THERMAL ANALYSIS OF HEAT TRANSFER THROUGH COMPOSITE WALL BY USING F.E.A. METHOD

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Abstract : It is very difficult to calculate and analyze with precision the thermal behavior of the walls of different materials attached to each other. The study of composite materials thermal behavior is useful for the determination of heat flux, temperature distribution, heat flow rate and thermal conductivity. These composite materials which can be implemented to many applications such as thermal ventilations, Insulators, metallic multiwall thermal protection systems, etc. In this study we are going to analyze the thermal behavior of four composites. For finding heat flux, temperature distribution, heat flow rate and thermal conductivity the finite element program method ANSYS is used. The experimental test is carried out for heat flux, temperature distribution, heat flow rate and thermal conductivity of composite materials.

Experimental Results are compared with the finite element ANSYS results and the validation is done.

***Key Words:* Thermal Conductivity, Composite Materials, Heat Flux, Conduction, Heat Flow Rate**

I. INTRODUCTION

The Study of composites is a philosophy of material design that allows for the optimum material composition along with structural design and optimization in one concurrent and interactive process. The scope of composite materials research and technology consists of Investigation of basic characteristics of the constituent and composite materials, Material optimization for given service conditions, Development of effective and efficient fabrication procedures and understanding of their effect on material properties. The amount of heat transferred per unit time is called heat transfer rate and is denoted by Q. The heat transfer rate has unit J/s which is equivalent to Watt. When the rate of heat transfer Q is available, then total amount of heat energy transferred ΔU during a time interval Δ t can be obtained form,

$$\Delta U = \int_0^{\Delta t} Q dt = Q\Delta t \text{(Joule)}$$

The rate of heat transfer per unit area normal to the direction of heat flow is called heat flux and is expressed as, q=Q/A.

II. OBJECTIVE OF WORK:-

The main objective of the present research work is to develop composite structure and to find the thermal behavior of that composite using Finite Element method, analytical method and Experimental method

Analytical method has been performed to obtain the relative values of temperature, heat flow rate and heat flux. After Analytical method, Experimental method has been performed to obtain the relative values of temperature, heat flux, heat flow rate and thermal conductivity. After analytical and experimental method, Finite Element Analysis has been performed to obtain the relative values of temperature, heat flow rate, heat flux and thermal conductivity. Finally a comparative study has been made between Finite Element Method and Experimental method.

III. METHODOLOGY:-

The experimental set up consists of three disks of equal diameters but variable thickness arranged to form a slab of same diameter and the heater ware placed at one side of composite wall. Three types of slabs are provided on heater which forms a composite structure.

Composition of materials:

1. MS-Hylum-wood
2. MS-Concrete-Fiber
3. MS-Fiber Glass-Brick
4. MS-Wood-Fiber Glass

Specifications:

Plate Dimensions:

Materials	Diameter (mm)	Thickness (mm)
MS	300	25
Fiber glass	300	20
Hylum	300	20
Wood	300	15
Brick	300	15

Concrete	300	15

Table 3.1:- Plate Dimensions

IV.MATHEMATICAL MODELING:-

The mathematical modelling is the idealization of the physical problems until defined set of (mathematical) constraints, representing the main features is established. Mathematical modeling is required not only in analytical work but also in actual heat- transfer practice, where a large commercial computer package is used.

T_1	T_2	T_3	T_4	Q (W)	q (W/m^2)
100	99.97	38.05	22.86	3.7202	52.6311
150	149.96	48.34	23.42	6.1050	86.3690
200	199.95	58.64	23.99	8.4898	120.106

Table 4.1:-MS-Hylum-Wood

T_1	T_2	T_3	T_4	Q (W)	q (W/m^2)
100	99.95	96.86	36.27	7.8519	111.08
150	149.92	144.85	45.42	12.885	182.28
200	199.89	192.84	54.57	17.918	253.49

Table 4.2:- MS-Concrete-Fiber Glass

T_1	T_2	T_3	T_4	Q (W)	q (W/m^2)
100	99.95	28.49	27.11	6.945	98.2562
150	149.93	32.66	30.39	11.397	161.24
200	199.90	36.82	33.67	15.849	224.225

Table 4.3:- MS-Fiber Glass-Brick

T_1	T_2	T_3	T_4	Q (W)	q (W/m^2)
100	99.96	71.63	31.45	5.206	73.653
150	149.95	103.46	37.53	8.5435	120.86
200	199.93	135.28	43.60	11.88	168.08

Table 4.4:- MS-Wood-Fiber Glass

V.EXPERIMENTATION:-

A composite slab consists of slab of three different materials which are MS, Hylum, & wood for one composite. There are such four composites of different materials. Slabs & heating element are circular in cross section. The instrument consists of three disks of equal diameters but variable thickness arranged to form a slab. The set up consists of a heater placed at one side of composite wall.

Experimental Result Table for Temperature Distribution:-

Sr. No.	Temperature	Q (W)	q (W/m^2)	K (W/m^0c)
1	100	5	70.82	0.0544
2	150	7.5	106.23	0.0497
3	200	9.0	127.47	0.0429

Table 5.1:-MS-Hylum-Wood

Sr. No.	Temperature	Q (W)	q (W/m^2)	K (W/m^0c)
1	100	8	113.31	0.0871
2	150	14	198.30	0.0929
3	200	18.6	263.45	0.0888

Table 5.2:- MS-Concrete-Fiber Glass

Sr. No.	Temperature	Q (W)	q (W/m^2)	K (W/m^0c)
1	100	7.3	103.39	0.0795

2	150	12.6	178.47	0.0836
3	200	16.8	237.96	0.0802

Table 5.3:- MS-Fiber Glass-Brick

Sr. No.	Temperature	Q(w)	q (W/m^2)	K (W/m^{0}c)
1	100	7.5	106.23	0.0817
2	150	9.5	134.56	0.0630
3	200	14	198.30	0.0668

Table 5.4:- MS-Wood-Fiber Glass

Experimental Result Table for Directional Heat Flux:-

Temperature (^{0}C)	MS-F-GB	MS-H-W	MS-C-FG	MS-W-FG
100	103.39	70.8	113.31	106.23
150	178.47	106.23	198.3	134.56
200	237.96	127.47	263.45	198.3

Table 5.5 Directional Heat Flux

Experimental Result Table for Heat Flow Rate:-

Temperature (^{0}C)	MS-F-GB	MS-H-W	MS-C-FG	MS-W-FG
100	7.3	5	8	7.5
150	12.6	7.5	14	9.5
200	16.8	9	18.6	14

Table 5.6 Heat Flow Rate

Experimental Result Table for Thermal Conductivity:-

Temperature (^{0}C)	MS-F-GB	MS-H-W	MS-C-FG	MS-W-FG
100	0.0795	0.0544	0.0871	0.0817
150	0.0836	0.0497	0.0929	0.063
200	0.0802	0.0429	0.0888	0.0668

Table5.7 Thermal Conductivity

VI.FINITE ELEMENT ANALYSIS:-

The finite element method is a numerical analysis technique for obtaining approximate solutions to a wide variety of engineering problems. Because of its diversity and flexibility as an analysis tool, it is receiving much attention in engineering schools and in industries. In more and more engineering situations today, we find that it is necessary to obtain approximate numerical solutions to problems rather than exact closed form solution.

ANSYS Result table for Temperature Distribution:-

Materials	T1	T2	T3	T4
MS-F-GB	100	99.95	28.49	27.12
MS-H-W	100	99.97	38.05	22.88
MS-C-FG	100	99.95	96.86	36.25
MS-W-FG	100	99.96	71.63	31.6

Table 6.1 Temperature Distribution at 100^{0}c

Materials	T1	T2	T3	T4
MS-F-GB	150	149.93	32.66	30.39
MS-H-W	150	149.96	48.34	23.45
MS-C-FG	150	149.92	144.85	45.42

MS-W-FG	150	149.95	103.46	37.82

Table 6.2 Temperature Distribution at 150^0c

Materials	T1	T2	T3	T4
MS-F-GB	200	199.9	36.82	33.67
MS-H-W	200	199.95	58.64	24.01
MS-C-FG	200	199.89	192.84	54.54
MS-W-FG	200	199.93	135.28	44.01

Table 6.3 Temperature Distribution at 200^0c

ANSYS Result table for Directional Heat Flux:-

Temperature (^{0}C)	MS-F-GB	MS-H-W	MS-C-FG	MS-W-FG
100	98.25	52.63	111.08	73.65
150	161.24	86.36	182.28	120.86
200	224.225	120.106	253.49	168.08

Table 6.4 Directional Heat Flux

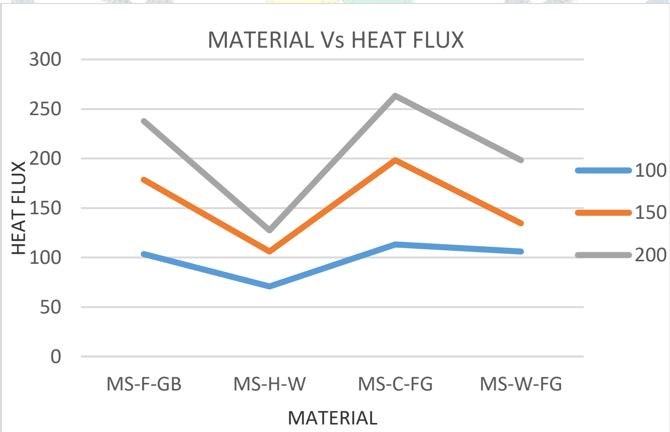
ANSYS Result table for Heat Flow Rate:-

Temperature (^{0}C)	MS-F-GB	MS-H-W	MS-C-FG	MS-W-FG
100	6.945	3.7602	7.8519	5.3114
150	11.397	6.1706	12.885	8.7162
200	15.85	8.5802	17.919	12.121

Table 6.5 Heat Flow Rate

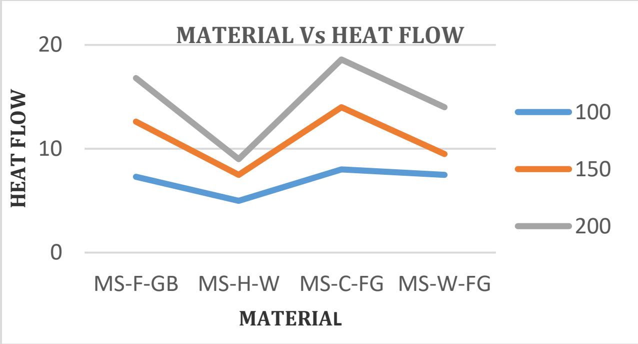
VII.GRAPHICAL RESULTS:-

Graphical Experimental Results of Materials Vs Heat Flux for all Composite Materials:-



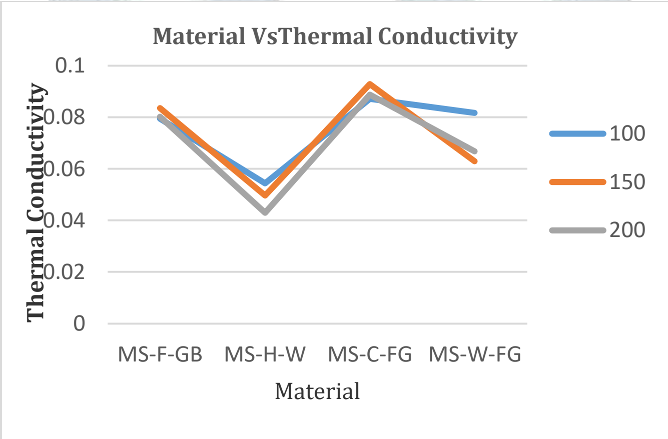
Graph 7.1 Materials Vs Heat Flux

Graphical Experimental Results of Materials Vs Heat Flow Rate for all Composite Materials:-



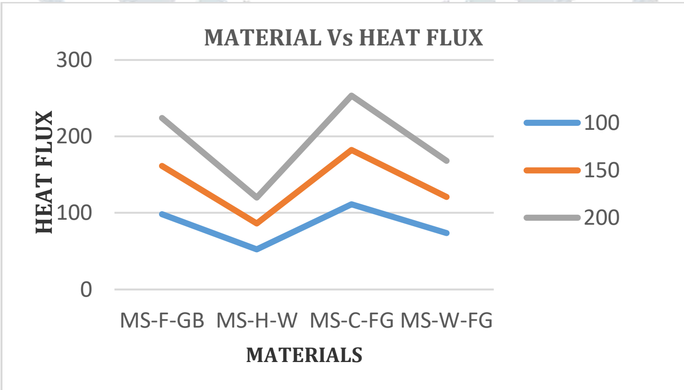
Graph 7.2 Materials Vs Heat Flow Rate

Graphical Experimental Result of Materials Vs Thermal Conductivity for all Composite Materials:-



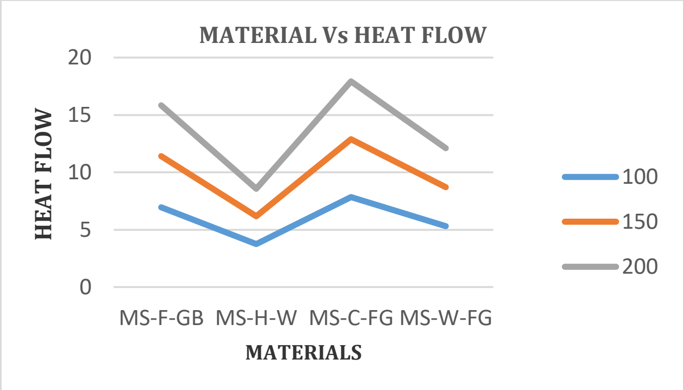
Graph 7.3 Materials Vs Thermal conductivity

Graphical ANSYS Results of Materials Vs Heat Flux for all Composite Materials:-



Graph 7.4 Materials Vs Heat Flux

Graphical ANSYS Results of Materials Vs Heat Flow rate for all Composite Materials:-



Graph 6.5 Materials Vs Heat Flow Rate

VIII. CONCLUSIONS:-

Based on the analytical, finite element and experimental investigation on the thermal behavior of different composites, it can be concluded that:

1) The results obtained from the proposed analytical method are in close approximation with the values obtained by FEM simulation using ANSYS.
2) The values obtained from the proposed analytical method are in close approximation with the values obtained from experimental values.
3) The study shows that the thermal conductivity of the composite material MS-Concrete-Fiber Glass is 0.0871MS-Fiber Glass-Brick is 0.0795 MS-Wood-Fiber Glass is 0.0817 &MS-Hylum-Wood is 0.0544
4) The study shows that the heat flow rate MS-Hylum-Wood is 5 MS-Concrete-Fiber Glass is 8MS-Fiber Glass-Brick is 7.3&MS-Wood-Fiber Glass is 7.5
5) The study shows that Heat flux of composite material MS-Hylum-Wood is 70.08 MS-Concrete-Fiber Glass is 113.31 MS-Fiber Glass-Brick is 103.39&MS-Wood-Fiber Glass is 106.23
6) The temperature distribution of MS-Hylum-Wood is 23.05 MS-Concrete-Fiber Glass is 370.2MS-Fiber Glass-Brick is 29.49&MS-Wood-Fiber Glass is 32.05
7) It is seen that the Finite element method (FEM) can be gainfully employed for determination of thermal behavior like heat flux, heat flow rate and temperature distribution of all composite walls.
8) Then it can be concluded that the composite MS-Hylum-Wood shows lower heat flux, temperature distribution, heat flow rate and thermal conductivity values than that of the other composites like MS-Concrete-Fiber Glass,MS-Fiber Glass-Brick &MS-Wood-Fiber Glass respectively.

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