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Impact Characterization of Fiber/Foam Reinforced Polymer Nanocomposites

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Abstract--Synthetic foam is light weight engineered foam which is incorporated in polymer matrix. The synthetic foam structure gives several advantages such as low density, high strength and low co-efficient of moisture absorption. It also possess good amount of tailor ability and can be casted into intricate shape. In this study, sandwich panels were fabricated with syntactic foam and 4-layered woven roving glass fiber/epoxy nanoclay composite laminates. The nanocomposites laminates were prepared by varying the nanoclay at a loading of 0, 1,2,3,4% by weight. The structure of the prepared nanocomposites is characterized by Scanning Electron Microscope (SEM) to find the quality of dispersion. High velocity gas gun impact test had been conducted at the velocity 130m/s. From the impact test the fracture surface area had been calculated. The impact surfaces were analyzed using SEM. The SEM image clearly showed a good interface bonding with fibre and synthetic foams when addition of nanoclay. So the better interface bonding reduces the damaged area.
Keywords: E-glass fiber, Synthetic foam epoxy resin, nanoclay, SEM.

I. INTRODUCTION

Syntactic foams are composite materials in which the matrix phase is reinforced with hollow particles called microballoons. They possess low moisture absorption, low thermal conductivity and high damage tolerance because of their compositions. Traditionally, syntactic foams are used in many high strength applications such as in aerospace and marine industries, thus there is a need to achieve both high compressive strength and high fracture strain with minimal increase in density [1]. Investigated the influence of carbon fiber reinforced epoxy composites were modified with 2 wt. % Montmorillonite nanoclay and 0.3 wt% multi-walled carbon nanotubes (MWCNTs). 3 point bending test, Dynamic Mechanical Analysis (DMA) and low velocity impact test (LVI) were conducted for characterizing modified samples [2]. Epoxy-polymer will be discussed first, followed by this epoxy polymer being modified by the addition of simple polymeric-modifiers and then by core–shell rubber particles [3]. Composites filled with varying concentrations of fly ash, aluminum oxide (Al2O3), magnesium hydroxide (Mg(OH)2) and hematite powder were fabricated by standard method and the mechanical properties such as ultimate tensile strength, impact strength and hardness of the fabricated composites were studied. The test results show that composites filled by 10% volume Mg (OH) 2 exhibited maximum ultimate tensile strength and hardness. Fly ash filled composites exhibited maximum impact strength [4].Glass-reinforced composites improved with addition of nano clay in epoxy matrix. This test was performed by impact testing machine, it was found that addition of 5wt% of nano clay shown very good results compare to other percentage of nano clay [5]. Dynamical mechanical analysis indicated that addition of TiO2 particles into nylon 6 matrix increased both the storage modulus and the glass transition temperature[6].Hybrid fabrics are made by combining different types of glass and strand compositions together, such as using high-strength glass strands or small diameter filaments in the longitudinal direction and less costly strands woven across the fabric. Hybrid glass fibers improve the mechanical properties and reduce the cost [7].Jinian Yang the foaming qualities of composites were remarkably improved in the presence of either PP-g-MAH or EOC-g-MAH. The best samples were achieved with minimum average cell diameters and maximum cell densities, when the content of either PP-g-MAH or EOC-g-MAH was added up to 8%. Increased compatibilizers promoted the wettability of PP to SGF, and PP-g-MAH showed the more obvious influence on enhancing SGF–polymer interfacial bonding that that of EOC-g-MAH Mechanical tests claimed that mechanical properties, except for compression strength, were all strengthened with growing compatibilizers. It was emphasized that EOC-g-MAH had much advantage of improving the impact toughness, whereas the PP-g-MAH was more beneficial of increasing the flexural and compression strength of SGF/PP foam composites [8].

II. EXPERIMENTAL

A. Materials and Sample Preparation

Volume 4 Issue V, May 2016
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The matrix material was Diglycidyl ether of Bisphenol-A in the trade of LY 556 and the curing agent is Tri-ethylenetetra amine of HY 951. Glass fiber of woven roving mat (WRM) with density of 610 g/m^2 is used in the present work. The primary step of the fabrication process involved dispersion of Nanoclay into epoxy resin. The Nanoclay was mixed into epoxy resin and mixture is stirred for 2hrs at 800 rpm using high speed mechanical stirrer. By applying a mechanical high shear dispersion process it was possible to distribute nanoparticles homogeneously within the matrix. As a next step, (10%) hardener was added into the epoxy-nano mixture and the stirring process continued for about 10 minutes. The nanocomposites laminates is prepared by hand lay-up techniques. The laminates of glass fiber reinforced with epoxy resin were prepared by hand layup method. The samples are cut into standard size for high velocity gas gun set up method. Shows the preparation of laminates by hand layup method Fig. 1.

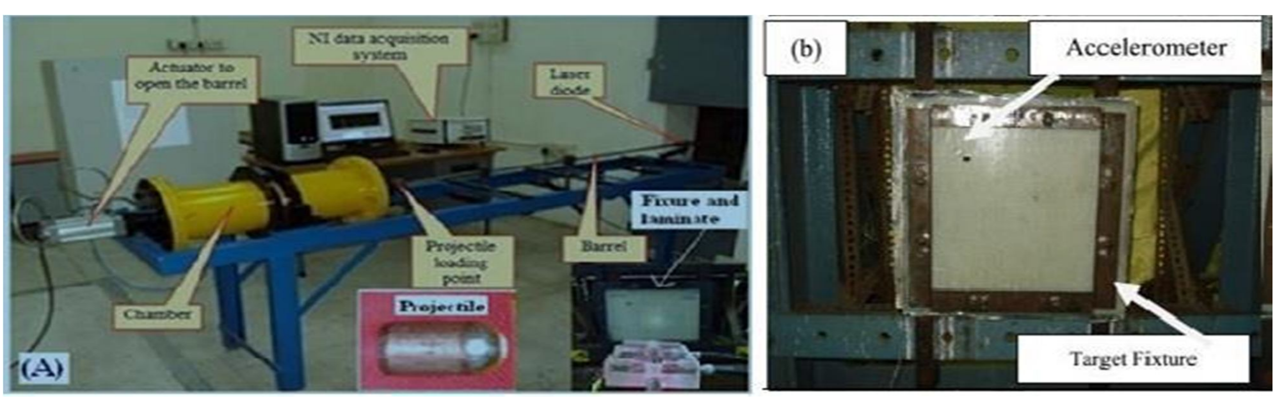
Fig. 1. Preparation of laminates by hand layup method

B. Scanning Electron Microscope (SEM)

The morphologies of the nanocomposites samples were observed by scanning electron microscope (HITACHI S-3400N) at different magnifications. The surfaces were then coated with a thin gold film to increase their conductance for SEM observation.

C. Gas Gun Impact Test Setup

An attempt was made to explore some of the simplest experimental ways of assessing the impact response and vibration damping characteristics of a material, in particular, GF/Al/Nanoclay/epoxy resin laminate panels, due to their importance on the subject of damage detection and modelling. ASTM E 756-04, standard test method, was referred for determining impact vibration damping characteristics of fiber reinforced hybrid nano-composite panels. This standard measures the damping properties such as loss factor (η) and Young's modulus 'E' or shear modulus 'G'. Composite laminate is a viscoelastic material, hence, viscoelastic damping, most common form of damping employed to solve noise and vibration related problems. It is a passive-based material (or viscoelastic) damping, usually in the form of add on treatments applied to a structure. The actual test set-up is shown in Fig.2 (a) whereas the schematic set-up is shown in Fig.2 (c). Meaningfully, the system comprises a powerful compressed gas gun, target holder, data acquisition system (DAS) and display units for measuring the time response of impacted panel vibration and velocity of the bullet. The DAS comprises signal processor, de-coder and matcher and amplifier along with optical velocity pick up. The panels (150 mm×150 mm) were fixed vertically in the target holder (fixture) by nuts and bolts in all the four sides as shown in Fig16 (b). The accelerometer KS80D weighing 70 g was fixed to the plate in the slot provided at the top right corner with the help of nut to measure the time response. The National Instruments Data Acquisition System (DAS) was used to pick up the dynamic parameters.



Volume 4 Issue V, May 2016
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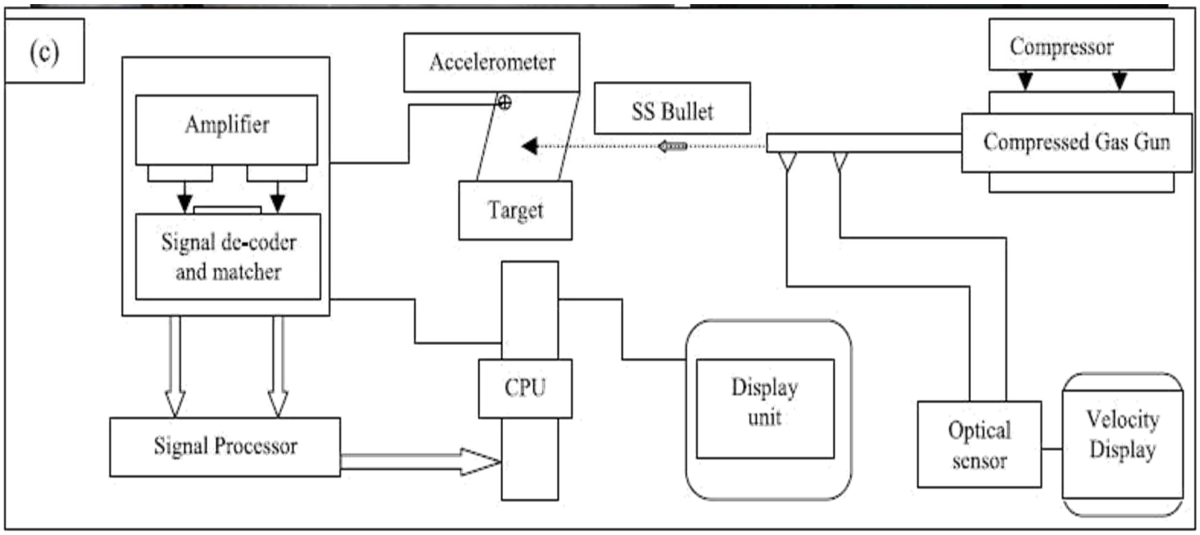

Fig.2 Actual test set-up (a), the target holder (b), and the schematic (c).

D. Syntactic Foams

Syntactic foams are composite materials in which the matrix phase is reinforced with hollow particles called micro balloons. Fig 3.They possess low moisture absorption, low thermal conductivity and high damage tolerance because of their compositions. Traditionally, syntactic foams ae used in many high strength applications such as in aerospace and marine industries, thus there is a need to achieve both high compressive strength and high fracture strain with minimal increase in density.

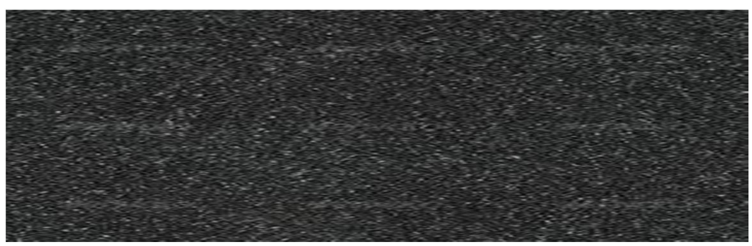

Fig. 3. Syntactic foam

III. RESULT AND DISCUSSION

A. Scanning Electron Microscopy (SEM)

The SEM technique was used to investigate the surface morphologies of the prepared samples. The surface morphologies of the nanoclay, the fabricated polymer nanocomposite laminates were examined under scanning electron microscope of model HITACHI S3400N. The structure of the 3wt % of nanoclay mixed with epoxy resin was shown in fig.3 and detailed a massive layered structure with some large flakes and some inter layer spaces. It is observed that uniform bonding and dispersion of nanoclay powder in the epoxy resin. This interfacial bonding structure improves the adhesive property between fiber and the syntactic foam

Pullout of fiber

Volume 4 Issue V, May 2016
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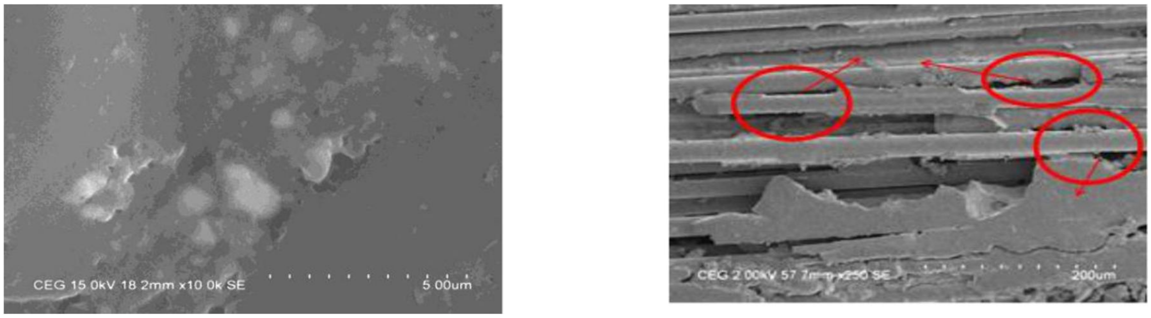


(a) b)

Fig.4 Structural morphology of (a) 3wt % of nanoclay in epoxy resin and surfaces of (b) 4wt % of nanoclay laminates.

From fig. 3(b) the formation of voids and the pullout of fibers were observed at 4wt % of nanoclay in the laminates. This is due to improper bonding between the filler and reinforcement materials. This type of surfaces provides interlinear failures on the laminates when the load applied on it. To avoid this type of formations proper mixing and uniform dispersion of filler materials in the resin was carried out. At 4wt % of nanoclay powder, due to less amount of filler content and minimized surface area distribution on the matrix face the formation of voids and pullout of fibers where observed.

3.2 Impact Properties of laminates in Fracture Area

(a) (b) (c) (d)

Fig.5 Fractography of front face at 130m/s (a) neat, (b) 1 wt%, (c) 3 wt% and (d) 4 wt% nanoclay samples

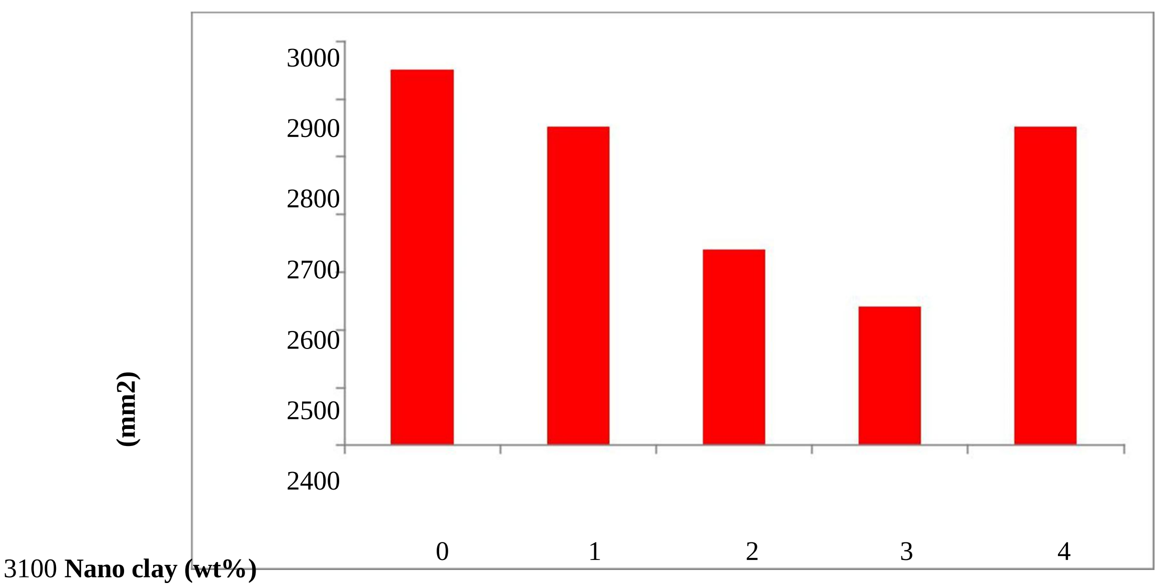
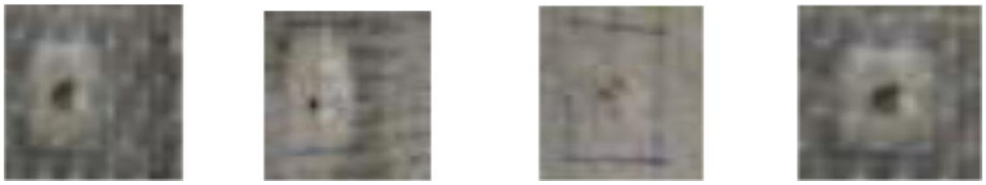
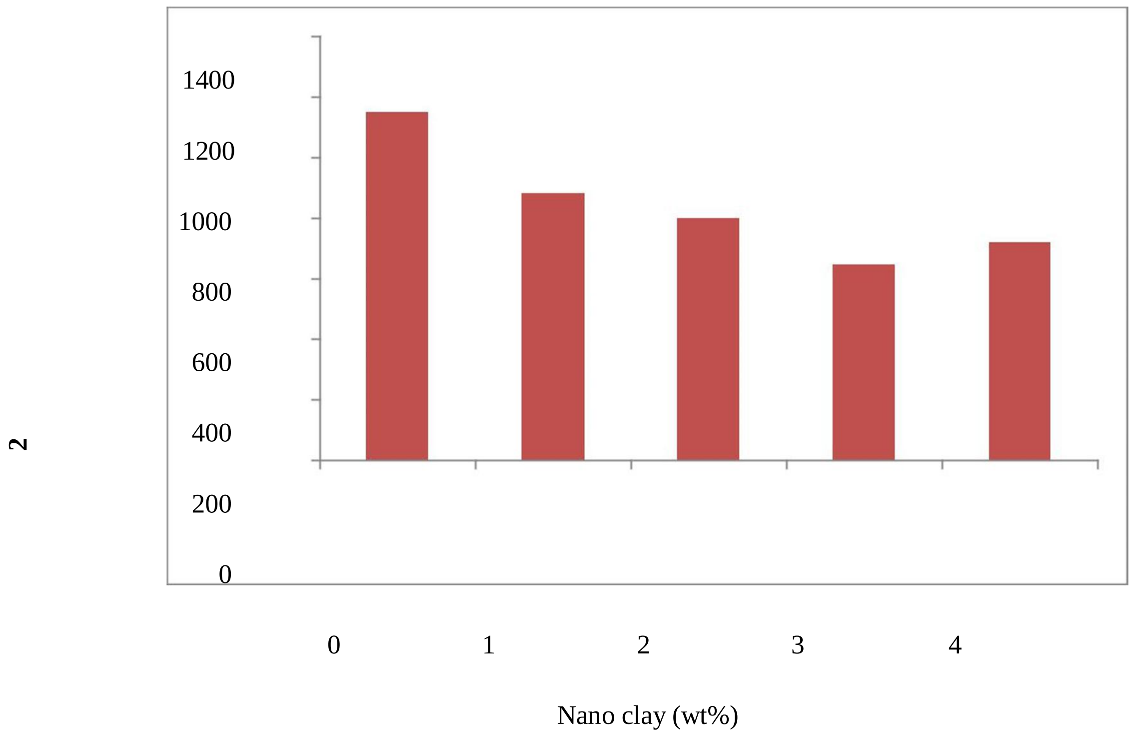


Fig. 6 Area of front surface fracture



(a) (b) (c) (d)

Fig.7 Fractography of back face at 130m/s (a) neat, (b) 1 wt%, (c) 3 wt% and (d) 4wt% nanoclay samples



International Journal for Research in Applied Science & Engineering Technology (IJRASET)

Fig.8 Area of back surface fracture

The damage on the front face was similar for all the samples, a circular indentation or round damage was recognized. The failure modes on these specimens are shown in Figure 5. The damage on the front face was similar for all the samples, a circular indentation or round damage was recognized. The failure modes on these specimens are shown in Fig 5. For the laminate impacted at 130m/s by a cylindrical impactor, there was extensive damage in the front face consisting of fibre breakage, penetration and delamination, and also propagation of surface crack. As seen from the image of damaged nanocomposites samples in Fig 5 (b) and (c), the failure mechanisms were surface cracks and minor matrix cracking. The Fractography of the back faces of the damaged nanocomposites samples as illustrated in Fig 6. It was observed that although neat epoxy sample survived extensive damages, it also gave into matrix cracking, delamination and surface splitting as in Figure 7 (a). The delamination area had expanded due to the weak interfacial bonding between fibre and matrix. However, the damage modes of the nanoclay samples involved a combination of matrix cracking and surface splitting as represented in Fig 7 (b) and (c).

From the Fig 6 it shows the front surface damage area had been controlled for the laminates with 3% nanoclay but for the laminates with 4% nanoclay the damaged area had been increased. From the Fig.7, shows the back surface damage area. Similar to front surface the back surface also the 3% laminates are showing the failure area had been controlled. The nanoclay samples penetration did not occur on the back face and the modes of failure were a combination of matrix cracking and surface splitting as represented in Fig.7 (b) and (c).

From the image of damaged 3 wt% sample (Fig7 (b)), it was observed that glass fibers adhered completely with the resin due to good interfacial bonding between fibre and matrix. It clearly indicates that on addition of nanoclay, progression damage was reduced and the hemispherical impactor failed to penetrate on the back face. Hence, it can be concluded that the nanocomposites samples offer a better protection against penetration than pure epoxy sample. The presence of stiffer nanoclay significantly reduced the surface cracks propagation and controlled delamination area on the back faces of the nanocomposites samples.

IV. CONCLUSION

The fabrication of nano composite laminates were successfully prepared by hand lay-up techniques.

Five laminates of varying weights of nanoclay such as 1, 2, 3 and 4 wt% and neat epoxy (without nanoclay) were successfully prepared.

Structural morphology of prepared laminates were examined under scanning electron microscope (SEM)

The SEM images obtained from the (3wt %) region that nanoclay were uniformly dispersed with the epoxy resin.

The surface failures of 1wt % of nanoclay mixed laminate detailed about the formation of voids and pullout of fibers due to less dispersion and improper bonding.

The addition of nanoclay improved the impact properties. From the results it clearly shows the nanocomposite with 3 wt% clay has higher impact strength.

The fracture area was controlled by the addition of nanoclay and 3 wt% clay nanocomposite was less when compared with other laminates.

It is observed that reduction of impact strength for concentration of 4 wt% nanoclay filled sample was due to agglomeration of clay in the matrix.

The optimum values are achieved at 3 wt% of nanoclay is added in the glass fibre /synthetic foam/epoxy nanocompositesn

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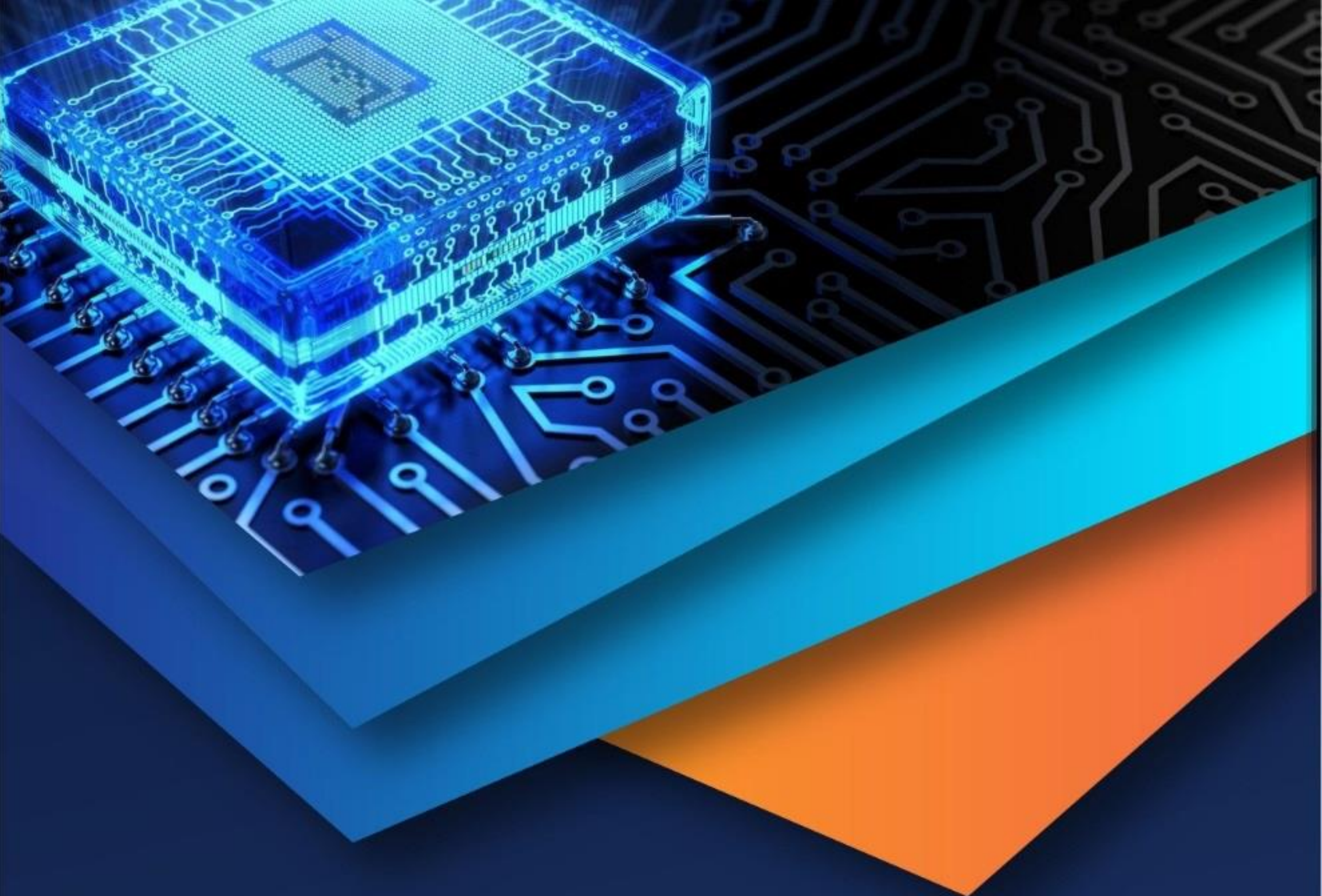

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