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Thermal Analysis of Composite Hollow Cylinders Using COMSOL Software

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Abstract: *The composite hollow 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 and stream turbine where the stream running in pipe. The stream generated in the boiler is taken into pipes up to the steam turbine.For these reasons it is necessary to know the temperature distribution in these composites. In this paper the thermal analysis of composite cylinders for a steady state heat transfer with convective boundary conditions is done with the help of COMSOL. Solution is obtained for steady state temperature distribution for a hollow cylinder by COMSOL software.*
Keywords*-Composite Cylinders, Thermal Analysis, COMSOL, Temperature.*

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I. Introduction:

The thermal resistance concept is used for calculation of heat flow rate through composite cylinder pipe medium. The steady state temperature distribution within these is governed by the differential equation[1].

1.1.Composite Systems:
The idea of thermal resistance is a useful tool for analyzing conduction through composite members[1].
1.2.Composite Hollow Cylinder: A typical composite hollow cylinder with both inside and outside experiencing convection. The figure includes the thermal network that represents the system.
The rate of heat transfer q is given by

$$q = \frac{T_{\infty,1} - T_{\infty,2}}{1/2\pi h_1 r_1 L + \ln(r_2/r_1)/2\pi k_1 L + \ln(r_3/r_2)/2\pi k_2 L + 1/2\pi h_2 r_3 L}$$

Once q has been determined, the inside surface $T_{s,1}$, the interface temperature T_2, and the outside surface temperature $T_{s,2}$ can be found[2].

$$T_{s,1} = T_{\infty,1} - q \frac{1}{2\pi h_1 r_1 L}$$

$$T_2 = T_{\infty,1} - q \left[\frac{1}{2\pi h_1 r_1 L} + \frac{\ln(r_2/r_1)}{2\pi k_1 L} \right]$$

$$T_{s,2} = T_{\infty,2} + q \frac{1}{2\pi h_2 r_3 L}$$

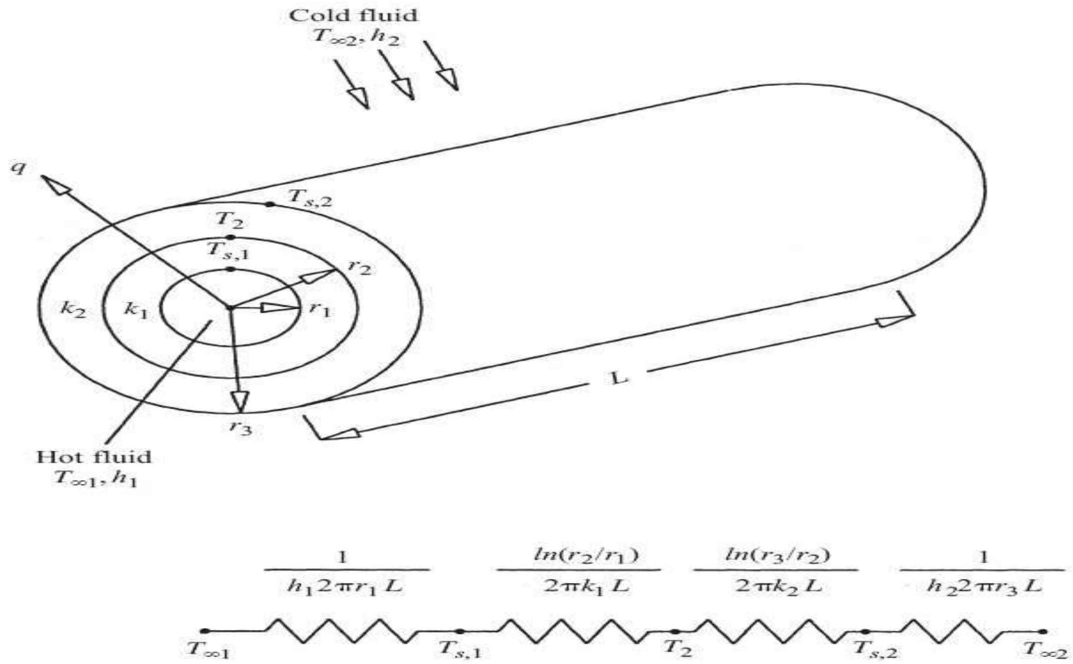

Fig.No.1. Series composite hollow cylinder and its thermal network.

II. Methodology:

Thermal analysis of composite hollow cylinders for a steady state heat transfer with convective boundary conditions is done with the help of COMSOLmultiphasic software which following some step[3].

2.1.Geometry:

Table No.2.1. Geometry

Units	
Length unit	Cm
Angular unit	Deg

Geometry statistics	
Description	**Value**
Space dimension	2
Number of domains	2
Number of boundaries	12
Number of vertices	12

2.1. (i).Circle 1 (C1)

Table No.2.1.(i).Circle 1(C1)

Position	
Description	**Value**
Position	{0, 0}

Size and shape	
Description	**Value**
Radius	2.5

2.1. (ii).Circle 2 (C2)

Table No.2.1.(ii).Circle 2(C2)

Position	
Description	**Value**
Position	{0, 0}

Size and shape	
Description	**Value**
Radius	2.5

2.1. (iii).Circle 3 (C3)

Table No.2.1.(iii).Circle 3(C3)

Position	
Description	**Value**
Position	{0, 0}

Size and shape	
Description	**Value**
Radius	2.75

2.1. (iv).Circle 4 (C4)

Table No.2.1.(iv).Circle 4(C4)

Position	
Description	**Value**
Position	{0, 0}

Size and shape	
Description	**Value**
Radius	5.75

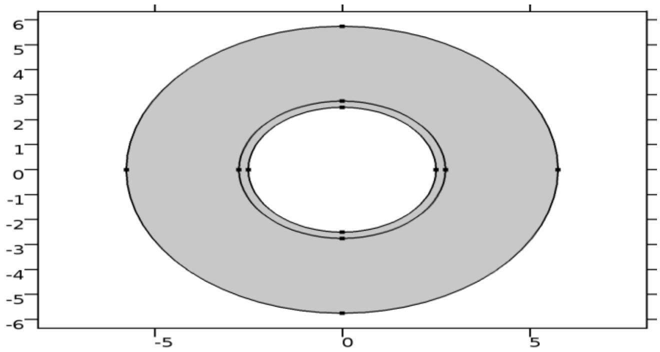

Fig.No.2. Geometry

2.2.Heat Transfer in Solids:

In the theory of heat transfer between solids and gasses, it is commonly assumed that the rate of heat exchange across a gas-solid interface is proportional to the difference between the temperature of the solid surface and that of the ambient gas.

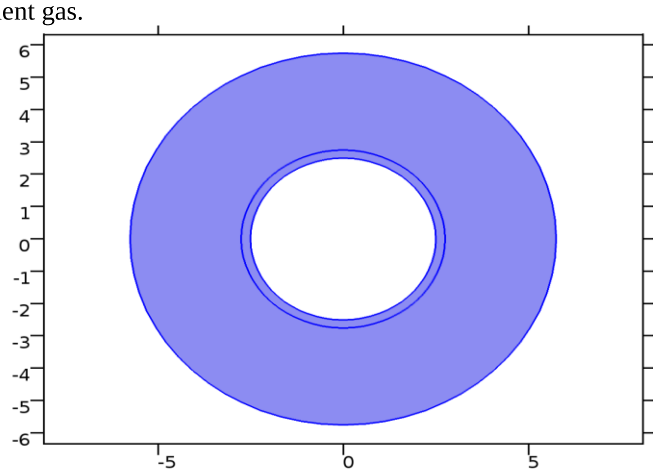

Fig.No.3.Heat Transfer in Solids

2.2.1. Equations:

$$d_z \rho C_p \mathbf{u} \cdot \nabla T + \nabla \cdot \mathbf{q} = d_z Q + q_0 + d_z Q_{ted}$$

$$\mathbf{q} = -d_z k \nabla T$$

2.3.Heat Transfer in Solids 1:

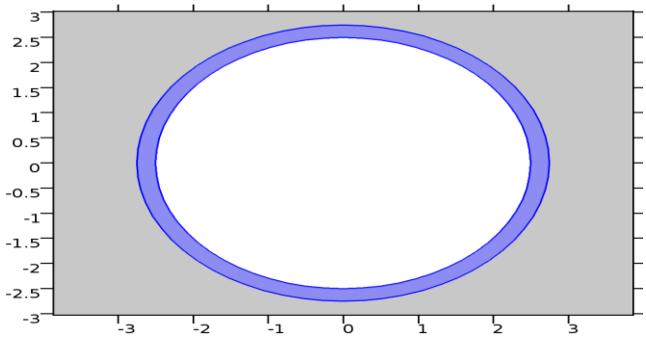

Fig.No.4.Heat Transfer in Solids 1

2.3.1. Equations:

$$d_z \rho C_p \mathbf{u} \cdot \nabla T + \nabla \cdot \mathbf{q} = d_z Q + q_0 + d_z Q_{ted}$$

$$\mathbf{q} = -d_z k \nabla T$$

2.4. Initial Values 1:

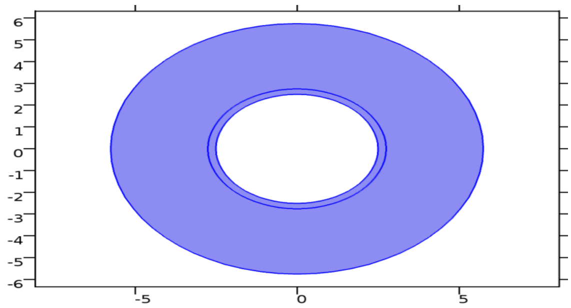

Fig.No.5.Initial Values 1

2.5. Thermal Insulation 1:

A Heat insulation material is one which has low thermal conductivity. Thermal insulation is provided in thermal system to reduce the heat losses. The stream generated in the boiler is taken into pipes up to the steam turbine. To reduce the heat losses, the pipe is lagged with some form of insulation material[6].

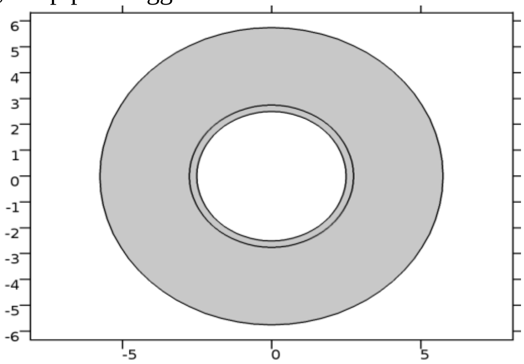

Fig.No.6. Thermal Insulation 1

2.5.1. Equations:

$$-\mathbf{n} \cdot \mathbf{q} = 0$$

2.6. Heat Transfer in Solids 2:

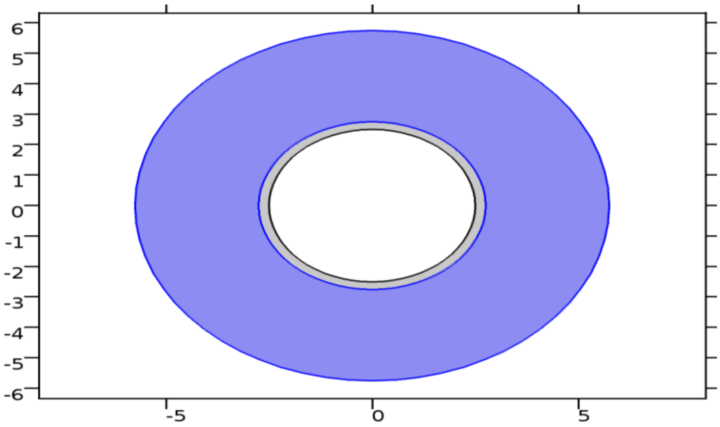

Fig.No.7. Heat Transfer in Solids

2.6.1. Equations:

$$d_z \rho C_p \mathbf{u} \cdot \nabla T + \nabla \cdot \mathbf{q} = d_z Q + q_0 + d_z Q_{ted}$$

$$\mathbf{q} = -d_z k \nabla T$$

2.7. Heat Flux 1:

Heat flux or thermal flux, sometimes also referred to as heat flux density or heat flow rate intensity is a flow of energy per unit of area per unit of time. In SI its units are watts per square metre ($W \cdot m^{-2}$) [4]. It has both a direction and a magnitude, and so it is a vector quantity. To define the heat flux at a certain point in space, one takes the limiting case where the size of the surface becomes infinitesimally small.

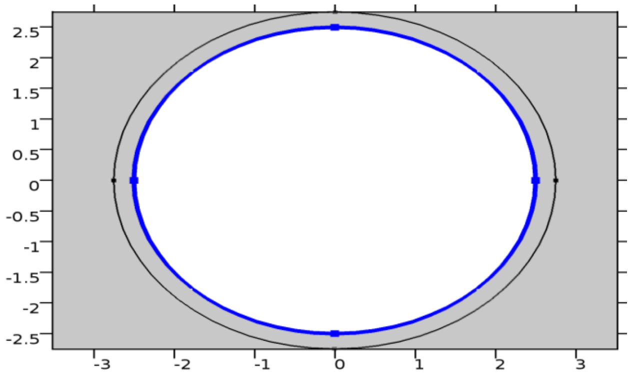

Fig.No.8. Heat Flux

2.7.1. Equations:

$$-\mathbf{n} \cdot \mathbf{q} = d_z q_0$$

2.8. Heat Flux 2:

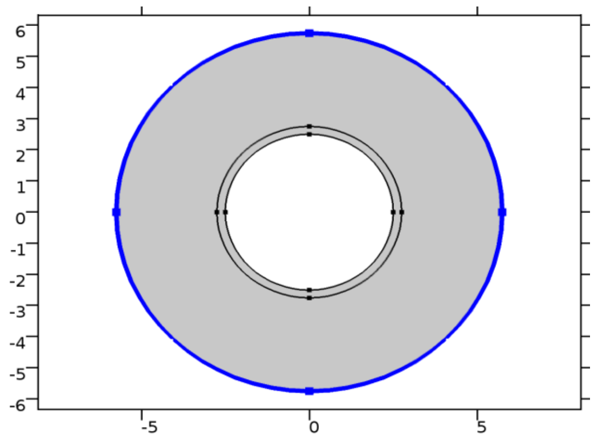

Fig.No.9. Heat Flux

2.8.1. Equations:

$$-\mathbf{n}\cdot\mathbf{q} = d_z q_0$$

III. Mesh Generation:

Mesh generation is the practice of generating a polygonal or polyhedral mesh that approximates a geometric domain. The term "grid generation" is often used interchangeably. Typical uses are for rendering to a computer screen or for physical simulation such as finite element analysis or computational fluid dynamics. The input model form can vary greatly but common sources are CAD, NURBS, B-rep, STL or a point cloud.[5] The field is highly interdisciplinary, with contributions found in mathematics, computer science, and engineering.

Threedimensionalmeshescreatedfor finiteelementanalysis needtoconsistof tetrahedra, pyramids, prisms or hexahedra. Those used for the finite volume method can consist of arbitrary polyhedra. Those used for finite difference methods usually need to consist of piecewise structured arrays of hexahedra known as multi-block structured meshes. A mesh is otherwise a discretization of a domain existing in one, two or three dimensions [4].

Mesh statistics

Description	**Value**
Minimum element quality	0.7706
Average element quality	0.9788
Triangular elements	800
Edge elements	148
Vertex elements	12

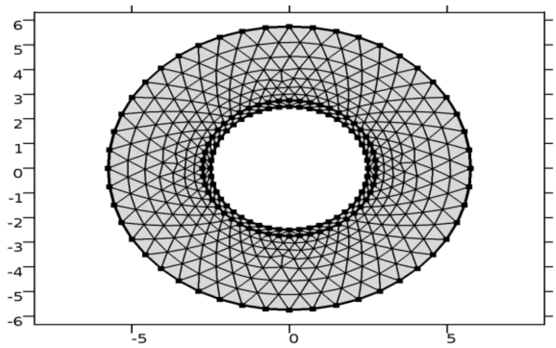

Fig.No.10.Mesh

3.1. Mesh Size:

Settings

Description	**Value**
Maximum element size	0.771
Minimum element size	0.00345
Curvature factor	0.3
Maximum element growth rate	1.3

3.2. Free Triangular 1 (Ftri1):

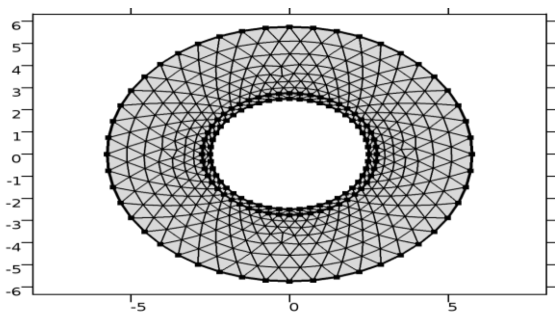

Fig.No.11.Free Triangular1

IV. Results and Discussion:

These problems are modeled and analyzed in COMSOL software. The same equations were used for the calculation of rate of heat transfer through composite hollow cylinders as discussed above the thermal analysis of composite hollow cylinder are analyzed for a steady state condition. 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 coordinate. So analysis of the above problems can be analyzed in transient state.

4.1. Temperature (Ht) :

Here,The heat transfer from inward to outward but insulated system are used for controlling heat transfer for inward to outward in the system. Higher temperatures are available inside the composite hollow cylinder as compare to outer surface of the composite hollow cylinder. Heat transfer from inward to outward surface of composite hollow cylinder decreases. Which is show in the fig.No.12.

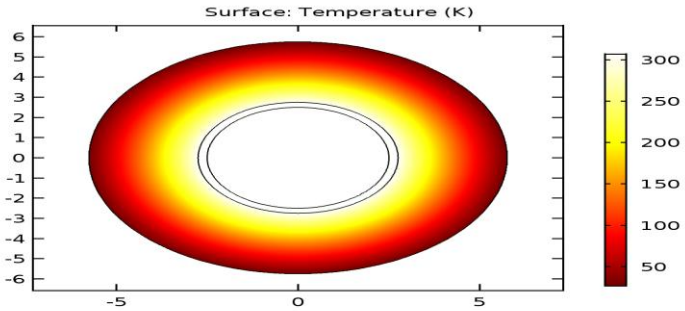

Fig.No.12. Surface: Temperature (K)

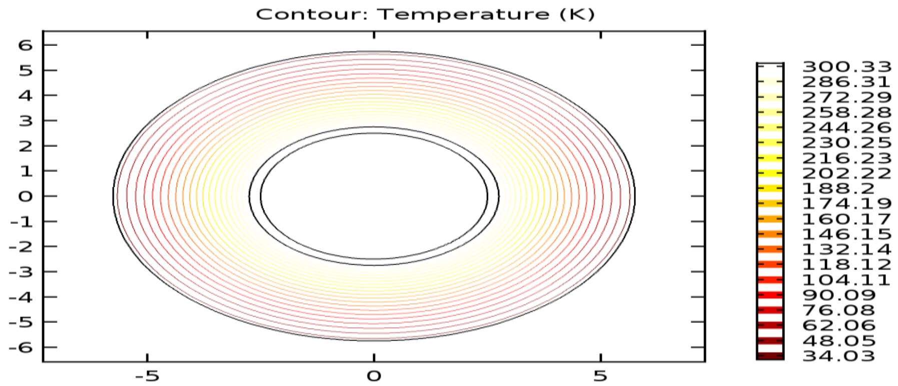

Fig.No.13.Contour: Temperature (K) Streamline: Total heat flux Streamline: Total heat flux

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