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Investigation of Critical Design Parameters Causing Shrinkage Related Castings Defects of Cast Iron Component Supported by Simulation

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Abstract *— Casting processes are widely used to produce many products and has to ability produced complicated shapes. Major casting defects such as shrinkage cavity, porosity, hot tears, sand inclusions, blow holes, sand erosion, sand wash cold shut and misrun occurs in small and medium size foundry as a result of improper selection of feeding and gating parameters. In this paper, approach for feeding and gating system evolution and its investigation is presented to achieve shrinkage porosity defect free casting and smooth, uniform and complete filling of mould with clean metal. A critical FG 300 cast iron grade automobile part produced by green sand casting process was chosen for investigation. Optimization of feeding and gating elements carried out by using AutoCAST-X1casting simulation software. We presented simulation and experimental studies by altering dimensions of gating and feeding elements. It was concluded that defect free casting could be obtained by gradually increase in feeder and feeder neck dimensions and modifying gating ratio 1:2:1.5 to 1:2:1.95 by performing several simulation iterations. We have found good agreement of simulation and experimental results of shrinkage porosity and achieve better feeder yield. We investigated feeder and feeder neck have the critical design parameters causing shrinkage related defects and gating ratio also keep in control to ensure smooth, uniform and complete filling of mould with clean metal.*

Keywords*- Feeder ;Feeder Neck; Gating Ratio; Shrinkage porosity; Simulation; Green sand Casting Process ,Cast Iron*

I. INTRODUCTION

In casting process, feeding and gating system plays vital role to achieve high quality of casting components. These systems directly affect the productivity, internal and external quality and yield.

Many small medium scale foundries conventional approach is used to design feeding and gating system based by experienced foundry engineer. Production of defect free casting is a challenge in foundry environment. One of the critical elements that has to be considered for producing a high quality sand casting product is the gating system design and feeding system design [1-2].

The solidification phenomenon carries on layer-by-layer staring from mold wall towards centre of casting and influenced by freezing range, cooling rate and thermal gradient. Solidification phenomenon of the molten metal related to major defects such as shrinkage, porosity and hot tear. These defects can be reduced by proper changes in feeding parameters, such as feeder location, feeder shape and size, feeder neck shape and size. Selecting of probable set of parameters lead to the preferred quality and yield. To predict type and location of solidification related defects and control them effectively by suitable design of feeding parameters. Mechanical properties of casting components such as strength, hardness, machinability etc significantly depends on the rate of solidification [3]. Essential condition of Casting feeders design should be such that feeder must freeze at the same time as or later than the casting, which has to be fulfilled by ensuring that the feeder has a modulus that is adequately larger than the 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 direct clean molten metal from ladle to the mould box cavity ensuring smooth, uniform, turbulence free and complete filling of mould cavity. So, design a good gating system based on understanding behavior of fluid flow during mould filling process. 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. [4]

II. LITERATURE REVIEW

Johnson W.H.et al [5] have investigated filling process of molten metal flow through runner by removing cope with multiple gates,such as finger,pencil,and horn shaped gates. Berger et al [6] have developed control volume hydraulic based model for gating design and introduced nonlinear optimization. Heine R.W. [7] developed feed path criterion to meet the principle of directional solidification and there should be positive feed paths at all parts of castings . Jong and Wang [8] described the optimal design of runner-system injection moulding based on flow simulation. They used fluid flow principals Bernoulli theorem ,the law of continuity and the effect of movement The pipe / node representation proposed by Kannan S. [9] facilitates data input and automatic assembly of the system of energy balance and continuity equations governing flow in the gating system. Wu M.H.et al[10] worked on feeding system for steel material .They have obtained critical modulus gradient equation based on moduli and center distance of the connected segments. Lee and Kim [11] used a modified complex method to reduce warpage by optimizing the thickness of different surfaces. Ravi B. and Srinivasan M. N [12] have proposed vector element method which traces the feed paths from any given point inside the casting to the nearest hot spot, provides a fast and reliable approach to casting solidification simulation with minimal user inputs and improve yield. Lam Y.C.[13] worked on Optimization of Gate Location for Plastic Injection Molding. Wu.S.H.[14] have developed feature Based parametric design for gating system applicable to a die casting. Katzarov I.H.[15] have developed mathematical and computer program for numerical simulation of nucleation, and amount of porosity distribution specific to car wheel. Jacob E *et. al.*, [16] demonstrated a narrative approach to the problem of feeder design by augmenting genetic algorithms with CAD to optimize the feeder dimensions. Tavakoli Rohallah and Davami Parviz [17] have developed an approach to obtain optimal feeder design in steel casting process based on evolutionary topology optimization. Joshi Durgesh and Ravi B.[18] have described mathematical modeling of L shaped casting to identify size and potential location of shrinkage porosity defect. Gupta Nandita [19] et al have simulated a rectangular object made by ductile iron poured in sand mould with the help of ProCAST software. They have reported that gating system ratio, geometry and riser size have a great influence on entry velocity molten metal into mould. Renukananda K.H. et al [20] have presented experimental and simulation studies discharge th rough multiple gates connected to a horizontal runner. Anerao Prashant R. and Mule Yeshwant S.[21]have worked on thermal analysis of feeder neck using finite element method for steel casting. Sutaria Mayur et al [22] have computed feed paths of casting solidification using level set method. Kotas Petr et al[23] have optimized solidification pattern by support of Niyama Criterion to eliminate various defects such as centerline shrinkage,porosity,macrosegregation and hot tear.Perzyk M. et al [24] have optimized side feeder system by means of solidification supported by simulation. They have recommended optimal distance between a side feeder and a casting wall. Kumar V.et al[25] have developed Auto_Die_Caster automated system which was used for design of multicavity die casting die. Choudhari C.M. et al [26] have designed and simulated cover plate having material of LM 6 by AUTOCAST-X. Huang Pei-Hsing [27] has optimized gating design for precision rotor made by stainless steel metal using investment casting process. Saravanan V.S.et al [28] have studied relationship between casting geometric modules and feeding distance of ductile iron bar shaped castings made by Sporadic Graphite Iron. Gong Xue-dan et al [29] optimized feeding system for traveling wheel steel casting based on back prpogation (BP) neural network and genetic algorithm. Hosseini Maryan Seyedeh and Utlu Zafer [30] have worked on clutch housing mould with the help of computational fluid dynamics (CFD) approach. Li Xiaobo et al [31] have investigated influence of melt flow on formation of porosity in defect band in high pressure die casting of AZ91D magnesium alloy. Pinto Helder and Silva F.J.G.[32] have optimized gating Zamark alloy by using finite element based simulation.

Review of information reveals that normally, researchers have appreciably contributed optimization of design factors for simple shape castings such as rectangle, L, round bar shapes. Also, they have significantly demonstrated applications of simulation. Castings produced in foundry industries have complicated shapes which will employed in various applications such as automobile, aerospace, railways ,shipping, medical devices, automobiles, sanitary, electrical machineries, home appliances. Found engineers preferred taper gating and feeding elements which are easy shakeout of castings and reduces production time. Hence attempt in this study to identify parameters related to feeding and gating system and investigate critical parameters causing shrinkage related defects for multiple cavity sand castings of cast iron.

In first step, identify feeding and gating parameters causing casting defects. Second step, select the parameters causing shrinkage related defects based on literature survey and experience. Third step simulation is performed to judge the effect of selected parameters and finally find out the critical parameters causing shrinkage related defects.

III. IDENTIFICATION OF DESIGN PARAMETERS CAUSING SOLIDIFICATION AND FLOW RELATED DEFECTS

Design parameters have vital role in production of defect free castings. However rejection levels due to design parameters observed more in small and medium scale foundry due to lack of importance of them. Proper understanding and setting of design parameters leads to improve quality characteristics of cast iron components produced using green sand mold. Design parameters identified for this study based on literature review and simple to manipulate shown in table1. Prime importance of this investigation is to conclude significance of each parameter against quality characteristics of castings.

3.1 Parameters Related to Feeder Design and Analysis

These parameters are linked to solidification phenomenon of metal which is great interesting for method engineers and software developers. In this section, attempt made to identify the shrinkage related defects and importance to realize progressive directional solidification. Results obtained after solidification phenomenon of the molten metal are major casting defects, such as shrinkage, porosity, hot tears etc. These defects can be reduced by correct changes in feeding parameters, such as feeder position, feeder contour and volume, feeder neck profile and volume. Setting the accurate set of feeding parameters that accomplish to the desired quality characteristics and yield, is important for foundrymen and complicated to achieve.

Table 1.Design Parameters

Design Parameters	
Parameters Related to Feeding System	**Parameters Related to Gating System**
Feeder modulus	Metallostatic head
Feeder Neck Modulus	Cavity fill time
Feed path	Gating ratio
Feeder Efficiency	Choke area
Feeder Yield	Gate velocity

3.1.1. Feeder Modulus

Provision of feeder to compensate volumetric contraction of the last freezing region of casting and volume of feeder should more than the shrinkage volume of last freezing region of casting component. Simultaneously, extra-larger feeders with large security margins are increase the cost and reduce yield and undersize feeder cannot satisfy the quality requirements of customers. Hence there is a requirement to understand and implement optimal size feeder dimensions and its implementation. There are numerous optimization ways but selecting and implementing the well-organized one is a challenge. The required modulus of the feeder is given by [16].

Modulus of feeder (Mf) = (Feeder design factor) X Modulus of casting (Mc) (1)

The multiplication factor mainly depends on the cast metal (for steel is over 1.2, ductile iron is more than 1.1, grey iron more than 1.1) The casting can be divided into different feeding sections [8] by isolating into simpler shapes at different sections called feeding unit. Modulus of each feeding section calculated independently. Feeder modulus calculation has based feeding last freezing section having highest modulus. Also, one consideration that modulus of hot spot region will increased after connecting the feeder because of reduced heat transfer area corresponding to feeder neck and need to further increase in feeder modulus/size .Different types of shapes available for feeder, but commonly used feeder shapes are rectangular, cylindrical, cruciform and spherical top. Efficiency of feeder is characterized by modulus [4].

3.1.2 Feeder Neck Modulus

After implementation optimal size feeder dimensions, shape and connecting point, feeder neck is designed. Feeder neck is middle part between feeder and casting. Feeder neck is an important parameter, designed in away to ensure declining modulus value towards the casting. This is done to ensure that the neck should solidify after the highest modulus section of casting and to maintain the flow of liquid metal from the feeder to casting hotspot. If feeder neck solidify before highest modulus section of casting causing solidification related defects.

The required modulus of the feeder is given by equation2.

Modulus of neck (Mn) = (Neck design Factor) * Modulus of casting (Mc) (2)

Neck design Factor is assigned empirically as 1.2 to 1.5 times the casting again depending on the cast metal. The shape of the feeder-neck depends on the feeder shape, feeder position and the connected portion of the casting. The most widely used neck shapes are cylindrical (for top cylindrical feeders) and rectangular (mainly for side feeders). The neck may also be tapered down with notch towards the casting [4], thereby gradually reducing the modulus towards the casting and easy for fettling. If casting consist of more than two feeding sections and intermediate feeding section have highest modulus than step by step increase modulus from the hot spot to the intermediate section to feeder neck to feeder.

3.1.3. Feed Path

The feed path criterion states that there should be positive feed paths to flow from the liquid to all feeding sections of the casting it is believed to feed. In order to satisfy the feed path condition, the principle of directional solidification is followed [8].

If casting consists of n number of feeding sections and i_{th} feeding section having highest modulus then the criterion is modified as follows:

$$M_f > M_n > M_i > M_h \quad (3)$$

Where M_f,M_n,M_i,and M_h are the moduli of feeder, feeder neck, intermediate feeding section and modulus of hot spot

3.1.4. Feeder Efficiency

It is the total feed metal required to the total volume of feeder, which is volume fraction of the feeder that is actually available for feeding. The feeding efficiency depends on the cooling rate of the feeder which in turn is affected by contour of the feeder and the presence of feedaid. This is compared with maximum possible efficiency of the feeder when connecting the common feeder between two castings. Open feeder have low efficiency (about 14%) .

The criterion is given by :

$$\text{Feeder Efficiency } (\eta f) = \frac{\alpha(Vc + \sum Vfi)}{(\eta fmax \sum_i Vfi)} \quad (4)$$

Where V_c= Volume of casting, V_f= Volume of i^{th} feeder,α= Volumetric shrinkage of cast metal, η_{fmax}= Maximum possible efficiency

3.1.5. Feeder Yield

Foundrymen have great interest to minimize the feeder size and more intention to use common feeder. Hence feeder yield is the significant criteria considered in foundry. Feeder yield achieved by minimization of feeder volume to meet shrinkage defect free castings. The criteria is given b

$$\text{Feeder Yield } Y(f) = \frac{NcVc}{(NcVc + \sum_i Vfi)} \quad (5)$$

Where N_c=Number of casting cavities per mould, V_c= Volume of casting, V_f= Volume of i^{th} feeder

The feed path criterion states that there should be positive feed paths to flow from the liquid to all feeding sections of the casting it is believed to feed. In order to satisfy the feed path condition, the principle of directional solidification is followed (Heine *et al.*, 1968).

3.2 Parameters Related to gating system

Design of gating system is important aspect of casting process that makes sure quality of casing components by controlling molten metal flow rate during mould filling pattern. The effect of gating elements and its importance by pouring cast iron into a green sand mould is investigated.

3.2.1. Metallostatic head

Metallostatic pressure is important gating parameter which control the velocity of molten metal flow through mould cavity. If high velocity and hot metal damage mold leads defects such as sand wash,sand inclusion. Velocity of ingate directly controlled by metallosatic head.Metallosatic head is calculated by equation 6. [4]

$$P= \rho gh \quad (6)$$

Where ρ= metal density, h= summation of mould height above filling point and pouring height

3.2.2. Cavity Filling Time

Filling time is the important design parameter of casting process. A casting fills too slowly can causing casting defects such as cold shut and misruns .Too fast filling can causing casting defects such as inclusions and blow holes. Proper filling of casting lies between slowest filling and fastest filling. The cavity filling time is based on casting weight in kg, average wall thickness t in mm and fluidity length L_f in mm. Fluid length and filling time are calculated by the generalized equation 7 and 8.[4]

$$L_f=(14.9\ CE +0.05T_p-155) \times 25.4\ mm \quad (7)$$

Where CE=%C +0.25% Si+0.5%P and T_p= Pouring Temperature in Fahrenheit

$$T_f=K_0(K_fL_f/1000)(K_s+K_t/20)(K_wW)^P \text{ second} \quad (8)$$

K_0= Overall coefficient,K_f,K_s,K_t, K_w coefficient for fluidity, size, thickness and weight respectively.For grey iron K_0= K_f =1, K_s=1.1 (Casting size 100-1000mm) K_t=1.4 (wall thickness up to 10mm) and K_w=1 and P=0.4

3.2.3. Gating ratio

In conventional approach gating system design proves to be an expensive and hard process. It is presented by A_s:A_r:A_g. Where A_s,A_r, and A_g are the cross sectional area of sprue exit ,runner and ingate .In case multiple runners and ingates total area must be considered. Gating ratios 1:2:1.5 are considered for cast iron to ensure turbulence free flow. [4]

3.2.4. Choke area

Chock is smallest cross section in gating system to fill given casting in a fixed time.It is used to control flow rate of molten metal by keeping a stable level of liquid metal in the pouring basin during pouring. [4]

The chock area can find by equation 9.

$$A_c= W/(\rho_c\ T_f\ v_s) \quad (9)$$

Where W, ρ_c ,T_f and v_s are Total weight of casting, metal density ,filling time and Sprue velocity respectively.

3.2.5. Gate Velocity

Velocity also changes with time from particular start to end of filling. The main factor for soft filling of the mould is the velocity and the position of ingates. The Velocity of ingates depend on metallostatic head and gating ratio.It is calculated by based on continuity equation 10. [4]

$$A_sV_s= A_gV_g \quad (10)$$

Where A_s and A_g are the cross section area of sprue and ingate , V_s and V_g are velocity at sprue and ingate respectively.

VI. CASTING SIMULATION

The solidification process involves the conversion of the hot liquid metal to solid and then succeeding cooling of the solid to the room temperature. Solidification and filling of molten metal after being poured into a mold cavity are important stages in the casting process which really affects the product superiority and yield. During the past twenty five years, computer modeling of solidification simulation has been widely employed by foundry engineers with an aim to predict the pattern of filling and solidification. Also, they have used casting simulation to predict shrinkage porosity and associated defects. Many numerical techniques such as finite difference method (FDM), finite element method (FEM), and boundary element method (BEM) etc. have been used to solve these differential equations with complex boundary conditions arising from material processing. There is also a method called vector element method (VEM) used for prediction of hot spot in casting. VEM have less processing time compare to other method. This method identify location of hot spot inside the casting and feed path which indicates the direction of the largest thermal gradient at any point within a casting to move along a path which moves to a hot spot. Simulation allows the foundrymen to analyze problems in-depth, quicker and before pouring, thus decisions to be made towards accurate design with defect free casting. Therefore, the costs and the time associated with the trial and error methods of experimental castings are reduced. It is evident that theoretical methods like symmetrically balanced gating system are good for simple parts but for complex designs, verification of process with casting simulations would yield better product at lesser time.

V. INDUSTRIAL CASE STUDY

Many casting components produced by green sand casting process are used in dynamic applications such as automobile, machines. They require to be free of internal as well as external defects and posses the desired mechanical properties to offer required functionality and service life.

5.1. Experimentation

In order to study the effect of design parameters following case studies examined by changing dimensions of feeding and the gating elements. The cast iron automobile component of overall size 750mm weighting 1.21 kg produced by green sand casting is selected .VEM based AutoCAST-X1 casting design and simulation software used for analysis the design parameters. Chemical composition of component shown table 2.Summary of geometry and design parameters of component shown table 3 .Three iterations have examined by altering dimensions of feeding and gating parameters based on equation number 1,2 ,6,7,8,9 and 10.

and calculated feeder efficiency and feeder yield by equation 4 and 5 as shown in table 4. Simulation results such as filling pattern, solidification pattern, solidification time and shrinkage porosity observed for each iteration.

Table 2. Chemical composition of FG-300b automobile cast iron component

	C%	Si%	Mn %	S%	P%	Cr%	Cu%
Specified	3.2 to 3.6	1.5 to 2.0	0.6 to 0.9	0.12 Max	0.15 Max	0.50 Max	0.50 Max
Actual	3.26	1.86	0.76	0.057	0.16	0.35	0.27

Table3 Summary of geometry and design parameters of component

Geometric Parameters	Component Length	117mm
	Minimum wall Thickness	7mm
	weight	1.28 kg
	Number of cavities	1
Design Parameters	Gating System adopted	parting Line
	Gate Type	Tapered
	Runner and ingate Type	Tapered
	sprue Type	Circular cross section
	feeder shape and Type	Tapered and Open
	Feeder Neck	Rectangular
	Mould Cavity Height	64mm

5.2. Results and Discussion

In first iteration small size sprue, large size pouring basin ,gating ratio 1:2:1.5 and small size feeder and feeder neck have employed. Filling pattern Simulation results shows that turbulence and not complete filling of mould due to more than 1 m/s ingate velocity shown in figure 1 (a).Solidification pattern result shows solidification of feeder before casting figure 2 (a) and found large size shrinkage porosity observed in casting figure 3(a).Figure 4 shows solidification of feeder, feeder neck, runner before casting. Feeder yield is 95.99 % but feeder efficiency is more than 14 % and found shrinkage porosity defect. We have found good agreement of simulation results of shrinkage by actual production of casting.

In second iteration increase size sprue, reduce size pouring basin ,gating ratio 1:2:1.95 and medium size feeder and feeder neck have employed. Filling pattern Simulation results shows that turbulence free filling achieved due to less than 1 m/s ingate velocity in figure 1 (b).Solidification pattern result shows solidification of feeder before casting figure 2 (b) and found small size shrinkage porosity observed in casting figure 3(b).Figure 4 shows solidification of feeder, feeder neck before casting. Feeder yield is 93.27 % but feeder efficiency is more than 14 % and found shrinkage porosity defect. We have found good agreement of simulation results of shrinkage porosity by actual production of casting.

We found better results of filling pattern as per second iteration hence in third larger size feeder have employed and no alteration of remaining design parameters .Filling pattern Simulation results shows that turbulence free filling achieved due to less than 1 m/s ingate velocity in figure 1 (c).Solidification pattern result shows solidification of feeder before casting figure 2 (c) and found small size shrinkage porosity observed in feeder which will removed in fettling figure 3(c).Figure 4 shows solidification of feeder, feeder neck after casting. Feeder yield is 85.40 % and feeder efficiency is 6.85 which is less than 14 % and no shrinkage porosity defect found inside casting. We have found good agreement of simulation results of shrinkage by actual production of casting. From above study it is found that feeding parameters such as feeder size and feeder neck size have close relation with shrinkage porosity and obtained better results of feeder efficiency and feeder yield.

Table 4.Experimental Details

Parameters	Iteration 1	Iteration 2	Iteration 3
Size of Moulding Box (Cope)	595mm X 560mm X 125mm	595mm X 560mm X 125mm	595mm X 560mm X 125mm
Size of Moulding Box (Drag)	595mm X 560mm X 100mm	595mm X 560mm X 100mm	595mm X 560mm X 100mm
Size of Sprue	Dt=11mm,Db=9mm,Hs=85mm	Dt=18mm,Db=16mm,Hs=85mm	Dt=18mm,Db=16mm,Hs=85mm
size of Pouring Basin	Circular C/S 80mm	Circular C/S 40mm	Circular C/S 40mm
Runner Size	Wb=15mm,Wt=12mm,H=10mm,L=70mm	Wb=21mm,Wt=17mm,H=14mm,L=70mm	Wb=21mm,Wt=17mm,H=14mm,L=70mm
Feeder Size	Db=20mm,Dt=10mm,Hf=30mm	Db=24mm,Dt=12mm,Hf=36mm	Db=32mm,Dt=16mm,Hf=48mm
Feeder Neck Size/ingate	T=8mm,W=14mm,L=10mm	Tn=10mm,Tw=25mm,L=10mm	Tn=10mm,Tw=25mm,L=10mm
Pouring temperature	1420 ^{0}C	1420 ^{0}C	1420 ^{0}C
Pouring time	3 second	1.76 second	1.76 second
Mesh size	4mm	4mm	4mm
Chock Area	12 mm X 6mm	8 mm X 16mm	8 mm X 16mm
Pouring Type	Gravity Pouring	Gravity Pouring	Gravity Pouring
Material Density	7.2 gm/cm3	7.2 gm/cm3	7.2 gm/cm3
Ingate velocity	1.0297m/s	0.78m/s	0.78m/s
Sprue Velocity	1.54 m/s	1.54 m/s	1.54 m/s
Fluid Length	839mm	839mm	839mm
Gating Ratio	1:2:1.5	1:2:1.95	1:2:1.95
Feeder Yield	95.99	93.27	85.40
Feeder Efficiency	24.95%	14.86%	6.85%
Where Dt=top diameter, Db=bottom diameter ,Hs and Hf height of sprue and feeder, Wb and Wt base width and top width of runner ,T=thickness			

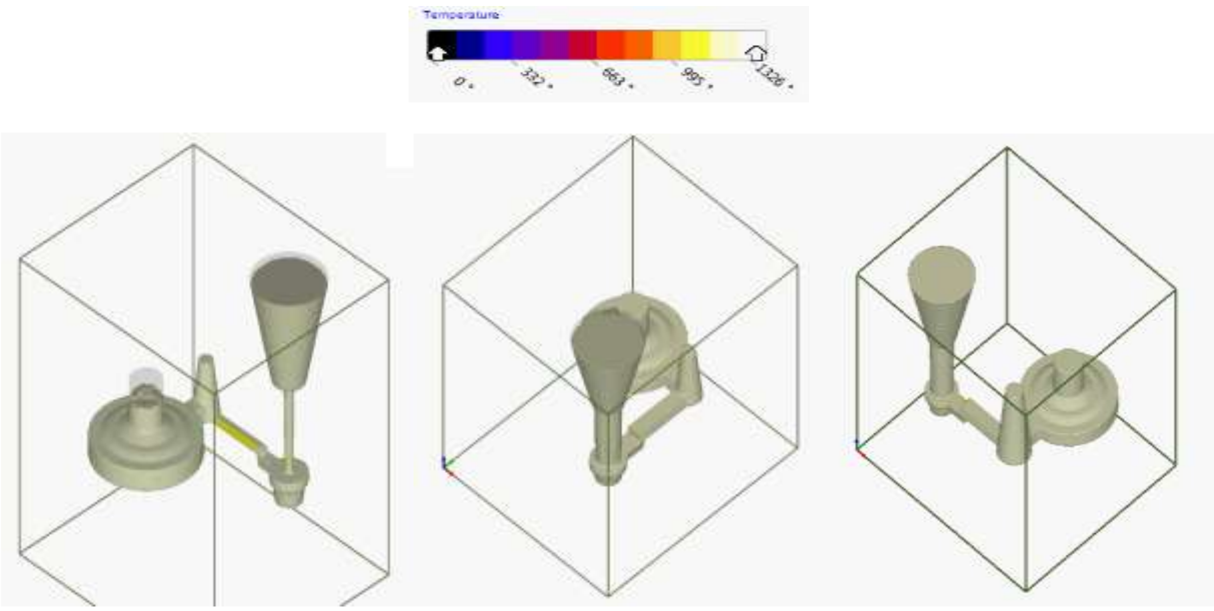

Figure 1 filling pattern results after iteration 1,2 and 3

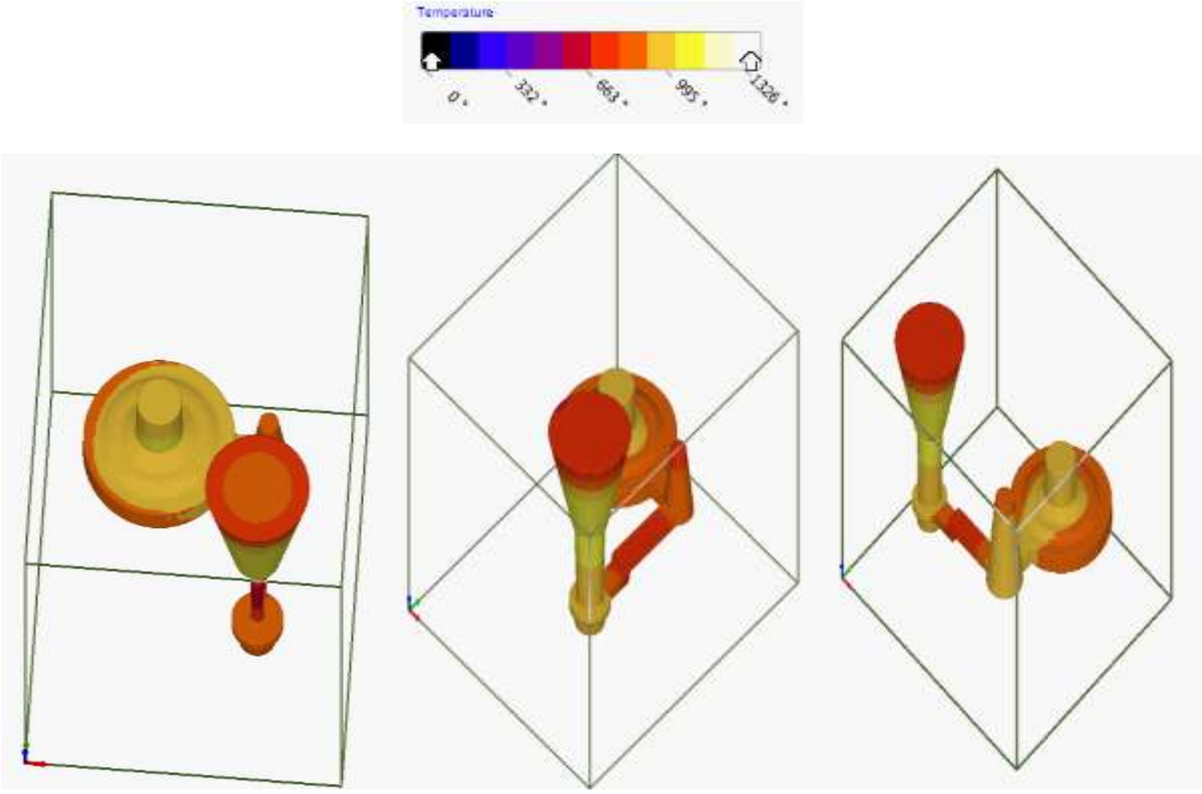

Figure 2.Solidification Pattern results after iteration 1,2 and 3

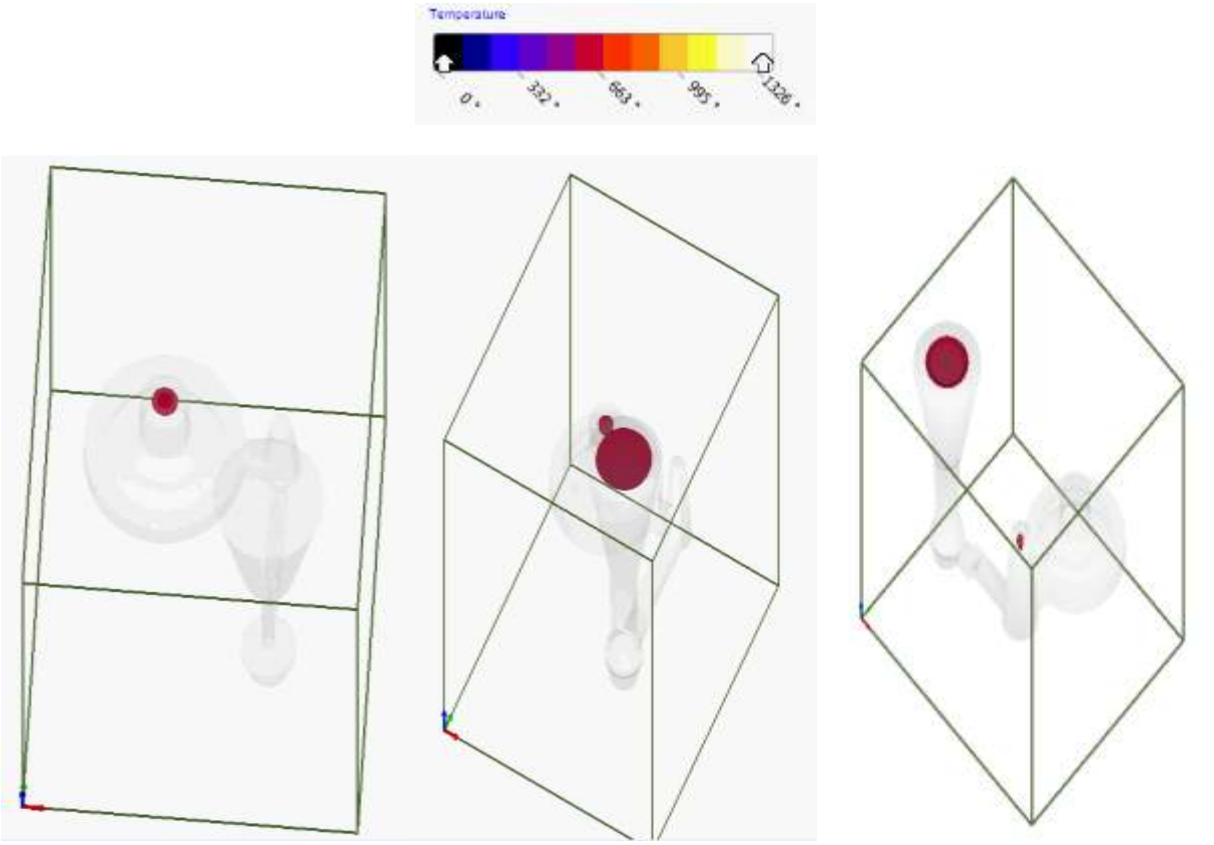

Figure3Shrinkage porosity in the casting results after iteration 1,2 and 3

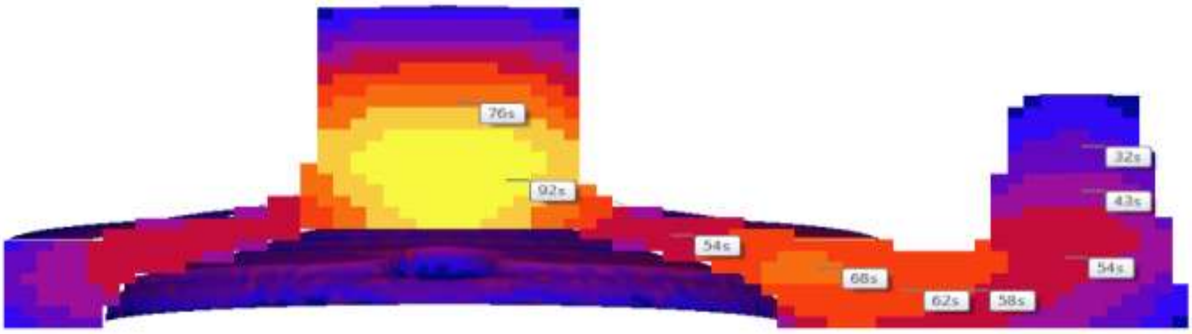

Figure 4 solidification time of sprue, feeder, feeder neck and component of iteration 2

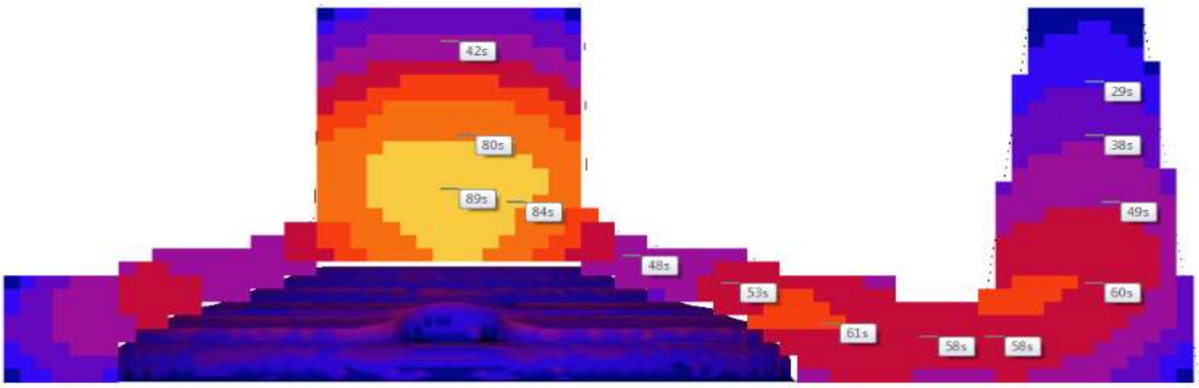

Figure 5 solidification time of sprue, feeder, feeder neck and component of iteration 2

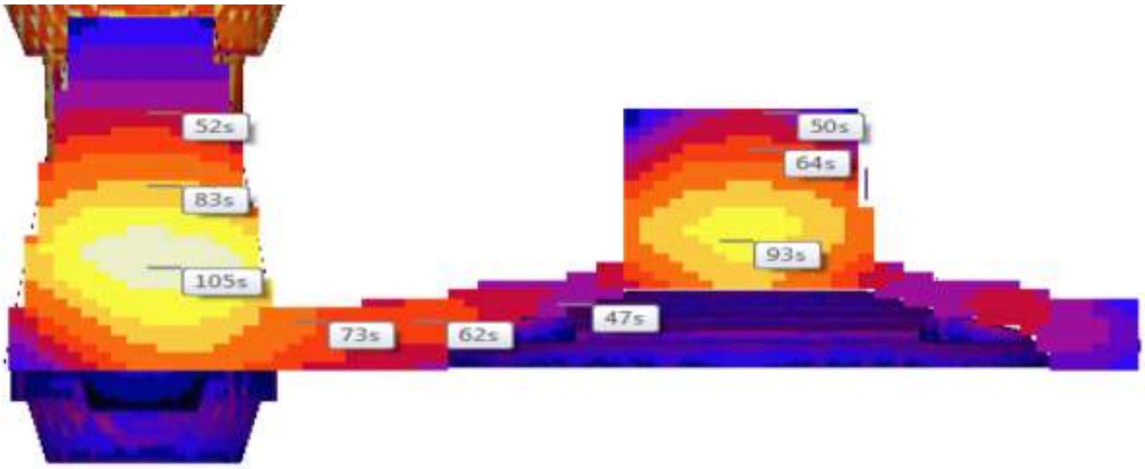

Figure 6 solidification time of sprue, feeder, feeder neck and component of iteration 3

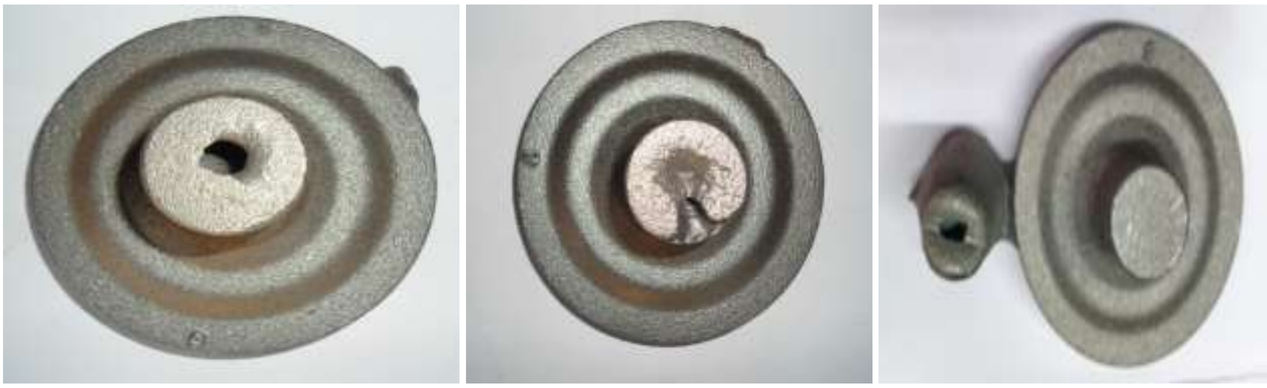

Figure7 experimental results after iteration 1,2 and 3

Figure 8. cross sections shows no internal porosity of component after implementation of iteration 3

VI. CONCLUSIONS

In present investigation a 3D component model was developed by creo 2.0 and simulation performed by AutoCAST-X1 to evaluate possible solidification and flow related defects for green sand casting of cast iron component. Three iterations were examined by altering feeding and gating parameters through VEM based simulation and optimum design parameters for single cavity was chosen trough this work. Remarkable conclusions from this study are:

1. In first iteration, ingate velocity was more than 1m/s causing turbulence flow of molten metal and inadequate feeder causing shrinkage porosity.
2. In second iteration, ingate velocity was less than 1m/s achieve complete, smooth and uniform filling of mould and medium size feeder and feeder neck reduces shrinkage porosity.
3.In third iteration found optimum size feeder which produce casting shrinkage porosity free casting and shift shrinkage porosity in body of feeder.
4. The VEM based AutoCAST-X1 software is more suitable for gravity casting process, less input required, less time of computing results and more user friendly.
5. Both feeding and gating parameters significantly effect on quality and yield of casting process.
6.Critical parameters investigated from this study are feeder size, feeder neck size which are directly linked with shrinkage porosity and accordingly effect the feeder efficiency and feeder yield .
7.Gating parameters specially gating ratio also keep in control to ensure smooth, uniform and complete filling of mould with clean metal. Hence control for appropriate size of gating elements important to achieve better quality.
8.To find optimum size of feeder and feeder neck based on iterative process required to overcome shrinkage porosity and achieve better results of feeder efficiency, feeder yield and reduce trails.
9. Current work could extended to optimize common feeder used for two adjacent casting based on iterative process. It will be useful to design and optimize feeding system in industry.
10. Tapered shape of feeding and gating elements reduces sand related defects such as sand drop, sand wash ,sand inclusion and fitting of casting become more easier.

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