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Simulation of Casting and Its Validation by Experiments

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Abstract

Now days in Industries it is very important to save time and money in manufacturing product, because there is lots of competition in industrial world. Main objective of this project is re-designed of component using Pro-cast software and increasing the product life of the components. Many researchers reported that about 90% of the defects in castings are due to wrong design of gating & risering system and only 10% due to manufacturing problems. to optimize gating/riser systems based on CAD and simulation technology with the goal of improving casting quality. Therefore in the thesis, an optimization framework is presented based on CAD and simulation technology. Given a CAD model of part design and after converted to a casting model. After analyzing simulation results, the gating/riser system design is optimized to improve casting quality. In this thesis, one journal bearing is used to verify the effectiveness of the optimization method. Compared with the initial design. Casting simulation process can able to solve these problems. The simulated results also compared with the experimental works..

Keywords: Casting, Sand casting.

Introduction

Casting is a manufacturing process for making complex shapes of metal materials in mass production. There are two main consecutive stages, filling process and solidification process, in casting production. In filling process gating system composed of pouring cup, runner, sprue, sprue well and ingate, is designed to guide liquid metal filling. Riser system is used to compensate shrinkage caused by casting solidification. How to improve the casting quality becomes important. Casting quality is heavily dependent on the success of riser system design, which currently is conducted mainly relied on technicians' experience. Therefore there is a need for the development of a computer-aided casting process design tool with CAD, simulation, and optimization functions to ensure the quality of casting. Casting process simulation was initially developed at universities starting from the early '70s, mainly in Europe and in the U.S., and is regarded as the most important innovation in casting technology over the last 50 years. The objective of the research presented in this thesis is to optimize riser systems based on CAD and simulation technology with the goal of improving casting quality such as reducing incomplete filling area, decreasing large porosity and increasing yield. Therefore in the thesis, a CAD and simulation technology based optimization framework is presented. Given a CAD model of part design and after its being converted to casting model, the first objective is to evaluate castability of the casting design. Then risers are presented parametrically. After analyzing simulation results, the original riser system design will be optimized to improve casting quality.

Sand casting processes

Sand casting consists of placing a pattern (having the shape of the desired casting) in sand to make an imprint, incorporating a gating system, filling the resulting cavity with molten metal, allowing the metal to cool until it solidifies[2]. Sand casting is still the most popular form of casting. The steps to make sand castings are illustrated in Fig

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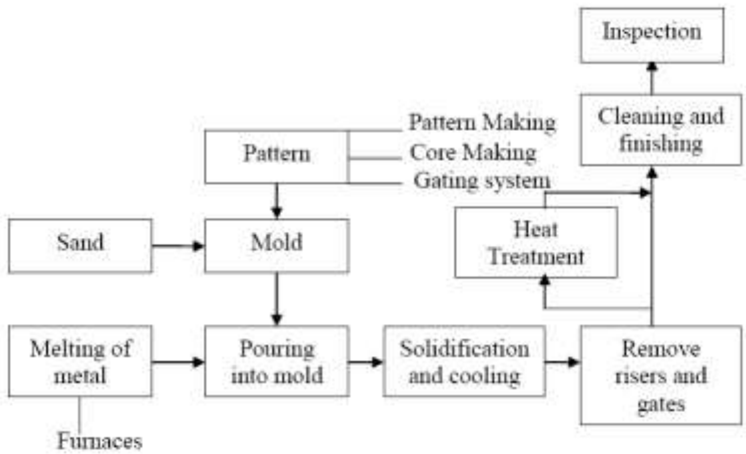


Fig Production steps in a typical sand casting processes.

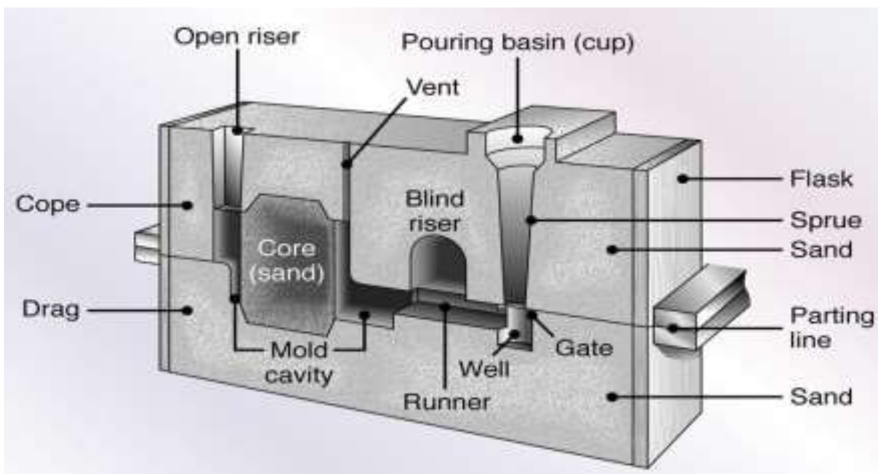
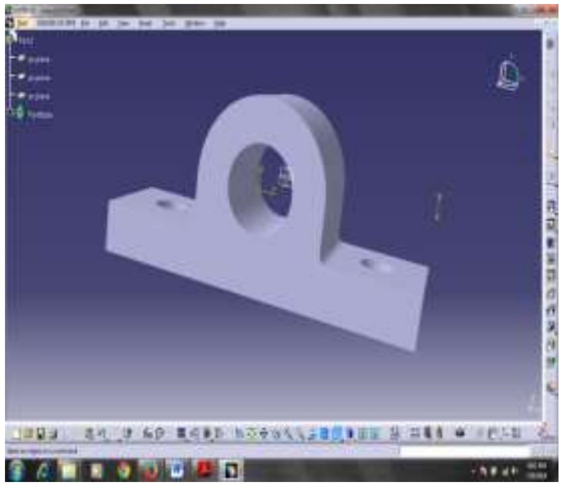


Fig Schematic illustration of a sand mold

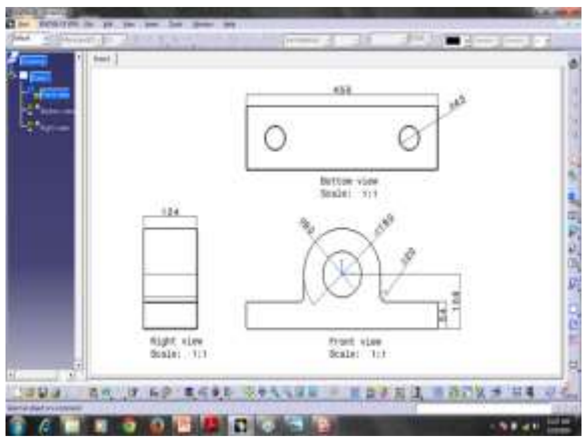
Gating/riser system design and optimization .

After pouring metal, it will flow through the gating system until the cavity is fully filled. Then the metal begins to cool and solidify with the occurrence of shrinkage. Riser system is designed to compensate such shrinkage. Gating/riser system has great effects on the final quality of casting. A foundry can produce the best quality moulds, cores and molten steel and still end up with a poor quality casting by using poorly designed gating and riser systems. So how to design a satisfied gating/riser system is very important.

Riser System A key element in producing quality steel castings is the proper design and sizing of the riser systems. A foundry can produce the best quality moulds, cores and molten steel and still end up with a poor quality casting by using poorly designed riser systems. A typical riser system is shown below.



journal bearing



dimension of journal bearing

Design of riser

According to the dimensions and wt. of component the riser design was done. Along with riser design, using different formulas other dimensions of elements like sprue, sprue well, runner, ingate also calculated.

Calculation

Design of riser by Modulus method:

Volume of the casting = $5*10^6$ mm^3

Surface area of the casting = $2.78*10^5$ mm^3

Volume of the riser = $\pi*D^3/4$

Surface area of the riser = $\pi.D^2 + \pi*D^2/4 = 1.25\pi D^2$

Where D is the riser diameter.

Modulus of the casting = volume of the casting / surface area of the casting

= $5*10^6 / 2.78*10^5$

= 17.98

According to the formula

Modulus of the riser = 1.2* Modulus of casting

= 1.2*8.953197097

= 21.58......................................Eq. 1

Now,

Modulus of riser = $(\pi*D^3/4) / (1.25\pi D^2)$

D/5...Eq.2

Comparing eq.1 & 2

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D = 107 mm

Pouring time- The time for complete filling of mould termed as pouring time.

Pouring time 't' = (2.4335 - 0.3953 log w)*√w sec.........For steel casting [40]

Where,

W = mass of the casting, kg

t = (2.4335- 0.3953log34.073)*√34.073

= 10.66 sec

Choke area = The main control area which meters the metal flow into mould cavity so that mould is completely filled within the calculated pouring time. Normally choke area happens to be at the bottom of the sprue.

Choke area/ sprue bottom area A = W/dtc√2gh

Where,

W = casting mass, kg

d = density of molten metal kg/mm3

H = effective height of metal head (sprue height) in mm

C = efficiency factor for gating system

t = pouring time (sec)

$A = 34.073/ (7.85*10^{-6} *10.66*.9*\sqrt{2*9810*110})$

$= 308\ mm^2$

$\Pi d^2/4 = 221$

d = 19.8 mm

Sprue top area = 2*sprue bottom area

$\pi D^2/4 = 2*308$

D = 28mm

Ingate and runner dimension:

Gating ratios

It is expressed as the ratio of sprue area to the total runner area to the total ingate area.

Gating ratio = sprue area : runner area : ingate area

Gating ratio of material

Casting	Sprue : Runner : Gate ratio
Steel	1:2:1.5
	1:3:3
	1:1:0.7
	1:2:2
- Fin-gated	1:1:1
Gray cast iron	1:4:4
- Pressurized system	1:1.3:1.1
Ductile iron, dry sand molds	10:9:8
- Shell molded, vertical pouring	1:2:2
- Pressure system	4:8:3
- Reverse choke	1.2:1:2
Aluminum	1:2:4
- Pressurized system	1:2:1
- Un-pressurized system	1:3:3
Brass	1:1:1 – 1:1:3

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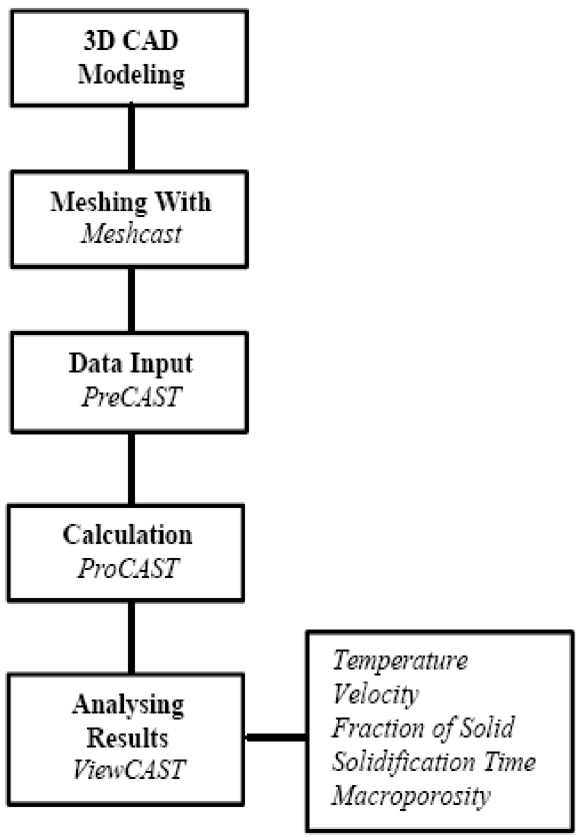
For steel we have taken gating ratio = 1 : 2 : 2
Runner area = 2 * sprue area
$\Pi d^2 /4 = 2* 308$
d = 28 mm
Sprue well top area = 5 * area of sprue base
$A^2 = 5*308$
a = 39.24mm
Where
a = side of square shape sprue well top
Sprue well depth = 2 * runner depth
= 2*28
= 56 mm

Simulation of CATIA model

The well design CATIA model of the journal bearing was simulated using casting simulation software PROCAST. The sequence of stages for simulation using ProCast is below



Stages in Procast Simulation.

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Optimization

Out of various simulations considering casting yield and sound component best design of riser was selected.

Result of simulation runs

Run	Porosity	Vol. Of casting (mm^3) in 10^6	Vol. Of casting + Gating + risering (mm^3) in 10^6	Mass of casting + gating+ risering (Kg)	Casting yield (%)
Run1	Yes	5	6.25	42.54	80
Run2	Yes	-	6.17	42	81
Run3	Yes	-	6.09	41.55	82
Run4	Yes	-	6.41	43.68	78
Run5	Yes	-	6.84	46.67	73
Run6	Yes	-	6.75	46	74
Run7	No	-	7.35	50.10	68
Run8	No	-	7.14	48.67	70
Run9	Yes	-	6.49	44.25	77
Run10	Yes		6.57	44.83	76
Run11	No		6.94	47.32	72

Result: The casting yield of the component (journal bearing) of simulation Run11 is optimum result and calculated as under.

Casting Yield

By the formula

Casting yield = (Vol. of the actual casting)/(Vol. Of the casting+ vol. Of gating &risering system)

$=5*10^6/6.94*10^6$

$= .72$

Casting Yield% = 72

Experimental details: For the component journal bearing taking the following parameters same the nos. Of simulations was carried out. The different simulation parameters are as given under

Step =40000
No. of Nodes = 116407
No. of Solids (TETRA/HEXA/WEDGE) = 600808
No. of Enclosure Elements = 0
No. of Materials = 2

Material:
Sand silica (mould)
Low carbon Steel (cast)
Sand silica temperature 25^0 C
Cast Steel
Pouring temp 1580^0C
Liquidus temp 1533^0C
Solidus temp 1509^0C

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Result and analysis

The different results of the optimum simulation (Run11) of component journal bearing are as under.

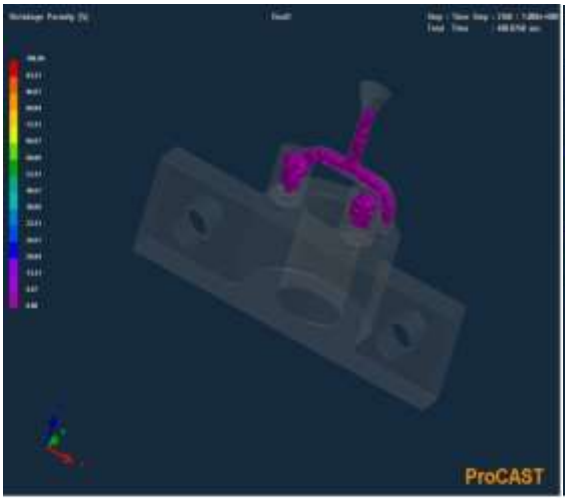

Fig. Shrinkage porosity

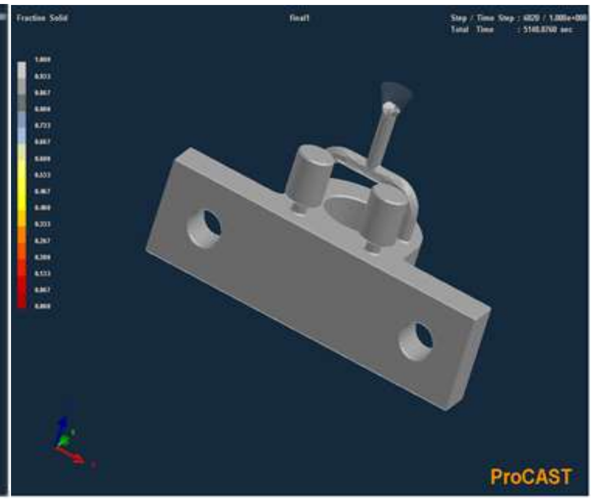

Fig. Fraction solid

Shrinkage porosity: The above fig. clearly shows that the shrinkage porosity defect is on the riser and the casting component journal bearing is free from shrinkage porosity defect. Thus a sound component is found by the simulation process using Pro-Cast, casting simulation software. **Fraction of solid:** The complete white coloured component shows that the journal bearing is totally solidified that can be verified from the side bar coloured graph, in which 1 represent 100% solidified component. The complete fraction of solid shows that there will be no more shrinkage of material which is going to be compensated by the riser.

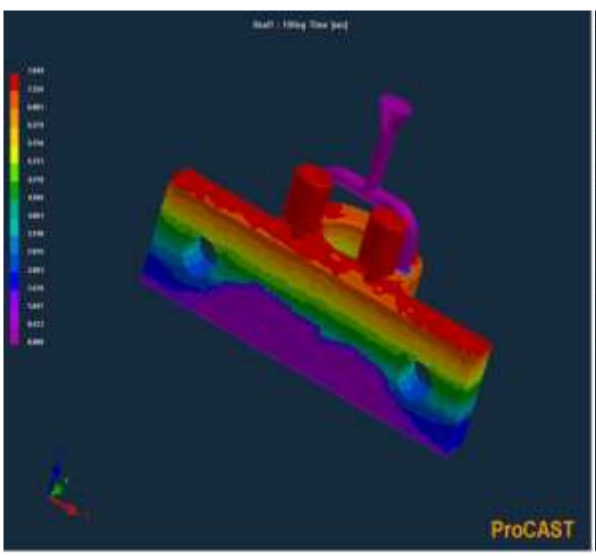

Fig. Fill time

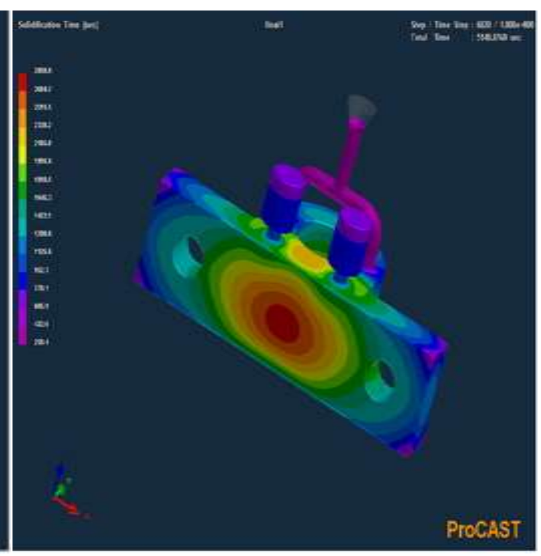

Fig. Solidification time

Fill time: Fill time represent time taken on which the particular part of the component is filled by the liquid metal. The fig. clearly depicts that the part that last to be filled is the riser. This is again a positive result of the casting simulation as riser lately fill can compensate material for casting. **Solidification Time:** The above fig. shows that the outer surfaces of the component which are direct contact with atmosphere are solidified firstly as heat transfer take place fastly. In order to solidify riser last, we can use insulating material in the riser which prevents the transfer of heat from the riser and restrict the solidification of metal in

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the riser. Again by using exothermic material in the riser in the form of sleeves keeps metal of the riser in liquid form.

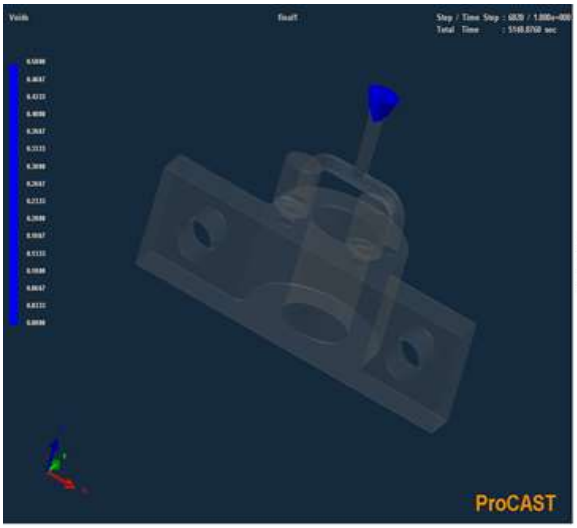
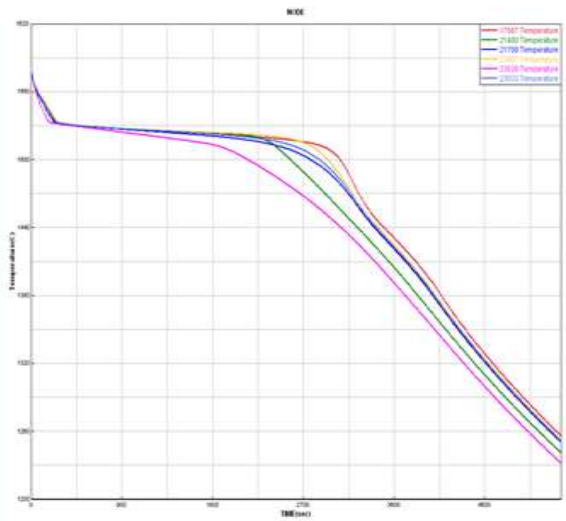


Fig. Voids



Temperature Vs. time graph

Voids or depression in the casting caused mainly by uncontrolled and haphazard solidification of the metal. It is due to wrong location or an improperly sized gating system, inadequate risers, or poor design of the casting involving abrupt changes of sectional thickness. The fig. clearly shows that void is in the sprue not in the casting and thus our casing component is void free. Hence a sound component is produced by ProCast simulation software. **Temperature Vs. Time Graph:** The temperature Vs. time graph was plotted for the low carbon steel after the completion of the simulation

Experimental Work For Validation

preperation of journal bearing pattern

making corebox with coreprint

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Mould preparation ***preheat of ladle***


melting of low carbon steel ***Pouring of low carbon steel for journal bearing***

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After solidification

Results: Casting simulation and experimental work were done .It was done without riser, one riser, two riser, at a different location. It was found that casting did have shrinkage porosity even with two riser .But when put in specific location, No shrinkage porosity of journal bearing. The result/output of the pro-Cast was also experimentally validated. The casting yield was the also calculated using 2 riser experimentally

Casting yield = (wt of casting/ wt of total amount poured)*100

= (38.500/55)* 100= 70 % (with risers)

Discussion: it was found that there are only two % variations in the casting yield doing experimental in workshop against the simulation result, simulation yield is 72% and experiment yield is 70%. It was obvious that the casting will have shrinkage porosity in the sprue and one riser section being thinnest among the only use of 2 riser and 2 ingate gating system at specific location in that zone /section. Through use of 2 risers and 2 ingates gating system would reduce yield of casting considerably but it have to be done to make the casting free from shrinkage porosity. This is acceptable to the customer.

Conclusion

- To overcome the problems of current gating/riser system, a method based on CAD and simulation technology is implemented.
- Casting simulation technology has sufficiently matured and has become an essential tool for casting defect troubleshooting and method optimization. It enables quality assurance and high yield without shop-floor trials, and considerably reduces the lead-time for the first good sample cast.
- By analysing simulation results, the optimized riser system is determined.
- By comparing the simulation result of optimized casting model with that of the original model, it can be concluded that the porosity volume decreased and the yield increased
- In shrinkage porosity diagram, it clearly shown that all shrinkage are at the riser and sprue and the component is shrinkage free which implies a sound casting.
- By using pro-cast simulation software the casting yield is found to be 72%. Which is greater than original one
- By moving the trial and error process into the virtual world and determine the cost of different design and process options. By minimizing real world trial and error (and surprises) making castings right the first time.
- From the above study it can be concluded that the defect analysis done by simulation help a

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practical foundry man to take decision and corrective actions can be taken to eliminate these defects with lesser efforts.

- Computer simulation can be a useful tool for rapid process development. Limitation of the conventional sand casting and gating design has been elaborated. Advantages of computer simulation based design enumerated.

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