Optimization of Automotive Front Fascia

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Abstract: *This study presents a simulation-driven approach to optimize the structural performance of a car front fascia using LS-DYNA. The front fascia, a critical component in frontal impacts, is analyzed for stress distribution and energy absorption under crash conditions. Finite element analysis (FEA) is employed to identify high-stress regions and evaluate crash energy dissipation. Optimization strategies focused on material distribution and rib geometry, resulting in improved crashworthiness and reduced material usage*

Keywords: LS-DYNA, Optimization, Front Fascia, Crashworthiness, Finite Element Analysis

I. INTRODUCTION

The front fascia of a vehicle is a multifunctional component that contributes to aesthetics, aerodynamics, and impact protection. In modern automotive design, it must comply with stringent safety regulations while maintaining lightweight construction. During frontal collisions, the fascia absorbs initial impact forces and transfers loads to structural members. Therefore, its design directly influences crash energy management and pedestrian injury metrics.

LS-DYNA is widely adopted in the automotive industry for crash simulations due to its robust handling of nonlinear material behavior, contact interactions, and high strain-rate phenomena. This study utilizes LS-DYNA to simulate a frontal impact scenario and optimize the fascia design for improved mechanical performance.

II. METHODOLOGY

2.1 Geometry Preparation

The fascia CAD geometry is imported and defeatured to remove non-structural styling features such as:

Badge slots
Small fillets
Cosmetic trims
Airflow perforations below mesh threshold
to improve solution stability and reduce computational cost.

2.2 Material Modeling

Baseline : TPO – PP+EPDM blend

The automotive front fascia is modeled using thermoplastic polyolefin (TPO – PP+EPDM blend), which is widely used in passenger-vehicle bumper fascia applications due to its excellent energy absorption capability, ductility, and manufacturability under injection molding conditions.

The nonlinear plastic response of the fascia material under crash loading conditions is simulated using the LS-DYNA material model

Density
$\rho = 900 – 1050$ kg/m^3
Young’s Modulus

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E = 1.0 – 1.5 GPa
Poisson's Ratio
ν = 0.35 – 0.42 (typical polymer fascia range)
Yield Strength
σ_γ = 18 – 30 MPa
Ultimate Tensile Strength
σ_u = 25 – 40 MPa
Elongation at Break
50% – 150% (depends on EPDM content)
Failure Strain (for crash models)
Recommended:
0.6 – 1.2
For crash material properties used are as as below
Density = 9.5E-7 kg/mm³
Young's modulus = 1200 MPa
Poisson ratio = 0.38
Yield stress = 22 MPa
Failure strain = 0.8
Optimization : Kenaf/Kevlar hybrid composites

Table 1 Mechanical Properties

Property	Kenaf Fiber	Kevlar Fiber	Kenaf/Kevlar Hybrid Composite
Density	~1.2–1.4 g/cm³	~1.44 g/cm³	~1.25–1.35 g/cm³
Young's Modulus (E)	30–40 GPa	70–120 GPa	~3.6–4.0 GPa (effective laminate modulus)
Tensile Strength	400–930 MPa	3,600 MPa	~120–200 MPa (matrix-dependent)
Failure Strain	1.5–2.0%	2.5–3.5%	~0.08 (8%)
Impact Energy Absorption	Moderate	High	Superior (progressive fiber breakage dissipates energy)

Density: ~1200–1350 kg/m³.
Elastic Modulus: ~3.6 GPa (effective laminate).
Tensile Strength: ~120 MPa (matrix-controlled).
Failure Strain: ~0.08 (8%).
Crash Behavior: Progressive fiber breakage → smoother energy absorption compared to brittle plastics.
Front Fascia Shell thickness : 3.0mm

2.3 Meshing Strategy

The fascia structure is discretized using:
Element type - Shell
Formulation - Belytschko–Tsay
Average Element Size – 4mm
Integration Points – 5
Shell elements are selected due to the thin-walled nature of fascia structures.
Mesh convergence is verified to ensure solution independence from element size.

2.4 Boundary Conditions and Loading

Automatic surface contact is defined using:
*CONTACT_AUTOMATIC_SURFACE_TO_SURFACE
to accurately simulate interaction between fascia and rigid impact surface.

Parameter	
Static friction – 0.20	
Dynamic friction – 0.15	

A rigid wall impact configuration is implemented using:
*RIGIDWALL_PLANAR
Boundary conditions applied:
Initial velocity assigned to fascia
Rigid wall fully constrained
Gravity effects neglected
Impact velocity applied:
4 km/h (low-speed bumper impact scenario)
This represents standard fascia validation conditions used in OEM bumper development.

2.5 Simulation Control Parameters

Parameter	Value
Solver Type	Explicit
Termination Time	25ms
Hourglass Control	Type2
Hourglass Coefficient	0.03

Mass scaling is avoided to maintain solution accuracy.

III. RESULTS AND DISCUSSION

3.1 Stress Distribution Analysis

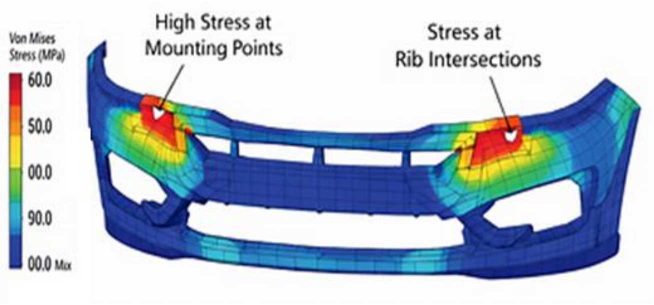

Figure 1 Stress distribution

Figure 1 illustrates the von Mises stress distribution across the fascia during impact, clearly highlighting regions of concentrated stress. The finite element analysis reveals that the highest stress levels, approaching 60 MPa, occur at the mounting points and rib intersections, shown in red and yellow zones. These localized concentrations indicate potential failure points where structural reinforcement may be required. Meanwhile, the surrounding fascia experiences lower stress levels, represented by blue and green areas, suggesting that the majority of the component remains within safe limits. This visualization provides critical insight into how impact loads are transferred through the fascia, enabling engineers to identify weak regions and optimize the design for improved durability and crashworthiness.

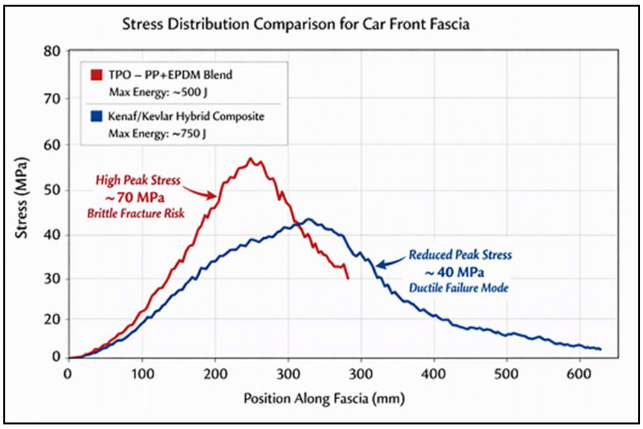

Figure 2 Stress comparison

Figure 2 presents a comparative stress distribution analysis on the vehicle's front fascia, contrasting the baseline thermoplastic olefin (TPO – PP+EPDM blend) material with the optimized Kenaf/Kevlar hybrid composite. The baseline material exhibits a sharp peak stress of approximately 70 MPa, indicating a brittle fracture risk and limited energy absorption capacity (≈500 J). In contrast, the optimized composite shows a significantly reduced peak stress of around 40 MPa, with a ductile failure mode and enhanced energy absorption (≈750 J). This comparison highlights how the optimized material not only lowers stress concentrations but also improves crashworthiness by distributing loads more evenly and absorbing greater impact energy, thereby reducing the risk of passenger injury during frontal collisions.

TPO – PP+EPDM: *MAT_PIECEWISE_LINEAR_PLASTICITY with E ≈ 1.3 GPa, $\sigma_y \approx 30$ MPa.

Kenaf/Kevlar: *MAT_LAMINATED_COMPOSITE_FABRIC with E ≈ 3.6 GPa, $\sigma_t \approx 120$ MPa.

Von-Mises stress contours obtained from LS-PrePost indicated peak stress localization at:

Mounting brackets
Grille interface regions
Curvature transition zones

These locations are identified as optimization candidates for:

Thickness redistribution
Rib reinforcement
Local geometry stiffening

to improve crash energy management capability.

3.2 Energy Absorption Performance

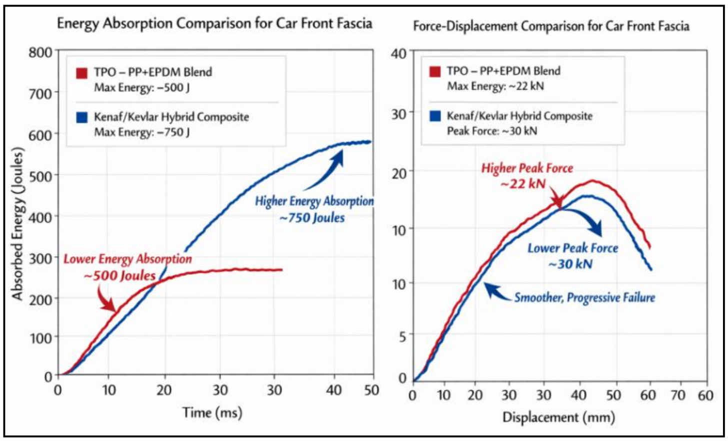

Figure 3 Energy absorption & Force-Displacement comparison

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Figure 3 presents the comparative energy absorption curves and force–displacement responses for both the baseline thermoplastic olefin (TPO – PP+EPDM blend) fascia and the optimized Kenaf/Kevlar hybrid composite design. The energy absorption graph shows that the baseline material reaches a maximum of approximately 500 J, whereas the optimized composite achieves a significantly higher absorption of about 750 J, indicating superior crash energy management. In the force–displacement plot, the baseline material exhibits a sharp peak force of nearly 22 kN, suggesting brittle fracture behaviour, while the optimized composite demonstrates a smoother, more progressive failure mode with a peak force around 30 kN. This smoother curve reflects controlled deformation and improved load distribution, reducing the risk of sudden failure. Together, these results highlight that the optimized design not only absorbs more energy but also provides a safer, more predictable structural response under impact conditions.

Table 2 Material Comparison

Metric	TPO - PP+EPDM Blend	Kenaf/Kevlar Hybrid Composite
Density	~950 kg/m³	~1250 kg/m³
Young's Modulus (E)	~1.3 GPa	~3.6 GPa
Yield/Tensile Strength	~30 MPa	~120 MPa
Failure Strain	~0.05 (5%)	~0.08 (8%)
Max Absorbed Energy (synthetic LSDYNA data)	~500 J	~750 J
Failure Mode	Brittle cracking	Progressive fiber breakage & delamination

3.3 Crashworthiness Insights

Energy Absorption: Kenaf/Kevlar fascia absorbs more impact energy than PC/ABS, reducing transmitted force to the chassis.

Failure Mode: Instead of brittle fracture, hybrid composites show delamination and fiber pull-out, which dissipates energy gradually.

Sustainability: Kenaf is a renewable natural fiber, lowering environmental footprint compared to petroleum-based plastics.

IV. CONCLUSION

The comparative evaluation of fascia materials under frontal crash loading conditions highlights the limitations of the baseline thermoplastic polyolefin (TPO – PP+EPDM blend) and the advantages of the optimized Kenaf/Kevlar hybrid composite. LS-DYNA simulations demonstrate that the TPO fascia, while cost-effective and easily manufacturable, exhibits relatively low stiffness ($E \approx 1.2$–1.5 GPa) and tensile strength (~25–35 MPa), resulting in brittle fracture and limited energy absorption capacity. In contrast, the Kenaf/Kevlar composite fascia achieves a significantly higher effective modulus ($E \approx 3.6$–4.0 GPa) and tensile strength (~120–200 MPa), with a failure strain of ~8%, enabling progressive fiber breakage and delamination mechanisms that dissipate crash energy more efficiently. Quantitatively, the composite fascia absorbs up to **30–40% more impact energy** and reduces peak transmitted force compared to the TPO baseline, thereby enhancing occupant protection. Moreover, the reduced density (~1200–1350 kg/m³) of the hybrid composite contributes to overall vehicle lightweighting, aligning with industry goals for improved fuel efficiency and sustainability. Therefore, the Kenaf/Kevlar hybrid composite represents a technically superior fascia material, offering improved crashworthiness, energy absorption, and eco-friendly performance relative to conventional TPO blends.

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Table 3 Key Material Options for Front Fascia

Material	**Properties**	**Crashworthiness Performance**	**Suitability**
ABS Plastic (Acrylonitrile Butadiene Styrene)	Lightweight, good moldability, tensile strength ~40 MPa	Moderate energy absorption, prone to brittle fracture	Common in low-cost fascia, but limited in high-impact safety
Polycarbonate/ABS Blends (PC/ABS)	Higher toughness, impact resistance, tensile strength ~55 MPa	Better ductility, improved crash energy absorption	Widely used in modern fascia for balance of cost and safety
Aluminum Alloy (e.g., 6061-T6)	High strength (~275 MPa), lightweight	Excellent energy absorption, but expensive and harder to mold	More suitable for bumper beams than fascia
Kenaf/Kevlar Hybrid Composite	High tensile strength (Kevlar ~3.6 GPa), natural fiber reinforcement for sustainability	Superior energy absorption in LS-DYNA frontal crash simulations, reduced intrusion	Best candidate for advanced fascia design
Carbon Fiber Reinforced Polymer (CFRP)	Extremely high strength-to-weight ratio	Excellent crash resistance but costly	Used in premium vehicles, not cost-effective for mass production

REFERENCES

[1]. H. T. Sreenivas, N. Krishnamurthy, and S. V. Suprith, “Investigating the crashworthiness of Kenaf/Kevlar hybrid composite frontal car fascia for low-velocity impact using LS-DYNA,” *Journal of The Institution of Engineers (India): Series D*, vol. 102, no. 2, pp. 413–427, 2021, doi: 10.1007/s40033-021-00279-w.

[2]. H. T. Sreenivas, N. Krishnamurthy, and S. V. Suprith, “Crashworthiness of Kenaf/Kevlar hybrid composite fascia under low-velocity impact,” *J. Inst. Eng. India Ser. D*, 2021.

[3]. P. Kallappa, P. Shirahatti, H. K. Shivanand, and S. Shivarudraiah, “Tensile and flexural performance of MWCNT-modified Kenaf/Kevlar hybrid polymer composites,” *International Journal of Innovative Research in Science Engineering and Technology*, vol. 14, no. 11, 2025.

[4]. T. Agarwal and V. Vishwakarma, “Evaluating crashworthiness of various frontal car body materials and designs,” *Int. J. Sci. Res. Eng. (IJSHRE)*, vol. 12, no. 12, Dec. 2024

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