COMPARISION OF STRUCTURAL AND THERMAL ANALYSIS OF DISC BRAKE USING VARIOUS MATERIALS

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ABSTRACT

Disc brakes are exposed to large thermal stresses during routine braking and extraordinary thermal stresses during hard braking. The aim of the project is to design, model a disc brake. Modeling is done using ANSYS. Structural and Thermal analysis is to be done on the disc brakes using various materials. Structural analysis is done on the disc brake to validate the strength of the disc brake and thermal analysis is done to analyze the thermal properties. Comparison can be done for displacement, stresses, thermal gradient etc. We are also providing manufacturing process for making disc brake and also preparing prototype. ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The aim of my research is to find different properties that might help us in future to optimize the working parameters and to increase the performance of the brake system. There is lot of upgrade in the technology of the automobile these days. The applications of the disk brake motivate researches, because disc brakes are used in automobiles, for light vehicles and agricultural machines. The aim of these researches is to realize the optimal function of the given construction, in order to increase the lifetime or the performance. Most brake-researches examine the thermal and tri-biological behavior, where the behavior of the different friction materials was checked at high temperature. Competition on the speed of vehicles going on in the market. But also this speed leads to accidents if vehicle don’t stop on time. Disc brakes in the vehicles give much better performance compare to drum to stop the vehicle also the heat generated during braking force can be easily dissipated as disc brakes are open to atmosphere. But the main problem is with the material used in the disc brakes in some vehicle. Manufacturers use disc of steel which have short life span and the weight is bulky near the tire. If disc loses its shape wobbling can caused near the tire causing a big problem. The main motto of this
thesis is to improve the strength of the disc by taking various materials for analysis. The design has been taken from real world.

**Key words:** Disc brake, ANSYS software, Different alloys

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http://www.iaeme.com/ijte/issues.asp?JType=IJTE&VType=5&IType=2

1. INTRODUCTION

Statistics show that vehicle companies manufactured more and more vehicles in the last few years. From 2001 to 2007 the number of cars increased, in 2007 there were 73 million cars manufactured, this number decreased and in 2009 the number of manufactured cars was 62 million. After the economic crisis the quantity of manufacturing increased again and by the end of 2014 there were 90 million cars produced. There are no cars without a brake system, which brake system can be of two types: disc brake and drum brake. The applications of the disk brake motivate researches, because disc brakes are used in automobiles, freight vehicles and agricultural machines. The aim of these researches is to realize the optimal function of the given construction, in order to increase the lifetime or the performance. Most brake-researches examine the thermal and tribological behaviour, where the behaviour of the different friction materials was checked at high temperature. In the examination various methods were used to check properties of the parts of the brake system. Sometimes a real system, sometimes a model was used to examine the properties of the parts. Nowadays we often use computer software in research because these programs are suitable to model the environment and can compare lots of different constructions.

2. LITERATURE REVIEW

In basic working operation, a disc or drum brake system has to reduce wheel speed when a driver desires vehicle deceleration. The kinetic energy generated by a vehicle in terms of wheel speed is converted into heat energy due to the application of the brake system. The friction force between disc/drum and brake pad/brake shoe applies friction torque to the wheel in the opposite direction of the car’s movement. This result in the reduction of vehicle speed and heat energy occurring in the brake disc/drum causes a temperature increment in the disc/drum swept area during the brake application. This physical action of the brake disc/drum causes heat conduction to the adjacent braking system components [1]. Lee [2] stated that inconsistent dissipation of heat inside the brake disc could cause deformation of the disc. Even worst, the disc deformation could also cause friction loss and consequently led to brake fade [3]. Furthermore, high temperatures of the brake disc could cause cracking in the brake disc material due to high thermal stresses. On top of that these factors also cause vibration [4, 5]. It is become common in the brake research RESEARCH A. Belhocine et al., Tribology in Industry Vol. 36, No. 4 (2014) 406-418 community to fully utilize finite element approach in order to identify and predict disc/drum brake structural performance. For instance, Koetniyom [6] performed temperature analysis on brake discs under heavy operating conditions. He found that the physical shape of vehicle brake discs play a significant role in determining the temperature characteristics including the overall brake efficiency. Kamnerdtong et al. [7] attempted to link the interaction between mechanical and thermal effects with disc movements and heat caused by frictions. They concluded that, from finite element analysis, temperatures on the disc surface changed at each point over the period, which indicates inconsistent dissipation and temperature differences in each side of the disc. Hence, inconsistent contact between disc and pad could affect material deformation.
Belhocine et al. [8] used the finite element software ANSYS to study the thermal behaviour of the dry contact between the discs of brake pads at the time of braking phase. Temperature distribution obtained by the transient thermal analysis was used in the calculations of the stresses on disc surface. Abdullah and Schlattmann [9] used finite element method to calculate the heat generated on the surfaces of friction clutch and temperature distribution for case of bands contact between flywheel and clutch disc, and between the clutch disc and pressure plate (one bad central and two bands) and compared with case of full contact between surfaces for single engagement and repeated engagements. In other work, Abdullah et al. [10] used the finite element method used to study the contact pressure and stresses during the full engagement period of the clutches using different contact algorithms. Moreover, sensitivity study for the contact pressure was presented to indicate the importance of the contact stiffness between contact surfaces. Akhtar et al. [11] employed finite element (FE) method to explain the transient thermoelastic phenomena of a dry clutch system. The effect of sliding speed on contact pressure distribution, temperature and heat flux generated along the frictional surfaces was analyzed.

3. BRAKE DISC DESIGN

- Firstly carry the old brake disc of Hyundai Santro Xing car from car garage. Analysis each hole, stud, rotor, ventilation slots & his velocity & collect all data like as inner diameter, outer diameter, hub length etc. & follow the brake disc to whole thesis works.
- And we have designed brake disc on designing software like as catia, solid works. with properly correct diameter, length,
- And import on ANSYS for analysis.
- Find out good mashing, total deformation, and equivalent stress.
- Find out total deformation, equivalent stress, equivalent strain, Weight & some other property of brake disc.

![Figure 1 Brake Disc Rotor](http://www.iaeme.com/ijte/index.asp)

4. MODELING DIMENSIONS

- Outer diameter = 240mm
- 1st Inner diameter =150mm
- 2nd inner diameter =145mm
- 3rd inner diameter =65mm
- Outer diameter distance from centre = 120
- Hub length = 42 mm
• Wheel stud = 15 mm
• Wheel stud distance from canter =52mm.
• Ventilating slots =11mm,5mm
• 38 slots Ventilation slots
• Slots angle 7 deg.

5. SOLID WORKS
We design brake disc on solid works with the help of suitable solid works commands. With suitable diameter. Solid works is a designing software its good & easy software as compare from catia, & AutoCAD. Parameters refer to constraints whose values determine the shape or geometry of the model or assembly. Parameters can be either numeric parameters, such as line lengths or circle diameters, or geometric parameters, such as tangent, parallel, concentric, horizontal or vertical, etc. Dimensions are added to the sketch to define the size and location of the geometry. Relations are used to define attributes such as tangency, parallelism, perpendicularity, and concentricity. The parametric nature of SOLIDWORKS means that the dimensions and relations drive the geometry, not the other way around. Numeric parameters can be associated with each other through the use of relations, which allow them to capture design intent. For example, you would want the hole at the top of a beverage can to stay at the top surface, regardless of the height or size of the can. SOLIDWORKS allows the user to specify that the hole is a feature on the top surface, and will then honor their design intent no matter what height they later assign to the can.

6. MATERIAL SELECTION
In material selection we have selected 4 alloy materials Which is light weight from cast iron & structural steel?&we will be made a good brake disc. As compare to present brake disc (cast iron alloy) & by the good alloy materials we will be find out good result.
• Structural steel alloy  (defalts on ansys analysis software)
• Cast iron alloy  (for comparing )
• Ti–6Al–4V titanium alloy (new material)
• Al-ni-co alloy  (new material)

| Table.1 Material Property of Structural Steel |
|------------------|------------------|
| Density          | 7.85 g/cm³       |
| Young modules    | 210Gpa           |
| Shear modules    | 75Gpa            |
| Bulk modules     | 175 Gpa          |
| Poisson ratio    | 0.26             |
| Thermal expansion| $11 \times 10^{-6} \text{.k}^{-1}$ |
| Thermal conductivity | 15 w/m-k     |
| Yield strength   | 250 Mpa          |
| Specific heat    | 420 JKg$^{-1} \text{.k}^{-1}$ |
Comparision of Structural and Thermal Analysis of Disc Brake using Various Materials

### Table 2 Material Property Of Al-Ni-Co Alloy

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>7.3 g/cc</td>
</tr>
<tr>
<td>Young modules</td>
<td>156 Gpa</td>
</tr>
<tr>
<td>Shear modules</td>
<td>76 Gpa</td>
</tr>
<tr>
<td>Bulk modules</td>
<td>180 Gpa</td>
</tr>
<tr>
<td>Poisson ratio</td>
<td>0.31</td>
</tr>
<tr>
<td>Thermal expansion</td>
<td>$12 \times 10^{-6}$/°C</td>
</tr>
<tr>
<td>Thermal conductivity</td>
<td>15 W/m-k</td>
</tr>
<tr>
<td>Yield strength</td>
<td>713 Mpa</td>
</tr>
<tr>
<td>Specific heat</td>
<td>430 J/kg.k</td>
</tr>
</tbody>
</table>

By these alloy materials we will be find out good materials for brake disc from cast iron through ansys analysis software. Value find out on each alloy materials. Value put one by one.

### 7. RESULTS

#### Total Deformation

Total deformation in static structural for structural steel alloy

![Total Deformation of Brake Disc](image)

**Figure 2** Total Deformation of Brake Disc

#### Equivalent Elastic Strain

Equivalent Elastic Strain in Static Structural for Structural Steel alloy
Equivalent Stress
Equivalent stress in static structural for structural steel alloy

Heat Flux
Heat Flux in Thermal Analysis for Structural Steel alloy

Figure 3 Equivalent Elastic Strain Of Brake Disc

Figure 4 Equivalent Stress of Brake Disc

Figure 5 Heat Flux of Brake Disc
8. FACTOR OF SAFETY & WEIGHT OF STRUCTURAL STEEL ALLOY OF BRAKE DISC

- Factor of safety of brake disc is 3.3 is minimum & 15 is maximum
- Weight of brake disc 3.2 kg

Cast Iron Alloy Result
In cast iron we will be find out
- Total deformation
- Equivalent elastic strain
- Stress
- Factor of safety(F.O.S.)
- Heat flux
- Weight

By the help of these property we will major the good material.

Total Deformation
Total deformation in static structural for cast iron alloy

![Figure 6 Total Deformation Of Brake Disc](image)

Equivalent Elastic Strain
Equivalent Elastic Strain in Static Structural for cast iron alloy

![Figure 7 Equivalent Elastic Strain Of Brake Disc](image)
Equivalent Stress
Equivalent stress in static structural for cast iron alloy

![Figure 8 Equivalent Stress of Brake Disc](image)

Heat Flux
Heat Flux in Thermal Analysis for cast iron alloy

![Figure 9 Heat Flux of Brake Disc](image)

Table 3 Final Result

<table>
<thead>
<tr>
<th>Properties</th>
<th>Cast iron (ALLOY)</th>
<th>Titanium (ALLOY)</th>
<th>Al-Ni-Co (ALLOY)</th>
<th>Structural Steel (ALLOY)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL (mm) DEFORMATION</td>
<td>0.0144</td>
<td>0.023</td>
<td>0.014</td>
<td>0.018</td>
</tr>
<tr>
<td>EQUIVALENT STRESS (mpa)</td>
<td>73.56</td>
<td>71.32</td>
<td>70.02</td>
<td>75.1</td>
</tr>
<tr>
<td>EQUIVALENT ELASTIC STRAIN</td>
<td>0.00044</td>
<td>0.00069</td>
<td>0.00029</td>
<td>0.0023</td>
</tr>
<tr>
<td>FACTOR OF SAFETY</td>
<td>3.71</td>
<td>6.613</td>
<td>5.5</td>
<td>2.21</td>
</tr>
<tr>
<td>TEMPERATURE (°F)</td>
<td>89</td>
<td>77.24</td>
<td>89.31</td>
<td>79.27</td>
</tr>
<tr>
<td>HEAT FLUX (w/mm²)</td>
<td>0.523</td>
<td>0.2</td>
<td>0.163</td>
<td>0.483</td>
</tr>
<tr>
<td>WEIGHT (kg)</td>
<td>3.10</td>
<td>1.523</td>
<td>2.72</td>
<td>3.21</td>
</tr>
</tbody>
</table>

We see that brake disc result is very good for new material alloy like as al-ni-co alloy & titanium alloy. After compare from cast iron & structural steel. After Having Modelled Some
Error Is Generate in Brake Disc. but through the meshing we decrease the errors & negative points. & apply both materials al-ni-co, titanium. & structural steel. by this process of brake disc we create meshing for decreasing error & negative points.

9. DISCUSSION
We see that brake disc result is very good for new material alloy like as al-ni-co alloy and titanium alloy. After compare from cast iron and structural steel. After Having Modelled Some Error Is Generate in Brake Disc. But through the meshing we decrease the errors and negative points. To apply both materials al-ni-co, titanium. And structural steel. by this process of brake disc we create meshing for decreasing error and negative points.

Total deformation is good, stress, strain is good & main aim reduced weight of brake disc. so we can say that al-ni-co alloy & titanium alloy is a very good material for brake disc. In this work, a disc-pad model has been analysed using two approaches, namely mechanical and thermomechanical analysis. In addition to this, three pad designs are also simulated to identify its influence on the stress distribution. By this methodology we can design brake disc on solid works. With standard data of brake disc. In this methodology of brake disc we create meshing for decreasing error & negative points. After modelling & meshing we calculate specific perimeter & variable data like as force & moment of inertia static structural result. & heat flux & final temperature for thermal analysis. al-ni-co alloy & titanium alloy is a good material for brake disc from compare to cast iron & structural steel.

REFERENCES


