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DESIGN AND ANALYSIS OF RISER FOR SAND CASTING

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Abstract

Casting is one of the earliest metals shaping method known to human beings. It is one of the cheapest methods for mass production of any part and can be effectively used to make complex shaped parts which are not easy to manufacture by other production process. Casting process is subjected to many defects and it is necessary to eliminate them. One of the main defects in castings is "Shrinkage Cavity", which can be eliminated by attaching a Riser to the casting. This paper describes the parameters to be considered while designing a Riser of an optimum size to get higher Casting Yield. Theoretically designed model has been analyzed thermally in ANSYS 12.0 simulation software to ensure that shrinkage cavity is completely eliminated from casting.

I. INTRODUCTION

CASTING is a metal shaping process by pouring the molten metal into a mould and allowing it to solidify. The resulting product can virtually have any configuration (pattern) the designer wants. Casting consists of various parts like cope, drag, pattern, sprue, runner, ingates, riser, etc. The process consists of design, solidification, shake out, finishing and heat treatment. Although casting is one of the cheapest methods it is associated with many defects like shrinkage cavity (hot spot), cold shuts, misrun, etc. In order to understand how a shrinkage cavity develops consider a mould of cube. Figure (a) shows a cube which is completely filled with liquid metal. As the time progresses, metal starts loosing heat through all the sides and as a result starts freezing from all the sides, equally trapping the liquid metal inside, as in figure (b). But further solidification and subsequent volumetric shrinkage and metal contraction due to change in temperature causes formation of void, as shown in figure (c). The solidification when complete, finally results in shrinkage cavity, as in figure (d). An optimal design of riser will help in reducing hot spots formation/ void formation/ shrinkage cavity by ensuring that molten metal can readily flow into the casting when the need arises. To eliminate the defect of hot spot riser is used in casting. It helps to fill in the cavity formed inside the casting.

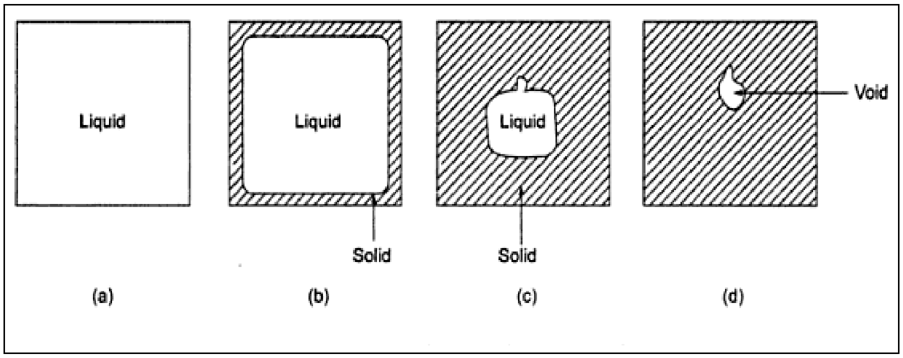

Fig. 1.Formation of shrinkage cavity [1].

Whenever the cavity is formed inside the casting the molten metal from the riser moves to that space and fills the cavity. In order to achieve this, the dimensions of the riser should be optimum so that the metal in the riser solidifies after the casting.

The main parameter that controls the solidification time of a casting is the casting modulus. The amount of heat content in a system is determined by its volume & the rate at which it loses heat is determined by its surface area [2]. Casting modulus is a ratio of volume of a casting to its surface area.

II. OBJECTIVE

The formation of hot spot inside the casting is a major defect in metals like aluminum and steel. In order to increase the yield of the casting it is necessary to optimize riser design which will also ensure removal of hot spot from the casting. Riser will ensure that the molten metal will move into the casting whenever it is desired.

The main objective of our project is to design a riser having higher value modulus that is, of solidification time as compared to casting. This will ensure that metal will remain in the molten state inside the riser until solidification of the casting is completed.

III. THEORETICAL STUDY

Initially for the case study a simple casting was designed with its various parts. Casting is a simple rectangular plate of aluminium. The size of the plate is 200mm × 200mm × 40 mm as shown in figure.

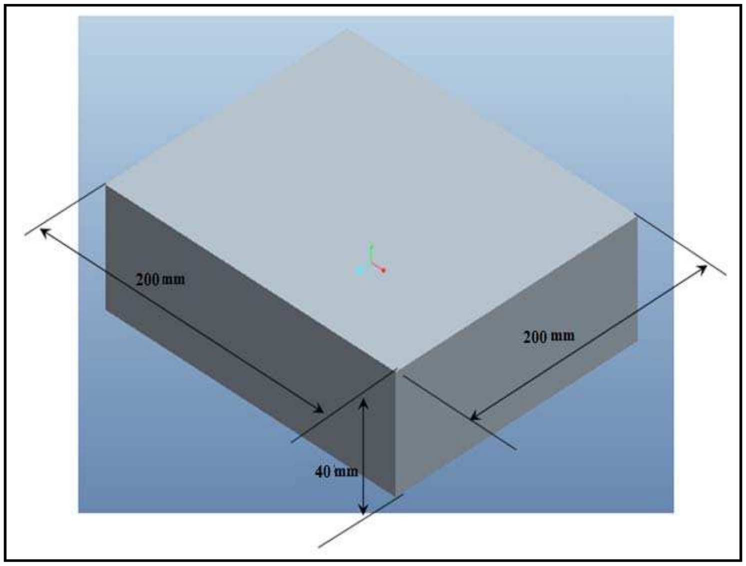

Fig. 2.Geometry of Casting

For design of patter following allowances were considered:

Shrinkage allowance[3]:

For 200 mm: 2.6 mm

For 40 mm: 0.52 mm

Draft allowance = 1.5° (on vertical sides only)

Machining allowance = 2 mm on each side

Tolerance = ± 1 mm

Details regarding the model:

Total surface area = 120835.92 mm^2

Total volume = 1848597.301 mm^3

Modulus = 15.29 mm.

Solidification time = 14.36 min.

Weight of the casting = 4.4089 kg

Design of gating system:

Pouring time =17.363 sec

Choke area = 98.46 mm^2

Sprue bottom diameter = 12 mm

Sprue top diameter = 15 mm

Sprue height = 42.5 mm

Total area of ingates= 452.38 mm^2

The design of riser was done using Caine's method[1]. The height of riser was assumed to be 70 mm and the height of riser neck was assumed to be 10 mm. Following formulae were used for finding the dimensions of casting.

Volume of the riser = $\pi r^2 h$

Surface area = $\pi r^2 + 2\pi rh$

Freezing ratio (X) = $(A_c / V_c) / (A_r / V_r)$

Where, A_c= Area of casting

V_c = Volume of casting

A_r = Surface area of riser

V_r = Volume of riser

$Y = V_r / V_c$

$X = ((a) / (Y-b))-c$

For aluminium:

a=0.1

b=0.03

c=1

The riser diameter by Caine's method is 55.244 mm.

For actual practice, Riser Diameter, D_r = 60 mm.

According to a research paper on optimum design of riser[8],

$D_n = 0.35 \times D_r$

Yield of feeder $= (V_c) / (V_c+V_f+V_n)$

$= 90.176$ %

Yield of casting $= (W_c)/ (W_g+ W_f)$

$= 82.18$ %

Where, W_c = weight of casting

W_g = weight of gating elements

W_f = weight of feeding elements

IV. SIMULATION

Simulation of casting was done to serve two main purposes. First, it was used to find the location of hot spot. Second, it was used to find the optimum dimension of riser so that hot spot shifted into the riser[4]. The effect of sleeve and air gap was also studied using simulation. These studies were done using both linear and quadratic elements and both free and mapped mesh was used.

The following properties were used for sand during the entire simulation:

TABLE I

PROPERTIES OF SAND

Conductivity	0.519 W/m K
Specific Heat	1172.304 J/kg K
Density	1495 kg/m^3

The following properties were used for aluminium during the entire simulation:

TABLE II

PROPERTIES OF ALUMINIUM

Temperature	Conductivity [6]	Enthalpy [7]
273K	234.43 W/m K	0 J/m^3
820K	216.01 W/m K	1.5533 × 109 J/m^3
933K	90.975 W/m K	1.7769 × 109 J/m^3
1043K	94.786 W/m K	2.0574 × 109 J/m^3

A. Identification of Hot Spot

The top view of the casting was simulated in ANSYS 12 software. At the end of simulation the last solidifying region was obtained.

1) Simulation using Linear Elements

For this study, PLANE 55 was used as the linear element. PLANE55 can be used as a plane element or as an axisymmetric ring element with a 2-D thermal conduction capability. The element has four nodes with a single degree of freedom, temperature, at each node.

The top view was modeled for free and mapped mesh as shown in the figure.

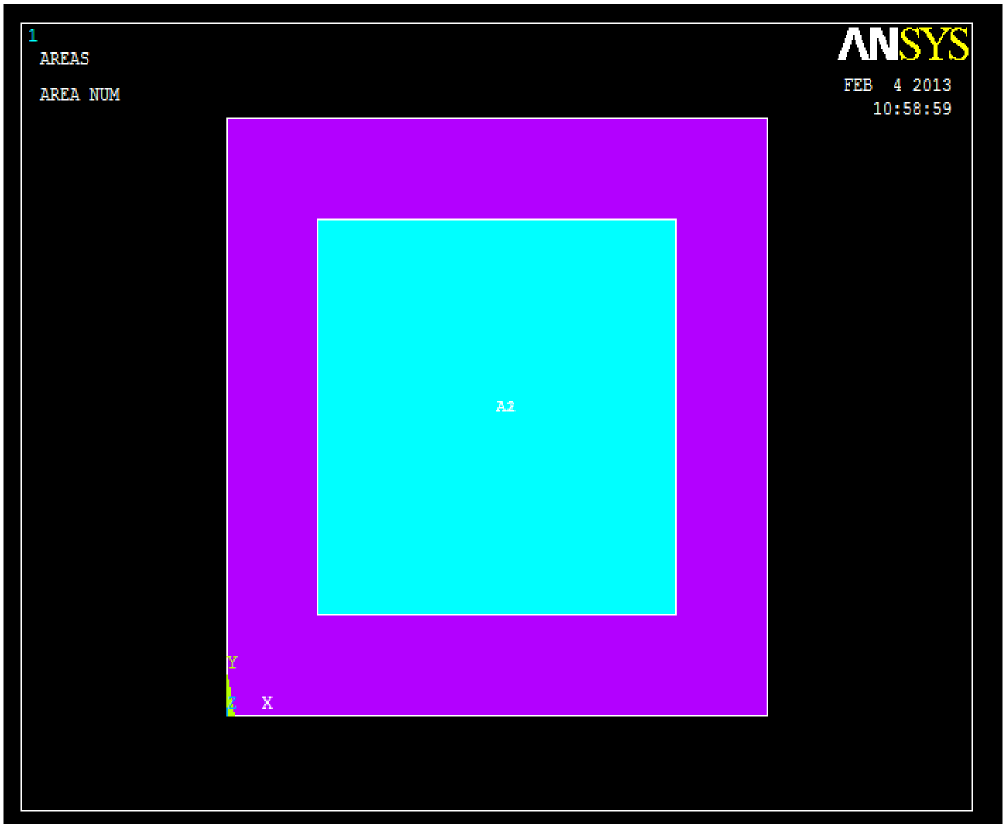

Fig. 3.Modeling of Casting with Free Mesh.

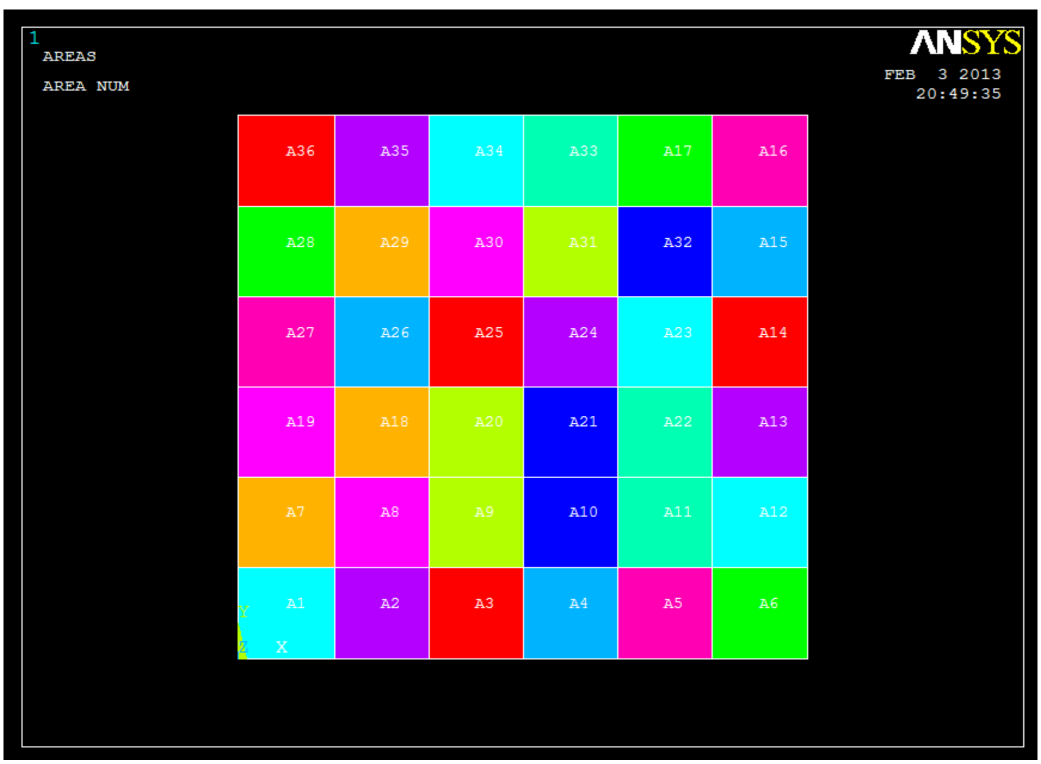

Fig. 4.Modeling of Casting with Mapped Mesh.

Then, the material properties were specified followed by meshing of geometries. The meshed geometries with free and mapped mesh are shown below.

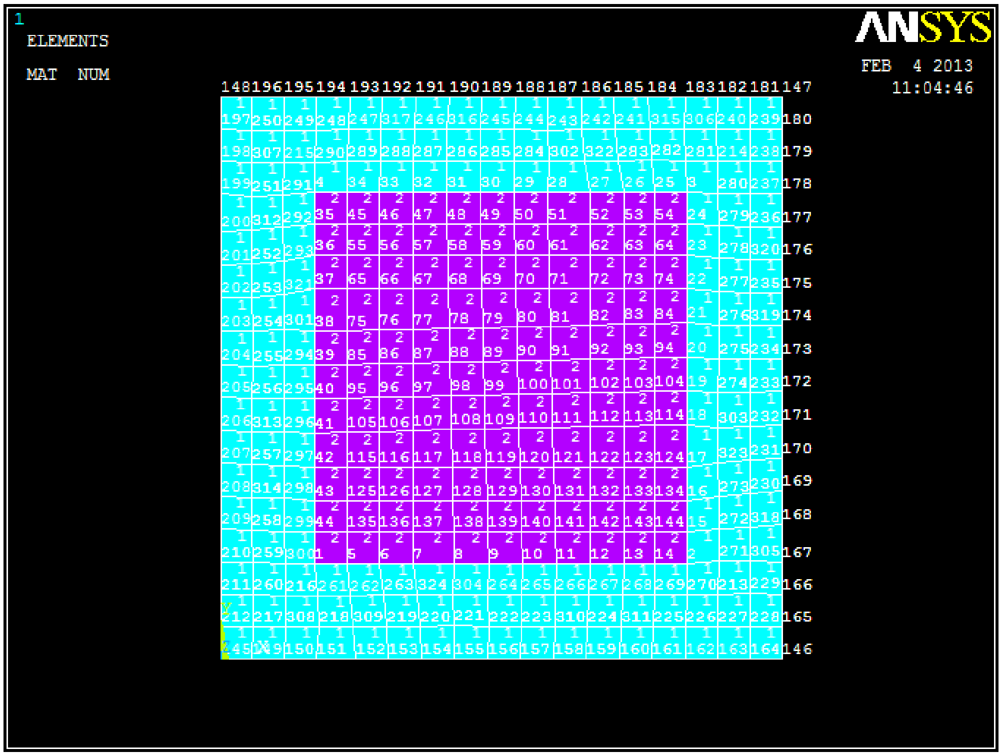

Fig.5 Free Mesh of Casting

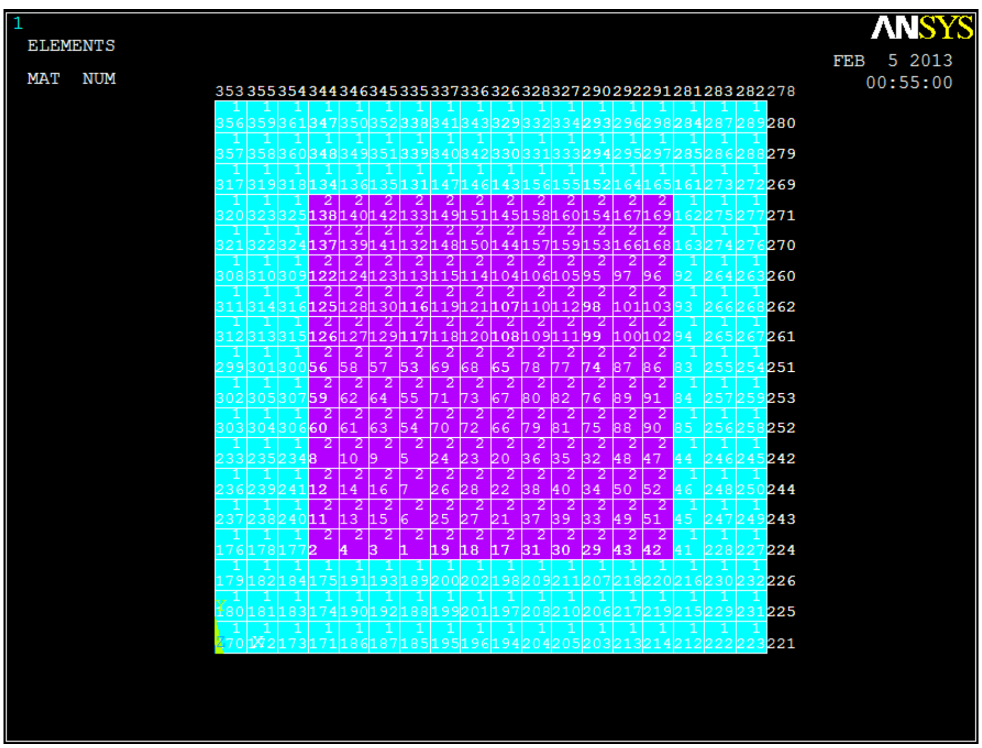

Fig. 6 Mapped Mesh of Casting

After meshing, convective load was applied on the outer boundaries of the casting. The ambient temperature was assumed to be 303 K. The initial temperature of molten aluminium was assumed 1043 K and the initial temperature of sand was assumed to be 303 K.

The temperature time plot of various nodes for free and mapped mesh was obtained as shown below:

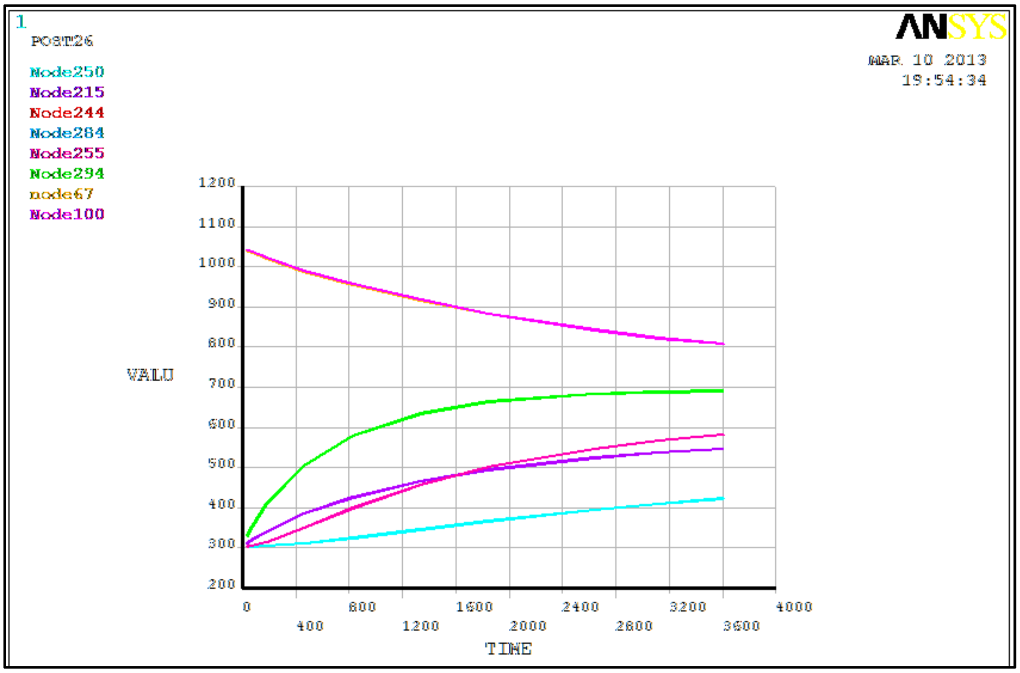

Fig. 7. Temperature Time Plot for Free Mesh

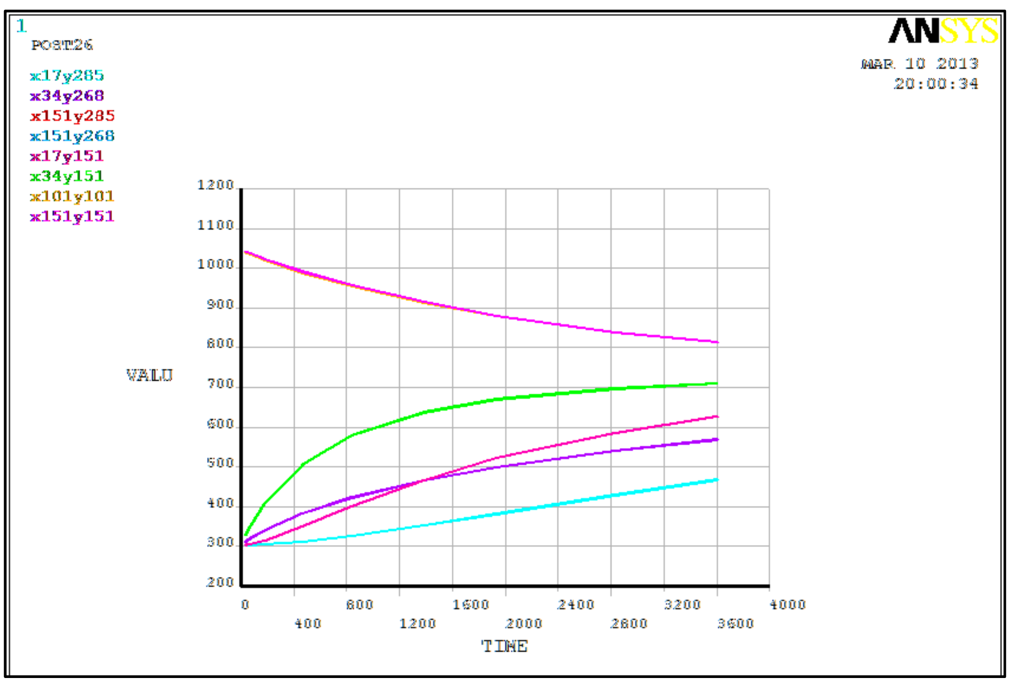

Fig. 8. Temperature Time Plot for Mapped Mesh

The animation was run for 1 hour and the location of hotspot for free and mapped mesh was obtained as shown below:

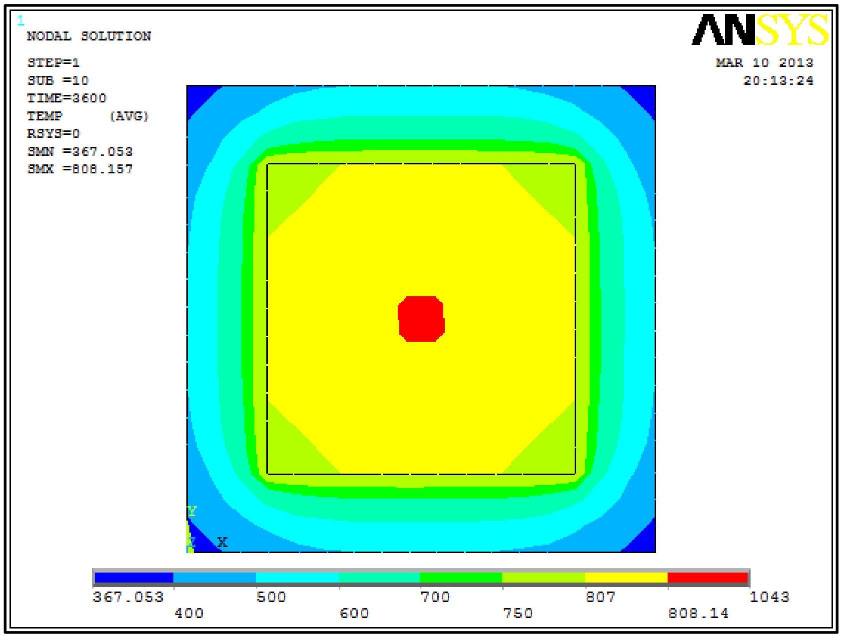

Fig. 9. Location of Hot Spot in Free Mes

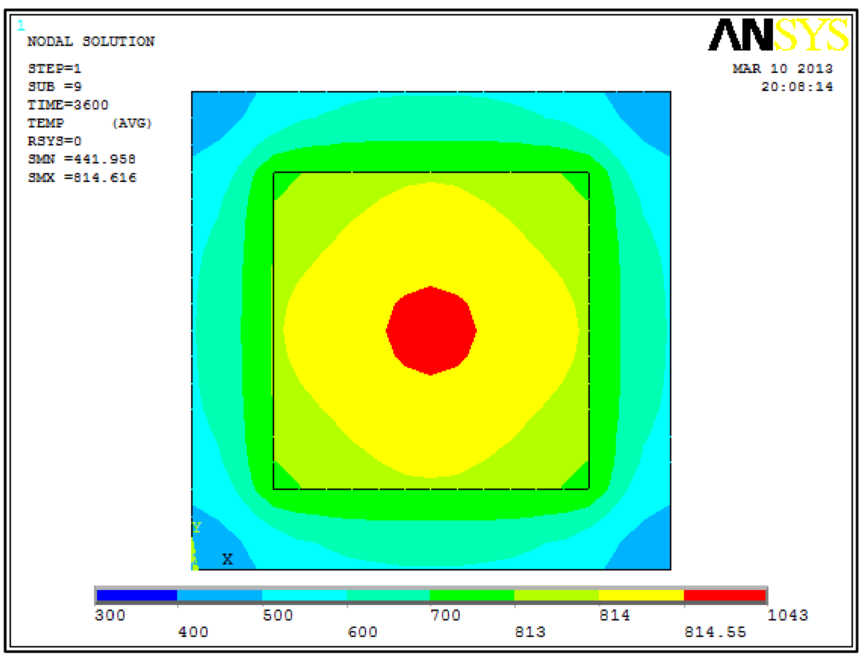

Fig. 10. Location of Hot Spot in Mapped Mesh

2) Simulation using Quadratic Elements

For this, study PLANE 77 and PLANE 35 were used as the quadratic elements. Same steps were followed for simulation using quadratic elements. The results obtained after the simulation showed that the minimum temperature in the entire casting drops below ambient temperature.

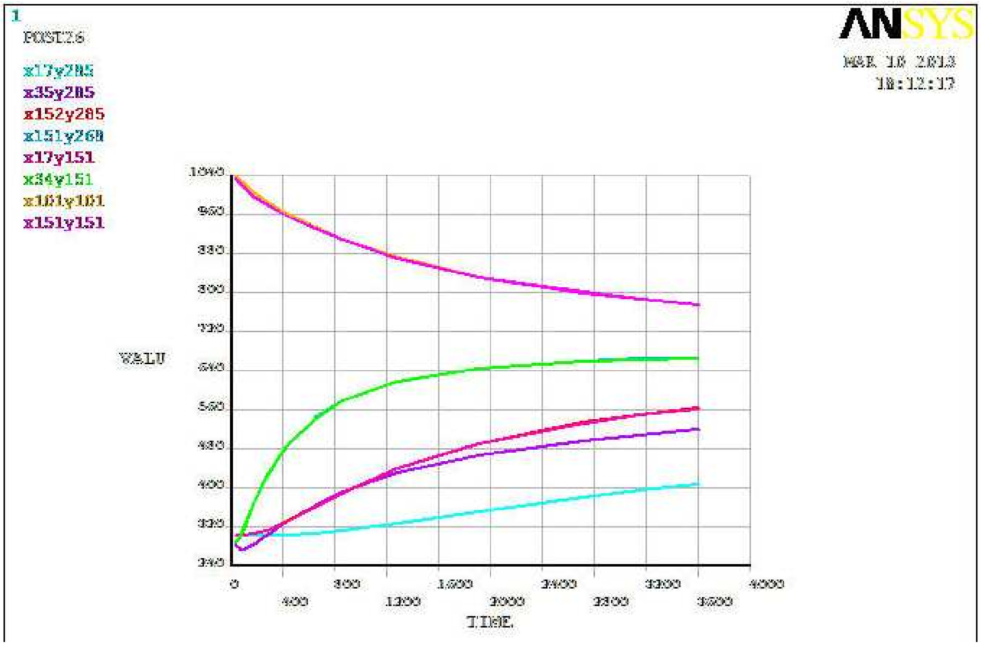

Fig. 11. Temperature Time Graph for PLANE 77 element

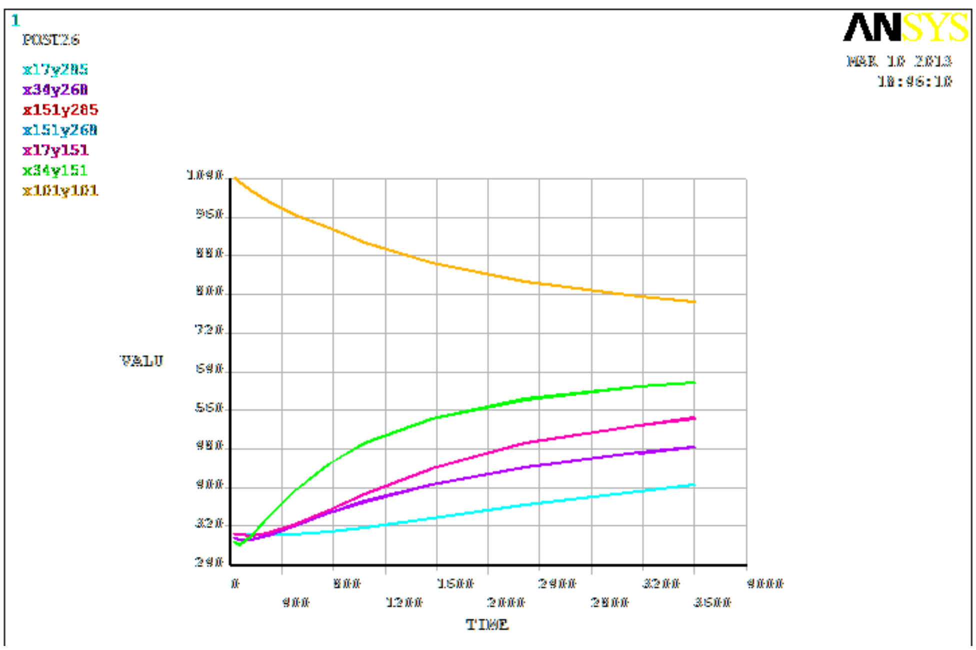

Fig. 12. Temperature Time Graph for PLANE 35 element

This is not possible as the minimum temperature specified during simulation was ambient temperature. Consequently, these results were not taken into account during further simulations.

B.Finding Optimum Riser Dimensions

Once, the location of hot spot was identified, the next objective was to find the optimum riser dimensions. For this purpose, following dimensions of riser were considered.

TABLE III

RISER DIMENSIONS

Sr. No.	Riser Diameter	Riser Height	Neck Diameter	Neck Height
1	30 mm	70 mm	10.5 mm	10 mm
2	40 mm	70 mm	14 mm	10 mm
3	50 mm	70 mm	17.5 mm	10 mm
4	60 mm	70 mm	21 mm	10 mm

The above risers were first modeled in ANSYS. These models were then meshed using PLANE 55 element and free mesh. The animation of these models yielded the following results.

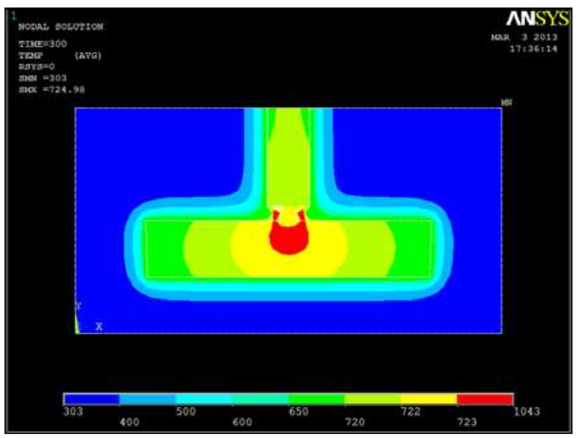

Fig. 13. Location of Hot Spot for Riser with Diameter 30

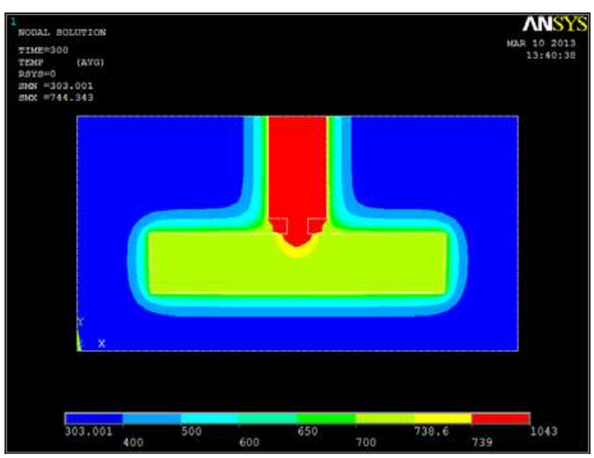

Fig. 14. Location of Hot Spot for Riser with Diameter 40

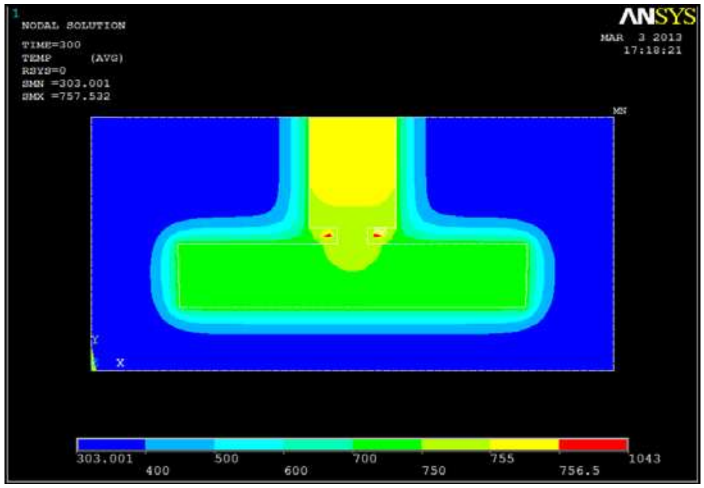

Fig. 15. Location of Hot Spot for Riser with Diameter 50

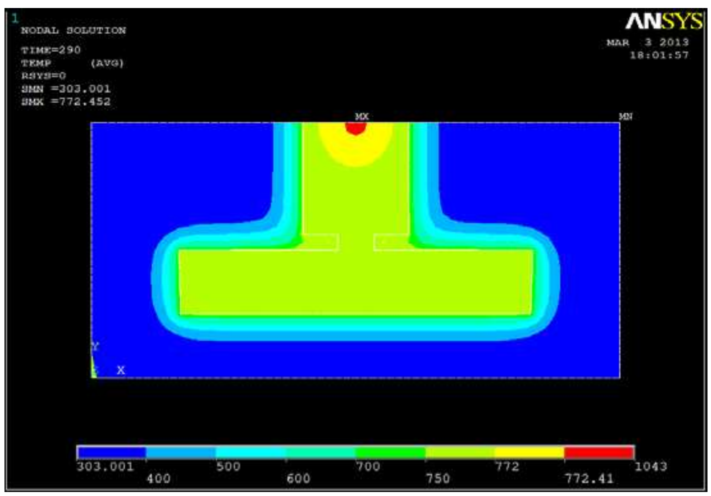

Fig. 16. Location of Hot Spot for Riser with Diameter 60

It is clear from the above figures that the hot spot shifts into the riser for diameter of 60 mm.

C.Effect of Sleeve on Riser Diameter

An insulating sleeve was used around the riser to slow down the rate of transfer of heat from the riser. A sleeve of 5 mm thickness was used around the riser of 50 mm diameter. The result of this simulation is shown below:

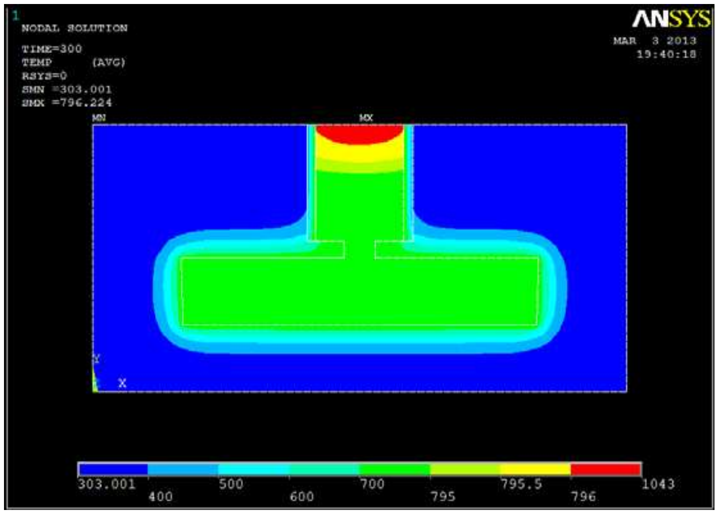

Fig. 17. Location of Hot Spot for Riser with Sleeve

As seen from the above figure, sleeve helps in maintaining the riser hot for a longer time. As a result, a riser of diameter 50 mm can be used instead of 60mm. this helps in increasing the casting yield.

D. Effect of Air Gap

The modeling of air gap in casting was done as follows:

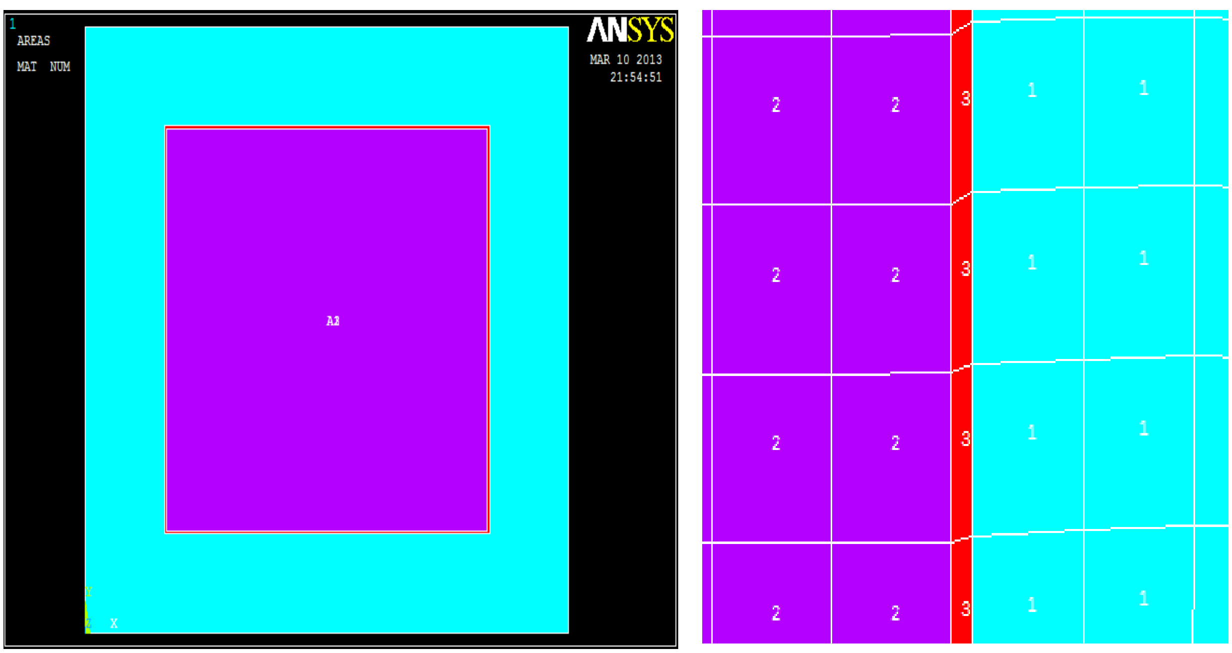

Fig. 18 Modeling of Air Gap

After the modeling was completed the casting was meshed using free mesh.

An air gap is formed only after aluminium solidifies. As aluminium solidifies at 933 K, the simulation was run from 933 K. The temperature time plot for various nodes was obtained as shown below:

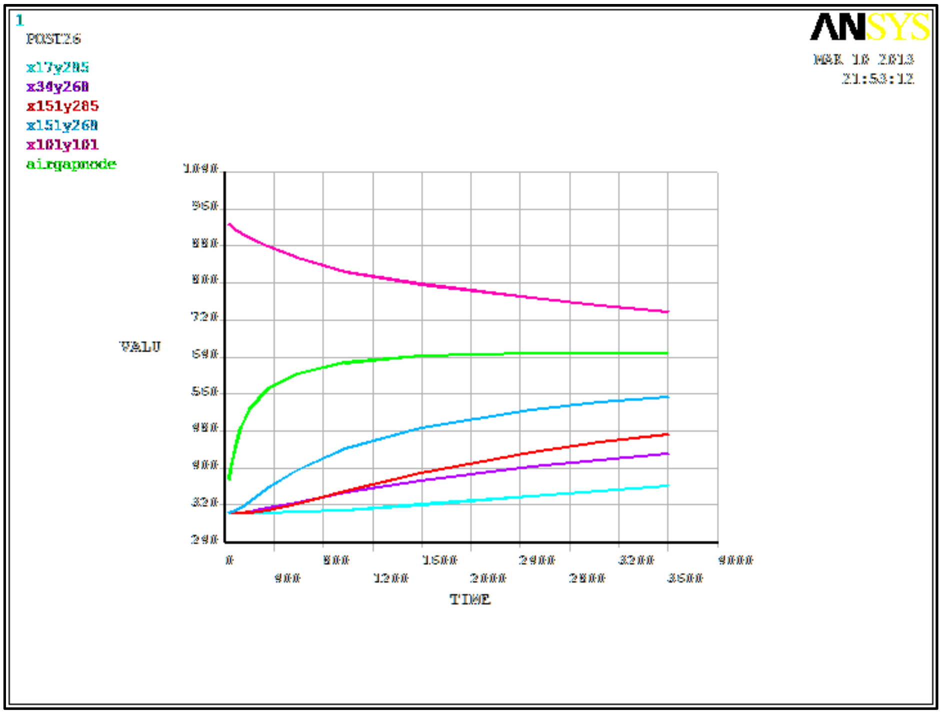

Fig. 19. Temperature Time Plot for Casting with Air Gap

From the above graph, it is seen that the maximum temperature at the end of simulation is 737.711 K.

For comparison, a similar model without air gap was made and the simulation was run from 933 K. The temperature time plot for various obtained is as follows:

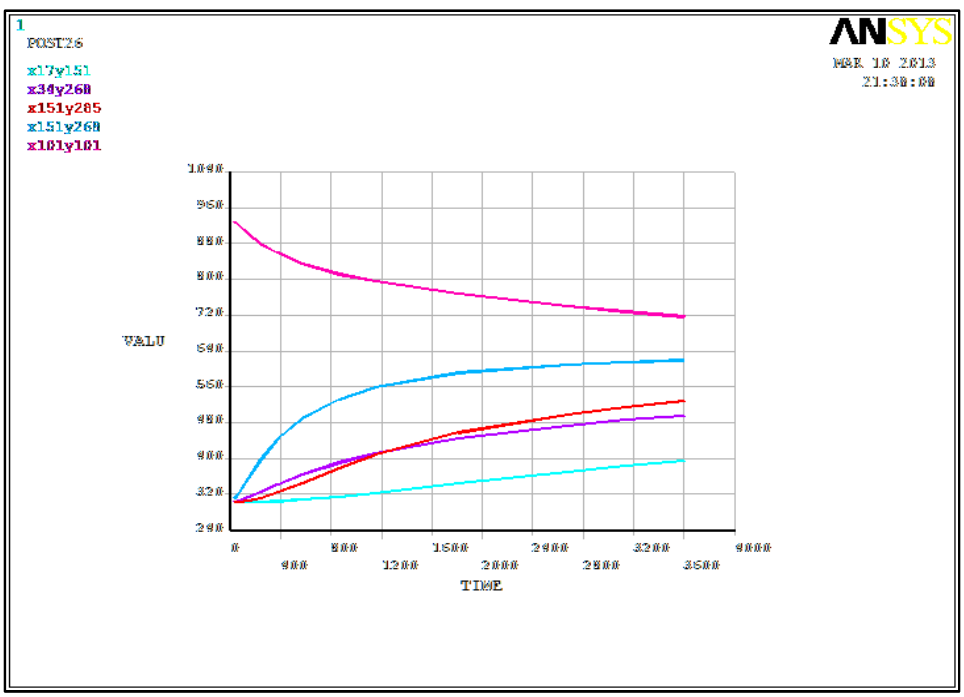

Fig. 20. Temperature Time Plot for Casting without Air Gap

From the above graph, it is seen that the maximum temperature at the end of simulation is 716.708 K.

V. ACTUAL TRIALS

The values obtained from theoretical calculations for design of pattern, gating system & riser were used to manufacture casting. The casting having riser diameter equal to 60 mm was found to be defect free. Also a defect free casting was obtained when a sleeve of 50mm diameter was used.

Fig. 21 Plate casting

VI. CONCLUSION

- ANSYS is a good tool to carry out solidification simulation.
- The optimized Riser dimensions were validated by simulation results and actual trials.
- Using sleeve as a feed aid helped in reducing riser dimensions there by increasing the Casting Yield.
- Simulation using other Thermal Solid MID-SIDE NODE Elements (Plane-35 & Plane 77) yielded absurd results & thus cannot be used for Transient Thermal Analysis in ANSYS.
- Results of Simulation of casting solidification with air gap between Sand & Metal prove that air acts as an insulator for heat transfer, but the effect can be neglected as there is no appreciable difference between the simulation results when air gap was not considered.

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