Prediction of Design Margin for Diesel Exhaust Fluid Tank Bracket by FEA Approach

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Abstract:- **Diesel exhaust fluid is used to minimize the air pollution created by diesel engine. It is an aqueous urea solution made with 32.5% urea and 67.5% deionized water. It is used to lower nitrogen oxides concentration. Diesel exhaust fluid tank is supported on bracket.**

The main objective of this project is to predict the robust FEA approach for diesel exhaust fluid tank bracket using Ansys Workbench tool. The current FEA analysis results are not close to test results. In this project, robust FEA modelling approach is developed which have frequency, acceleration and strain responses of simulation close to test results

Keywords: Diesel exhaust fluid tank bracket, Modal analysis, Power spectral density analysis.

I. INTRODUCTION:

In mechanical engineering, a bracket is intermediate component for fixing one part to another. Bracket is the intermediate between the two components and fixes the one to the other. It is used to support or hold the components together.

II. ANALYSIS:

Analysis of bracket is carried out in Ansys workbench tool. The assembly consist of fixture, bracket and tank. The fixture and bracket are made of aluminum and structural steel respectively. Diesel exhaust fluid tank is made of high-density polyethylene rubber. Properties of materials are shown in table 1.

FEA model of bracket is shown in fig. (1). Fig (a) shows the FEA model of bracket in axial and lateral direction to obtain the frequency, acceleration and strain responses. Fig (b) shows the FEA model of bracket in vertical direction. The model is rotated because the gap between bracket and slip plate of shaker table in testing was less. To consider the actual testing condition, FEA model of bracket is rotated by 90^0 in simulation. Modal analysis is required before performing random vibration analysis.

Table 1. Properties of materials

Sr. No.	Component name	Assigned material	Density (Kg/m³)	Young's modulus (GPa)	Poisson's ratio
1	Bracket	Structural steel	7800	210	0.3
2	DEF tank	HDPE rubber	935	1	0.46
3	Fixture	Aluminum	2770	71	0.33
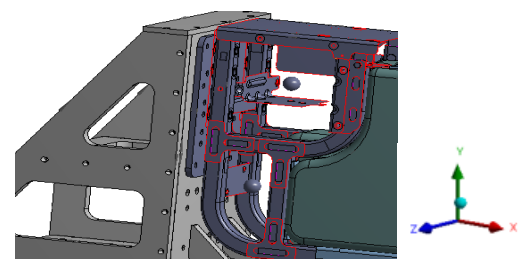
(a)
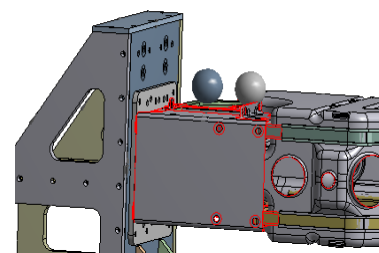
(b)

Fig 1. (a) FEA model of bracket for axial and lateral direction (b) FEA model of bracket for vertical direction

Triangular element is used for meshing of fixture. Bracket and tank are meshed with quadrilateral element. The contact used between bracket and fixture for current model is bonded contact. Fixed support is given to the base plate of fixture.
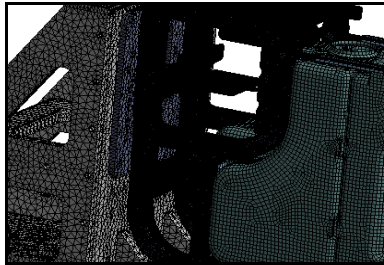

Fig 2. Mesh model

Modal analysis and random vibration analysis:

Modal analysis is used to determine the mode shapes and modal frequencies of bracket. Mode shape represents a specific pattern of vibration executed by a mechanical system at a specific frequency.

The governing equation for modal analysis is given as,

$$M\ddot{x}(t) + K*x(t) = 0$$
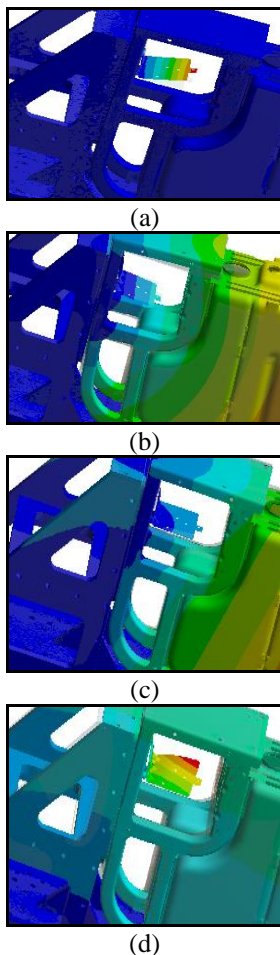

(a)

(b)

(c)

(d)

Fig 3. Mode shapes

Fig 3. (a) and fig 3. (d) show the same mode shape. Deformation of bracket is observed in vertical direction. Fig

3. (b) and (c) shows the same mode shape. Deformation of bracket is observed at the DEF tank.

For performing random vibration, power spectral density analysis is used to determine the frequency, acceleration and strain responses. The input PSD profile is applied to the base plate of fixture. The input frequency range is from 0-1000 Hz.

III. TESTING:

Bracket is tested on shaker table for random vibration to obtain frequency, acceleration and strain responses. Bracket is fixed with fixture on slip late of shaker table. The test setup of bracket is shown in fig 4.

(a)

(b)

Fig 4. (a) Test setup of bracket for axial and lateral direction (b) Test setup of bracket for vertical direction

IV. COMPARISON OF TESTING TO SIMULATION RESULTS:

The acceleration versus frequency graph for testing and simulation is plotted to find frequency at different peaks and compare it.

(a) Axial (X) direction:

The axial direction frequencies of bracket at different peaks is considered for comparison between testing and simulation results. The gap between testing and simulation for cceleration Grms and strain rms is determined in terms of percentage difference.
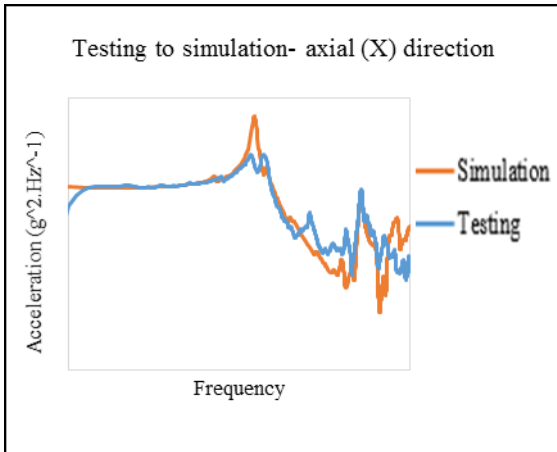
Fig 5. Acceleration versus frequency response in X direction

(i) Frequency response:

Table 2. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	4.76%	4.02%	NA

(ii) Acceleration and strain response:

The percentage difference of acceleration Grms and strain rms are 41.80% and 4.64% respectively. The acceleration Grms of simulation is not close to test result.

(b) Lateral (Z) direction:

The lateral direction frequencies of bracket at different peaks is considered for comparison between testing and simulation results. The gap between testing and simulation for cceleration Grms and strain rms is determined in terms of percentage difference.
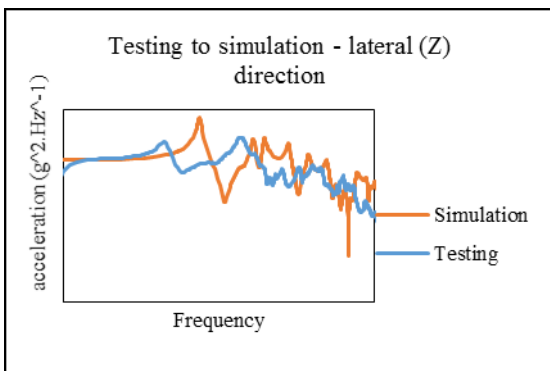

Fig 6. Acceleration versus frequency in Z direction

(i) Frequency response:

Table 3. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	39.48%	17.67%	7.34%

(ii) Acceleration and strain response:
The percentage difference of acceleration Grms and strain rms are 37.74% and 27.22% respectively. Acceleration Grms

and strain rms values of simulation are not close to test results.

(C) Vertical (Y) direction:
To find responses in vertical direction, bracket is rotated by 90^0.Because in testing the gap between testing and slip plate of shaker table is minimum. To avoid damages to bracket, it is rotated.

The vertical direction frequencies of bracket at different peaks is considered for comparison between testing and simulation results. The gap between testing and simulation for acceleration Grms and strain rms is determined in terms of percentage difference.
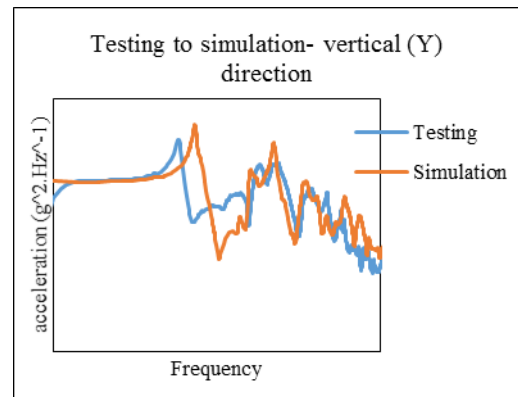

Fig 7. Acceleration versus frequency in Y direction

(i) Frequency response:

Table 4. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	20.11%	0.79%	12.47%

(ii) Acceleration and strain response:
The percentage difference of acceleration Grms and strain rms are 22.30% and 73.28% respectively.

The gap between testing and simulation results are not close to test results for Z and Y direction of bracket. The percentage gap of acceleration Grms is not close to test result in X direction of bracket. Hence different FEA modelling approaches are used in Ansys Workbench tool to get results close to test results.

V. DIFFERENT FEA MODELLING APPROACHES:

1. Beam contact for bolted joint:
In bonded contact load is directly transferred through flanges. In beam contact, load is transferred from one flange through beam to other flange. This type of contact is considered to replicate the actual load transfer through bolt joint.
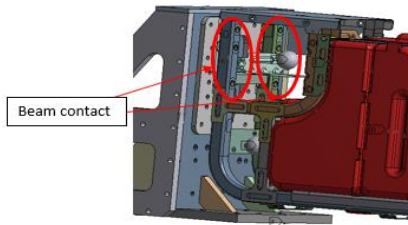
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Fig 8. Location of Beam contact

Comparison of testing to simulation results
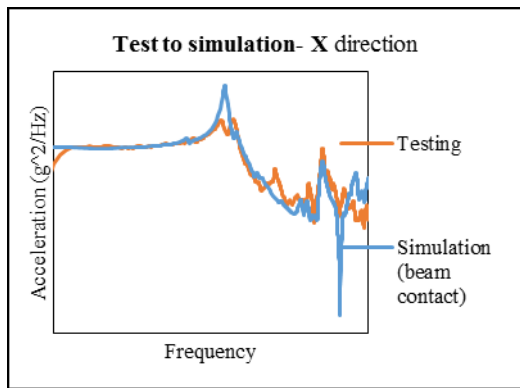
(a) *Axial (X) direction:*

Fig 9. Acceleration versus frequency in X direction

(i)   Frequency response:

Table 5. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	5.20%	4.75%	NA

(ii) Acceleration and strain response:
The percentage difference of acceleration Grms and strain rms are 42.27% and 2.51% respectively.
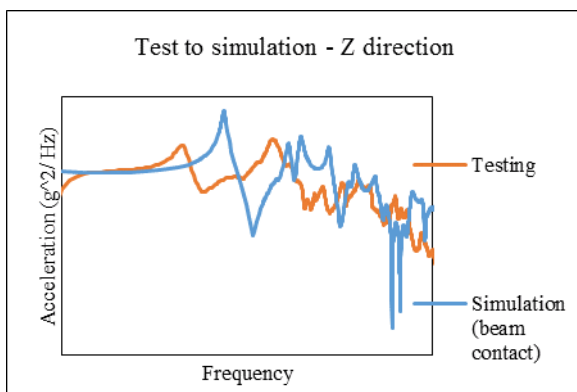
(b) Lateral (Z) direction:

Fig 10. Acceleration versus frequency in Z direction

(i)   Frequency response:

Table 6. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	39.62%	17.01%	7.36%

(ii) Acceleration and strain response:
The percentage difference of acceleration Grms and strain rms are 37.25% and 27.05% respectively. The results are not within acceptance limit for beam contact between fixture and bracket.
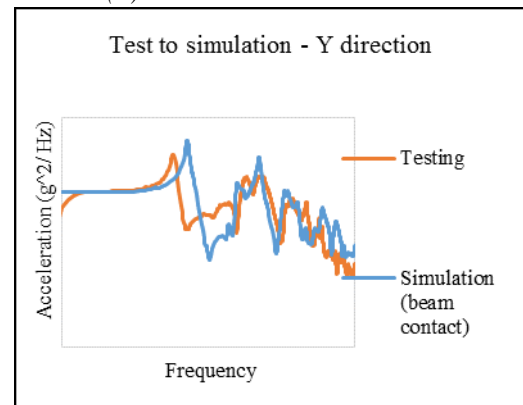
(c)   Vertical (Y) direction:

Fig 11. Acceleration versus frequency in Y direction

(i)   Frequency response:
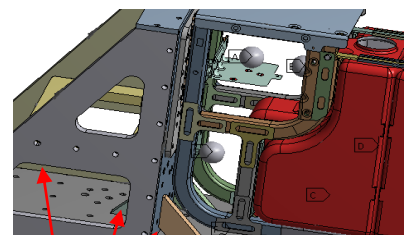
Table 7. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	19.23%	0.64%	13.30%

(ii) Acceleration and strain response:
The percentage difference of acceleration Grms and strain rms are 23.15% and 66.27% respectively.

2. No separation contact:

To restrict sliding motion and separation between parts in normal direction and allow sliding motion in tangential direction of fixture no separation contact is given between vertical and horizontal plate of fixture.

No separation Contact

Fig. 12. Location of no separation contact

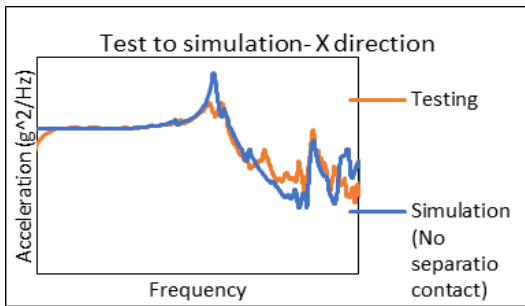Comparison of testing to simulation results:

(a) Axial direction:

Fig 13. Acceleration versus frequency in X direction

(i) Frequency response:

Table 8. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	6.55%	3.80%	19.80%

(ii) Acceleration and strain response:

The percentage difference of acceleration Grms and strain rms are 40.58% and 54.37% respectively.
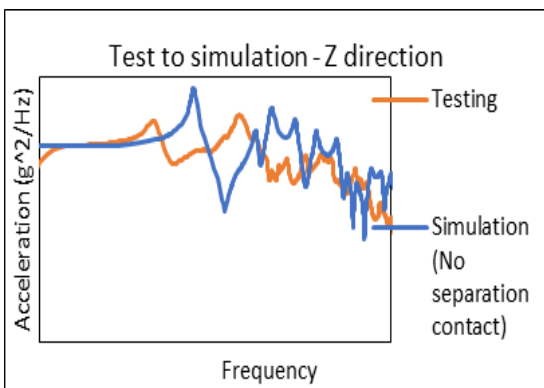
(b) Lateral (Z) direction:

Fig 14. Acceleration versus frequency in Z direction

(i) Frequency response:

Table 9. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	40.02%	16.12%	8.89%

(ii) Acceleration and strain response:

The percentage difference of acceleration Grms and strain rms are 44.44% and 5.32% respectively. The acceleration Grms of simulation is not matching with testing result.
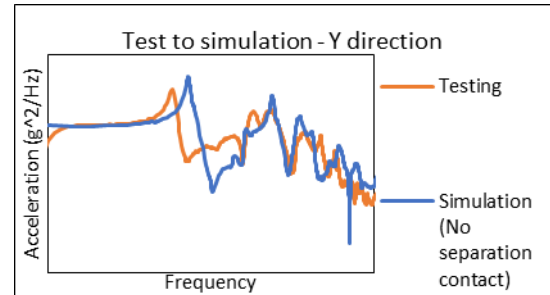
(c) Vertical (Y) direction:

Fig 15. Acceleration versus frequency in Y direction

(i) Frequency response:

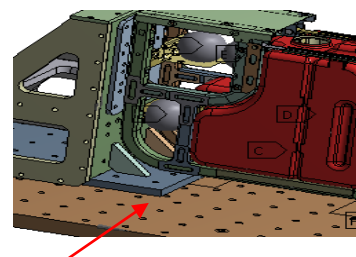Table 10. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	19.51%	0.71%	10.56%

(ii) Acceleration and strain response:

The gap between testing and simulation results for acceleration Grms and strain rms are 21.92% and 78.10% respectively.

3. Considering slip plate of shaker table:

To consider the actual contacts between slip plate and fixture in testing condition, slip plate of shaker table is considered. The input is applied to slip plate instead of base plate of fixture. This can affect the input profile transmitted to bracket.

Slip pate

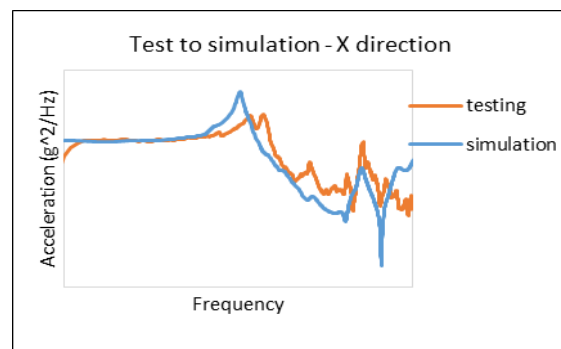Fig. 16. Bracket with slip plate of shaker table

(a) Axial (X) direction:

Fig 17. Acceleration versus frequency in X direction of bracket

(i) Frequency response:

Table 11. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	13.16%	NA	4.22%

(ii) Acceleration and strain response:

The gap between testing and simulation results for acceleration Grms and srain rms are 45.38% and 40.25% respectively.
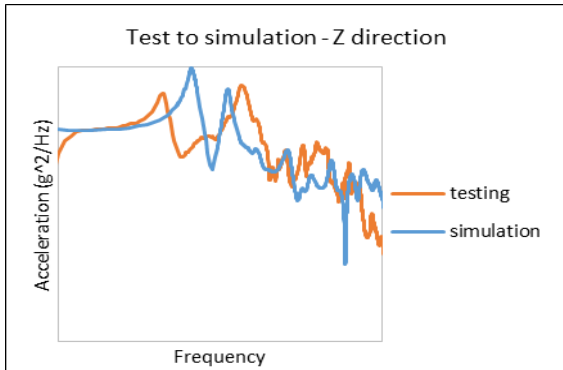
(b) Lateral (Z) direction:

Fig 18. Acceleration versus frequency in Z direction of bracket

(i) Frequency response:

Table 12. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	32.32%	19.00%	2.06%

(ii) Acceleration and strain response:

The gap between testing and simulation results for acceleration Grms and srain rms are 32.48% and 68.30% respectively.
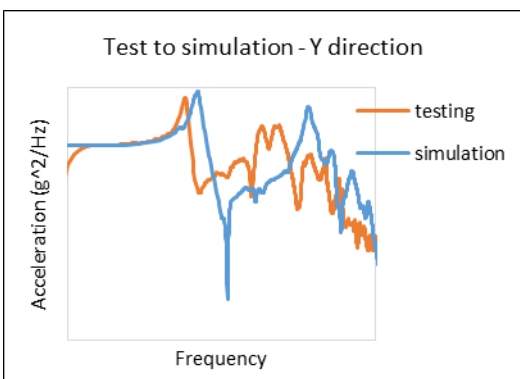
(c) Vertical (Y) direction:

Fig 19. Acceleration versus frequency in Y direction of bracket

(i) Frequency response:

Table 13. Comparison of testing to simulation results

Frequency	1 peak	2 peak	3 peak
Percentage difference	18.82%	2.70%	NA

(ii) Acceleration and strain response:

The gap between testing and simulation results for acceleration Grms and strain rms are 30.17% and 24.96% respectively.

4. With slip plate considering material damping:

Material damping factor of structural steel, EPDM rubber and magnesium is considered. Damping factor considered for structural steel, EPDM rubber and magnesium material are 2%, 5% and 1% respectively. There is no change in frequency response but the amplitude of acceleration and strain is reduced.

Acceleration and strain response:

The gap between testing and simulation results for acceleration Grms and strain rms are given in table.

Table 14. Comparison of testing to simulation results

Percentage difference	X direction	Y direction	Z direction
Acceleration Grms	28.43%	0.68%	4.76%
Strain rms	0.94%	3.82%	7.06%

VI. SUMMARY/ CONCLUSION:

This paper presents the modal and random vibration analysis of bracket. Different FEA modelling approaches are used to determine the robust approach that gives results close to test results. From different modelling approaches, bracket with slip plate of shaker table considering material damping shows frequency, acceleration Grms and strain rms response close to test results as compared to other FEA modelling approaches. Hence recommended robust FEA analysis approach is considering slip plate of shaker table with material damping.

Note: The values of frequency, acceleration (g^2/ Hz), acceleration Grms and strain rms are not displayed as the data is confindential of Cummins India ltd.

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