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Design and stress analysis of disc wheel using FEA

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Abstract
Each single system has been studied and developed in order to meet safety requirement. Instead of having air bag, good suspension systems, good handling and safe cornering, there is one most critical system in the vehicle which is brake systems. Without brake system in the vehicle will put a passenger in unsafe position. Therefore, it is must for all vehicles to have proper brake system.
The disc brake is a device for slowing or stopping the rotation of a wheel. Repetitive braking of the vehicle leads to heat generation during each braking event. 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. Disc brake model and analysis is done using ANSYS 14.5. The main purpose of this study is to analysis the thermo mechanical behavior of the dry contact of the brake disc during the braking phase.
The coupled thermal-structural analysis is used to determine the deformation and the Von Mises stress established in the disc for the both solid and ventilated disc with two different materials to enhance performance of the rotor disc. A comparison between analytical and results obtained from FEM is done and all the values obtained from the analysis are less than their allowable values. Hence best suitable design, material and rotor disc is suggested based on the performance, strength and rigidity criteria.

Keywords: Design, Stress Analysis, Disc Wheel, FEA

1. Introduction

A brake is a device by means of which artificial frictional resistance is applied to moving machine member, in order to stop the motion of a machine. In the process of performing this function, the brakes absorb either kinetic energy of the moving member or the potential energy given up by objects being lowered by hoists, elevators etc. The energy absorbed by brakes is dissipated in the form of heat. This heat is dissipated in the surrounding atmosphere to stop the vehicle, so the brake system should have following requirements:

- The brakes must be strong enough to stop the vehicle with in a minimum distance in an emergency.
- The driver must have proper control over the vehicle during braking and vehicle must not skid.
- The brakes must have well anti-fade characteristics i.e. their effectiveness should not decrease with constant prolonged application.
- The brakes should have good anti-wear properties.

1.1 Principle

The principle used is the applied force (pressure) acts on the brake pads, which comes into contact with the moving disc. At this point of time due to friction the relative motion is constrained.

1.2 Working

When the brakes are applied, hydraulically actuated pistons move the friction pads in to contact with the disc, applying equal and opposite forces on the later. On releasing the brakes the rubber-sealing ring acts as return spring and retracts the pistons and the friction pads away from the disc. The main components of the disc brake are:

- The Brake pads
- The caliper, which contains the piston

● The Rotor, which is mounted to the hub

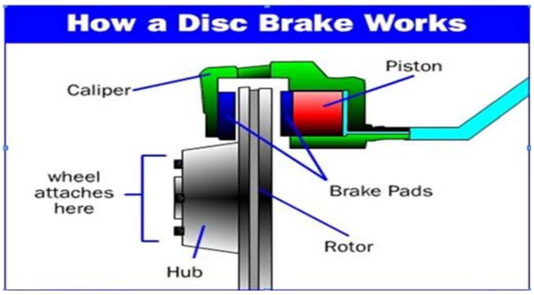

Fig 1: Principle of Disc brake

Most car disc brakes are vented as shown in the below figure:

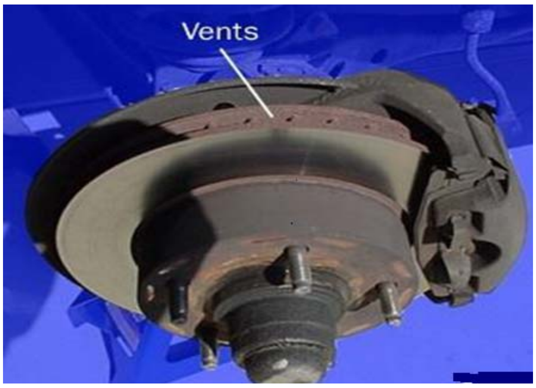

Fig 2: Working of Disc brake

2. Problems in Disc Brakes

In the course of brake operation, frictional heat is dissipated mostly into pads and a disk, and an occasional uneven temperature distribution on the components could induce severe thermo elastic distortion of the disk. The thermal distortion of a normally flat surface into a highly deformed state, called thermo elastic transition. It sometimes occurs in a sequence of stable continuously related states s operating conditions change. At other times, however, the stable evolution behavior of the sliding system crosses a threshold whereupon a sudden change of contact conditions occurs as the result of instability. This invokes a feedback loop that comprises the localized elevation of frictional heating, the resultant localized bulging, a localized pressure increases as the result of bulging, and further elevation of frictional heating as the result of the pressure increase.

2.1. Disc Damage Modes

Discs are usually damaged in one of four ways: scarring, cracking, warping or excessive rusting.

2.2. Excessive Lateral Run-Out

The difference between minimum and maximum value on the dial is called lateral run out. Typical hub/disc assembly run out specifications for passenger vehicles are around 0.0020" or 50 micrometers. Run out can be caused either by deformation of the disc itself or by run out in the underlying wheel hub face or by contamination between the disc surface and the underlying hub mounting surface

2.3. Scarring

Scarring can occur if brake pads are not changed promptly when they reach the end of their service life and are considered worn out. To prevent scarring, it is prudent to periodically inspect the brake pads for wear.

2.4. Cracking

Cracking is limited mostly to drilled discs, which may develop small cracks around edges of holes drilled near the edge of the disc due to the disc's uneven rate of expansion in severe duty environments. A brake disc is a heat sink, but the loss of heat sink mass may be balanced by increased surface area to radiate away heat. Small hairline cracks may appear in any cross drilled metal disc as a normal wear mechanism, but in the severe case the disc will fail catastrophically. No repair is possible for the cracks, and if cracking becomes severe, the disc must be replaced.

2.5. Rusting

The discs are commonly made from cast iron and a certain amount of what is known as "surface rust" is normal. The disc contact area for the brake pads will be kept clean by regular use, but a vehicle that is stored for an extended period can develop significant rust in the contact area that may reduce braking power for a time until the rusted layer is worn off again. Over time, vented brake discs may develop severe rust corrosion inside the ventilation slots, compromising the strength of the structure and needing replacement.

3. Design in PRO-E

PRO-E software is the standard in the 3D product design, featuring industry-leading productivity tools that promote one of the best practices in design while ensuring compliance regarding industry and company standards. The designing of PRO-E solution allow you to design you faster than any other software. The figure shows the solid model of the disc brake by using PRO-E. By taking the car disc wheel dimension we have to draw the disc model in PRO-E.
The assumptions which are made while modeling the process are given below

- The rotor disc material is considered as homogenous and isotropic.
- The problem domain is considered as axis-symmetric.
- Inertia & body force effects are negligible during the analysis.
- No stress in rotor disc before the application of brake.
- Brakes are applied on the all 4 wheels.
- Rotor disc is of Solid type

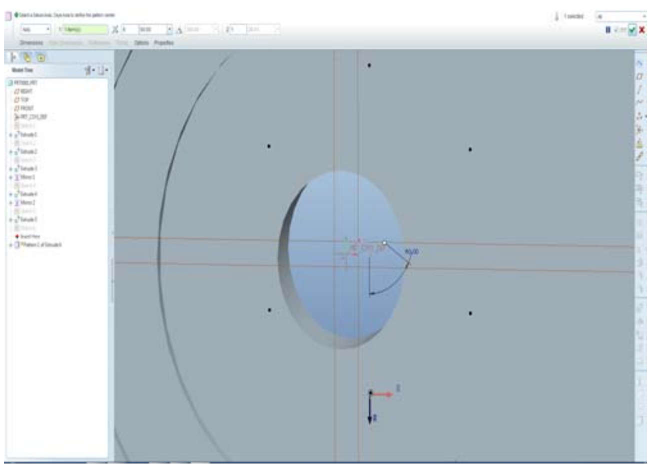

Fig 3: Final model

This is the Final model

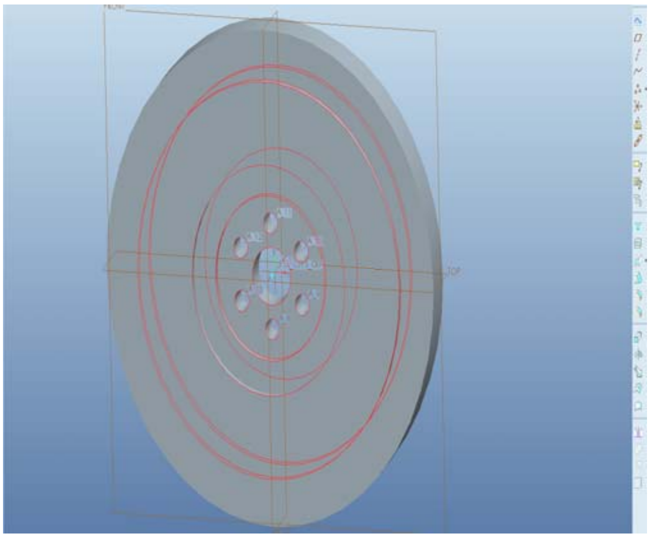

Fig 4: Default view

4. Structural Analysis
4.1 Steel

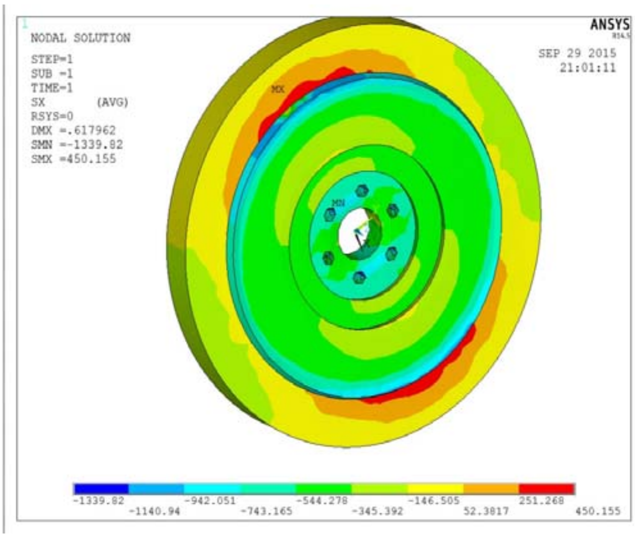

Fig 5: Stress

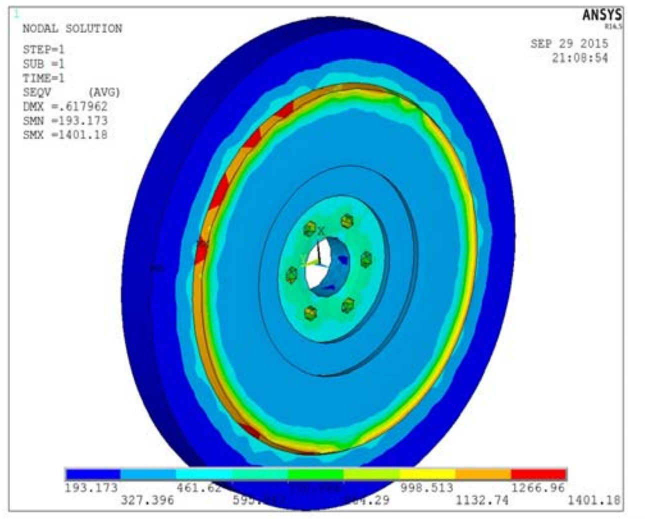

Fig 6: Von Mises stress

4.2 Aluminium

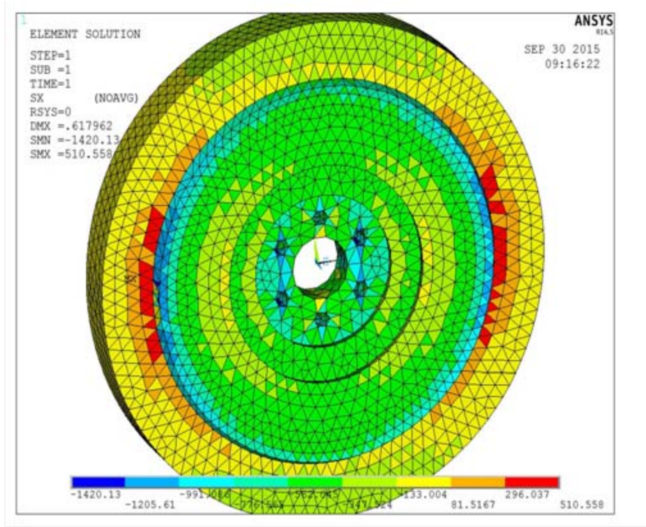

Fig 7: Stress

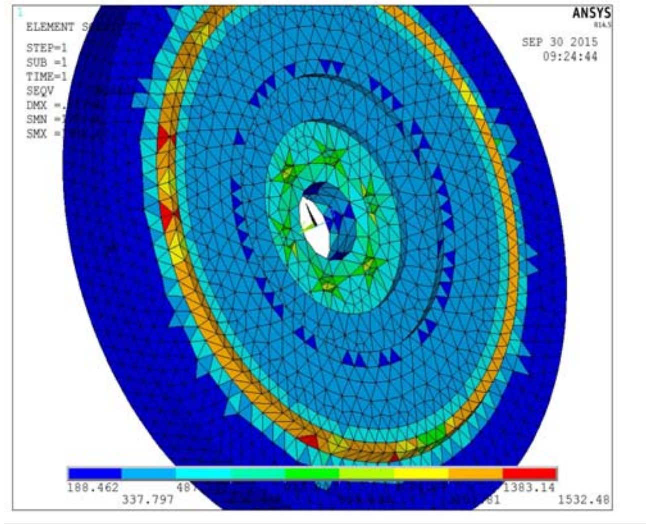

Fig 8: Von mises stress

5. Comparative Results
5.1. Comparison between Steel and Aluminum

Table 1: steel vs Aluminum

Material	Stress	Strain	Von-mises stress
Steel	4140	33-e5	67.91
Aluminum	510.558	0.00594	1401.18

6. Conclusion
In this paper, I have designed a four wheeler disc wheel. The modeling of disc wheel is done using PRO-E.
I have also done the structural analysis on the disc wheel using two materials Stainless Steel and Aluminium.
By observing the results, for all the materials the stress values are less than their permissible yield stress values. So my design is safe.
By comparing the results of two materials, the stress values of stainless steel is less than the Aluminium.
Therefore I conclude that the stainless steel is better material, high machinability and rust free.

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