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Solidification of an Aluminum Flywheel Casting Contained in a Sand Mold

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Abstract: ***Sand casting technologies have now emerged as practical and commercial ways of manufacturing high integrity near net shape castings. A variety of castings have found their way into general engineering applications. Castings that serve these specific applications have to achieve the quality requirements of superior mechanical properties and zero-porosity. To achieve these objectives within a limited time frame in a product development process, CAD technologies with numerical analysis combined with process simulation tools are increasingly used to optimize form filling and solidification of the cast parts. In this process the molten aluminum is introduced in the mold at 800^0C, the ambient temperature and mold are at 30^0C. The top and side faces of the mold exchange heat with the environment by free convection. 2D Axi-symmetric behavior is assumed for sand mold and aluminum casting. Transient thermal analysis is considered for 1500 sec.***
Keywords: **Casting, phase change, flywheel, solidification, transient analysis.**

I. INTRODUCTION

A flywheel is a mechanical device that has a large shortening moment used as a storage device for rotational energy. Flywheels resist changes in their spin speed, which helps the shaft to remain stable when exercising volatile torque on it through the power source. Flywheels have become the subject of intense research as energy storage devices for use in vehicles. The flywheel energy storage systems are an attractive alternative to electrochemical batteries due to the higher energy density stored, long service life, the inevitable charging state and the ecologically clean nature. Flywheel is basically a rechargeable battery. It is used to absorb electrical energy from a source, store it as circulation energy for movement, and then deliver it to the load in a timely manner, in a form that meets the needs of the load.

The input power may differ from the output power in its temporal profile, frequency, or other attributes. It is converted by the input electronics into a form appropriate for efficiently driving a variable-speed motor. The motor spins the flywheel, which stores energy mechanically, slowing down as it delivers energy to a load. That decrease in mechanical energy is converted into electrical form by the generator. A challenge facing the motor and the generator designer is to size the system for the amount of storage (energy) and delivery rate (power) required and also to minimize losses. The output electronics convert the variable-frequency output from the generator into the electric power required by the load. Since the input and output are typically separated in a timely manner, many approaches combine the motor and generator into a single machine, and place the input and output electronics into a single module, to reduce weight and cost.

Modern high-speed flywheels differ from their forebears in being lighter and spinning much faster. Since the energy stored in a flywheel increases only linearly with its moment of inertia but goes up as the square of its rotational speed, the tradeoff is a good one. But it does raise two issues: flywheel strength and losses caused due to air friction. To keep from flying apart, modern flywheels are complex structures based on extremely strong materials like carbon fibers.

II. COMPUTATION METHODOLOGY

Flywheel wheel engineering design to optimize energy storage by computer-aided analysis. This document specifically examines the five most common geometric shapes and ranges according to energy storage performance using the suggested procedure.

A. Computational analysis of flywheel Design

A suggested full parameter model is illustrated in Fig .1, where t is the thickness (t = 5.08 cm or 2 ″) and h is the radius of the steering wheel (h = 14605 cm or 5.75 ″). Although many materials of better strength and low density are available in the market, to serve the purpose of this study, an example of the characteristic of AISI 1006 steel (cold drawn), with a flexible modulus of E = 205 GPa, density ρ = 7,872 g / Cc, Poisson ratio υ = 0.29. Fig .2 shows the casting of fly wheel in ANSYS workbench.

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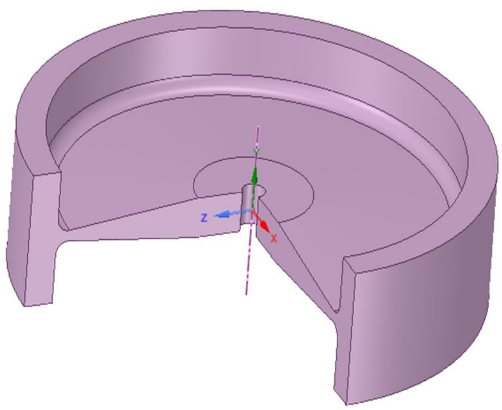
The fly wheel casting system was meshed with sizing of 2e-3m and using plane quad element. The total nodes and elements are 3283 and 10414. The meshed structure was shown in Fig .3. The transient thermal analysis was performed by considering the following steps. Fig .4 shows clearly the boundary condition given in the ANSYS. The solution was completed by satisfying the convergence criteria and the global min temp curve shown in Fig .5.



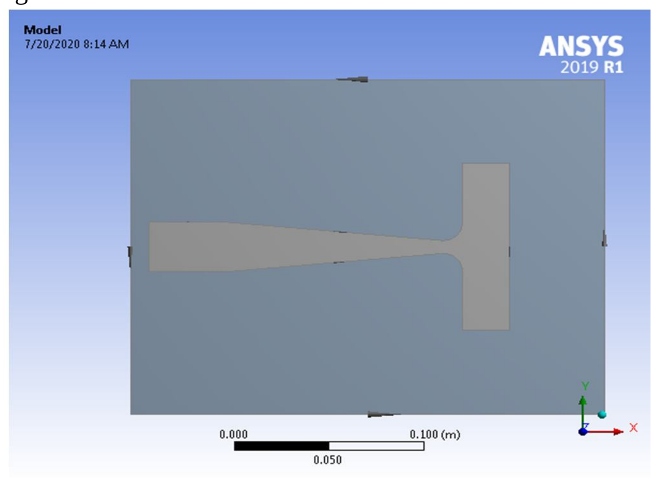


Fig .1 3D wheel model and Fig .2 Casting of Fly wheel in ANSYS

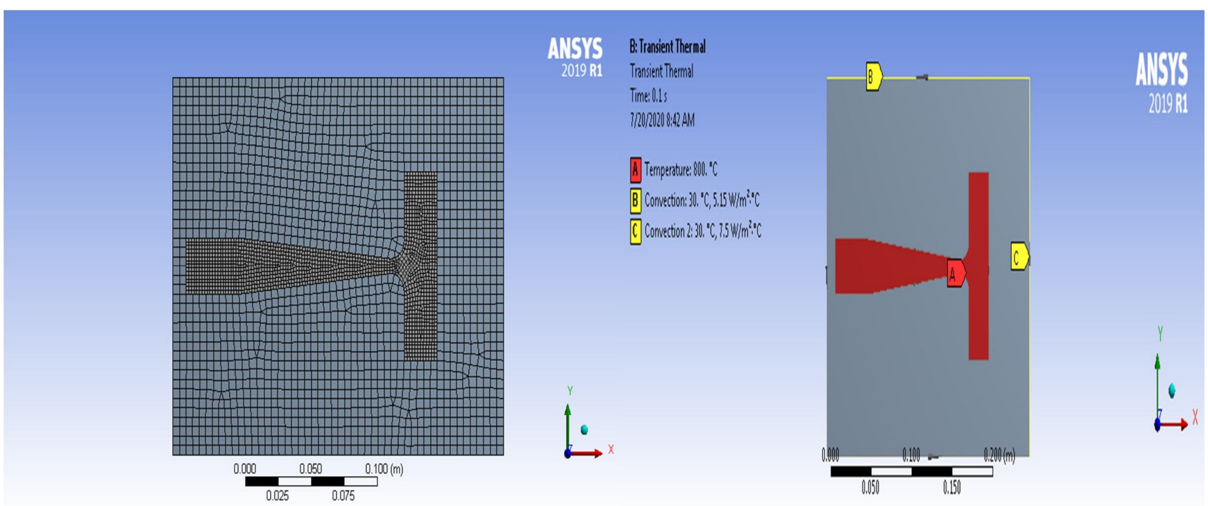
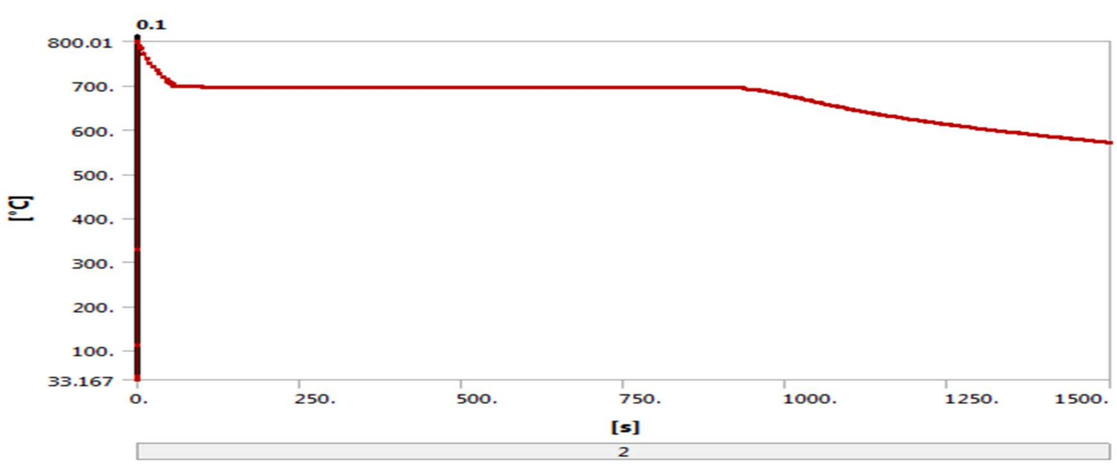


Fig .3 Meshing of Fly wheel and Fig .4 Boundary conditions



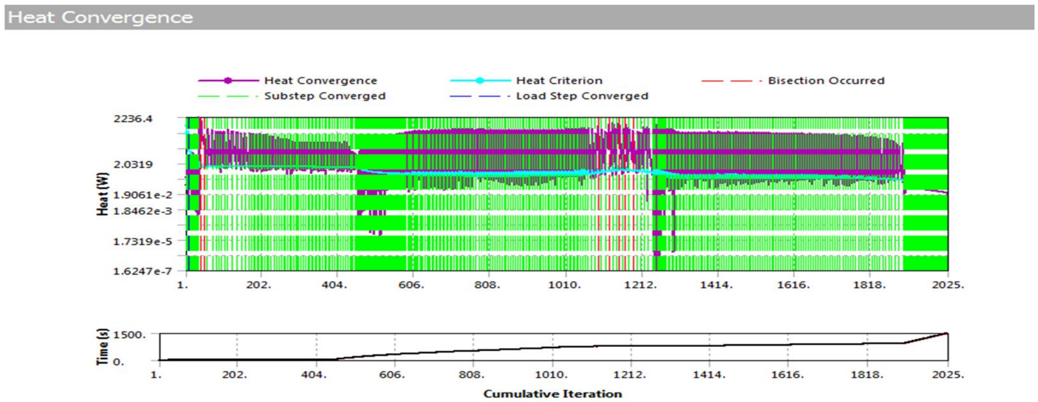


Fig .5 Temperatures - Global Minimum Convergence curve

III. RESULTS AND DISCUSSIONS

n the present work 2D axi-symmetric model has been developed and done analysis using Ansys workbench. From temperature plot distribution along 1500 sec has been observed the leveling off in the material phase transition region (695 to 697 ^{0}C) during the solidification process.

From temperature contours it's been observed the phase transformation from liquid as started in between 40 to 70 S. At 100 sec it clearly in transition state from liquid is observed. As it solidifies over time 450 sec to 700 sec. It completely transformed to solid at 1100 sec but a slightly higher temperature has been observed. After 1500 sec of transient analysis it completely reached the final temperatures of about 555^{0} C minimum temperatures and 560^{0} C maximum temperatures in aluminum wheel.

Phase transisition Colour code: liquid = Red; transistion = Green; Solid= Blue in Fig .6 and .7.

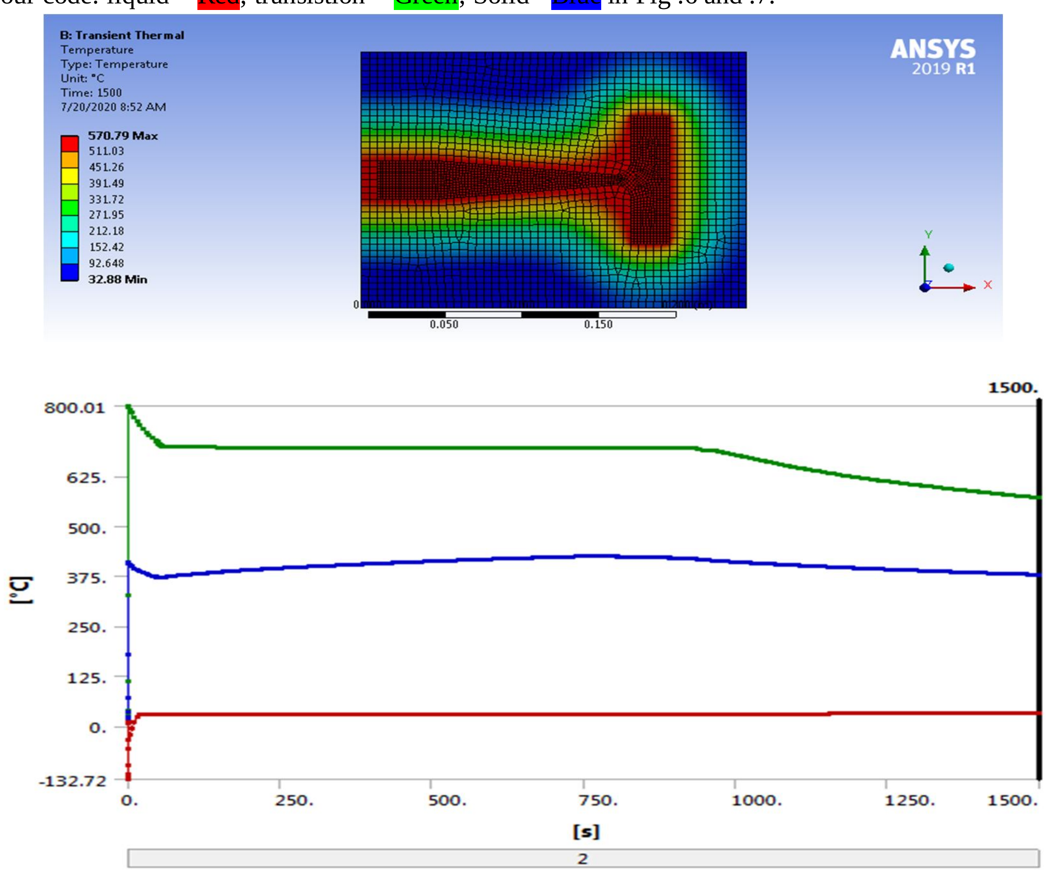


Fig .6 Overall Temperature distribution contour

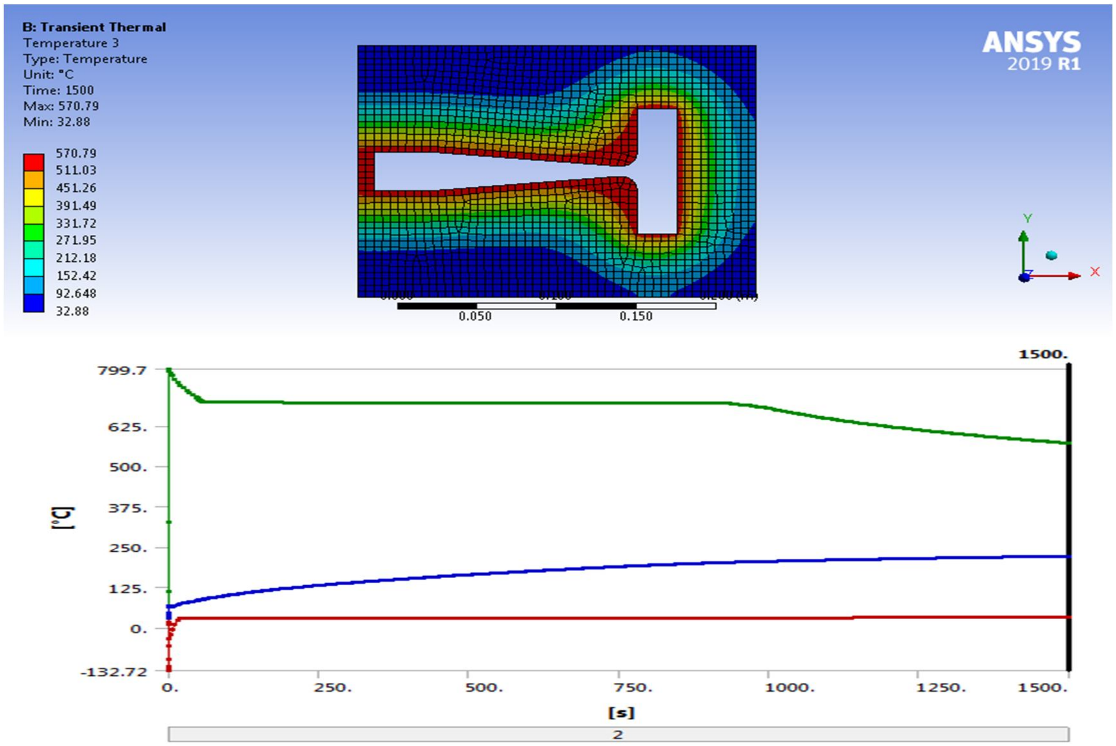


Fig .7 Temperature distributions on sand mold

TABLE I
ALUMINIUM - ISOTROPIC THERMAL CONDUCTIVITY

Thermal Conductivity W m^-1 C^-1	Temperature C
206	0
208	100
215	200
228	300
249	400
268	530
290	800

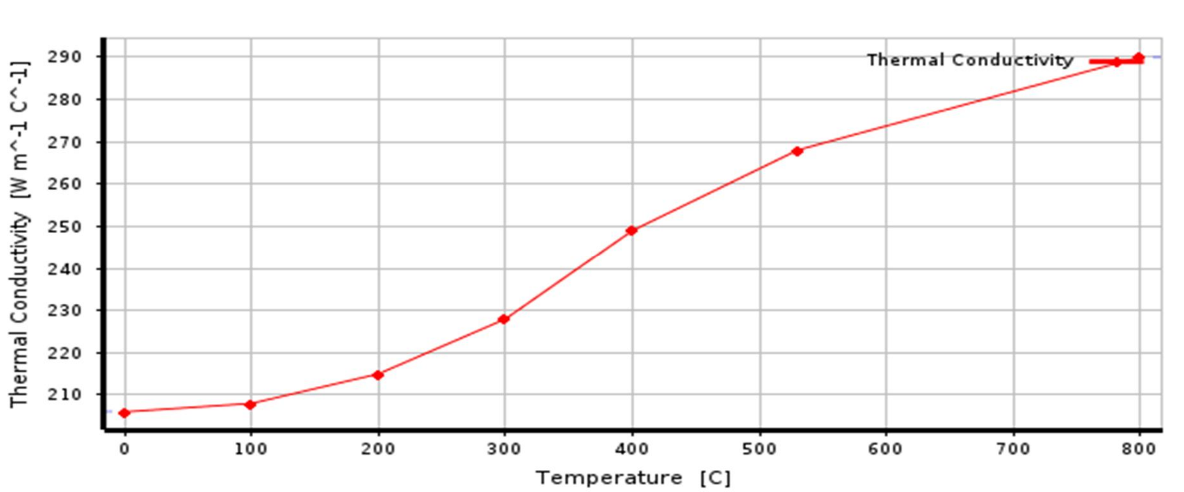
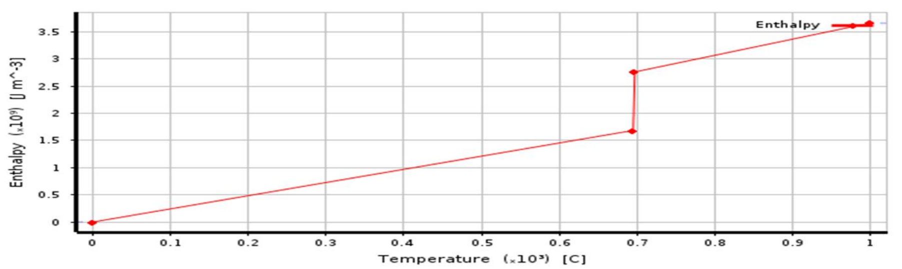
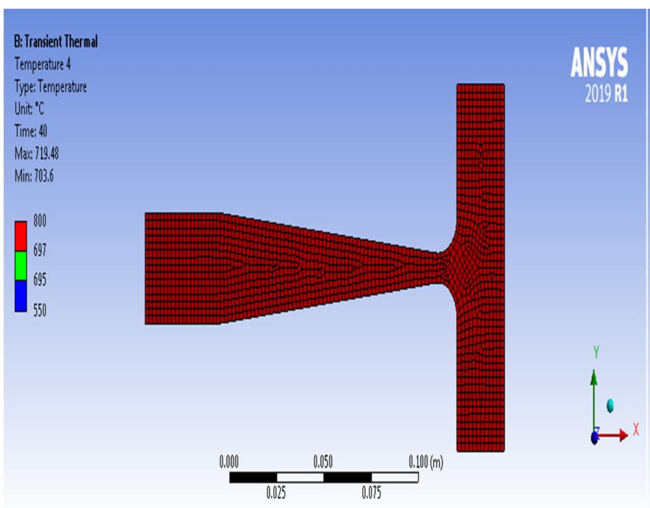


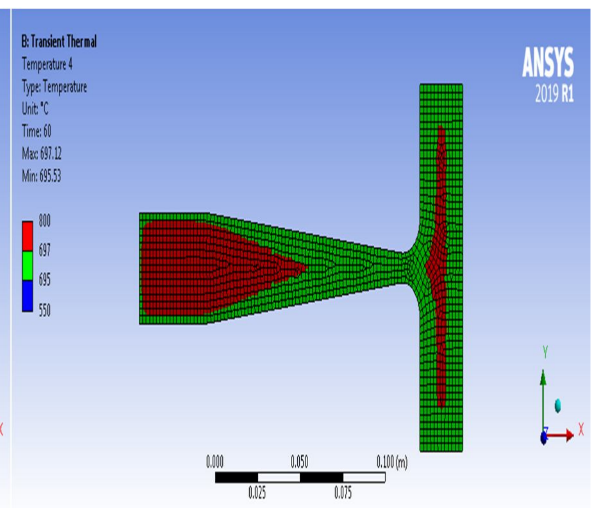
TABLE II
Aluminium -Enthalpy

Enthalpy J m^-3	Temperature C
1.e-005	0
1.6857e+009	695
2.7614e+009	697
3.6626e+009	1000

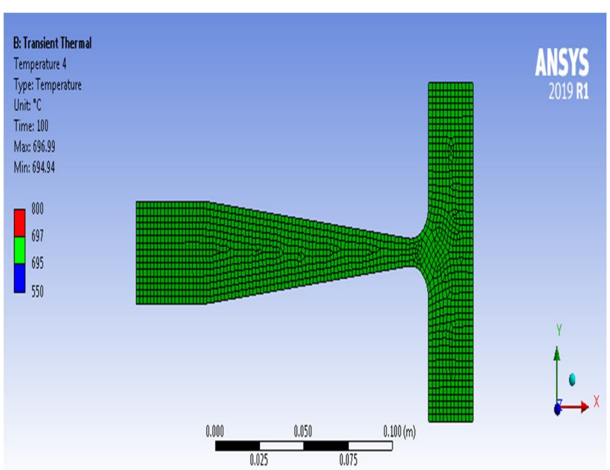




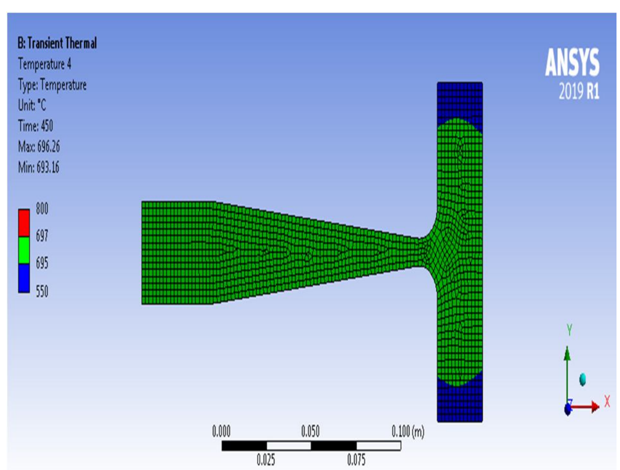
Time 40 s



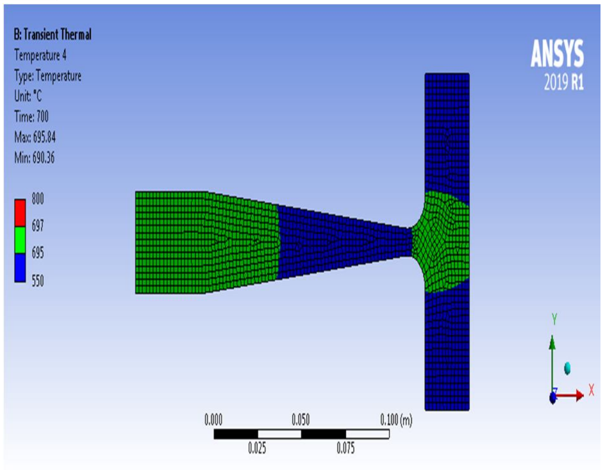
Time 60 s



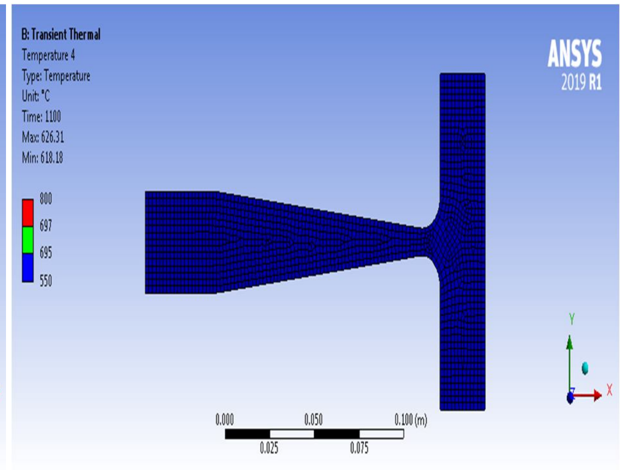
Time 100 s



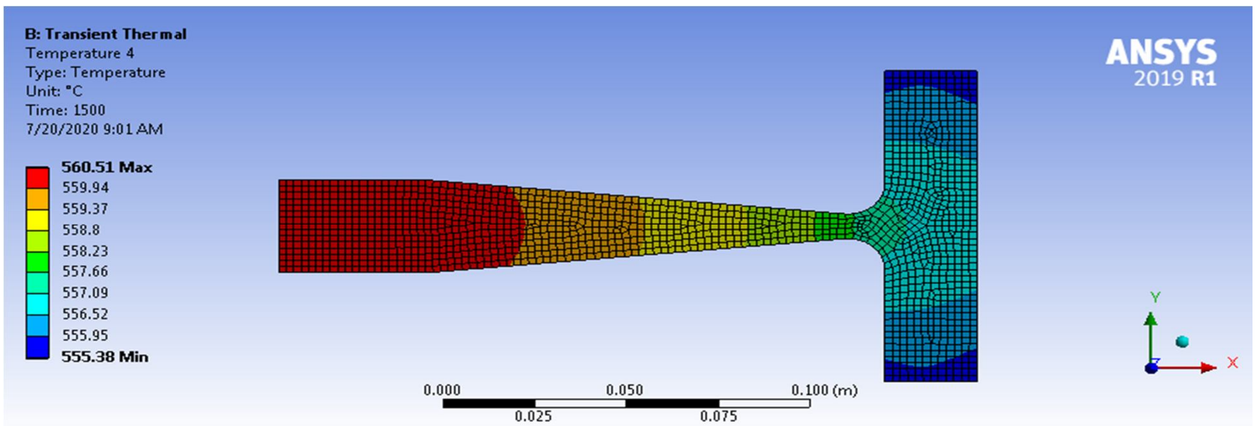
Time: 450 s



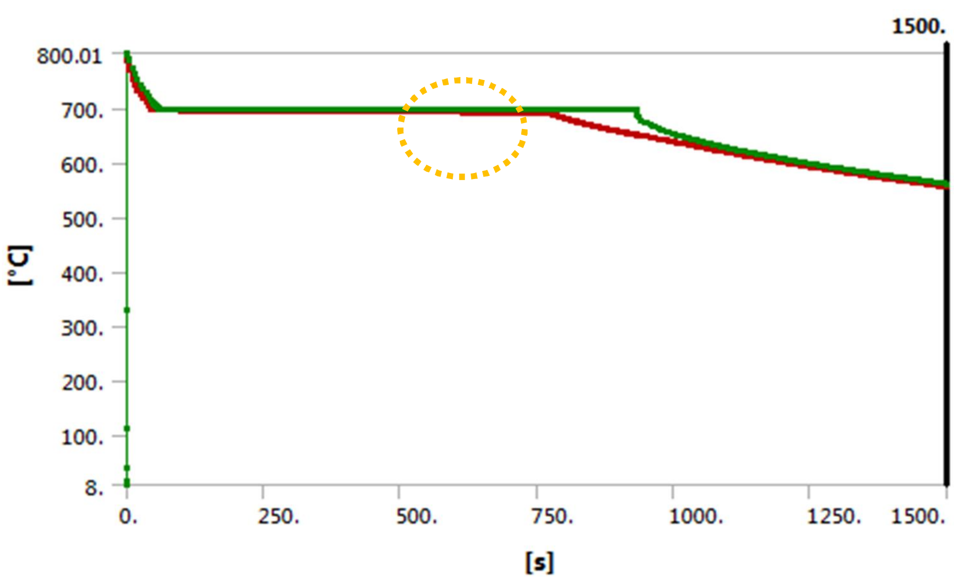
Time: 700 s



Time: 1100 s



Time 1500 s



Temperature distribution on Aluminum wheel during 1500 seconds (Green - max temperature; Red - Min temperatures).

IV. CONCLUSIONS

In the present work 2D axi-symmetric model has been developed and done analysis using ANSYS workbench. From temperature plot distribution along 1500 sec has been observed the leveling off in the material phase transition region (695 to 697^0 C) during the solidification process. From temperature contours its been observed the phase transformation from liquid as started in between 40 to 70 S. At 100 sec it clearly in transition state from liquid is observed. As it solidifies over time 450 secs to 700 secs. It completely transformed to solid at 1100 sec but slightly higher temperatures have been observed. After 1500 sec of transient analysis it completely reached the final temperatures of about 555^0 C minimum temperatures and 560 maximum temperatures in aluminum wheel.

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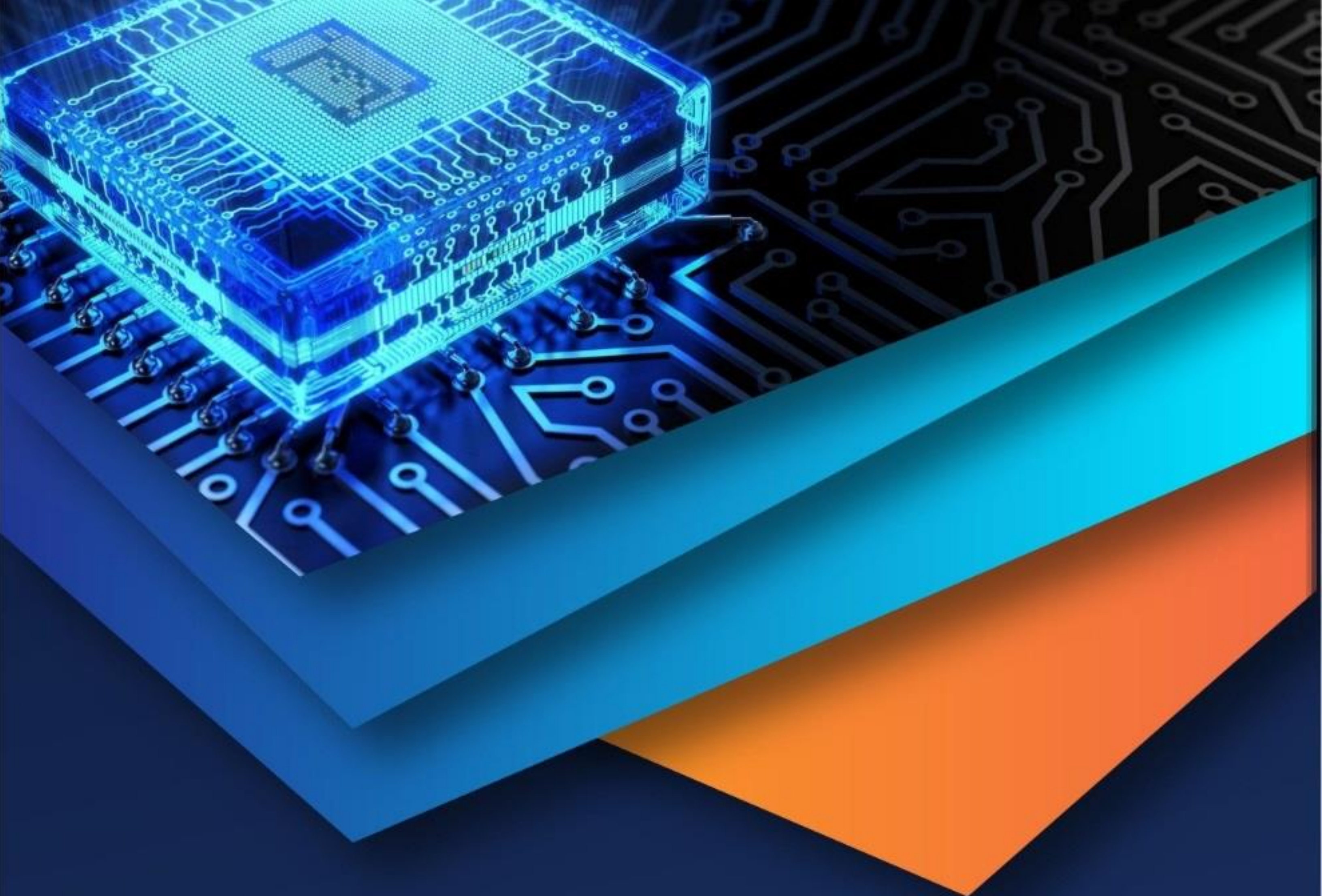

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