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Experimental Investigation and Thermal Analysis of Round Structure Composite Wall Bricks

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***Abstract:** It is very difficult to calculate and analyze with precision the thermal behavior of the different materials attached. The study of composite material's thermal behavior is useful for the determination of heat flux, temperature distribution, heat flow rate, and thermal conductivity. These composite materials can be implemented in 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.
Keywords: Thermal Conductivity, Composite Materials, Heat Flux, Conduction, Heat Flow Rate

I. INTRODUCTION

A composite (or composite material) is defined as a material that consists of at least two constituents (distinct phases or combinations of phases) that are bonded together along the interface in the composite, each of which originates from a separate material that pre-exists the composite. Heat is a form of energy in transit due to temperature differences. Heat transfer is the transmission of energy from one region to another region as a result of temperature differences between them. Whenever there is a temperature difference in a medium so within a media, heat transfer must occur. The amount of heat transferred per unit of time is called the heat transfer rate and is denoted by Q. The heat transfer rate h as unit J/s which is equivalent to watt. When the rate of heat transfer Q is available, then the total amount of heat energy transferred ΔU during a time interval Δt can be obtained.

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

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. RELATED WORK

A lot of research is going on to study the heat transfer through composite. The research papers dealing with the thermal analysis of composite have been studied. Some of the research papers reviews are given below:

J. Raymond, et, studied thermal and ventilation performance in composite walls in traditional wood frame single houses. For a standard composite wall, the channel width and its surface emissivity are varied and their effect on the overall performance is evaluated. There is no optimum width to minimize heat transfer or to maximize the humidity transport.

Wei Chen explained heat transfer and flow in a composite solar wall with a porous absorber. The excess heat is stored in the porous absorber and wall by the incident solar radiation and there is a temperature gradient in the porous layer. Therefore, the porous absorber works as a thermal insulator to a degree when no solar shining is available.

Abdulaziz Almujahid1, et al, studied the heat transfer across building wall systems is now a globally important research topic that bears wide consequences on energy consumption as well as conservation in buildings.

Patrick Glouannec et al studied an experimental and numerical design of an insulation wall for refrigerated vans. The thermo physical properties of the insulating multilayer panel, the external environment impact (solar irradiation, temperature, etc.), and durability are taken into account. Different tools are used to characterize the thermal performances of the insulation walls and the thermal properties of the insulation materials are measured. In addition, an experiment at the wall scale is carried out and a 2D FEM model of heat and mass transfer within the wall is formulated. Three configurations are studied with this design approach.

Multilayer insulation walls containing reflective multi-foil insulation, aerogel, and phase change materials (PCM) are tested. Promising results are obtained with these materials, especially the reduction of peak heat transfer and energy consumption during the daytime period. Furthermore, the major influence of solar irradiation is highlighted as it can increase the peak heat transfer crossing the insulation wall by up to 43%. Wei Chen explained heat transfer and flow in a composite solar wall with a porous absorber. The unsteady numerical simulation is employed to analyze the performance of the flow and temperature field in the composite solar wall. The excess heat is stored in the porous absorber and wall by the incident solar radiation and there is a temperature gradient in the porous layer. Therefore, the porous absorber works as a thermal insulator to a degree when no solar shining is available. The influence of the porosity within the porous absorber on the airflow in the porous absorber is significant.

III. METHODOLOGY

In engineering applications, we deal with many problems. Heat Transfer through composite walls is one of them. It is the transport of energy between two or more bodies of different thermal conductivity arranged in series or parallel. For example, a fastener joining two mediums also acts as one of the layers between these mediums. Hence, the thermal conductivity of the fastener is also very much necessary in determining the overall heat transfer through the medium. A composite slab consists of a slab of three different materials which are MS, fiberglass, and brick for one composite and MS, Hylum, and Wood for another composite. Slabs & heating elements are circular in cross-section. The experimental setup consists of three disks of equal diameters but variable thickness arranged to form a slab of the same diameter and the heater was placed at one side of the composite wall. Three types of slabs are provided on the heater which forms a composite structure. A small hand-press frame was provided to ensure the perfect contact between the slabs. A dimmer stat was used for varying the input to the heater and the volt meter and ammeter readings were recorded. Thermocouples are placed between interfaces of the slabs, to read the temperature at the surface.

A. Composition of Materials

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

B. Specifications

Plate Dimensions:

Materials	Diameter (mm)	Thickness (mm)
MS	300	16
Fiberglass	300	19
Hylum	300	20
Wood	300	15
Brick	300	15
Concrete	300	15

Table 1: Plate materials and dimensions

A schematic representation of the experiment is shown in Fig. 2. It consists of different material wall bricks that have thermal conductivity variations

Fig. 2. Schematic representation of the Refrigeration system

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IV. EXPERIMENTATION

A composite slab consists of a slab of three different materials which are MS, Hylum, & wood for one composite. There are four composites of different materials. Slabs & heating elements are circular in cross-section. The instrument consists of three disks of equal diameters but variable thicknesses arranged to form a slab. The setup consists of a heater placed at one side of the composite wall and experimentation is done.

A. Experimental Result Table for Temperature Distribution

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

Table 4.1:-MS-Hylum-Wood

Sr. No.	Temperature	Q (W)	q (W/m2)	K(W/m0c)
1	100	8	113.31	0.0871
2	150	14	198.30	0.0929
3	200	18.6	263.45	0.0888

Table 4.2:- MS-Concrete-Fiber Glass

Sr. No.	Temperature	Q (W)	q (W/m2)	K (W/m0c)
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 4.3:- MS-Fiber Glass-Brick

Sr. No.	Temperature	Q(w)	q (W/m2)	K (W/m0c)
1	100	7.5	106.23	0.0817
2	150	9.5	134.56	0.0630
3	200	14	198.30	0.0668

Table 4.4:- MS-Wood-Fiber Glass

B. 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 4.5 Directional Heat Flux

C. 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 4.6 Heat Flow Rate

D. Experimental Result Table for Thermal Conductivity

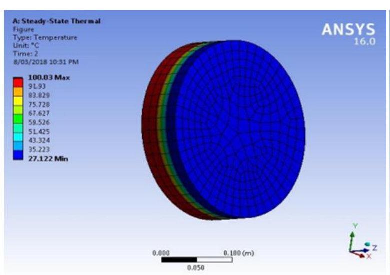
Temperature (^{0}C)	MS-F-GB	MS-H-W	MS-C-FG	MS-W-FG
100	0.0795	0.0544	0.0871	0.0817
150	0.0836	0.0497	0.0929	0.063
200	0.0802	0.0429	0.0888	0.0668

Table4.7 Thermal Conductivity

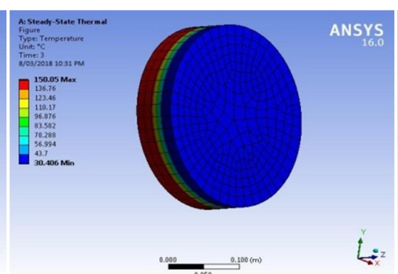
V. FINITE ELEMENT ANALYSIS

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 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 solutions.

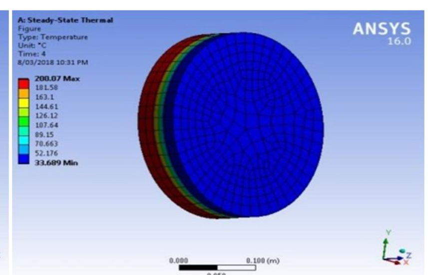
A. Temperature Distribution in MS-Fiber Glass-Brick



(At100 ^{0}C)

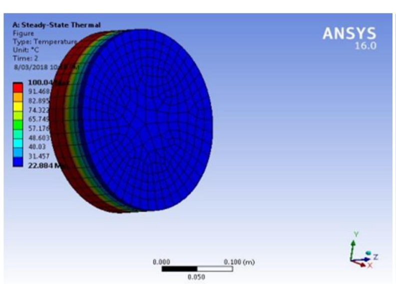


(At150 ^{0}C)

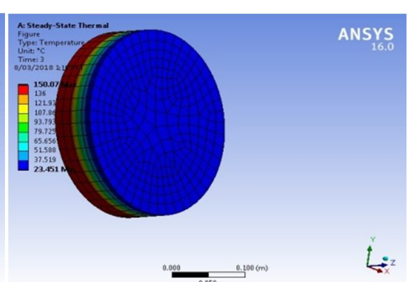


(At200 ^{0}C)

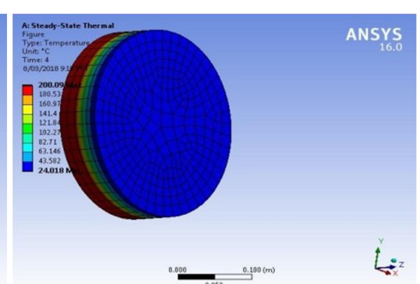
B. Temperature Distribution in MS-Hylum-Wood



(At100 ^{0}C)



(At150 ^{0}C)



(At200 ^{0}C)

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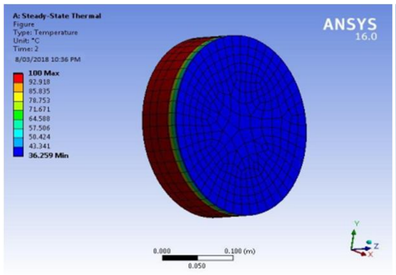
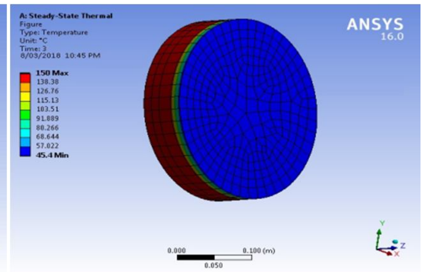
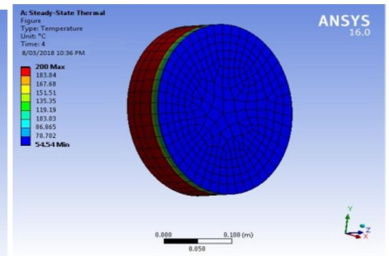
C. Temperature Distribution in MS-Concrete-Fiber Glass



(At100 ^{0}C)

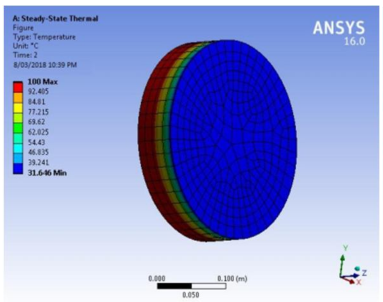


(At150 ^{0}C)

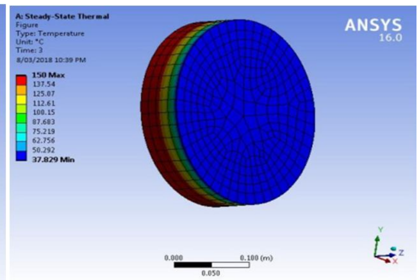


(At200 ^{0}C)

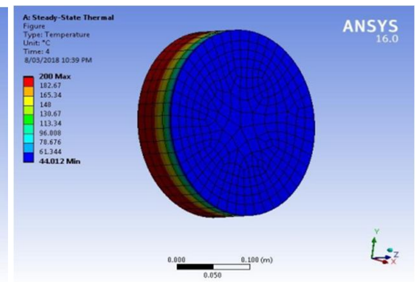
D. Temperature Distribution in MS-Wood-Fiber Glass



(At100 ^{0}C)



(At150 ^{0}C)



(At200 ^{0}C)

E. 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 5.1 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 5.2 Temperature Distribution at 150^{0}c

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 5.3 Temperature Distribution at 200^{0}c

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F. 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 5.4 Directional Heat Flux

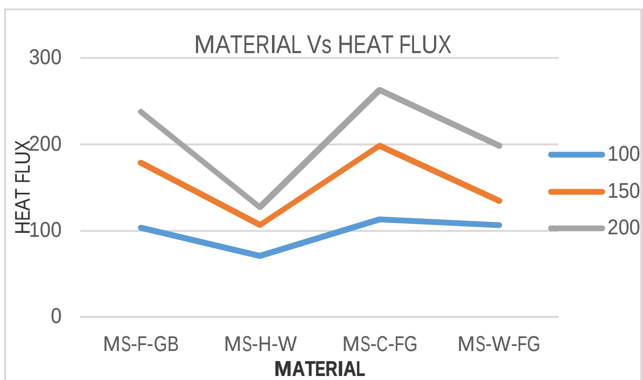
G. ANSYS Result table for Heat Flow Rate

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 5.5 Heat Flow Rate

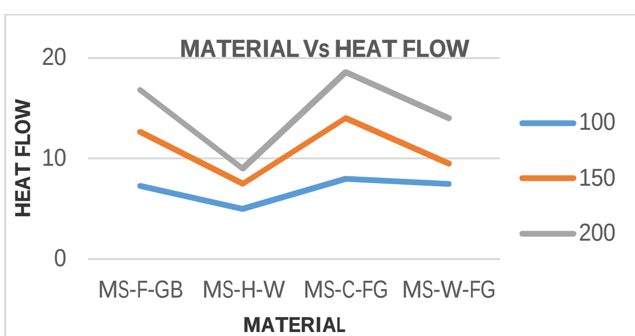
VI. GRAPHICAL RESULTS

A. Graphical Experimental Results of Materials vs. Heat Flux for all Composite Materials



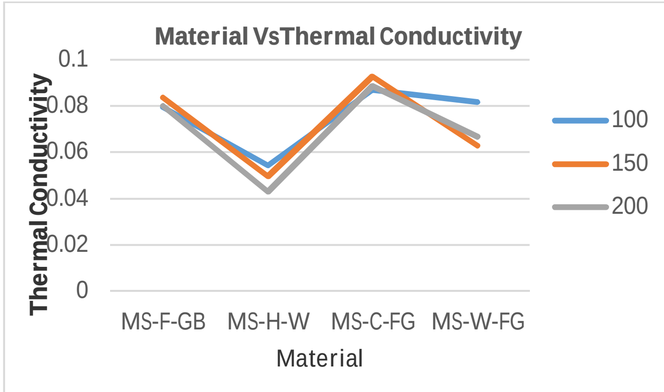
Graph 6.1 Materials Vs Heat Flux

B. Graphical Experimental Results of Materials vs. Heat Flow Rate for all Composite Materials



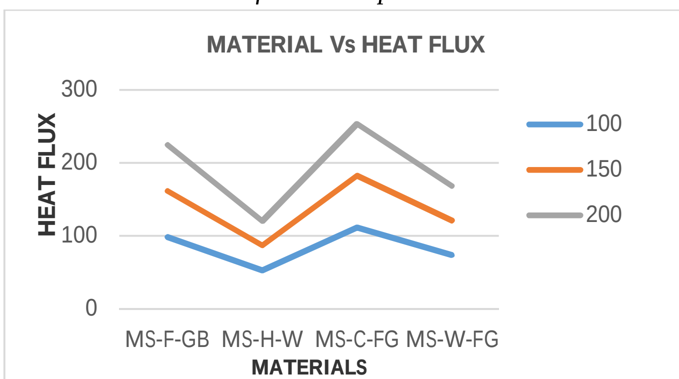
Graph 6.2 Materials Vs Heat Flow Rate

C. Graphical Experimental Result of Materials Vs Thermal Conductivity for all Composite Materials



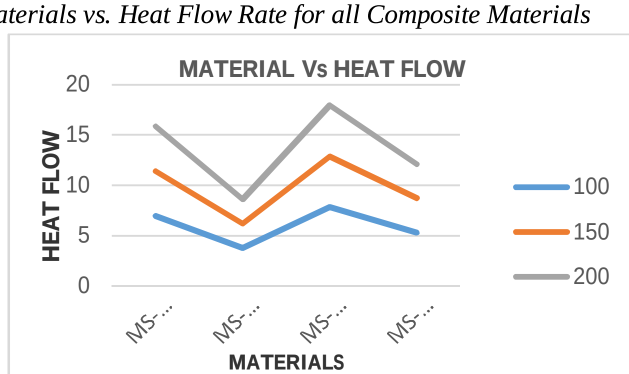
Graph 6.3 Materials Vs Thermal conductivity

D. Graphical ANSYS Results of Materials vs. Heat Flux for all Composite Materials



Graph 6.4 Materials Vs Heat Flux

E. Graphical ANSYS Results of Materials vs. Heat Flow Rate for all Composite Materials



Graph 6.5 Materials Vs Heat Flow Rate

VII. CONCLUSION

Based on the analytical, finite element, and experimental investigation of 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 the 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 the 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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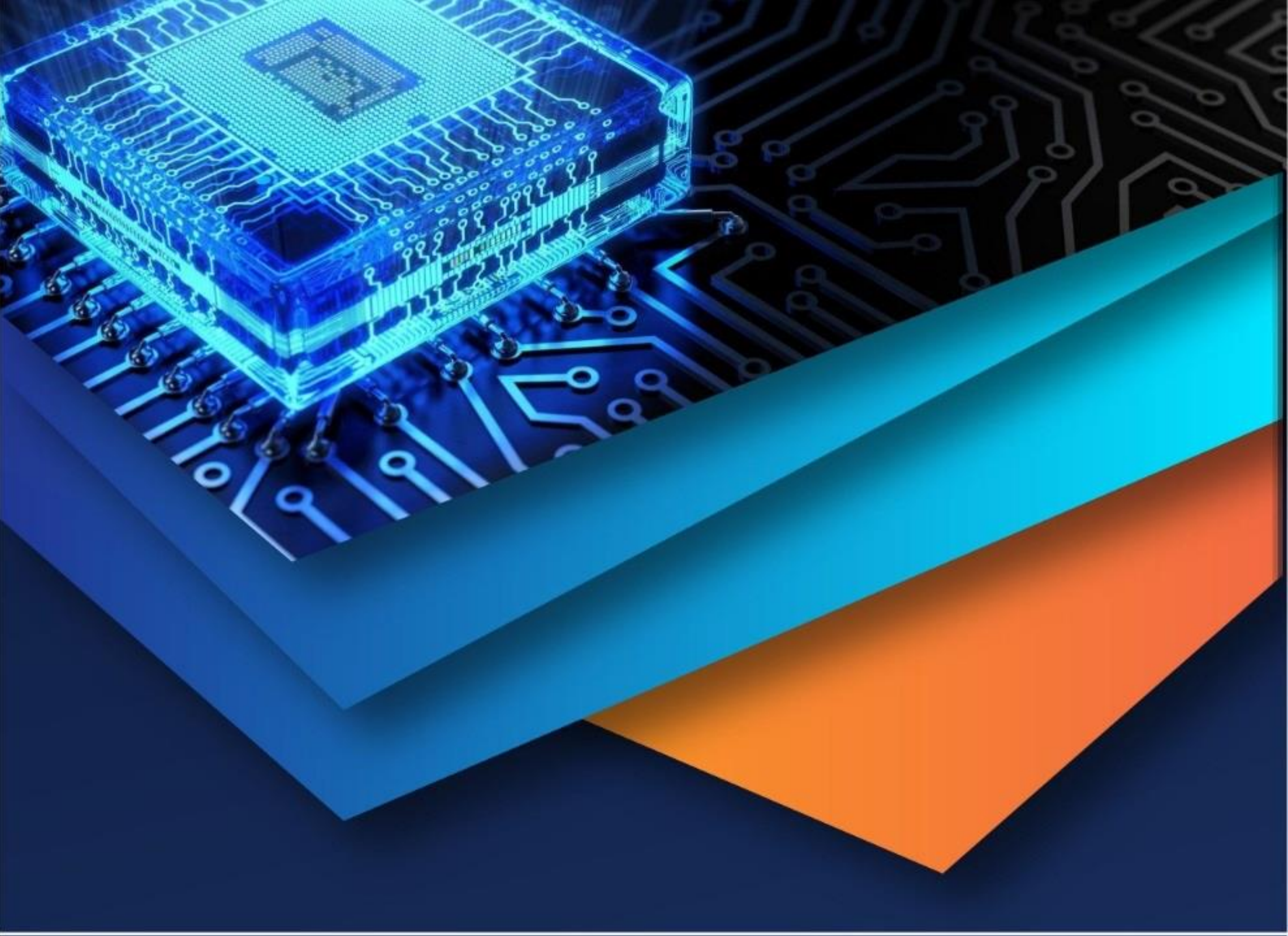

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