TRANSIENT THERMAL AND STRUCTURAL ANALYSIS OF ROTOR DISC OF DISK BRAKE

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ABSTRACT

Transient Thermal and Structural Analysis of the Rotor Disc of Disk Brake is aimed at evaluating the performance of disc brake rotor of a car under severe braking conditions and thereby assist in disc rotor design and analysis. In the present work, an attempt has been made to investigate the suitable hybrid composite material which is lighter than cast iron and has good Young’s modulus, Yield strength and density properties. Aluminum base metal matrix composite and High Strength Glass Fiber composites have a promising friction and wear behavior as a Disk brake rotor. The transient thermo elastic analysis of Disc brakes in repeated brake applications has been performed and the results were compared. The suitable material for the braking operation is S2 glass fiber and all the values obtained from the analysis are less than their allowable values. Hence the brake Disc design is safe based on the strength and rigidity criteria. By identifying the true design features, the extended service life and long term stability is assured.

KEYWORDS : Disc Brakes, Geometrical modelling, Finite element method, Results and discussion of pad and rotor disc brakes

Brakes are often described according to several characteristics including: Peak force - The peak force is the maximum decelerating effect that can be obtained. The peak force is often greater than the friction limit of the tires, in which case the brake can cause a wheel skid.

- Continuous power dissipation - Brakes typically get hot in use, and fail when the temperature gets too high. The greatest amount of power (energy per unit time) that can be dissipated through the brake without failure is the continuous power dissipation. Continuous power dissipation often depends on e.g., the temperature and speed of ambient cooling air. Fade - As a brake heats, it may become less effective, called brake fade. Some designs are inherently prone to fade, while other designs are relatively immune. Further, use considerations, such as cooling, often have a big effect on fade.

- Smoothness - A brake that is grabby, pulses, has chatter, or otherwise exerts varying brake force may lead to skids. For example, railroad wheels have little traction, and friction brakes without an anti-skid mechanism often lead to skids, which increases maintenance costs and leads to a "thump thump" feeling for riders inside.

- Power - Brakes are often described as "powerful" when a small human application force leads to a braking force that is higher than typical for other brakes in the same class. This notion of "powerful" does not relate to continuous power dissipation, and may be confusing in that a brake may be "powerful" and brake strongly with a gentle brake application, yet have lower (worse) peak force than a less "powerful" brake.

- Durability - Friction brakes have wear surfaces that must be renewed periodically. Wear surfaces include the brake shoes or pads, and also the brake disc or drum. There may be tradeoffs, for example a wear surface that generates high peak force may also wear quickly.

- Weight - Brakes are often "added weight" in that they serve no other function. Further, brakes are often mounted on wheels, and unsprung weight can significantly hurt traction in some circumstances. "Weight" may mean the brake itself, or may include additional support structure.

- Noise - Brakes usually create some minor noise when applied, but often create squeal or grinding noises that are quite loud.

The present study was conducted to analyze which the geometry of vents in motorcycle disk brakes affects the surface of the disk.

In order to analyze the thermal characteristics of disk brakes, thermal deformation analysis and thermal stress analysis due to heat transfer was carried out through the finite element analysis for ventilated disk and solid disk. By comparing the maximum temperature in the braking process, the ventilated disk showed a lower temperature than the solid disk and effect of temperature increase and decrease, depending on the vent area generated in the flange part of the disk. The thermal deformation in ventilated disk type occurs in all directions by 0.1162 mm, thermal
distribution in the circumferential direction showed large
deviation, about 0.017 mm due to the vents.

Deformation, Von Mises stress and contact pressures at pad are investigated by coupled thermo-
mechanical. These simulation results are satisfactorily verified by comparing with similar literature result. Thus,
this study provides effective reference for design and engineering application of brake disc and brake pad.

**Geometrical Modeling**

The model is constructed by using CATIA V5R21,
The explode view of the model as shown in Figure 4.

**Finite Element Method**

Import the IGS file to hypermesh and clean up the
gometry. In meshing Rtria mesh was done on whole outer
surface of the model and then tetra mesh (4 noded triangular
elements) is obtained. hexa (8 noded) solid meshing is made
to bush and metal sleeve.

**Results and Discussion of PAD with Different Rotor Materials**

Thermal and structural analysis is performed in
order to know the maximum nodal temperature,
displacement, contact pressure and Frictional shear stress
developed on a pad for different rotor material on a disc brake.

**Pad Rotor**

**Aluminum Metal Matrix Composites (ALMMC)**

Results obtained the above figures and table, by
changing rotor material of the disc brake there is a
considerably affects the pad surface. Hence from the above
table, it's concluded that S2 glass has less frictional shear

![Disc Brake](image1)

![Meshed Model](image2)

![3D Modeling](image3)
Table 2.1: The Material Property of the Pad

<table>
<thead>
<tr>
<th>Material Properties</th>
<th>Pad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal conductivity, k (w/m. C)</td>
<td>5</td>
</tr>
<tr>
<td>Density, (kg/m³)</td>
<td>1400</td>
</tr>
<tr>
<td>Specific Heat, c (J/Kg. C)</td>
<td>1000</td>
</tr>
<tr>
<td>Possion’s ratio</td>
<td>0.25</td>
</tr>
<tr>
<td>Thermal expansion, (10⁻⁶ / C)</td>
<td>10</td>
</tr>
<tr>
<td>Elastic modulus, E (GPa)</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 2.2: The Material Property of the Brake Assembly

<table>
<thead>
<tr>
<th>Properties</th>
<th>Cast iron</th>
<th>AIMMC</th>
<th>S2 glass</th>
<th>E glass</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density, ρ</td>
<td>7100 kg/m³</td>
<td>2765.2 kg/m³</td>
<td>2460 kg/m³</td>
<td>2580 kg/m³</td>
</tr>
<tr>
<td>Young’s modulus, E</td>
<td>125 GPa</td>
<td>98.5 GPa</td>
<td>86.9 GPa</td>
<td>72.3 GPa</td>
</tr>
<tr>
<td>Thermal conductivity, k</td>
<td>54 W/m.K</td>
<td>181.65 W/m.K</td>
<td>1.45 W/m.K</td>
<td>1.3 W/m.K</td>
</tr>
<tr>
<td>Specific Heat C₀</td>
<td>586 J/Kg .K</td>
<td>826.8 J/Kg.K</td>
<td>737 J/Kg.K</td>
<td>810 J/Kg.K</td>
</tr>
<tr>
<td>Possion’s ratio</td>
<td>0.25</td>
<td>0.33</td>
<td>0.28</td>
<td>0.22</td>
</tr>
<tr>
<td>Coefficient of expansion, α</td>
<td>8.1*10⁻⁶/ K</td>
<td>17.5*10⁻⁶/ K</td>
<td>0.9*10⁻⁶/ K</td>
<td>5.4*10⁻⁶/ K</td>
</tr>
</tbody>
</table>

Table 3.1: Mesh Details

<table>
<thead>
<tr>
<th>Nodes</th>
<th>36745</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements</td>
<td>32787</td>
</tr>
</tbody>
</table>

The type of element used for structural analysis is C3D8 & for Thermal analysis is DCC3D8.

Figure 4.1: a, b, c and d Shows the Maximum Pad Nodal Temperature, Displacement, Contact Pressure and Frictional Shear Stress for Pad with Rotor Material ALMMC.

For Different Materials for Pad the Same Procedure Has Been Followed and the results are Tabulated.
Table 4.1: Comparison for a Pad Having Different Rotor Disc Brake Materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>Pad with Rotor Different Material</th>
<th>Nodal Temperature</th>
<th>Displacement</th>
<th>Contact pressure</th>
<th>Frictional shear stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALMMC</td>
<td></td>
<td>20</td>
<td>0.02</td>
<td>1.92</td>
<td>0.03</td>
</tr>
<tr>
<td>CI</td>
<td></td>
<td>20</td>
<td>0.009</td>
<td>1.917</td>
<td>0.034</td>
</tr>
<tr>
<td>E-glass</td>
<td></td>
<td>20</td>
<td>0.01</td>
<td>1.944</td>
<td>0.035</td>
</tr>
<tr>
<td>S2 - glass</td>
<td></td>
<td>20</td>
<td>0.01</td>
<td>1.93</td>
<td>0.03</td>
</tr>
<tr>
<td>Steel</td>
<td></td>
<td>20</td>
<td>0.015</td>
<td>1.908</td>
<td>0.041</td>
</tr>
</tbody>
</table>

stress when comparing with respect to the different rotor materials.

And also from the above table, it's concluded that by changing rotor material of the disc brake won't have much effect on the performance of the pad surface.

Figure 4.2 (a): Displacement for Pad Having Different Rotor Material

Figure 4.2 (b): Contact Pressure for Pad Having Different Rotor Material

Figure 4.2 (c): Friction Al Shear Stress For Pad Having Different Rotor Material

The above Three Graphs Shows The Comparision of Different Tests For Different Materials

Parametric Studies on Rotor Disc for Different Materials

Thermal and structural analysis is performed in order to know the displacement, rotor stress component, contact pressure and Frictional shear stress developed on a rotor disc brake for different materials as shown in figures below.

Rotor Disc Brake - Aluminum Metal Matrix Composites (ALMMC)
For different materials for Rotor disc brake the same procedure has been followed and the results are tabulated.

Observing all the above figures, the rotor having different material on a disc brake in order to obtain the Maximum displacement, stress component, contact pressure and Frictional shear stress. Hence one can declare that from the above figures that E glass having less frictional shear stress than the other materials.

Figure 5.1: a, b, c and d Shows the Maximum Displacement, Stress Component, Contact Pressure and Frictional Shear Stress for ALMMC Rotor Disc Brake.

![Figure 5.1: Rotor Displacement for Different Material](image1)

![Figure 5.2 (a): Rotor Displacement for Different Material](image2)

![Figure 5.2 (b): Rotor Stress Component for Different Material](image3)
Table 5.1: Comparison for a Different Rotor Disc Brake Material

<table>
<thead>
<tr>
<th>Materials</th>
<th>Pad with Rotor Different Material</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Displacement</td>
<td>Stress Component</td>
<td>Contact pressure</td>
<td>Frictional shear stress</td>
</tr>
<tr>
<td>ALMMC</td>
<td>150.05</td>
<td>255.7</td>
<td>22.73</td>
<td>2.7</td>
</tr>
<tr>
<td>CI</td>
<td>150.046</td>
<td>352.407</td>
<td>25.987</td>
<td>3.074</td>
</tr>
<tr>
<td>E-glass</td>
<td>150.058</td>
<td>349.186</td>
<td>16.354</td>
<td>2.239</td>
</tr>
<tr>
<td>S2 grown</td>
<td>150.05</td>
<td>346.18</td>
<td>18.05</td>
<td>2.45</td>
</tr>
<tr>
<td>Steel</td>
<td>15.04</td>
<td>351.626</td>
<td>16.684</td>
<td>2.269</td>
</tr>
</tbody>
</table>

CONCLUSION

In order to improve the braking efficiency and provide greater stability to vehicle an investigation was carried out and the suitable hybrid composite material which is lighter than cast iron and has good Young's modulus, Yield strength and density properties. The low weight, the hardness, the stable characteristics also in case of high pressure and temperature and resistance to thermal shock.

The transient thermo elastic analysis of Disc brakes in repeated brake applications has been performed. Abaqus software is applied to the thermo elastic contact problem with frictional heat generation. To obtain the simulation of thermo elastic behavior appearing in Disc brakes, the coupled heat conduction and elastic equations are solved with contact problems. The effects of the friction material properties on the contact ratio of friction...
surfaces are examined and the larger influential properties are found to be the thermal expansion coefficient and the elastic modulus.

It is observed that the orthotropic Disc brake scan provide better brake performance than the isotropic ones because of uniform and mild pressure distributions. The present study can provide a useful design tool and improve the brake performance of Disc brake system. From calculation we can conclude that that E glass fibre is the suitable material for the braking operation and all the values obtained from the analysis are less than their allowable values. Hence the brake Disc design is safe based on the strength and rigidity criteria.

REFERENCES


