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Investigation of the Use of Hybrid Composite Materials Formed Using Two Different Resins in Vehicle Bumpers

Fethiye YALÇIN[1], Mustafa ÖZCANLI[2], Berkay KARAÇOR[3*]

[1,2,3]Çukurova University, Engineering Faculty, Automotive Engineering Department, 01330, Adana

[1]https://orcid.org/0000-0001-7697-5654
[2]https://orcid.org/0000-0001-6088-2912
[3]https://orcid.org/0000-0001-5208-366X
*Corresponding author: bkaracor@cu.edu.tr

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ABSTRACT

As efforts to reduce vehicle weight in today's vehicles accelerate, efforts to find new types of materials that can replace traditional materials have accelerated. In this study, carbon fiber was used as a reinforcement element together with glass fiber for lightening in vehicle bumpers. While vinyl ester and polyester were chosen as the matrix material for the piece to be produced, production was made by the hand lay-up method. The produced samples were first subjected to tensile test and their mechanical values were determined. The mechanical test results were introduced to the ANSYS program, and separate analyzes were made for the materials produced on the same bumper design and the results were compared. According to the results of the analysis, there was 2.13 times decrease in total deformations in glass fiber/carbon fiber/vinyl ester hybrid composites compared to glass fiber/vinyl ester homogeneous composites. In terms of equivalent stresses, 8% reduction was achieved in the carbon fiber /glass fiber/vinyl ester hybrid composite compared to the carbon/vinyl ester homogeneous composite. It was concluded that the choice of reinforcement and matrix is important for creating bumper material and improving the mechanical values of the bumper.

İki Farklı Reçine Kullanılarak Oluşturulan Hibrit Kompozit Malzemelerin Araç Tamponlarında Kullanımının Araştırılması

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ÖZ

Günümüz araçlarında araç ağırlığını düşürme çabaları hızlanırken, geleneksel malzemelerin yerini alabilecek yeni malzeme türleri bulma çabaları da hızlanmıştır. Bu çalışmada araç tamponlarında aydınlatma için cam elyaf ile birlikte takviye elemanı olarak karbon elyaf kullanılmıştır. Üretilecek parça için matris malzemesi olarak vinil ester ve polyester seçilirken, el yatırması yöntemiyle üretim yapıldı. Üretilen numuneler önce çekme testine tabi tutulmuş ve mekanik değerleri belirlenmiştir. Mekanik test sonuçları ANSYS programına tanıtılmış, aynı tampon tasarımı üzerinde üretilen malzemeler için ayrı ayrı analizler yapılmış ve sonuçlar karşılaştırılmıştır. Analiz sonuçlarına göre cam elyaf/vinil ester homojen kompozitlere göre cam elyaf/karbon elyaf/vinil ester hibrit kompozitlerde toplam deformasyonlarda 2,13 kat azalma olmuştur. Eşdeğer gerilmeler açısından, karbon/vinil ester homojen bileşiğe kıyasla karbon elyaf / cam elyaf / vinilester hibrit kompozitte %8 azalma sağlanmıştır. Tampon malzemesinin oluşturulmasında ve tamponun mekanik değerlerinin iyileştirilmesinde takviye ve matris seçiminin önemli olduğu sonucuna varılmıştır.

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1. Introduction

In order to save fuel in automobiles, the first thing to focus on is to lighten the parts of automobiles. With the developing technology, the change in the efforts to lighten the vehicle is accelerating and the orientation to alternative materials begins (Durgun et al., 2013; Basith et al., 2021). Composite materials are also at the forefront of this trend. Composite materials are typically made up of two elements, the matrix and the reinforcement. The materials used for the reinforcement bear the load on the composite substance. The reinforcement part determines the toughness of the composite material, as well as mechanical characteristics like strength and impact resistance. The matrix material holds the composite together and is also responsible for stopping the development and progression of deformation in the composite material. The matrix material joins the reinforcing materials under pressure and distributes the force evenly throughout the component, preventing the composite from rupturing or fracturing. Despite having a low initial viscosity from the matrix material, it is desirable to have the ability to solidify easily. Appropriate matrix material selection is taken into account in order to obtain the desired results from the reinforcement element. The characteristics of the composite substance are determined by the properties of the chosen matrix and reinforcement element (Turkmen and Koksal, 2013; Karacor, 2020; Yıldızhan et al., 2022). Matrix materials utilized in the manufacture of composite materials include epoxy, polyester, vinyl ester, and phenolic resins. In this investigation, polyester and vinyl ester are employed. Polyester is the most basic and cost-effective resin and is widely employed in the composite sector. Polyester is quickly manufactured and is very resistant to environmental factors also has a low viscosity. Polyester resin has the drawback of having a brittle structure and limited chemical resistance. The bond formation is hampered by the exothermic process. Vinyl ester has handling properties comparable to polyester and performance properties similar to epoxy. It also has high corrosion resistance and is more resistant to abrasion and fracturing than polyester. Although vinyl esters offer better physical qualities than epoxy resins, they do not need sophisticated procedures or specialized handling abilities (Associates, 1999; Genç, 2006; Türkmen and Durmuş, 2013; Şen, 2020).

The fibers, which are the reinforcing components employed in conjunction with the matrix material, are the fundamental element of composite construction. The strength and characteristics of the fibers utilized are critical to the composite material's strength (Bağcı, 2010). From synthetic fibers, glass fibers and carbon fibers were used in this study.

Glass fibers are chemically resistant and simple to produce and are the most often used fiber reinforcement in polymer composites. Even though their tensile strength is outstanding, they can degenerate if overloaded over an extended period of time. Depending on the type of stone used in manufacture, several varieties of glass fiber can be generated E-glass, S-glass, R-glass, C-glass, and D-glass are the most regularly used glass fibers. E-glass is the most common form of glass used in the automobile industry (Genç, 2006; Serin et al., 2022). Carbon fibers are a type of fiber that evolved after glass fibers and are commonly utilized. Although they are more durable than glass fiber, they are more expensive to produce. Carbon fibers have a strong and rigid structure as well as excellent corrosion resistance. Their most basic properties are their low density, high strength, and toughness. Carbon fibers, which have very high wear and fatigue resistance, are not affected by moisture and have high friction resistance. The strength and stiffness qualities in carbon fibers are enhanced when combined with the resin (Bağcı, 2010; Türkmen and Durmuş, 2013). Hybrid composites not only provide an appropriate balance between the advantages and disadvantages of the components that make up the composite, but are also structures in which the advantageous side of one of the components that make up the composite can compensate for the deficit of the other. In this way, cost-effective performance data is achieved with a hybrid composite design (Jani et al., 2016; Karacor and Özcanlı, 2023). In today's car sector, efficiency is increasingly important. As a result, the use of lightweight, high-strength materials is becoming more common in the car industry. Composite materials are among these materials that are appropriate for the specified properties and are presently used in many fields. Many components of today's cars, including fenders, front and rear bumpers, spoilers, headlamp masks, front and rear masks, trunk lids, door panels, and dashboards, are made of composite materials (Belingardi et al., 2015; Ramachandra, 2017; Ahmad et al., 2020).

When the literature is examined, it is seen that composite materials were used in vehicle bumpers, but it has been determined that static analysis studies have not been carried out on this design according to our examinations. Wang and Li examined the mechanical characteristics of aramid and glass fiber reinforced woven textiles and epoxy resin under tension, compression, bending, and shear circumstances. The non-linear tension test revealed that aramid fiber reinforced composites exhibited distortions when compared to glass fiber reinforced composites and had significantly reduced strength in compression, bending, and shear tests (Wang and Li, 2015). Hu et al. investigated the weight and impact strength of car bumpers. The carbon fiber reinforced plastic bumper beam is expected to take the position of the conventional high-strength steel bumper beam. The carbon fiber reinforced plastic bumper beam's energy absorption capabilities and dynamic reaction traits were examined and compared to those of the steel bumper beam. The results show that the carbon fiber reinforced plastic buffer beam has better energy absorption capacities and dynamic response characteristics than the steel bumper beam; weight is also reduced by approximately 50% by using carbon fiber reinforcement (Hu et al., 2015).

The bumper, which is one of the automotive elements, is the first part of the car that is exposed to the impact. Especially when it comes to pedestrian safety, the importance of the front bumper increases even more. If the bumper is too hard, most of the kinetic energy will not be absorbed, causing serious injury to the person hit (Reddy Mudem and Jani, 2019). In our literature review, it is limited to defining composite materials on vehicle bumpers by means of finite element analysis as in our current study. Instead of the traditional material utilized in the vehicle's rear bumper, the optimization of alternative composite materials was investigated in this study. 2 diverse reinforcing materials and 2 different matrix materials using the hand lay-up process, and 6 distinct composite materials were created. Tensile tests were conducted on 6 dissimilar composite materials made under identical conditions, and their mechanical properties were compared. The mechanical results received from the test were fed into the ANSYS analysis software. For six different materials, the force was applied to the intended rear bumper. It is aimed to determine whether these 6 different materials can be used in vehicle bumpers by presenting the total deformation, equivalent stress, and safety factor values obtained in the ANSYS program.

2. Material and Method

2.1. Material

For this study, two different resins were preferred both in terms of cost and in order to examine the mechanical properties of two different matrices with artificial fibers. Table 1 displays the parameters of polyester and Vinyl ester, which were employed in this work to create a composite material. The mixing ratio for polyester and vinyl ester resin is resin: cobalt: perox ratio of 1: 0.0002: 0.02 weight.

Table 1. Mechanical properties of resins (Boytek, 2023a, 2023b)

Material	Tensile Strength (MPa)	Bending Strength (MPa)
Polyester Boytek 452	72	130
Vinyl ester Boytek bve 780	85	145

The usage of E-glass was determined to be suitable in this investigation. Table 2 indicates the properties of fibers. Figure 1 demonstrates the carbon and glass fiber used in the study.

Table 2. Properties of fibers (Kompozitshop, 2023a,2023b)

Fabric	Weave	Weight (g/m²)	Thickness (mm)	Density(g/cm^3)	Elongation (%)	Tensile Modulus (GPa)
Glass fiber	Twill	500	0.12	2.6	3.5-4	73
Carbon fiber	Twill	250	0.1	1.79	1.6	240

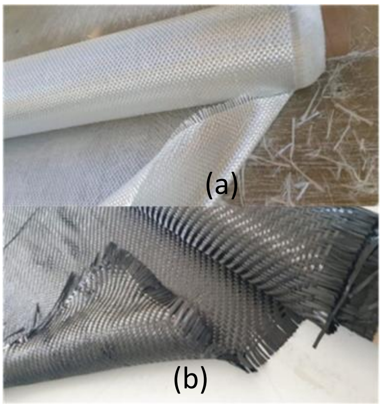


Figure 1. (a): Woven glass fiber (500 g/m²) and (b): Woven carbon fiber (250 g/m²)

2.2. Method

2.2.1. Hand Lay Up Method

The hand lay-up process is the most conventional process of the production methods. In order for the production surface to be smooth, the mold to be produced must be clean and smooth. Applying the resin to the mold is the first step in this manufacturing process. Then, the reinforcing element is placed on top of the resin and the resin is saturated with the reinforcing material. Production ends after the resin is distributed evenly throughout the mold and appropriate thickness measurements are obtained. The product is allowed to cure at room temperature before being removed from the mold, and after a certain period of time, it is removed from the mold and the product is ready (Prabhakaran et al., 2012).

In this work, for preparing the production, the surface was waxed and left to dry. Another layer of wax was added when it had dried. This procedure was carried out three times in all. To readily extract the created plate from the glass surface, wax is added to the surface. Figure 2 depicts the application of hand lay-up production steps. A3-sized fiber textiles were cut. Because the resins include cobalt, cobalt was not added again. The resin contained 0.7% MEK (methyl ethyl ketone). The prepared resin mixture was applied to the dry clean surface using a brush. The initial layer of fiber was applied to the resin, and the resin on the surface was brushed into the fiber. Layers of fibers were used. The fibers were piled, and then the resin was put between the fiber layers using a brush. A roller was used to create homogeneous plates and evenly dispersed resin, as well as to remove excess resin. Trapped air between the layers of plates was removed using a roller, resulting in a more homogenous structure for the manufacture and testing of specimens. With the help of a roller, the excess resin was removed from the system.

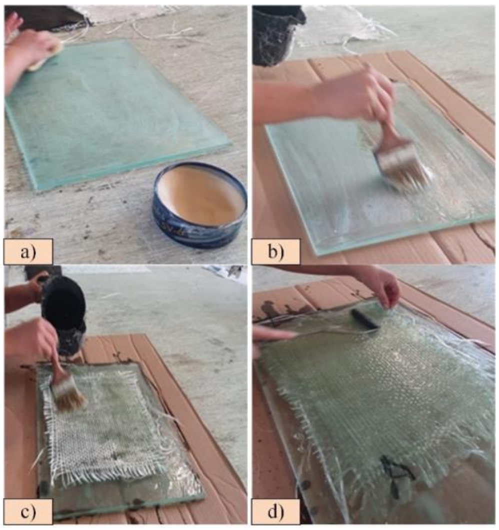


Figure 2. (a) Surface application of wax (b) Resin application (c) Resin application between fiber layers (d) Using a roller to remove excess resin

Each plate was made to be 4 mm thick in order to have similar plates. A glass plate was added on the upper surface to smooth it out and even out the pressure distribution on the plate. In this way, both surfaces of each plate were smooth and equal in thickness. Following the completion of the drying process, the plates were detached from the glass plates and post-cured. The post-curing procedure took two hours at 90 degrees Celsius.

There were six plates made: glass fiber/polyester, glass fiber/vinyl ester, carbon fiber/polyester, carbon fiber/vinyl ester, hybrid of glass fiber and carbon fiber/polyester, and hybrid of glass fiber and carbon fiber/vinyl ester. These six plates were manufactured under identical circumstances. Table 3 depicts the specimens' abbreviations. In hybrid composites, the fiber layer order is glass fiber-carbon fiber-glass fiber-carbon fiber, starting from the first row, and 19 layers of glass fiber and 18 layers of glass fiber are used.

Table 3. Codes of specimen

Specimens	Abbreviations
Glass fiber and polyester resin	GP
Glass fiber and vinyl ester resin	GV
Carbon fiber and polyester resin	CP
Carbon fiber and vinyl ester resin	CV
Glass fiber and carbon fiber and polyester resin	GCP
Glass fiber and carbon fiber and vinyl ester resin	GCV

Despite their advantages, composites also present some challenges and limitations in terms of engineering design. One of the main challenges is the complexity and cost of composite manufacturing and processing, which often requires specialized equipment, techniques, and labor. Another challenge is the characterization and modeling of composite behavior and performance, which requires advanced analytical and numerical tools and experimental methods. There are also challenges such as the reliability and durability of composite structures and components, which depend on the quality of materials, design, manufacturing and maintenance, as well as the environmental impact and sustainability of composite materials, which include issues such as energy consumption, waste generation, recycling or disposal.

2.3. Abrasive Water Jet

During the abrasive water jet (AWJ) cutting process, a pump mechanism raises the water pressure to roughly 4000 bar, and the high-pressure water is supplied to the cutting head. Because the AWJ process does not include burning, there is no heat-affected zone in the material, and the mechanical and chemical characteristics of the material do not change in the cutting zones of the cut material. The cutting speed is fast. The cutting surface is smooth and devoid of burrs. The cutting force used throughout the procedure is quite low (Akkurt, 2004; Armağan and Arici, 2017). The plates created are made of composite materials. Because it has a fibrous structure, wrong cutting action results in erroneous mechanical test results. Furthermore, because the resins are combustible materials, even after the post-curing process is done, they may burn when cut in a machine such as a CNC Laser cutting machine. For all of these reasons, the abrasive water jet approach was chosen. A cutting plan was developed in accordance with the TS EN ISO 527-2 standard tensile test specimen dimensions type 1B. An abrasive water jet was used to cut five specimens from each plate. Figure 3 depicts specimen dimensions.

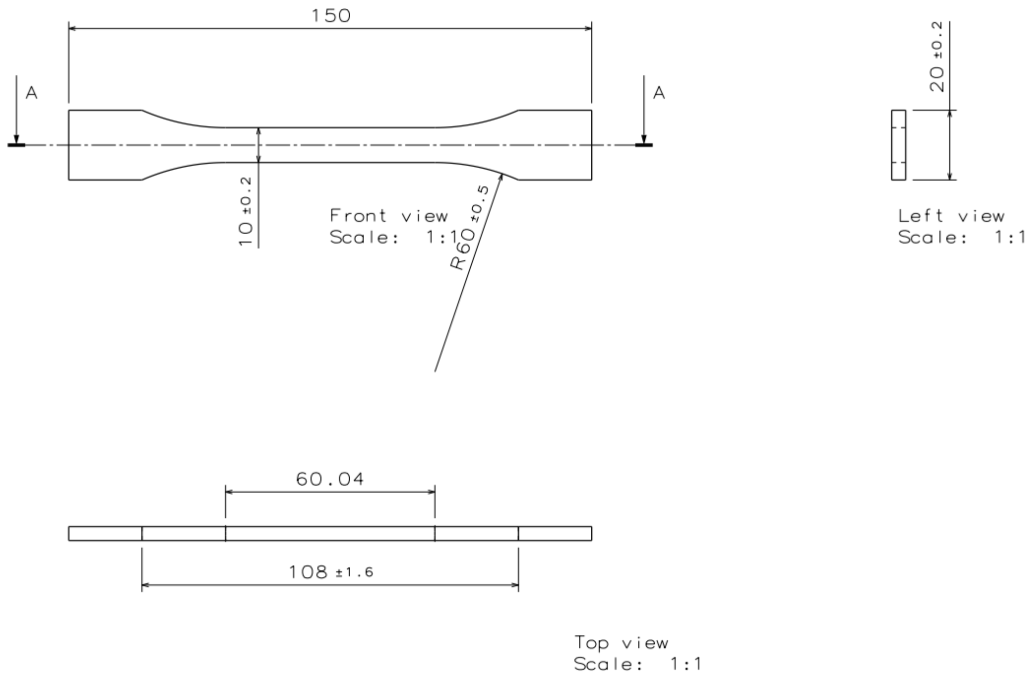


Figure 3. ISO 527-2 Type 1B tensile test specimen dimensions (mm)(British Standard Institution, 2012)

2.4. Tensile Test

The tensile test determines a material's resistance to a static or slowly applied force. The standard diameter and length samples are placed in the testing machine. When tensile and compression tests must be done often, a universal testing machine is utilized. When force is applied to a specimen, a strain gauge or extensometer measures how far it extends between the gage markings. As a result, the variation in sample length is measured relative to the original length. The tensile test can provide information on a material's strength, young modulus, and ductility (Askeland et al., 2011).

The ratio of expansion along one axis to contraction along the opposite axis in a material subjected to tensile or compression forces is defined as the Poisson ratio. When tensile stress is applied to a rubber band, the band lengthens axially and contracts in the transverse direction, causing it to also become thinner as it lengthens. At the same time, when compressive forces are applied to a rubber ball, the material shrinks longitudinally and expands laterally in the transverse axis, which is also described as Poisson's ratio. The equation for calculating Poisson's ratio is given as $\nu=(-\varepsilon_{trans})/\varepsilon_{axis}$. ε_{trans} (transverse strain) is measured in the direction perpendicular to the applied force, while εaxis (axial strain) is measured in the direction of the applied force. The poisson ratios in the article results were also obtained through the measuring devices on the testing machine (Instron,2023).

The poisson ratio compares the longitudinal elastic deformation caused by simple stretching or compression to the lateral deformation that occurs concurrently. The surface of the specimens is painted to identify them from one another and to reduce light reflection off the surface, as an extensometer is a light-sensitive equipment that may result in false measurement. As a result, the specimens' surfaces were coated with matte black spray paint. To perform the tensile test, the applied paints were allowed to dry.

Different dye colors were employed to differentiate the specimens from one another. Each hue represents a different substance from which the specimen was created.

Bars in the shape of a dog bone with a thickness of 4 mm, a width of 20 mm, and a length of 150 mm were prepared, taking into account the ISO 527-2 Type 1B standard. Tensile testing was carried out using a SCHIMADZU tensile test machine having a capacity of 100 kN according to ISO 527-2 Type 1B standard. The testing speed was chosen to be 2 mm/min. The percent extension in gauge length and percent decrease in the breadth of the test specimen were determined using an extensometer. The tensile test was performed on all of the specimens under identical conditions. Figure 4 depicts specimens cut in accordance with the standard.

Figure 4. Tensile test specimens

2.5. Finite Element Method

The FEM is a numerical computation method used to identify flaws in a structure when forces are applied. The FEM’s practical application is Finite Element Analysis (FEA). ANSYS is an FEA application that may be used for a variety of purposes. ANSYS can tackle static and dynamic structural analysis, transient heat transfer issues, static or time-varying magnetic analysis, and other fields and coupled-field applications (Prabhakaran et al., 2012; Akhil et al., 2016; Özarslan, 2016).

The static analysis is used to determine the structure's deformation and stress distribution. To choose the optimal material for the bumper, many analyses such as static analysis are necessary. ANSYS 17.0 was utilized as a tool in this project to attain the project goal. The materials employed in the creation of the catalysts, as well as their characteristics, were identified in this chapter. The phases of the catalyst synthesis process were then thoroughly discussed. The next part provided technical information on the instruments used to create the catalyst and study its chemical and structural characteristics. The mechanical characteristics of the generated composite materials are not available in Engineering Data Sources for this project. This information must be combined with engineering data in order to perform static studies in ANSYS. Density, poisson ratio, yield strength, ultimate tensile strength, and young modulus are some of the mechanical characteristics used in static analysis in ANSYS.

The bumper was developed considering the rates of commercial buses produced in Turkey. The bumper measurements are indicated in Figure 5, and the thickness was set at 3 mm. As given in Figure 5, the width of the bumper is 233.72 mm and the length is 3095.84 mm. Design dimensions were taken from a specific type of bus produced by TEMSA company.

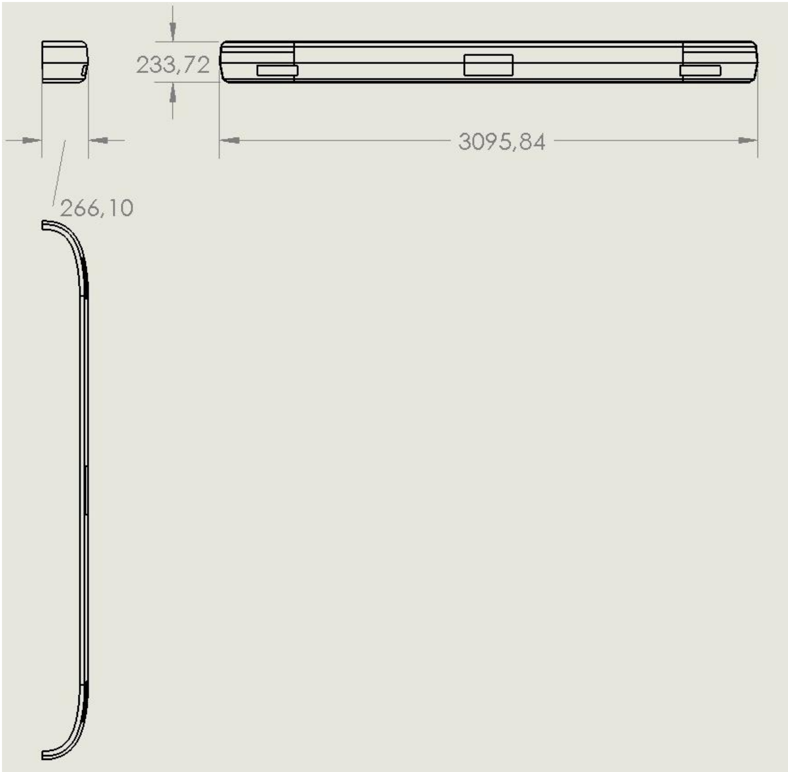
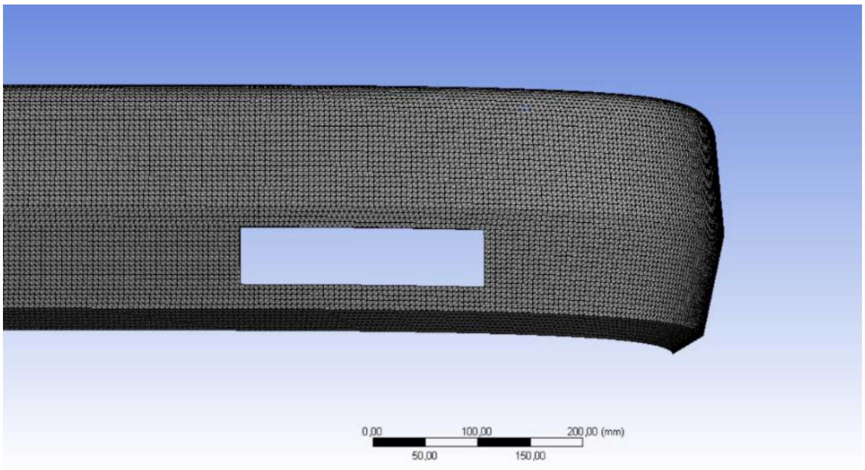
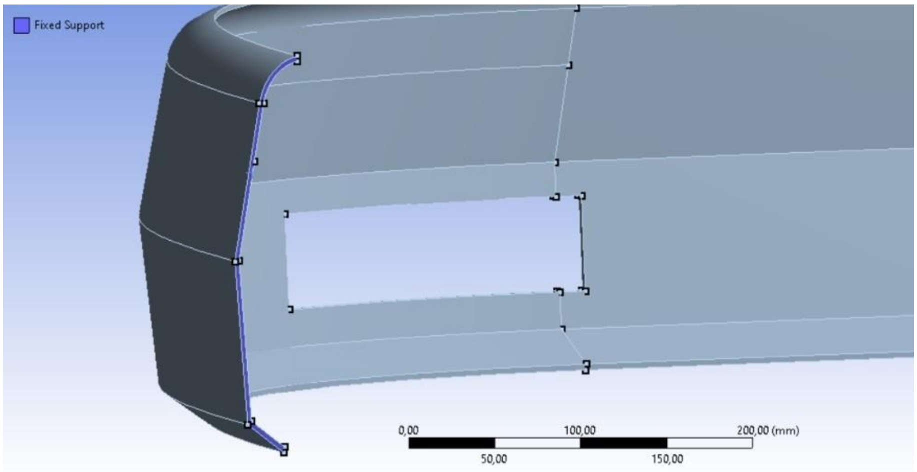


Figure 5. Bumper dimensions

Special sizing and face meshing were applied to the object. Total number of nodes is 4584214 and the number of elements is 2776908. As method tetrahedron- patch confirming was selected. Figure 6a depicts the bumper model's full meshing. Mesh optimization was performed on the design. While the average element quality value was 0.81 mm, the average skew value was 0.26. The bumper model was fitted on both sides when the meshing procedure was done. Figure 6b depicts fixed support faces. The aim of the study is to compare 6 different materials with respect to each other. Several values were tried while determining the force value to be applied to the bumper. A force of 400 N was applied to the bumper to compare the von mises stresses and safety factors of the materials. It was evident that several of the materials could not withstand such stress, hence the safety factors were less than one. Figure 6c depicts the surface of the bumper model to which the force is applied as well as the force direction.



(a)



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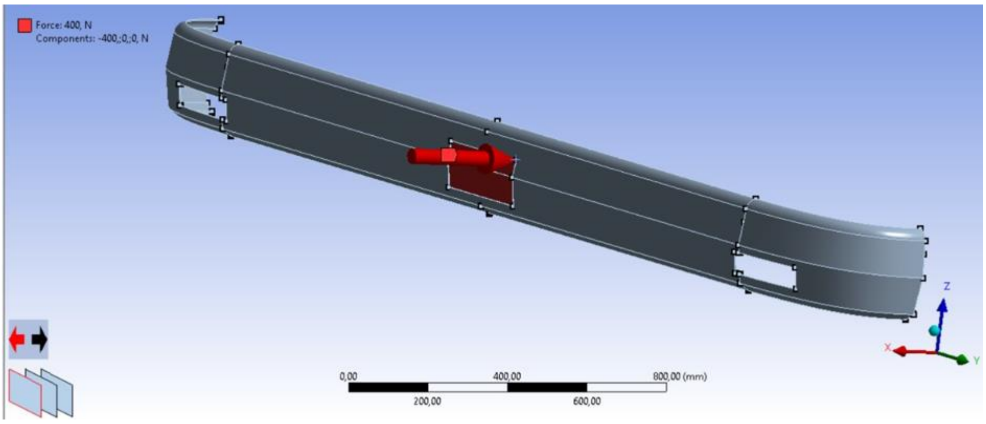

(c)

Figure 6. (a) Bumper mesh model (b) Fixed support zones (c) The force's application surface

3. Results and Discussion

Table 4 displays the mechanical characteristics of the composite structures based on the results of tensile tests. Table 5 displays static analysis results based on the ANSYS analysis.

Table 4. Mechanical characteristics of specimens

Specimen	Density(kg/m^3)	Poisson ratio	Yield stress (MPa)	Ultimate tensile stress (MPa)	Young modulus (GPa)
GP	1879	0.4	90	274	18.0
GV	1759	0.266	94	341	20.5
CP	1373	0.251	151	378	41.8
CV	1397	0.215	160	510	57.8
GCP	1662	0.34	129	380	38.4
GCV	1457	0.1	110	370	31.1

The findings of six different materials were compared in terms of their safety factor and von mises stresses and total deformation, as calculated by ANSYS.

Table 5. Comparison of static analysis results of materials

Materials	Safety factor	Von mises stresses (MPa)	Total deformation (mm)
GP	0.907	99.218	83.028
GV	0.849	110.67	72.698
CP	1.35	111.85	35.518
CV	1.399	114.37	25.659
GCP	1.245	103.56	38.867
GCV	0.915	120.23	47.224

When safety factor values are compared, GV material has the lowest value, while CV material has the highest value with 1.64 times that of GV material. Considering the von mises stress value, GCV material has the highest value, while GP has the lowest value. Von mises stress value of GCV material is 1.21 times that of GP material. In the total deformation comparison, the CV material has the lowest value, while the GP material has the highest value, 3.24 times that of the CV material. Ozarslan developed and evaluated carbon fiber and resin composite materials. The effect created by the use of composite materials in vehicle parts is emphasized in this study. He used the test findings of the experimental results to create the vehicle chassis in 3D in Solidworks drawing software. While the total deformation is 2.734 mm in aluminum material, it is 14.142 mm in carbon fiber - epoxy composite material. The von mises stress value is 5.6% better in carbon fiber-epoxy composite material than in aluminum material (Özarslan, 2016).

Şen aimed to optimize glass fiber, glass and carbon hybrid fiber reinforced composite and carbon fiber, glass and aramid hybrid fiber reinforced composite materials instead of polymer polypropylene material in the front fender of the vehicle. As a result of the study, the impact resistance value of the glass fiber reinforced material is five times higher than that of the polypropylene material. It has been understood from this study how the effect of using carbon and glass fiber has significant results on the front fender part (Şen, 2020). Sujon et al. examined how conventional metallic and alloy materials are being displaced in industrial uses by fiber-based composite materials. The findings obtained from the finite element analysis (FEM) program were compared with the experimental results. The highest UTS (Ultimate Tensile Strength) was obtained for sample $C_2J_3C_2J_3$ (571 MPa), while the lowest UTS was found for sample $J_3C_4J_3$ (496 MPa), which is 13% lower than $C_2J_3C_2J_3$. The $C_2J_6C_2$ sample has the second highest UTS (548 MPa), which is just 4% lower than the greatest UTS. ($C_2J_3C_2J_3$). The representation as $C_2J_3C_2J_3$ is explained as 3 layers of jute on 2 layers of carbon, 2 layers of carbon, and 3 layers of jute (Sujon et al., 2020).

When the overall deformation data were reviewed, the material with the best value was found to be the material composed of carbon and vinyl ester. Compared to the other materials, the deformation value of the composite composed of glass fiber and polyester was quite high. When the entire table is studied, it is clear that the deformation value varies according to the kind of fiber. The study found that the density of CP and CV composite materials made using carbon fiber was lower than that of the other four materials. The yield stress value was 77.78% and the ultimate tensile stress value was 86.13% higher in the tensile test results of the composite material generated with carbon fiber and vinyl ester than in the composite material made with glass fiber and polyester. When the young modulus values of GP and GV composite materials were compared, they were close to each other and the lowest. The GP composite material had a young modulus value that was roughly double that of the GP and GV composite materials. Tensile test findings of GCP and GCV materials, which were hybrid composite materials, indicated that the mechanical properties were average when compared to the other four materials.

In similar studies conducted in the literature, attention was drawn to parameters such as creating the bumper material from hybrid composite materials and increasing the energy absorbing ability of the material. Neelima et al. focused on bumper beam selection under various factors such as shape and substance. In their research, they used steel, aluminum, carbon fiber epoxy, and S2 glass epoxy. These materials' stress, deformation, and weight were examined. Carbon fiber epoxy values from the research were compared to the 6 materials used in our investigation. The findings of density, poisson ratio, and young modulus of tested materials using ANSYS software are presented in Table 6. Comparing the mechanical values of carbon fiber epoxy with the materials used in this research, the density value is found to be similar to the substance composed of glass fiber, carbon fiber, and polyester. Carbon fiber epoxy substance, on the other hand, has a much greater young modulus value than other materials (Neelima et al., 2016).

Table 6. Mechanical properties of specimens and carbon fiber epoxy from Neelima et al. research

Specimen	Density (kg /m³)	Poisson ratio	Young modulus (GPa)
GP	1879	0.4	18.0
GV	1759	0.266	20.5
CP	1373	0.251	41.8
CV	1397	0.215	57.8
GCP	1662	0.34	38.4
GCV	1457	0.1	31.1
Carbon fiber epoxy	1600	0.15	85.0

4. Conclusion

The purpose of this research is to identify a composite material for the manufacture of a lightweight bumper with improved mechanical qualities. In the scope of the study, six distinct composite materials were identified and manufactured. Tensile tests were done on the manufactured composite materials, and the mechanical data of the materials were compared. An ANSYS bumper model was created, and the mechanical properties of six different composite materials were entered. Static analysis results from ANSYS materials were compared by applying the same force in the same region with the same direction. The composite material comprised of carbon fiber and polyester had the lowest density of the six different composite materials tested. The results of the tensile tests indicate that the composite of carbon fiber and vinyl ester exhibited better mechanical characteristics in terms of yield strength, ultimate tensile strength, and modulus of elasticity. According to ANSYS static study results, the GCV hybrid composite has the highest maximum von misses stress, while the CV composite has the highest safety factor value. When the safety factor, von mises stress, total deformation, and cost criteria are considered, it is obvious that the GCV hybrid composite has the most optimal values. The choice of fiber to lighten the bumper and the choice of resin to increase the mechanical qualities of the bumper were found to be relevant in this investigation. It is acceptable to conduct an optimization study, considering the mechanical values derived from the composites based on the cost criteria, utilization area, and the required mechanical attributes. The results of the study indicate that the bumpers to be used in vehicles will be both lighter and more durable if they are manufactured from composite materials, and shed light on the use of natural fibers as reinforcement elements in future bumper designs of this type.

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Statement of Conflict of Interest

The authors have no conflicts of interest to declare.

Author’s Contributions

The authors declare that they have contributed equally to the article.

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