ISSN 2229-5518

Transient Thermal and Structural Analysis of the Rotor Disc of Disc 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 there by assist in disc rotor design and analysis. An investigation into usage of new materials is required which improve braking efficiency and provide greater stability to vehicle. This investigation can be done using ANSYS software. ANSYS 11.0 is a dedicated finite element package used for determining the temperature distribution, variation of the stresses and deformation across the disc brake profile. 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.

Index Terms— *Rotor Disc, Disk Brake*

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1 Introduction

Disc brake consists of a cast iron disc bolted to the wheel hub and a stationary housing called caliper. The caliper is connected to some stationary part of the vehicle like the axle casing or the stub axle as is cast in two parts each part containing a piston. In between each piston and the disc there is a friction pad held in position by retaining pins, spring plates. The passages are so connected to another one for bleeding. Each cylinder contains rubber-sealing ring between the cylinder and piston. A schematic diagram is shown in the figure. Due to the application of brakes on the car disc brake rotor, heat generation takes place due to friction and this temperature so generated has to be conducted and dispersed across the disc rotor cross section. An investigation into usage of new materials is required which improve braking efficiency and provide greater stability to vehicle.

2. Rotor Disc of Disc Brake

The Disc brake discs are commonly manufactured out of grey cast iron. The SAE maintains a specification for the manufacture of grey iron for various applications. For normal car and light truck applications, the SAE specification is J431 G3000 (superseded to G10). This specification dictates the correct range of hardness, chemical composition, tensile strength, and other properties necessary for the intended use. Some racing cars and airplanes use brakes with carbon fiber discs and carbon fiber pads to reduce weight. Wear rates tend to be high, and braking may be poor or grabby until the brake is hot. The materials used for rotor disc are explained in detail. It is investigated the temperature distribution, the thermal deformation, and the thermal stress of automotive brake disks have quite close relations with car safety; therefore, much research in this field has been performed [15].

2.1 Cast Iron:

Cast iron usually refers to grey cast iron, but identifies a large group of ferrous alloys, which solidify with a eutectic. Iron accounts for more than 95%, while the main alloying elements are carbon and silicon. The amount of carbon in cast iron is the range 2.1-4%, as ferrous alloys with less are denoted carbon steel by definition. Cast irons contain appreciable amounts of silicon, normally 1-3%, and consequently these alloys should be considered ternary Fe-C-Si alloys. Here graphite is present in the form of flakes. Disc brake discs are commonly manufactured out of a material called grey cast iron.

2.2 Aluminum Metal Matrix Composites:

Aluminum is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. Aluminum matrix composites (AMCs) refer to the class of light weight high performance aluminum centric material systems. The reinforcement in AMCs could be in the form of continuous or discontinuous fibers, whisker or particulates, in volume fractions ranging from a few percent to 70%. In the last few years, AMCs have been utilized in high-tech structural and functional applications including aerospace, defense, automotive, and thermal management areas, as well as in sports and recreation.

There has been interest in using aluminum based metal matrix composites for brake disc and drum materials in recent years. While much lighter than cast iron they are not as resistant to high temperatures and are sometimes only used on rear axles of automobiles because the energy dissipation requirements are not high as compared to front axle. While the friction and wear of al-mmc were high speeds and loads the behavior could be greatly improved beyond that of iron discs, given the correct match of pad and disc material.

2.3 E Glass Fiber:

The use of E-Glass as the reinforcement material in polymer matrix composites is extremely common. Optimal strength properties are gained when straight, continuous fibers are aligned parallel in a single direction. To promote strength in other directions, laminate structures can be constructed, with continuous fibers aligned in other directions. Fiber dimension and to some extent properties can be controlled by the process variables such as melt temperature (hence viscosity) and drawing/spinning rate. The temperature window that can be used to produce a melt of suitable viscosity is quite large, making this composition suitable for fiber forming.

2.4 S2 Glass Fiber

High-strength glass fibers are used in applications requiring greater strength and lower weight. High-strength glass is generally known as S-type glass in the United States, R-glass in Europe and T-glass in Japan. S-glass was originally developed for military applications in the 1960s, and a lower cost version, S-2 glass, was later developed for commercial applications.

The higher strength fibers fall into the S-2 category. Glass fibers in general are considered to be the "heavier" fibers within the reinforcement market although Boron also weighs in at about the same density. However, it is important to remember that the density of aluminum is about 2.8 gm/cm3 and steel about 7.8 gm/cm3. The cost difference between the E-glass fiber set and S2-glass fiber materials are about 8:1 with S2 being the higher price. However, many advanced composites use the S2-glass version because of the higher strength performance while E-glass is the traditional commercial and industrial product that dominates the world consumption in the FRP market.

3. Modeling of the Rotor Disc

Based on the specifications the element type chosen is PLANE 77.The following Figure shows the schematic diagram of the 8-noded thermal solid element. The element has one degree of freedom, temperature at each node. The 8-node elements have compatible temperature shapes and are well suited to model curved boundaries.

The 8-node thermal element is applicable to a two dimensional, steady state or transient thermal analysis. The type of mesh generation considered here is a free mesh since the 2D figure is not a regular shape. Axis-symmetric element 77 is used to model in
ANSYS by considering axis-symmetric geometry.

Table 1.1 Rotor Disc

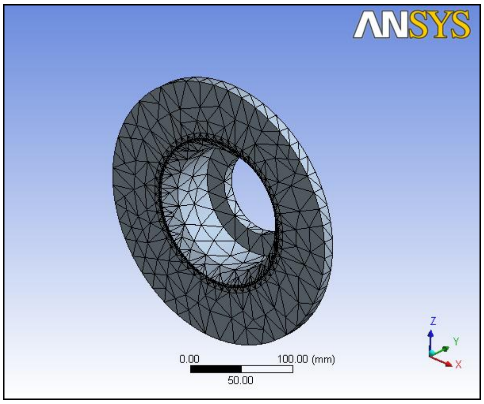

Fig.1 Isometric View of Rotor Disc

4. Results and Discussions

The investigation into usage of new materials is required which improves the braking efficiency and provide greater stability to vehicle. 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 of the , the resistance to thermal shock and the ductility provide long life time of the brake disk and avoid all problems resulting of loading, which are typical for the classic grey cast iron brake disks. The most suitable hybrid composites materials are

5. Conclusion

The transient thermo elastic analysis of Disc brakes in repeated brake applications has been performed. ANSYS 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 brakes can 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 Table 6.1 we can say that S2 glass fiber is the suitable material for the braking operation and all the values obtained from the analysis are less than

ISSN 2229-5518

their allowable values. Hence the brake Disc design is safe based on the strength and rigidity criteria.

5.1 Future Scope of the Project

In the present work, the suitable hybrid composite material which is lighter than cast iron and has good Young's modulus, Yield strength and density properties is been investigated.A transient thermal analysis will be carried out to investigate the temperature variation across the disc using axisymmetric elements. Further structural analysis will also be carried out by coupling thermal analysis.

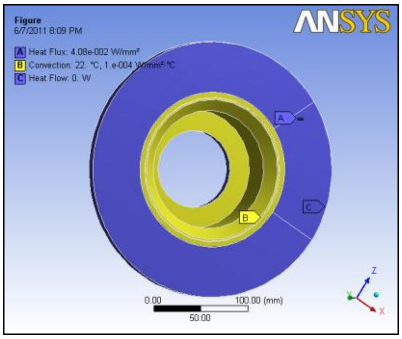

Fig.2 Thermal Loading

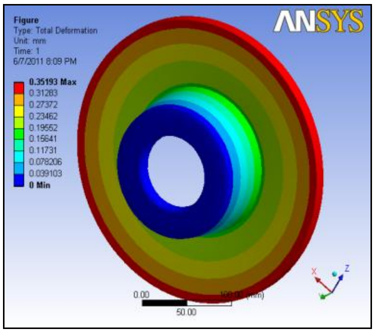

Fig.3 Total Deformation

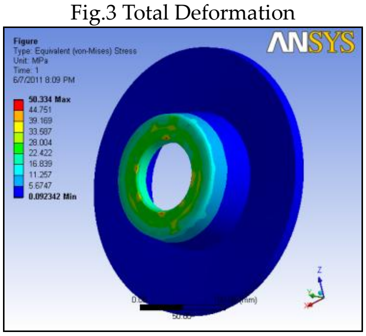

Fig.4 Equivalent Stress

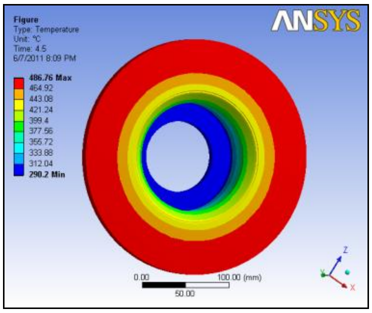

Fig.5 Temperature distribution

Table 1:
Comparison of results

Material	Deformation	Von-misses Stresses (MPa)		Temperature (°C)	
	mm	max	min	max	min
Cast Iron	0.35191	50.334	0.92342	486.76	290.2
AlMMC	0.35229	211.98	2.7269	29.232	21.9
E-Glass	1.036	274.14	0.44893	1219.8	22.019
S2 Glass	0.16097	50.197	0.079753	66.137	11.867

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