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Design and Thermal Analysis of Disc Brake using ANSYS

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Abstract

The disc brake is a device for slowing or stopping the rotation of a wheel.Structural Analysis of the Rotor Disc of Disk Brake is aimed at evaluating theperformance of disc brake rotor of a sports bike under severe braking conditionsand there by assist in disc rotor design and analysis. Disc brake model andanalysis is done using ANSYS workbench 16. The main aim of the project isreducing thermal deformation by changing design of disc brake, which isachieved by generating hole on inner surface which allows atmospheric airflow, which in result reduces the thermal stress and minimizes the chances ofdevelopment of crack. The thermal analysis is used to determine the thermaldeformation and total heat dissipates in the disc. Hence best suitable design,disc is suggested based on the performance.

Keyword: ANSYS, Disc Brake , Cast iron , Thermal Analysis

Introduction

The disc brake is a wheel brake which slows down rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers. The brake disc or rotor is usually made of cast iron. This is connected to the wheel and the axle. To stop the wheel, friction material in the form of brake pads, mounted on a device called a brake caliper, is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc and attached wheel to slow or stop. Brakes convert motion to heat, and if the brakes get too hot, they become less effective, aphenomenon known as brake fade. 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 resisting performance, because the disc is more readily cooled. As a consequence discsare less prone to the "brake fade". Disc brakes recover more quickly from immersion wet brakes are less effective. By contrast, a disc brake has no self servo effect and its braking force is always proportional to the pressureplaced on the brake pad by the braking system via any brake servo, braking pedal or lever, this tends to give the driver better "feel" to avoid impending lockup. Drums are also prone to "bell mouthing", and trap worn lining material within the assembly, both causes various braking problems. Without brake system in the vehicle passenger tends to be in unsafe condition. Therefore, it is a must for all vehicles to have proper brake system. Due to critical system in the vehicle, many of researchers have conducted a study on entire brake system components.

2. Problems on Disc Brake

In the course of brake operation, frictional heat is dissipated mostly intopads and a disk, and an occasional uneven temperature distribution on thecomponents could induce

severe thermo elastic distortion of the disk. Thethermal distortion of a normally flat surface into a highly deformed state calledthermo elastic transition. Friction brakes act by generating frictional forces astwo or more surfaces rub against each other.The stopping power or capacity of as friction brake depends on the areain contact and coefficient of friction of the working surfaces as well as on theactuation pressure applied. Wear occurs on the working surfaces, and thedurability of a given brake depends on the type of friction material used for thereplaceable surfaces of the brake.Disc usually damaged in one of four ways-scarring, cracking, warping, or excessive rusting. We introduced this cut pattern on the disc which was made up of material other than cast iron. The numbers of cut pattern introduced in disc are evaluated. If the number of cut is increase in the disc, the area of contract between the disc and pads were reduces, so efficiency of brake is high. It can help to increase the heat transfer rate and the area of contact between disc and pads are not reduces hence the efficiency of brake must be same.

3.Literature Survey

Dr.M.Sakthivel, K.Kanthavel, DeepanMarudachalam M.G, R.Palaniet.al. (1989),[1] discussed in detail about each single system in order to meet safety requirement. Instead of having air bag,good suspension systems, good handling and safe cornering, there is one mostcritical system in the vehicle which is brake systems. Without brake system inthe vehicle will put a passenger in unsafe position. Therefore, it is must for allvehicles to have proper brake system. In this paper carbon ceramic matrix discbrake material use for calculating normal force, shear force and piston force.And also calculating the brake distance of disc brake. The standard disc braketwo wheelers model using in Ansys and done the Thermal analysis and Modalanalysis also calculate the deflection and Heat flux, Temperature of disc brakemodel. This is important to understand action force and friction force on thedisc brake new material, how disc brake works more efficiently, which can helpto reduce the accident that may happen in each day.Mark A. Flick, Richard W. Radinsky, and RusselL.Kirk bride et.al. (1987),[2] deals with the effect of aftermarket linings on braking efficiency. Even though the study is on brake linings, it gives an idea about the braking efficiency values with respect to friction material. It also provide theinformation's about the torque versus pressure data, brake effectiveness, braking efficiency under Bladen condition for different peak tire/road friction values. From this literature, the frictional coefficient values are taken care off inthis work to the workable limits.Ouyang, Cao and Mottershead et.al. (2003),[3] presented a paper aboutthe vibration and squeal of a disc brake. The authors analyzed the abovecharacteristics through finite modeling and experimental verifications. In their investigations, the authors, considered the dynamics of the whole system andestablished the squeal and vibration frequencies. The concepts used in thisliterature for finite element modeling is incorporated to the required extent inthis work for the finite element analysis the designed brake disc.RudalfLimpert, Franco E Gamero and Ron Boyer et.al. (1974), [4] discussed in detail in his paper about the brake balance for straight and curved braking. The authors discussed about the stopping distance, brake force and braking

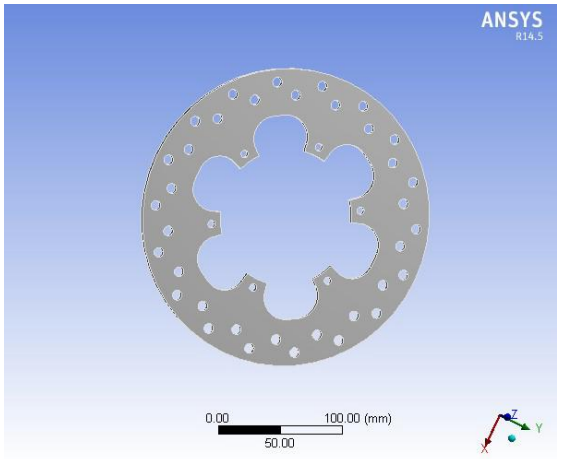
dynamics. The basic concepts related to the above performance parameters were considered for the analysis of performance of the designed brake disc in this work.Electrovac (power cooling subtracts)version 1.0/ THS) et.al.(2001),[5] published the paper on the basic properties for aluminium - silicon carbide metal matrix composites. This literature basically deals with manufacture of base plates using this metal matrix composite. It also gives the specifications and design rules and manufacturing standards. This silicon carbide based metal matrix composite is chosen as one of the alternate material for the brake disc in this investigation.ThomasValvano and Kwangjin Lee et.al. (2000),[6] deals with an analytical method for the prediction of thermal distortion of a brake rotor. It suggests that, the severe thermal distortion of a brake rotor can affect important brake system characteristics such as the system response and brake judder propensity. The authors formulated and developed a thermal stress and distortion analysis procedure using finite element methods. The basic concepts and the above procedure from this literature is incorporated in this integratedinvestigations.Abd Rahim Abu-Bakar, HuajiangOuyang et.al.et.al.(2002),[7] publisheda paper on the detailed and refined finite element model of a real disc brake considers the surface roughness of brake pads and allows the investigation intothe contact pressure distribution affected by the surface roughness and wear. Italso includes transient analysis of heat transfer and its influence on the contactpressure distribution. The focus is on the numerical analysisusing the finiteelement method. The simulation results are supported with measured data inorder to verify predictions.Swapnil R. Abhang, D.P.Bhaskar et.al.(2014),[8]describes that 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. In this paper carbon ceramic matrix disc brake material use for calculating normal force, shear force and piston force.Denholm et.al. (1998),[9] discussed in detail about the cast iron metal matrix composites rotors and drums. This literature gives the material properties of cast iron metal matrix composites, factors for the effective design of rotor based on this material and also its performance and thermal characteristics.R.S.Kajabe, R.R.Navthar, S.P.Nehakar et.al (2015),[10] discussed in detail about the disc barke rotor by modeling & analysis of different shapes of slots of different vehicles disc brake rotor with same material. On the aspect of weight parameter implementation of new disc brake and heat dissipation

4. Material and Modeling

The material of the disc taken in the current study considers grey cast iron.The properties of the grey cast iron are detailed in table 1.

Table 1 Properties of Cast Iron

S No	Property	Value	SI Unit
1	Poisson's	0.27	-



	ratio			
2	Mass density	7300	kg/m³	
3	Specific heat conductivity		874	J/kgC
4	Thermal conductivity		48	W/mk
5	Brinell hardness		207-241	HRC
6	Tensile yield strength		250	MPa
7	Compressive yield strength		250	MPa
8	Tensile ultimate strength		460	MPa

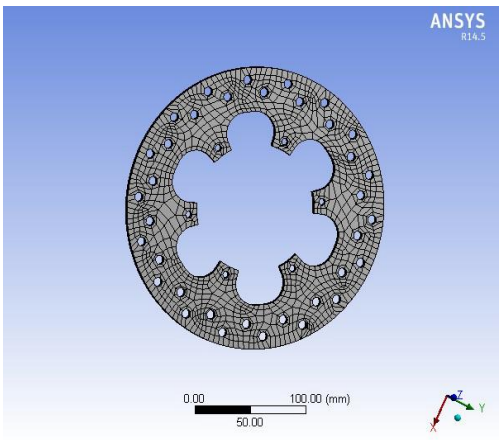
The 3D model of the disc brake is created using ANSYS modoller and shown in figure 1. Figure 2 shows the meshed model of the disc brake

Fig 1

Fig 2

4. Modification of Existing Design

The disc brake considered is drilled additional holes in drilling machine A Digital Read Out (DRO) is a communication device between the operator and the machine tool. The focus of information



communicated by the DRO is the measurement of the movement of the machine table stated in terms of direction, distance and location. Direction is expressed in terms of left or right (X-axis), back or forth (Y-axis) and up or down (Z-axis).Distance is interms of the drawing dimension. Location is defined in terms of an actual pointat which measuring takes place. The DROs function is to display the changes inthese positions as a work piece is moved.Drills, vertical boring dills and universal horizontal/vertical dills. Most system retrofits will require either a VUE, Wizard 411, 200S, Wizard 550, 300S, Wizard 1000 or a DRILLPWR with a minimum of two encoders. Retrofitted to almost any lathe or vertical drilling lathe. Most system retrofits will require either a VUE, Wizard 411,200S,Wizard 550,300S or Wizard 1000 for drilling with a minimum of two scales (don't forget that the 300S and Wizard 1000 can accommodate up to four (machine tool axes).Scale resolutionis normally 5µm for the Z or longitudinal axis and 1µm for the X or cross slideaxis. Drilling tools are used as follows. Figure 3 shows the setup for drilling holes in disc brake.

Figure 3 Drilling of Holes in Disc Brake

Table 2Disc Brake Data

S.No	Rotor Disc Data	Values
1	Rotor disc dimension	230×10^-3 m
2	Rotor material	Grey cast iron
3	Pad brake area	2000×10^-6 m
4	Coefficient of friction	0.5
5	Maximum temperature	250℃
6	Maximum pressure	MPa
7	Mass of disc	0.5 Kg
8	Grade	ASTM A48 class 40 , Grey cast iron
9	Diameter of disc	230mm
10	Plate width	4 mm
11	Centre between two holes	360/15 = 24°

Table 3 Numerical Simuation Results of Disc Brake after drilling the Hole

Parameter	Min	Max
Total Deformation (mm)	0	0.01446
Equivalent Stress (MPa)	0.11585	68.239

5. Results and Discussion

The current sections details about the results of static and thermal analysis carried out in the disc brake and the inference of the study.

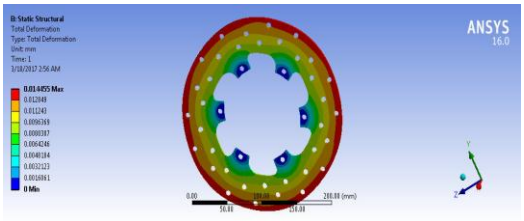


Figure 4 Total Deformation of Disc Brake

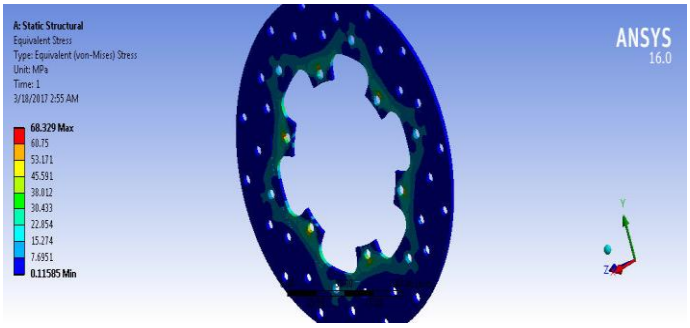


Figure 6Equivalent Stress of Disc Brake

The analysis of disc brake shows that the deformation,stress ,tenmperatureand total heat flux generated in the disc brake . Table 3 shows numerical analysis values

Temperature	17.35	70
Total heat flux	1.66E-05	4.768

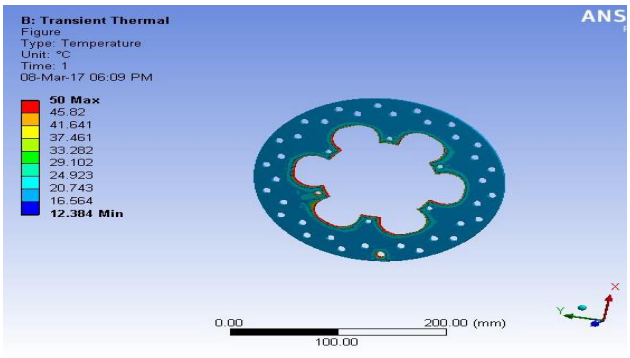


Figure 7 Temperature Distribution of Disc Brake

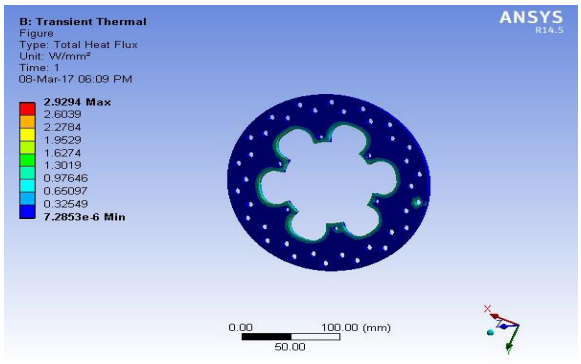


Figure 8 Total Heat Flux of Disc Brake

Conclusion

The numerical simulation of disc brake with hole and without hole has been carried out and

- The analsyis of disc brake without hole shows lesser deformation and formation of equivalent stress but the thermal based properties are found to be less.
- The presence of holes have increased the deformation , stress formed but the thermal properties betting decreased.

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