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# Static Performance of Exhaust Stack Mounting Bracket for Mining Equipment

**Nandeesh M N[1], Shivaprakash.S[2]**

PG Student, Mechanical Engineering, New Horizon College of Engineering, Bangalore, India [1]

Assistant Professor, Mechanical Engineering Department, New Horizon College of Engineering, Bangalore, India [2]

**Abstract**: Engine exhaust stack mounting plays a vital role in reducing noise, vibration and ruggedness caused due to excitation and thus providing efficient role in enhancing vehicle performance and durability. The objective of the paper is to perform the static analysis of the mounting stack and work deals with checking the deformation of engine stack due to self-weight. This paper is the initial study for the dynamic analysis and to demonstrate necessity of exhaust bracket in exhaust stack of mining equipment. Analyses are performed for two iterations, one with gravity load without bracket and with bracket and deformations are obtained for both instances. Gravity load is applied at the excitation points in all three directions. A Novel bracket is designed to restrict the deformation and which is used for the dynamic analysis.

**Keywords**: Exhaust mount Bracket, Self-weight, Static structure, Mining equipment.

## I. INTRODUCTION

An engine which perfectly balanced for forces and moments will have no tendency to move or transmit shock or vibration to the supporting structure or base which it is attached. Elastic the mounts are need for supporting an exhaust stack mounting and adjacent components. The flexible mounts are required to prevent the fatigue failure of most critical parts or most dynamic load experiencing component to reduce the amplitude of engine vibration which is transmitted to the vehicle's body structure; to reduce human discomfort and repeating loads by isolating the engine vibrations from body via the elastic parts such as brackets. Hence the mounting brackets must be designed with various aspects which comprise of withstanding the dynamic load, available space to installation, static strength, serviceability and effective cost and function should be accomplished successfully with some tolerance [2].

To separate the vibration caused by the engine unstable disturbances, i.e. in order to ensure low values of vibration transmissibility, low elastic stiffness and damping are needed as the forces transmitted to the structure are related to the stiffness and damping of the mounts. On the other hand, if the mount's elastic stiffness and damping are too low, the transient response of the engine mount system can become challenging in the case of shock excitations caused, for example, by sudden vehicle and engine acceleration and deceleration, braking and riding on uneven roads. Hence, from this point of view, high elastic stiffness and damping are required to minimize the engine motion and absorb engine shake [1].

The Exhaust bracket is the interface between the engine body and exhaust stack and its characteristics should be determined. Form static perspective, the main function of the bracket is to avoid the deformation of the stack and to absorb the some part of vibrational loads. To achieve the best vibration isolation for the engine, a mounting system is used to mount the engine in place. The mounting system will provide isolation that will in turn minimize the transmitted forces to/from the engine to the frame. On the other hand, it will also prevent engine bounce caused from shock excitation [3]. This goal is achieved by making the dynamic stiffness and damping of the mounting system frequency and amplitude dependent.

A typical mounting system consists of engine and a number of mounts that connect the engine to the supporting frame. The major objective of the engine mount is to isolate the engine disturbances from being transferred to the supporting structure. These disturbances will excite the engine six DOF vibration modes. To isolate vibrations caused by engine unbalanced disturbances, low elastic stiffness as well as low damping are used since the transmitted forces depends on the values of the stiffness and damping of the mounts. In mining equipment, the capacity of the load caring member should be high as more vibration loads generates due to the random loads.

In some of the cases the brackets are attached to adjusted component by welding and in most of the design the exhaust brackets are attached through bolted joints. Usually the holes are placed in the corners of the bracket, sufficient edge to distance ratio should be maintained in order to prevent the shear tear out due to random loads [4].

Normally the space available for the secondary structure is very limited. The Bracket has to be installed in the appropriate location which should prevent the maximum stiffeness in all the direction and should sustain all the loading direction and combination of loading direction [5].

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Different types of engine mounts, form simple elastomeric to complex hydraulic, passive to active have been widely used based on the application and investigated to enhance the vibration isolation and noise. Mining equipment comes under the category of high- frequency vibrations structure.

## II. METHODOLOGY

The Static study is to show the necessity of the bracket in the exhaust stack installation. Entire stack FE model is generated which comprise of Engine, Tubo charger, manifold, compressor, water pump. Bracket is installed between the heat shield and engine as shown in Fig 1.

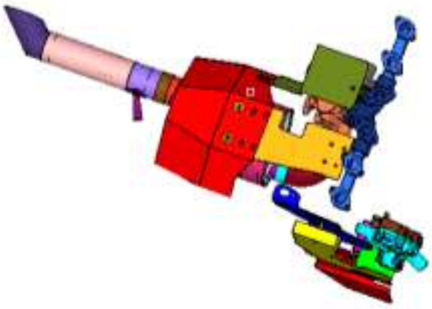

Fig.1. Installation of bracket in exhaust stack

Initially study is performed without bracket to check the deflection, here the boundary condition are given at engine excitation points by considering gravity load. The excitation point refers to acceleration points. In line with dynamic analysis, the three excitation point is constrained in all the three direction. In second study, Novel bracket design is introduced in the stack which attached between the heat shield and engine member where direct vibrational load is generated. The bracket is attached with six bolted joints towards heat shield side and 4 bolted joint attachment towards engine or manifold side. Similar constrained is applied at the excitation points and gravity load is applied to check the deformation at the various locations. Some of the iterations are carried out to finalize the bracket design by considering the thickness, stiffeness and space available to installation. Initial design is shown in Fig. 2.

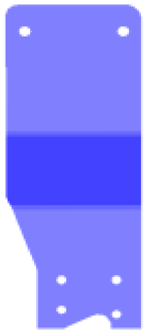

Fig. 2. Initial design of mounting bracket

Due to change in the design requirement, the bracket design is changed to accommodate the installation requirement and final design is shown in Fig 3.

Fig.3. View of exhaust mounting bracket

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## III. FINITE ELEMENT ANALYSIS

The importance of the meshing in the whole process of analysis is very important from the point of result implementation. By size and shape of the meshing accurate results can be obtained. In terms of the mesh's characteristics, where it was possible, hexahedral elements were used to build the mesh, while in certain regions the complexity of the geometry made inadequate the use of this element shape, being opted the use of tetrahedral shapes. As the bracket is having definite shape and thin structure, Shell elements are used in meshing. Fig 3 shows the meshing model.

Fig. 4. View of meshing model

Material properties
Steel material is used for bracket. Initially for study, aluminium is used due to the excess deformation it has been replaced by steel which can withstand more dynamic loads compare to aluminium
Young's modulus – 2.0E+5 N/mm$^2$
Poisson's ratio – 0.30
Density – 7.8e-09 ton/mm$^2$

Elements details are shown in Table 1.

TABLE I Element Details in mounting stack

| | |
|---|---|
| Number of shell elements | 3133 |
| Number of RBE2 elements | 10 |
| Element thickness | 6 mm |

## IV. SELF - WEIGHT ANALYSIS

Modelling > meshing > Boundary conditions > Static Structure > Results Interpretation

A. Iteration A- With Bracket
Initially, two concepts were designed to check the bracket stability and performance of the bracket. Initial concept design display more deformation compare to optimized bracket. By considering thickness and stiffeness, the bracket is modelled and optimised bracket yields a better results.

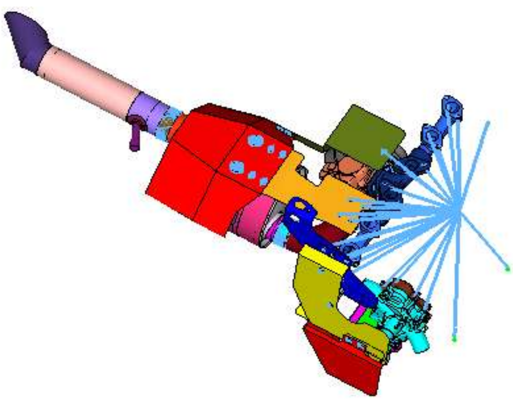

Fig. 5. Bracket attached to the Engine points

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Fig. 4 shows the engine attachments to the mounting stack through RBE2 elements. Upper side of the bracket is attached to heat shield with 4 RBE2 elements and 4 RBE2 elements to engine which generates vibrational loads.
Small cut-out is provided at the mid section. Purpose of the cut-out is for wire installations.
The assembly stack consists of manifold, heat shield, compressor, turbo, muffler and exhaust pipes. As shown in Fig 4 all the attachments apart from the bracket were also modelled with RBE2 elements.

B. Boundary Condition

Constraint is applied to the three excitation points as shown in Fig 5. An appropriate study has been performed to identify the excitation points by considering the fore aft direction, axial direction of both top and bottom side. More number of points leads to complexity in data processing.

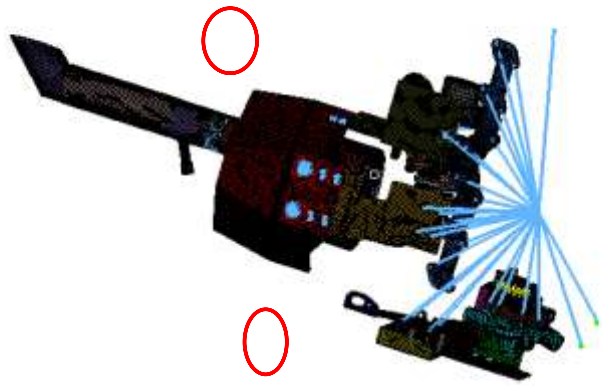

Fig.6. Exhaust stack meshed model with excitation points

All the three points are constrained with 6 DOF (Translation and Rotation) and mainly engine itself is considered as rigid body. Excitation refers to acceleration. Accelerometer is placed at this point and time domain engine acceleration data is obtained which is used for the dynamic analysis. Totally three CBUSH element is added at the excitation points.

C. Loading condition

Gravity is load is applied in all the direction and combination of loads is also introduced to capture the combined effects. Combine loads are introduced in X and Y direction and Y and Z direction. To provide the gravity load at three excitation points, CBUSH elements are introduced at each excitation point and in turn CBUSH elements are attached to the RBE2 elements. Thus, Load will be transferred from excitation point to bracket through CBUSH and RBE2 elements.

D. Post Processing of the Exhaust Mounting Bracket

The acceptability of the design of engine mounting bracket needs to be considered from the outcome of the analysis. The guidance for the modification of the bracket need to be available if the design is not considered to be acceptable. The acceptance and design modification criteria for the engine mounting bracket are as follows.
Model acceptance criteria: The maximum Von-Misses stress must be less than the material yield strength for the duration of the component. The deflection is considered and the maximum Von-Misses stress must be less than the yield strength for abuse load case Nastran solver is used to perform the analysis. Displacement and stress plots were captured for entire stack assembly and mounting bracket only.
The maximum displacement for the entire stack is obtained as 2.223 mm as shown in Fig.6 and for the bracket the maximum displacement is found to be 0.7129 mm as captured in Fig.7. The above mentioned deformation is maximum of all the directions and combination of two directions.

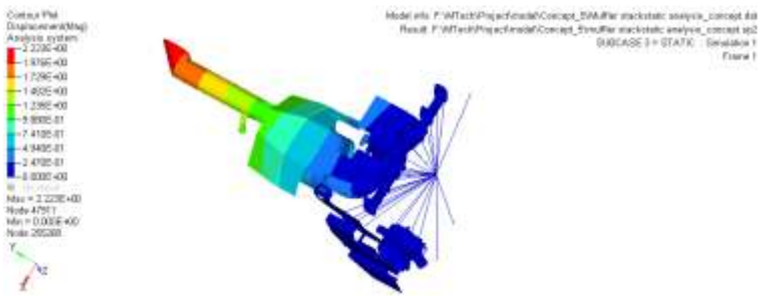

Fig. 7. Deformation plot for the entire stack

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Stress plots are also captured to identify the maximum stress location in entire stack and in bracket.
Maximum stress is found to be near the attachment location. The maximum stress for entire assembly is 37.75 MPa. Attachment is between engine and bracket as shown in Fig 8 and 9.

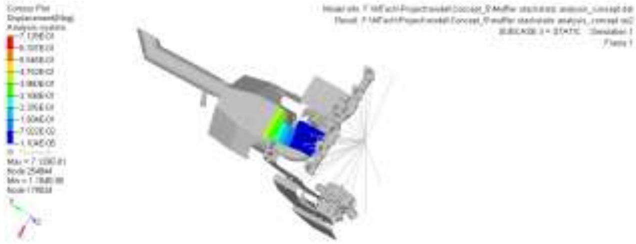

Fig. 8. Deformation plot for the bracket

TABLE II DISPLACEMENT RESULTS FOR WITH BRACKET CONFIGURATION

| | |
|---|---|
| maximum deformation for entire stack | 2.223 mm |
| Max displacement on Bracket | 0.7129 mm |

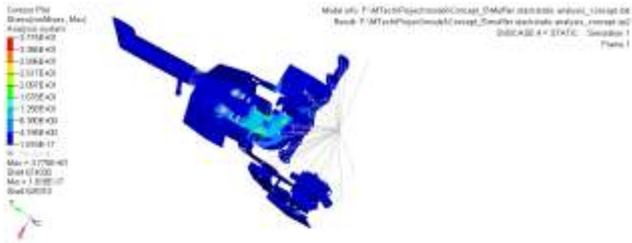

Fig. 9. Stress plot for exhaust assembly

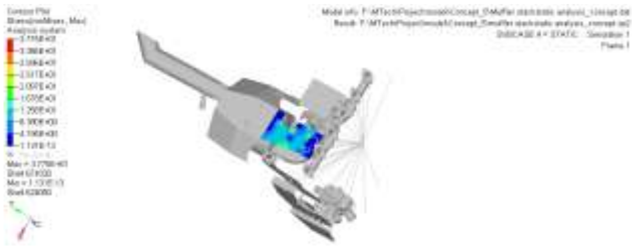

Fig. 10. Stress plot for bracket

TABLE III VON MISES RESULTS FOR WITH BRACKET CONFIGURATION

| | |
|---|---|
| Maximum Von mises stress for entire stack | 37.75 MPa |
| Max Von mises Stress on Bracket | 37.75 MPa |

E. Iteration B- Without Bracket configuration

In the second iteration, attached bracket is ignored and all the RBE2 elements to the brackets are detached. With the same boundary condition analysis is performed and deformations are obtained for all the three directions. Practically, deformations should be high in without bracket compare to with bracket. As there is no connection between engine and shield, upper portion of the stack tends to deform more. Applied load will be directly transferred to the upper portion.

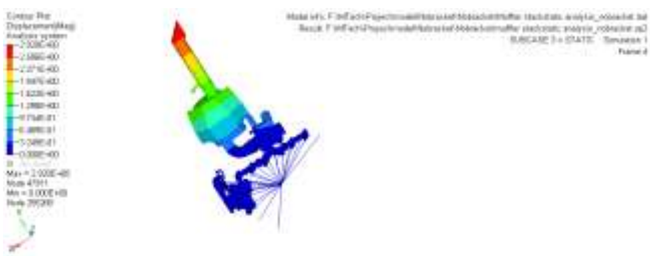

Fig. 11. Deformation plot for without bracket

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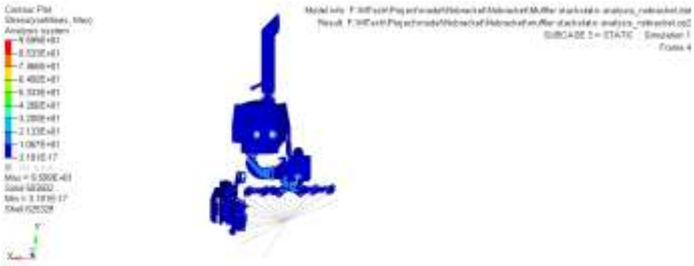

Fig. 12. Von mises plot for without bracket

The maximum Von mises stress for entire stack without bracket is found to be 95.99 MPa and maximum deformation for the for the stack is 2.92 mm

With the above results it can be observed that deformation of the entire stack s bracket is considered be high than the with bracket configuration. Von mises stress is found to be high for without bracket configuration. Therefore, Bracket is necessary for the exhaust mounting stack which will avoid the excess deformation and sustain the dynamic loads.

TABLE IV Displacement results for without bracket configuration

| | |
|---|---|
| Maximum Deformation for entire stack | 2.92 mm |

TABLE V VON MISES RESULTS FOR WITHOUT BRACKET CONFIGURATION

| | |
|---|---|
| Maximum Von mises stress | 95.99 MPa |

## V. CONCLUSION

In this work, the static performance of exhaust stack mounting bracket is analysed for understanding the necessity of the bracket in the exhaust stack. Special attention was given to bracket concept design with couple of iterations were followed to finalized the bracket design which suits all parameters and provide the effective results by provided space. Maximum strength is obtained by optimizing the bracket. Keeping in mind the bracket is designed to sustain the vibration loads and it should withstand infinite number of cycles. Small cut-out in the bracket helps for hydraulic wire installation which is very much required in the mining operation. The three excitation point or loading point is identified and these points will cover the entire assembly in all the direction right from fore aft, lateral and axial directions. This helps to capture the results in all the directions from both top and bottom side. CBUSH elements are introduced for more accuracy. Gravity load is applied in all three direction and combine load is applied to capture the combined effects. The results are interpreted for the two configurations. For the bracket configuration the maximum deformation is comparatively less than the without bracket configuration and maximum von mises stress in the bracket is captured for further studies.

Without bracket configuration yields more stress and deformation. This leads to failure of structure in early stage.

In summary, by above results it can be observed that bracket is very much necessary on the exhaust mounting system which will avoid the excess deformation and provide the path for the load transfer and sustain the vibrational loads or dynamic loads.

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