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Investigation of Battery Pack Bracket and its Life under External Force & Vibrational Condition

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Abstract— **Battery-powered automobiles are emerging as a promising alternative to internal combustion engine vehicles in response to the internationally strengthening regulation on carbon dioxide emissions. Due to the heavy weight of the electric drive unit, the weight savings of the electric vehicles are often attempted on body structures by using lightweight materials such as fibre-reinforced composites with traditional metal alloys. In the present study, a new multi-material design of a battery pack structure is proposed, and its performance is evaluated through random vibration fatigue tests. The fatigue tests are virtually performed on a full-scale finite element model of the battery pack. The virtual tests embody boundary and loading conditions required by a real industry specification. The vibration loading is specified in the form of a power spectral density and the fatigue analysis is conducted accordingly in frequency domain. The cumulative fatigue damage and lives of each component composing the batter pack structure are predicted. The present modeling approach could benefit the preliminary design of an automotive body structure because the performance evaluation on various prototypes can be efficiently conducted without a physical model.**

***Keywords*— Battery bracket of vehicle, Design optimization, Mechanical properties, Lightweight Material, Composites, Fatigue test, FEA & Static Structural Analysis.**

I. Introduction

Electric machines are recently used as a power source for automotive vehicles in addition to internal combustion engines. The electric powertrains require heavy batteries, which is an obstacle to improving fuel efficiency. Automobile manufacturers attempt to reduce the vehicle weight by implementing lightweight materials such as fibre-reinforced plastic composites together with conventional metals for the structure protecting battery packs. The multi-material battery pack structure design must satisfy various structural requirements including fatigue safety. The battery pack structure should endure random vibration loads occurring while the car is driving. Such a safe design with minimized weight can be typically achieved by an iterative process of prototyping, fatigue testing, evaluating, and refining the prototype. However, physical fatigue tests are extremely time-consuming and expensive. Alternatively, finite element (FE)-based fatigue analysis can significantly save time and cost in the preliminary design stage.

In the present study, the typical mode-based approach is utilized to evaluate fatigue damage and life of the proposed multi-material battery pack bracket structure. Virtual fatigue tests are performed on the full-scale FE model subjected to random vibration loading specified by frequency-domain data. The fatigue safety of the proposed design is evaluated with the estimation of cumulative damage. This numerical analysis will be performed using commercial software packages, ANSYS, Abaqus or fe-safe. Several studies have applied the FE method for fatigue analysis. Baek et al predicted the fatigue life of the freight car bogie frame by utilizing FE stress analysis and probabilistic S–N curves. They compared the predicted results with the fatigue lives obtained from the strain history measured during in-service loading.

II. Material Selection

The current battery tray material is structural steel, and this has been implicit before. Apart from that, the other common materials that are used in automotive manufacturing industry, especially automotive factories were noted, according to extensive technical research. The material selection is carried out based on application. The structural steel is replacing with the material like glass fibre and Aluminium. The selection of different material is based on the simple decision matrix with consideration of requirement like light weight, rigidity, corrosion and cheaper in cost. The criteria are made for all three materials with requirement it is found that the glass fibre is best suited with requirement.

TABLE 1
PROPERTIES OF BATTERY TRAY MATERIALS

Material	Density [g/cm³]	Yield Strength [MPa]	Tensile Strength [MPa]
Steel	7.86	250	300
Aluminium	2.71	275	295
Glass Fibre	1.5 - 1.57	269 - 448	280 - 810

III. MATERIAL-1: ASTM A36 HOT ROLLED STEEL PLATE

A36 steel product shall have ultimate tensile strengths ranges from 58,000 to 79,800 psi. It is not an exact number for it is affected by its chemical composition and production method. In tensile testing, ASTM A36 steel bar can elongate to around 20% of its original length. It also shows excellent impact strength at room temperature.

TABLE 2
MECHANICAL PROPERTIES OF ASTM A36 HOT ROLLED STEEL PLATE

Properties	Metric	Imperial
Density	7.85 g/cm^3	0.284 lb/in^3
Tensile strength	400 - 550 MPa	58000 - 79800 psi
Yield strength	250 MPa	36300 psi
Elongation at Break (in 200 mm)	20%	20%
Elongation at Break (in 200 mm)	23%	23%
Modulus of Elasticity	200 GPa	29000 ksi
Bulk Modulus (typical for steel)	140 GPa	20300 ksi
Poisson Ratio	0.260	0.260
Shear Modulus	79.3 GPa	11500 ksi

IV. MATERIAL-2: MATERIAL ALUMINIUM 3003 GRADE

A key benefit of Aluminium is its natural resistance to rust and corrosion. Unlike steel, Aluminium is protected by a layer of Aluminium oxide, which acts to protect the metal from exposure with air and oxygen two elements that are needed for the oxidative effects of corrosion. When it comes to strength properties, Aluminium makes for a very desirable metal, as it is more malleable and elastic than steel. It is also very easy to shape, making it one of the most suitable materials for metal fabrication.

TABLE 3
MECHANICAL PROPERTIES OF ALUMINIUM 3003 GRADE

Properties	Metric	Imperial
Density	2.73 g/cm^3	0.0939 lb/in^3

Melting point	644°C	1190°F
Tensile strength	130 MPa	18855 psi
Yield strength	125 MPa	18130 psi
Shear strength	83 MPa	12039 psi
Fatigue strength	55 MPa	7977 psi
Elastic modulus	70-80 GPa	10153-11603 ksi
Poisson's ratio	0.33	0.33
Elongation	10%	10%
Hardness	35	35

V. MATERIAL-3: GLASS FIBRE

The strength-to weight ratio of Fiberglass Reinforced Plastic compared to metal or wood products can be up to 5 times bigger. The fiberglass strength is maintained since the fibers carry the load while the resin distributes the weight throughout the composite parts as required.

TABLE 4
MECHANICAL PROPERTIES OF GLASS FIBRE

Glass fibre Type	Description	Density (g/cm^3)	Tensile Strength (GPa)	Young's Modulus (GPa)
E-glass	E for good electrical insulation	2.54	1.7–3.5	69–72
S-glass	S for high silica, able to withstand high temperatures	2.48	2.0–4.5	85
C-glass	C for corrosion resistant	2.48	1.7–2.8	70
Cemfil	Alkali resistant glass fibre	2.70		80

VI. STATIC STRUCTURAL ANALYSIS

Boundary conditions and mesh configuration has been kept constant throughout the solution, only material & design has been changed. In this iteration modification in design has been made to reduce the Material mass while manufacturing it.

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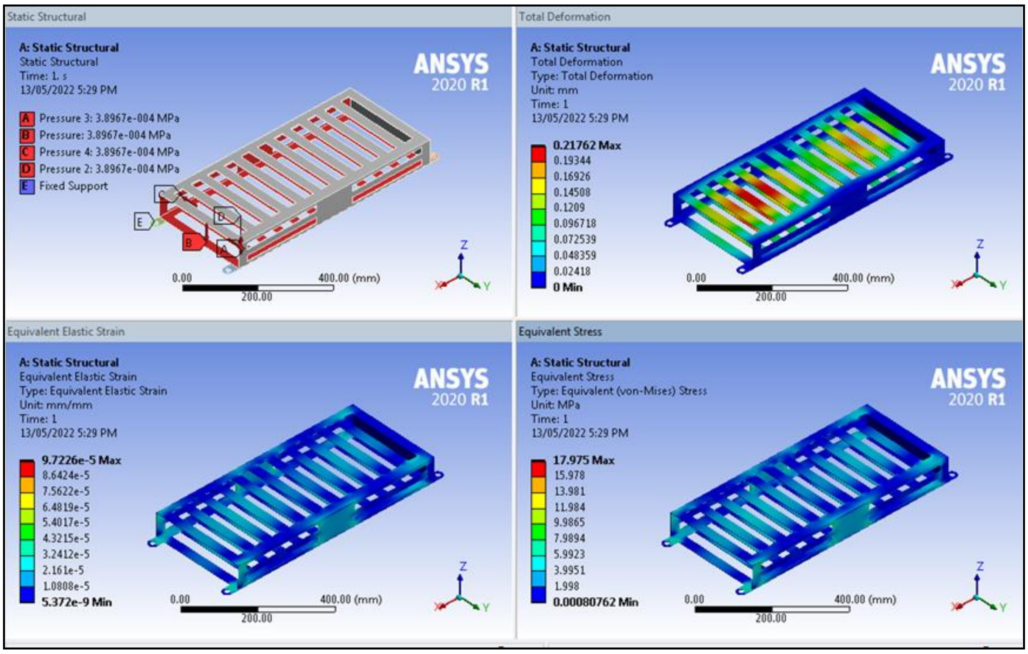

Fig. 1 Overall result at 2 mm thickness for modified design

This iteration is solved, by setting up the optimization strategy to its least stress condition so, that the modified design should not address to the maximum stress concentration factors.

In modified design the stress is inducing 2Mpa more than the hexagonal case with mass of 0.5444 kg. overall, the part body is experiencing 17.975 MPa which is less than the 205 MPa of steel yield stress.

In next iteration we will set the part body to its mass reduction strategy because the stress induced on the bracket is very much lesser, after optimization, the stress factors of brackets must be lower than the yield strength of material.

VII. Static Structural Analysis – Material Glass Fibre

Using Same boundary Condition & Mesh Configuration on optimized part design 2 the geometry from steel has been changed to E-Glass. This comparison is made because composite makes material more weightless and provides same strength as the low carbon fibre.

TABLE 5
MECHANICAL PROPERTIES OF GLASS FIBRE

Bounding Box	
Length X	770. mm
Length Y	311. mm
Length Z	80. mm
Properties	
Volume	5.822e+005 mm^3
Mass	1.5137 kg
Scale Factor Value	1.

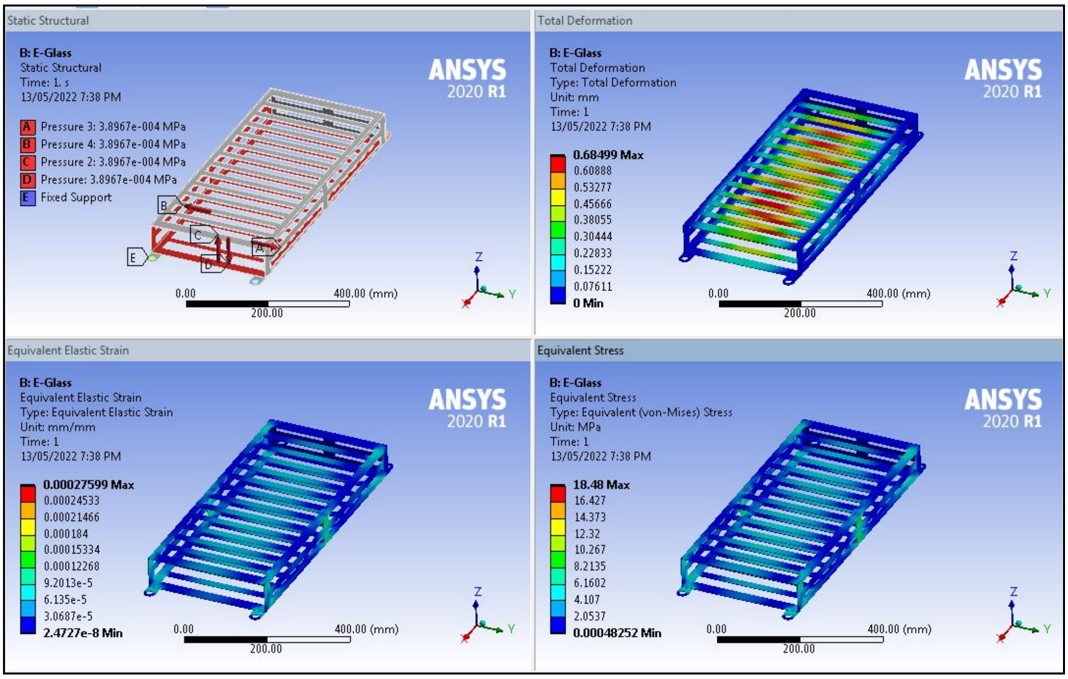

Fig. 2 Overall result for Glass Fiber

VIII. Static Structural Analysis – Material Aluminium

5052 Aluminium is frequently used for general sheet metal work, heat exchangers, flooring panels, rivets and wires, chemical drums and other equipment, pressure vessels, treadplate, containers, and more.

TABLE 6
MECHANICAL PROPERTIES OF ALUMINIUM

Bounding Box	
Length X	770. mm
Length Y	311. mm
Length Z	80. mm
Properties	
Volume	5.822e+005 mm³
Mass	1.5603 kg
Scale Factor Value	1.

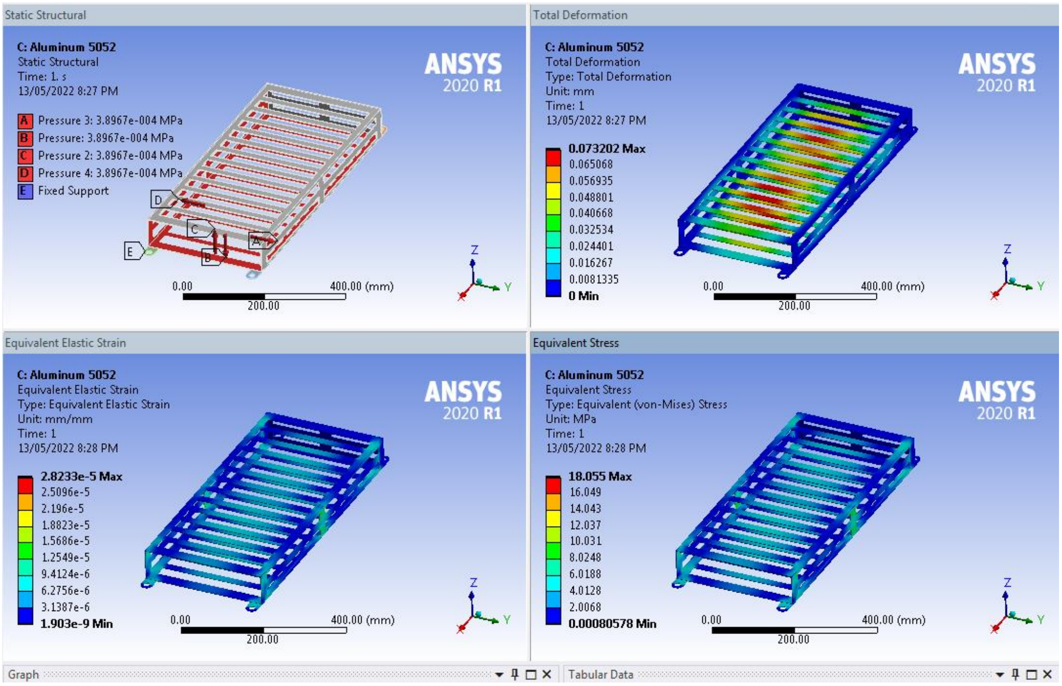

Fig. 3 Overall result for Aluminium

IX. Conclusions

FEA Static Structural Analysis had been successfully conducted on battery bracket for the self-load condition, to investigate the stress concentration factor & vibrational modes of frequency for a defined boundary condition. Finally, all the results were observed and noted down.

TABLE 7
OVERALL RESULTS

Sr. No.	Material	Type of analysis	Deformation in mm	Strain	Stress in MPa	Mass in Kg
1.	Structural steel	Optimization 1	0.21760	$9.772e^{-5}$	17.975	5.590
2.	Structural steel	Optimization 2	0.25772	$9.850e^{-5}$	18.163	4.570
3.	E-Glass	Optimization 2	0.68499	$2.750e^{-5}$	18.480	1.513
4.	Aluminium 5052	Optimization 2	0.07320	$2.82e^{-5}$	18.050	1.560

From the above observation table one can conclude that, if the part body has a much larger volume with mass, then the body part mass can be reduced with the help of topology optimization mass reduction strategy. Form the above FEA solution Aluminum & E-glass Material is showing better results with minimum weight condition and stress concentration factors are equal. fabricating E-glass can affect in cost modulation while fabricating it, it will be better to take Aluminum 5052 material for the bracket.

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