A FINITE ELEMENT ANALYSIS OF DIESEL ENGINE TEST BED USING DIFFERENT MATERIALS FOR REDUCING DIESEL ENGINE BED VIBRATIONS

Sagar Magdum
M.Tech Student
Rajarambapu Institute of Technology
Islampur, India
magdumsagar3003@gmail.com

Dr. S. D. Yadav
Professor
Rajarambapu Institute of Technology
Islampur, India
sanjay.yadav@ritindia.edu

Abstract—The main objective of this research work is to study the effect of mechanical properties of material on natural frequency, mode shape and frequency response of diesel engine test bed. For the frequency, deformation and frequency response revaluation mechanical properties of the material are play important role. Two materials have different density. Mild steel has very strong and radially available natural material and grey cast iron has damping property. Study of mode shape and frequency response of diesel engine test bed was performed using finite element simulation. The vibration response of the mild steel and grey cast iron shows the variation in natural frequency and also variation in vibration mode shape. First seven mode are studied for vibration response. CATIA R20 was used for cad designing of diesel engine test bed. FEA based ANSYS 16 is used for modal and frequency response analysis. The fixed –fixed constraints and gas force of piston are considered as boundary condition for the simulation of results.

Keywords—diesel engine test bed, mode shape, frequency analysis, FG-260

I. INTRODUCTION

Most of the researcher have found mechanical vibration of engine. The vibration due to gas forces on piston, unbalancing of crankshaft are the major sources of the engine vibration. The heavy engines are subjected to noise and vibration under excitation conditions. This vibration are transferred towards the engine mounting
test bed. Mechanical properties of the material effect the vibration signature pattern. The different characteristics of mild steel and grey cast iron FG -260 shows in the simulation result such as mode shape and frequency response. Grey cast iron have a damping property to reduce the vibration and mild steel have very strong material and made from radially available natural material.

II. ESTABLISHMENT OF 3D MODEL
From reverse engineering data, the generated CAD model of existing test bed and newly designed test bed as shown in figure. The designed engine test bed has connecting holes used for constraining. The .iges file is imported in ANSYS 16.0 FEA based software for modal and frequency response analysis.

III. MATERIAL PROPERTIES AND BOUNDARY CONDITIONS
For modal analysis mechanical properties are used such as elastic modulus, poisons ratio and material density. This paper concern with the mechanical properties effect on natural frequency without considering manufacturing prospects. The existing test bed was made with mild steel and newly grey cast iron of grade FG- 260. The mechanical properties are (mild steel grade elastic modulus 2.05e11 (pa), poisson ratio 0.29, material density 7850 Kg/m3) (Grey cast iron Fg-260 elastic modulus 1.28e11 (pa), poisson ratio 0.26, material density 7200 Kg/m3).

In actual condition, diesel engine test bed is tightly fixed on the base foundation in engine test cell using connecting bolts. The fixed-fixed boundary condition is suitable for the diesel engine test bed analysis, it constraints the motion of holes position. The following are the some theoretical calculation of boundary condition which are used at a time of analysis of diesel engine test bed.

1. Engine natural frequency
The present engine is 4 stroke so, natural frequency of 4 stroke engine is defined as,

\[
f_b = \frac{\text{RPM} \times \text{Number of cylinder}}{2 \times 60}
\]

\[
f_b = \frac{1500 \times 12}{2 \times 60} = 150 \text{ Hz}
\]

2. Force on Piston (TDC position only)
Force on piston = gas pressure × area of piston
Force on piston = 13 \times \frac{\pi(115)^2}{4}
Force on piston = 13234.96N

This is a force acting on a single cylinder. For analysis purpose to consider all 12 cylinder force at a time. Therefore total force of engine apply on engine test bed is,

Total force = 13234.96 \times 12
Total force = 158819.52 N

Dead weight of engine

Total weight of engine is 1300 Kg
It is converted into the newton.
Therefore, 1300\times 9.81
Dead weight of engine = 12,753 N
IV. ANALYSIS OF ENGINE TEST BED

ANSYS was used to pre-determine the basic two important parameter analysis: modal analysis, harmonic response analysis.

Initially the engine test bed is inserted in ANSYS R16 and is further undergone Meshing as initial stage

A. Meshing

The figure shows that the mesh generation of diesel engine test bed. It is also called as Discretization. Domain is discretized into a finite set of control volumes or cells. The discretized domain is called the grid or the mesh. General conservation equations for mass, momentum, energy are discretized into algebraic equations [7]. The mesh used for our consideration was Tetrahedron to minutely analyze the diesel engine test bed.

Fig-2: Meshing of existing diesel engine test bed

B. Modal analysis

The first six mode shapes and corresponding natural frequency present the numerical simulation. The natural frequency varies from 62 to 182 Hz. figure shows the vibration mode shapes and corresponding natural frequency of the mild steel material and the figure shows the vibration mode shapes and corresponding natural frequency of the FG 260 material.

For simulation fixed-fixed constraints based boundary condition was used. At the front side of the diesel engine test bed maximum deformation is found.

Mode 4 deformation $f_4 = 94.239$  

Mode 5 deformation $f_5 = 94.239$  

Mode 6 deformation $f_6 = 154.23$
Table 1

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Mode</th>
<th>Frequency (Hz)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
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<td>62.282</td>
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<tr>
<td>2.</td>
<td>2</td>
<td>71.925</td>
</tr>
<tr>
<td>3.</td>
<td>3</td>
<td>82.624</td>
</tr>
<tr>
<td>4.</td>
<td>4</td>
<td>94.239</td>
</tr>
<tr>
<td>5.</td>
<td>5</td>
<td>152.44</td>
</tr>
<tr>
<td>6.</td>
<td>6</td>
<td>154.23</td>
</tr>
<tr>
<td>7.</td>
<td>7</td>
<td>182.17</td>
</tr>
</tbody>
</table>

Figure 4 shows the natural frequency and mode shapes of FG 260 material. The frequency varies from 171 to 423. The frequency f₆ shows the highest frequency for the FG 260 material. The mode 6 shows minimum deformation and mode 4 shows maximum deformation. The high deformation causes damage to the engine test bed.
5

Fig 4: Mode shape and natural frequency of FG-260

TABLE II

<table>
<thead>
<tr>
<th>Sr.No</th>
<th>Mode</th>
<th>Frequency (Hz)</th>
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</thead>
<tbody>
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<td>4.</td>
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<td>418.42</td>
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<tr>
<td>6.</td>
<td>6</td>
<td>422.79</td>
</tr>
</tbody>
</table>

C. Harmonic response analysis

Harmonic analysis are used to determine the steady state response of a linear structure to load that vary sinusoidally with time. Thus enabling you to verify whether or not your design will successfully overcome resonance, fatigue and other harmful effects of forced vibration. The important result obtained from a frequency response analysis usually include the displacements, velocity and acceleration of grid points as well as the forces and stresses of elements [15].

The below graphs shows the frequency response of engine test bed at various mode shapes and natural frequency for mild steel material.

Fig 5: Frequency vs deformation

The above graph shows the frequency vs deformation variation at each mode of frequency. The range of frequency taken from 90 Hz to 250 Hz because the resonance condition occurs at mode 5. At mode 5 is seen that deformation is higher than other frequency range and it is 141.24 mm.

Fig 6: Frequency vs velocity
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The above graph shows the frequency vs deformation variation at each mode of frequency. The range of frequency taken from 90 Hz to 250 Hz because the resonance condition occurs at mode 5. At mode 5 is seen that velocity is higher than other frequency range and it is 1.3524e+5 mm/s

![Frequency vs Deformation Graph](image1)

**Fig 8:** Frequency vs deformation

The above graph shows the frequency vs acceleration variation at each mode of frequency. At mode 5 is seen that acceleration is higher than other frequency range and it is 1.295e+8 mm/sec².

From the above graph it is seen that the deformation, velocity and acceleration is maximum at mode 5 due to the resonance condition. So design of existing diesel engine test bed is not proper design for the engine testing application.

The below graphs shows the frequency response of the engine test bed of material FG 260.

![Frequency vs Acceleration Graph](image2)

**Fig 9:** Frequency vs Velocity

![Frequency vs Velocity Graph](image3)
The above graph shows the frequency vs deformation variation at each mode of frequency. The range of frequency taken from 170 Hz to 450 Hz because the resonance condition is avoid. In the frequency vs velocity graph shows the variation at each mode of frequency.

V. CONCLUSION

From this work, it is concluded that the mechanical properties are directly related with natural frequency, mode shape and also frequency responses. Two different materials were evaluated for first seven natural frequency and comparison graph was prepared. The frequency range of mild steel material is in between the 62 to 182 Hz. At mode five frequency is 152 Hz and it matches with the engine natural frequency. So that resonance condition is occurs at mode 5, because of that it is chance to breakdown carden shaft and dynamometer due to the resonance condition.

Another range of natural frequency found for FG 260 material. The range in between the 171 to 422 Hz. So, the resonate condition is avoided and also the frequency response it is found that the value of deformation, velocity and acceleration are minimum as compared to the value of using mild steel material.

References


