International Journal of Engineering Research
Volume No.5 Issue: Special 2, pp: 403-406
ISSN:2319-6890)(online),2347-5013(print)
11-12 Feb. 2016

Shrinkage Defect Elimination in Ductile Iron Casting using Virtual Solidification Simulation

N.Veman Reddy, Ramanathan S., Ammineni Syam Prasad
Department of Mechanical Engineering, MVSR Engineering College, Hyderabad, A.P. India
nvemanr@gmail.com, rama.bhp@gmail.com, syampnaidu@gmail.com

Abstract: ***The vital stage in manufacture of castings is the formation of solid casting from molten metal when poured into mould cavity. The various complex transformations that occur during the process influence the quality of the casting. The design of risering system which ensure freedom from shrinkage and other solidification oriented defects in the casting play a vital role in the quality and yield of the casting. A good design will produce castings free from these defects and considerably improve the yield. this paper describes the removal of shrinkage defect in Ductile Iron casting by redesigning the risering system using Virtual casting simulation software MAGMASOFT and CAD software PRO-ENGINEER.***

Keywords: Ductile iron, risering system, casting, shrinkage, simulation, Modulus.

I. Introduction

Ductile iron is cast ferrous alloy with mechanical properties equal to that of steel and founding characteristics as good as cast iron. Liquid cast iron contains carbon in excess of its solubility in solid iron, Hence during freezing this excess carbon precipitates out in the form of pure crystalline graphite, proper treatment with modifiers such as magnesium, cerium the graphite will separate as spheroids or nodules. Cast iron with its graphite in spheroidal form is ductile iron. The factors which affect the soundness of ductile iron casting are (i) Solidification and cooling rate (ii) risering system design. Risering is the act of compensating for volume changes which any liquid and solidifying casting undergoes. Riser is required to compensate (i) liquid contraction (primary Shrinkage) (ii) Solidification contraction (During freezing). Figure 1 shows the volume change pattern for Steel, White iron brass and Figure 2 shows the volume change patterns for graphitic irons.

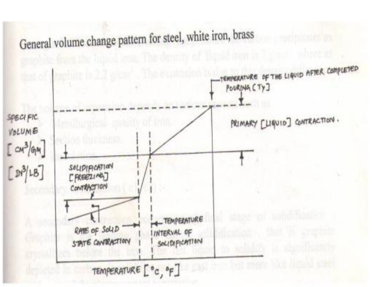

Figure 1

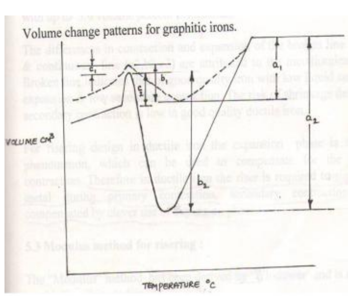

Figure 2

In figure 2 (a1 ,a2) is the primary contraction or liquid contraction this is usually 0.016 to 0.024% vol/oc, (b1 ,b2) is the expansion phase during solidification at freezing temperature carbon precipitates as graphite the density of liquid iron is 7g/cm3 where as graphite is 2.2g/cm3, expansion is due to this density difference. Secondary contraction (c1,c2) occurs during final stage of solidification, The last liquid to solidify is significantly depleted in carbon which solidifies just like liquid steel with upto 3% volume contraction.

In ductile iron casting the expansion phase is a welcome phenomenon, by clever use of expansion phase secondary contraction can be compensated.

II. Soldification Simulation and Riser Design Calculations

A Ductile iron casting of ASTM A536 Grade with shrinkage defect at riser neck area is selected for study. Figure 3 shows the casting with shrinkage defect. Virtual Solidification simulation of the casting using MAGMASOFT casting simulation software with the process parameters are given in Table 1 and properties of green sand in Table 2.

Table 1: Process Parameters

Process parameter	Value used in simulation
Temperature of molten metal	1400^0C
Cast alloy	A-536 grade 60-45-12
Mould material	Green sand at 30^0C
Pour time	5 sec
treatment	Inoculation treatment yield 90%, Graphite precipitation factor ‘7’

Table 2: Properties of Green Sand

Thermal Conductivity	0.730 W/m k.
Specific Heat	676J/kg k.
Density	1515 kg/m^3
Moisture	3%
Permeability	250 cm^3/min


Figure 3


Figure 4

Figure 4, show casting with gating system figure 5, 6, &7 show uneven temperature distribution in the casting and creation of hot spots at riser neck area aggravating the chance of porosity / shrinkage formation.

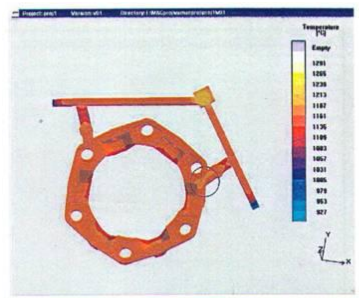
Figure 5

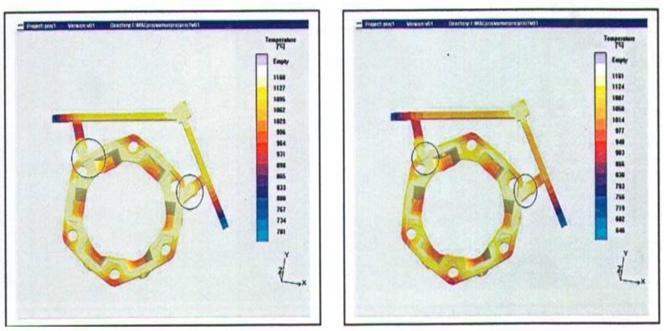
Figure 6

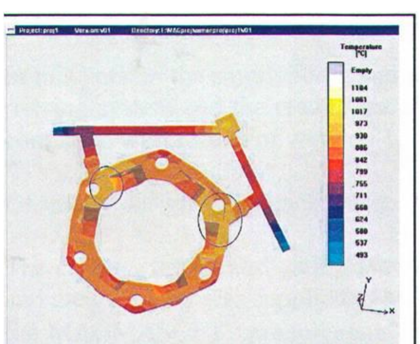
Figure 7

Figure 8 show the presence of porosity/shrinkage at areas near to feeder neck in the casting.

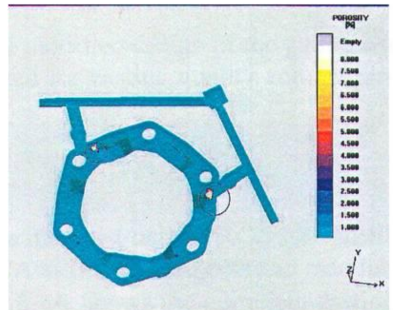
Figure 8

Riser design calculations:

Modulus method is used for riser design calculations.
Modulus M = Casting volume/ Total cooling surface area.
Volume of the casting = 632082 mm^3.
Surface area of the casting = 167356 mm^2.
Modulus of the casting M = 3.77mm or 0.377cm.
As the modulus is < 0.4 cm and the mould is of green sand which is considered as weak mould from figure 9 directly applied riser is chosen with only liquid contraction compensation with gating system.

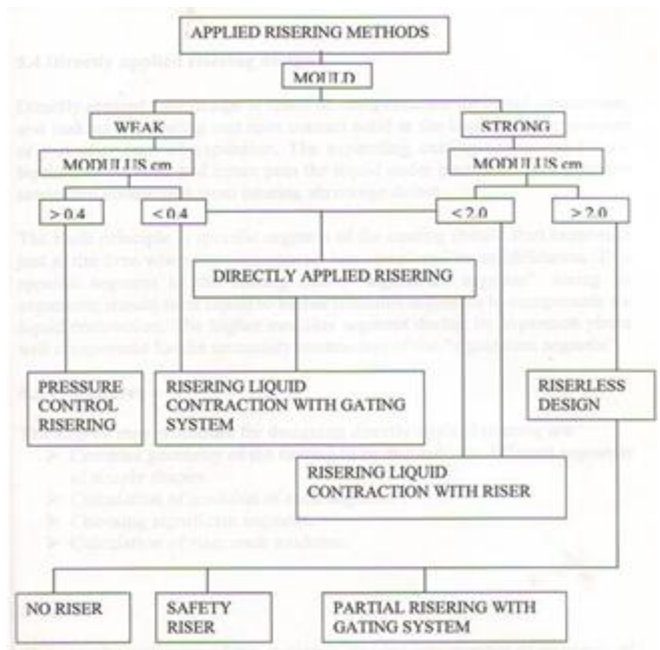

Figure: 9

Figure 9 shows Procedure for applied riser design involves (i) Division of casting geometry into different segments of simple shapes (ii) Calculation of modulus of each segment (iii) choosing of significant segment (segment with lowest modulus) (iv) Neck area calculation. The geometry of the casting is divided into 3 simple segments as shown in figures 10, 11 and 12.

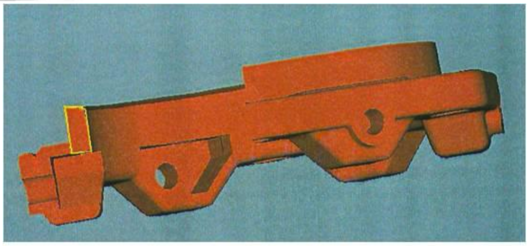
Figure 10

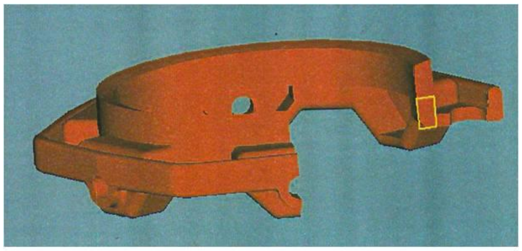
Figure 11

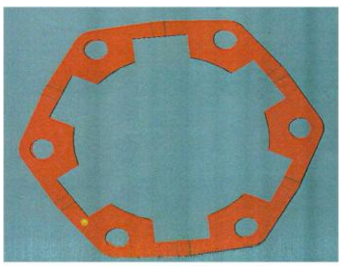
Figure 12

The modulus value for segment 1 = 197579mm^3/36614mm^2 = 5.4 mm
The modulus value for segment 2 = 59911.5mm^3/12516mm^2 = 4.8mm
The modulus value for segment 3 = 118598mm^3/29706mm^2 = 4 mm
Segment 3 is chosen as significant segment, and the modulus of neck is taken as M_n =2.8 mm (from ductile iron data book)

Liquid contraction calculation:

Pouring temperature of the casting is 1400 °C , Eutectic temperature of the metal is 1150 °C temperature range for liquid contraction calculation is 1400-1150 = 250°C . Taking average liquid contraction as 0.02%vol/°C, The amount of liquid contraction is 0.02 * 250 = 5 % volume of casting. Volume of liquid metal to be compensated is 31594 mm^3. Mass of liquid metal to be compensated is 0.23 Kg.
This liquid metal is compensated by gating system itself without any riser and the riser neck is substituted with ingates of modulus 2.8mm.

III. Results and Tables

Gating and Riser system of the casting is modified with liquid metal compensation by gating system itself with out any riser and the riser neck is substituted with ingate of modulus 2.8mm figure 13 show the casting with modified gating system.

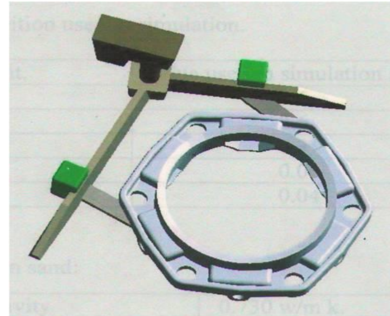
Figure 13

Solidification simulation of the casting is done with the modified gating system. Figure 14, &15show the temperature distribution throughout the casting to be uniform. This simultaneous freezing of the casting prevents directional solidification and prevents the Hot spot at neck area. Figure 16 show the temperature of ingates to be lower than the casting this causes ingates to solidify earlier than casting this prevents backflow of metal from casting into gating system during expansion phase of solidifying casting this puts the liquid metal in casting area under pressure which will compensate for secondary contraction of the casting. This cutting off of the casting from ingates and putting metal in casting area under pressure prevents the occurrence of shrinkage and porosity. Porosity results from software as shown in figure 17 show no trace of shrinkage or porosity.

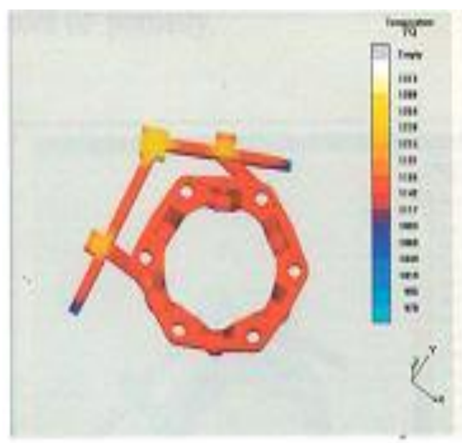
Figure 14

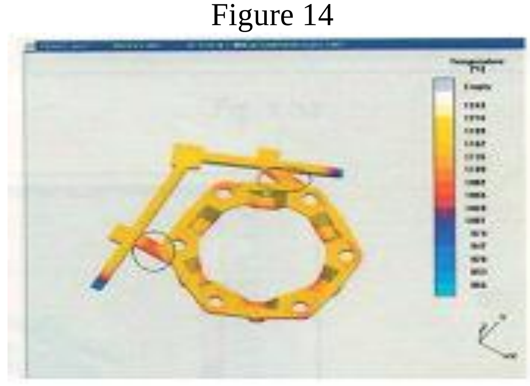
Figure 15

Figure 16

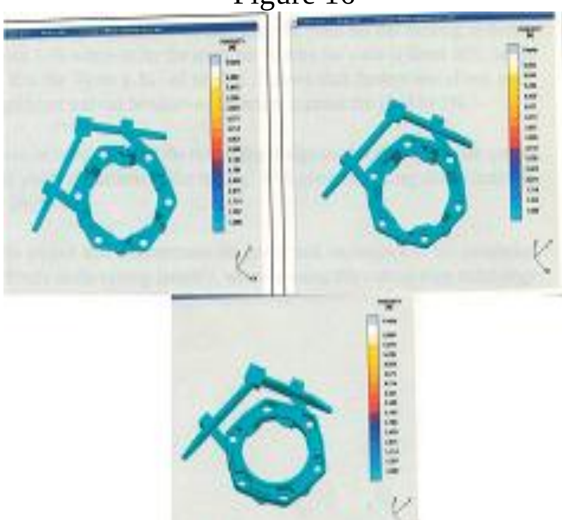

Figure 17

IV. Conclusion

Virtual solidification simulation of ductile iron casting shows that riser and gating system design has a very strong effect on the soundness of the casting , simulation results also show that by simultaneous solidification of the casting and by clever use of expansion phase of liquid metal shrinkage & porosity defects in casting can be prevented.

References

i. *Roberts R, LoperCRJR and Heine RW, Riser designs AFS Trans 77, P.373 (1969).*

ii. *R.Ruxanda, L Beltran-Sanchez, J massone, DM Stefansescu, Proceedings of cast iron division, AFS 105th casting congress, American foundry Soc, Des Plaines, IL 2001, p.37*

iii. *IL Svensson, M. Wessen, in: BG Thomos, C.Beckermann (Eds) Modelling of casting welding and advanced wsolidification processes VII, The Mettalurgical society, Warrendale, PA, 1998, p-443*

iv. *A.V. Catalina, S.Sen, PA Curreri, in: DM Stefansescu, R.Ruxanda, M.Tierean, C.Serban (Eds), The science of casting and solidification, Edithura Lux, Libris, Brasov, 2001, p.44*

v. *IL Fredriksson, JT Thorgrimsson, IL Svensson, in: H. Fredriksson (Ed), state of the art of compute simulation of casting and solidification process, Les editions de physique, Les Ulis, France, 1986, pp 267-275.*

vi. *Ohanaka.T, Computer simulation of solidification of castings. Proc, Solidification processing Sheffield.*

vii. *The new mettalurgy of casdt metals castings, second dedition by John Campbell.*

viii. *Casting practice, the ten rules of casting by John Campbell.*

ix. *Ductile iron- The essentials of gating & Risening system design-2000*

x. *Magma soft casting simulation manual V4.1*