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TRANSIENT STATE ANALYSIS OF CYLINDRICAL FIN USING SIMULATION METHOD AND COMPARE DIFFERENT FIN MATERIAL

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ABSTRACT

Fins are extensively used in heat exchanging devices in automobiles radiators, industrial sectors, power plants, newer technology like fuel cells. Generally, the material used for the application of fins is aluminium alloys. In this present work Thermal behaviour of cylindrical fin is numerically investigated using Ansys APDL Software for different materials like Brass, Aluminium and Copper. Transient state analysis is carried out for the cylindrical fin under the convection and a specified base temperature condition. The length, base thickness, and end thickness of the fin is specified.. Transient solutions had been derived earlier by various researchers. Thermal conductivity of the fin material is specified. A constant temperature condition is applied at the base of the fin convective boundary conditions applied at the tip of the fin. Comparative study is being done among the fin material here used to find out the best material under the conditions. Base heat transfer rate, time to reach steady state, temperature distribution at different times, steady state temperature distribution is investigated

Keywords: Transient, Fin, Conduction, Natural Convection, Finite element technique

I. INTRODUCTION

Fins are the extended surfaces used for enhancing the dissipation of heat transfer rate. The transient response of fins is important in a wide range of engineering devices, automobiles and industrial sectors. Heat transfer is the study of the rate at which energy is transferred across a surface of interest due to temperature gradients at the surface, and temperature difference between the difference surfaces. This variation in temperature is governed by the principle of energy conservation which when applied to a control volume it will states that the sum of the flow of energy and heat across the system is the work done on the system and the energy stored and converted within the system will be zero. The term “extended surface” is commonly used to depict an important special case involving heat transfer by conduction within a solid and heat transfer by convection from the boundaries of the solid. In the study of heat transfer a fin is a surface that extends from an object to increase the rate of heat transfer to or from the environment by increasing convection rate. The amount of conduction, convection or radiation of an object determines the amount of heat or energy it transfers. By increasing the temperature difference between the object and the environment increasing the convection heat transfer coefficient or increasing the surface area of the object increases the heat transfer rate. Adding a fin to an object however it increases the surface area and can sometimes be an economical solution to heat transfer problems. Extended surfaces have fins attached to the primary surface on one side of a two-fluid or a multi fluid heat exchanger. The fins can be of a variety of geometry plain wavy or interrupted and can be attached to the inside, outside or from both sides of circular, flat or oval tubes, or parting sheets for the purpose of improving the rate of transfer heat. Transient heat conduction analysis for the fins is being considered for simplifying heat transfer queries. The objective of conduction analysis is to determine the temperature field in a body and how the temperature varies within the portion of the body. The temperature field usually depends on boundary conditions, initial condition, and geometry and material properties of the body. The literature survey regarding the work being done so far in the field of the analysis of transient heat conduction through fins indicates that many researchers have done notable work. The most notable and the initial work being done by Donaldson and Shouman [1], which Study the transient temperature distribution in a convecting straight fin of constant area for two distinct cases, namely, a step change in base temperature, and a step change in base heat flow rate. Sonn [2] considered the effect of profile curvature on the optimum dimensions of longitudinal fins of triangular, concave and convex parabolic profile. Razelos and Satyaprakash [3] presented an analysis for optimum longitudinal fin of trapezoidal section based on an assumption of negligible heat loss from the fin tip and negligible surface curvature effect and finally suggested a correlation for the optimality criteria. Mao and Rooke [4], which Study the Laplace transform method to study straight fins with three different transients: a step change in base temperature; a step change in base heat flux and a step change in fluid temperature. Aziz and Kraus [5], "Transient Heat Transfer in Extended Surfaces. An analytical solution for straight fin with combined heat and mass transfer is applied by Sharqawyand Zubair [6]. Kevin D. Cole [7], who attempt towards the development of analytical solution for the fins for improved convergence form of the transient temperature in flux base fins. A. Moradi [8], three different profiles of the straight fin that has a temperature-dependent thermal conductivity are investigated by differential transformation method DTM and compared with numerical solution. Raseelo J Moitsheki [9], Transient heat transfer in longitudinal fins of various profiles with temperature-dependent thermal conductivity and heat transfer coefficient. Dipankar Bhanja [10], Thermal analysis of porous pin fin used for electronic cooling. Y. Pratapa Reddy [11], Temperature Distribution Analysis of Composite Pin Fin By Experimental and Finite Element Method. Jia Ma, Feng Xu [12], Transient flows in a differently heated cavity with a fin at different positions on the sidewall are investigated using a scaling analysis and direct numerical simulations.

II. PROBLEM SPECIFICATION

Considering cylindrical fin of length 120 mm and diameter 6 mm conducts heat away from its base at 150 ^{0}C and transfers it to a surrounding fluid at 30 ^{0}C through convection. The convection heat transfer coefficient is 10 W/m^2 K. Objective of the study are the time required to reach steady state. The steady state temperature distribution (using a transient analysis).The temperature distribution after 8000 seconds. The steady state heat transfer rate through the base of the fin (using a transient analysis).The steady state temperature distribution and heat transfer rate through the base using a steady state thermal analysis. For the transient analysis, we assumed that the fin has an initial temperature of 30 ^{0}C Analysis is done to find out the above results by taking different materials Brass, Aluminium and Copper individually.

The temperature distribution of cylindrical fin is calculated using the fact that the base of the fin is attached to the wall which is at temperature of 150 ^{0}C.

A. Physical Model and Formulation

Heat flow through a straight fin of uniform circular cross section:

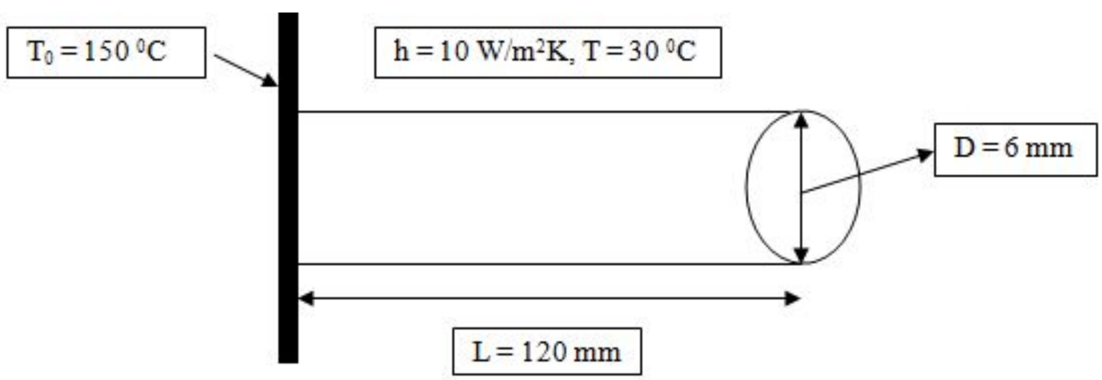

Fig. Specification of fin

$T_0 = 150\ ^0C$
$L = 120$ mm
$D = 6$ mm

Here L stands for the length by which the fin protrudes or extends from the primary surface is called protruding length.

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K = thermal conductivity of fin material
h = convective heat transfer coefficient
T_∞ = ambient or surrounding temperature
$A = (\pi/4)D^2$ (cross sectional area of fin)
$P = \pi D$ (perimeter of fin)

Temperature is a function of x-direction

B. Assumptions in Analysis of Fins

i. In the analysis of fins, we consider steady operation with no heat generation in the fin.
ii. Thermal conductivity *k* of the material to remain constant.
iii. We also assume the convection heat transfer coefficient h to be constant and uniform over the entire surface of the fin for convenience in the analysis.

The boundary conditions are

(i) At $x = 0$, $\theta = \theta_0$
(ii) Heat conducted to the fin at x = l = heat convected from the end to the surroundings.

i.e. $-k\, A_{cs}\, [dt/dx]_{x=l} = h\, A_{su}\, (t - t_a)$

Where A_{cs} (cross sectional area for heat conduction) equals A_{su} (surface area from which the convective heat transport takes place), at the tip of the fin.

i.e., $A_{cs} = A_{su}$

Thus $dt/dx = -h\theta/k$ at $x = l$

Temperature distribution along the length of the fin is given by:
$\theta/\theta_0 = (t - t_a)/(t_0 - t_a) = \{ \cosh[m(l - x)] + (h/km)\sinh[m(l - x)] \}/\{ \cosh(ml) + (h/km)\sinh(ml)\}$

The rate of heat flow from the fin is given by

$Q_{fin} = \sqrt{(PhkAcs)}\, (t_0 - t_a)\{ \tanh(ml) + (h/km) \}/\{ 1 + (h/km)\tanh(ml) \}$.

III. MODELLING & STIMULATION

A. Computational Modelling

The method consists of using FEM technique to solve the problem by taking help of ANSYS APDL Software. Modelling is done by the pre-processor part. After that material is given to the model and then meshing is done by taking Tet 10 Node 87 element and turning on smart size to 4 as edge length.

- ***Loading***
  Loads are defined in the pre-processor as base temperature and convective heat transfer surrounding according to the problem.

- ***Solution***
  Setting the analysis type to transient and then moving to the solution part by solve option. Similarly for the steady state analysis setting the analysis type to Steady state and then solving the part by solve option.

- ***Post processing***
  After getting solution results are analyzed in post processing. Contours are plotted for temperature distribution. Graphs are also plotted for time to reach steady state pertaining to different material.

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B. Material Properties

Properties of material selected for analysis are shown in Table 1.1

Table 1.1 Properties of Brass, Aluminium and Copper

Properties	Brass	Aluminium	Copper
Density(kg/m^3)	8000	2702	8933
Specific Heat(J/kg)	380	903	385
Thermal Conductivity (W/m-K)	120	204	386

IV. RESULTS & DISCUSSION

Modelling and Analysis is performed in ANSYS APDL for the above discussed cylindrical fin problem for different material. Results for different material are shown as following:

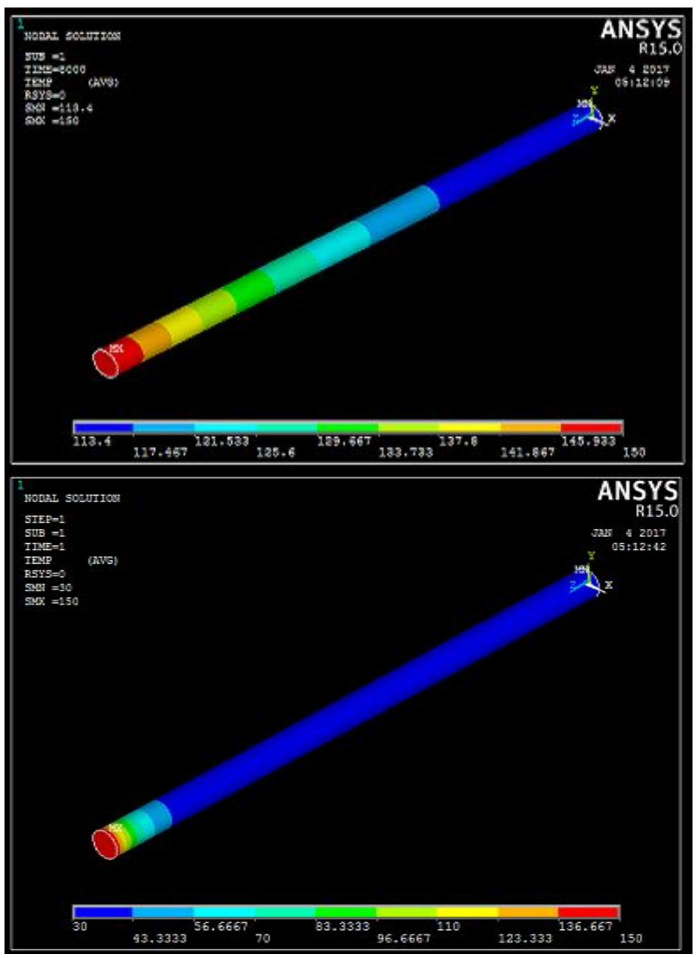

Fig. Temperature distribution at 8000 seconds for brass fin in Transient Analysis

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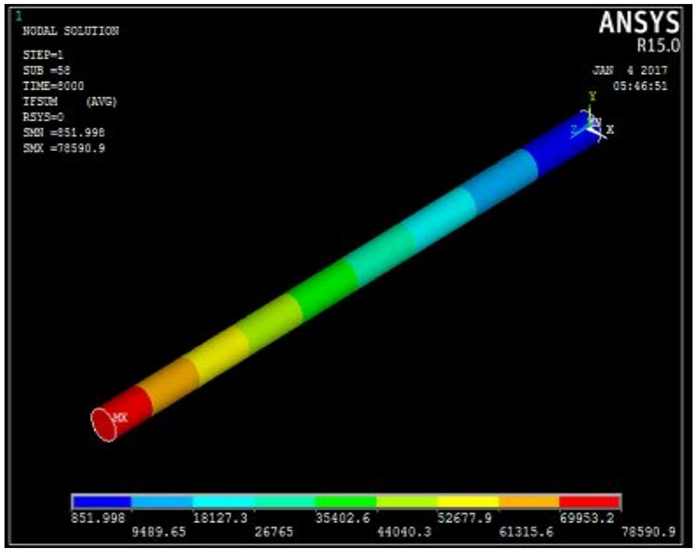

Fig. Heat flux (W/m^2) variation for brass fin material

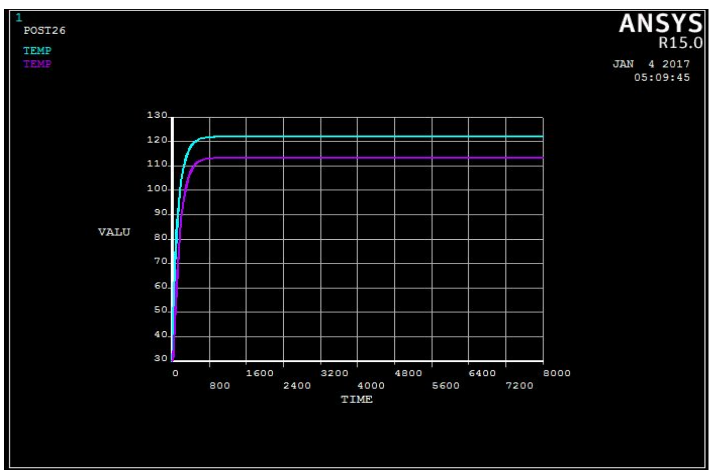

Fig. Response time or time to reach steady state for brass material

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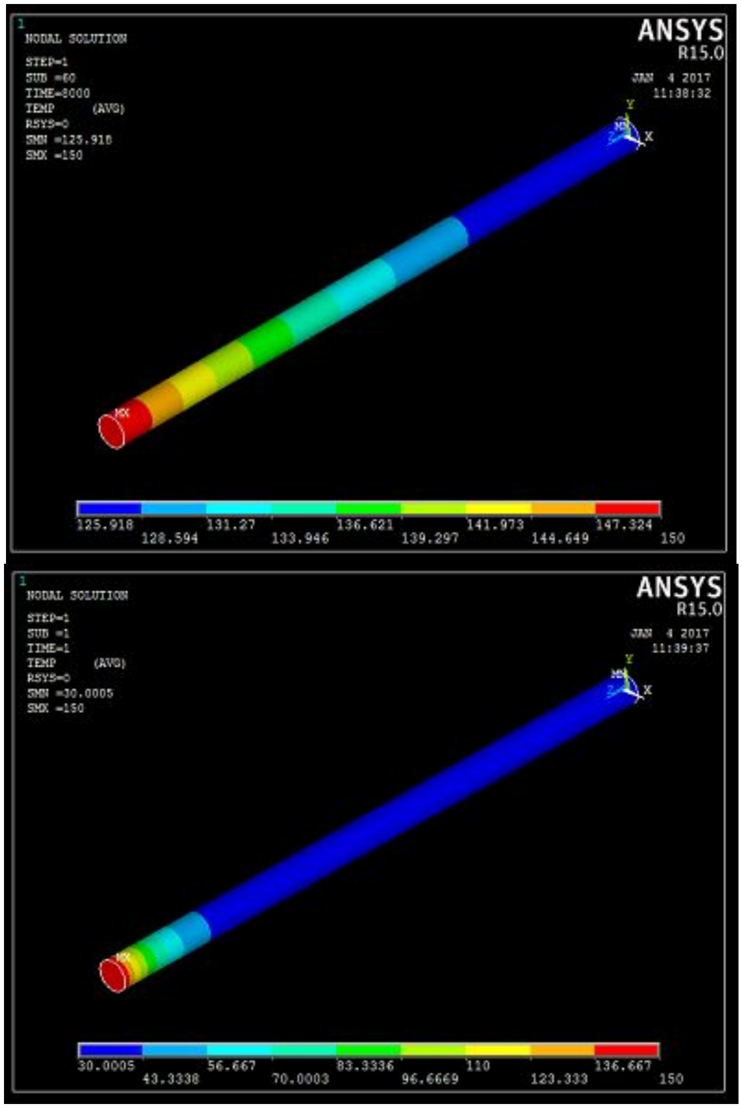

Fig. Temperature distribution at 8000 seconds for aluminium fin in Transient Analysis

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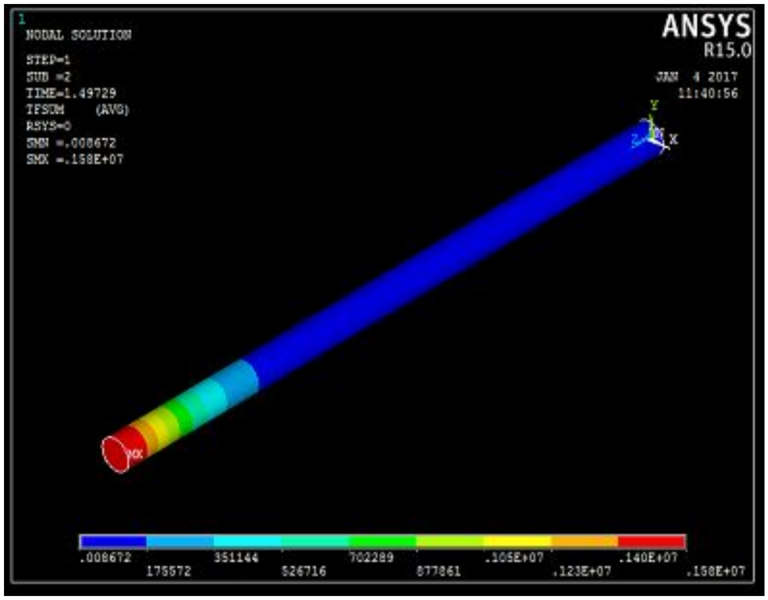

Fig. Heat flux (W/m^2) variation for aluminium fin material

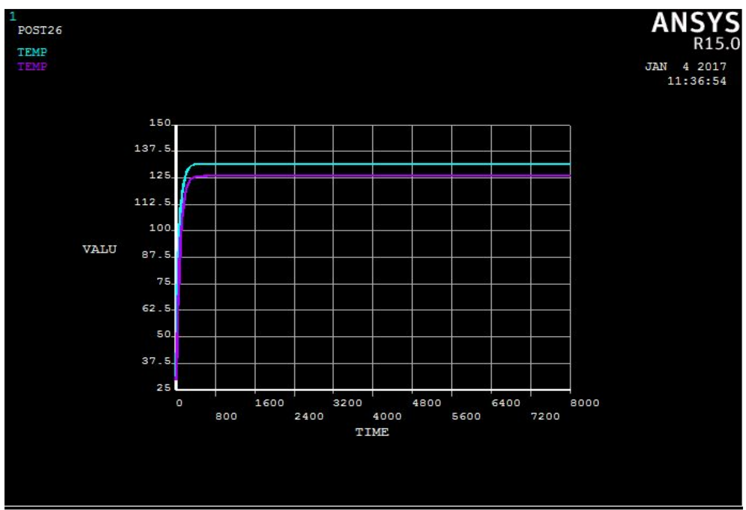

Fig. Response time or time to reach steady state for aluminium material

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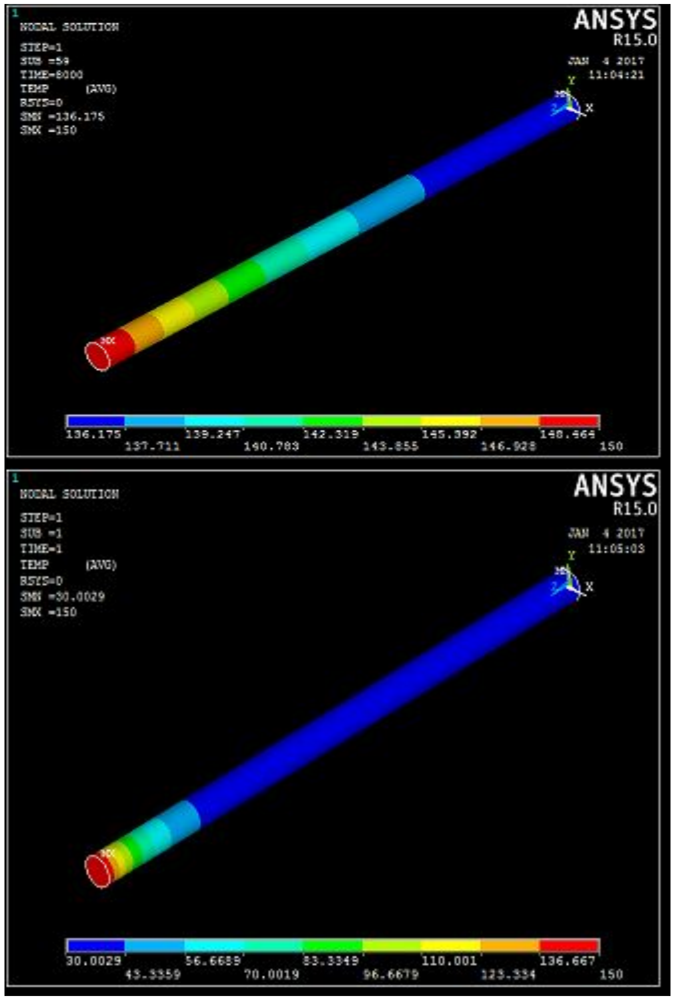

Fig. Temperature distribution at 8000 seconds for copper fin in Transient Analysis

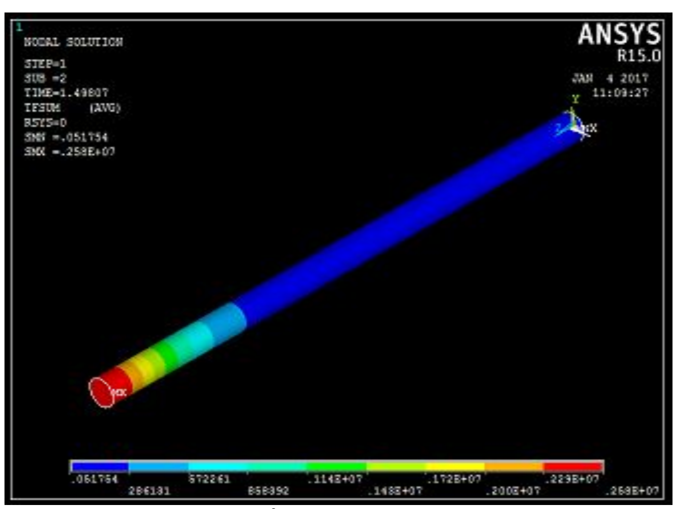

Fig. Heat flux (W/m^2) variation for copper fin material

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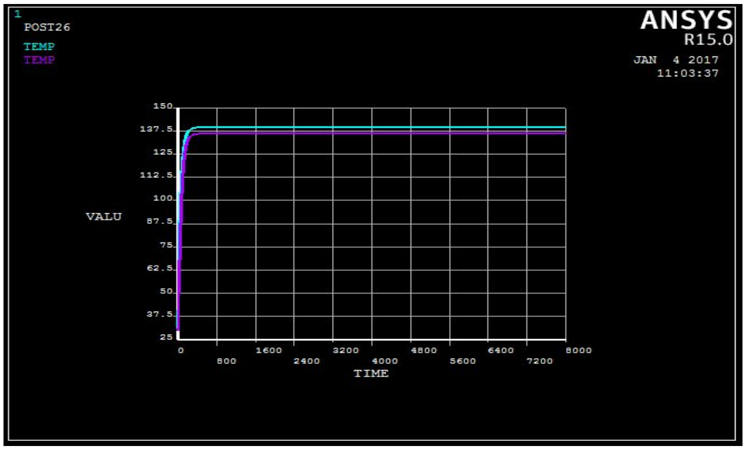

Fig. Response time or time to reach steady state for copper material

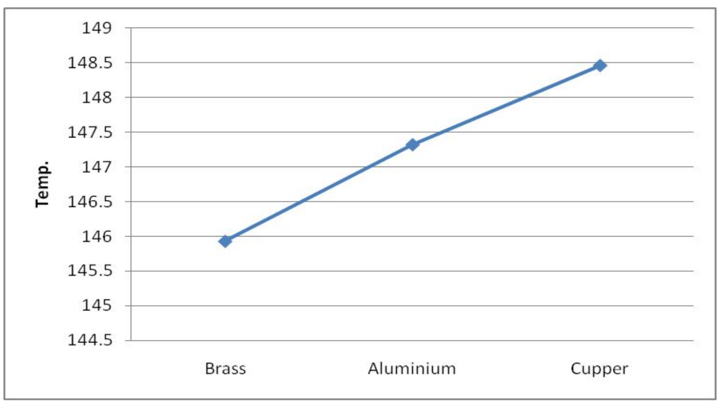

Fig. material vs. temp

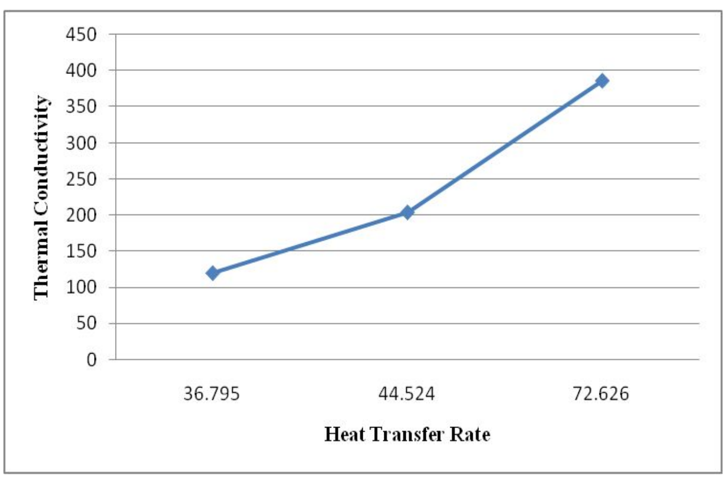

Fig. heat transfer rate vs. thermal conductivity

It is observed from the fig., as the material conductivity increases, response time i.e. the time required to reach steady state also increases. It is analyzed that temperature distribution at 8000 seconds. Therefore, the transient analysis is validated with the steady state analysis. It is concluded from the fig. that as the conductivity of material increases, heat transfer rate of material also increases. In the present study copper possessing the high rate of heat transfer because of its higher thermal conductivity, while brass material fin possessing the lowest rate of heat transfer because the thermal conductivity is low.

V. CONCLUSION

A computational study of cylindrical fin of different materials are discussed. Brass, Aluminium and Copper are used as fin material. Key conclusion of this study can be summarized as follows:

- Response time for Copper fin is minimum and maximum for brass to reach steady state.
- Steady state analysis data is in good agreement with transient analysis data.
- Minimum temperature of fin at steady state is increases with increase in material conductivity.

Heat transfer rate is maximum for copper material because of its higher conductivity and minimum for brass.

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