Vibration Analysis and Weight Reduction for Compressor Mounting Bracket Using Composite Material

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Abstract - *Parameter like amount of car and ammunition ability mostly afflicted by weight of the Vehicle in the automotive industries. As per the assurance accepted this is actual important to Design ablaze weight component. The air conditioners acclimated in cars are army on a bracket in the bonnet. This activity intends to assay the bracket and optimize the weight by replacing the actual of the bracket. Weight abridgement is not alone abate the raw Material cost, but as well increases the efficiency, admitting actual minute. The abstraction of the Materials is done as per the claim of the bracket design. This abstraction as well highlights the factors for the abortion of the ascent bracket and the aftereffect of the enhancement by various analyses beating analysis, anamorphosis assay and Von-Mises accent analysis. In this project, we accept advised an Compressor ascent bracket. The clay of the bracket is done in clay software and analyzed application ANSYS Software. By using FFT analyzer vibration and noise is calculated . Comparison of theoretical, FEA and experimental results for compressor mounting bracket .The bottle cilia Bracket is advised application architecture of abstracts and analyzed in ANSYS. Total 70 % of Weight abridgement in the bracket architecture is achieved. Model frequencies of the animate and Blended brackets are to be checked. By checking the vibration in terms of motor rpm connection to probe acceleration and displacement is less of GRFP material then the steel material. By the weight reduction of compressor mounting bracket the noise of bracket of GFRP is reduced then steel bracket.*

Key Words: **Compressor mounting bracket, ANSYS, Design of Experiments, FFT analyzer, Sound level meter.**

1.INTRODUCTION

Heating, ventilation and aerating and cooling (HVAC) is the innovation of indoor and vehicular ecological solace. Its will likely give warm solace and worthy indoor air quality. Air conditioning framework configuration is a sub train of mechanical designing, in view of the standards of thermodynamics, liquid mechanics and warmth exchange. The three focal elements of Heating, ventilation, and aerating and cooling are interrelated, particularly with the need to give warm solace and satisfactory indoor air quality inside sensible establishment, activity, and upkeep costs. Air conditioning frameworks can give ventilation, diminish air invasion, and keep up weight connections between spaces.

The methods for air conveyance and expulsion from spaces is known as room air dissemination. Ventilation is the way toward changing or supplanting air in any space to control temperature or evacuate any mix of dampness, smells, smoke, warm, dust, airborne microscopic organisms, or carbon dioxide, and to renew oxygen. Ventilation incorporates both the trading of air with the outside and also course of air inside the building. It is a standout among the most imperative variables for keeping up worthy indoor air quality in structures. Techniques for ventilating a building might be partitioned into mechanical/constrained and regular composes. Mechanical, or constrained, ventilation is given by an air handler (AH) and used to control indoor air quality. Abundance dampness, scents, and contaminants can frequently be controlled by means of weakening or supplanting with outside air. In any case, in sticky atmospheres more vitality is required to expel abundance dampness from ventilation air. Characteristic ventilation is the ventilation of a working with outside air without utilizing fans or other mechanical frameworks. It very well may be by means of operable windows, louvers, or stream vents when spaces are little and the design grants. In more mind boggling plans, warm air is permitted to rise and stream out high building openings to the outside (stack impact), making cool outside air be drawn into low building openings. Characteristic ventilation plans can utilize almost no vitality, yet mind must be taken to guarantee comfort. In warm or muggy atmospheres, keeping up warm solace exclusively by means of common ventilation probably won't be conceivable. Aerating and cooling frameworks are utilized, either as reinforcements or supplements. Air-side economizers likewise use outside air to condition spaces, however do as such utilizing fans, conduits, dampers, and control frameworks to present and disperse cool open air when suitable..

1.1 Refrigeration Cycle

A complete vapor compression cycle is shown on the Fig.1 below and shown schematically in the same figure, entirely in the evaporator and produces a refrigerating effect. It is then induced by the compressor at state point 1, and is compressed isentropically to point 2. It is next condensed to liquid in the condenser, and the latent heat of condensation is rejected to the atmosphere as the heat sink. The liquid refrigerant, at state point 3, flows through an

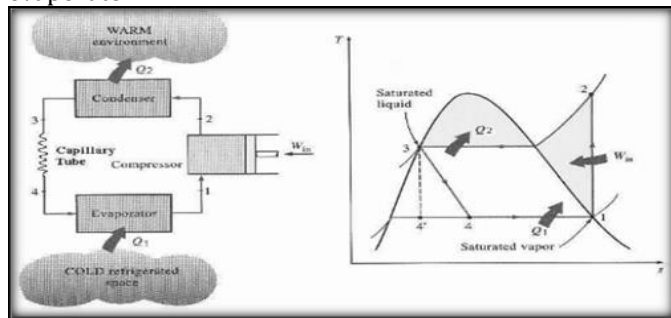expansion valve, which reduces the pressure to that of the evaporator.

Fig.1. Schematic Diagram of Refrigeration v-c Cycle and TS diagram.

2.LITERATURE REVIEW

R. P. Kumar, Dr. K Rambabu, describes the study of the optimized design of the Air-Conditioner compressor mounting bracket [1]. Harshal Bankar, P. Baskar, concludes the use of dynamics analysis technique is used for the simulation of the compressor mounting bracket for various vibration load [2]. M. Singh • D. Singh • J. S. Sain deals with Cost effectiveness, simulation And improves the quality of product [3]. Vyankatesh D. Pawade1 , Pushkaraj D. Sonawane highlights the factors for the failure of the mounting bracket and the effect of the optimization by various analysis [4]. Umesh S. Ghorpade,etc.Al Early in improvement the building of the engine mounting system should be rapidly checked and precisely analyzed, without sample of a vehicle authorization. Engine bracket has been designed as a framework to support engine [5].

2.2 Problem Specification:

Weight decrease, vibration and sound diminishment of compressor mounted section of car is one of the measure territory of concentrate in the present building ponders. We have to outline the compressor bolster section for Ashok Leyland 220 Bus, utilizing diverse materials including regular and also composite materials. We have to discover ideal answer for this present application's help section notwithstanding thinking about material and assembling costs.

3.THEORETICAL DESIGN

Compressor is installed on the bracket with the help of bolts, which allows us to change the width of the bracket which can be less or more than the width of the compressor. Bolts and base of the compressor may have shape which will help us bolting the compressor to the plate. This leads to shape of side closed L bracket, Dimension of the bracket will be 446 mm in length and 150 mm in width.
Following stress needs to be checked
  Shear Stress.
  Direct and Bending Stress

 Let 17.4kg weight on the bracket.
 Material for manufacturing of bracket is selected as steel.
 Forces acting on the component installed on automobile are as follows 3g loading in all three directions independently acting on the component when applied on the compressor.
 Area of the plate under compressor is 450mm by 150mm
 For DOE of design calculations as sample calculations are considered. Area of plate under the compressor:-
 Area of the plate under compressor is 450mm by 150mm
 So area of plate under the compressor:-
 A = 450 × 150 = 6750 mm^2

load acting = 17.4 kg × 3 × 9.81

load acting = 17.4 × 3 × 9.81

load acting L = 512.08 N

Direct Stress = 512.08 / 67500

σ direct= 0.0079 Mpa

So direct stress is negligible.
 Design thickness of plate according to shear limit.
 Small area under shear is width wise
 Which is
 A (shear) = W × t
 A(shear)= 150 × t

Force = 512.08 N

τ = F / A (shear)

τ = 512.08 / 150 × t

τ_{all} = 3.14 / t

τ_{all} = 0.5 × S_{yt} / fos

Factor of safety selected as 2

τ_{all}= 0.5 × 150 / 2

τ_{all} = 37.5 Mpa

Hence

t = 3.14 / 37.5 = 0.099 mm

38 gauge sheet should be selected which is approx. 0.152 mm thick.
 Also we must check thickness according to bending stress.
 Bending forces acting on base plate are on the center of compressor or acting downwards.
 512 N downward causes couple with distance of 75mm frame support at cross-section B just near the support bending stress will be caused by 512 N as follows
 M = F × W / 2

M = 512 × 150 / 2

M = 38.400 N.mm

According to bending we know that
M / I = σ / Y = F / R
σ is maximum when Y = max
Where
Y = distance of stress from neutral axis

Y = t / 2

$I = bd^3/12$

$I = 150 × t^3 / 12$

$\sigma_{all} = M × Y / I = 38400 × 6 / 150 × t^2$

$\sigma_{all} × t^2 = 1536$

$\sigma_{all} = 150 / 2 = 75$ Mpa

$t^2 = 20.48$

t = 4.53 mm

Nearest gauge for the mounting is 7

According to these calculations different materials are selected and DOE is performed to select the best alternative for the design for the compressor support system links.

Table 1. Various design for materials and weight

Mt (N-mm)	Material	SYT	E	Density (kg/m^3)	Allowable Stress	t	Volume	Weight (kg)	per Kg cost	Material cost
38406.15	MS (AISI 1018)	370	205000	7.87E-06	185	2.88	518700.93	4.08	60	244.93
38406.15	SS 304	205	193000	8.00E-06	102.50	3.87	696852.65	5.57	175	975.59
38406.15	304 L	170	193000	8.00E-06	85	4.25	765232.53	6.12	175	1071.33
38406.15	304 H	205	193000	8.00E-06	102.50	3.87	696852.65	5.57	175	975.59
38406.15	SS321	205	193000	8.03E-06	102.50	3.87	696852.65	5.59	205	1146.70
38406.15	SS 310	205	200000	8.00E-06	102.50	3.87	696852.65	5.57	310	1728.19
38406.15	SS 316 H	205	193000	8.00E-06	102.50	3.87	696852.65	5.57	300	1672.45
38406.15	SS 420	345	200000	7.80E-06	172.50	2.98	537165.78	4.19	94	393.85
38406.15	SS 309	310	200000	8.00E-06	155	3.15	566678.90	4.53	290	1314.70
38406.15	AL 6063	90	600000	2.70E-06	45	5.84	1051711.52	2.84	250	709.91
38406.15	AL 2014	414	723000	2.80E-06	207	2.72	490363.02	1.37	400	549.21
38406.15	AL 6351	150	750000	2.70E-06	75	4.53	814652.24	2.20	270	593.88

From material list table I we selected MS (AISI 1018) as design material. This is used to manufacture the steel design. Calculations are repeated for GFRP material. And values for cost and weight are calculated. Best selected steel has weight of 4.1 kg and costs around 245 Rs for material, as shown in the graph. When designed using GFRP material. Allowable stress for material is 200 MPa, and cost per kg for GFRP material is 160 Rs. Values for the GFRP are put in the calculations and thickness for the bracket is calculated. Where ρ – Density of GFRP material which is 1.70 E-6 kg/mm^3 so design of GFRP with 4 mm is selected as the weight reduction alternative which only costs 240 Rs, which is similar as material cost of the steel which provides around 70 % weight reduction

4. FEA ANALYSIS

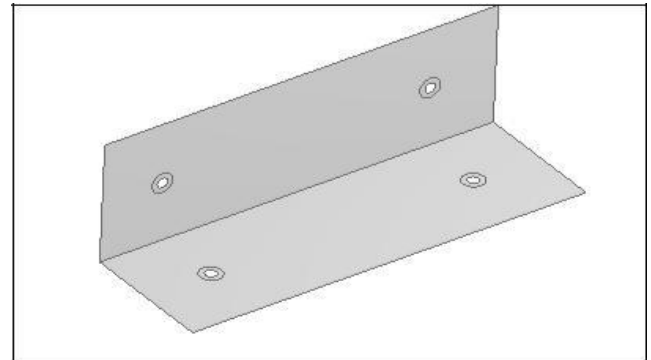## 4.1 Steel Bracket

Steel bracket of AISI 1018 material.

Fig.3 Geometry of compressor support bracket using steel material

Meshing is performed on the bracket using shell elements of 2D with element type Shell 181. Rectangular mesh elements are used to create the grid. Image of the meshing module shown in Fig.4   total of 0.13 million elements and approximately same number of nodes are used to create the meshing.
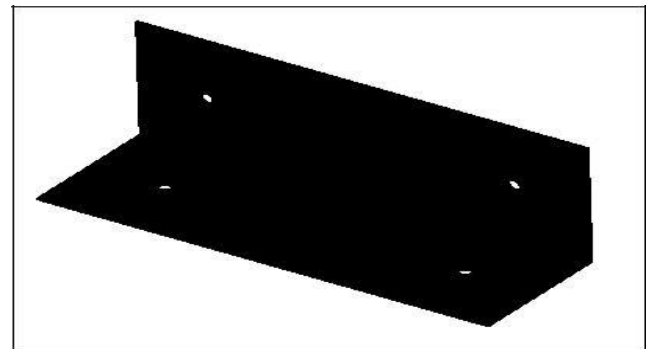

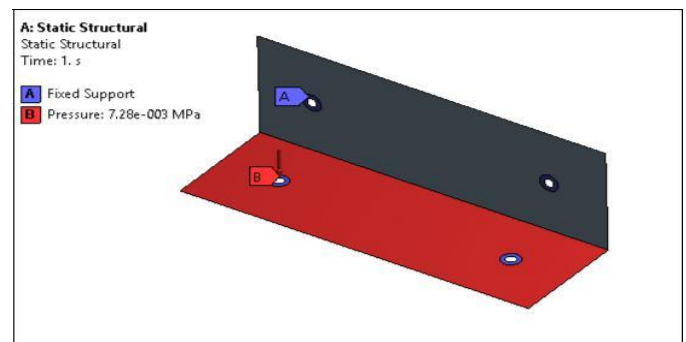Fig.4 Meshed model of Compressor mounting bracket using steel material

Fig.5 Boundary condition of compressor mounting bracket using steel material

Boundary condition for the static analysis is on "A"point as shown in the Fig 5. It shows that total of 0.00728 MPa pressure is applied on the surface to simulate 512.08 N load due to 3 g acceleration of the compressor assembly towards the base. Also All four bolt holes are applied with fixed boundary conditions to simulate its bolting connection with the chassis. Total mass of the bracket is around 4 kg.
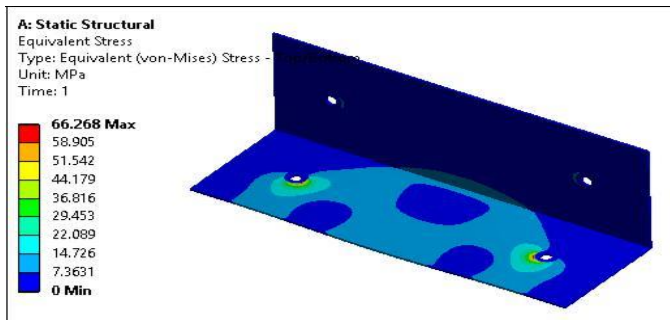

Fig.6 Von Mises stress of Compressor mounting Bracket using steel material

Von Mises stress shows that maximum stress at the steel bracket of compressor due to 3 g loading is 66.27 MPa which is well within the acceptance criteria of 185 MPa . So it shows that steel design is safe according to static FEA results
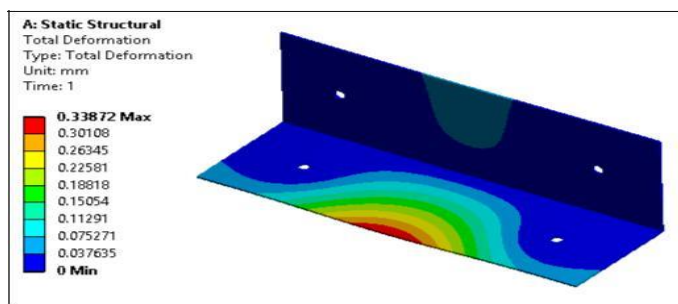

Fig.7 Total deformation of Compressor mounting Bracket using steel material

Total deformation of the steel bracket in fig.4.7 the maximum deformation in the bracket observed as 0.34 mm which is negligible considering only 1/3 of the load is applied continuously on the bracket in actual conditions
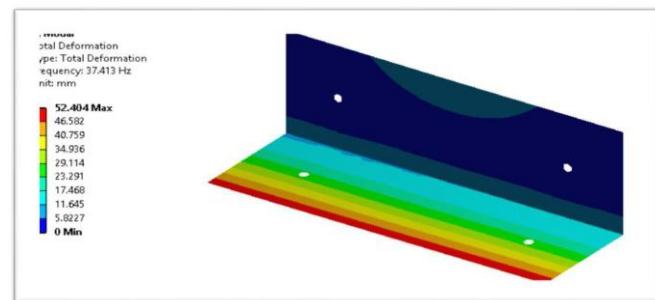

Fig.8.Mode shape plot at 1st natural frequency of steel bracket 37.4 Hz
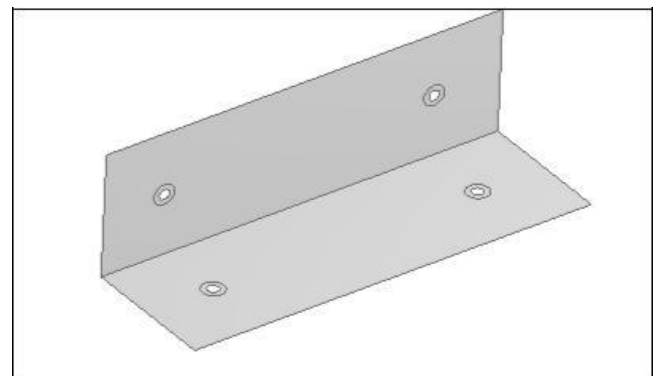
4.2 GFRP design bracket

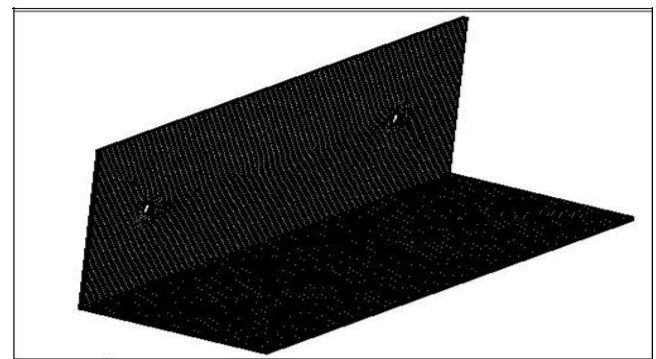Fig.9 Geometry of compressor mounting bracket using GFRP material

Fig.10 Meshed model of compressor mounting brackets using GFRP material

meshed model for GFRP compressor support bracket. Nodes are used in meshing is 5 lakh and elements are around 5 lakh 33 thousand elements are used. Solid model created in preprocessing module for ACP ANSY is imported in the static analysis module of the ANSYS. Following boundary conditions are applied on the model.
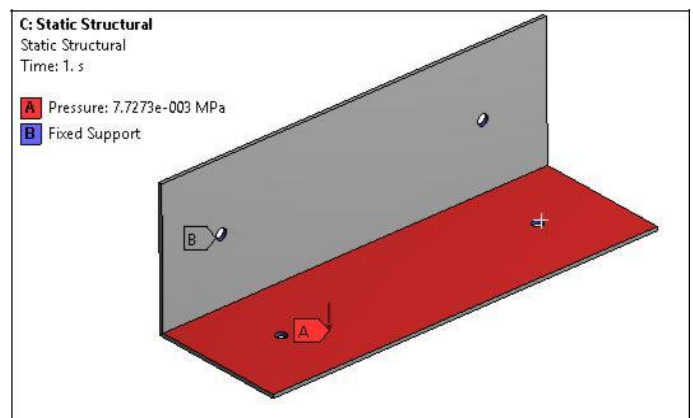

Fig.11 Boundary conditions of compressor mounting bracket using GFRP material

Boundary conditions on point "B" the compression mounting bracket. Horizontal face is applied with the pressure of 0.007723 MPa to simulate the 512.08 N force applied due to 3 gram loading of the weight of compressor assembly. Loading calculations are done in the design chapter. Load is assumed to be distributed all along the surface of the bracket. Fixed degrees of freedom are applied to all four bolding locations where bracket is bolted to the chassis. From fig. show that the results for the analysis ran on the GFRP bracket using these boundary conditions.
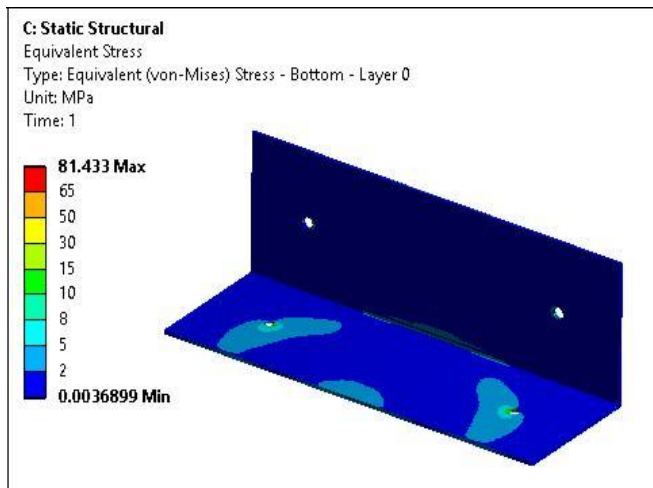

Fig.12 Von Mises stress of compressor mounting bracket using GFRP material

Maximum von Mises stress of compressor mounting bracket using GFRP material is 81.43 MPa which is point stress. Stress is within the acceptance criteria of 100 MPa used in design. Maximum deformation compressor mounting bracket using GFRP shows as 3.46 mm. this is acceptable deformation which is within the acceptable limit at 3g loading. In terms of gravitational load 1.5 mm. GFRP material being less stiff material that steel material the results are as per expectation.
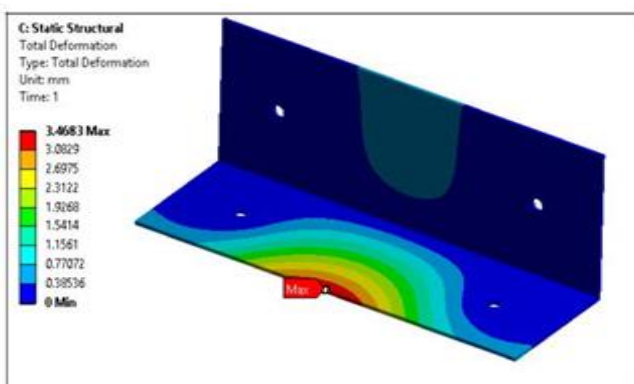

Fig.13 Maximum deformation compressor mounting bracket using GFRP material.
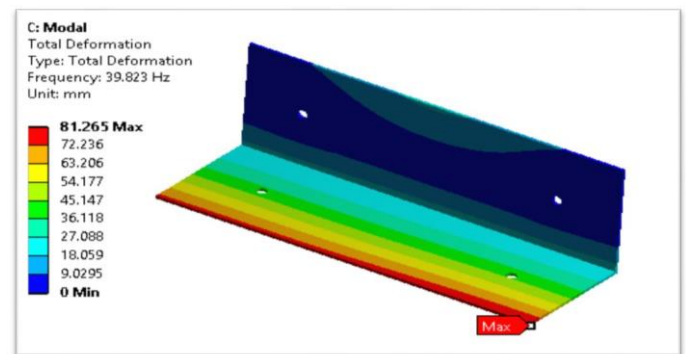

Fig.14 Mode shape plot at 1st natural frequency of GFRP bracket 39.82 Hz

5. EXPERIMENTAL VALIDATION

5.1 Test Set up for Vibration Analysis utilizing FFT Analyzer:

Subsequent to ascertaining the common recurrence of the fuel tank mounting section utilizing FEA, the same is approved by utilizing FFT analyzer. The fuel tank section is mounted on the installation to reproduce the real mounting states of the vehicle. The vertical side of the section is connected to the installation to reenact the limit conditions like the vehicle and the even side is kept free.

5.2 Exploratory methodology for modular investigation on FFT analyzer:

1)   Start the FFT analyzer.
2)   Go to Run-up mode ⏵ Set ⏵ New set (Rename) ⏵ OK.
3)   Set the scopes of Force Amplitude, Frequency and Scale for Graphs.
4)   A Force of sufficiency estimated by transducer in the sledge is connected on the section by the mallet which is furnished with FFT analyzer and comparing comes about (Natural frequencies) are gotten on FFT analyzer.

5.3 Method for assurance of characteristic frequencies is as per the following:

1)   Select a pinnacle estimation of vibration.

2)   Check stage contrast for that pinnacle esteem, it is relied upon to be 90°. On the off chance that this condition is fulfilled at that point go for third step and if not then choose next pick and take after stages 1 and 2.

3)   Check rationality for that relating pick, it is required to be one in a perfect world (0.75 to 1 can likewise be picked). In the event that this condition is fulfilled at that point comparing pinnacle will give first regular recurrence and if not then choose next pinnacle and take after stages 1, 2 and 3 once more. Along these lines we

can get First common frequencies by utilizing FFT analyzer.

Fig.15 FFT analyzer testing for bracket

Process

1)   Start the FFT analyzer.
2)   Go to Run-up– mode-Set - New set (Rename) - OK.
3)   Set the scopes of Force Amplitude, Frequency and Scale for Graphs.
4)   A Force of little adequacy is connected on a steel leaf spring by a mallet which is furnished with FFT analyzer and comparing comes about (Natural frequencies) are acquired on FFT analyzer. These outcomes are demonstrated as follows
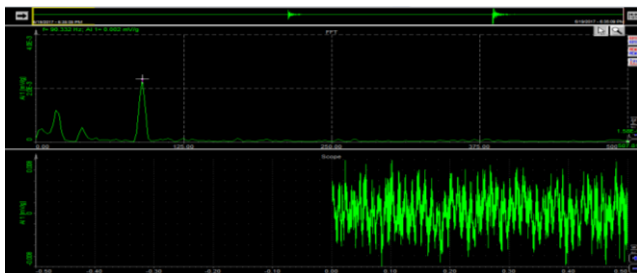

Fig.16 FFT Analyzer testing Screen shot

5.4 Results for Steel :-

Table 2 Result for Steel

Rpm	Acceleration m/(s²) (overall rms)	Velocity mm/s (peak)	Displacement um (pk-pk)
100	12.4203	25.5349	297.9504
200	15.2623	47.6635	413.3204
300	16.9701	32.6739	330.2616
400	17.6031	26.0352	222.9477
500	18.1271	26.8332	60.5819
600	15.6892	29.9485	125.9852
700	19.8294	34.6446	215.2648
800	21.4861	31.3476	106.5486
900	20.8524	33.9148	80.2465

Thus the rpm of motor increases acceleration and displacement get change i.e steel has more displacement.

5.5 Results for GFRP:-

Table 3 Result for GFRP

Rpm	Acceleration m/(s*s) (overall rms)	Velocity mm/s (peak)	Displacement um (pk-pk)
100	9.6203	32.0379	235.5620
200	10.1550	32.1732	345.8054
300	11.7532	15.2034	265.3466
400	14.2972	17.6303	169.0902
500	16.2631	19.3567	58.7726
600	14.9485	21.2651	111.6326
700	16.6585	24.3265	187.3526
800	18.6594	20.3265	74.6352
900	17.2150	26.3265	63.6215

Thus the rpm of motor increases acceleration and displacement get change.ie less displacement then steel.

5.6 Noise measurement for steel:-

Table 4 Noise Measurement for Steel

Speed (rpm)	Noise (dB)
100	78
200	80
300	83
400	86
500	89
600	89
700	91
800	93
900	95

Noise measurement of steel increases by motor rpm but it is comparatively more than GFRP material
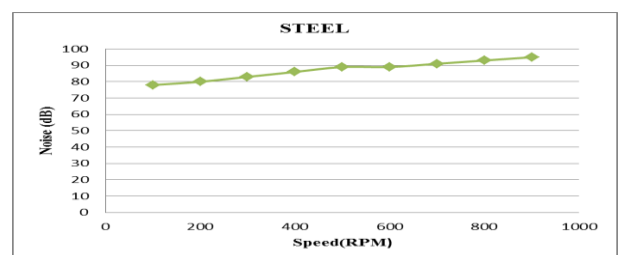
5.7 Chart of noise measurement for steel:-

Chart 1 Noise measurement for Steel.

5.8 GFRP Noise:-

Table 5 Noise Measurement for GFRP

Speed	Noise (dB)
100	72
200	74
300	76
400	79
500	82
600	84
700	86
800	87
900	89

Noise measurement of GFRP material is less than the steel

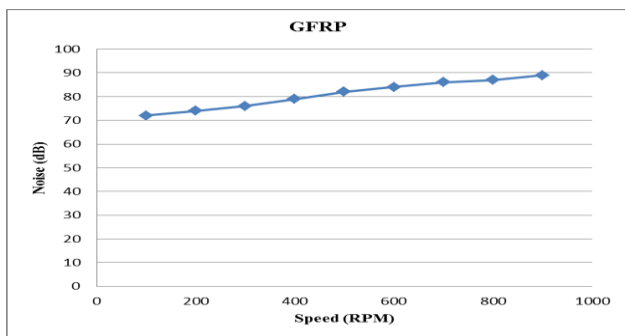### 5.9 Chart of noise measurement for steel:-

Chart 2 Noise measurement for GFRP

6.RESULT AND DISCUSSION

FEA results table shows that us the comparison of FEA results between steel and GFRP material designs of bracket. Following observations are made from the analysis results table.

Table.5 FEA Results Summary

Iteration	FEA Max Stress (mpa)	FEA Max deformation (mm)	Weight (grams)	% Material Removed
Steel	66.27	0.3387	4008	0
GFRP	81.43	3.47	1200	70.06%

Table.6 Deformation FEA & Experimental

	FEA For Steel	Experimental For steel	% Error	FEA For GFRP	Experimental For GFRP	% Error
Deformation	0.3387	0.37	0.94%	0.347	0.35	0.8%

FEA result rundown table demonstrates that the greatest pressure saw in the steel section is 66.27 MPa which is well inside the acknowledgment criteria for the steel plan. GFRP plan FEA that the most extreme pressure saw in the section is 81.43 MPa which is inside the acknowledgment criteria of the GFRP material. Add up to twisting saw in the steel and GFRP plans in FEA are 0.34 mm and 3.47 mm separately. Despite the fact that disfigurements saw in GFRP material outline are very high they are well inside the acknowledgment criteria for the general stacking of the section so comes about for FEA are worthy farthest point. Weight of the steel section was seen to be 4.1 kg in while GFRP section outline for a similar application weighs just around 1.2 kg. General 2800 grams weight is lessened. From the table number 4 it is watch that the distortion is FEA for steel was 0.338mm while in explore it was watch 0.35mm rate mistake is 9.24% For

GFRP section FEA comes about shows misshapening 3.47 mm and test testing it was 3.50 mm which extremely shut to FEA comes about rate blunder was 0.8%.

By checking the vibration in terms of motor rpm connection to probe acceleration and displacement is less of GRFP material then the steel material. By the weight reducation of compressor mounting bracket the noise of bracket of GFRP is reduced then steel bracket.

7. CONCLUSIONS

- FEA and testing sections of the task it can be reasoned that best appropriate steel for the assembling of the compressor bolster section with minimum material cost is AISI 1018 MS for which weight 4.1 kg.

- Utilizing GFRP when intended for a similar application section weights 1.2 kg which is 70 % less weight than the steel plan.

- First normal Frequency GFRP 39.82 Hz which is 2.4 Hz higher than the old steel outline of the mounting section which indicates vibration properties for the section are enhanced with decreased weight.

- By checking the vibration in terms of motor rpm connection to probe acceleration and displacement is less of GRFP material then the steel material.

- By changing of compressor mounting bracket the noise of bracket of GFRP is reduced then steel bracket.

8. FUTURE SCOPE

• The compressor mounting section can be produced and utilized as a part of the present vehicle.

• Likewise, interchange metals can be thought of for assembling low weight air conditioning mounting section.

• Other composite materials, for example, carbon fiber, Kevlar, aramid and so forth can be attempted and tried for assembling of the air conditioner mounting section.

• Dynamic examination can be performed on the section to ensure that it can withstand the vibration stacking connected on it all through the vehicle's life.

• Exhaustion examination and testing can be performed to confirm the impact of streamlining on life of the secti

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