

CFD Simulation of Unsteady State Thermal Analysis for Circular Fins

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Abstract
Analytical solutions to the unsteady heat conduction for a two dimensional cylindrical fin with general boundary conditions obtained by the principle of separation variables. In this research, a computational fluid dynamics (CFD) model of the cylindrical fins is implemented with the help of ANSYS Multiphysics software. The material used for this purpose is steel. In this analysis, the partial differentiation is directly transformed into ordinary differential equations. The results obtained computationally are found in well agreement with the obtained analytically.
Keywords: ANSYS Multiphysics 11, heat conduction, analytical temperature distribution, fins.

1. Introduction:

Fins are used for the heat transfer purpose in different devices such as heating and cooling equipments. So, it is necessary to investigate and determine the temperature and the heat transfer rate by fin. Transient thermal analysis illustrates the correct values of the temperature that is varying with time. For proper estimation and control of the fin performance, it is necessary to know the dynamic response of temperature distribution when an unpredictable or expected change occurs. Analytical solution are particular important and useful for they may be used in an on line computation. To manufacture fin, the various types of materials like aluminum, copper, carbon steel etc will be used. Though in cooling and heating, there are various types of fins which are having different sizes and shapes.

It is necessary to perceive the temperature distribution of fins under steady and unsteady thermal condition for proper prediction and control of the fin performance. Analytical solutions are especially available since they may be used in an online computer. The main purpose of this paper is to bring into the analytical transient solutions by using the method of separation of variables. The lateral surface and the tip are subjected to a general situation included heat flux at the base. It is important work to know the general temperature profile in the fins since they describe the detail manner in which the heat transfer is affected by the heat flux and surrounding fluid.

Number of elements of fin=17023
Number of elements of fin=26441

2. Literature Review

Many number of research analyses have been carried out on the fins. Racelos [1] pointed out the schmidr diffin parabolic profile is valid for optimized fin. Aizz and Kraus [2] supplied optimum dimensions of longitudinal radiating fins. Look and Kang [3] observed that when the top surface biot number is small, the effect of fin tip convection coefficient is important but its ffect decreases apparently as the value of the tip biot number increases. Su and Wang [4] described transient analysis solutions for two dimensional cylindrical pin fin without heat flux at base. The numerical differential equation is iterated and converged though the CFD package ANSYS Multiphysics.

h	Heat transfer coefficient
K	Thermal conductivity
C_p	Specific heat
ρ	Density
T	Temperature distribution
D	Diameter in mm
R	Radius in mm
t	Time in sec

3. Problem formulation:
In this paper assuming, cylindrical fins is used for various parameters as follows.

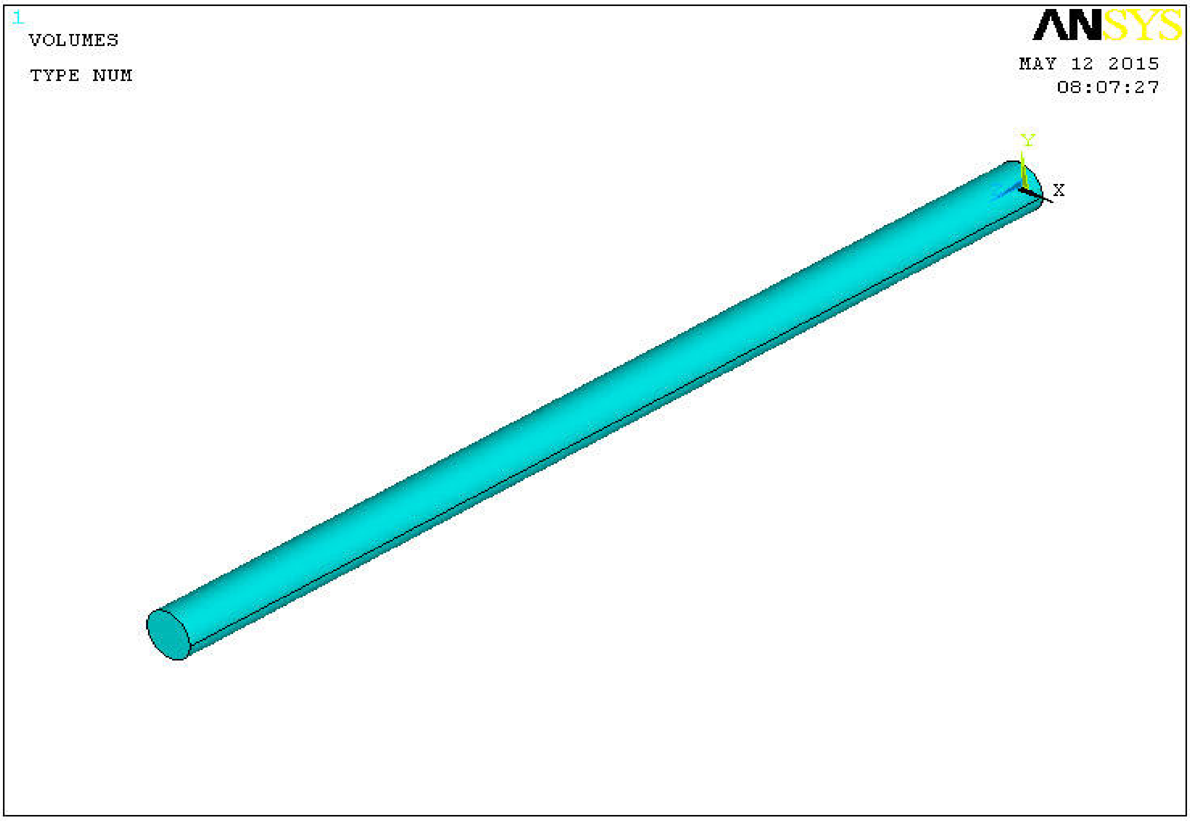

Fig. 1: Cylindrical fin without meshing

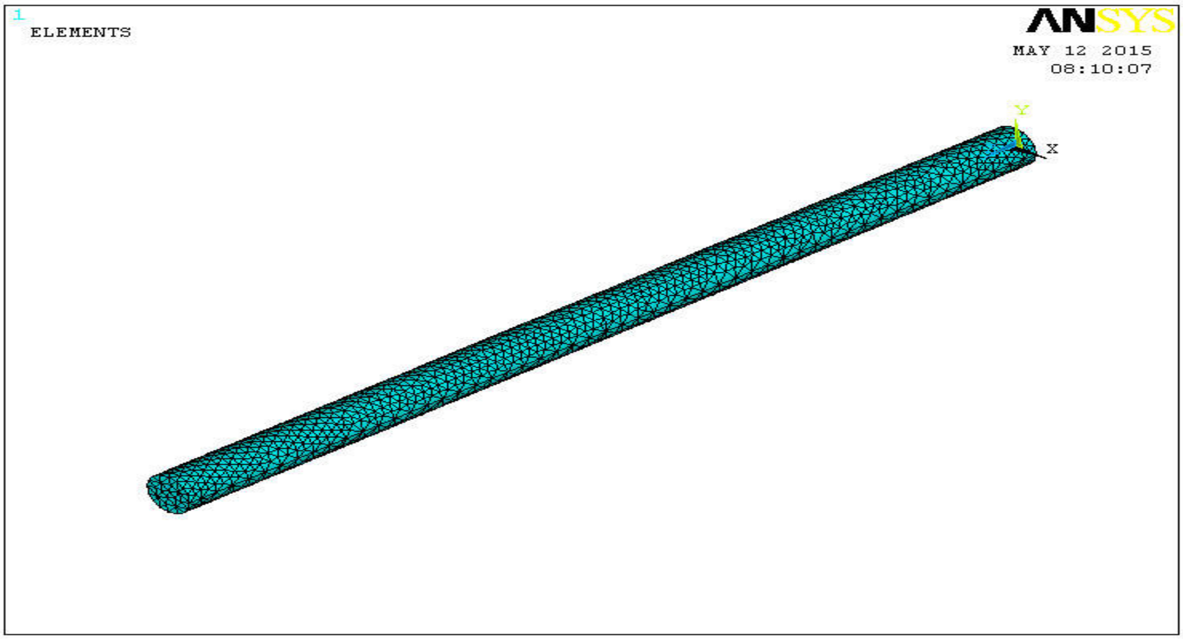

Fig. 2: Cylindrical fin with meshing

The material properties of fins are given in table (1).

Table (1): Material properties of fin

Fin diameter	0.006 m
Fin length	0.12 m
Tf	30 centigrade
h	10 W/m^2.k
Tb	150 centigrade
K	120 W/m.k
Density	8000 kg/m3
Specific heat	380 J/kg.k

5. Analytical Solution

A number of restrictive assumptions are presented before studying the transient analysis of two dimensional cylindrical fin. The main assumptions are homogeneous material properties and thickness, constant convective heat transfer coefficient and ambient temperature, no heat source in inner pat of the fin and no thermal radiation effects.

$$\frac{1}{\alpha}\frac{\partial u*(x*,y*,t*)}{\delta t*} = \frac{\partial^2 u*(x*,y*,t)}{\delta x*^2} + \frac{\partial^2 u*(x*,y*,t*)}{\delta y*^2} \qquad (1)$$

Initially, the fin is equilibrium with the surrounding fluid.

$$t^*=0 \quad u^*(x^*,y^*,0) = u^*_\infty \qquad (2)$$

Boundary conditions:

$$t^* > 0 \quad x^* = 0, -k\frac{\partial u^*(0,y^*,t^*)}{\delta x^*} = q_0 \qquad (3)$$

$$x^* = A^*,$$

$$-k\frac{\partial u^*(A^*,y^*,t^*)}{\delta x^*} = h_T[u^*(A^*,y^*,t^*) - u^*_\infty] \qquad (4)$$

$$y^* = 0,$$

$$-k\frac{\partial u^*(x^*,0,t^*)}{\partial y^*} = h_b[u^*(x^*,0,t^*) - u^*_\infty] \qquad (5)$$

$$y^* = L^*$$

$$-k\frac{\partial u^*(x^*,L^*,t^*)}{\partial y^*} = h_t[u^*(x^*,L^*,t^*) - u^*_\infty] \quad (6)$$

Separate variables in y direction, the temperature distribution will be written as…..

$$U(x,y,t)=\sum_{m=1}^{\infty} u_m(x,t)(cos\alpha_m y - \frac{Bib}{\alpha_m}\sin\alpha_m y)$$

Where , α_m is the m th positive root of the transcendental equation….

$$\tan\alpha_m L=\frac{\alpha_m(Bib+Bit)}{\alpha_m^2-(Bib)(Bit)}$$

6. Modeling and Simulation:

The whole analysis is carried out with the help of software "ANSYS 11". ANSYS Multiphysics 11 is computational fluid dynamics (CFD) software package to simulate fins problems. It uses the finite element method to solve the governing equations for a cylindrical geometry and grid generation is done by ANSYS 11.

7. Results and Discussion:

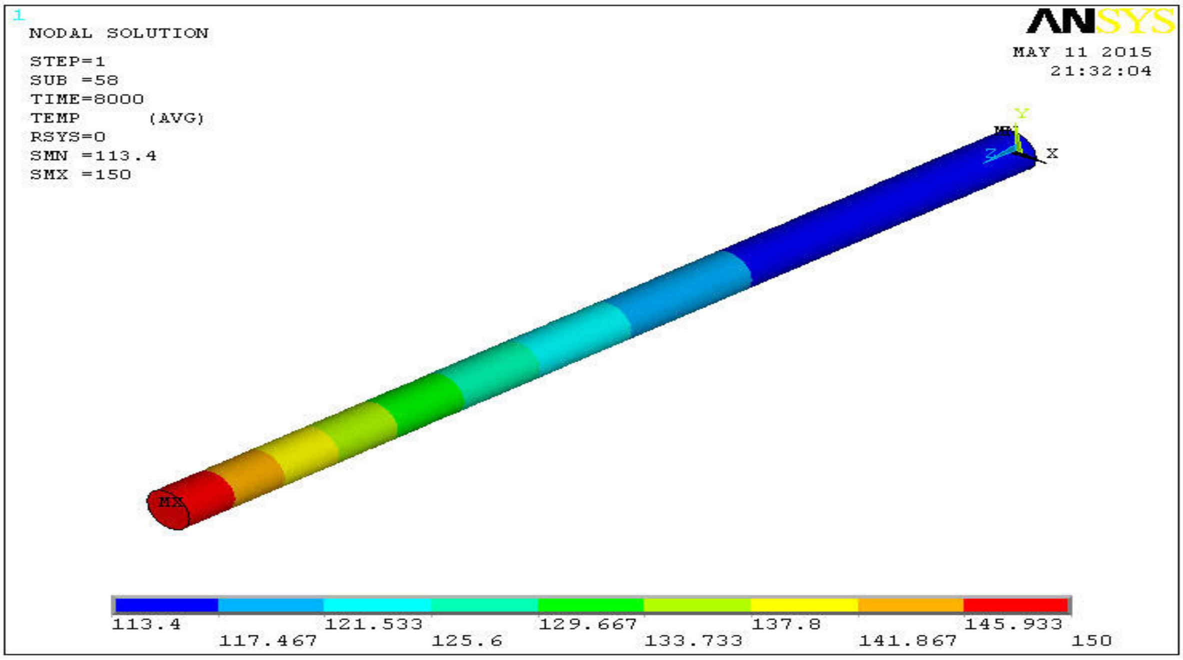

Fig. 3: Contour Temperature distribution of cylindrical fin cross section

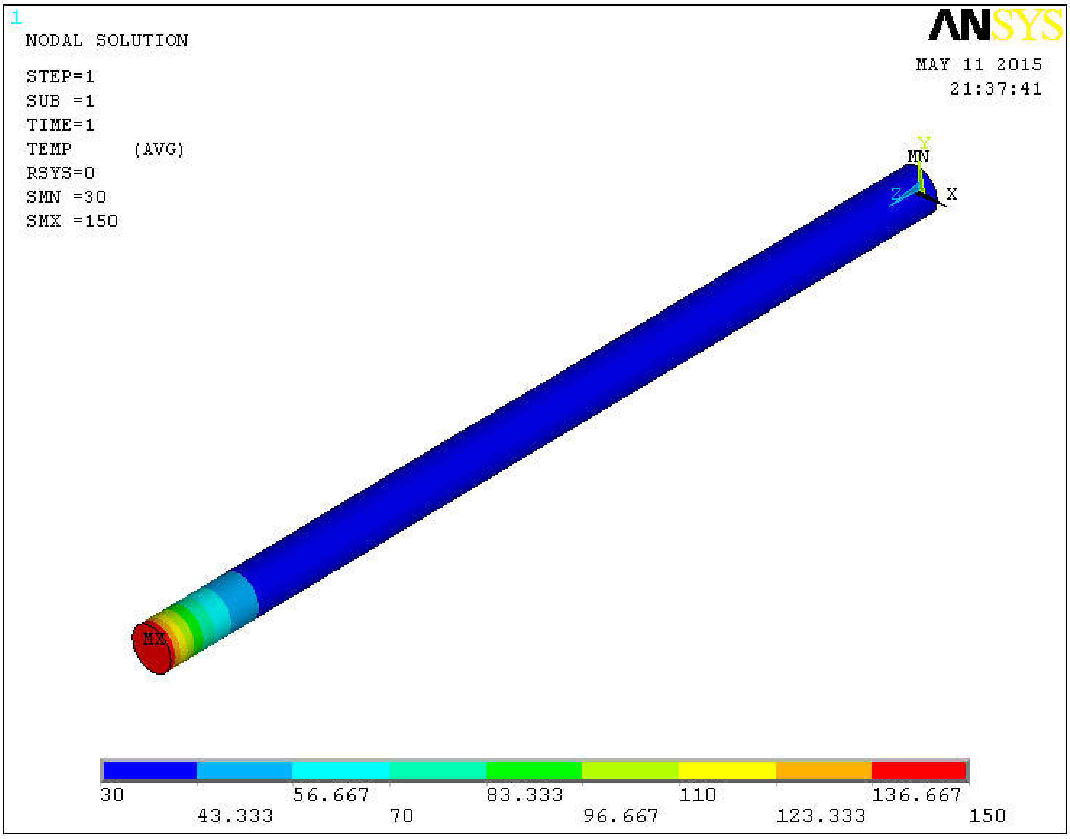

Fig. 4: Contour Temperature distribution on the fin at the start of heat flow of cylindrical fin cross section

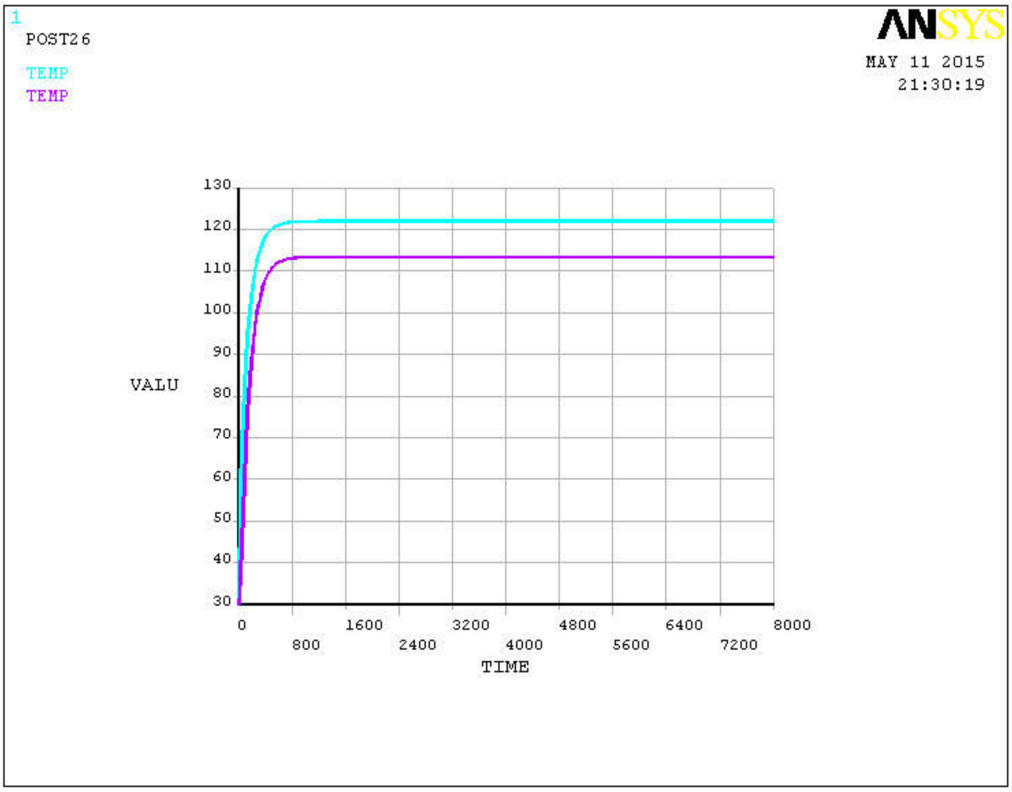

Fig. 5: Temperature v/s Time graph for Cylindrical fin

In the above result, the values with respect to time and also the graph values are presented. The behavior of the temperature on the cylindrical fin at various set of time is shown in the figure (3). For cylindrical fin as shown in figure (3), the graph shows the variation between temperature and time. With the increase in time, the temperature first increases and after some time, the temperature remains constant. The temperature distribution of fin increases with time at the start of heat flow as shown in figure (4).

8. Conclusions

In this paper, the accurate values of temperature with respect to the varying time.

Principle of seperable variables are applied to heat conduction subjected in cylindrical fins subjected to lateral surface to provide a simplified formulation that can be used to identify the temperature and heat transfer rate. The temperature distribution and the heat transfer rate are formed in a fourier series and exponential type.

The temperature distribution falls monotonically along the coordinate x for all various surface biot number. For larger values of surface biot number Bit or BiT, the more heat convection on lateral surface and the more thermal energy is efficiently transferred into environmental through the surface, also result in heat transfer rate reaches time invariant early.

References

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