STEADY STATE HEAT TRANSFER THROUGH GLARE COMPOSITE CYLINDER

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Abstract

Glass reinforced aluminium (GLARE) is a fiber metal laminate (FML) composed of several very thin layers of metal (usually aluminium) interspersed with layers of glass-fiber pre-preg, bonded together with a matrix such as epoxy. The uni-directional pre-preg layers may be aligned in different directions to suit predicted stress conditions. Glare laminate is produced using autoclave technology Allows existing manufacturing technology.

Multilayer cylinder applications are more common and are used to reduce heat loss in pipes. The pipes are generally covered with one or more layers of insulation called Lagging of pipe. Such cylinders covered with multi layer are called is known as composite cylinder. In this present paper we are going to find out the heat transfer through these composite cylinders. Here we compared the values obtained from the analysis through Ansys software. 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 a typical uncoupled thermal and structural solution, a steady-state temperature distribution is mapped from the thermal model to the structural model.

Key Words: Composite cylinder, Ansys, Temperature, Steady State, Glare

Objective

The objective of this work is to provide the temperature distribution for subsequent thermal stress analysis. Thermal analysis of composite cylinders for a steady state heat transfer with convective boundary conditions for different layer is done with the help of Ansys. Solution is obtained for steady state temperature distribution for a hollow cylinder.

Modelling

Typical Steps Involved in Model Generation Within ANSYS

A common modeling session might follow this general outline .

Begin by planning your approach. Determine your objectives, decide what basic form your model will take, choose appropriate element types, and consider how you will establish an appropriate mesh density. You will typically do this general planning before you initiate your ANSYS session.

- Enter the preprocessor (PREP7) to initiate your model-building session. Most often, you will build your model using solid modeling procedures.
- Establish a working plane.
- Generate basic geometric features using geometric primitives and Boolean operators.
- Activate the appropriate coordinate system.
- Generate other solid model features from the bottom up. That is, create keypoints, and then define lines, areas, and volumes as needed.
- Use more Boolean operators or number controls to join separate solid model regions together as appropriate.
- Create tables of element attributes (element types, real constants, material properties, and element coordinate systems).

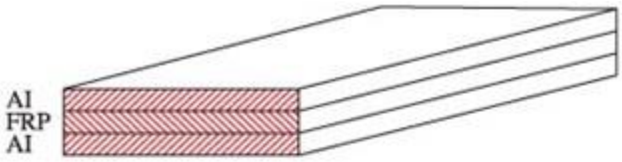
- Set element attribute pointers.
- Set meshing controls to establish your desired mesh density if desired. This step is not always required because default element sizes exist when you enter the program . (If you want the program to refine the mesh automatically, exit the preprocessor at this point, and activate adaptive meshing.)
- Create nodes and elements by meshing your solid model.
- After you have generated nodes and elements, add features such as surface-to-surface contact elements, coupled degrees of freedom, and constraint equations.
- Save your model data to Jobname.DB.
- Exit the preprocessor.

Review of literature

- **Vogelesang et ai.(1970)-** The history of Glare can be traced back to early bonded wood and bonded metal aircraft structures. True fiber-metal laminates, comprised of alternating thin layers of aluminum and fiber-reinforced plastic composites, were first developed in the 1970s. The first commercial FML was Arall, an aramid-aluminum FML developed at the Delft University of Technology (Delft). Arall was used in a few select aircraft components, but it had structural limitations that prevented wider use. Glare, a glass-aluminum FML, was developed in part to overcome these limitations.
- **De Havilland (1980)**The several patents mention among others as inventors, then professors and researchers at the Faculty of Aerospace Engineering, Delft University of Technology, where much of the R & D on FML was done in the 1970s and 1980s. The fruition of FML development marks a step in the long history of research that started in 1945 at Fokker, where earlier bonding experience at de Havilland inspired investigation into the improved properties of bonded aluminium laminates compared to monolithic aluminium.
- **Vlot(1985)**Vlot was introduced to Arall in 1985, as an undergraduate at Delft. He remained active in the development of Glare and its application to the A380 until his untimely death in April of 2002. Arall was introduced in 1981, and Glare was selected for the A380 in 2001, so Vlot's career spanned almost the entire lifetime of the material.
- **Akzo Nobel(1987)** NASA got interested in reinforcing metal parts with composite materials as part of the Space Shuttle program led to the introduction of fibers to the bond layers, and the concept of FMLs was bornGLARE is a relatively successful FML, patented by Akzo Nobel in 1987.
- **M. Kawai et al. (1990)**studied the off-axis inelastic and fracture behavior of Aluminum-GFRP hybrid laminates under static tensile loading conditions. They have found that the tensile fracture strength is almost two times as large as that of the monolithic aluminium alloy in the fiber direction, and it is about five times the value of the GRP layers in the transversedirection.
- **L. B. Vogelesang and A. Vlot 2000** the fatigue behavior, corrosion and flame resistance of hybrid Aluminum-Glass fiber laminates have been evaluated . They reported that the hybrid laminates have betterfatigueresistance,corrosionresistanceandflameresistancethanmonolithicaluminiumalloy.
- **G.Reyesand H. Kang 2007**investigated the mechanical behaviour of thermoplastic glass fiber reinforced polypropylene composite and aluminium alloy hybrid laminates. They found that these laminates showed excellent forming properties similar to that of monolithic aluminium alloy of comparable thickness.

Material

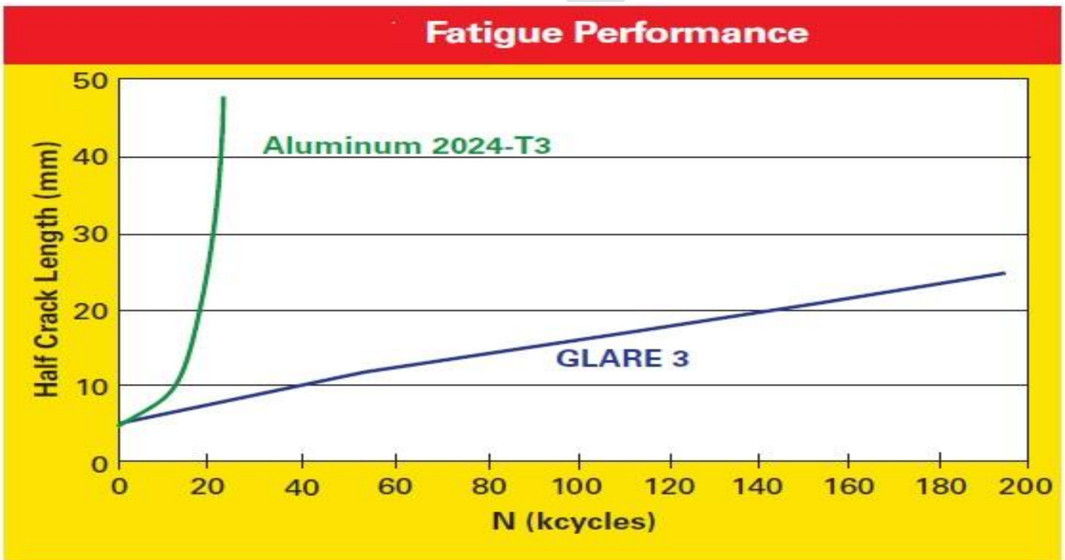
Glass reinforced aluminium (GLARE) is a fiber metal laminate (FML) composed of several very thin layers of metal (usually aluminium) interspersed with layers of glass-fiber pre-preg, bonded together with a matrix such as epoxy. The uni-directional pre-preg layers may be aligned in different directions to suit predicted stress conditions. Glare laminate is produced using autoclave technology Allows existing manufacturing technology and investments to be used continuous S-2 Glass fibers bridge the aluminum splices Allows tailor-made skins of any size, not limited by the width of aluminum rolls.Furthermore, it is possible to "tailor" the material during design and manufacture such that the number, type and alignment of layers can suit the local stresses and shapes throughout the aircraft. This allows the production of double-curved sections, complex integrated panels or very large sheets, for example. While a simple manufactured sheet of GLARE is more expensive than an equivalent sheet of aluminium, considerable production savings can be made using the aforementioned optimization. There may be any number of aluminium and FRP layers but the ratio between the number of aluminium and FRP layers should be (n+1)/n where n is the number of FRP layers so that the outermost layer is always aluminium on both sides. Earlier research works on such hybrid laminates have demonstrated that these laminates are superior to composite or monolithic aluminium. Outstanding fatigue resistance and impact properties, impressive mechanical properties, solid fire resistance, and lightning strike resistance are some of GLARE laminates many desirable attributes. the enhanced fatigue properties offered by GLARE over the traditional 2024-T3 aluminium alloy used in aircraft structure.



Aluminium-GFRP sandwich panel.

Advantages of Fiber-Metal Laminate

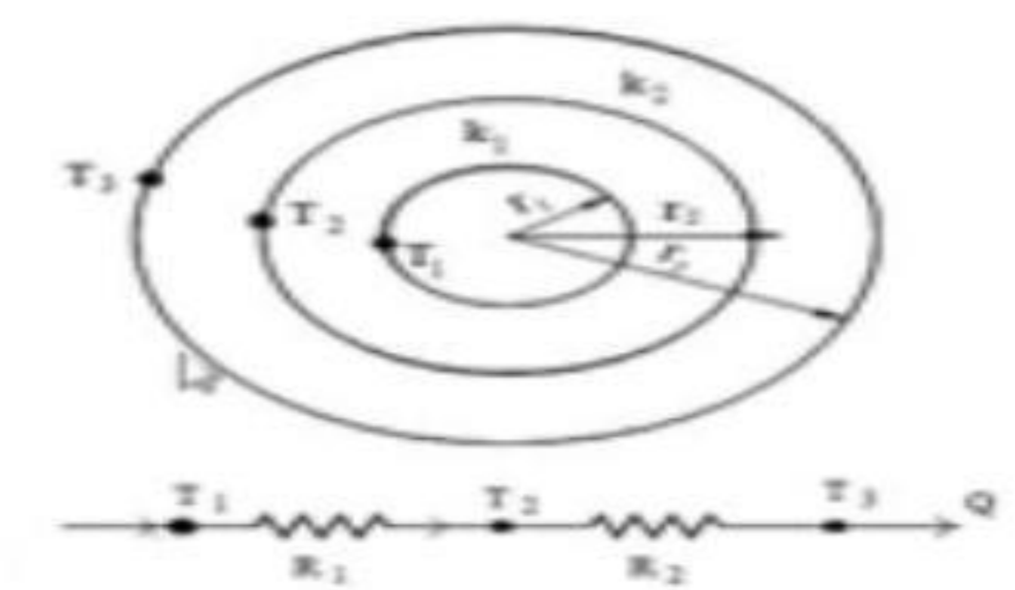
Property	GLARE	2024-T3 Aluminum
Weight	0.7 - 0.9	1
Strength	1 - 2	1
Fatigue	3 - 100	1
Damage Tolerance	1 - 2	1
Impact Blast Resistance	2 - 10	1
Flame Resistance	5 - 50	1
Lightning Strike	1.5 - 2.5	1
Thermal Insulation	100 - 150	1
Corrosion Resistance	2 - 10	1
Reparability	1+	1
Maintenance	1+	1



Methodology

Cylinders covered with multi layer are called Glare composite cylinder. Let us consider a cylinder of radius **r1** lagged with two layers of insulation having conductivities **K1** and **K2** as shown in fig below. The outer layer is of glass and inner layer is from aluminium. The inner surface of the cylinder is at **T1** and the outer most surface is at **T3.** Let **T1>T3** and heat passes through the two layers of insulation. The different parameters and conditions are following.

A pipe carring hot fluid with 250 mm. internal diameter and 150 mm. thickness is covered with a layer of insulation 100 mm. Thermal conductivity of Al=121 w/mk and glass 1.45 w/mk. Outside heat transfer co-efficient is 50 w/m^{2}k . Inner temperature in 317 c and ambient tempreture = 25c .Find the heat transfer per unit length of the pipe and temperature variation across pipe and insulation.



Thermal Analysis Results :

1. Temperature variation across the cylinder

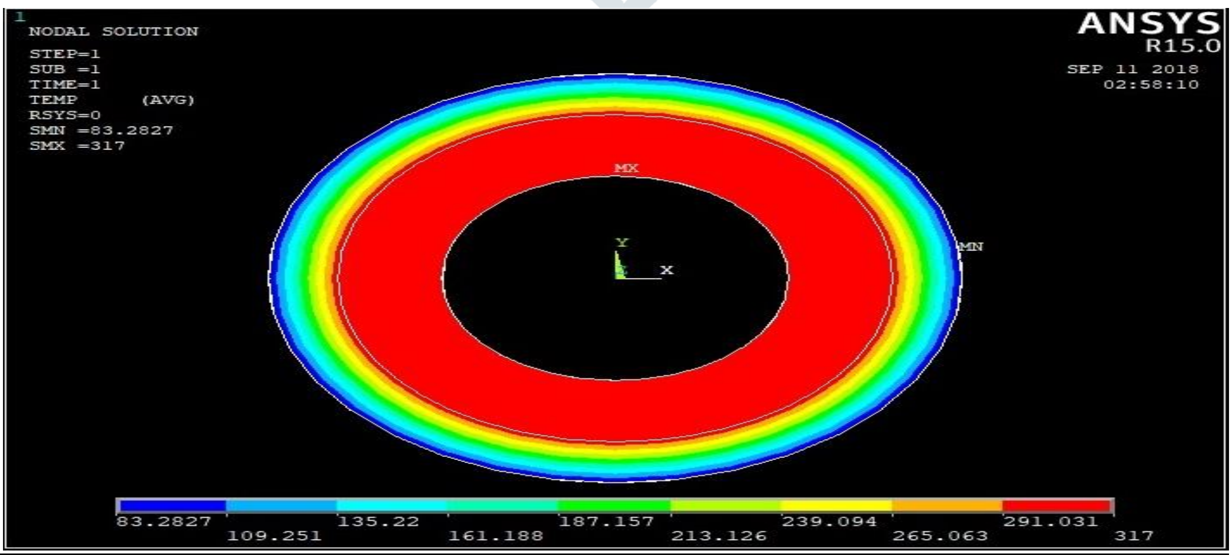


Fig 1

Temperature variation across the cylinder. Therefore, from the Ansys analysis surface temperature of insulation is 83.28 oC and maximum tempreture 317 c.

2. Graphical representation

Graph Shows tempreture variation with respect to thickness.

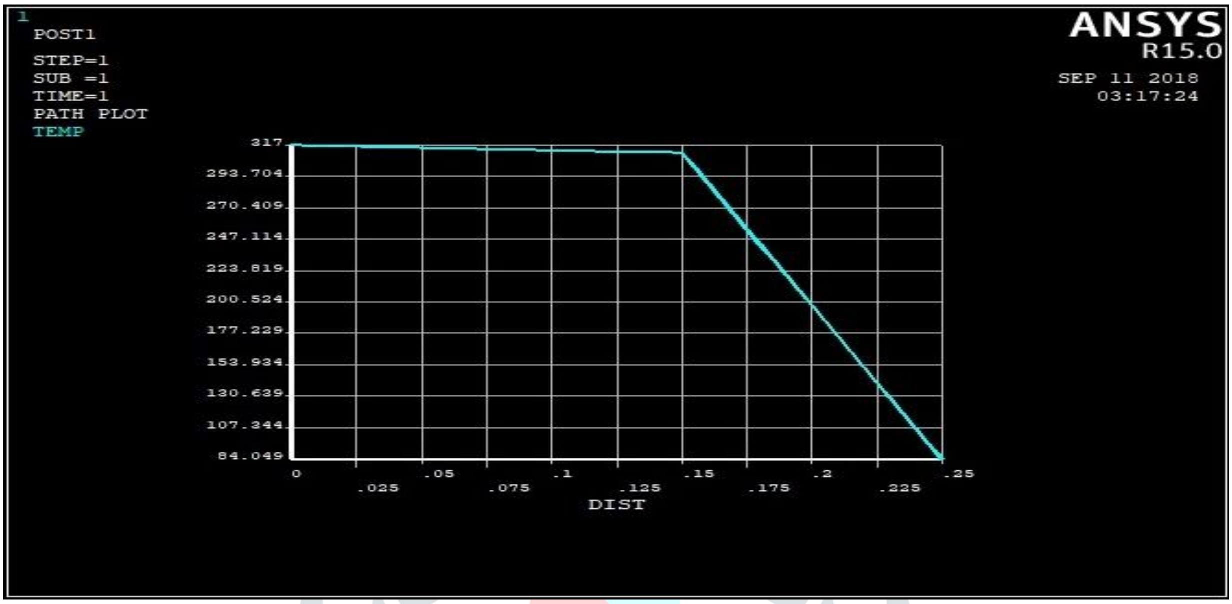


Fig 2

3. Thermal flux

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 ($W \cdot m^{-2}$). Since inner side is made up of aluminium then it has more flux density than outer surface.

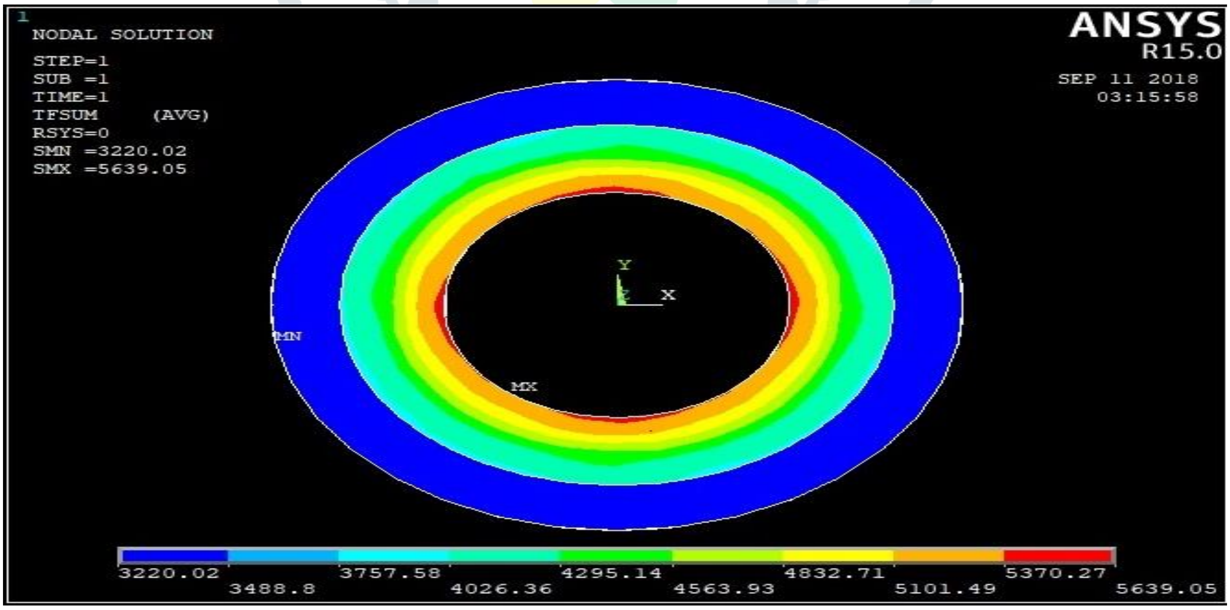


Fig 3

Since inner side is made up of aluminium then it has more flux density than outer surface.

4. **Heat flow**

The amount of heat transferred across an isothermal surface in a unit time. Heatflowhas the same dimensions as power andis measured in watts (W) or kilocalories per hour (kcal/hr); 1 W = 0.86 .k cal/hr.

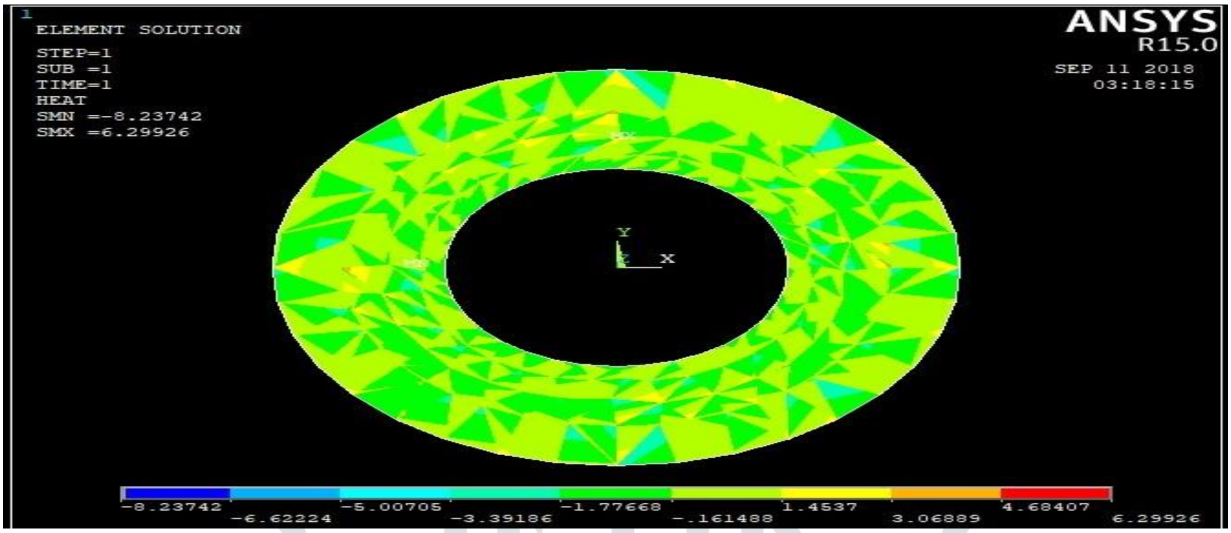


Fig 4

Internal surface is made up of Al so heat transfer rate is more.i.e 6.29 Kw.

5. Thermal gradient

A temperature gradient is a physical quantity that describes in which direction and at what rate the temperature changes the most rapidly around a particular location. The temperature gradient is a dimensional quantity expressed in units of degrees (on a particular temperature scale) per unit length.

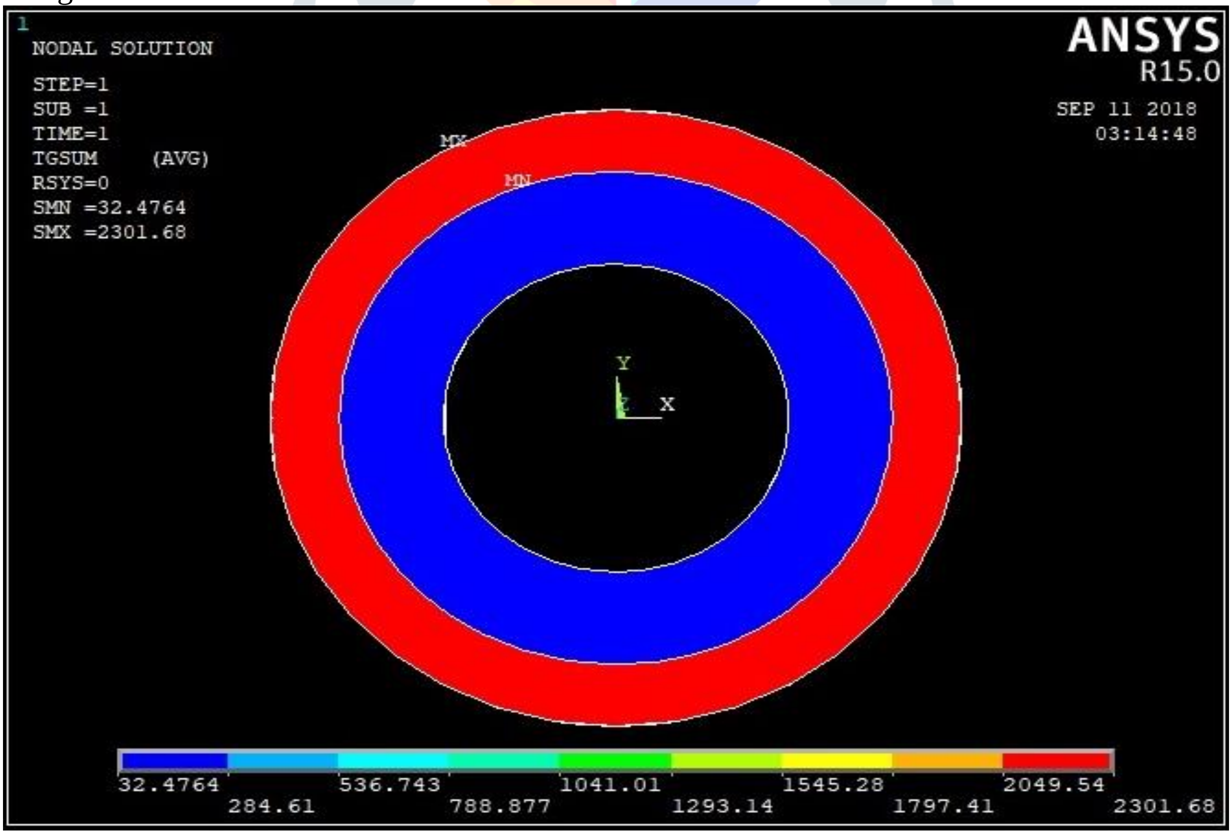


Fig 5

In this result tempreture is flowing from inwards to outwards direction.

Theoretically

Given:

T_1= 317 c T_2 = 25 c K_{pipe} = 141 w/mK K_{ins} =1.45 w/mK h= 50 w/m^2K

$r_1 = 0.125 \ m \ \ r_2 = 0.125 + 0.15 = 0.275 \ m \ r_3 = 0.275 + 0.1 = 0.375 \ m$

$$R_{Pipe} = \frac{\ln\left(\frac{r_2}{r_1}\right)}{2\pi K_{Pipe} L} = \frac{\ln\left(\frac{0.275}{0.125}\right)}{2\pi \times 121 \times 1} = \frac{0.788}{760.26} = 1.03 \times 10^{-3} \quad c/w$$

$$R_{ins} = \frac{\ln\left(\frac{r_3}{r_2}\right)}{2\pi K_{in} L} = \frac{\ln\left(\frac{0.375}{0.275}\right)}{2\pi \times 1.45 \times 1} = \frac{0.310}{9.11} = 0.034 \quad c/m$$

$$R_b = \frac{1}{h_o 2\pi L r_3} = \frac{1}{50 \times 2\pi \times 0.375 \times 1} = 8.488 \times 10^{-3} \quad c/m$$

$$R_{total} = R_{Pipe} + R_{ins} + R_b = 0.043 \quad c/m$$

$$Q = \frac{T_{inside} - T_{outside}}{R_{total}} = \frac{590 - 298}{0.043} = 6.28k \quad W$$

$$T_{inside} - T_1 = QR$$

$$T_1 - T_2 = QR_{Pipe}$$
$$T_2 - T_3 = QR_{insulation}$$

$$T_3 - T_{Out} = QR_b$$

T_{inside} = 317 c T_{out}= 83.27 c

Conclusion

This analysis we have found out the temperature variation,Thermal Flux,Heat Flow, across Glare cylinder and surface temperature of a given composite cylinder using Ansys and theoretically. Both the solutions were almost equal. 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 for future work. Further, there is a lot of scope to develop hybrid combinations with advanced fibrous reinforcements. Already this research has initiated efforts towards realising some of the above for futuristic research and developmental programmes related to more focussed reliable use of these natural fiber composites for high-end and advanced industrial application areas.

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