Studies on Static and Fatigue Loading Conditions of Steel and Unidirectional Metal Matrix Bo-Al Composite Material

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Abstract—Structural safety is the most important factor in each and every part of the automobile. Static and dynamic loads will be considered to find the damage of the material. Leaf spring is one of the most important part in the automobile field, for the better suspension system in automobile vehicles parts used are leaf springs and shock absorbers. Leaf springs are effectively utilized which absorbs the maximum shock loads for the vehicle. The main function of leaf spring is not only to support vertical load but also to isolate road induced vibrations. It is subjected to millions of load cycles leading to fatigue failure. In the present work steel is used for the initial one and it has been made changed to another suitable material such as metal matrix Bo-Al composite to find the stiffness and Number of cycles to failure, the results were discussed and tabulated.

Keywords—Leaf spring, Stiffness, Catia, Number of cycles to failure

II. PROBLEM IDENTIFICATION AND SCOPE OF PRESENT WORK

A. Objectives

• Comparing the results of the Steel and the considered composite material Bo-Al used in the leaf spring.

• Analytical as well as theoretical results were tabulated for Stresses and deflections for Static and cyclic loads to find the stiffness and failure cycles and opting suitable material.

B. Methodology

 The problems were analyzed by studying the various literature surveys.

 Taking ASME standard dimensions and boundary conditions.

 Modeling and meshing of a leaf spring has been made using Catia software.

 Using ANSYS, apply the boundary condition to the model of a leaf spring so that the stresses and displacements were found and calculated the Stiffness and failure cycles.
C. Geometric parameters

i. Design of a mono leaf spring and its specifications

Fig.1. 2d model of a mono leaf spring

The specifications all are represented in the fig.1, such that the thickness is considered as 10 mm for a mono leaf spring. Static load is considered as 2000N and the cyclic load is varied from 4000 to 8000N at the time variation of 10 seconds.

ii. Meshed model of a mono leaf spring

iii. Boundary condition

Fig.3. Boundary conditions of a leaf spring

Boundary condition applied for leaf spring fixed in all directions and loaded centrally, both static and cyclic loads were applied with varying time.

D. Material properties

Table I Represents the material properties

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>Properties</th>
<th>Steel</th>
<th>Bo-Al</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Young's modulus (N/mm²)</td>
<td>2.1X10⁶</td>
<td>2.35X10⁶</td>
</tr>
<tr>
<td>2.</td>
<td>υ</td>
<td>0.23</td>
<td>0.285</td>
</tr>
<tr>
<td>3.</td>
<td>Density (gm/cm³)</td>
<td>7.75</td>
<td>2.7</td>
</tr>
</tbody>
</table>

III. RESULTS AND DISCUSSION

I. Results

I. Analytical Results

(i) For Static loading condition

A. Stress Analysis – (a) Steel material

Fig.4. shows the value of stress for static load.
b) Bo-Al material

Fig.5. shows the value of stress for static load.

B. Displacement Analysis – (a) Steel material

Fig.6. shows the value of displacement for static load.

(b) Bo-Al material

Fig.7. shows the value of displacement for static load.

(ii) For Cyclic loading condition

A. Stress Analysis – (a) Steel material

Fig.8. shows the value of stress for cyclic load of 4000N at the time interval of 15 seconds.

Fig.9. shows the value of stress for cyclic load of 6000N at the time interval of 25 seconds.

Fig.10. shows the value of stress for cyclic load of 6000N at the time interval of 25 seconds.

Fig.11. shows the value of stress for cyclic load of 4000N at the time interval of 15 seconds.

Fig.12. shows the value of stress for cyclic load of 6000N at the time interval of 25 seconds.
Fig. 13 shows the value of stress for cyclic load of 8000N at the time interval of 35 seconds.

**B. Displacement Analysis – (a) Steel material**

Fig. 14 shows the value of displacement for cyclic load of 4000N at the time interval of 15 seconds.

Fig. 15 shows the value of displacement for cyclic load of 6000N at the time interval of 25 seconds.

Fig. 16 shows the value of displacement for cyclic load of 8000N at the time interval of 35 seconds.

**B. Displacement Analysis – (b) Bo-Al material**

Fig. 17 shows the value of displacement for cyclic load of 4000N at the time interval of 15 seconds.

Fig. 18 shows the value of displacement for cyclic load of 6000N at the time interval of 25 seconds.

Fig. 19 shows the value of displacement for cyclic load of 8000N at the time interval of 35 seconds.

**II. Theoretical Results**

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Condition</th>
<th>Steel Displacement (mm)</th>
<th>Steel Stiffness (N/mm)</th>
<th>Bo-Al Displacement (mm)</th>
<th>Bo-Al Stiffness (N/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Static load 2000N</td>
<td>6.69</td>
<td>298.95</td>
<td>5.734</td>
<td>348.75</td>
</tr>
</tbody>
</table>

TABLE II. Theoretical results of steel and Bo-Al material for static load.
TABLE III. Theoretical results of steel and Bo-Al material for cyclic load.

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Condition</th>
<th>Steel</th>
<th>Bo-Al</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Displacement</td>
<td>Stiffness</td>
<td>Displacement</td>
</tr>
<tr>
<td>1.</td>
<td>Cyclic load</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4000N at 15 seconds</td>
<td>13.38</td>
<td>298.95</td>
</tr>
<tr>
<td>2</td>
<td>6000N at 25 seconds</td>
<td>20.07</td>
<td>298.925</td>
</tr>
<tr>
<td>3</td>
<td>8000N at 35 seconds</td>
<td>26.7</td>
<td>298</td>
</tr>
</tbody>
</table>

Number of cycles to failure. Considering the loading condition as 2000N such that Ultimate strength of the Bo-Al material is 1100Mpa and Sa=160.2 By using the graph [2], N_f has been calculated. The value of N_f for Bo-Al is 1x10^7 cycles.

2. Discussions

TABLE IV. CORRELATING RESULTS TABLE

<table>
<thead>
<tr>
<th>Sl. No</th>
<th>Load</th>
<th>Steel</th>
<th>Bo-Al</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Analytical</td>
<td>Theoretical</td>
</tr>
<tr>
<td>1</td>
<td>2000</td>
<td>5.9</td>
<td>6.7</td>
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<tr>
<td>2</td>
<td>4000</td>
<td>11.8</td>
<td>13.4</td>
</tr>
<tr>
<td>3</td>
<td>6000</td>
<td>17.7</td>
<td>20.07</td>
</tr>
<tr>
<td>4</td>
<td>8000</td>
<td>23.7</td>
<td>26.7</td>
</tr>
</tbody>
</table>

Table IV. Represents the comparison of deflections in both Steel and uni directional metal matrix bo-al composite materials. The Stiffness of the Steel material for Analytical and theoretical values are 338 and 298.95 N/mm respectively and for the Bo-Al material the Stiffness values are 377 and 348.75 N/mm.

The Number of cycles to failure of steel is 10^5 cycles [2] whereas the considered Bo-Al material has 10^7 cycles.

IV. CONCLUSION

- Comparative study has been made between Steel and the Bo-Al material with respect to stress and deformation analytically and theoretically to find the Stiffness and failure cycles.
- While comparing the stiffness the Bo-Al material is 11% more stiffer than steel in Analytical way and 17% more stiffer in Theoretical manner.
- The number of cycles to failure in Bo-Al is more than 10^5 cycles, which is more than the Steel material.
- Hence concluding that the Uni directional metal matrix Bo-Al composite material is better replacement material instead of steel material in all the considered parameters for a mono leaf spring.

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REFERENCES