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Experimental Investigation of Thermal Properties of Coir-Based Epoxy Composites

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Abstract: ***Natural-fibre-reinforced polymer composites are being investigated for applications that require a balance of thermal response, manufacturability and material-resource efficiency. This study organizes and critically evaluates the thermal-property results reported for epoxy-based composites associated with coconut coir and glass fibre. The source apparatus comprises an aluminium–composite–plywood layered assembly, a nominal heater input of 30 W and nine temperature-measurement locations. Using the calculations recorded in the thesis, the reported thermal-conductivity estimates are 1.12, 0.91 and 0.89 W m^{-1} K^{-1} for specimens labelled as containing 4, 20 and 8 g of coir, respectively. A separate six-entry summary table reports conductivity decreasing from 0.90 to 0.68 W m^{-1} K^{-1} across nominal reinforcement levels 0–100, equivalent to a 24.4% endpoint decrease within that table. These two result groups are not directly comparable because the reinforcement basis and specimen mapping are not documented consistently. The specific-heat values also require recalculation because the source uses a power value without specifying heating duration or absorbed energy. The study therefore presents a transparent preliminary analysis, derives the relevant series thermal-resistance formulation and identifies the measurement records required for validation. The current evidence indicates variation among reported values but does not establish a statistically supported composition–conductivity relationship or confirm suitability for a specific insulation application.***

Keywords- coconut coir; epoxy composite; glass fibre; thermal conductivity; thermal resistance; thermal characterization; natural-fibre composite.

I. INTRODUCTION

Fibre-reinforced polymer composites combine a matrix with one or more reinforcement types to obtain a property balance that may be difficult to achieve with a single constituent. Natural fibres have attracted attention because of their availability and potential resource-efficiency benefits, while epoxy matrices are widely used in composite fabrication because of their adhesion and dimensional stability [1–4]. Coconut coir is a plant-derived reinforcement of particular interest in regions where coconut husk is readily available. Reviews of coir composites describe a broad range of processing routes and applications, but also emphasize that measured properties depend on fibre form, treatment, matrix, interfacial quality and manufacturing conditions [5,6].

For thermal applications, conductivity, heat capacity, diffusivity and thermal resistance describe different aspects of response. Conductivity quantifies steady heat transfer under a temperature gradient, whereas diffusivity depends on conductivity, density and specific heat. A low conductivity value alone is not sufficient to establish insulation performance or high-temperature durability [7–10]. The present work examines the numerical evidence available in the supplied thesis rather than claiming a new experimental campaign. Its contribution is a concise, traceable presentation of the reported setup and results, alongside an explicit assessment of their limitations.

A. Study objectives

The objectives are to

(i) document the layered test arrangement and governing equations,

(ii) report the conductivity values without merging inconsistent datasets,

(iii) assess whether the reported thermal properties can be verified from the available inputs, and

(iv) specify the corrections needed before drawing application-level conclusions.

II. BACKGROUND AND RELATED WORK

Natural-fibre composites are sensitive to reinforcement geometry, fibre–matrix interaction, moisture and fabrication quality. Foundational reviews by Faruk et al., Bledzki and Gassan, John and Thomas, and Pickering et al. establish the broad material-design context [1–4]. Coir-specific reviews provide more direct context for the present material system [5,6].

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Research on natural-fibre-reinforced epoxy composites and natural/synthetic hybrid systems further indicates that composition and processing must be documented together when comparing properties [7,8].

Thermal characterization requires particular care because the methods used to measure conductivity, heat capacity, thermal stability and dynamic mechanical response are not interchangeable. Neto reviewed thermal characterization of natural and hybrid fibre composites [9], while Thangavel et al. considered experimental and computational approaches for hemp- and jute-based composites [10]. Studies on flax/polypropylene laminates and natural-fibre insulation composites likewise show that microstructure and formulation influence heat transfer [11,12]. These results are supporting evidence; values reported for different fibres, matrices and specimen architectures should not be treated as direct reference values for coir/glass-fibre/epoxy specimens.

Closely related work has examined coconut-shell particles in epoxy, coir-powder-filled epoxy and epoxy composites reinforced with coconut coir and orange peel [13–15]. Shell particles, powder and longer fibres differ in morphology and packing, so their results are relevant to material selection but cannot validate the current specimens directly. Fibre treatment and fabrication are also important: chemical treatment, surface modification and manufacturing method can alter moisture response, wetting and interface quality [16–18].

For steady conduction, Fourier's law and a thermal-resistance network provide the basic analytical framework [19–21]. ASTM C177 and ASTM E1225 describe recognized approaches to thermal-transmission and conductivity measurement, respectively [22,23]. They are methodological references only; the available description does not demonstrate that the apparatus used here complies with either standard. Thermal degradation and fire response must also be considered separately from conductivity when an application involves elevated temperatures [24-26].

A. Research gap

The immediate gap is not a lack of general interest in natural-fibre composites, but the absence of a fully traceable chain connecting each specimen formulation to its temperature measurements, effective heat rate and calculated properties. The thesis contains three worked-example estimates and a separate summary series, but the composition basis and graph data are not reconciled. This manuscript retains that distinction and avoids asserting causality or statistical significance.

III. MATERIALS AND EXPERIMENTAL ARRANGEMENT

The source describes an epoxy resin and hardener, coconut coir and glass fibre. The resin/hardener ratio, coir treatment, glass-fibre quantity and orientation, specimen density, and curing schedule are not fully documented. These variables are summarized in Table 1 because they are necessary for reproducibility and for attributing any observed change to a particular reinforcement.

Table 1. Material and experimental details reported in the source and remaining traceability requirements.

Component/parameter	Information stated in source	Information requiring confirmation
Epoxy resin and hardener	Two-part system shown in photographs	Grade, density, batch and mass ratio
Coconut coir	Specimens labelled 4 g, 8 g and 20 g	Drying, treatment, fibre length and moisture
Glass fibre	Identified as a reinforcement	Mass fraction, form, orientation and distribution
Composite layer	Nominal thickness 6 mm	Actual thickness of each specimen and density
Heater / heat-flow area	Nominal 30 W; area 0.00385 m² appears in one calculation	Measured voltage/current, effective heat rate and verified area

The photographed arrangement is shown in Fig. 1. The thesis describes a layered assembly consisting of a 4 mm aluminium plate, a 6 mm composite specimen and a 4 mm plywood layer. Nine temperature locations (T1–T9) are listed, but their exact physical positions and the unit of the tabulated readings are not confirmed. Figure 2 presents the idealized heat path used to explain the calculation; it is a schematic, not a verified sensor map.



Fig. 1. Photograph of the experimental heating and temperature-measurement arrangement reproduced from the supplied thesis.

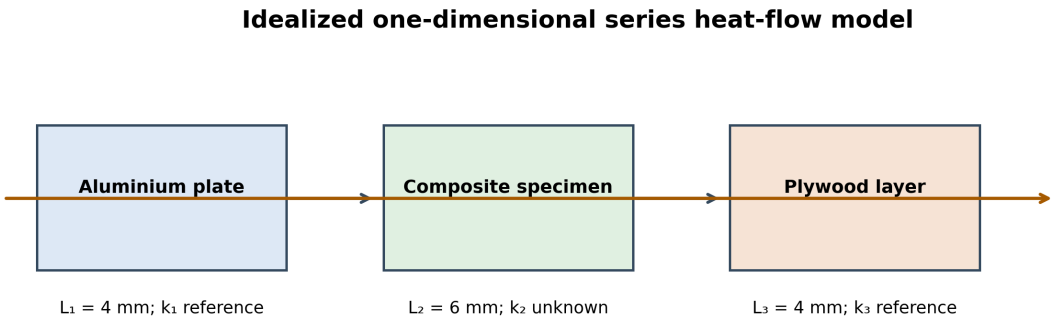

Fig. 2. Idealized one-dimensional heat-flow path through the aluminium–composite–plywood stack; sensor positions and contact resistance remain to be verified.

IV. MATHEMATICAL FORMULATION AND DATA HANDLING

A. Conductivity of a single layer

For steady, one-dimensional conduction through a homogeneous layer, Fourier's law gives:

$$\dot{Q} = \frac{kA(T_h - T_c)}{L}, \qquad k = \frac{\dot{Q}L}{A(T_h - T_c)}$$

where $\dot{Q}$ is the heat-transfer rate through the specimen, k is thermal conductivity, A is the heat-flow area, L is specimen thickness, and $T_h - T_c$ is the temperature difference across the layer. The equation assumes steady state, approximately one-dimensional heat flow and a known heat rate through the specimen.

B. Layered thermal resistance

For a layer i, the ideal conductive resistance is $R_i = \frac{L_i}{k_i A}$. For layers arranged in series, $R_{\text{total}} = \sum_i \frac{L_i}{k_i A}$, and the heat rate is $\dot{Q} = \frac{T_{\text{hot}} - T_{\text{cold}}}{R_{\text{total}}}$. The unknown composite conductivity can be isolated as:

$$k_2 = \frac{L_2}{A\left[\frac{T_{\text{hot}} - T_{\text{cold}}}{\dot{Q}} - \frac{L_1}{k_1 A} - \frac{L_3}{k_3 A}\right]}$$

This expression is valid only if the same heat rate crosses each layer and contact resistance and side losses are negligible or explicitly included. The nominal electrical input is not automatically the heat rate through the specimen:

$$P_{\text{elec}} = VI = \dot{Q}_{\text{specimen}} + \dot{Q}_{\text{loss}} + \frac{dU_{\text{fixture}}}{dt}$$

C. Related thermal properties

Thermal diffusivity is $\alpha = k/(\rho c_p)$, where ρ is bulk density and c_p is specific heat capacity. Specific heat requires energy, not power alone: $c_p = Q/(m\Delta T)$, with Q in joules. If constant power P is applied for time t, the supplied electrical energy is Pt; the energy absorbed by the specimen may be lower because of fixture storage and environmental losses. These relationships show why the source's specific-heat and diffusivity values cannot be validated without duration, density and heat-loss information.

D. Data handling

The conductivity values in the three worked examples were transcribed separately from the six-entry summary table. The original T1–T9 readings were not reinterpreted as independent replicates because the source does not specify whether the three rows per specimen are time points or separate specimens. No inferential statistical tests were performed, and no missing numerical values were reconstructed.

V. RESULTS AND DISCUSSION

A. Conductivity estimates from worked examples

The three worked calculations report conductivities of 1.12 W m^{-1} K^{-1} for the specimen labelled 4 g coir, 0.91 W m^{-1} K^{-1} for 20 g coir, and 0.89 W m^{-1} K^{-1} for 8 g coir. Figure 3 compares these source-calculated estimates. The 4 g-labelled specimen has the largest reported value, whereas the 20 g and 8 g values differ by 0.02 W m^{-1} K^{-1}. Because the formulation records are incomplete and the heat rate is not independently established, these values should be treated as reported estimates rather than validated material properties.

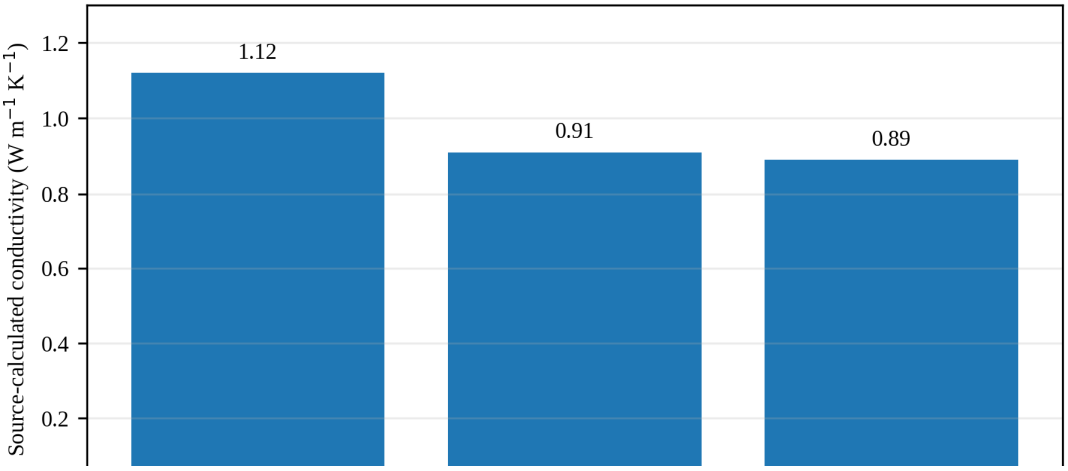

Fig. 3. Conductivity estimates transcribed from the three worked examples in the source thesis; values have not been independently validated.

B. Separate summary series

A separate summary table reports conductivity values of 0.90, 0.83, 0.81, 0.79, 0.75 and 0.68 W m^{-1} K^{-1} at nominal reinforcement levels 0, 20, 30, 40, 60 and 100. Table 2 reproduces the values and retains the source's reinforcement-level labels without assuming that they represent verified volume percentages. Within this series, the endpoint difference is −0.22 W m^{-1} K^{-1}, corresponding to a 24.4% decrease relative to the first entry. Figure 4 visualizes this reported sequence.

Table 2. Thermal-property values transcribed from the source summary table. Units for c_p and the definition/units of R are unresolved; α is reported with the stated scale.

Reported level	k (W m^{-1} K^{-1})	α (×10^{-6} m^2 s^{-1})	c_p (as reported)	R (as reported)
0	0.90	4.12	0.113	2.3041

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20	0.83	6.47	0.035	2.9710
30	0.81	7.50	0.010	3.3131
40	0.79	8.30	0.006	3.4552
60	0.75	10.70	0.004	3.9702
100	0.68	12.40	0.002	7.2512

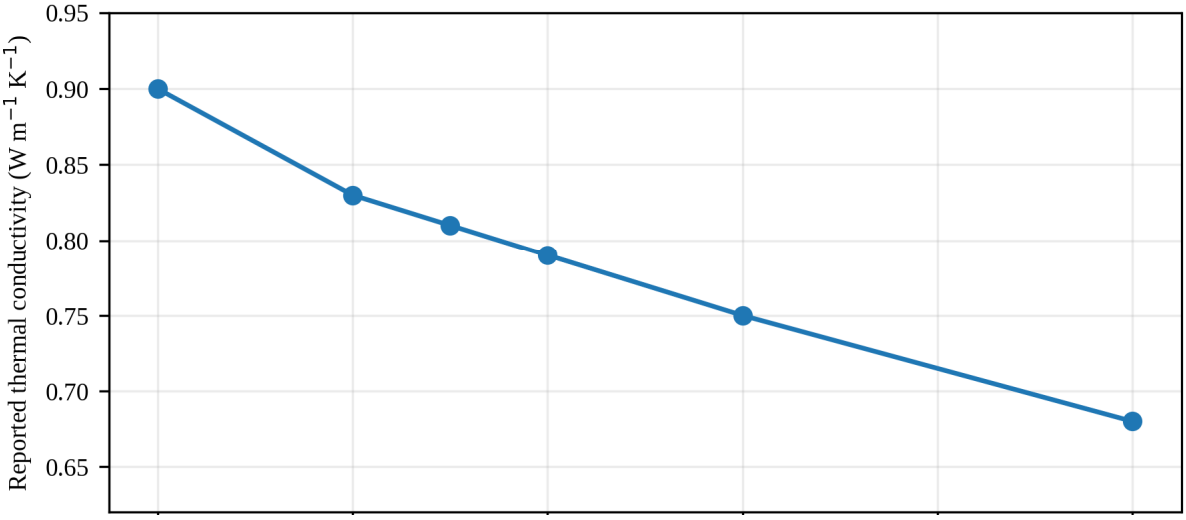

Fig. 4. Conductivity values from the separate summary table; the reinforcement-level basis requires confirmation

The two result groups should not be merged. The worked examples are labelled by coir mass, whereas the summary table uses a nominal level from 0 to 100. The source does not provide a specimen-by-specimen mapping between these datasets, and the supplied original graphs show a different trend and range. The discrepancy may reflect different experimental series, transcription, axis labelling or calculation procedures; the available record does not establish which explanation is correct.

C. Reliability of the reported thermal properties

The reported conductivity values cannot yet be regarded as definitive because the sensor map, boundary temperatures, actual heat rate, calibration details and uncertainty estimates are unavailable. The source describes a nominal 30 W heater input, but the fraction of this power crossing the specimen is unknown. The area of 0.00385 m² appears in one calculation, while the constants used in other examples are not fully derived. The layered resistance model is appropriate in principle, but its numerical application depends on verified geometry, reference conductivities and boundary measurements.

The summary table also lists diffusivity increasing from 4.12 to 12.40 × 10^{-6} m² s^{-1} as reported conductivity decreases. This is not necessarily physically impossible because diffusivity depends on ρc_p as well as k, but the values cannot be checked without density and valid specific heat. The listed c_p values range from 0.113 to 0.002, yet their units are unclear and the source calculation substitutes 30 W for Q without documenting a heating duration. Since watts measure power and joules measure energy, this calculation is dimensionally incomplete. The reported resistance values likewise require clarification as total resistance (K W^{-1}) or area-specific resistance (m² K W^{-1}).

D. Implications for composite insulation

The summary series suggests that conductivity decreases across its reported reinforcement levels, but the unverified level basis and disagreement with the worked examples prevent attributing this pattern to coir fraction. A low conductivity estimate relative to metals is not enough to demonstrate practical insulation suitability. Comparisons should use reference materials tested under comparable conditions, and any intended application should define acceptable conductivity, moisture response, mechanical integrity, durability and service temperature.

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E. Data quality and corrective actions

Table 3. Principal data-quality issues and the actions needed before quantitative claims are finalized.

Issue identified	Consequence	Required action
Unclear composition basis	Cannot isolate coir effect or compare specimens	Record coir, glass fibre, resin and hardener masses; calculate fractions from verified densities
Unmapped T1–T9 readings	Temperature drop across composite is uncertain	Provide a dimensioned drawing and identify sensor positions, units and calibration
Nominal power used as heat rate	Conductivity may be biased by losses and thermal storage	Measure voltage/current, define steady state and estimate heat losses using a reference test
Inconsistent graphs and tables	Trend cannot be reconciled or replicated	Recover the source spreadsheet and regenerate all plots from one master dataset
Specific heat/diffusivity inputs incomplete	Derived properties cannot be verified	Measure density; use energy in joules and document heating time or measure c_p independently
No replicate/uncertainty record	No basis for statistical significance	Test independent specimens and report mean, spread and uncertainty

These issues do not invalidate the value of the preliminary experiment; they define the evidence required to convert the reported calculations into reproducible measurements. The first priority is recovery of the laboratory notebook and original spreadsheet, followed by formulation traceability and validation of the heat balance.

VI. CONCLUSIONS

This manuscript has organized the available experimental record for epoxy-based composites associated with coconut coir and glass fibre and evaluated the reported thermal-property calculations. The source's worked examples give conductivity estimates of 1.12, 0.91 and 0.89 W m^{-1} K^{-1} for specimens labelled as containing 4, 20 and 8 g of coir. A separate summary table reports conductivity decreasing from 0.90 to 0.68 W m^{-1} K^{-1} across six nominal levels, a 24.4% endpoint decrease within that table. These datasets have been retained separately because the specimen mapping and reinforcement basis are not documented consistently.

A layered thermal-resistance model was stated to show how composite conductivity may be calculated from geometry, boundary temperatures and heat rate. Its application remains conditional on steady one-dimensional conduction, verified layer dimensions, known reference properties, a mapped sensor arrangement and correction for contact resistance and heat loss. The specific-heat calculation is dimensionally incomplete because the source uses a power value without a documented time interval, and the diffusivity and resistance values therefore require verification.

Accordingly, the available evidence supports only a preliminary assessment that the reported formulations exhibit different thermal responses. It does not establish a validated optimum composition, statistical significance, or suitability for a particular insulation application. The immediate next steps are to reconcile the raw data, document every formulation, measure actual electrical input and heating duration, calibrate the temperature sensors, repeat tests on independent specimens and report uncertainty. Only after these steps should the final conductivity, specific heat and diffusivity values be used for material selection.

VII. ACKNOWLEDGMENT

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VIII. CONFLICT OF INTEREST

The author(s) should declare any financial or personal relationships that could influence the work, or state that no competing interests exist.

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IX. DATA AVAILABILITY

The underlying temperature observations and summary values are reproduced from the supplied thesis. The original spreadsheet, complete specimen formulations, calibration records and sensor map were not available in the supplied material and should be archived or provided as supplementary material when recovered.

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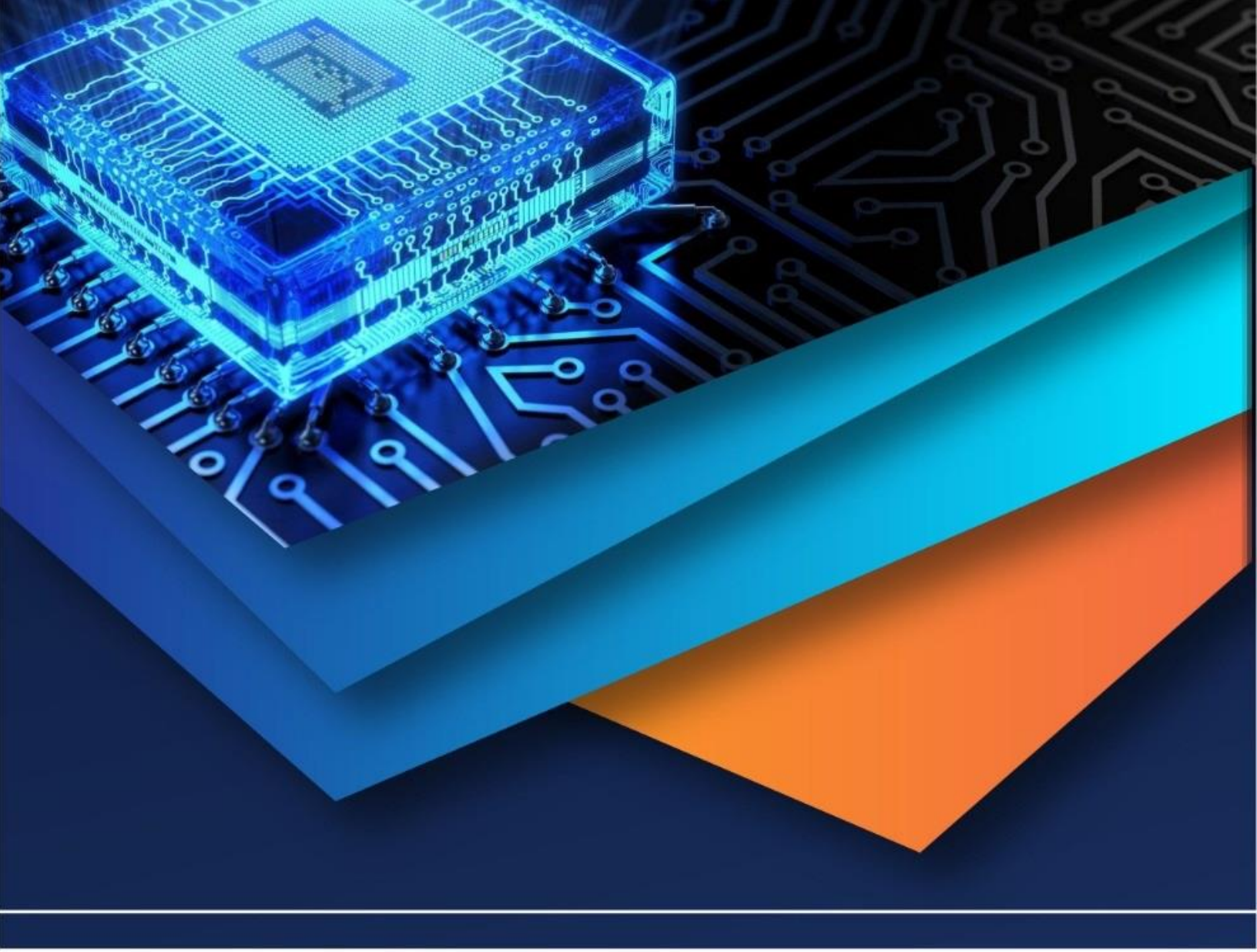

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