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FEA Simulation of Sand-Casting Process using ANSYS

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Abstract : Finite Element Analysis (FEA) has proven to be an effective tool for evaluating the thermal characteristics of mould casting processes. This paper presents an FEA-based investigation into the thermal behavior of various molten metals and alloys, including aluminum alloy, copper, alloy 617, and alloy 945, within a sand mould. Through thermal modeling, key parameters such as cooling curves and heat flow at the mould-metal interface were determined.

The FEA results indicate that copper exhibits the highest heat flux, measured at 75.848 W/mm², reflecting a significant rate of heat transfer. In contrast, alloy 617 shows the lowest heat flux of 5.602 W/mm², and its maximum core temperature was recorded at 978.16K after 10 seconds. Alloy 945 demonstrated a core temperature of 1339.9K, with the interface region stabilizing at approximately 627.7K.

The temperature variations and heat flux data obtained from these simulations are crucial for optimizing casting processes, improving casting quality, and reducing overall development costs. The detailed contour plots of temperature and heat flux offer valuable insights for the strategic placement of feeders and other feeding aids, which can enhance casting soundness and reduce defects.

***IndexTerms* - Finite Element Analysis (FEA), Thermal Characteristics, Mould Casting, Sand Mould, Cooling Curve Heat Flux, Temperature Distribution, Molten Metals, Aluminium Alloy**

I. INTRODUCTION

Sand casting, also described as sand moulded casting, is a metal casting method in which the mould is made of sand. The phrase "sand casting" can also apply to an object made using the sand-casting technique. Sand castings are made in foundries, which are specialist industries. Sand casting accounts for more than 70% of all metal castings. Including for steel foundries, sand casting is reasonably inexpensive & suitably refractory[1]. A strong bonding ingredient (typically clay) is added or occurs with the sand in addition to the sand. To improve the clay's solidity & flexibility, as well as make the aggregate suitable for moulding, the mixture is wet, usually with water but sometimes with other materials.The sand is usually held in a beaker, which is a series of frames or mould boxes. Mold chambers & gates are carved directly into the sand or compacted around images or designs[2,13].

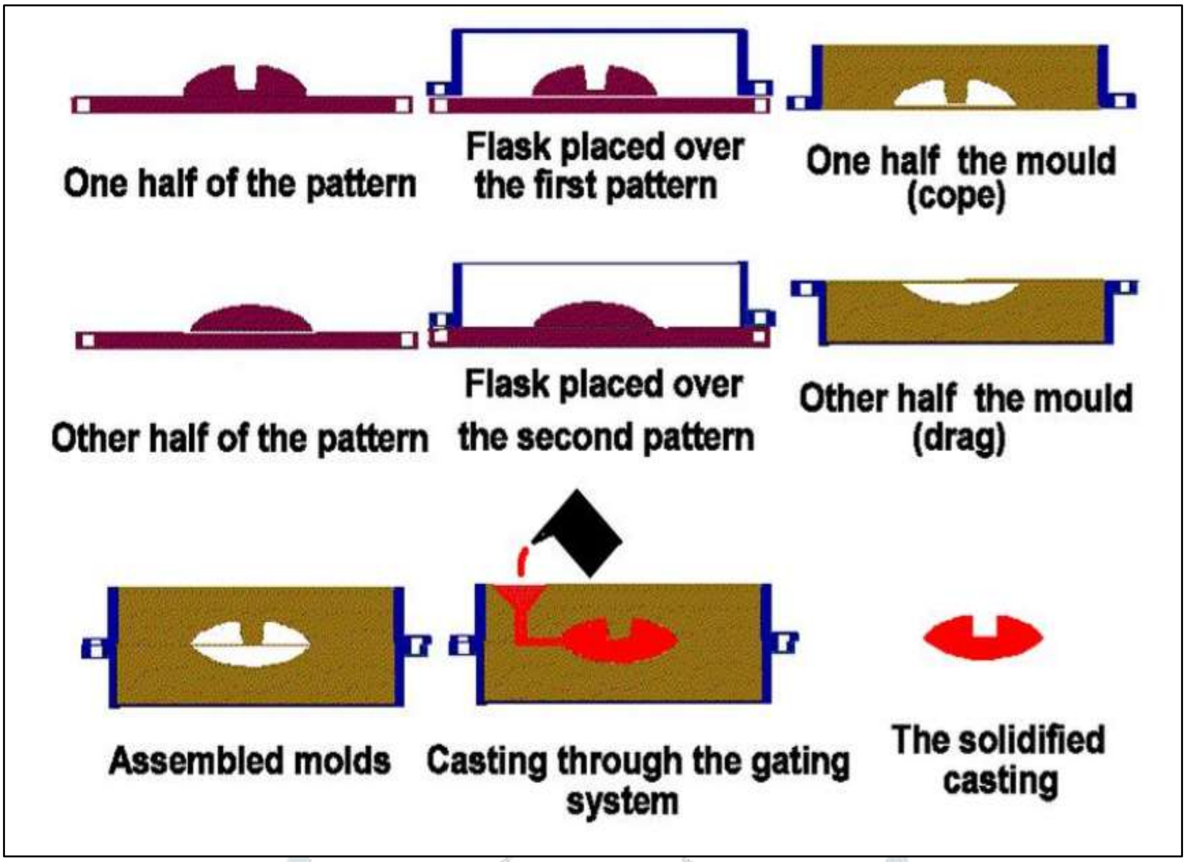

Figure 1: Steps in Casting Process[32]

II. Background

Santos C A et al [1] (2002)symbolises the creation of a program that integrates heuristic search approaches for use in metallurgical businesses, notably those that use continuously casting to produce steel billets and slabs. When compared to the cooling pattern used in a real slab continuous caster, a simulation produced by the intelligent method showed that the adjustments recommended by the prototype ensured ingot performance and could lead to a significant decrease in water usage and a boost in casting manufacturing.

Sushilkumar et al [2] (2011)analyse casting faults and come to the conclusion that Six Sigma, i.e. (DMAIC) approach of variables, could enhance quality at a lower feasible cost. It is also feasible to determine the signal factor levels at which the noise factors have the least effect on the response characteristics. Their case study has led to the optimization of process parameters in the green sand castings process, which helps to reduce casting faults. Moisture content (4.0%), green strength (1990 g/cm2), pouring temperature (14100C), & mould hardness number vertical & horizontal (72 & 85) are the optimal parameter settings for green sand casting.

Mane V.V et al [3] (2011) Cause-and-effect graphs, design of experiments, if-then rules, ANN were used to analyse casting defects. The researcher outlines a three-step process for identifying, analysing, and correcting casting defects. The flaws are categorised according to their appearance, size, location, consistency, stage of finding, etc inspection procedure. This aids in the accurate detection of flaws. The potential sources of defects are divided into concept, material, and management implementation for defect assessment.

Dr.Shivappa D.N [4] (2012) Sand drop, blow hole, misfit, and overweight are the four most common flaws found in casting failures, according to TSB Castings. These flaws have been noted to occur often at specific areas. Casting mismatches are caused by a lack of locators and incorrect core setup. Oversizing occurs as a result of mould lift and bulging. (i) Sand Drop: Proper cleaning of the mould before closing, ensuring that sand does not enter the sleeve, replace nobake core with shell core, provide pads at bottom face, and modify the loose component layout to prevent core crushing were selected as remedial steps to solve the aforementioned flaws. (ii) Blow Hole: Changes to the gating system; flow offs will be linked directly to the top surface of the long member. (iii) Mismatch: Six locators were provided for appropriate core configuration, three of which are metallic and three of which are self-locators. (iv)Oversize:

Jadhav B. and Jadhav S [5] (2013)For the sake of research, authors focused on Cold Shut as a casting defect. Pattern forming, moulding, core making, melting pouring, shell breaking, shot blasting, and other procedures are all part of the casting process. It's difficult to make a casting without flaws. The defect reduction achieved by changing alloy composition and pouring temperature is depicted in this study. Check sheet, pareto analysis, cause effect diagram, flow chart, scatter diagram, histogram, control chart are the seven quality management methodologies used to evaluate and decrease errors.

III. Proposed Method

The design of sand mould is established in 3D parametric design software. The model is established using sketch & extrude tool. Two different features are developed in part modelling and then assembled to generate mould casting design. The complete design of sand mould is shown in figure 2 below..

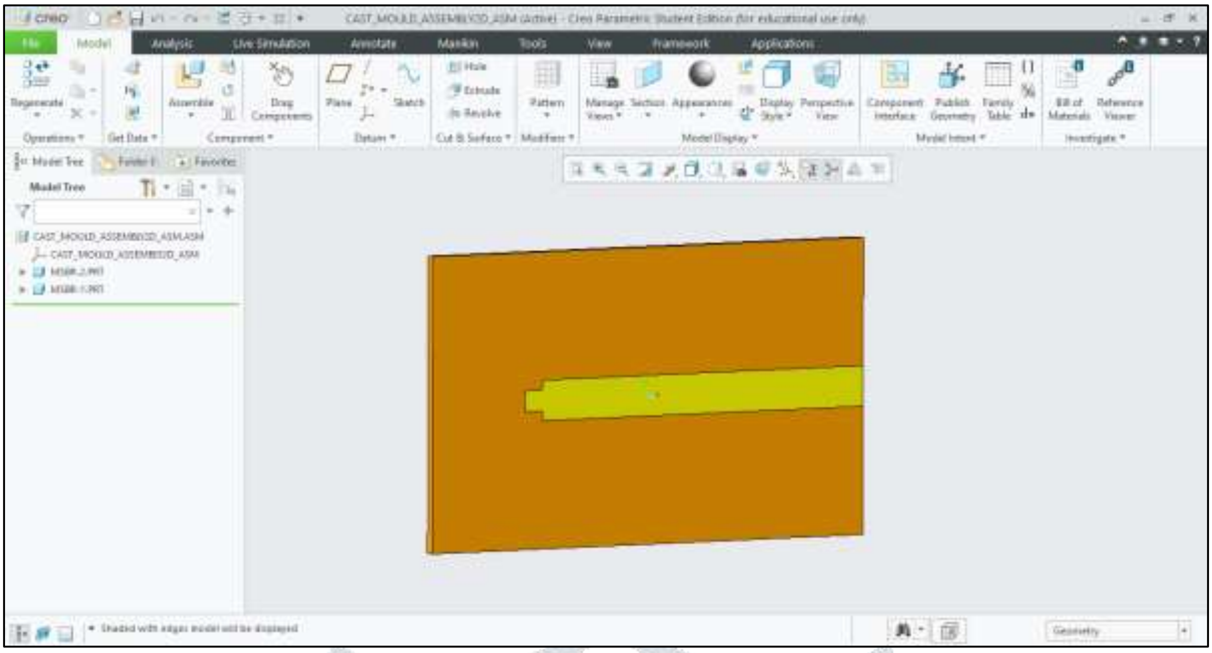

Figure 2: CAD model of mould casting

Importing CAD Modelling

The CAD model of mould casting is imported in ANSYS design modeller as shown in figure 3 below. The imported model of mould casting is checked for geometric errors like hard edges, surface imperfections and other similar defects.

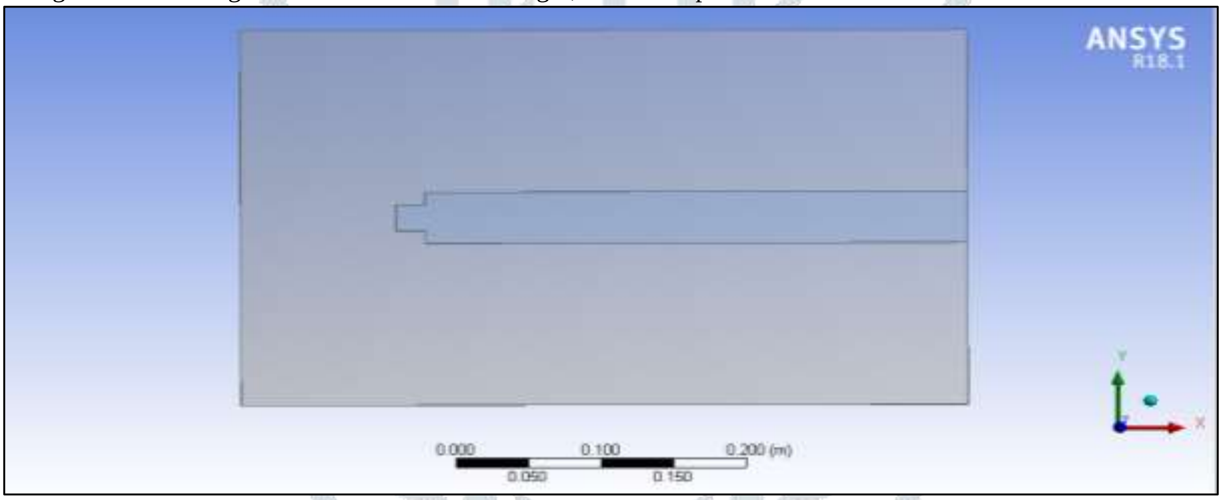

Figure 3: Imported CAD model of mould casting

Meshing

The model of mould casting is meshed using hexahedral element type. The hexahedral element is brick type element which has 8 nodes with 3DOF/node. The amount of components generated is 4396 & set of nodes generated is 25764.

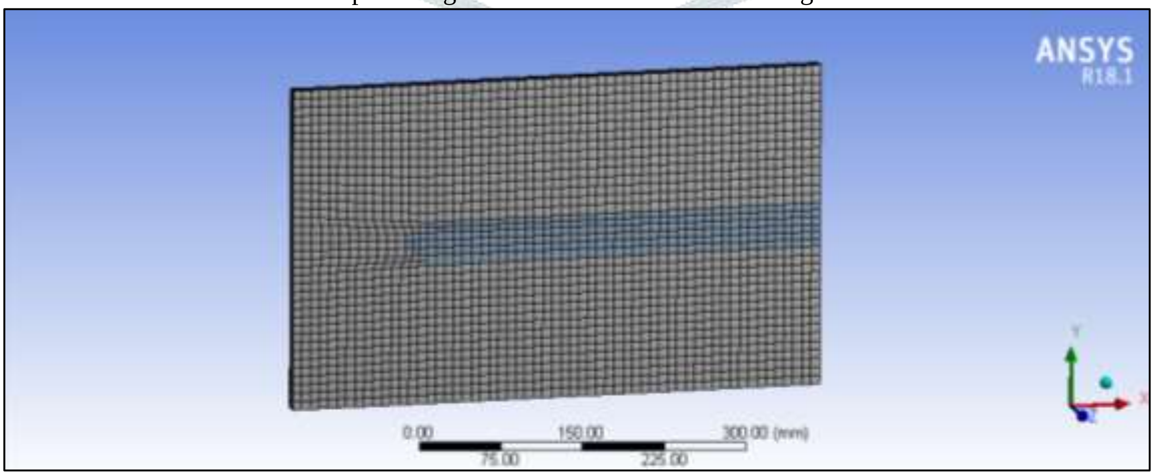

Figure 4: Hexahedral element mesh

Loads and Boundary Condition

The thermal loads & boundary conditions are implemented on mould casting. The thermal conditions include molten metal temperature of 973K. The convection coefficient is applied on other surface with film coefficient of 0.00001 W/mm^2K and ambient temperature of 303K.

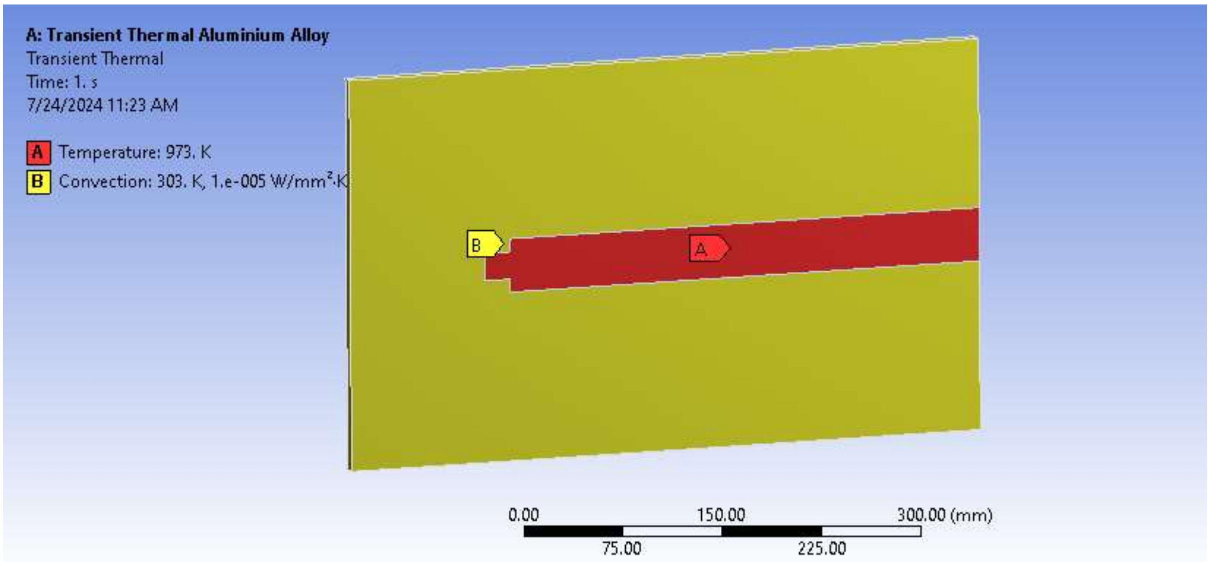

Figure 5: Loads and boundary condition

The thermal analysis is conducted on sand casting under transient conditions. The material properties are defined for different simulations which are shown in figure 4.1 below.

Table 1: Material properties of alloys

Material Name	Density (Kg/m^3)	Thermal Conductivity (W / mK)	Specific heat (J /Kg K)
Aluminium Alloy	2770	175	875
Copper Alloy	8300	401	385
Alloy 617	8323	27.87	643
Alloy 945	8200	29.5	690

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IV. Result Discussion

From the transient thermal evaluation, the temperature distribution plot and thermal flux plot is generated for copper alloy. The temperature distribution plot is generated for different time intervals i.e.

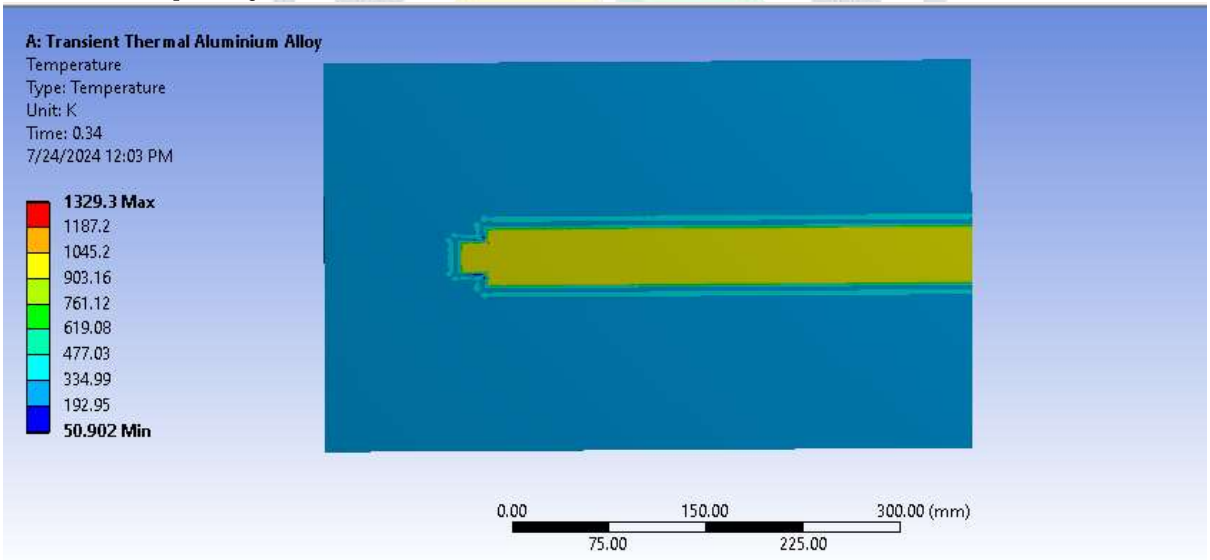

Figure 6: Contour plots of temperature at .34 counter

The temperature distribution plot is obtained at .34 counter secs as shown in figure 5.1 above. The temperature of the core is 1329.3K and at the interface region is nearly 477K.

Table 2: Temperature table

Location	Temperature obtained from ANSYS (K)	Experimental value of temperature [8]
P_1	877	883
P_2	888	893
P_3	871	875

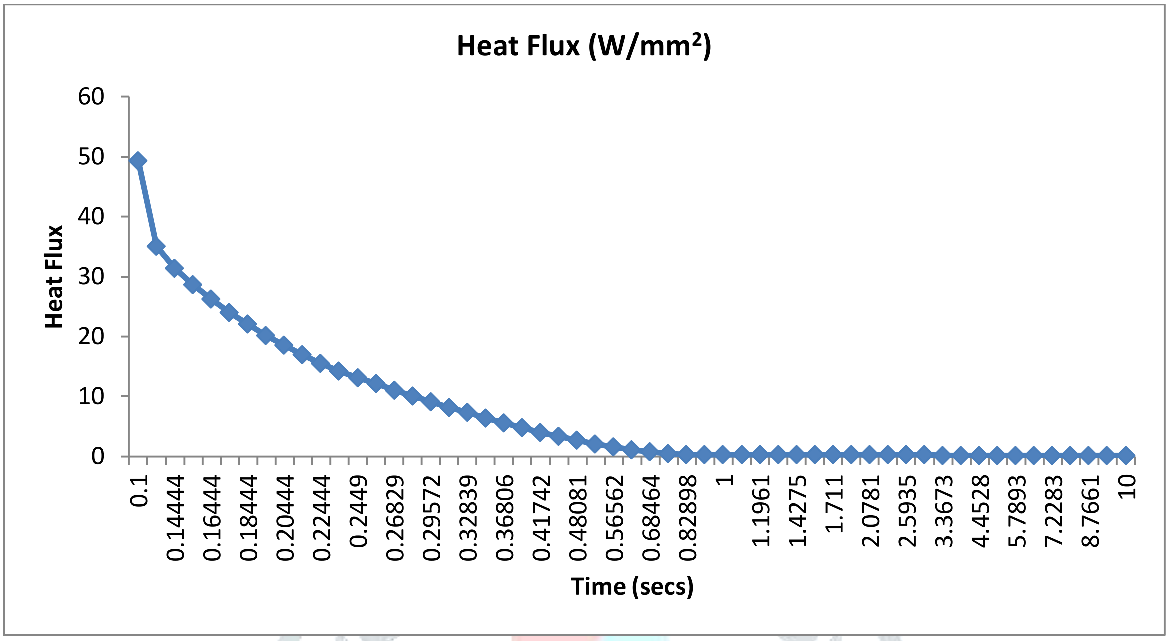

Figure 7: Heat flux plot for aluminium alloy

The variation of heat flux for aluminium alloy with respect to time is shown in figure 7 above. The heat flux is maximum initially with magnitude of 49.356 W/mm^2 which reduces almost linearly and reaches to stagnant value at .82 secs of simulation.

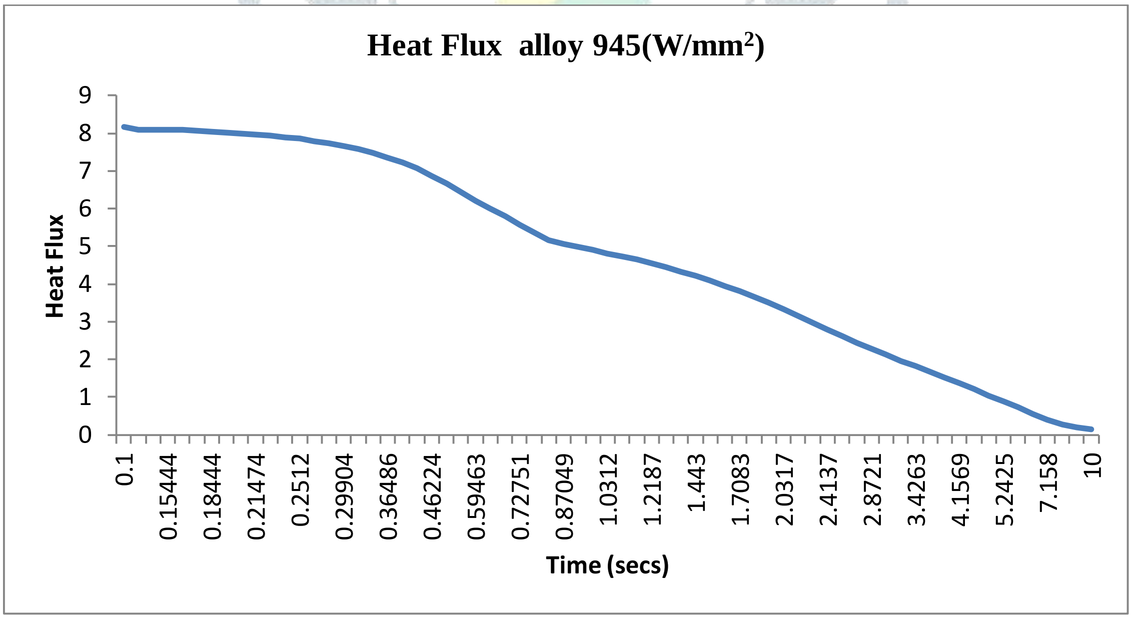

Figure 8: Heat flux plot for alloy 945

The variation of heat flux for alloy 945 with respect to time is shown in figure 8 above. The heat flux is maximum initially with magnitude of 8.1593 W/mm^2 which reduces gradually thereafter. The heat flux reduces gradually and reaches to minimum value by the end of simulation i.e. 10 and the magnitude of heat flux is .188 W/mm^2.

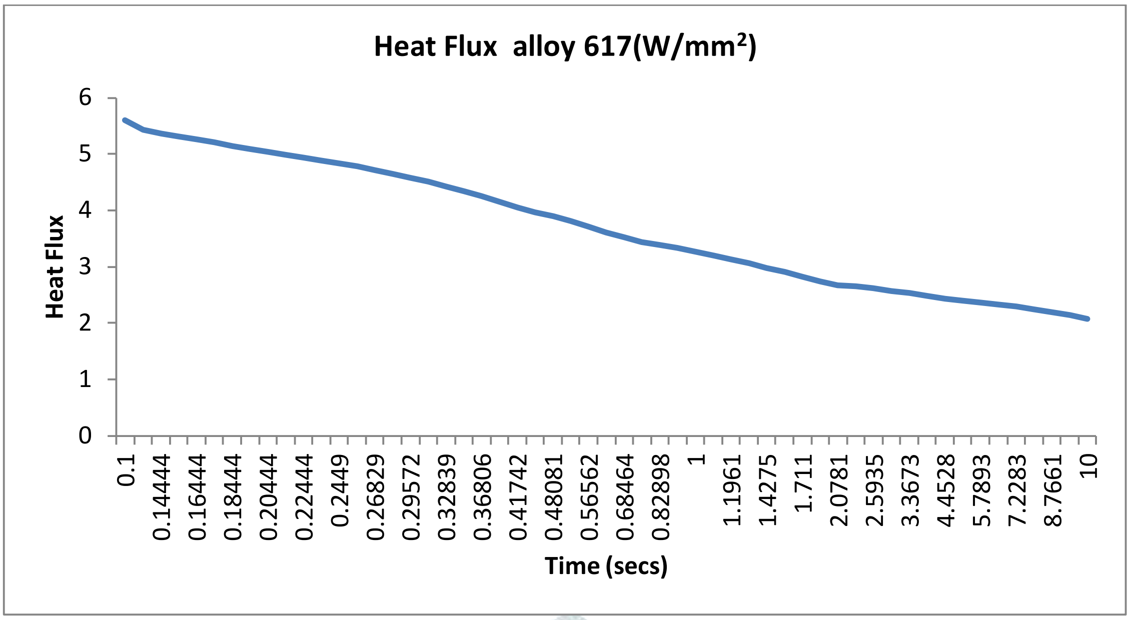

Figure 9: Heat flux plot for alloy 617

The variation of heat flux for alloy 617 with respect to time is shown in figure 9 above. The heat flux is maximum initially with magnitude of 5.4231 W/mm^2 which reduces gradually thereafter and linearly. The heat flux reduces gradually and reaches to minimum value by the end of simulation i.e. 10 and the magnitude of heat flux is 2.0822 W/mm^2.

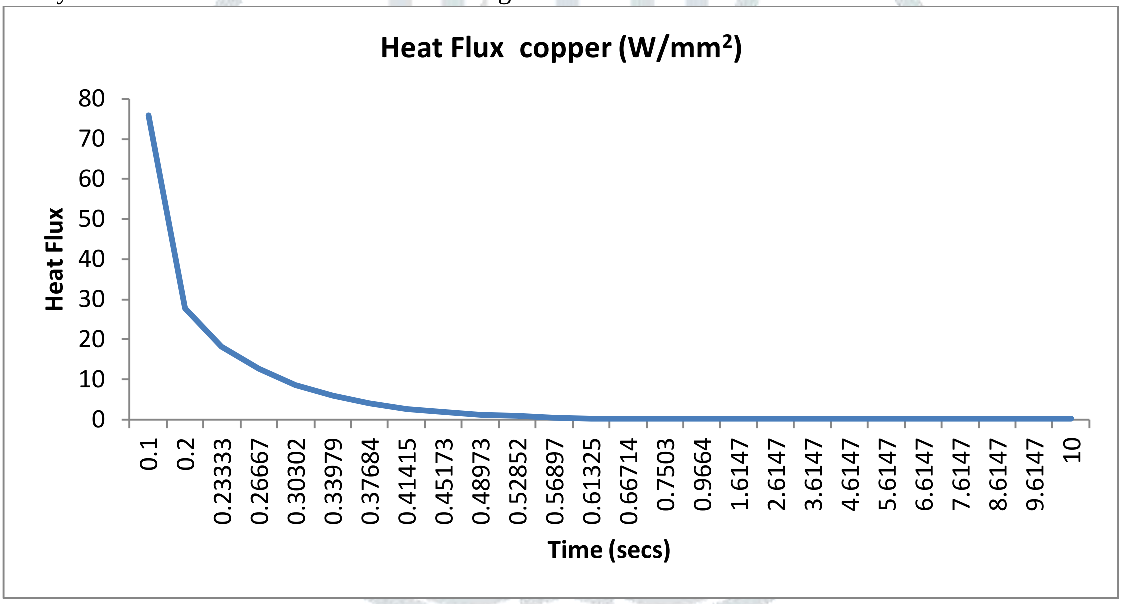

Figure 10: Heat flux plot for copper

The variation of heat flux for copper w.r.t time is shown in figure 10 above. The heat flux is maximum initially with magnitude of 75.848 W/mm^2 which reduces gradually thereafter and linearly. The heat flux reduces gradually and reaches to minimum value by the end of simulation.

V. Conclusion

Finite Element Analysis (FEA) is a powerful tool for evaluating the thermal characteristics of mould casting processes. This study utilizes FEA to analyze the thermal behavior of various molten metals and alloys within a sand mould, specifically focusing on aluminum alloy, copper, alloy 617, and alloy 945. Thermal modeling of the casting process provides critical insights into the cooling curves and heat flow dynamics at the interface between the mould and the molten metal.

Findings

The detailed findings from the FEA analysis are as follows:

1. For copper, the maximum heat flux observed is 75.848 W/mm^2, indicating a significant rate of heat transfer compared to the other materials.
2. Alloy 945 shows a temperature distribution where the core temperature reaches 1339.9K, while the interface region stabilizes around 627.7K.

3. Alloy 617 demonstrates the lowest heat flux among the materials analyzed, with a value of 5.602 W/mm².
4. The maximum core temperature for alloy 617 is recorded at 978.16K after 10 seconds.
5. Copper alloy consistently exhibits the highest heat flux, reaffirming its substantial thermal conductivity and heat transfer capability.

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