ANALYSIS OF HEAT DISSIPATION ON DISC BRAKE UNDER CONSTANT MECHANICAL LOADING

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ABSTRACT:

Each system is designed and developed in order to meet safety requirement .The brake system is one the main system for safe travelling. The Brakes must be strong enough to prevent the vehicle to skid. When a brake is applied the kinetic energy is converted into mechanical energy which must be dissipated by heat. The aim of our paper is to analysis of heat dissipation on Disc brake under constant mechanical loading. Here, the modeling is done using CATIA software and analysis is done using ANSYS Software .The ANSYS is general-purpose finite element analysis (FEA) software package .Finite Element Analysis is a numerical method of deconstructing the complex system into very small pieces. Heat dissipation is done on the Disc brake which is made of different material such as cast iron, stainless steel and titanium alloy. The paper deals with the thermal analysis of 3 different disk plates when constant mechanical load is applied on it. In the paper, the attempt was to study the heat distribution of the different disc brake and best suitable design is preferred for better performance.

Key words:Disc brake, thermal analysis, thermo mechanical analysis, ANSYS Simulation, CATIA model, conduction, convection.

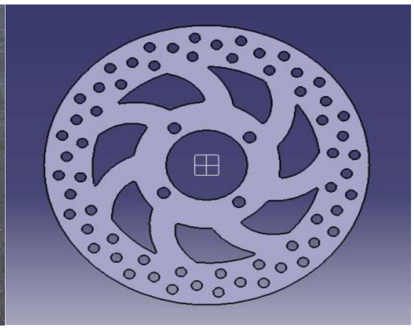
I. INTRODUCTION

The brake is the one of the most important safety components. Today, most of the automobile is equipped with disc brake system because of efficient braking. During stopping, the brake disc gets hotter due to the friction caused between the brake pads and disc. When braking, there is a conversion of kinetic energy to thermal energy. The higher the temperature of the brake disc will cause the cracks in the surfaces of the disc brake and also plastic deformation of the brake.The brakes is typically made of steel, but in some cases the material can be made of composition such as reinforced carbon-carbon or ceramic matrix composition. The disc brakes may be brake that slows rotation of the wheel by the friction caused by pushing restraint against a brake disc with a collection of calipers. To stop the wheel rotation, friction material are fixed to brake pads to arrest the motion. Friction causes the disc and attached wheel to slow or stop .The technology of braking performance evaluation has been generally developed with technology of speed improvement of railroad vehicle. Nowadays, technology of the test and evaluation from single braking parts to running testing of integration performance is systematically established .An interaction between a brake disc and friction material of automotive brake is characterized by variety of dry contact phenomena. These phenomena area unit influenced by brake operation conditions (applied pressure, speed, and brake interface temperature) and material characteristics of a friction couple.

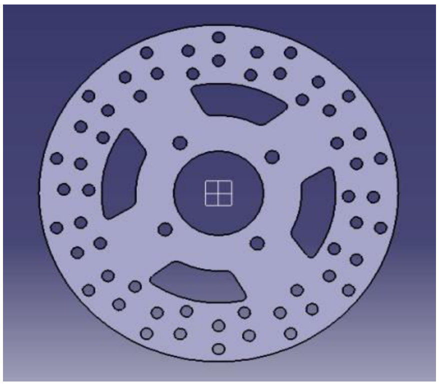
The coefficient of friction must be comparatively high and keep a stable level no matter natural action, humidity, age, degree of wear and corrosion, presence of dirt and water spraying from the road Braking performance of a vehicle can significantly be affected by the temperature rise in the brake components The braking performance is significantly affected by the temperature rise in the process of halting the vehicle. Each moment (time step) throughout the continual braking method provides a special price of temperature distribution as a results of the resistance heat generated on the rotor surface that can cause high temperature rise . [4] discussed about a disclosure which is made regarding a driving alert system which is designed in the form of a neck cushion which has the capability to sense the posture of the drivers neck position so as to identify whether the driver is alert and if he is dozing of. The system is made intelligent to obtain data from the movement so as to produce triggers to alert the user and to keep him/her awake to avoid accidents. The system is also linked to a mobile computing device so as to provide a report of the analysis done. The drivers location can also be tracked using the same.When the temperature rise exceeds the critical value for a given material, it leads to undesirable effects in the operation of the rotor such as thermal elastic instability (TEI), premature wear, brake fluid vaporization (BFV) and thermally excited vibrations (TEV). Disc style brakes developmental and use began in England in the 1890s. The caliper-type automobile hydraulic brakes was first patentable by Frederick William Lanchester in his Birmingham, UK factory in 1902 and used successfully on Lanchester cars. Compare to drum brakes, disc brakes offer better stopping operation, because the disc is more promptly cooled. As an aftermath discs are less prostrate to the "brake fade"; and disc brakes retrieve more quickly from submersion (wet brakes are less effective). Most drum brakes styles have a minimum of one leading shoe, which gives a servo effect. By demarcation, a disc brake has no self-servo effect and its braking force is always relative to the pressure placed on the brake pad by the braking system via any brake servo, braking pedal or lever, this tends to afford the driver amend "feel" to avoid approaching lockup. [6] discussed about a disclosure which is made regarding a gear blocking gear cover for the four wheeler vehicle where the protective cover has been with touch sensors and biometric sensors. Here in case of theft even if the car is started without a key the gear system is locked using biometric locks which can read the palm of the user to unlock the gear system thus protecting the vehicle against any form of theft. This device can be attached to any type of four wheeler vehicle. Drums are also prostrate to "bell mouthing", and ambuscade worn lining material within the assembly, both causes of various braking troubles.

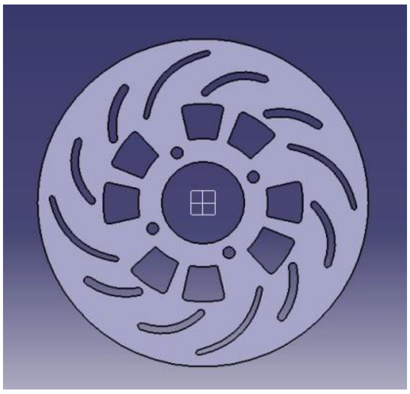
II. DESIGN PROCEDURE FOR DISC BRAKE

2.1 Figure of Disc Brake:



2.2 Modeling of Disc (Disc 1:)





Disc 2: **Disc 3:**

2.3Theoretical Calculations:

The rotor model heat flux is calculated for the car moving with a velocity 13.88 m/s (50kmph) and the following is the calculation procedure.

Data:

1) Mass of the vehicle =180 kg

2) Initial velocity (u) = 13.88 m/s (50 kmph)

3) Vehicle speed at the end of the braking application (v) = 0 m/s

4) Brake rotor diameter = 0.220 m

5) Weight distribution 25% on each side (γ) =0.25

6) Percentage of kinetic energy that disc absorbs (60%) k=0.6

7) Acceleration due to gravity, g =9.81m/s2

8) Coefficient of friction for dry pavement, μ=0.7

(a) Energy generated during braking

$K.E=k*1/2*m(u-v)^2/2$

(b) To calculate deceleration time

Deceleration time = Braking time = 3s

(c) Braking Power:

Braking power during continued braking is obtained by differentiating energy with respect to time

Pb = K.E/ t

(d) Calculate the Heat Flux (Q):

Heat Flux is defined as the amount of heat transferred per unit area per unit time, from or to a surface.

Q=Pb/A

Heat conduction

We can outline physical phenomenon because the heat by the direct collision of molecules. The high K.E. transfers thermal energy towards the lower K.E. area. High-speed particles clash with particles moving at a slow speed, as a result, slow speed particles increase their kinetic energy. This is a typical variety of heat transfer and takes place through physical contact.

Q= [K.A. (T1-T2)]/d

where,

- Q is the transfer of heat per unit time in W.
- K is that the thermal physical phenomenon of the fabricW/m.K.
- A is the area of the disc brake m2
- T1 is the temperature of the inner side in K
- T2 is the temperature of the outer side in K.
- d is the thickness of the disc brake in mm

Heat Convection

When fluid is heated, it carries thermal energy along with it and moves away from the source. The kind of head transfer is called as convection. The liquid over the new surface expands and rises up.

Q = hc · A · (Ts – Ta)

Where

hc=Convective Heat Transfer coefficient in W/m2K

A=Area of the disc brake in m2

Ts=Surface temperature in K s

Ta=Ambient temperature in K

Heat Radiation

Thermal radiation is generated by the emission of magnetism waves. These waves take away the energy from the emitting body. Radiation takes place through a vacuum or clear medium which may be either solid or liquid. Thermal radiation is that the results of the random motion of molecules within the matter. Movement of charged electrons and protons is to blame for the emission of radiation.

Thermal radiation can be calculated by Stefan-Boltzmann law:

Q= σ · A• (T1)4

Where,

σ is Stefan’s constant,

σ = 5.67 x 10 -8 W/m2/K

III. Analysis

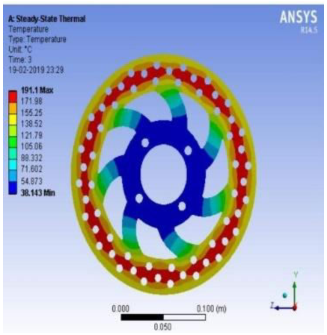
3.1Analysis Data for Stainless Steel:

S.No	Properties	Values	Units
1.	Density	7750	Kg/m^3
2.	Young's Modulus	1.93e+011	pa
3.	Poisson's Ratio	0.31	--
4.	Bulk Modulus	1.693e+011	pa
5.	Shear Modulus	7.3664e+010	pa
6.	Tensile Ultimate Strength	5.86e+008	pa
7.	Compressive Ultimate Strength	2.07e+008	pa
8.	Thermal Conductivity	36	W m^-1 C^-1
9.	Specific Heat	480	J kg^-1 C^-1

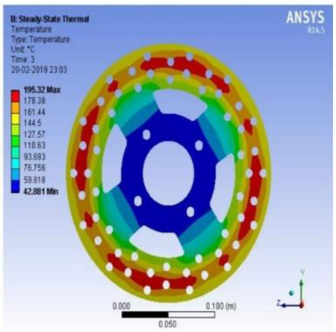
Table 1 Mechanical Properties for Stainless Steel

3.2 Result Analysis for Stainless Steel:

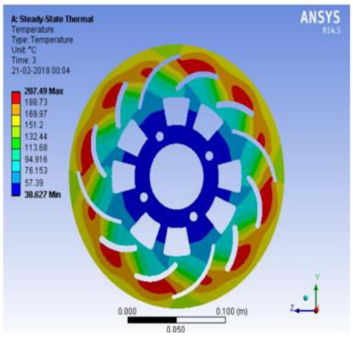
Disc 1:



Disc 2:



Disc 3:



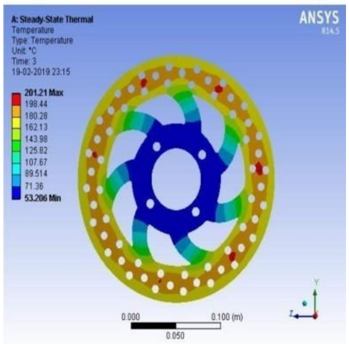
3.3 Analysis Data forCast Iron:

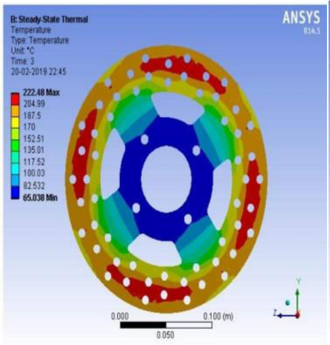
S.No	Properties	Values	Units
1.	Density	7200	Kg/m^3
2.	Young's Modulus	1.1e+011	pa
3.	Poisson's Ratio	0.28	---
4.	Bulk Modulus	8.3333e+010	pa
5.	Shear Modulus	4.2969e+010	pa
6.	Tensile Ultimate Strength	2.4e+008	pa
7.	Compressive Ultimate Strength	8.2e+008	pa
8.	Thermal Conductivity	52	W m^-1 C^-1
9.	Specific Heat	447	J kg^-1 C^-1

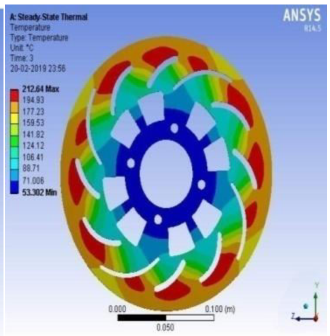
Table 2 Mechanical Properties for Cast Iron

3.4 Analysis Resultfor Cast Iron:

Disc 1: **Disc 2: Disc 3:**





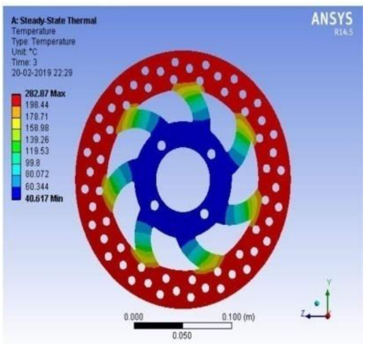


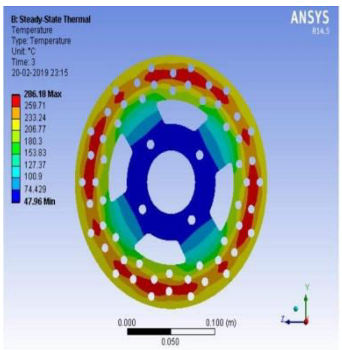
3.5Analysis Data for Titanium

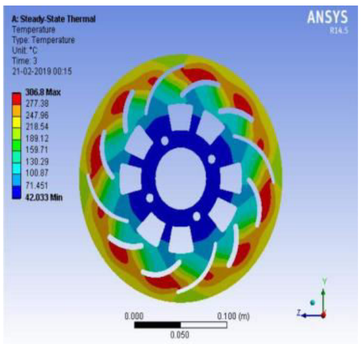
S.No	Properties	Values	Units
1.	Density	4500	Kg/m^3
2.	Young's Modulus	9.6e+010	pa
3.	Poisson's Ratio	0.36	--
4.	Bulk Modulus	1.1429e+011	pa
5.	Shear Modulus	3.5294e+010	pa
6.	Tensile Ultimate Strength	1.07e+009	pa
7.	Compressive Ultimate Strength	9.3e+008	pa
8.	Thermal Conductivity	21	W m^-1 C^-1
9.	Specific Heat	522	J kg^-1 C^-1

Table 3 Mechanical Properties for Cast Iron

3.6 Analysis Result for Titanium:







Disc 1: **Disc 2:** **Disc 3:**

IV. Comparison and Result

Result	Temperature Distribution (°C)					
Material	Cast Iron		Stainless Steel		Titanium	
	Min	Max	Min	Max	Min	Max
Disc 1	53.206	201.21	42.881	195.32	40.617	282.87
Disc 2	65.038	222.48	38.143	191.1	47.96	286.18
Disc 3	53.302	212.64	38.627	207.49	42.033	306.8

Table 4 Comparison of Temperature Distribution Results

V. Results and Discussion

For all the Disc models, the stainless steel material exhibit lower heat generation than cast iron and titanium, because the heat transfer coefficient of stainless steel is high when comparing the other materials. The heat flux is also important in considering the heat generation, when heat flux is high, the heat generation is also high. When the area of disc brake is more, the heat generation is minimized because the heat gets dissipated easily

VI. Future Scope

In future the performance of disc brake will be checked and the design and material of the disc will be modified by implementing the new design.

VII. Conclusion

From our study of various design patterns for different materials we have analyzed that the maximum temperature rise for stainless steel is much less as compared to cast iron and titanium alloy and thus on the basic of thermal analysis, stainless steel is the best preferable material for manufacturing disc brake. In stainless steel material disc 1 is less heat generate as compared to disc 2 and disc 3. So disc 1 design is best preferable for making a disc brakes.

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