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Design and Fabrication of Bicycle Frame Using Fiber Reinforced Plastic

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Abstract: ***The basic objective in this research paper is to design and fabricate the bicycle frame. The geometry of the frame is triangular which consists of three hollow structural elements which bear the load. The dimensions of the frame and the reaction forces are calculated using the principles of engineering mechanics. The material used for the frame is Glass Fibre Reinforced Plastic (GFRP). The orientation of the glass fibre is along the length of fibre direction i.e., zero degrees with reference to the tube axis. Additional cloth wrapping is also considered in order to reduce the crushing loads. The volume fraction of fibre should be minimum 50 percent. The manufacturing method used in fabrication of the frame is Pressure Bag Moulding. Metallic tooling and metallic joints are used in the moulding of the hollow structures. Pressure bag moulding is similar to the vacuum bag moulding method except that air pressure, usually 30-50 psi, is applied to a rubber bag or polythene tubular film which forces the composite layer to be in touch with the inside profile of the tool. Composite materials increase the speed of the cycle and also increase its strength and durability. Thus a composite frame which is 3 times stronger than steel and 4 times lighter than steel will have a higher efficiency and such bicycles come under the category of advanced bicycles.***

Keywords: ***Glass fibre reinforced plastic, Pressure bag moulding, fibre, fibre direction, volume fraction, polythene tubular film.***

I. INTRODUCTION

Bicycles have been part of everyday life for more than 100 years now. They constituted a vital means of transportation. International racers are continually seeking frames which perform better in order to ultimately achieve higher speeds for the same amount of frame energy input. In order to achieve this goal, advanced composite materials have been used in making of frames for some years now. However, in order to design and fabricate a frame with these materials, a thorough engineering knowledge of composite materials and the means of analysing the structure as a complex bicycle frame are essential. A bicycle frame should have low weight, high lateral stiffness and moderate vertical stiffness. Because of chain load, frame undergoes lateral deformation during pedalling. This lateral deformation is larger when the rider pushes on right pedal (a pro rider may apply a force up to two times his weight). Most of the bicycles built today utilize heat treated alloy steel or aluminium or titanium alloy tubing to minimize their weight. The tubes are then welded together to create the desired frame geometry. [1] Historically, the most commonly used material for the tubes of a normal bicycle is the alloy steel. Alloy steel is steel to which other alloying elements have been intentionally added to modify the characteristics of steel. The alloying elements include Manganese, Nickel, Chromium, Molybdenum, Boron, Titanium, etc. Using these high performance alloys the cost of the bicycle increases. Generally Carbon steel frames are fairly inexpensive. Occasionally, diamond shaped frames have been formed from sections other than tubes. [1]

Composite materials are the materials that have a combination of two or more materials (reinforcing elements, fillers, composite matrix, binder), differing in form or composition on a macro scale. Rather, they are a judicious mixture of the reinforcement and the matrix. Composites composed of reinforced fibres and matrix has high strength-to-weight ratio and high stiffness-to-weight ratio. The unique advantages over monolithic materials are high strength, high stiffness, low density, corrosion resistance, wear resistance, and environmental stability [2]. Due to above advantages of composites, the laminated fibre-reinforced composite materials such as carbon/epoxy or glass/polyester composites are widely used in aircraft, aerospace, military, automotive, marine and sports applications. In the design process of the bicycle, the structural analysis of the frame is a very important stage. With the aid of Engineering Mechanics analysis the numerical calculations such as the forces in each member can be predicted. These force calculations can be used in finding the stresses in each member of the frame. The ANSYS software usually plays a major role in determining stresses and deformations in the frame for the given load conditions.

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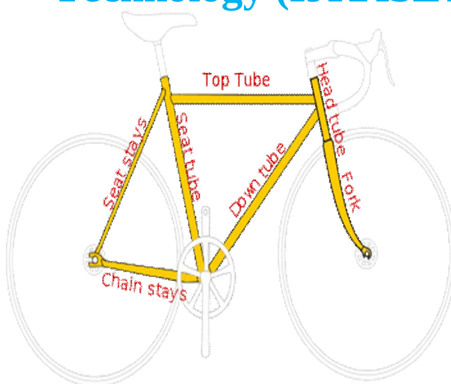

Fig 1: Bicycle with fame tubes.

II. MATERIAL SELECTION

For the fabrication of the bicycle frame, we have considered E-Glass as the fibre, the unidirectional cloth for increasing the strength of each tube of the bicycle frame. We have also used general purpose resin as the reinforcing phase.

A. Fibre-E glass

Glass fibre is formed when thin strands of silica-based or other formulation glass is extruded into many fibres with small diameters suitable for textile processing. These are useful because of their high ratio of surface area to weight. However, the increased surface area makes them more susceptible to chemical attack. Glass fibre has roughly comparable mechanical properties to other fibres such as polymers and carbon fibre. Although not as strong or as rigid as carbon fibre, it is much cheaper and significantly less brittle when used in composites. Glass fibres are therefore used as a reinforcing agent for many polymer products; to form a very strong and relatively lightweight fibre-reinforced polymer (FRP) composite material called glass-reinforced plastic (GRP), also popularly known as "fiberglass". This structural material product contains little or no air or gas, is denser, and is a much poorer thermal insulator than is glass wool. The most common types of glass fibre used in fiberglass is E-glass, which is alumino-borosilicate glass with less than 1% w/w alkali oxides, mainly used for glass-reinforced plastics. E-glass does not actually melt, but softens instead, the softening point being "the temperature at which a 0.55–0.77 mm diameter fibre 235 mm long, elongates under its own weight at 1 mm/min when suspended vertically and heated at the rate of 5 °C per minute". The strain point is reached when the glass has a viscosity of 1014.5 poise. This E-glass cloth has high strength, high stiffness, relatively low density, good electrical insulation and is non-flammable, resistant to heat.

Composition of the E-Glass fibre

	E-Glass with boron	E-Glass without boron
SiO_2	56%	59%
Al_2O_3	16%	13%
B_2O_3	7%	-
CaO	20%	23%
MgO	5%	3%
Na_2O	1%	0.7%
K_2O, F_2, Fe_2O_3	0.2%	0.2%

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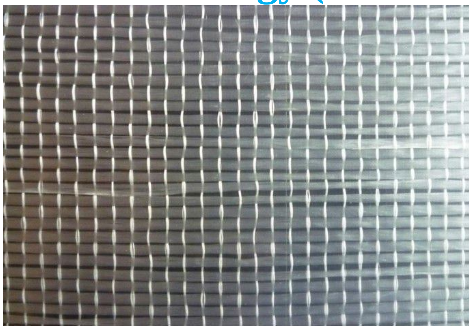

Fig 2: E-Glass Fibre

B. Uni-directional cloth (UD cloth)

The UD cloth is used in order to increase the strength of the tube of the bicycle frame. A unidirectional (UD) fabric is one in which the majority of fibres run in one direction only. A small amount of fibre or other material may run in other directions with the main intention being to hold the primary fibres in position, although the other fibres may also offer some structural properties. True unidirectional fabrics offer the ability to place fibre in the component exactly where it is required, and in the optimum quantity (no more or less than required). As well as this, UD fibres are straight and uncrimped. This results in the highest possible fibre properties from a fabric in composite component construction. For mechanical properties, unidirectional fabrics can only be improved on by prepreg unidirectional tape, where there is no secondary material at all holding the unidirectional fibres in place.

C. Construction of the UD cloth

There are various methods of maintaining the primary fibres in position in a unidirectional including weaving, stitching, and bonding. As with other fabrics, the surface quality of a unidirectional fabric is determined by two main factors: the combination of tex and thread count of the primary fibre and the amount and type of the secondary fibre. The drape, surface smoothness and stability of a fabric are controlled primarily by the construction style, while the area weight, porosity and (to a lesser degree) wet out are determined by selecting the appropriate combination of fibre tex and numbers of fibres per cm.

Warp or weft unidirectional can be made by the stitching process (see information in the 'Multiaxial' section of this publication). However, in order to gain adequate stability, it is usually necessary to add a mat or tissue to the face of the fabric. Therefore, together with the stitching thread required to assemble the fibres, there is a relatively large amount of secondary, parasitic material in this type of UD fabric, which tends to reduce the laminate properties.

Furthermore the high cost of set up of the 0° layer of a stitching line and the relatively slow speed of production means that these fabrics can be relatively expensive.

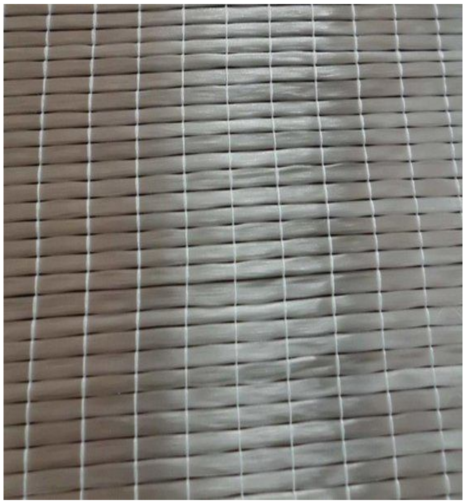

Fig 3: Uni-directional cloth

III. DESIGN OF BICYCLE FRAME

The basic parts in order to design the bicycle frame are the top tube that connects the top of the head tube to the top of the seat tube,

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down tube that connects the head tube to the bottom bracket shell, seat tube that contains the seat post of the bike, which connects to the saddle, chain stays that run parallel to the chain, connecting the bottom bracket shell to the rear fork ends or dropouts, seat stays connect the top of the seat tube (often at or near the same point as the top tube) to the rear fork dropouts, bottom bracket shell is a short and wide tube, relative to the other tubes in the frame that runs side to side and holds the bottom bracket. In this particular technical paper, we design the top tube, seat tube, down tube. [2]

A. Dimensions of the frame

Type of tube	Length of the tube	Outer diameter of the tube	Inner diameter of the tube	Thickness of the layup
Down tube	65cm	3.0cm	2.2cm	0.4cm
Seat tube	52cm	3.0cm	2.2cm	0.4cm
Top tube	60cm	3.0cm	2.2cm	0.4cm

Table 1: Dimensions of the frame

The fibre used is 0.5 mill E-glass, 2.75 mill UD cloth, 0.25 E-glass and 0.5 mill E-glass alternatively. Four layers of above mentioned fibre are applied to obtain a thickness of 0.4cm.

B. Force Calculations for each element

The forces on each member of the bicycle frame are determined with the help of Engineering Mechanics concepts, taking into consideration the length of each tube and the angle made with each tube.

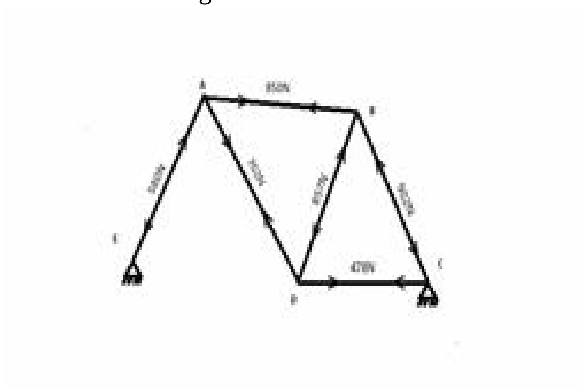

Fig 4: Forces on each element

The forces on each member are tabulated as follows:

Member	Force value	Type of force
AB	850N	Tensile
BD	857N	Compression
AD	702N	Tensile
BC	902N	Compression
CD	478N	Tensile
AE	580N	Compression

Table 2: Forces for each member of the frame

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C. Stress calculations on the three composite members

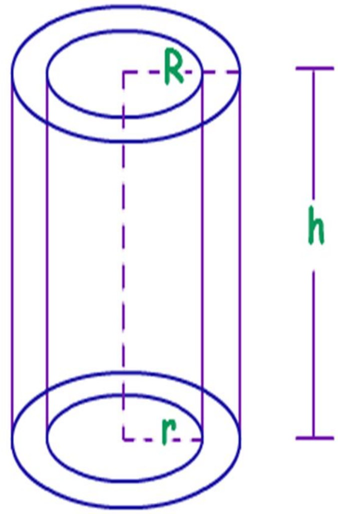

Fig 5: Frame rod

R = 15mm; thickness = 4mm
r = 22mm; h = 4feet

Member	Stress value
AB	$2.6N/mm^2$ (Tensile stress)
BD	$2.62N/mm^2$ (Compressive stress)
AD	$2.14N/mm^2$ (Tensile stress)

Table 3: Stresses on each member

From the properties of E glass fibre table mentioned earlier. We have yield stress 10-20 MPa.
We know that Working stress = yield stress / factor of safety. Taken factor of safety 2 for bicycles, we obtain the working stress as $5N/mm^2$. Finding the maximum load that can be bared.

Working stress = force / area of the composite tube

$5 = F/ \pi (R^2-r^2)$

$5 = F/326.7$

$F = 1633.5N$

On the 3 composite rods the maximum force was 857N which is less than the maximum force that can withstand (857N<1633.5N). So the bicycle frame is safe for the applied load.

IV. FABRICATION OF THE BICYCLE

A. Manufacturing method

The manufacturing method of the bicycle frame is the "Pressure bag moulding". This process is related to vacuum bag moulding in exactly the same way as it sounds. A solid female mould is used along with a flexible male mould. The reinforcement is placed inside the female mould with just enough resin to allow the fabric to stick in place (wet layup). A measured amount of resin is then liberally brushed indiscriminately into the mould and the mould is then clamped to a machine that contains the male flexible mould. The flexible male membrane is then inflated with heated compressed air or possibly steam. The female mould can also be heated. Excess resin is forced out along with trapped air. This process is extensively used in the production of composite helmets due to the lower cost of unskilled labor. Cycle times for a helmet bag moulding machine vary from 20 to 45 minutes, but the finished shells require no further curing if the moulds are heated.

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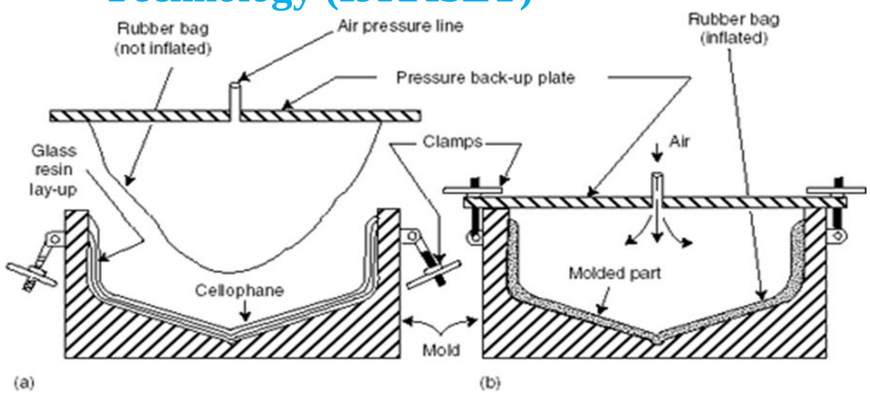

Fig 6: Pressure bag moulding

B. Manufacturing procedure

The materials used in the manufacturing of the bicycle frame are E-glass cloth, UD cloth, general purpose resin, Plaster of Paris, accelerator, and hardener.

C. Tube manufacturing

Draw the required shape of the component on a ply wood piece and prepare a tool. Prepare a mixture of Plaster of Paris (POP), water and little amount of salt for faster cure. Using the above prepare a specimen and leave it to cure. For the mould preparation mix 200 grams of GP resin, 10ml accelerator, and 200 grams chalk powder. Stir until a thick mixture is obtained.

Fig 7: Tube manufacturing

D. Component preparation and fitting

E-Glass cloth, UD cloth are placed alternatively after applying resin and hardener. Take a pressure bag and insert a mandrel of 21mm. Now close the mould, fix the two halves with fasteners, supply constant pressure of air into the pressure bag such that it pushes the component to the walls of mould and leave it to cure. Separate the mould and remove the mandrel and pressure bag from the component. Cut the component into desired lengths. Now the three tubes made in the similar process are fixed to the bicycle using welding process.

Fig 8: Component fitting

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V. COST AND WEIGHT ANALYSIS

In order to decide whether the composite made bicycle frame is effective in terms of cost and weight, we perform the cost and weight analysis for the composite material and compare it with the original material of the bicycle, i.e. alloy steel.

A. E-Glass cloth

The three rods that are used for the frame building of the bicycle are 4 feet rods in height. We require 4 layers of E-glass cloth for every rod of the frame and for every layer we require 100 grams of cloth and 100 grams of resin. For each layer we need a total of 200 grams of both cloth and resin. This implies that therefore, for 4 layers we need a total of 800 grams of both resin and cloth. Therefore, the 3 rods of bicycle frame weigh 2.4kg. The E-glass cloth costs Rs 160/- per kg, then four layers of E-glass cloth costs Rs 64/-. Similarly, 1000 grams of resin costs Rs 90/-, then 4 layers of resin costs Rs 36/-. The total cost of both cloth and resin for rod costs Rs 100/-. The total cost of three rods costs Rs 300/-.

B. Alloy steel

From the pre-requites, the density of alloy steel is 8 gram/cc. Mass of alloy steel rod = 1.4kg. Therefore, the mass frame of bicycle consisting of 3 rods is 4.2 kg. Also, the alloy steel costs about Rs 120/- per kg.Therefore, from the cost and weight analysis, the weight of the bicycle reduces by 38% and cost reduces by 25%.

VI. CONCLUSION

By using E-glass fibre the bicycle frame produced is of 3.3 kgs which is less when compared to the bicycle frame manufactured by alloy steels, with more applications and properties. The cost of the bicycle frame made is around 300 rupees which is less than that of normal bicycle frame. Due to better applications and properties to that of a normal bicycle frame with low cost and weight, these glass fibre bicycle frame comes as future source of bicycles. By replacing the alloy steel with E-glass fibre, tensile strength increases by six times when compared to alloys steel. Also, composites are less noise while in operation and provide lower vibration transmission than metals, they exhibit excellent corrosion resistance.

REFERENCES

[1] Sagar Paradeshi, Pankaj Desle, “Design and Development of Effective Low Weight Racing Bicycle Frame”, International Journal of Innovative Research in Science, Engineering and Technology, Volume 3, Issue 12, December 2014.

[2] Arun Sam Varghese, Sreejith N.K., “Structural Analysis of Bicycle Frame Using Composite Laminate”, International Journal of Engineering Trends and Technology, Volume 28, October 2015.

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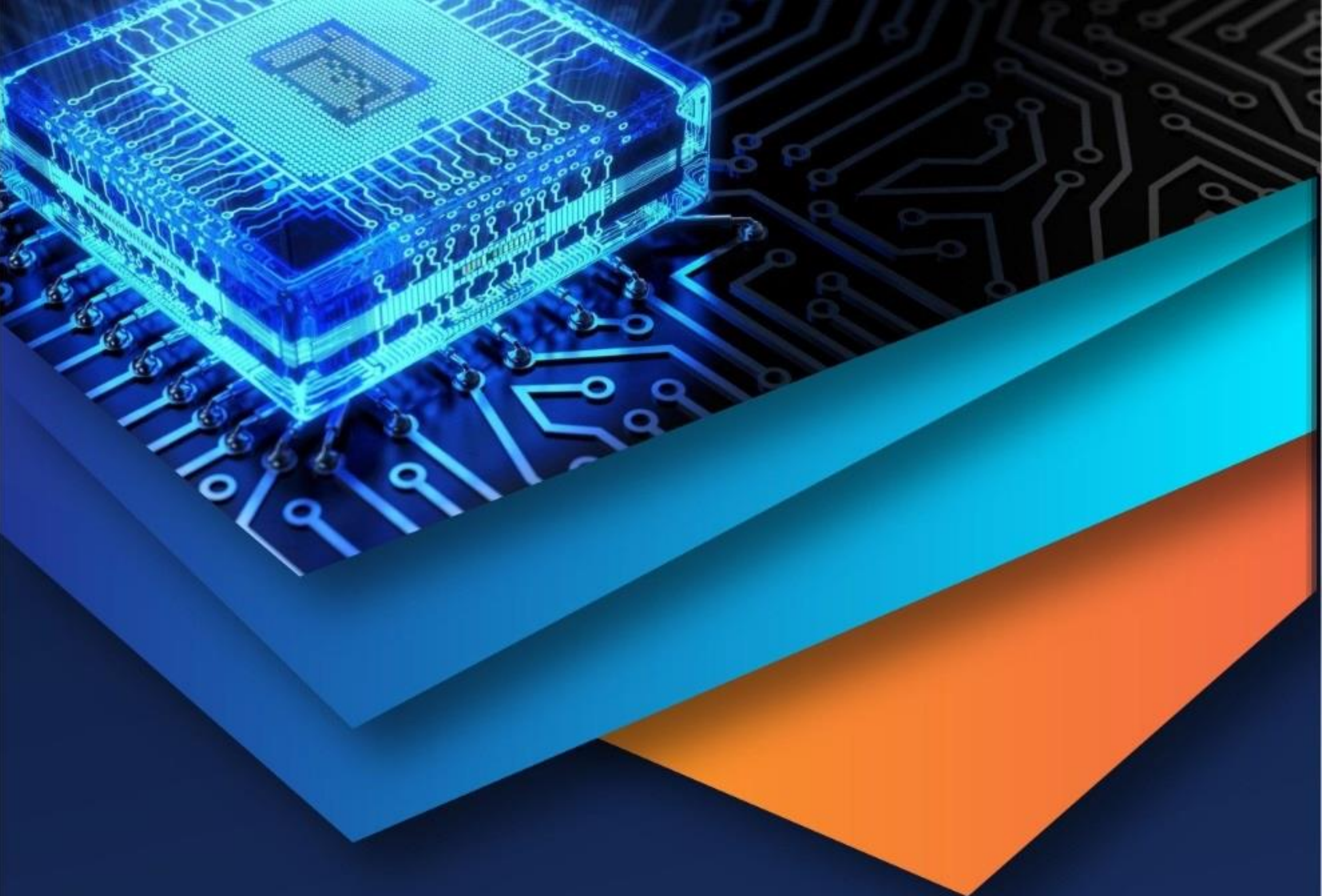

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