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Thermal Analysis of Composite Slab, Cylinders

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Abstract: Composite walls are used in design of hot furnaces; similarly composite cylinders are used in design of steam pipes and electrical cable wires where insulating material is added to them so as to avoid the heat transfer to surroundings. For these reasons it is necessary to know the temperature distribution in these composites.

In this paper the thermal analysis of composite slabs, cylinders for a steady state heat transfer with convective boundary conditions is done with the help of Ansys. Solution is obtained for steady state temperature distribution for a hollow cylinder and a composite slab by analytical method. The analytical solution is shown to compare well with the finite element solution

Keywords- composite walls, composite cylinders, thermal analysis,

1. INTRODUCTION

The thermal resistance concept is used for calculation of heat flow rate through composite medium. The steady state temperature distribution within these is governed by the differential equation.

$$\frac{d}{dx}\left(k\,\frac{dT}{dx}\right)=0$$

1.1 steady heat conduction in plane walls

Heat transfer through the wall of a house can be modelled as steady and one-dimensional. The temperature of the wall in this case depends on one direction only (say the x-direction) and can be expressed as T(x). for steady operation In steady operation, the rate of heat transfer through the wall is constant. Fourier's law of heat conduction .

The rate of heat conduction through a plane wall is proportional to the average thermal conductivity, the wall area, and the temperature difference, but is inversely proportional to the wall thickness

1.2heat conduction in cylinders and spheres

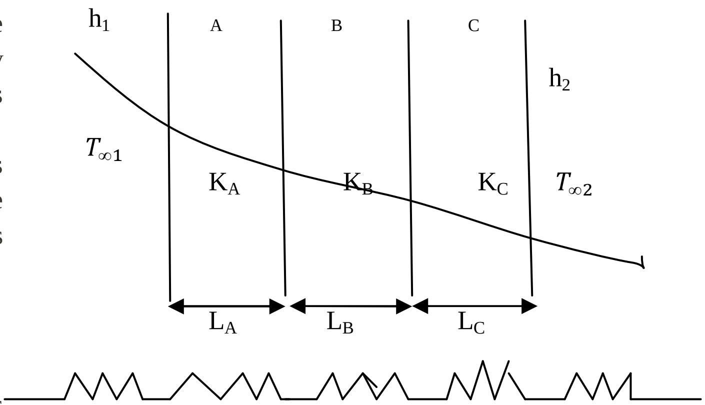
Heat transfer through the pipe can be modelled as steady and one-dimensional. The temperature of the pipe depends on one direction only (the radial r-direction) and can be expressed as T = T(r). The temperature is independent of the azimuthally angle or the axial distance. This situation is approximated in practice in long cylindrical Heat is lost from a hot-water pipe to pipes and air outside in the radial direction, containers. and thus heat transfer from a long pipe is one-dimensional.

2. EQUATIONS

2.1Composite walls:

Consider three blocks, A, B and C, as shown. They are insulated on top, bottom, front and back. Since the energy will flow first through block A and then through blocks B and C, we say that these blocks are thermally in a series arrangement.

Thermal resistance network for heat transfer through a plane wall subjected to convection on both sides,



$$\frac{1}{h_1\,A}\quad \frac{L_A}{K_A\,A}\quad \frac{L_B}{K_B\,A}\quad \frac{L_C}{K_C\,A}\quad \frac{1}{h_2 A}$$

Fig.1 composite wall

The steady state heat flow rate through the walls is given by

$$q_x = \frac{T_{\infty 1} - T_{\infty 2}}{\Sigma R_t} = \frac{T_{\infty 1} - T_{\infty 2}}{\frac{1}{h_1 A} + \frac{L_A}{K_A A} + \frac{L_B}{K_B A} + \frac{L_C}{K_C A} + \frac{1}{h_2 A}}$$

2.2Composite cylinders:

1-D radial conduction through a cylinder:

One frequently encountered problem is that of heat flow through the walls of a pipe or through the insulation placed around a pipe. Consider the cylinder shown. The pipe is either insulated on the ends or is of sufficient length, L, that heat losses through the ends are negligible. Assume no heat sources within the wall of the tube. If T1>T2, heat will flow outward, rdially, from the inside radius, R1, to the outside radius, R2. The process will be described by the Fourier Law.

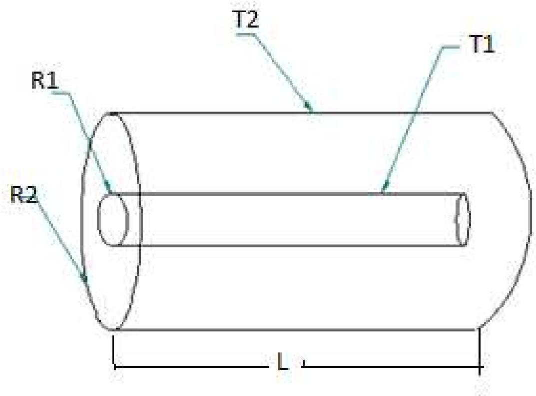


Fig. 2 Composite cylinder

The differential equation governing heat diffusion is:

$$\frac{1}{r}\frac{d}{dr}\left(r\ \frac{dT}{dr}\right)=0$$

For Multilayered Cylinders the thermal resistance network for heat transfer through a 2-layered composite cylinder subjected to convection on both sides.

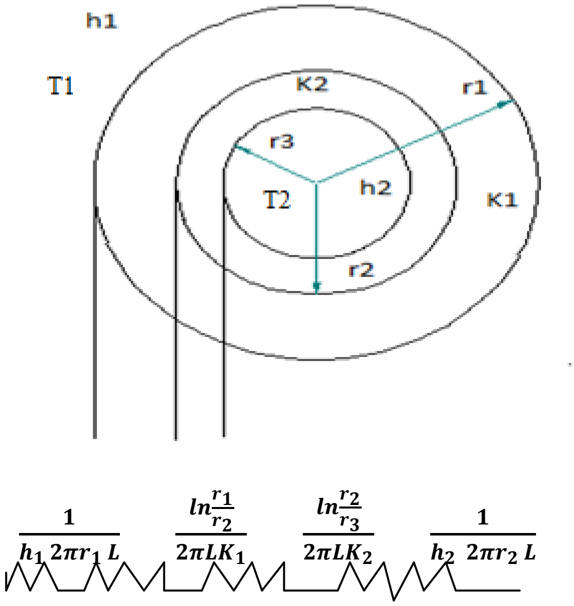


Fig. 3 Electrical analogy for composite cylinder

The steady state heat flow rate through the cylinder is given by

$$q_x = \frac{T_2 - T_1}{\Sigma R_t}$$

3. RESULTS AND CONCLUSION

In this paper 2 problems were taken i.e one on composite wall and another on composite cylinder. These problems are modelled and analyzed in Ansys software and validated with analytical results. The same equations were used for the calculation of rate of heat transfer through composite wall and cylinders as discussed above.

3.1Composite slab:

A composite slab consists of one layer of brick 0.501m thick and two layers of insulation. The inner layer of insulation is 0.1m thick and the outer layer is 0.06m thick. The thermal conductivities of the brick, inner layer and the outer layers are 15w/mk, 0.12 w/mk and 0.082w/mk respectively.

The brick side is exposed to gases at 800C and the outer insulation is exposed to ambient air at 30C. The brick side and air side heat transfer co-efficients are 300 w/m^{2}k and 150 w/m^{2}k respectively. Find the heat transfer rate through this composite slab and the interface temperatures.

The problem is solved in Ansys software and validated with analytical solutions

Table. 1 Results of composite wall

Interface temperatures in C	Heat transfer rate " q" in W/m^2
T1=798.41 T2=782.58 T3=383.17 T4=33.15	479.48

3.2 Composite cylinders

A pipe carrying hot fluid with 0.2m internal diameter and 0.1m thick is covered with layer of insulation 0.08m thick. The thermal conductivities of the pipe and insulation are 40w/m-k and 0.75w/m-k respectively.

The outside heat transfer coefficients are $50w/m^2k$. If the temperature of inner surface of the pipe is 300 C and ambient temperature is 25C, find the heat transfer per unit length of pipe and temperature variation across the pipe and insulation.By analytical method

Heat transfer rate in Watts= 3220

Table 2. Interface temperatures at different positions

Position along radial direction	Temperature in C
R1=0.20m R2=0.28m	291.141 61.53

3.3 Ansys Results

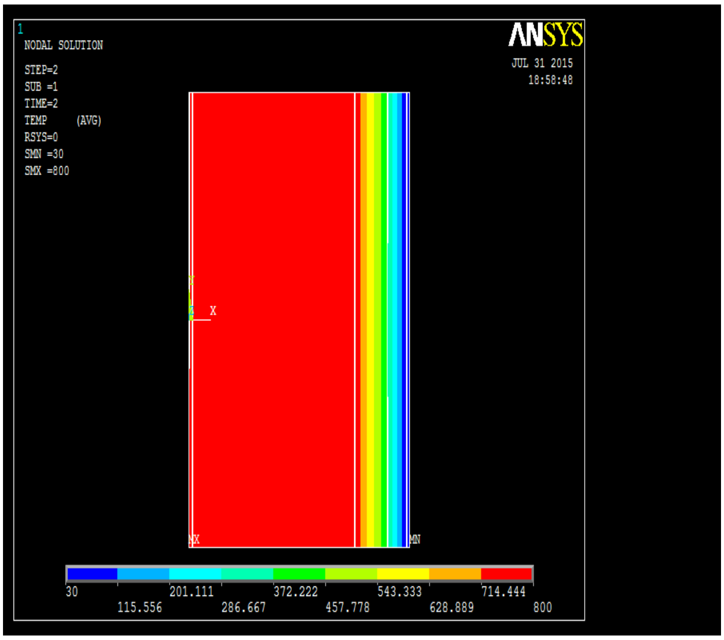


Fig. 4 Contour plot for nodal temperature results for composite wall

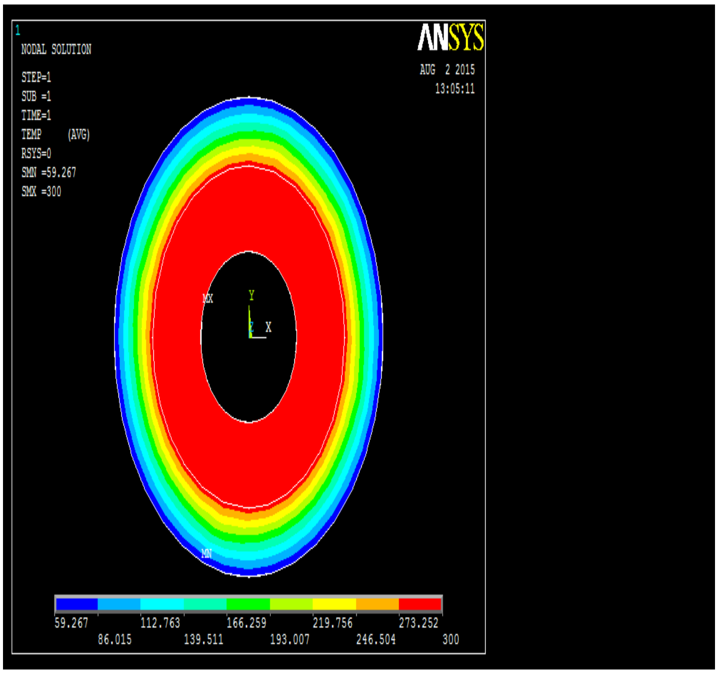


Fig. 5 Contour plot for nodal temperature results in front view for composite cylinder

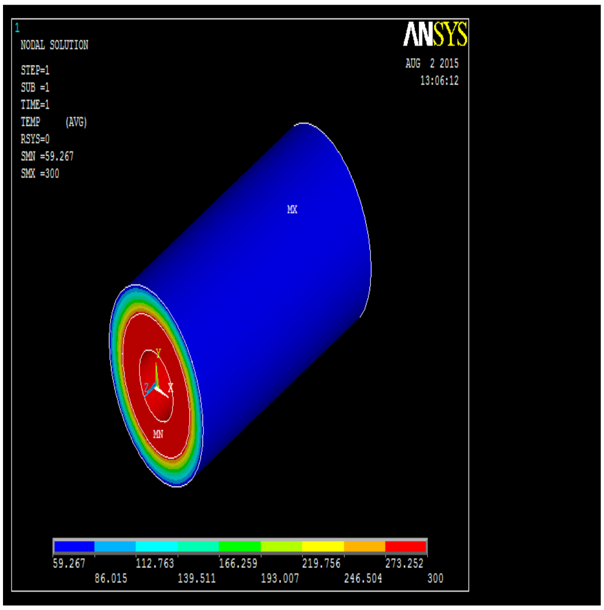


Fig. 6 Contour plot for nodal temperature results in isometric view for composite cylinder

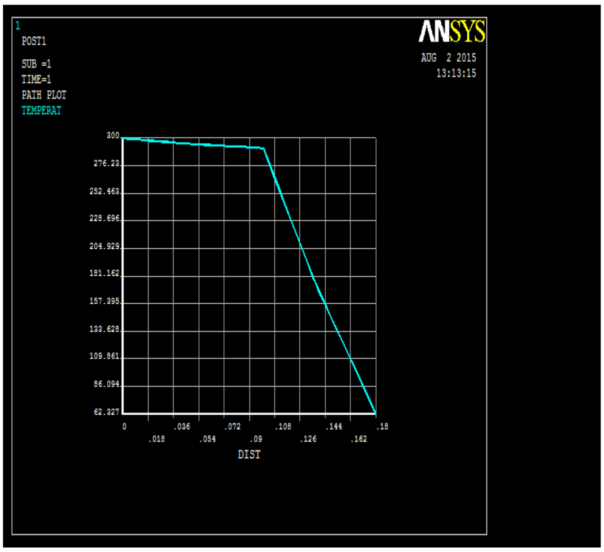


Fig. 7 Temperature variation across cylinder walls

4. CONCLUSION

In this paper the thermal analysis of composite slab, cylinder are analysed for a steady state condition.

By comparing the results of above two problems it is concluded that results from the analytical method is well with the finite element solution**.**

Since most of the practical problems encountered heat transfer in unsteady state i.e temperature variation and heat transfer rate will vary along space and time co ordinate. So analysis of the above problems can be analyzed in transient state.

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