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A Review on the Use and Application of Polymer Composites in Automotive Industries

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Abstract: Early the use of composite materials in a large-scale commercial application started during the World War II that is in late 1940s and early 1950s with marine applications for the military; but today, composite products are manufactured by a variety of industries. The increase in environmental concern has enhanced concern to reduce the carbon emission, to make the transport system more economical and with a concern to maximise the fuel efficiency with a interest to combat fuel shortage across the globe the vehicle manufacturers across the globe is focusing their attention on the use of alternative material to reduce the body mass of the vehicles, it is learnt that the metal in white which is made of sheet metal accounts to an amount of 30-65% of weight of the vehicle. With an emphasis to reduce the vehicle mass the use of composite material specifically the use of polymer composites for commercial application begin in the early sixties. Presently the major users of polymer composites are the, Automobile industries, Aerospace industries, Marine industries, Chemical industries, Transportation and logistics industries, Construction industries etc. the use of polymer laminated composite in automobile industry has drastically increased in the recent decade due to their superior specific property, which has led to low fuel consumption, higher passenger/load carrying capacity and decreased maintenance cost. Currently the major players in the automotive industries are using polymer based composites to an extent of 30-60% of the overall material; considerably the use of laminated composites is increasing from day to day. The increase in the consumption of the polymer composite in automotive industry is mainly because of the development of knowledge and technology about these materials which has enhanced material property like high strength to weight ratio, higher stiffness to weight ratio, improved fatigue resistance, corrosion resistance, higher resistance to thermal expansion, excellent optical and magnetic properties, wear resistance, toughness etc.,. In early days the use of polymer composites was limited only to secondary structural applications; their use in primary structural application has increased. The use of thermoplastics in place of thermosetting plastics is increasing due to its extensive mechanical properties and capabilities of recycling. The present paper presents a comprehensive review on the use of polymer composites and emphasises the application and use of polymer composites in automotive industries. This review article may help the automotive industry in exploring the possibilities of using the composites in many more automotive components.

I. INTRODUCTION

A composite material is a combination of two or more chemically different materials with a distinct interface between them. It has properties and characteristics that are enhanced from its constituent materials though constituent materials maintain separate identities in the composite. The major constituents of a composite can be broadly classified as reinforcement in the form of fibres or particulates and polymer matrix. The reinforcements are the major load resisting component of a composite [1]. The polymer matrix holds the reinforcements in place, protects the reinforcements from an adverse environmental condition and also acts as a path for stress transfer between fibres [2].There is increasing interest in weight reduction in order to permit both energy conservation [3] and increased motoring economy. Reduction in the weight of an automobile structure achieves primary weight-saving and if carried to sufficiently great lengths enables the designer to use smaller power plants, thus achieving substantial secondary improvements in fuel economy. The majority of automotive applications involve Glass-Reinforced plastics because the extra cost of carbon or aramid fibre makes these fibres to rarely consider being acceptable in this market. Even so, the cost of using GRP is usually being weighed against the much lower cost of pressed steel components, and the substitution is if then rejected on purely economic grounds, leaving aside the question of reducing vehicle weight, enhancing fuel efficiency, reducing corrosion of body parts and energy savings[4]. A wide range of car and truck body mouldings, panels and doors is currently in service, including complete front-end mouldings, fascia's, bumper mouldings, and various kinds of trim. There is considerable interest in the use of controlled-crush components based on the high energy-absorbing qualities of materials like GRP. Leaf and coil springs and truck drive shafts are also in service, and GRP wheel rims and inlet manifolds have been described in the literature. Selective reinforcement of aluminium alloy components, such as pistons and connecting rods, with alumina fibres is much discussed with reference to increased temperature capability[5]. High strength and stiffness with low self-weight, design flexibility, non-corrosiveness and non-magnetic response, fatigue resistant easy mould ability to shape are some of the advantages of FRP composites over conventional materials such as steel and concrete. However, high volume implementation of FRP materials for structural application in automotive industry as a replacement for conventional materials still requires tremendous research and development efforts [6].

The use of composite materials is not very new, they were used in the automobiles as early as 1930s.In the year 1930 the Ford company (Henry ford) attempted to build car body from composite material, soya oil was used to produce phenolic resin and in turn to produce a wood filled composite material, this wood filled composite material was used in car body [7]. The application of fibre reinforced polymer (FRP) composite materials is advancing at a rapid pace since 1960s and is implemented more frequently in aerospace, automotive, electronics, chemical and construction fields. In 1953 Chevrolet corvette was unveiled at GM motorama and was the first car to use structural composite and is regarded as the birth of composite in automotive sector, its body was made from fibre glass and rexin[8]. In 1950 the use of glass fibre reinforced material and cold setting polyester resins were commercially available, in 1954 Singer Hunter Manufactured bonnet and side valences for the car from Glass Fibre Reinforced Polymer (GRP)[9]. Low volume car manufacturers produced hand laid GRP in 1960s, its application was limited to low volume, high value specialist sport car manufacturing [10]. In 1980s the Pontiac fiero was claimed as the first mass production composite intensive car body. It had a space frame chassis and body made using different composite materials [11]. In late 90s, Rover group turned to BMW later, is working closely with researchers at the University of Warwick, under the collaboration called EPIC-Engineering polymer integrated capability and then became SALVO-Structurally advanced light weight vehicle objective. Objective of SALVO is to provide information on new materials, manufacturing technologies and facilitating the integration of such materials and technologies into automotive manufacturing [12].The mass of the vehicle contributes to 75% of fuel consumption in the vehicles [13].The outer body made from sheet metal (steel metal sheet) is called the Body in white (BIW), Body in white accounts to ¼ of the total weight of the automobile. Substantial weight savings can be achieved by selecting alternative materials, fibre reinforced composites are competitive materials for BIW, manufacturers of Jaguar have reported a substantial savings to an extent of 45% and a stiffness increase of 60% in comparison to steel metal[14]. Carbon fibre reinforced composite is extensively used in aerospace applications and is not highly used in automotive because of its heavy cost. It is learnt that carbon fibre components can result in 50-70% of weight savings over steel [12]. The development of affordable fibre reinforced composite will result in improving vehicle efficiency through weight reduction in automotive application. Weight reduction is not only the act of material replacement but is also a result of optimising the design. Designers play a important role in arriving at the optimal design of automobile structures [15]. Giant manufacturers of automobiles like jaguar realised the importance of weight savings and replaced the body panels and structural parts by aluminium instead of steel and could be able to achieve an overall weight savings of about 40% and an increase of stiffness of 60%[16].To increase the weight saving benefits beyond 40% there is a need of the use of advanced composite materials. Carbon fibre reinforced composites are widely used in aerospace applications and their use in automotive application is limited due to its high costs. It is estimated that a weight savings to an extent of 50-70% can be achieved in relation with steel and 20-40 % with respect to Aluminium, when replaced with carbon fibre components [17].

The advances in the development of the materials manufacturing at a affordable cost has resulted in the development of carbon fibre reinforced composites at affordable cost used for automotive industry, resulting in vehicle efficiency through weight reduction. The objective of weight reduction is not only achieved through the use of alternate materials but is also dependent on the development of optimised designs with lean weight designs and high specific strength are produced from an appropriate material[18].Designers should consider issues such as production costs, mechanical stability, mechanical performance, durability, reliability, repair ability, maintain ability and finally recyclability when attempting to replace light weight alternatives to steel. Any industry/business firm is established with an objective of making profit, the substitution of alternative light weight material largely depends on the final cost of the product. The end of life value (ELV) directive in European countries stipulates the manufacturers to recycle /reuse the automotive parts to an extent of 95% recovery. The directive forces the manufacturers to think of the strategies to be adopted to recycle the manufactured product.

The scrap material is used for the land fill, it may not be possible to salvage only ferrous materials. The recycling of light weight material will pose a serious financial implications[19].The future application of FRP's in automotive industry is greatly influenced by the ability to successfully to recycle the FRP used in automotive industries. Research is in rapid progress to address the recycling problems associated with the fibre reinforced composites. Fibre reinforced composites are typically used with in the automotive industry for applications such as body panels, suspension, steering, brakes and other accessories. Fibre reinforced polymers are predominantly used in non-structural and cosmetic components. In the last decade there is a significant progress in the structural application of fibre reinforced composites [22].

High performance composites are commonly restricted to low volume structural applications, such as in racing cars. Fibre reinforced composites are designed to transmit primary loads; these fibre reinforced composite laminates will generally have a reinforcement volume fraction greater than 35%. Intermediate performance materials having volume fraction less than 35% are used for semi structural applications, these semi structural components are designed to transmit secondary loads and often used as under body parts, mats etc. Cosmetic parts made of fibre reinforced composites having volume fraction 20% are called low performance fibre reinforced composites. Low performance fibre reinforced composite are not designed to transmit any load[23].Components such as inlet manifolds, floor panels, roof panels, Dash board, door trims, interior components and light housings are manufactured with high dimensional precision. In these process structural long fibre reinforced thermos-plastic components are extensively used, the use of injection moulding process resulted in high production rates its usage is increasing at a rate of 30% in the European and American automobile sector in the last decade[21].

Materials	Youngs Modulus(E) Gpa	Density g/cm^3	Body Weight Kg

A cast aluminium frame used as a support lid to support the rear differential, bolted directly to the rear axle in Volvo vehicle V70XCAWD was replaced by glass reinforced poly propylene. The fibre reinforced component achieved enhancement in strength and weight reduction to an extent of 27% and the component manufacturing time was less than 4 Minutes which was much lesser than its counterpart Aluminium[16].The bumper of BMW M3 used E glass /nylon 6 Tow flex as a structural material gained higher energy absorption and 60% reduction in weight[24]. The most commonly used Fibre reinforced composites for automotive applications are in the form of sheet moulding compounds (SMC).Sheet moulding composites accounts to about 50-60% of total automotive thermos-set composites market, which contains a thermos-set composite reinforced with either chopped glass fibres, long glass fibres, long carbon fibres[25]. Approximately around 95,000 tonnes of (sheet moulding compounds) thermos-set composites are used in Europe alone [26].SMC can be commonly used in low performance applications such as boots (deck lids) and wings (Fenders). SMC is an attractive alternative to either steel or aluminium structures because of its styling flexibility, reduced weight, lower cost of production. The high tooling cost make the use of SMC uneconomical for short production runs when compared with alternative composite processes. Automation using robots in the production of composites enabled General Motors to produce composites in large volumes [26]. Ford Company used Glass fibre reinforced sheet moulding composites for 60% of the body panels in thunder bird manufactured in 2002, the tooling costs were reported to be 50% lower than that for steel [16]. Efforts are laid to intensify the use of Fibre reinforced composites for the main stream automotive applications that is for the structural application and to exploit its high strength to weight ratio, stiffness and energy absorbing capabilities [27].Earlier composites were only considered only for high performance applications.

The commercial vehicles uses panels manufactured using random fibres which limits the mechanical properties to 20-40% of aligned material and the manufacturing cycle time ranges between 100-200 seconds, resulting in high production volumes and therefore feasible for large size components such as panels used for commercial vehicles [28]. The changing demands in the automotive industry have forced the manufacturers Hexcel [29], quantum composites [30] and Menzolite–Fibron to use carbon reinforced SMC in their product range. Fiber reinforced composites provides alternative material design solutions enhancing specific strength and stiffness and providing appreciable weight savings. The fibre reinforced composite offers significant freedom to the designer by optimising strength and stiffness of the structure for a specific application. The carbon reinforced SMC offers better performance in the continuous form rather than the discontinuous carbon fibre formats [31].

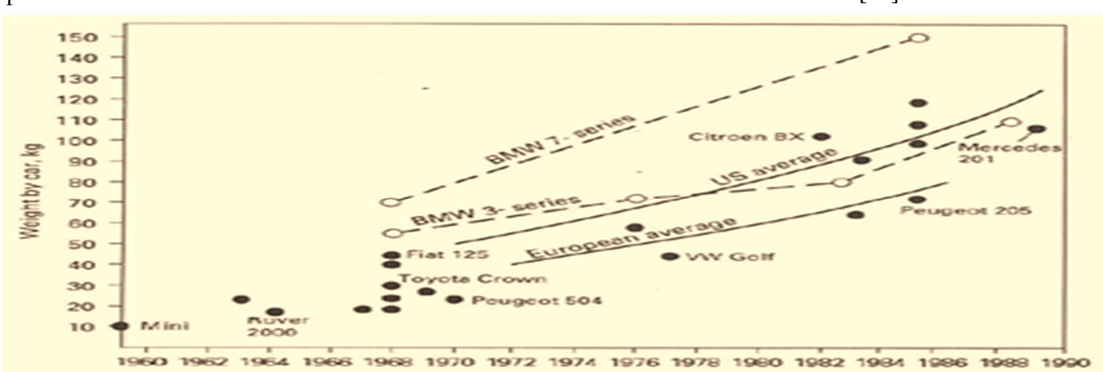

Fig.1 Use of Polymer Composites in Automotive Industries

Table 1.Youngs modulus, Density and body weight

Steel	190-210	7.8	~750
Aluminium	~70	2.7	~260
Carbon Fibre composites	~125-150	1.6	~155

From the above Table.1, it is evident that the carbon fiber reinforced composite has better young's modulus than that of the aluminum and closer to that of mild steel.

The objective of most of the big automobile giant like BMW is to develop solutions for environmentally and economically sensible recycling materials. This approach has proven successful in BMW. BMW vehicles can be economically, and almost completely, recycled. In a comparison with a BMW 5-series touring side frame made of steel, the lighter CFRP frame performed extremely well in terms of environmental compatibility, i.e. energy consumption, potential greenhouse effects, and resource depletion. This goes to show that CFRP is a valuable material when it comes to environmental aspects. It has outstanding potential for environmental compatibility throughout the total lifecycle. BMW has conducted further tests on CFRP materials in series production. These tests are designed to benchmark CFRP processes along with the economic aspects of its use in manufacturing. The automotive industry is one sector where composite materials are used significantly, especially in cars, scooters and helmets. The growth rate of composites in the automotive sector is as follows (Refer table.2) [1].

Table.2 Composites Growth Rate in the automobile sector in Indian scenario

Sl.No.	Segment	Growth rate	2011	2012	2013	2014
1	Passenger car	9.0%	7.08	7.72	8.42	9.6
2	Scooter	5.0%	5.80	6.17	6.48	7.4
3	Helmets for two-wheelers	14.0%	7.69	8.77	10.00	11.3
	Total (in tons)		20.69	22.67	24.90	28.30

Table.3 represents the growth rate of composites in automobile Sector [1].

Consumption of composites in Indian scenario. All figures in(Thousand) tons						
S.No.	Sector	2010	2011	2012	2013	2014
1	Wind energy	15.79	20.27	25.96	33.20	42.46
2	Industrial	26	7.695	32.59	36.51	40.92
3	Railways	8	9.60	11.52	13.82	16.59
4	Automobile	20.69	22.67	24.9	26.3	28.1
5	Oil & gas	1.5	1.6	1.7	1.8	1.9
6	Building & construction	35.00	39.50	44.65	48.92	55.40
7	Marine	1	1.4	1.8	2.30	3
8	Total (in '000 tons)	107.98	124.14	143.12	162.85	188.37

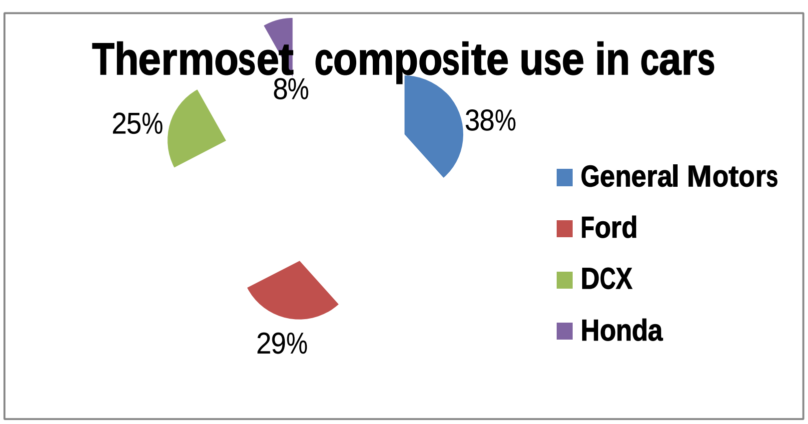

Figure.2 Graph shows the percentage use of thermoset composites by various automobile manufacturers.

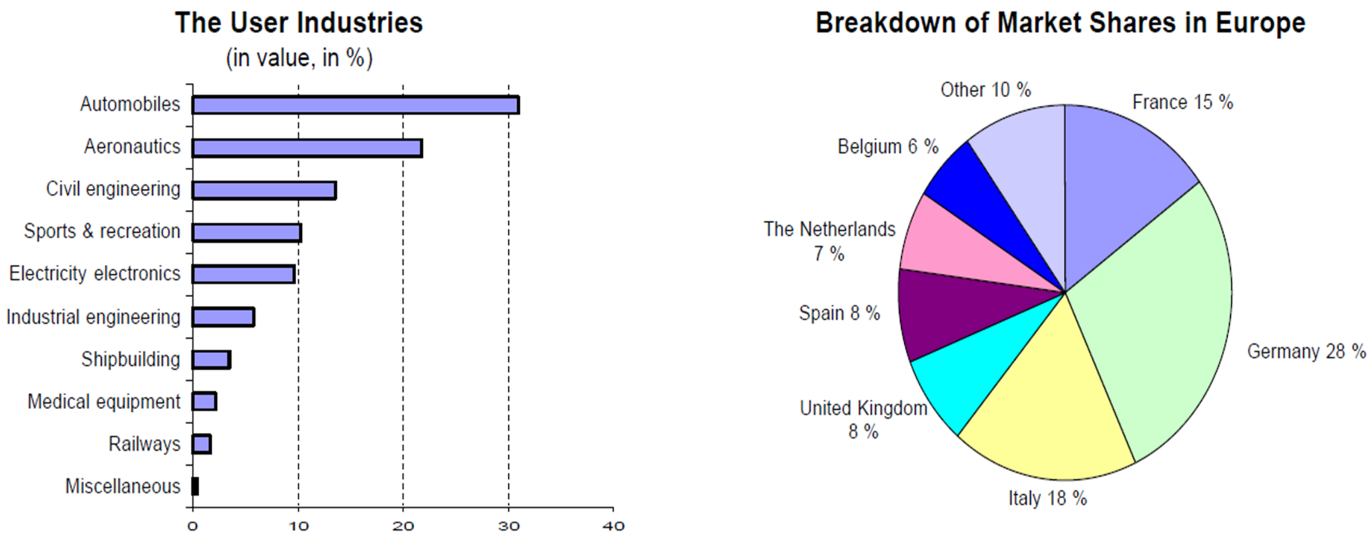

Figure.3 Graph shows the polymer composites user industry and the market share in the Europe.

From the Table.2 and Table.3 and Figure.2 and Figure.3, it is clearly evident that the use of polymers in the field of automotive application is going to grow in a rapid manner in the coming days.

II. CONCLUSION

The present review makes an effort to cover the various findings in the field of use and application of composite polymers applied to automotive application this review paper may help the automotive designers, engineers working in the automotive sectors, fabricators of the automotive industry in understanding the current trend and the type of material being used in the current automotive industrial applications. The future application of the of the composite materials in the automotive industry is highly promising and reflects a high growth rate. The cost acts as the final arbitrator in the selection of a particular material for a specific application. Further it is evident from the findings that there is a drastic research happening in the area of polymer composites especially in the automotive sector to enhance the fuel efficiency of the automobiles, greater mechanical strength and finally to add new stylish look to the automobiles.

The future of automotive materials undoubtedly the existing trends will tend to increase and the use of polymer for various applications from bumper to bonnets will continue. The domain of the steel will be challenged by the polymer composite materials. Extensive research is happening in various polymer fields to replace the structural components from the advanced polymer composites. From this it is clear that future material will be the one which can be completely recyclable and will have higher mechanical properties lower weight and higher self-life.

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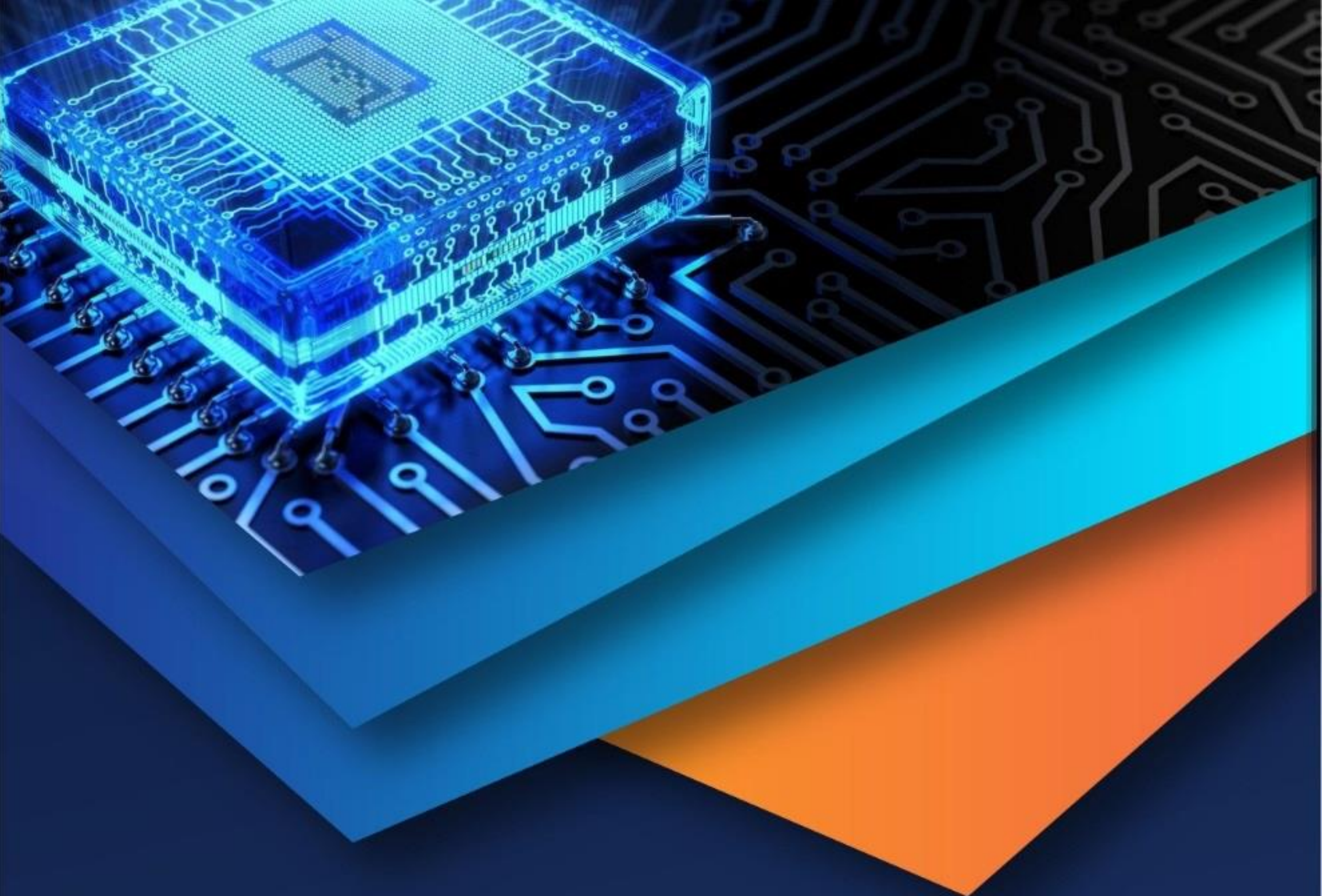

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