# Finite Element Simulation and Investigation of Thin Wall Impeller Casting

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## ABSTRACT

*In case of casting of thin wall impeller structure, the prediction of shrinkage defect is a difficult operation and failure of such thin wall structure is a commonly encountered problem. Such failures are due to non-uniform heat transfer rate. The uniformity of heat transfer rate may enhance by placing the runner at appropriate position and riser based on the geometrical attributes. An attempt is made for the analysis of optimization in the placement of runner and riser. The present work focuses on the simulation of aluminum thin wall pump impeller blade using commercially available software (ANSYS) and experiments for optimum placement of risers and reducing defects.*

**Keywords:** *Casting, Thin Wall Impeller, Casting Defects, Simulation.*

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## 1. INTRODUCTION:-

Among different casting defects, solidification shrinkage defects (macro, micro and centerline shrinkage) can be predicted fairly accurately. Flow-related defects (cold shuts and blow holes) can be simulated but may not always match actual observations. Cooling stress related defects (cracks), micro-structure and mechanical properties are difficult to simulate, and extensive calibration experiments may be needed for practical use. From the above it is clear that it is advisable to start with solidification simulation, which requires relatively less inputs, gives fairly reliable results, has a high impact on quality (shrinkage accounts for nearly half of all defects) as well as yield (feeder size optimization), and thus gives a high benefit to cost ratio. There are at least three (long term) benefits, which accrue after using simulation for some time (few months to years)

• Quality improvement reduces the (avoidable) costs associated with producing defective castings, including their transport, and warranty or penalties.

• Yield improvement reduces the effective melting cost per casting, and increases the net production capacity of the foundry (without adding melting or moulding units).

• Faster development of castings through virtual trials eliminates the wastage of production resources, and improves the rate of conversion from enquiries to orders, giving foundries an opportunity to select higher value orders.

## 2. RESEARCH METHODOLOGY:-

For the finite element analysis of solidification of thin wall structure the open type pump impeller having smaller thickness of the blades is selected so that it will resemble to thin wall structure. Another reason of selecting open type impeller is that the construction can be easily exposed to the observer. Further, as the impeller geometry is symmetric, only three blades can be taken for simulation. Thus ½ geometry can be considered in the simulation which will help to save lot of simulation time without sacrificing the results and its investigation.

## 3. CORE AREA OF WORK:-

However various combinations of blade thickness, inlet velocity and liquidus temperature were taken on experimental basis to arrive at the best possible combination. Tentatively 8 different combination types are taken for the analysis based on the assumption mentioned earlier. Different combinations types of inlet velocity, liquids temperature and impeller blade thickness are designed for simulation experiments given in below table 1.

**Table 1.** Design of simulation experiments

| Combination Type | Inlet velocity(m/s) | Liquidus Temp.(K) | Thickness(m) |
|---|---|---|---|
| A | 0.00101 | 1000 | 0.01 |
| B | 0.00101 | 1200 | 0.01 |
| C | 0.002 | 1200 | 0.01 |
| D | 0.002 | 1000 | 0.01 |
| E | 0.00101 | 1000 | 0.015 |
| F | 0.00101 | 1200 | 0.015 |
| G | 0.002 | 1000 | 0.015 |
| H | 0.002 | 1200 | 0.015 |

The simulation of solidification of impeller casting is then processed based on following considerations.

(1) Molten metal moves downwards with the force of gravity.
(2)The speed of the molten metal is much larger than that of solidification.
(3) The volume of shrinkage cavities is equal to the total volume contraction due to solidification.
(4)Molten metal has full fluidity in a mushy zone.

# 4. SIMULATION RESULTS :-

**Table 2.** Simulation Results of Designed Simulation Experiments

| Type | Mass flow inlet(kg/s) $*10^{-7}$ | Heat transf.(w) $*10^{9}$ | Wall shear stress(Pascal) | Heat Flux ($w/m^2$) | Heat transfer coei($w/m^2k$) | Nusselt no | Enthalpy (J/Kg) |
|---|---|---|---|---|---|---|---|
| A | 5.085 | $6.788*10^{14}$ | $1.2529*10^{11}$ | 1779.18 | 2.59 | 107.4 | 102504.92 |
| B | 5.085 | $3.66*10^{9}$ | $7.932*10^{5}$ | 299.69 | 25.31 | 1046.03 | 151961 |
| C | 0.10069 | $5.94*10^{9}$ | $3.1799*10^{6}$ | 312.31 | 26.37 | 1090.03 | 102504.92 |
| D | 0.10069 | $1.489*10^{9}$ | $1.483*10^{6}$ | 288.84 | 24.39 | 1008.14 | 151961 |
| E | 5.085 | $6.78*10^{14}$ | $7.6353*10^{10}$ | 1671.27 | 2.44 | 100.98 | 102504.92 |
| F | 7.62 | $4.214*10^{11}$ | $1.71024*10^{7}$ | 1191.93 | 1.73 | 71.51 | 138965 |
| G | 0.10069 | $1.642*10^{11}$ | 156.6 | 1190.958 | 1.72 | 71.24 | 102504.92 |
| H | 0.10069 | $1.642*10^{11}$ | 156.6 | 1190.58 | 1.72 | 71.24 | 102504.92 |

Taking the overall interfacial averaged heat transfer coefficient as h, the convective boundary conditions have been applied. For type A to E Nu is on higher side and hence the resulting shear stress is also high; this high shear stress leads to reduced strength of the thin impeller wall and may lead to failure during operation.

Although higher value of heat transfer coefficient means high heat transfer but does not mean that there will not be turbulence in initial flow of molten metal. This can be seen for type A to E, although the heat transfer rate is high still there is high shear stress compared to G and H. It is observed that there is very high shear stress at the tip of the blade as well as at the start of the blade curvature, which is the most common spot where the failure takes place. Inspite of higher heat transfer rate, there is uneven temperature distribution as shown in Figure 7.

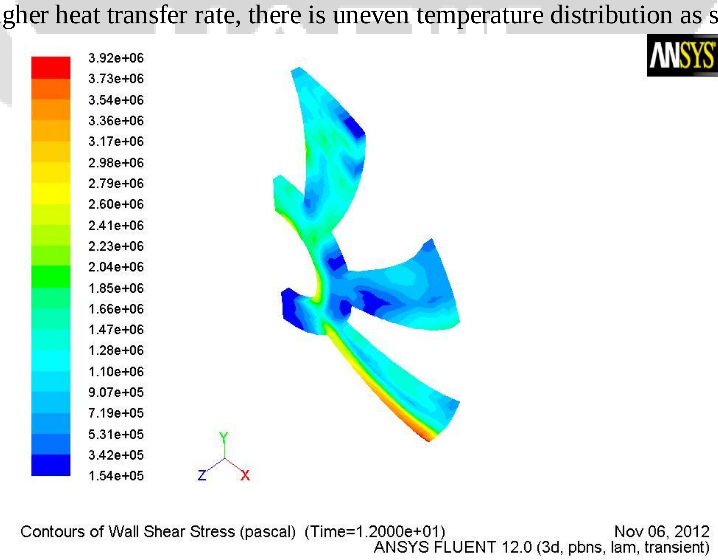



**Figure 6:** Shear stress contours for type B

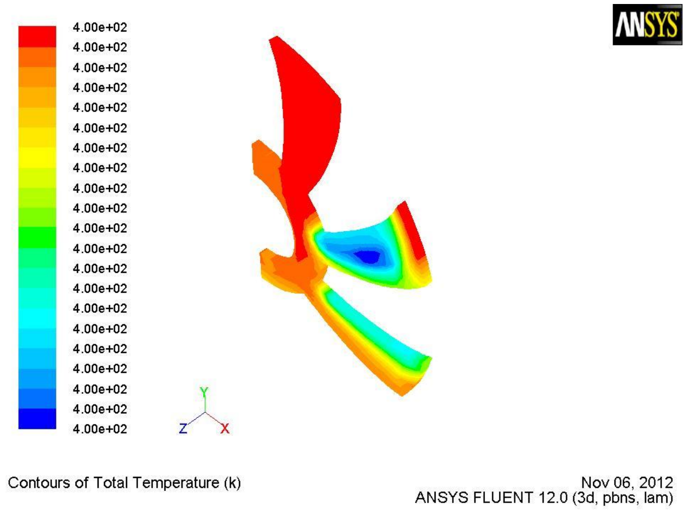



**Figure 7:** Temperature contours for type B

However, from table 2, it can be seen that the Nusselt number for type F, G, H is below 100 which indicates that there is no turbulence in the molten metal resulting in low wall shear stress for G and H.

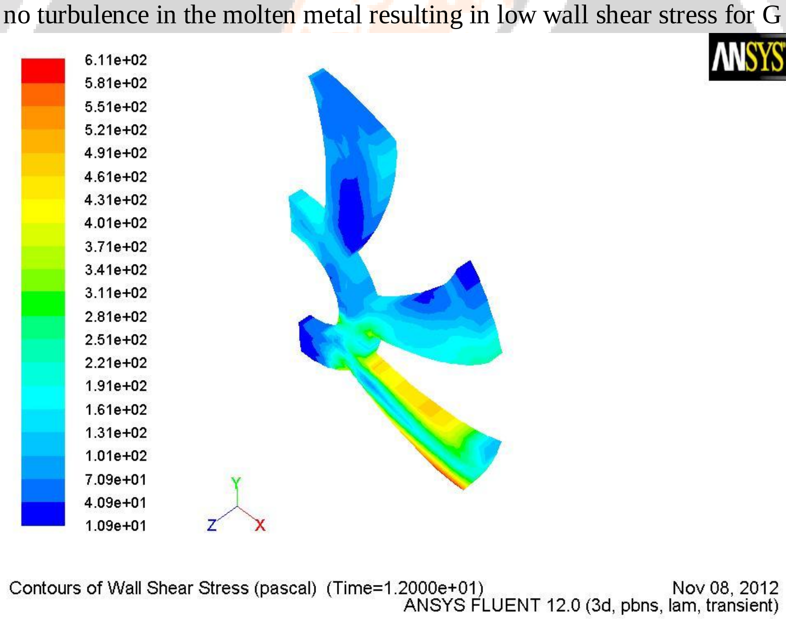



**Figure 8:** Shear stress Contours for type G

All the values of the parameters for these two types are nearly same. The contours of wall shear stress for G one among two is given in the Figure 8. The contours of total temperature are given in Figure 9.The contours are comparatively uniform indicating uniform cooling of the casting, thus indicating proper directional solidification. Hence there is a reduction in shrinkage related defects.

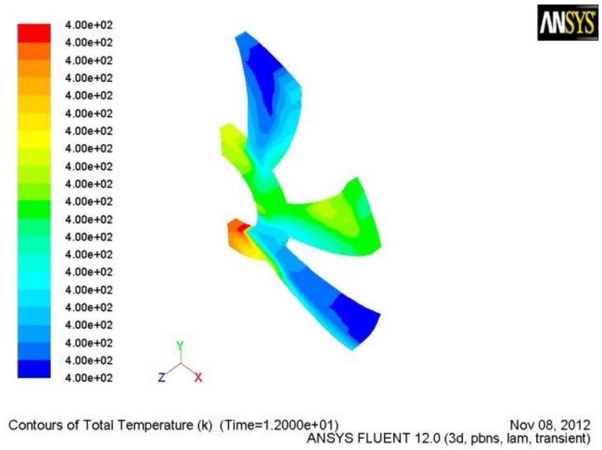
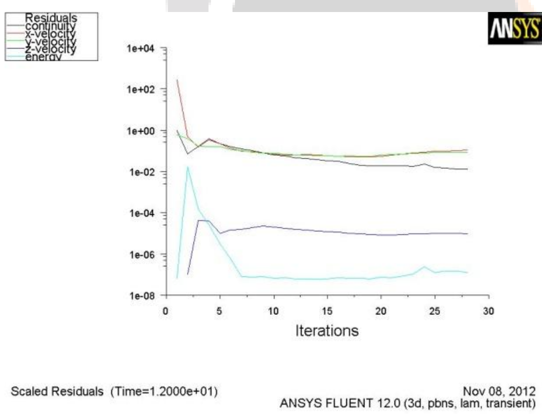



**Figure 9:** Temperature Contours for type G

At around 30 iterations, from Fig 10, it was observed that the variation in velocity in all the three directions is negligible and the system has achieved the dynamic equilibrium, indicating that the pressure within is tending towards almost same. But for type B as shown in Fig 11, there are very high fluctuations in velocity in all the directions and has taken almost 60 iterations to stabilize, this can also be one of the reason for high wall shear stress in it.



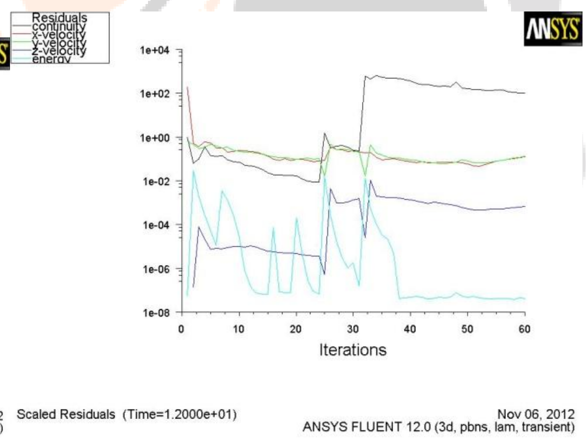




**Figure 10:** Velocity fluctuations for type G

**Figure 11:** Velocity fluctuations for type B

## 5. CONCLUSION:-

From the various combinations selected during the simulation it is seen that if the thickness and the inlet velocity are properly selected, then distribution of wall shear stress and the temperature will be uniform thus avoiding the defects in the casting. Further, it is observed that thickness of the structure plays an important role as compared to the angle of curvature in the casting of thin wall impeller.

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