow hole defects. The radiography test is found is nearest result in simulation software we will use various materials with different the solidification interval to be able to obtain proper boundary conditions. Also, the temperature of the mold will be varying.

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