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Thermal Analysis of Casting using ANSYS

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Abstract: ***In today's environment of competition, foundry industries are required to minimize rejections caused due to casting defects. From long time casting method was considered an art practiced with trial and error method. This research deals with the temperature- time history analysis of different alloy materials using Finite Element Analysis. The software used for analysis is ANSYS workbench and CAD model is developed in ANSYS design modeler. The transient thermal analysis of four metal alloys conducted has enabled to detrmine cooling characteristics by temperature vs time curve and total heat flux. These temperature variations are an important factor in improving the casting quality, reduced cost of development and speeding up the improvement of the product***

Keywords: FEA analysis, Mould Casting, Foundry Defects, Thermal Curve, Transient Analysis

I. INTRODUCTION

Sand casting involves usage of sand as mould material which are produced in foundries. More than 70% of casted metal are developed by process of sand casting. In sand casting clay which is bonding agent is mixed with sand. This mixture is wetted using water and other substances to improve strength and plasticity of clay used to make aggregate for moulding. The sand casting system consists of mould cavities, gate systems and patters carved directly into sand.

II. LITERATURE REVIEW

K. Siekanski etal [1] has analysed casting defects using various quality control tools like ishikawa diagram, pareto charts which are used for data analysis.

The ishikawa diagram analyses failure up to five different reasons. Pareto diagram analyses casting defect like kiss run, shaggy, displacement, depression, hot crack. The findings have shown that the factors like employee behaviour, noncompliance of process influenced production process.

Uaday dabara etal. [2] has analysed casting defects using Taguchi method of design of experiments and computed aided casting simulations.

Taguchi design of experiments analyzed sand drop, bad mould, blow holes, cuts and washes, etc while filling and solidification related defects such as shrinkage porosity, hot tears are determined using computer aided analysis. The findings have shown that rejection percentage of castings due to sand related defects reduced from 10% to 3.59%.

L.A. Dobrzański etal. [3] has analysed casting defects using automatic quality assessment for determining type and classes of defects developed during casting the elements from aluminium alloys. X-ray images are used to flaw detection and preparation of neural network data using standardization by image analysis. The use of computer generated information enabled in cost reduction and environmental pollution.

Dr. D.N. Shivappa, and Mr Rohit, [4] has investigated on casting defects like sand drop, blow hole, mismatch and oversize in TSB castings caused due to improper mould cleaning, lack of locators, improper gating design. The corrective measures included mould cleaning, replacement of no-bake cores and modification of loose piece design, proper clamping of moulds to withstand pouring pressure.

Achamyeleh A. Kassie, Samuel B. Assfaw,[5] has conducted 9 design of experiments using Taguchi optimization method by changing selected variables and different results were obtained.

III.OBJECTIVE

This research presents a systematic procedure to obtain the temperature history of all points inside the casting, plot the progress of solidification fronts at different instants of time, and identify the last freezing regions. The materials analyzed in the research are alloy 945, alloy 617, aluminium alloy, copper alloy.

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IV. RESEARCH METHODOLOGY

The CAD model of mould is developed using Creo 2.0 design software which is sketch based , parametric 3D modelling software developed by PTC having properties of parent child relationship and bi-directional associativity. The CAD model is developed using sketch and extrude tool which is assembled later.

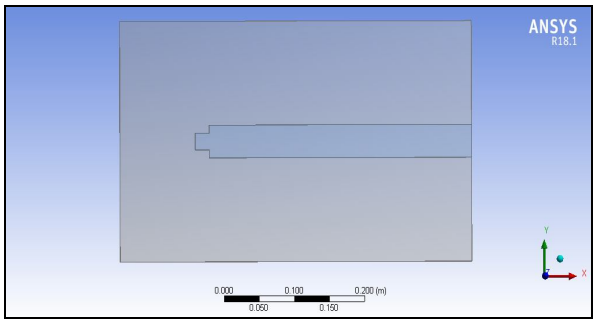

Figure 1: CAD model of mould casting

The CAD model developed is meshed using brick elements with fine element sizing, adaptive shape function, transition fast and inflation normal.

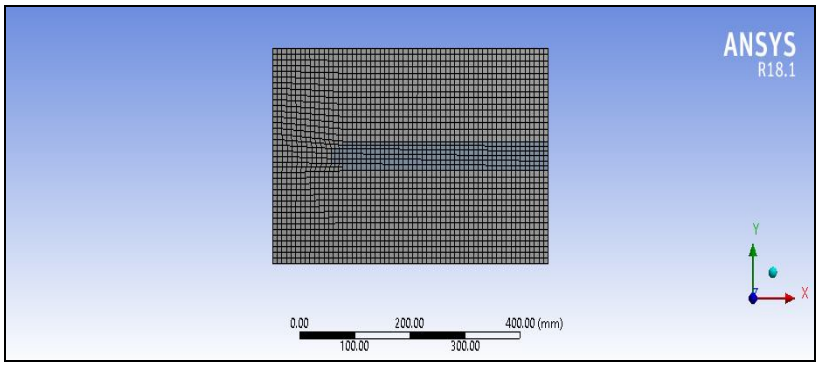

Figure 2: CAD model of mould casting

`The thermal loads which include temperature and convections are applied onto the specimen. The inner mould material is applied with temperature of 973K and convection is applied on remaining faces with convection coefficient of 10 W/m^{2}K and ambient temperature 303K.

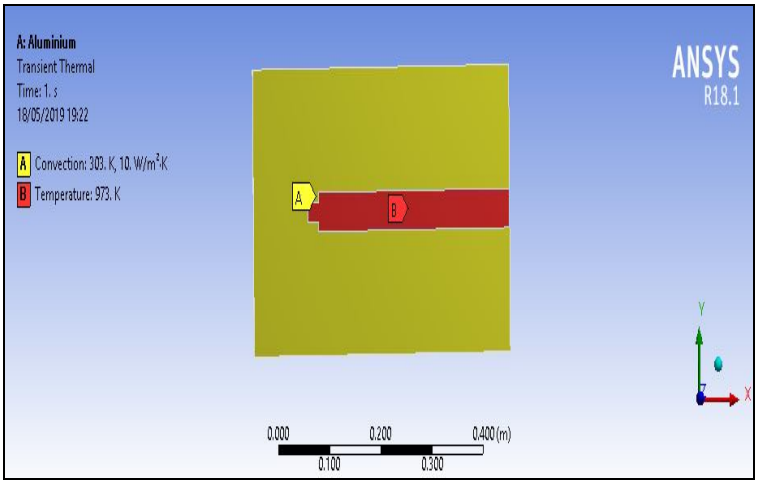

Figure 3: Loads and boundary condition

The element stiffness matrix is formulated, assemblage of global stiffness matrix along with matrix multiplications, inversions and addition.

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V. RESULTS AND DISCUSSION

Transient thermal analysis is conducted using different alloy materials like copper alloy, aluminium alloy, alloy 617 and alloy 945. Temperature vs time curve are plotted along with heat flux.

Table 1: Material properties of alloys

Material Name	Density (Kg/m^3)	Thermal Conductivity (W / m K)	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

The transient thermal analysis of mould casting for copper alloy is conducted and temperature plot is developed. The temperature plot shows maximum temperature at core and reduces by convection as shown in figure 4 below.

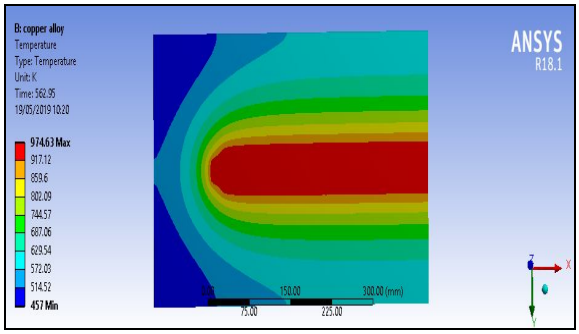

Figure 4: Contour plots of temperature at 562.95 counter

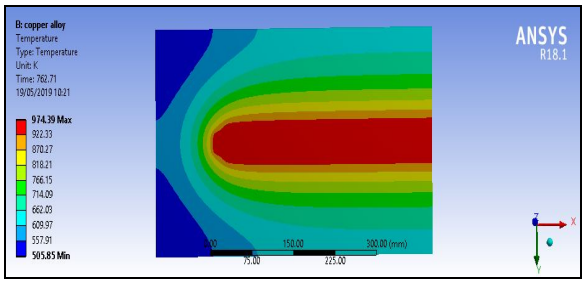

Figure 5: Contour plots of temperature at 762.7 counters

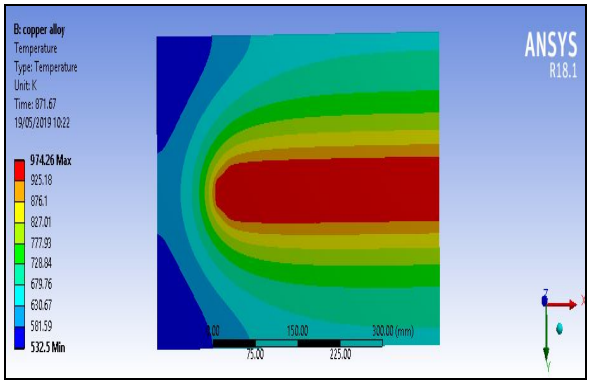

Figure 6: Contour plots of temperature at 871 counters

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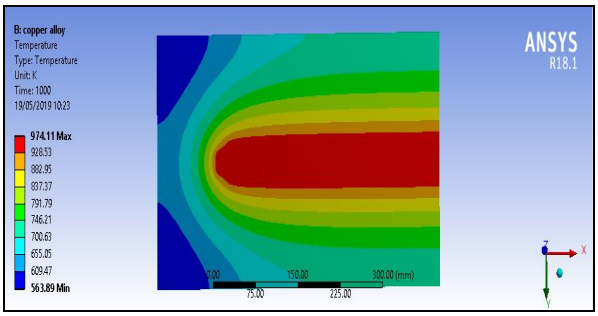

Figure 7: Contour plots of temperature at 1000 counters

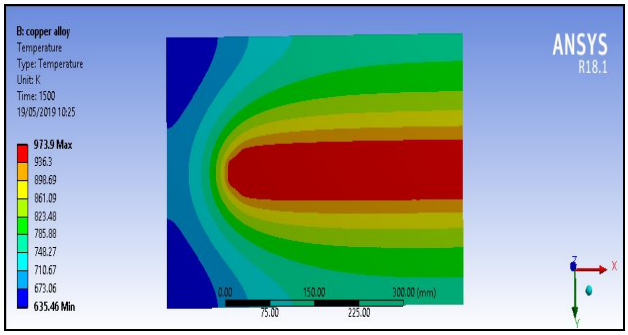

Figure 8: Contour plots of temperature at 1500 counters

The maximum temperature generated is at core with magnitude of 973.71K and reduces outside of core region. The minimum temperature reached is 635.4K and on intermediate regions temperature plot is shown by green contours with magnitude range of 785.8K to 823.4K .

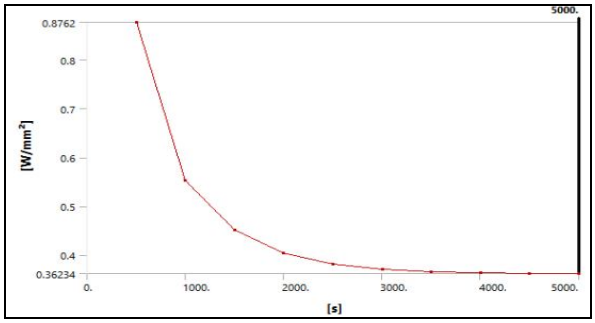

Figure 9: Heat flux vs time plot for copper alloy

The maximum heat flux value is at starting of simulation with magnitude of .87 W/mm^2 and reduces to constant value of .36 W/mm^2 by end of 4000 counters as shown by figure 9 above.

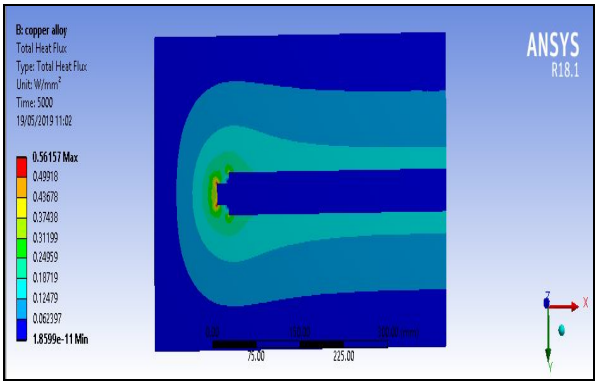

Figure 10: Total heat flux

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The maximum heat flux is generated near core region with magnitude of .56 W/mm^2 and reduces away from core near sand mould. The flux on outer region of core is .06W/mm^2. The transient thermal analysis of mould casting for aluminium alloy is conducted and temperature plot is developed. The temperature plot shows maximum temperature at core and reduces by convection as shown in figures below.

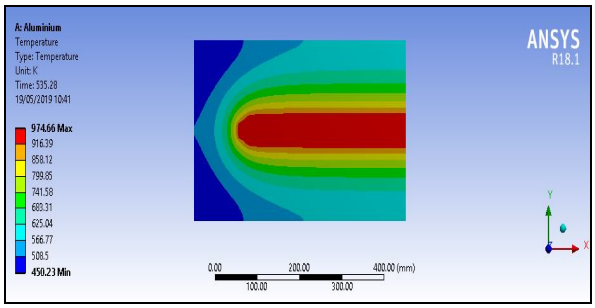

Figure 11: Temperature plot at 535 counters

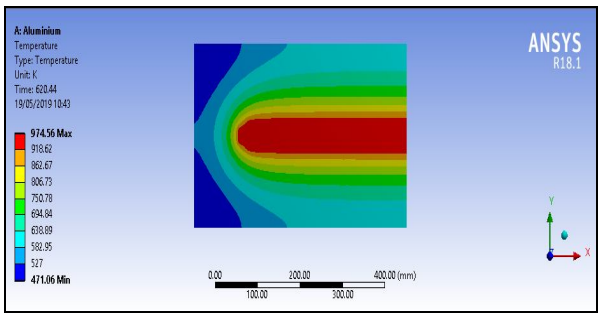

Figure 12: Temperature plot at 620 counters

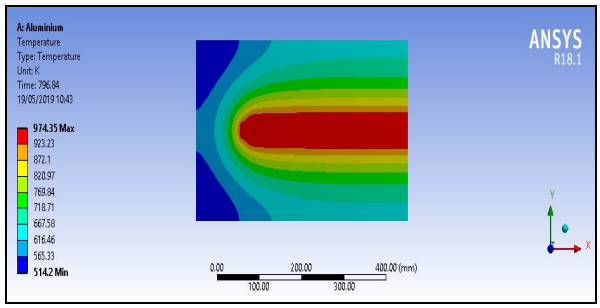

Figure 13: Temperature plot at 769.8 counters

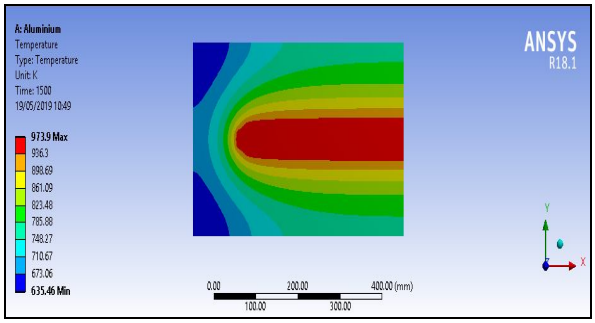

Figure 14: Temperature plot at 1500 counters

The maximum temperature generated is at core with magnitude of 973.9K and reduces outside of core region. The minimum temperature reached is 635.46K and on intermediate regions temperature plot is shown by green contours with magnitude range of 823.4K to 861.09K.

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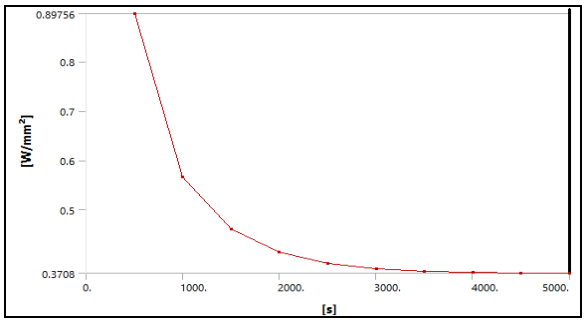

Figure 15: Heat flux vs time plot for aluminium alloy

The maximum heat flux value is at starting of simulation with magnitude of .89 W/mm^2 and reduces to constant value of .37 W/mm^2 by end of 4000 counters as shown by figure 15 above.

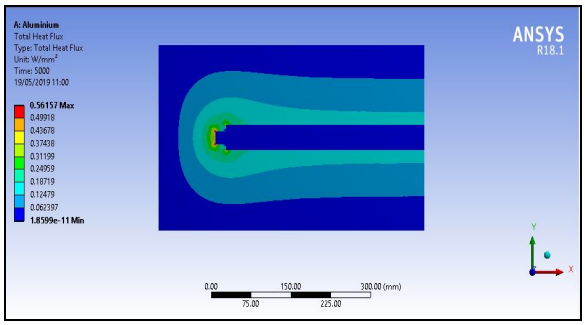

Figure 16: Total heat flux at 5000 counters

The maximum heat flux is generated near core region with magnitude of .56 W/mm^2 and reduces away from core near sand mould. The flux on outer region of core is 06W/mm^2. The transient thermal analysis of mould casting for alloy 617 is conducted and temperature plot is developed. The temperature plot shows maximum temperature at core and reduces by convection as shown in figures below.

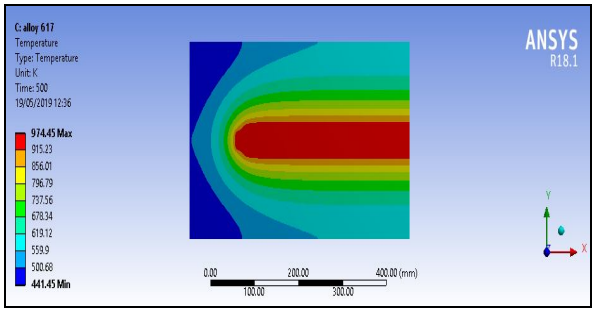

Figure 17: Temperature plot at 500 counters

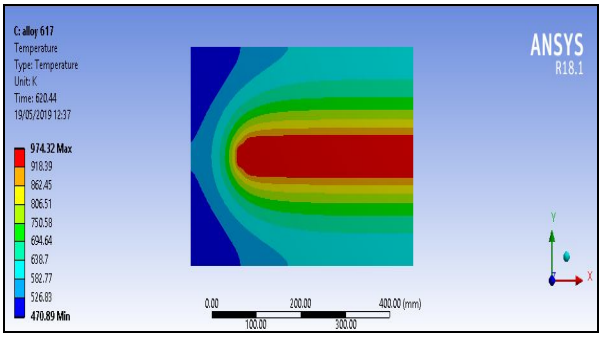

Figure 18: Temperature plot at 620 counters

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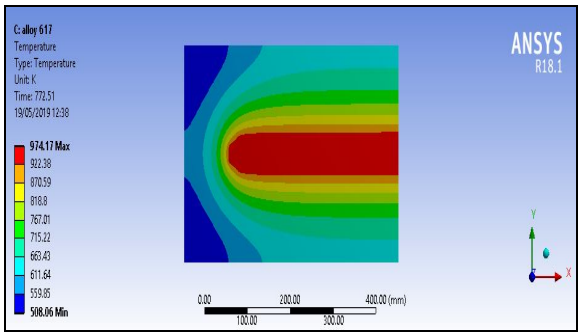

Figure 19: Temperature plot at 772 counters

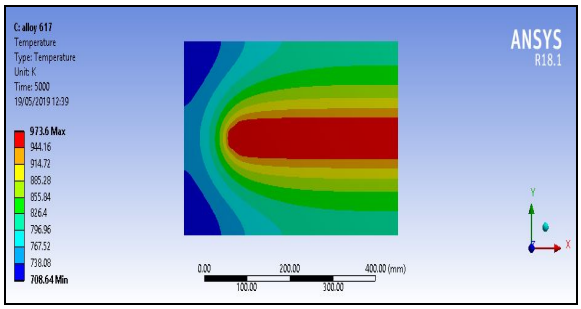

Figure 20: Temperature plot at 5000 counters

The maximum temperature generated is at core with magnitude of 973.6K and reduces outside of core region. The minimum temperature reached is 708.64K and on intermediate regions temperature plot is shown by green contours with magnitude range of 826.4K to 855.84K.

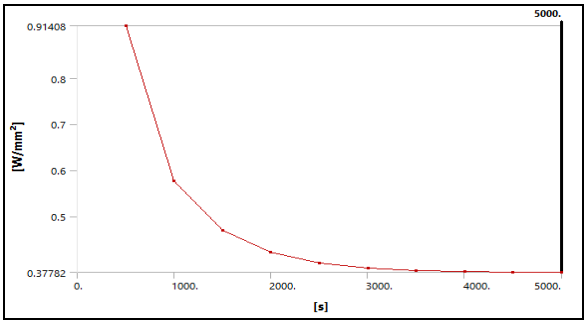

Figure 21: Heat flux vs time plot

The maximum heat flux value is at starting of simulation with magnitude of .91 W/mm^2 and reduces to constant value of .37 W/mm^2 by end of 4000 counters as shown by figure 21 above.

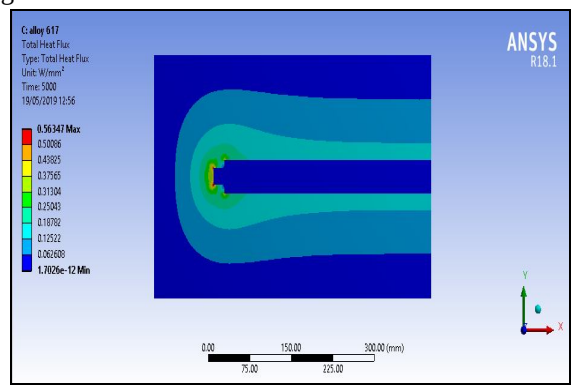

Figure 22: Total heat flux at 5000 counters

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The maximum heat flux is generated near core region with magnitude of .5634 W/mm^2 and reduces away from core near sand mould. The flux on outer region of core is 062W/mm^2. The transient thermal analysis of mould casting for alloy 945 is conducted and temperature plot is developed. The temperature plot shows maximum temperature at core and reduces by convection as shown in figures below.

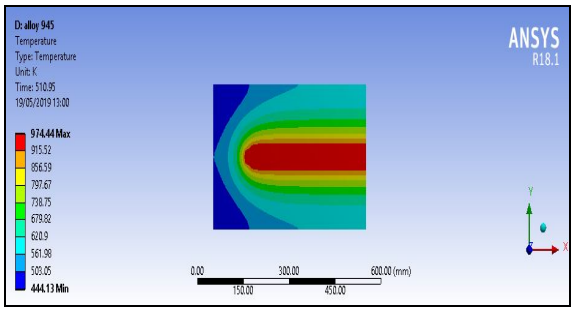

Figure 23: Temperature plot at 510 counters

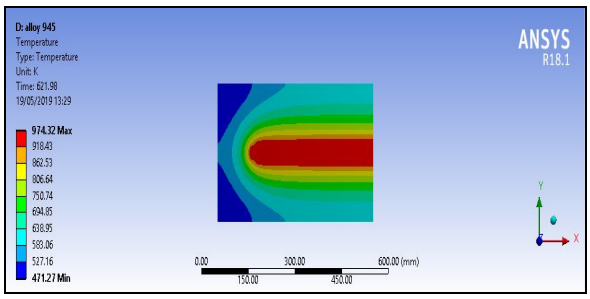

Figure 24: Temperature plot at 620 counters

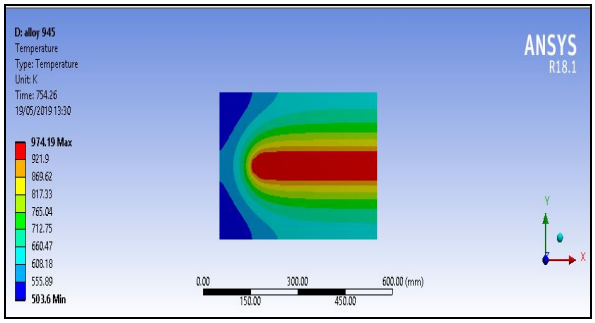

Figure 25: Temperature plot at 754 counters

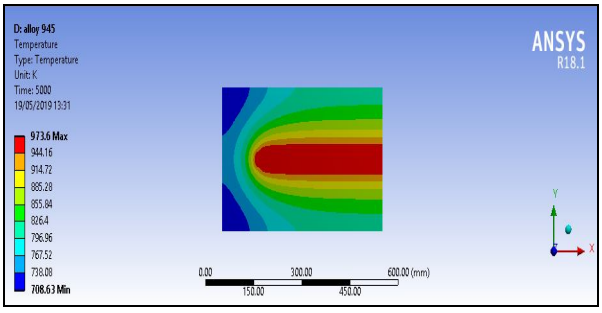

Figure 26: Temperature plot at 5000 counters

The maximum temperature generated is at core with magnitude of 973.6K and reduces outside of core region. The minimum temperature reached is 708.64K and on intermediate regions temperature plot is shown by green contours with magnitude range of 826.4K to 855.84K.

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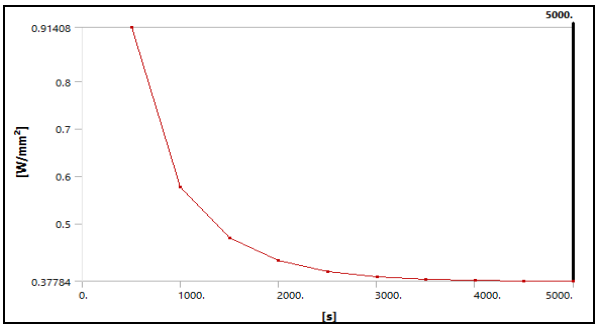

Figure 27: Heat flux vs time plot

The maximum heat flux value is at starting of simulation with magnitude of .914 W/mm^2 and reduces to constant value of .377 W/mm^2 by end of 4000 counters as shown by figure 27 above.

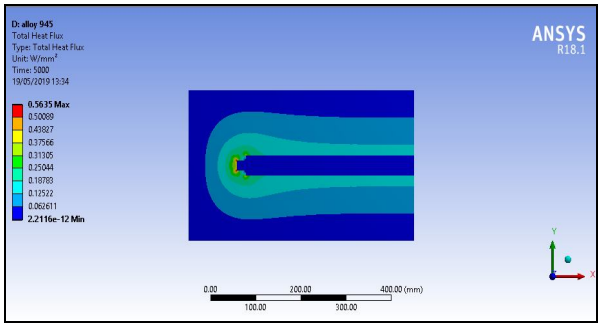

Figure 28: Total heat flux at 5000 counters

The maximum heat flux is generated near core region with magnitude of .5635 W/mm^2 and reduces away from core near sand mould. The flux on outer region of core is 062W/mm^2

VI. CONCLUSION

Accurate modeling of the metal casting process prior to creating a mold design demands reliable knowledge of the interfacial heat transfer coefficient at the mold metal interface as a function of both time and location. The phenomena concerned with the gap forming between the mold and the solidifying metal are complex but need to be understood before any modeling is attempted. Simulation of the solidification process enables visualization of the progress of freezing inside a casting and identification of the last freezing regions or hot spots. This facilitated the placement and design of feeders and feeding aids in order to maximize yield while ensuring casting soundness without expensive and time-consuming trial runs.

The transient thermal analysis of four metal alloys conducted has enabled to detrmine cooling characteristics by temperature vs time curve and total heat flux. These temperature variations are an important factor in improving the casting quality, reduced cost of development and speeding up the improvement of the product

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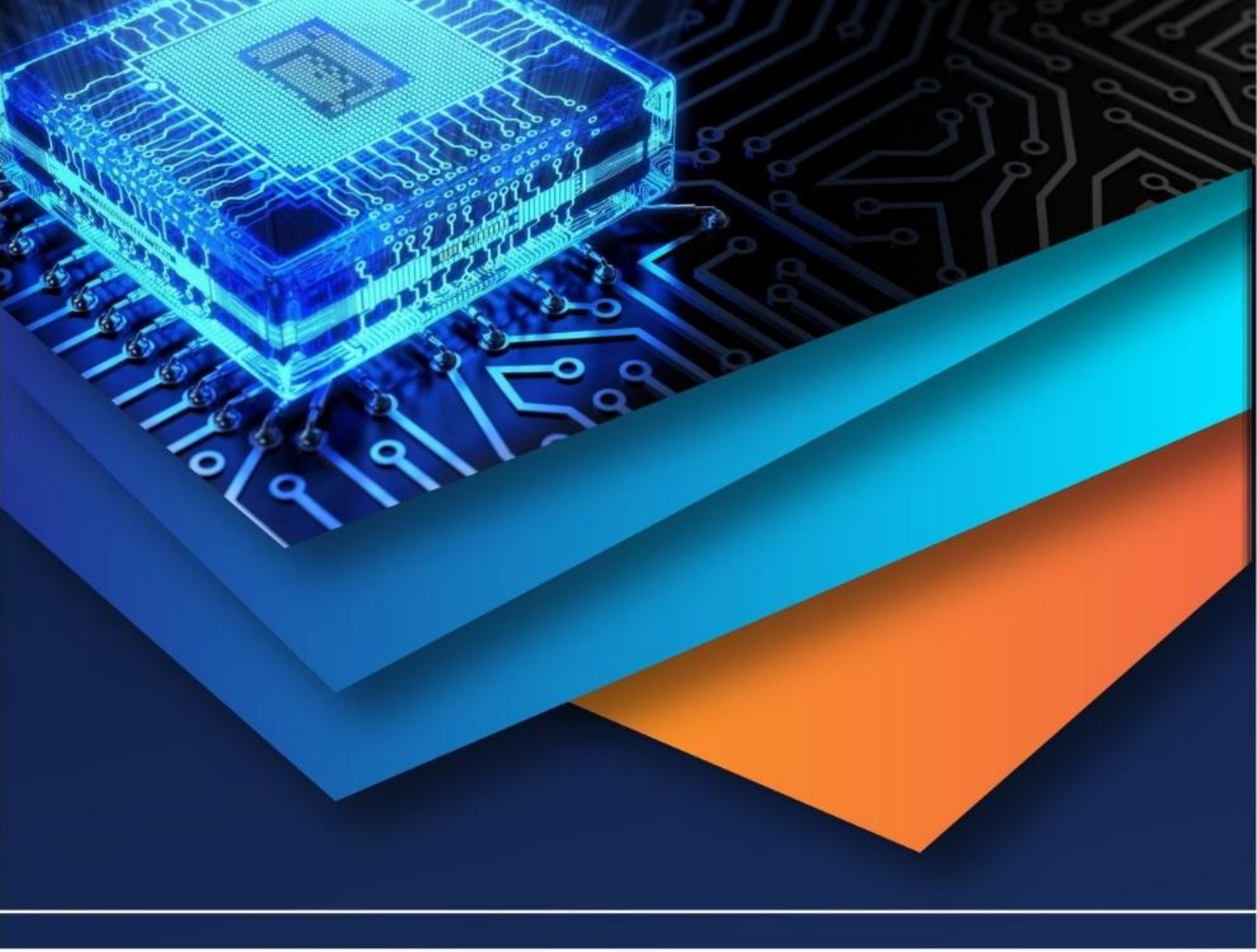

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