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Thermal Analysis of Casting using ANSYS: A Review

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Abstract
The major requirement of any foundry is to provide the high quality casting products. Since the quality is depended upon thermal stress and solidification of the casting, a thermal analysis is a key area to work on. Heat transfer coefficient is the vital element of any thermal analysis. Mould and the casting interface is the most critical area that gets affected during the solidification. Heat transfer ratio at the inter face will give an explanation about temperature distribution and thermal stress analysis. ANSYS helps to understand the heat flow of casting. The moment when the molten metal solidifies is the most important instant and at that time transient thermal analysis is required to forecast the outcome of the casting solidification and to understand its behaviour.

Keywords: *ANSYS, casting, temperature distribution and thermal analysis, heat transfer coefficient*

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INTRODUCTION

Casting is one of the oldest manufacturing processes that produce variety of domestic and industrial products. From melting the metal/alloy to machining of the final goods have many stages which affect the final output in a different manner. The most important instant is when the object solidifies and goes through various transient temperature flow variations that produce stress levels in different areas causing problems and defects.

There is a lot of work already been done in the thermal analysis in the casting zone. In this study a review of such work has been prepared and steps to solve thermal analysis using ANSYS are discussed. Thermal analysis software helps the tedious process of finding and understanding the heat flow of the casting during the solidification procedure. To analyze the process various programming tools like Pro-cast, Opt-cast ANSYS etc; are available to give out the results of thermal analysis.

Following are the various methods of elimination of casting defects and carrying out as explained by various authors:

XU Yan *et al.* say that in the new age of casting thermal stress is a vital parameter that affects badly on the job output, requiring the temperature analysis of the casting object. Unusual and irregular cooling creates thermal stress and uncertainty. The heat transfer ratio between casting and mold can be badly affected by the thermal stress and deformations changing the contact between molds and casting contact.

To study the interaction between sand mold and casting surface contact element method was used and the contact data was given to analyze the heat transfer system which evaluates the heat transfer coefficient based on gap and pressure between two surfaces. After these two paths of thermal and mechanical phenomena were coupled using method looking for stress analysis in stress frame specimen and cylinder block. Here, it has been found that results were way more accurate and precise then without considerations of contact effect and heat transfer rate.

Furthermore, a system integrating and analyzing thermal and mechanical effect was evolved and utilized during casting solidification. And as stated above more accurate results were found using coupled thermo mechanical analysis. Integrated system needs to be applied to numeric solution of the casting solidification [6]. Hsien-Chi Sun *et al.*

is studying the temperature distribution with

an experimental data related to green sand cylindrical aluminum casting. Experimental data helps to calculate the effective heat transfer coefficient between mold and the metal using four different formulae. Symmetrically organized thermo couple is utilized in the temperature measurement which has been proven to be much feasible, that decreases the effects of the heat transfer on casting solidification, temperature of metal and mould interface is calculated by extrapolation technique to identify the effective heat transfer co efficient. In accordance of the previous heat transfer co efficient a lump capacity method is used to calculate the average mean value of effective heat transfer co efficient. An experimental detail was very much coincided with the numerical profiles found on the basis of temperature curves. At last a finite element analysis was carried out using FIDAP software to understand temperature distribution with the help of effective heat transfer found in the experimental study. The predicted time for casting solidification found to be near accurate as the study says [5].

VikramPratap Singh Tomar *et al.* says casting solidification embodies a huge deal with several profiles like metal flow, temperature gradient and heat transfer. These stages are complex and takes place between the casting and mould. Casting quality is influenced by the thermo-physical properties of the molten metal and mould cavity. Heat transfer from metal cast to atmosphere through mould walls play vital role. Here in this paper a numerical simulation of aluminum casting using ANSYS software is carried out. It is considered that a thermo physical property of aluminum is temperature dependant and green sand mould properties are constant. At the mould cavity wall for ease of operations [1].

Sunanda Das *et al.* worked to predict and analyze a casting defect, FEA based ANSYS software is hugely utilized. Temperature distribution and thermal stress distribution are the key element of casting analysis, to predict them after casting solidification, transient thermal analysis and couple-field analysis of software ANSYS can be utilized. Completing the validation of the thermal analysis, to analyze thermal stress and shrinkage couple field analysis is carried out.

Few modifications are simulated and tested after couple field analysis to check if they are feasible and optimum then the previous consideration in the base paper. At the first case mullite has replaced the first modification sand giving lesser mold shrinkage, lesser thermal stress and higher cast shrinkage. For the sand-mullite composite mold least shrinkage is found as well as lesser shrinkage for the cast is also found while the thermal stress is higher than the mullite mold [3].

CM Choudhari says that physicists, metallurgists, casting engineers and software developers are always interested in the phenomena of metal casting solidification process. Non-uniform and non linear transient phenomena possess challenge in the area of analysis and modeling. This paper attempts to understand heat flow inside the casting body and also from the casting to the mould interface, at last obtaining the temperature history of every point inside the casting. When the hottest region inside the casting is solidifying, that instant of the time is considered to be the most important. Transient thermal analysis using ANSYS helps finding temperature distribution. These details are compared with experimental temperature results and a very reliable good agreement has been found. After then metal pouring system and gating system can also be analyzed for improving the casting qualities, also helping in reduction of development cost and material utilization [4].

Chaitanya Mathkar *et al.* explain in this study of casting, an effort has been done to reduce the time required in the development of the casting object called pump adaptor component (PAC). Computer simulation using magma-soft software has been carried out to understand and visualize the entire solidification process which is impossible to study during the actual casting procedure. With such simulation temperature distribution, porosity analysis, air entrapments can, unfilled mould be observed. Using solid works software a model of pump adaptor has been created and fed to the magma-soft simulation software. Using FEM concept meshing is done about the object. Two process parameters like pouring time and velocity are used as input values of the simulation. Simulation gives detailed idea about the process and predicts temperature distribution and porosity level [2]. MEI LI *et al.* says Opt-cast is a fine amalgamation of the regular commercial casting simulation and the thermal optimization software called i-SIGHT. There are mainly two types of optimization are conducted in Opt-cast in which one utilizes inverse modeling approach to find out boundary condition values like HTCs (coefficient of interfacial heat transfer) and second is casting process variables optimization with minimizing cycle time while maintaining casting quality. Here in this study the identification of HTC using Opt-cast and water quenching process in described. To carry out the thermal analysis of V8 engine block, the optimum value of HTC for given casting are applied. Enough accuracy is maintained for enabling the prediction mechanical properties and micro level structure. For analyzing residual stress of the cylinder head, optimized HTC for the water quenching was applied [7].

METHODOLOGY

Modelling of a Casting Process

In a regular casting simulation software the simulation takes following three steps (Figures 1–4):

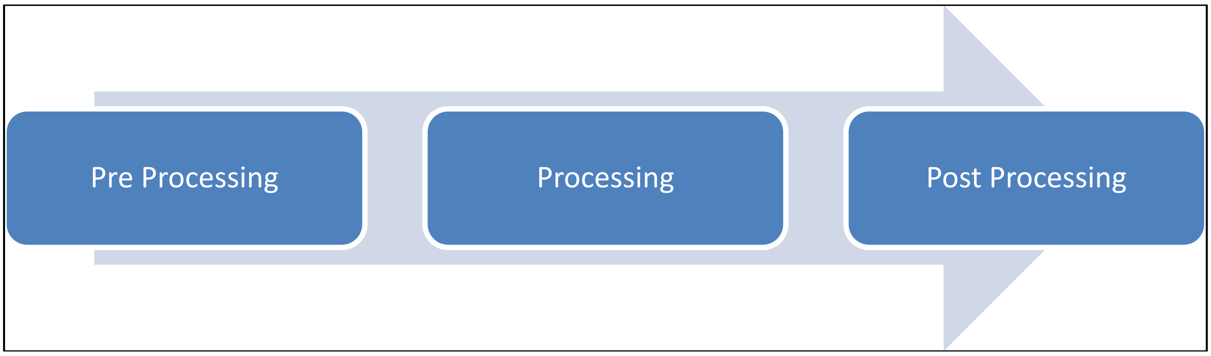

Fig. 1: *Steps of Analysis.*

1) In pre-processor stage following jobs are done:

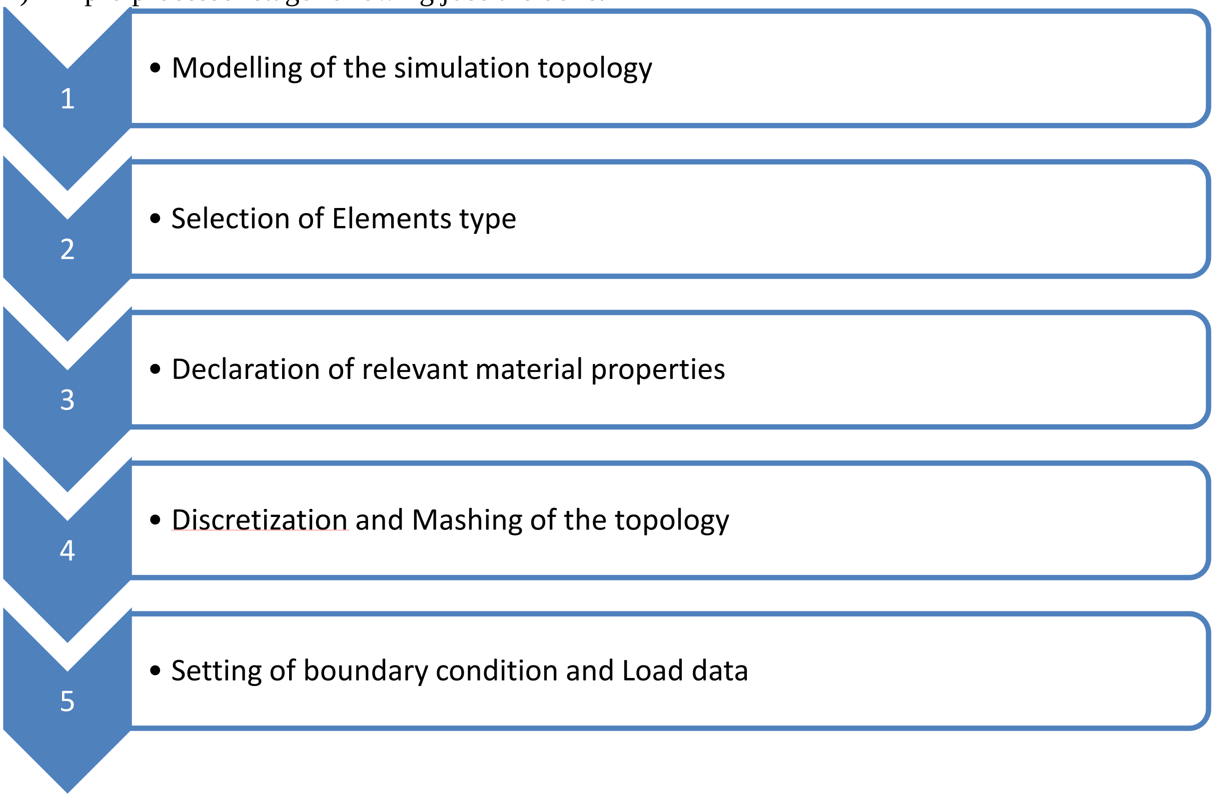

Fig. 2: *Steps of Pre-processing.*

2) In the main processing stage following jobs are done.

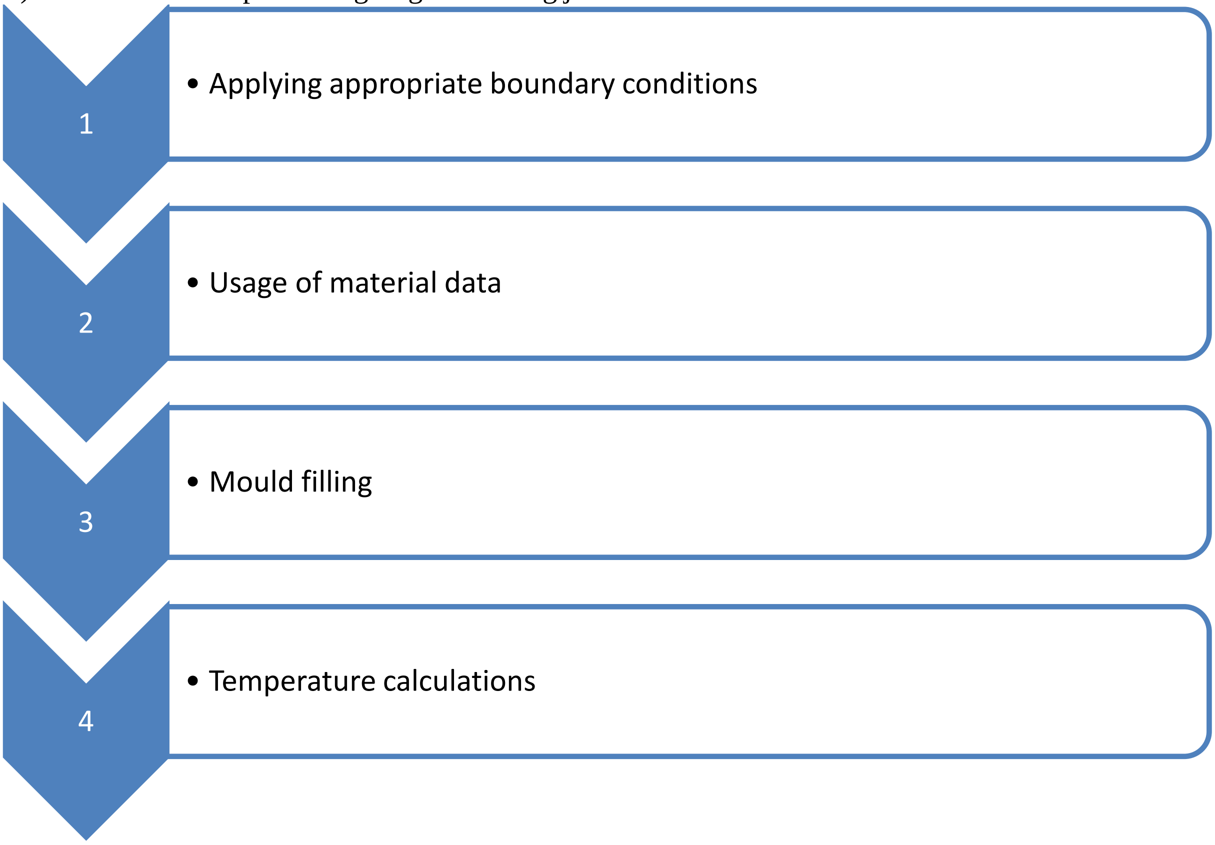

Fig. 3: *Steps of Main Processing.*

3) In the Post processing stage following jobs are done

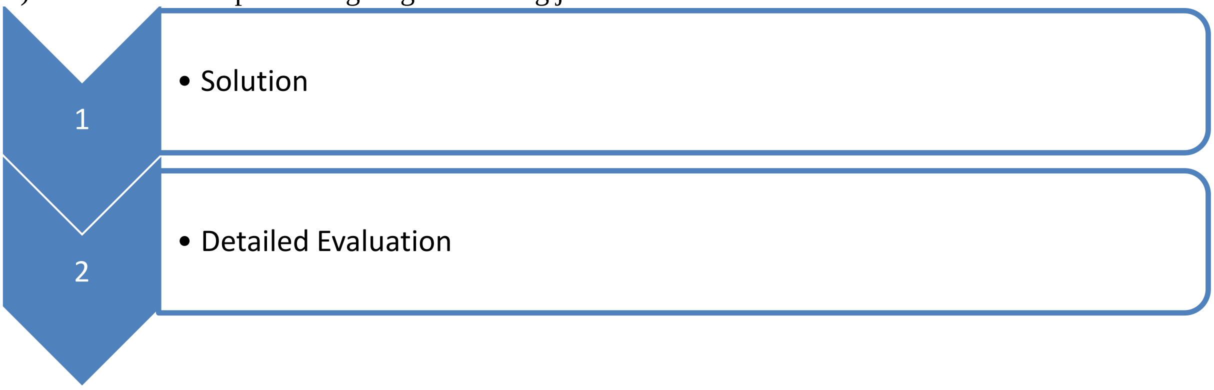

Fig. 4: *Steps of Post-processing.*

Choudhari CM, has studied a shaft and its casting procedure and also understood its solidification and thermal analysis using ANSYS software from the recent history it can be noticed that the foundry men are very much fascinated by the numerical solution methods and they are quite feasible and accurate upto certain extent [4]. The casting model is described as a numbers of simple elements and also the equation of unsteady heat conduction is applied to these elements to find heat flow solution and temperature at different nodal points over period of time (Figure 5). To carry this out tools like FDM (finite difference), FEM (finite element), BEM (boundary element) are available. Heat flow analysis has been researched by many authors that has been discussed and reviewed here [4]. Coming down to the thermal analysis of Shaft by ANSYS tool we require a 3D model to be analyzed and simulated. Due to axi-symmetric shape of the casting object only half of the object needs to be modelled in to ANSYS environment (Figure 6).

Material properties are another essential attribute to carry out the thermal analysis. Here the two materials has to be considered, one for the mould and other for the casting, here they are sand and aluminium. Sand has all the properties constant behaving, irrespective of the temperature; therefore properties demanded by the software for sand are conductivity, density, and specific heat. Here, it is to be noticed that material properties like enthalpy and specific heat will change according to the temperature variation.

Total 3556 triangular element are found for the discretization purpose of the model. Total 7346 number of nodes have been generated, from that 1263 belong to casting region and 6083 belong to mould region (Figure 7).

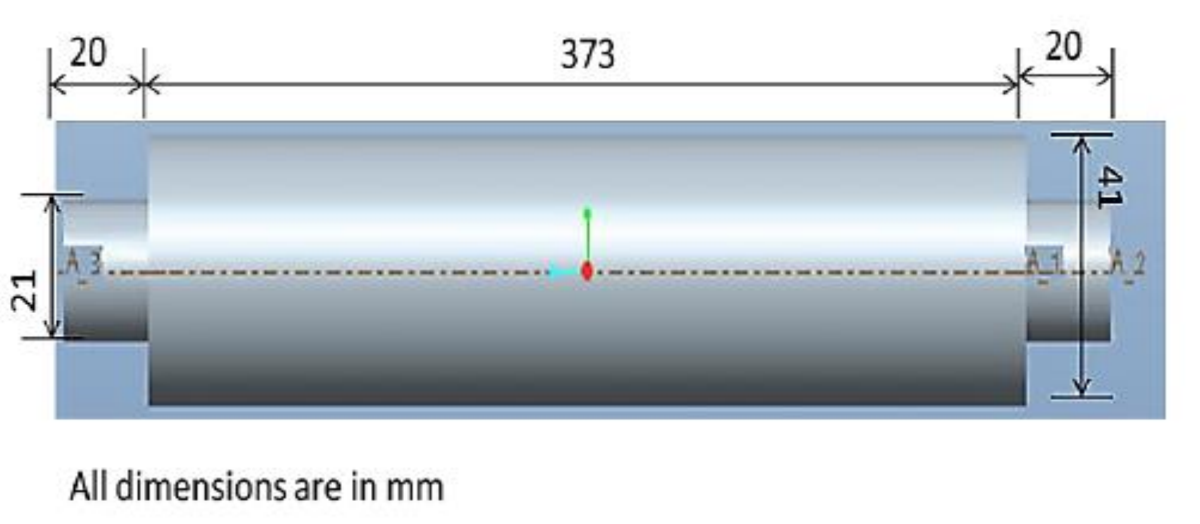

Fig. 5: *Casting Job-shaft. [4]*

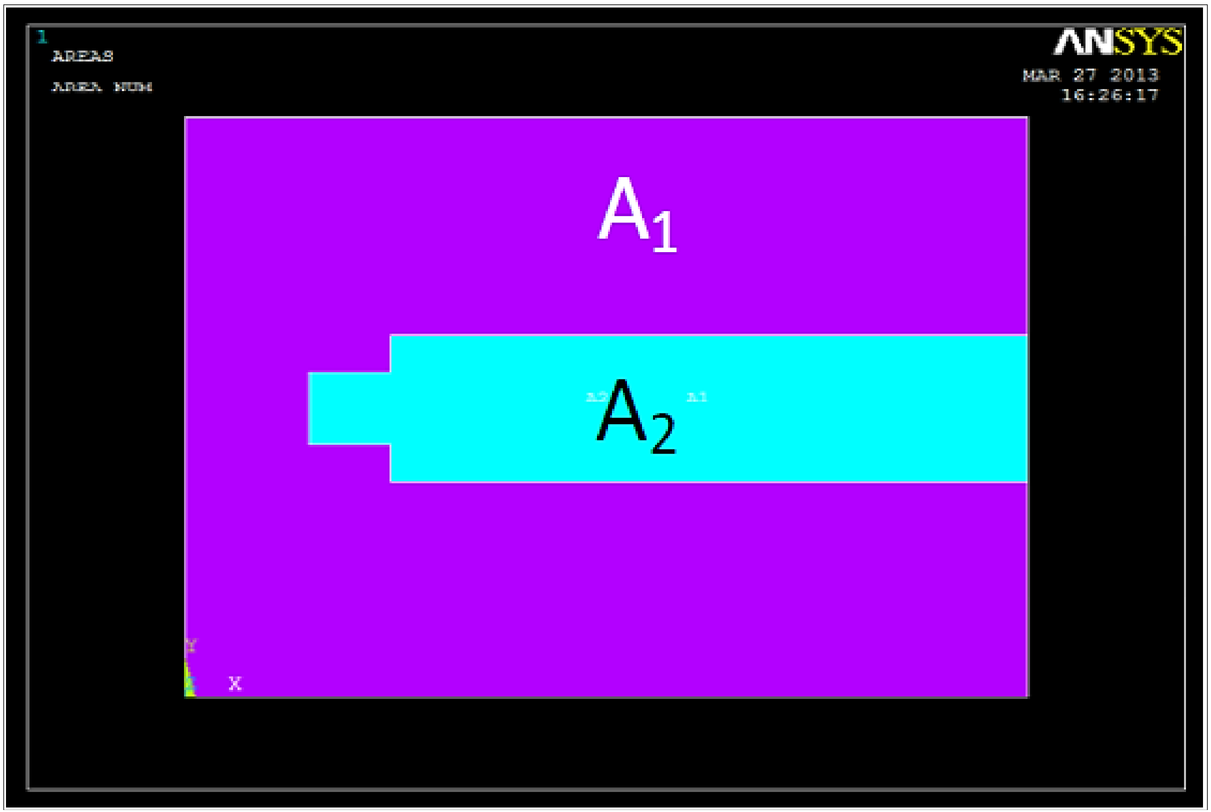

Fig. 6: *Area Plot [4].*

Now, it is to apply the convective loading and boundary condition for the given geometry. Here the convective loading was to apply to the lines of the model exposed to the ambient air. Loading that has applied to solid modelling entities are automatically transferred to the finite element modelling during the solution part (Figure 8). In this study the HTC has been taken as 10 $W/m^2 K$ between sand and air also ambient air temperature as 303 K. The mould is initially at an ambient temperature of 303 K and the molten metal is at 973 K. After this the final solution is obtained by the software. ANSYS software helps carrying out the simulation and understanding the situation. It is the second phase of the process. Here convergence plot is generated time history post-processing is the tool that shows temperature variation of any mould area. Identification of temperature of node points is based on Location of thermocouples. Temperature profiles have been generated during analysis at two different instance; t= 36 and t= 3600 sec (Figures 9–10).

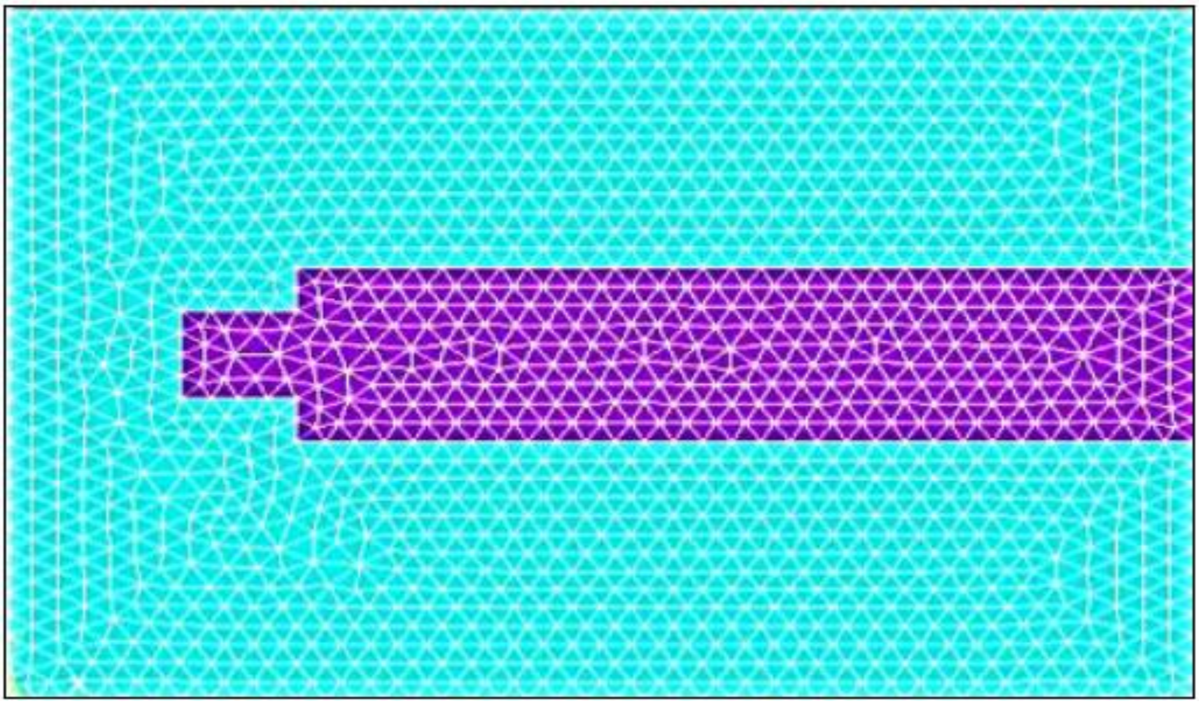

Fig. 7*: Mesh View [4].*

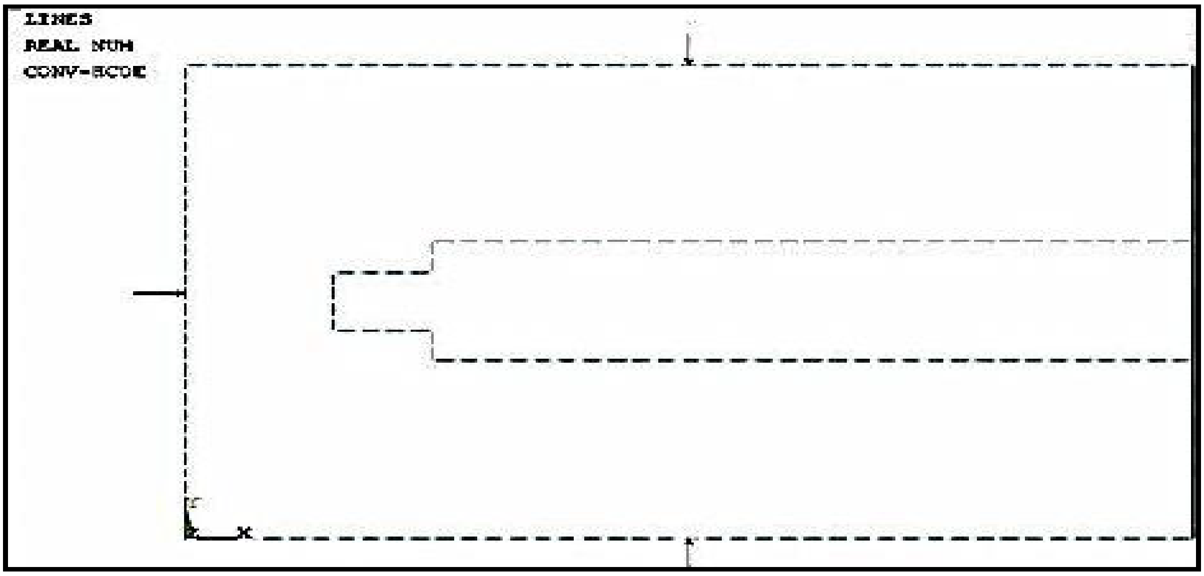

Fig. 8: *Application of Convective Load [4].*

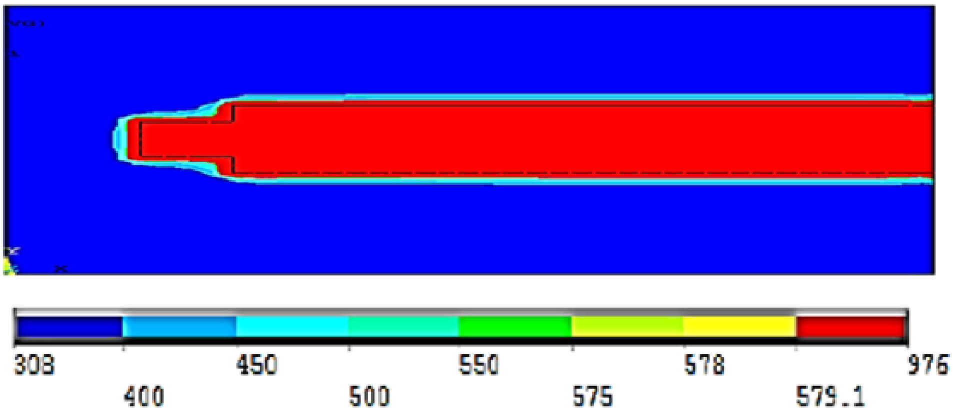

Fig. 8(a): *(Temperature Profile), t=36 sec, Tmax=878.901 K*

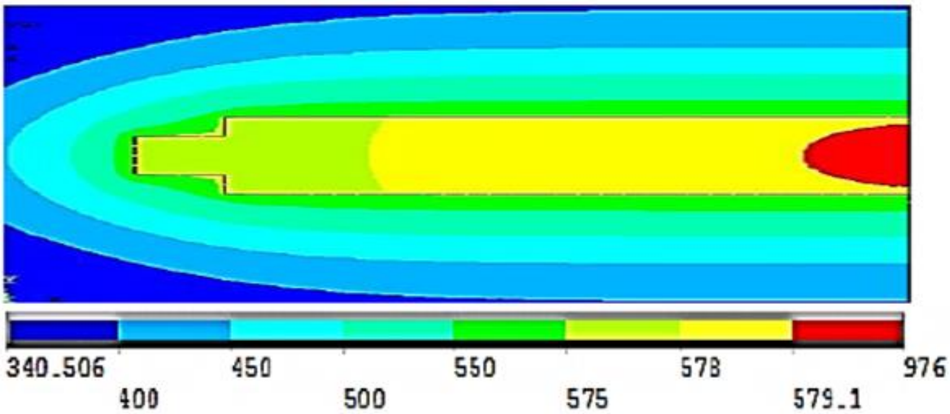

Fig. 8(b): *(Temperature Profile), t=3600 sec, Tmax=579.146 K*

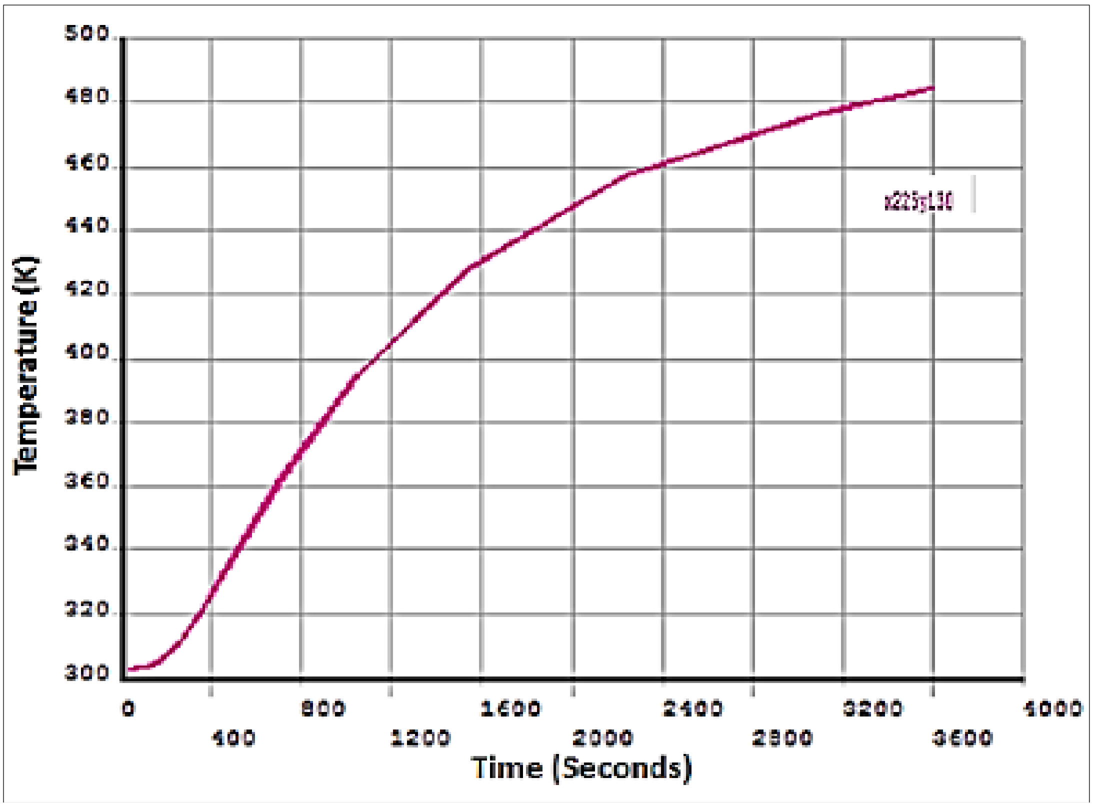

Fig. 9: *Graph Plotted between Temperature vs. Time (Profile).*

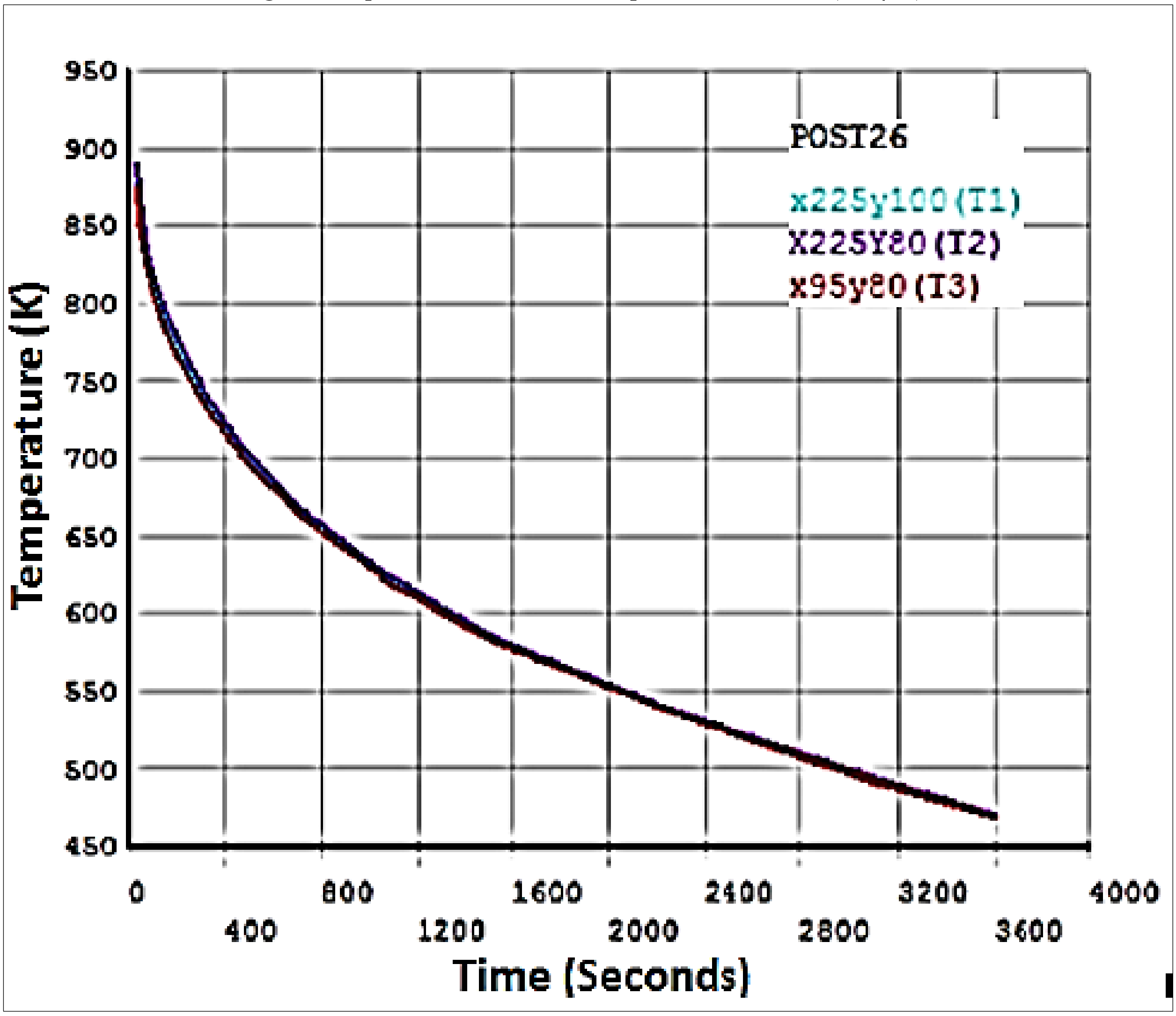

Fig. 10: *Temperature Variation over a Period of One Hour obtained by ANSYS for Casting Region [4].*

CONCLUSION

After analyzing above mentioned methods we can conclude that the ANSYS simulation and analysis can explain the heat flow studies and temperature analysis is the key element for understand the thermal analysis and also helps predicting the porosity and defects in the casting process. Thermal stress can cause severe defects like shrinkage and deformation in the casting object and to solve this thermal analysis is helpful.

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