

Structural and Thermal Analysis of Disc Brake Rotor

Yogesh Muli¹, Dhananjay R. Dolas²

¹ U.G Student, Dept. of Mechanical Engineering, MGM'JNEC, Aurangabad, India

² Associate Professor, Dept. of Mechanical Engineering, MGM'JNEC, Aurangabad, India

ABSTRACT: The technology of engine develops very fast even the system of the car, luxury or comforts everything that develops by the innovation of engineer. Although the engineer gives priority for safety measure, but most consumers still have inadequate of knowledge in safety system. Disc brake is a device for slowing or stopping the rotation of a wheel. A brake disc (or rotor), usually made of stainless steel or ceramic composites (including carbon, Kevlar and silica), is connected to wheel and/or the axel. To stop the wheel, friction material in the form of brake pads (mounted on device called a brake caliper) is forced mechanically, hydraulically, and pneumatically or electromagnetically against both side of the disc. Friction causes the disc and attached wheel to slow or stop. Brakes converts friction to heat, but if the brakes get too hot, they will cease to work because they cannot dissipate enough heat. This condition of failure is known as brake fade. Disc brakes are exposed to large stresses during braking and extraordinary stresses during hard braking. Objective of this work is to design a disc brake rotor and carry out its structural analysis and thermal analysis by using finite element analysis method, to study effect of various forces which arise during braking action. The analysis is carried out for different materials and optimum material is selected on basis of this results. The present study is helpful for design engineers to improve the brake performance of disc brake system

KEYWORDS: Brake disc, FEA, Structural analysis, Thermal analysis,

I. INTRODUCTION

A brake is device by means of which artificial friction resistance is applied to moving member, in order to stop the motion of machine. In the process of performing this function brakes absorbs kinetic energy of moving member. The energy absorb by brake is dissipated in form of heat. This heat is liberated in surrounding atmosphere to stop the vehicle, so the brake system should have following requirements:

- The brake must be strong enough to stop the vehicle within a minimum distance in an emergency.
- The driver must have proper control over the vehicle during braking and vehicle must not skid.
- The brake 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.

There are different types of brakes, both between vehicles and within a vehicle. The brakes used to stop a vehicle while driving are known as the service brakes, which are either a disc and drum brake.

Disc brakes: Disc-style brakes development and use began in England in the 1890s. The first caliper-type automobile disc brake was patented by Frederick William Lanchester in his Birmingham, UK factory in 1902 and used successfully on Lanchester cars. Compared to drum brakes, disc brakes offer better stopping performance, because the disc is more readily cooled. A disk brake consists of a cast iron disk 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 disk there is a friction pad held in position by retaining pins, spring plates etc. passages are drilled in the caliper for the fluid to enter or leave each housing. The passages are also connected to another one for bleeding. Each cylinder contains rubber-sealing ring between the cylinder and piston

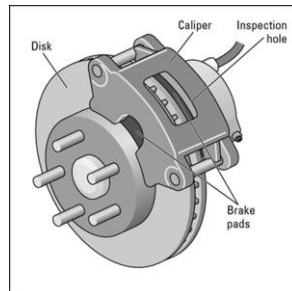


Fig1. Disc brake system

II. RELATED WORK

Automobile braking system various studies are carried by different researcher, according our studies carried out literature survey as mentioned

Gaikwad et al. [1] presented thermal analysis of disc brake rotor with slot shape optimization which studies about disc brake Rotor by analysis of different shapes of slots of different vehicle's disc brake rotor. Optimum shape design obtained changing the disc shaped by thermal analysis. N. Balasubramanyam et al. [2] performed transient analysis for the thermo elastic contact problem of the disk brakes with heat generation using the finite element analysis. To analyze the thermo elastic phenomenon occurring in the disk brakes, the occupied heat conduction and elastic equations are solved with contact problems. In this process cast iron disc was used and results were obtained using ANSYS software. Tiwari et al. [3] investigated the structural fields of the solid disc brake during short and emergency braking. Investigation was done using finite element software ANSYS. 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. Observed that the orthotropic disc brakes can provide better brake performance than the isotropic ones because of uniform and mild pressure distributions. Ajmire et al. [4] carried out transient thermal and static structural analysis of disc brake rotor of bike under severe braking condition to assist in disc rotor design and analysis. Compared between the rotor disc of a standard motorcycle "Bajaj Pulsar" and a non-standard rotor disc to find out the relationship value between brake torque, rotor disc dimension etc. Shinde et al. [1] carried out structural and thermal analysis on various design of disc rotor to find out optimum design. Variation in design of rotor was done by varying shapes and arrangement of slots on disc. Modeling of disc was carried out in PRO-E and analysis was done by using ANSYS (F.E.A) software. From thermal analysis concluded that elliptical type of cut pattern has better heat transfer than circular type of cut pattern. Structural analysis showed that elliptical type cut pattern is weaker to withstand braking forces when compared to circular type of cut pattern.

III. PROBLEM ASSUMPTIONS

The Society of Automotive Engineers (SAE) Handbook contains requirements and testing procedures for automotive braking systems. Without elaborating on the details of every test, the deceleration requirements for in-service brake performance of passenger vehicles and light duty trucks up to 4500 kg is between 2.4 m/s² and 5 m/s² not to exceed 6 m/s². In this research structural analysis carried out brake disc rotor of a domestic passenger car having mass of 1650kg. All the calculations are based on the assumptions that vehicle is having initial velocity of 60km/h.

IV. FINITE ELEMENT MODEL AND SIMULATION

ANSYS computer code also allows the determination and visualization of the structural deformations and thermal stress due to sliding contact between the disc and the pads. The results of the contact calculations described in this section relate to the displacements or the total deformations during the loading. In this section deformation and thermal analysis of Aluminium alloy brake rotor and stainless steel brake rotor analysed. The detailed properties of materials as follows.

Table 1: properties of Materials

| Properties | Aluminium Alloy | Stainless steel | Units |
|---------------------------|-----------------|-----------------|---------------------|
| Density | 2.71 | 7.15 | g/cc |
| Tensile Strength ultimate | 90 | 152 | MPa |
| Yield Strength | 35 | – | MPa |
| Modulus of Elasticity | 69 | 83 | GPa |
| Poisson's Ratio | 0.33 | 0.29 | – |
| Thermal conductivity | 237.5 | 13.8 | W/m°C |
| Specific heat | 875 | 480 | J/Kg ⁰ C |

In this work, a three dimensional CAD and FE model consists solid disc as shown in above figure. ANSYS is fully utilized to simulate structural deformation the disc brake during single braking stop application. Meshing involves division of the entire of model into small pieces called elements. The elements used for the meshed model are tetrahedral 3D elements. The finite element model of the rotor was carried out such that the resulting elements came to 57441 with a total of 96623 nodes. Boundary condition applied to model for structural analysis were fixed support and moment. Fixed support is applied to hole which are used to fasten the disc to wheels. While applying boundary conditions it is assumed that disc is fixed and moment is applied to rotate it, this rotation is opposed by fixed support. Thermal boundary conditions include heat flux, coefficient of convective heat transfer and ambient temperature

RESULT OF ANSYS:

Deformation and Von-Misses

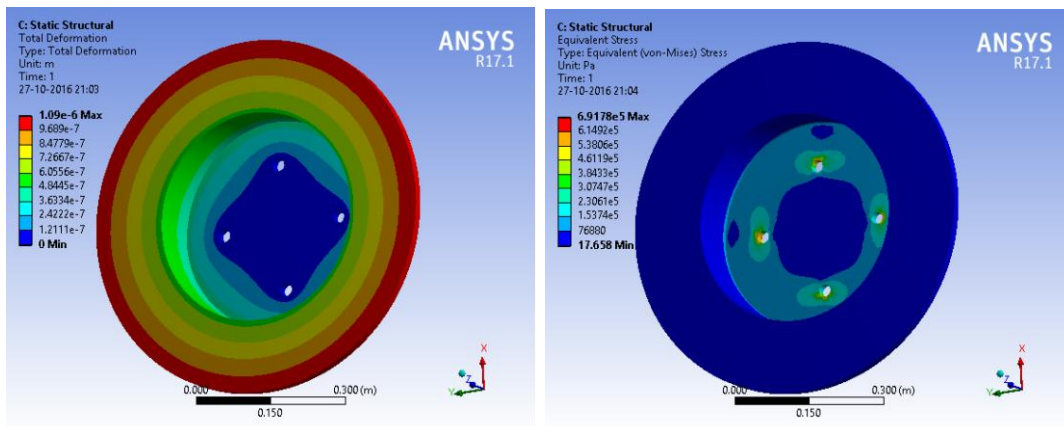


Fig 2: Total deformation and von-misses stress for aluminum alloy

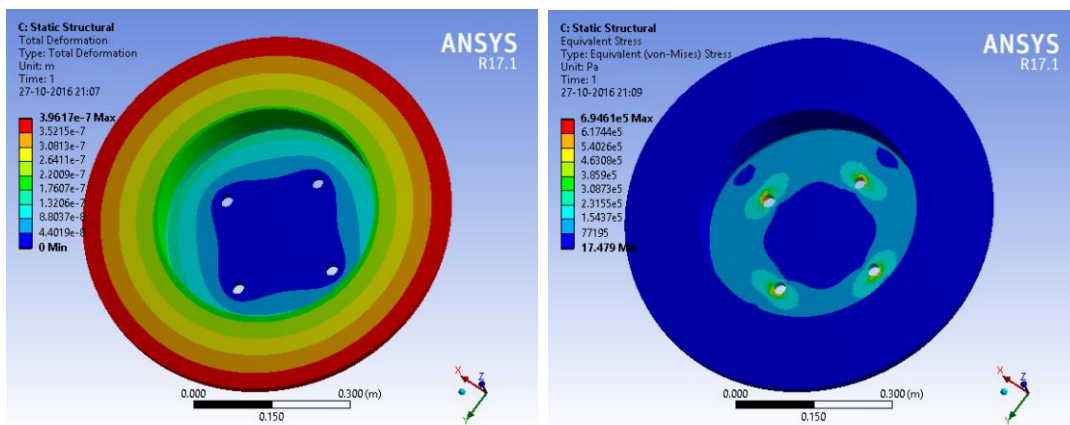


Fig 3: Total deformation and von-misses stress for stainless steel

Thermal analysis: thermal analysis results are shown in fig 4

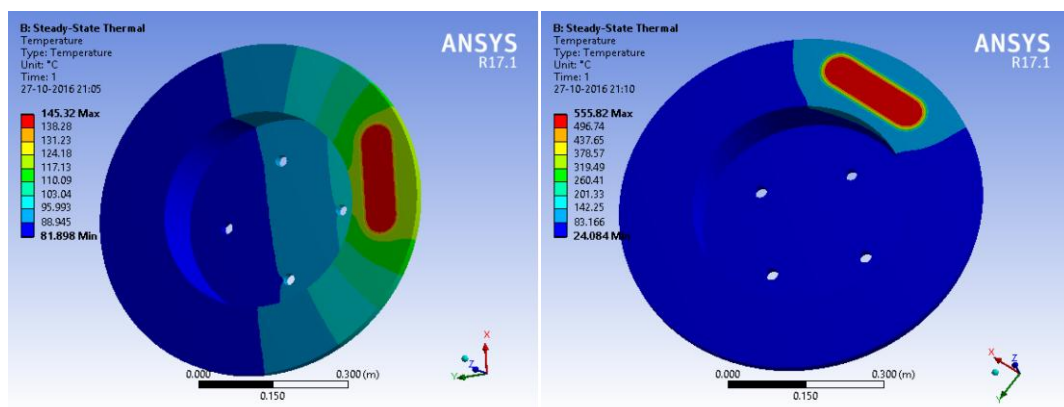


Fig 4: Temperature distribution for aluminum alloy and stainless steel

V. CONCLUSION

Structural analysis is done on disc rotor for two materials stainless steel and Aluminum alloy. A present used material for disc brake is stainless steel. We are replacing the material with Aluminum alloy, since its density is less than that of stainless steel thereby reducing the weight of disc brake. By observing the stress values obtained in structural analysis, they are less than the yield stress value of Aluminum alloy, so using Aluminum alloy for disc brake is safe. And also by comparing with other materials, the stress value is less for aluminum alloy moreover temperature rise in aluminum is also less than that of stainless steel. So using Aluminum alloy is better. Reducing weight of disc rotor, Braking system becomes less bulky and compact. Moreover, with increased weight braking force also increases, hence weight reduction can result in effective performance of disc brake

Table 4: Comparison Table

| Materials | Maximum temperature | Equivalent stress(Pa) | Density (Kg/m ³) | Ultimate strength (Pa) |
|-----------------|---------------------|-----------------------------|------------------------------|---------------------------|
| Stainless steel | 555.82 | 6.946×10⁵ | 8055 | 620×10⁶ |
| Aluminum Alloy | 145.32 | 6.91×10⁵ | 2689 | 90×10⁶ |

Failure criteria of disc brake rotor is equivalent stress, for both Aluminum as well as stainless steel equivalent stress is less than ultimate strength hence both design are safe. But weight of stainless steel is more than that of Aluminum, hence to reduce weight of disc brake rotor it should be made of Aluminum alloy. Hence where the repetitive braking and high temperature is observed during braking, aluminum alloy brake rotor should be used in place of gray cast iron

REFERENCES

- [1] Guru Murthy Nashi, T N Charyulu, K.Gowtham, P Satish Reddy,"Coupled Structural / Thermal Analysis of Disc Brake", International Journal of Research in Engineering and Technology,
- [2] N. Balasubramanyam, Prof. Smt. G. Prasanthi," Design and Analysis of Disc Brake Rotor for a Two Wheeler", International Journal of Mechanical and Industrial Technology (IJMIT), Vol. 1, Issue 1, pp: (7-12), -March 2014.
- [3] Mr. Pappu S. Gaikwad, Pro. Kaustubh S. Mangrulkar," Design and Thermal Analysis of Disc Brake Rotor with Weight Optimization", IJSRD - International Journal for Scientific Research & Development| Vol. 3, Issue 02, pp 1003-1006 2015.
- [4] Susmitha Sankatala, Dr Dhara Eshwar ,"Design Evaluation and Optimization of a Disc Brake",International Journal & Magazine of Engineering, Technology, Management and Research, - Volume No: 2, Issue No: 7..pp321-332, 2015
- [5] Abhishek Kumar Tiwari, Akhilesh Kumar Tiwari,Pramod Yadav, Harigovind Singh Yadav, Shyam Bihari Lal,"Finite Element Analysis of Disc Brake by ANSYS Workbench",IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 2, pp1954-1959, Apr-May, 2014,
- [6] R. S. Kajabe, R.R.Navthar,"Optimization of Disc Brake Rotor with Modified Shape",International Journal of Research In Aeronautical And Mechanical Engineering, pp 52-60, March 2015.
- [7] Vaibhav A. Ajmire and Sangeeta N. Bansode,"Structure Optimization of Disc Brake",International Journal of Scientific Engineering and Applied Science (IJSEAS) - Volume-1, Issue-7, pp457-461 , October 2015,