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Design And Optimization Of B-Pillar Trim Using Composite Materials

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Abstract- The B-pillar is one of the most important structural part of a vehicle designed to protect passengers during side impacts and rollover accidents. The B-pillar trim, which covers the pillar structure, adds both safety and aesthetic value by improving energy absorption and reducing injury risks in collisions. This research focuses on the study, design, and optimization of B-pillar trims using composite materials for vehicles across different segments. The B-pillar trim acts as a protective and aesthetic cover over the structural B-pillar. It prevents direct contact with the metal surface, enhances passenger comfort, safety and contributes to energy absorption during side impacts, improving overall safety. B -pillar trims are used in all types of vehicles from entry-level hatchbacks to premium SUVs and luxury sedans. cars use cost-effective polymer-based trims, mid and high-segment vehicles often use fiber-reinforced composite trims for improved strength and appearance. After a collision, the B-pillar trim experience stress such as compression. Compression test is performed on a Universal Testing Machine (UTM) to measure the mechanical strength and stiffness of the B-pillar trim. These tests help validate Finite Element Analysis results with experimental data. Conventional B-pillar trims made of polypropylene and similar materials often have poor load-bearing strength and low crash resistance. They may deform or fail to absorb energy effectively during side-impact collisions, reducing their protective capability. This research presents the use of E-glass fiber and carbon fiber reinforcements to enhance the strength, stiffness, and durability of B-pillar trims. These materials significantly improve impact resistance and reduce deformation while keeping the design lightweight. Finite Element Analysis (FEA) was used to simulate real-world loading conditions on various B-pillar trim materials. The results showed that composite trims exhibit reduced deformation and higher stress resistance compared to conventional plastic trims. The experimental and simulation results confirm that composite-reinforced B-pillar trims greatly improve crash performance. Carbon fiber composites showed the highest strength (5027.7 N), followed by E-glass fiber (2167.2 N), compared to the original polypropylene trim (460.44 N). The study concludes that using composite materials makes vehicles safer and more fuel-efficient due to weight reduction and enhanced structural integrity.

Keywords: B-Pillar Trim, Composite Materials, Finite Element Analysis, B-Pillar, Automotive Safety.

Introduction

The increasing demand for safer, lighter, and more fuel-efficient vehicles has driven significant advancements in the use of composite materials in the automotive industry. Traditional polymer-based components, while cost-effective, often fall short in meeting stringent safety and performance requirements under crash loading conditions. Among these structural components, the B-pillar plays a crucial role in ensuring occupant safety during side-impact collisions, as it directly contributes to load distribution, energy absorption, and overall structural integrity of the vehicle body.

In recent years, research has focused on replacing conventional materials with advanced fiber-reinforced composites to enhance crashworthiness without significantly increasing weight. Composites such as E-glass fiber and carbon fiber offer superior strength-to-weight ratios, improved energy absorption capacity, and enhanced stiffness compared to polypropylene (PP) and other thermoplastics traditionally used in interior trim parts. Their adoption in critical structural zones such as the B-pillar trim not only improves mechanical performance but also aligns with industry efforts toward light weighting and sustainability. Finite element analysis (FEA) has emerged as a powerful tool for simulating and optimizing automotive components under realistic loading conditions. Nonlinear FEA enables accurate prediction of deformation, stress distribution, strain, and failure behavior, thereby reducing reliance on costly experimental trials. By integrating FEA with composite material modeling, it becomes possible to optimize component design for maximum load-bearing capacity and safety performance.

This study aims to design and optimize a B-pillar trim using composite reinforcements and evaluate its performance under nonlinear static loading. The original polypropylene trim is compared against E-glass fiber and carbon fiber composite designs to determine their effectiveness in improving structural performance. The outcomes of this research provide insights into material selection and design optimization strategies that can enhance occupant safety while contributing to the development of lightweight and durable automotive structures.

I. Literature Review

1. Fardin Khan & Nayem Hossain (2025)

This review highlights the growing role of composites in automotive applications, focusing on their strength-to-weight benefits and crash performance. The authors discuss key challenges such as joining, recycling, and cost that limit broader use despite proven safety advantages. They emphasize that fiber orientation and hybrid composites improve energy absorption in crash scenarios. Their work underlines the importance of careful material selection and processing in vehicle components like the B-pillar.

2. Abdulqadir & Tarlochan (2022)

The study introduces a composite hat-structure concept for B-pillars and door beams to enhance side-impact safety. FEA and design optimization showed improved stiffness and controlled deformation compared to metals. The authors also highlight hybrid manufacturing methods suitable for large-scale production.

3. Kang et al. (2021)

Kang and colleagues demonstrate a hybrid molding method to reinforce a center pillar with composite inserts. Their FEA and experiments show reduced deformation and better load distribution compared to unreinforced designs. The process allows efficient integration of long fibers into thermoplastics, improving strength without excessive weight. This study shows how manufacturable reinforcement methods can enhance pillar safety.

4. Gardyński, Caban & Barta (2018)

This paper reviews glass- and carbon-fiber composites for vehicle bodywork, comparing cost, strength, and crash performance. Carbon fiber offers superior stiffness, while glass fiber provides cost-effective energy absorption. The authors note recyclability and repair challenges that influence large-scale adoption. Their findings support the balance of performance and feasibility when selecting composites for pillars.

5. Jiayu Guo & Shuyang Liu (2024)

Guo and Liu analyze B-pillar crashworthiness improvements through reinforcement design and optimized geometry. Their simulations show that localized stiffening significantly reduces intrusion in side impacts. They stress the importance of validating these findings with experimental crash tests. This work directly relates to optimizing B-pillar trims for better crash resistance.

6. Wen Zhang & Jun Xu (2022)

This review covers lightweight materials in automobiles, including high-strength steels, alloys, and composites. It highlights composites' advantages in stiffness-to-weight ratio and crash performance but notes integration challenges in multi-material structures. The authors also emphasize sustainability and lifecycle concerns. Their insights show why composites are increasingly applied to critical components like pillars.

7. Meiqin Liang & Shang Wang (2023)

Liang and Wang simulate three-point bending of hollow beams using Abaqus to study deformation and failure. Their results validate how geometry and imperfections affect bending strength. The study provides guidance on meshing and boundary conditions for thin-walled structures. These insights are useful for simulating composite B-pillar trims under load.

8. Changappa & Kumar (2021)

This paper applies FEA to assess B-pillar trims under FMVSS head crash conditions. The study links trim stiffness to head injury criteria and suggests reinforcement strategies for improved safety. It highlights how local design changes affect occupant protection outcomes. Their work demonstrates the value of regulatory-based simulations for trim optimization.

9. Hye Rin Gu & Seung Jin Kim (2017)

The authors examine eco-friendly kenaf fiber nonwovens for automotive pillar trims. Tests showed sufficient stiffness and energy absorption while offering sustainability advantages. They also discuss hybridization with synthetic fibers to enhance strength. This study suggests natural fibers as a viable option for greener B-pillar trims.

10. Swami & Jadhav (2024)

This study experimentally evaluates B-pillar reinforcement using composite materials. Results showed marked improvements in bending strength and stiffness compared to unreinforced designs. Fiber orientation and ply stacking were identified as key design factors. Their findings confirm the structural benefits of composites in B-pillar applications.

Novelty of work: Unlike earlier studies that primarily addressed either material selection or structural geometry, this work integrates nonlinear finite element analysis (FEA) with composite reinforcement strategies to evaluate deformation, stress, strain, and reaction forces under realistic loading conditions. By comparing polypropylene with E-glass fiber and carbon fiber composites, the study highlights how material substitution can dramatically enhance load-bearing capacity—with carbon fiber showing more than a tenfold improvement over the original trim. Additionally, the research not only demonstrates the mechanical superiority of composites but also emphasizes their role in achieving lightweighting without compromising safety, directly addressing current industry challenges of fuel efficiency and crashworthiness. This integrated approach provides new insights into the practical application of composites for occupant protection and structural optimization in automotive components.

I. Problem Statement

- Conventional B-pillar trims made of polypropylene (PP) and other thermoplastics often fail to deliver adequate load-bearing capacity and energy absorption under crash conditions.

- Existing research focuses mainly on structural B-pillars or metallic intrusion beams, while the mechanical role of the trim has received limited attention. There is also a lack of nonlinear finite element analysis supported by experimental validation to evaluate reinforced trim performance. A systematic approach is needed to design, reinforce, and evaluate a stronger yet lightweight B-pillar trim suitable for modern vehicle safety requirements.

- With the growing emphasis on lightweight, high-performance, and sustainable materials, there is a pressing need to explore advanced alternatives that can increase safety.
.
- This gap highlights the necessity of a detailed design and optimization study that evaluates composite-based B-pillar trims under realistic loading conditions to enhance crashworthiness while reducing weight.

II. Objectives

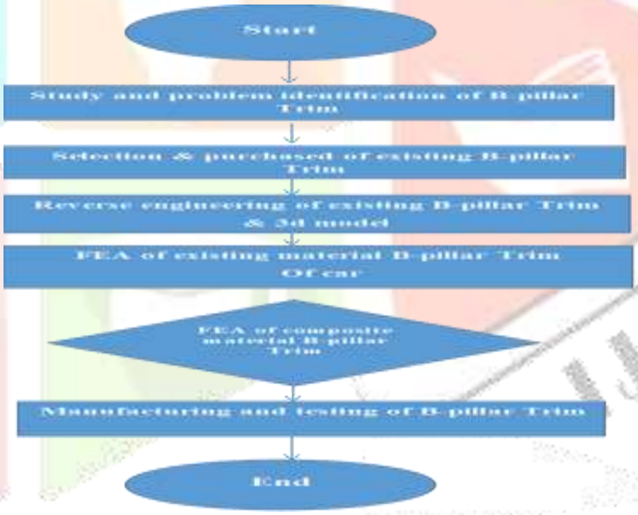
1. To analyze the existing B-pillar trim of a passenger vehicle and identify the limitations and structural weaknesses that affect its performance during side-impact loading.

2. To develop a 3D CAD model of the B-pillar trim and evaluate its deformation behavior through finite element analysis under realistic static indentation conditions.

3. To strengthen the B-pillar trim by applying suitable composite reinforcements on the B-surface and study how different composite materials improve its stiffness and load-carrying capacity.

4. To validate the improved design by performing laboratory test such as dent test and compare the experimental results with the finite element analysis outcome then determine the most effective reinforcement material.

Research Methodology



III. Finite Element Analysis

A mathematical technique called finite element analysis breaks down complicated circumstances into a number of discrete problems. It is intrinsically more difficult to analyze non-linear FEA analysis problems than linear ones. The "principle of superposition," which asserts that the deflection, stress, or strain in a system caused by several forces is equal to the algebraic sum of their effects when applied independently, is no longer true. The accuracy of the approximation analytical technique known as finite element analysis depends on the following factors:

- The CAD model's quality
- Material properties used (also known as related assumptions)

In nonlinear FEA, the following relationships (which are anticipated to be linear in linear FEA) may be broken: The following relationships, which are anticipated to be linear in linear FEA, may be disrupted in nonlinear FEA:

a) Large Deformations: When the strain reaches one or two percent, the majority of metals become useless. For instance, plastics, rubbers, and elastomers can be stretched to hundreds of percent, necessitating finite (large) strain analysis.

b) The connection among strain and displacement is no longer linear. This is true if the tensions remain equal but the rotations increase. It is no longer possible to ignore the distorted shape's modifications. A quadratic or logarithmic strain-displacement relationship is required for buckling, rubber analysis, metal forging, and other physics applications (Green-Strain). Real stress or Cauchy stress should be employed instead of engineering stress because of geometric changes.

c) The connection between stress and strain may become nonlinear. even when the applied stress falls within the usable stress range of the material. The majority of metals, rubbers, elastomers, and certain composite materials with uneven tension and compression characteristics exhibit this behavior.

d) It could be necessary to change the initial equilibrium equations that link stress and loads. due to the geometrical variations in shape of the building. These interactions lead the load in nonlinear FEA to no longer be proportionate to the displacement.

Software Analysis Methodology

Step 1: Material Data Definition

All materials used in the study—polypropylene (PP), carbon-fiber composite, and E-glass composite—were defined in the Engineering Data module. Each material was assigned its respective elastic, plastic, and orthotropic properties as required. Nonlinear stress–strain curves were included to accurately simulate the deformation characteristics of polymers and composite laminates.

Step 2: Importing and Preparing Geometry

The 3D B-pillar trim model created in SOLIDWORKS was imported into ANSYS Workbench. Minor geometric clean-up operations such as removing sliver faces, simplifying ribs where necessary, and ensuring watertight surfaces were performed in SpaceClaim to improve mesh quality without altering the functional design.

Step 3: Material Assignment, Contacts & Meshing

The PP trim and composite reinforcement layers were assigned their respective material models within the Mechanical interface. Contact definitions were established between the indenter and trim using a frictionless formulation to replicate real indentation behavior. The model was discretized using tetrahedral solid elements with mesh refinement applied to the loading region and rib intersections to capture stress gradients more accurately.

Step 4: Application of Boundary Conditions and Loads

Fixed supports were applied at the mounting locations to simulate the actual installation of the trim in a vehicle. A displacement-controlled load of 5 mm was applied to a rigid spherical indenter positioned over the critical region of the B-pillar trim. This approach ensured stable convergence for nonlinear deformation and provided a direct basis for comparison with experimental indentation results.

Step 5: Consideration of Nonlinear Effects

Geometric and material nonlinearities were activated to account for large deformations and plastic behavior of the PP and composite materials. The solution was executed using the Newton–Raphson iterative scheme, allowing the model to update stiffness matrices at each load increment until convergence was achieved.

Step 6: Solution and Post-Processing

Upon solving, key output parameters—including total deformation, stress, equivalent strain, strain energy distribution, and reaction forces—were extracted. These results were used to compare the structural performance of the baseline PP trim and the reinforced composite variants. The simulation outcomes were further correlated with experimental testing for validation

4.1 FEA of Optimize B Pillar Trim Component

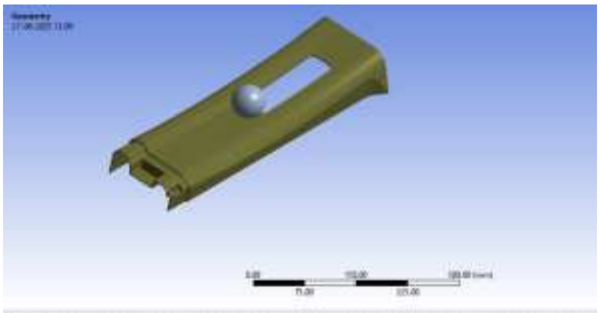


Fig. 4.1 B-Pillar Trim with Loading Nose Spherical Ball (Original Component CAD)

Material properties are set as PP and ABS, actual component is made up of PP material. Following are the components material properties as shown in Table 4.1, as per the Engineering material library used for Non-Linear FEA.

	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Isotropic Elasticity		
4	Derive from	Young's Modulus and Poisson...	
5	Young's Modulus	2900	MPa
6	Poisson's Ratio	0.3	
7	Bulk Modulus	2416.7	MPa
8	Shear Modulus	1115.4	MPa
9	Bilinear Isotropic Hardening		
10	Yield Strength	51	MPa
11	Tangent Modulus	[illegible]	MPa

Table 4.1 B-Pillar Material Properties of Original Component

4.1.1 Meshing of Original B Pillar Trim Component

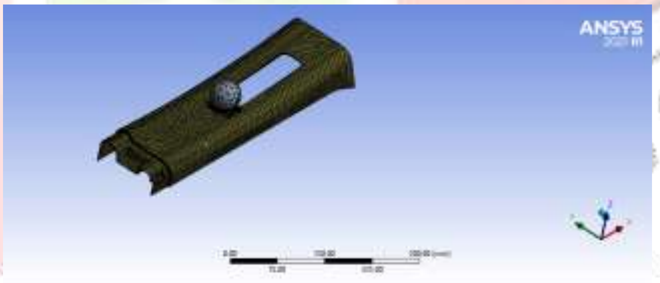


Fig. 4.2 Meshing Details of Original B-Pillar Trim

The node and element generate on the b pillar was 51005 and 26029 respectively as shown in Fig 4.2. Fig 4.3 shows the boundary conditions for the component.

4.1.2 Boundary condition for Optimize B Pillar Trim Component

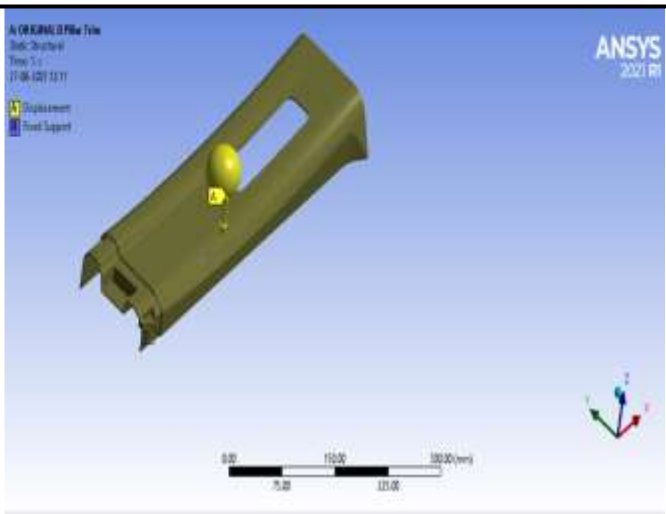


Fig. 4.3 Boundary Condition of Original B-Pillar Trim

Results - Original B Pillar Trim Component

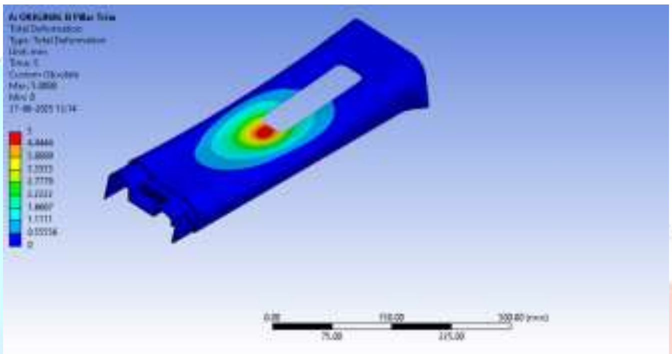


Fig. 4.4 Total Deformation of Original B-Pillar Trim

The Total deformation generated on the Original B-pillar trim is kept as 5mm as shown in Fig 4.4.

A] Equivalent Stress - Original B Pillar Trim Component

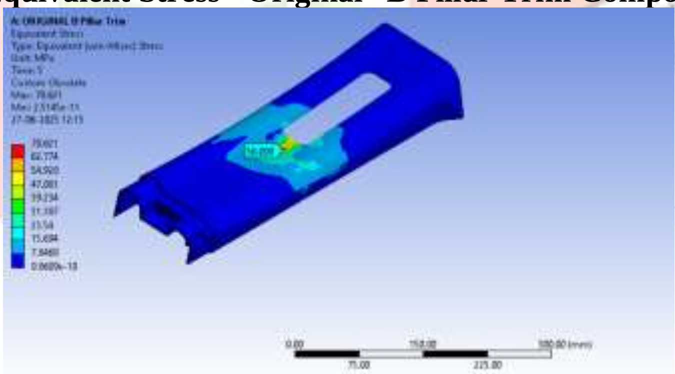


Fig. 4.5 Equivalent Stress of Original B-Pillar Trim

The maximum Equivalent Stress generate on the Original B-pillar was 70.62 MPa as shown in Fig 4.5

B] Equivalent Elastic strain - Original B Pillar Trim Component

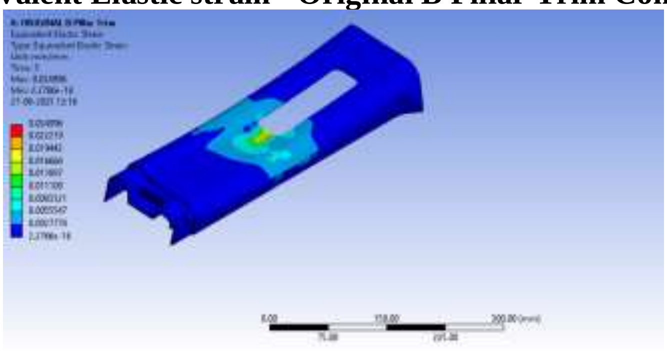
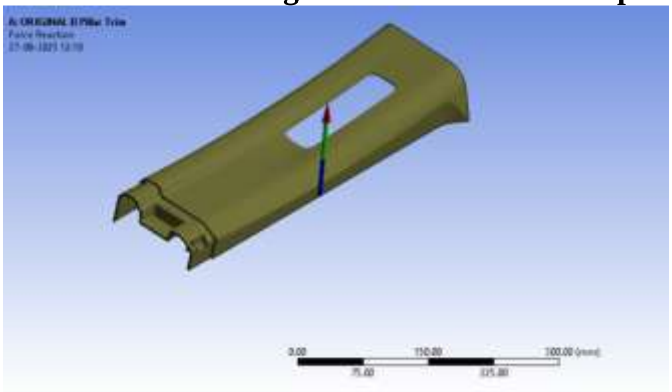


Fig. 4.6 Equivalent Elastic Strain of Original B-Pillar

The maximum Equivalent Elastic strain on Original B pillar was 0.0249 as shown in Fig 4.6

C] Force Reaction - Original B Pillar Trim Component



Results

Maximum Value Over Time	
X Axis	-0.594 N
Y Axis	52.791 N
Z Axis	457.36 N
Total	460.44 N

Fig. 4.7 Force Reaction of Original B-Pillar

The maximum reaction force observed on Original B pillar was 460.44 N as shown in Fig 4.7

4.2 FEA of Optimize Composite B Pillar Trim Component

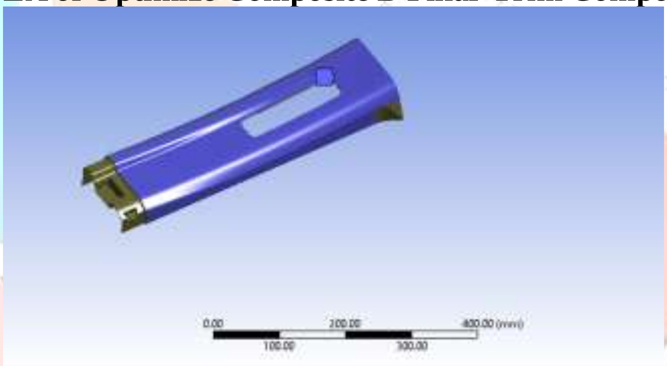


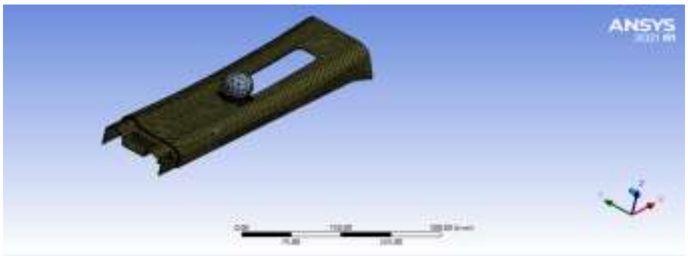
Fig. 4.3 B-Pillar Trim with Loading Nose Spherical Ball

Properties of Outline Row 13: Epoxy E-Glass UD

	A	B	C
1	Property	Value	Unit
2	Density	2000	kg m^-3
3	Orthotropic Elasticity		
4	Young's Modulus X direction	4.5E+10	Pa
5	Young's Modulus Y direction	1E+10	Pa
6	Young's Modulus Z direction	1E+10	Pa
7	Poisson's Ratio XY	0.3	
8	Poisson's Ratio YZ	0.4	
9	Poisson's Ratio XZ	0.3	
10	Shear Modulus XY	5E+09	Pa
11	Shear Modulus YZ	3.8462E+09	Pa
12	Shear Modulus XZ	5E+09	Pa

Table 4.3 B-Pillar Material Properties of composite Component

4.2.1 Meshing of E glass fiber composite B Pillar Trim Component

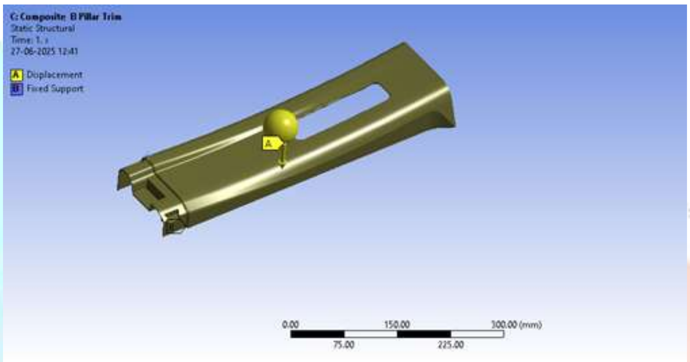


Statistics	
Nodes	51005
Elements	26029

Fig. Meshing Details of E glass fiber composite B-Pillar Trim

The node and element generate on the b pillar was 51005 and 26029 respectively as shown in Fig. shows the boundary conditions for the component.

4.2.2 Boundary condition for E glass fiber composite B Pillar Trim Component



Tabular Data

	Steps	Time [s]	X [mm]	Y [mm]	Z [mm]
1	1	0.	= 0.	= 0.	0.
2	1	1.	0.	0.	-1.
3	2	2.	= 0.	= 0.	-2.
4	3	3.	= 0.	= 0.	-3.
5	4	4.	= 0.	= 0.	-4.
6	5	5.	= 0.	= 0.	-5.

Fig. 4.3 Boundary Condition of E glass fiber composite B-Pillar Trim

Results - E glass fiber composite B Pillar Trim Component

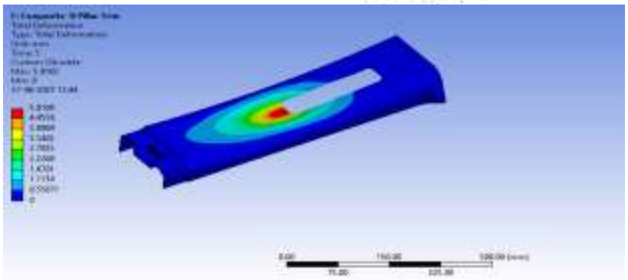


Fig. 4.4 Total Deformation of E glass fiber composite B-Pillar Trim

The Total deformation generated on the E glass fiber composite B-pillar trim is kept as 5.01 mm as shown in Fig 4.4.

D] Equivalent Stress - E glass fiber composite B Pillar Trim Component

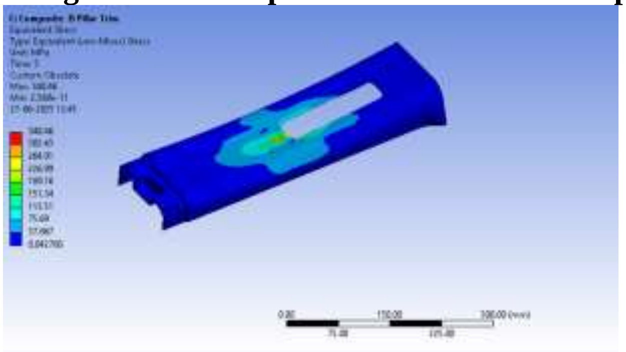


Fig. 4.5 Equivalent Stress of E glass fiber composite B-Pillar Trim

The maximum Equivalent Stress generate on the E glass fiber composite B-pillar was 340.46 MPa as shown in Fig 4.5

E] Equivalent Elastic strain - E glass fiber composite B Pillar Trim Component

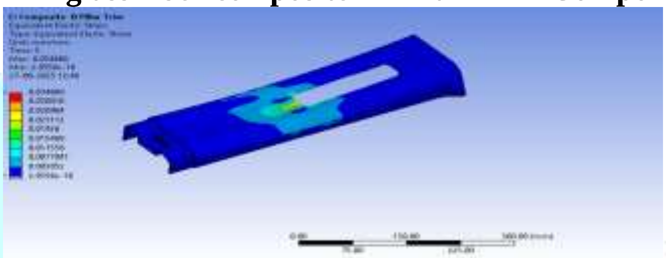
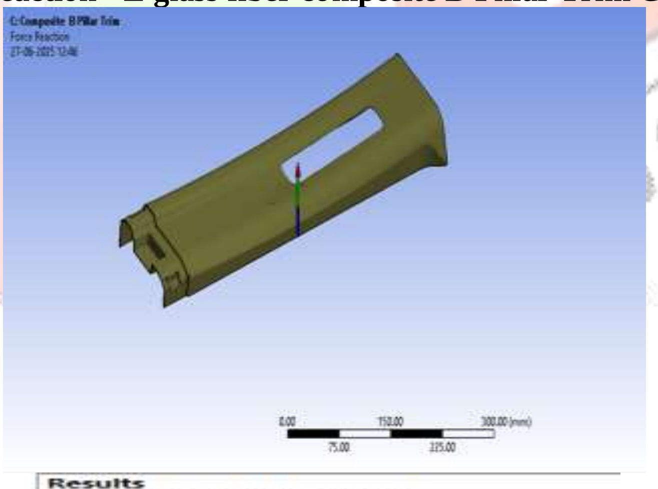


Fig. 4.6 Equivalent Elastic Strain of E glass fiber composite B-Pillar Trim

The maximum Equivalent Elastic strain on E glass fiber composite B pillar Trim was 0.034668 as shown in Fig 4.6

F] Force Reaction - E glass fiber composite B Pillar Trim Component



Results	
Maximum Value Over Time	
X Axis	-2.2668 N
Y Axis	245.58 N
Z Axis	2153.1 N
Total	2167.2 N

Fig. 4.7 Force Reaction of E glass fiber composite B-Pillar trim

The maximum reaction force observed on E glass fiber composite B pillar Trim was 2167.2 N as shown in Fig 4.7

4.3 fea of optimize composite carbon fiber B Pillar Trim Component

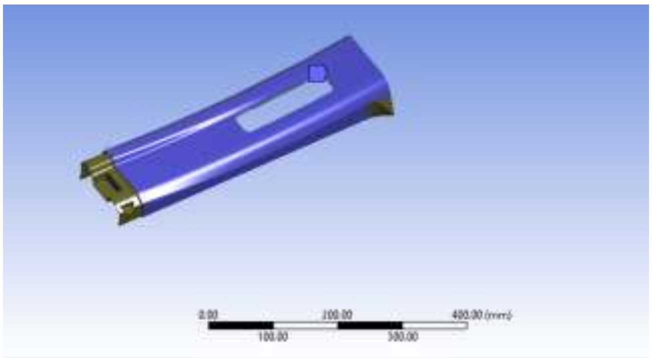
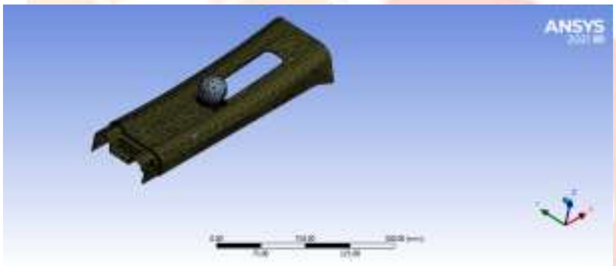


Fig. 4.3 B-Pillar Trim with Loading Nose Spherical Ball

	A	B	C
1	Property	Value	Unit
2	Density	1490	kg m^-3
3	Orthotropic Secant Coefficient of Thermal Expansion		
8	Orthotropic Elasticity		
9	Young's Modulus X direction	9.182E+10	Pa
10	Young's Modulus Y direction	9.182E+10	Pa
11	Young's Modulus Z direction	9E+09	Pa
12	Poisson's Ratio XY	0.05	
13	Poisson's Ratio YZ	0.3	
14	Poisson's Ratio XZ	0.3	
15	Shear Modulus XY	3.6E+09	Pa
16	Shear Modulus YZ	3E+09	Pa
17	Shear Modulus XZ	3E+09	Pa

Table 4.3 B-Pillar Material Properties of composite Component

4.3.1 Meshing of carbon fiber composite B Pillar Trim Component

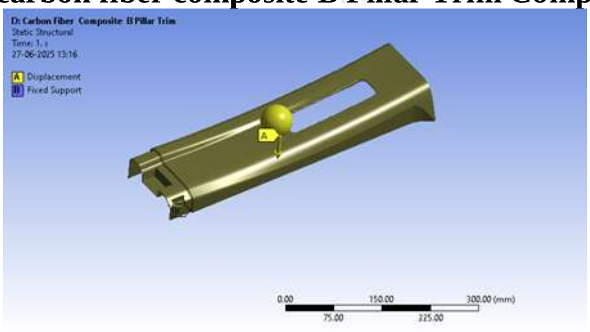


Statistics	
Nodes	51005
Elements	26029

Fig. Meshing Details of carbon fiber B-Pillar Trim

The node and element generate on the b pillar was 51005 and 26029 respectively as shown in Fig shows the boundary conditions for the component.

4.3.2 Boundary condition for carbon fiber composite B Pillar Trim Component



Tabular Data

	Steps	Time [s]	X [mm]	Y [mm]	Z [mm]
1	1	0.	= 0.	= 0.	0.
2	1	1.	0.	0.	-1.
3	2	2.	= 0.	= 0.	-2.
4	3	3.	= 0.	= 0.	-3.
5	4	4.	= 0.	= 0.	-4.
6	5	5.	= 0.	= 0.	-5.

Fig. 4.3 Boundary Condition of carbon fiber composite B-Pillar Trim

Results - carbon fiber composite B Pillar Trim Component

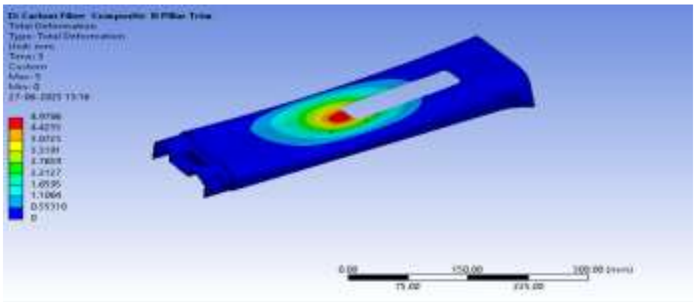


Fig. 4.4 Total Deformation of carbon fiber composite B-Pillar Trim

The Total deformation generated on the carbon fiber composite B-pillar trim is kept as 5 mm as shown in Fig 4.4.

G] Equivalent Stress - carbon fiber composite B Pillar Trim Component

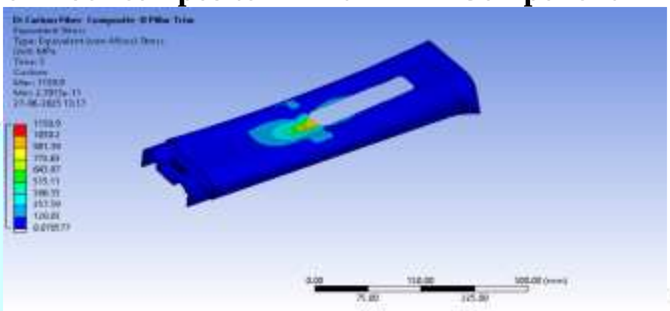


Fig. 4.5 Equivalent Stress of carbon fiber composite B-Pillar Trim

The maximum Equivalent Stress generate on the carbon fiber composite B-pillar was 1158.9 MPa, as shown in Fig 4.5

H] Equivalent Elastic strain - carbon fiber composite B Pillar Trim Component

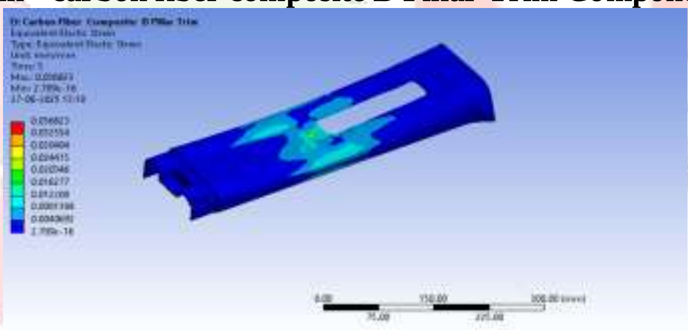


Fig. 4.6 Equivalent Elastic Strain of carbon fiber composite B-Pillar Trim

The maximum Equivalent Elastic strain on carbon fiber composite B pillar Trim was 0.036623 as shown in Fig 4.6

I] Force Reaction - carbon fiber composite B Pillar Trim Component

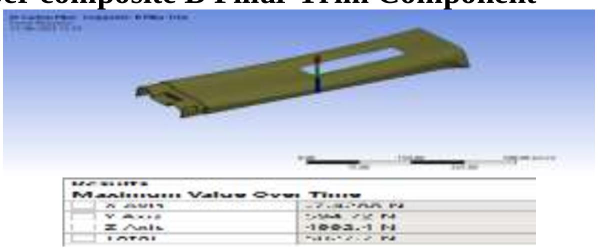


Fig. 4.7 Force Reaction of carbon fiber composite B-Pillar trim

The maximum reaction force observed on carbon fiber composite B pillar Trim was 5027.7 N as shown in Fig 4.7

Fea Result

SR NO	COMPONENT	FORCE REACTION (N)
1	**Original B Pillar Trim**	**460.44 N**
2	**E glass fibre reinforces B Pillar Trim**	2167.2 N
3	**carbon fibre composite reinforced B Pillar Trim**	**5027.7 N**

V. Manufacturing of the component

1. Preparation:
• **Cleaning:** The B Pillar Trim surface must be clean and free of dust, dirt, grease, and loose particles. This ensures proper adhesion of the resin to the pillar.
• **Surface Roughening:** If the B Pillar trim surface is very smooth, it may be beneficial to roughen it slightly using sandpaper or a grinding tool. This increases the surface area and enhances mechanical bonding.
2. Carbon fiber Preparation:
• **Cutting:** The carbon fiber mat is cut into sheets or patterns that match the dimensions of the B Pillar trim surface. The size of the sheets may vary depending on the complexity of the B Pillar trim shape.
3. Resin Preparation:
• **Epoxy Resin and Hardener Mixing:** The epoxy resin and hardener are mixed in the correct proportions according to the manufacturer's instructions. This is crucial for proper curing and achieving the desired mechanical properties.
• **Homogeneity:** Thorough mixing is essential to ensure a homogeneous mixture. Incomplete mixing can result in weak spots in the laminate.

Fig. 5.1 Preparation of Resin and hardener

4. Hand Layup Process:
• **First Resin Layer:** A thin layer of the resin mixture is applied to the B Pillar trim surface using a brush or roller. This layer acts as a bonding agent.
• **First carbon fiber Layer:** The layer of carbon fiber is carefully placed onto the wet resin.

Fig. 5.2 Hand layup process of the b-pillar trim

5. Curing:

• **Curing Time:** The laminate is allowed to cure for the recommended time. The curing time will vary depending on the type of epoxy resin and hardener used.

Fig. 5.3 Carbon fiber reinforced B-Pillar trim

VI. Experimental procedure

• B Pillar was initially kept under UTM base with fixed base support.
• Single force is applied for 5 mm deformation as per FEA analysis.
• UTM load with respective deformation is been recorded in UTM monitor with graph of force Vs. CHT.
After testing, the load–displacement data and deformation patterns were compared with the FEA results to validate the improved trim performance.

Fig. 6.2 CFR B-Pillar Trim kept under UTM

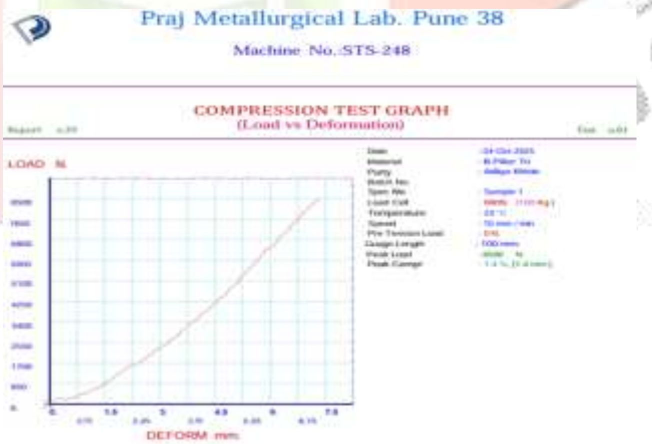


Fig. 6.3 CFR B-Pillar Trim Compression Test Graph

Fig.6.4 Comparison of UTM Results and FEA Results for Carbon Fiber Reinforced B-Pillar Trim

Universal Testing Machine (UTM) under the same 5 mm indentation conditions used in the FEA simulation. The comparison between both results is summarized below:

I. A. FEA Result (Carbon Fibre Trim)
- Predicted peak reaction force at 5 mm indentation: 5027.7 N

II. B. UTM Experimental Result
- Measured peak reaction force at 5 mm indentation: 5100 N
- A 1.4% deviation indicates excellent correlation between simulation and physical testing.

Conclusion

The data clearly indicates that reinforcing the B-pillar trim with composite materials significantly enhances its load-bearing capacity compared to the original trim.

- The original polypropylene B-pillar trim shows a low reaction force of 460.44 N, indicating limited strength and poor resistance to localized loading.
- Reinforcement with E-glass fibre significantly improves performance, achieving 2167.2 N, which is approximately 4.7 times stronger than the original trim.
- The carbon-fibre-reinforced trim delivers the highest improvement, with an FEA-predicted reaction force of 5027.7 N, showing an increase of more than **10 times** over the baseline component.
- The UTM experimental **test** recorded a reaction force of 5100 N for the carbon-fiber trim, closely matching the FEA prediction and confirming the reliability of the simulation model.
- Overall, both E-glass and carbon fiber composites provide substantial structural enhancement, with carbon fiber offering the best load-bearing capacity and superior suitability for safety-critical applications.
- These improvements demonstrate that composite-reinforced B-pillar trims can significantly contribute to higher safety and better occupant protection in automotive interiors. The very small difference between FEA (5027.7 N) and UTM (5100 N) validates that the finite element model is highly reliable and capable of accurately predicting the performance of composite-reinforced B-pillar trim components under indentation loading.

Future scope

- More types of composite combinations (like mixing carbon fiber with E-glass) can be tested to find an option that gives good strength at a lower cost.
- Long-term tests like vibration, fatigue, and environmental exposure can be done to check how the reinforced trim performs over years of vehicle use.
- Advanced manufacturing methods, such as vacuum bagging or resin transfer molding, can be explored to improve quality and make large-scale production easier
- The effect of reinforcement on cabin comfort, sound levels, and fitting with other interior parts can also be studied.

Reference

1. Fardin Khan, Nayem Hossain. Advances of composite materials in automobile applications – A review. Journal of Engineering Research 13 (2025) 1001–1023 https://doi.org/10.1016/j.jer.2024.02.017
2. Abdulqadir, S.F.; Tarlochan, F. Composite Hat Structure Design for Vehicle Safety: Potential Application to B-Pillar and Door Intrusion Beam. Materials 2022, 15, 1084. https://doi.org/10.3390/ma15031084
3. Kang, J.-H.; Lee, J.-W.; Kim, J.-H.; Ahn, T.-M.; Ko, D.-C. Design of Center Pillar with Composite Reinforcements Using Hybrid Molding Method. Materials 2021, 14, 2047. https://doi.org/10.3390 /ma14082047
4. Leszek Gardyński, Jacek Caban2, Dalibor Barta RESEARCH OF COMPOSITE MATERIALS USED IN THE CONSTRUCTION OF VEHICLE BODYWORK. Advances in Science and Technology Research Journal Volume 12, No. 3, September 2018, pages 181–187 DOI: 10.12913/22998624/92096

5. Jiayu Guo, Shuyang Liu Improving the crashworthiness of B-pillars in side-collisions. Proceedings of the 2nd International Conference on Mechatronics and Smart Systems DOI: 10.54254/2755-2721/78/20240455
6. Wen Zhang, Jun Xu. Advanced lightweight materials for Automobiles: A review. Materials & Design 221 (2022) 110994 https://doi.org/10.1016/j.matdes.2022.110994
7. Meiqin Liang, Shang Wang, Simulation and Analysis of Three-point Bending Experiment with Hollow Beam Based on Abaqus. Journal of Physics: Conference Series 2566 (2023) 012063 IOP Publishing doi:10.1088/1742-6596/2566/1/012063
8. CHANGAPPA T. P., S DINESH KUMAR, FMVSS Head Crash Target Point Bp2 FEA Simulation Using B Pillar Trim. AUG 2021 | IRE Journals | Volume 5 Issue 2 | ISSN: 2456-8880
9. Hye Rin Gua, Seung Jin Kim, PHYSICAL PROPERTIES OF ECO-FRIENDLY KENAF FIBER IMBEDDED NONWOVEN FOR AUTOMOTIVE PILLAR TRIM. Procedia Engineering 200 (2017) 45–52
10. Prof. Dr. M. C. Swami1, Prof. Monika S Jadhav. "Reinforcement of B- Pillar in Automotive with Composite Material and Evaluation of Bending Strength" International Journal of Enhanced Research in Science, Technology & Engineering ISSN: 2319-7463, Vol. 13 Issue 8, August-2024.
11. Baskara, T., Cimendag, M. & Yılmaz Ulu, E. (2021). Analysis and Simulation of B-Pillar for a VehicleJournal of Current Research on Engineering, Science and Technology, 7 (1), 1-18.