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THERMO STRUCTURAL ANALYSIS OF DISC BRAKE ROTOR

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Abstract: Disk brakes are widely used for reducing velocity for their characteristics of braking stability, controllability and their ability to provide a wide ranging torque. The frictional heat generated on the interface of rotor can cause high temperature, which leads to undesirable effects such as brake fade phenomena, local scoring, thermal cracking and thermoelastic instability. In the course of braking the parameters of the processes like load, temperature and conditions of contact vary with time So, to consider the effects of moving heat source with relative sliding speed variation a transient thermal analysis is performed for four seconds of braking duration to characterize the temperature fields of the solid rotor with appropriate thermal boundary conditions. For the present analysis of solid rotor, ANSYS is used as a FEA tool. Once the brake rotor temperature distribution is obtained a transient structural analysis is performed to predict the failure of the disk rotor.

Keywords: Surface Texturing, Tribology, Dimples, Polyamide, HDPE, Wear, Friction.

I. 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 [1,2].

Due to the application of brakes on the car disc brake rotor, heat generation takes place due to friction. The frictional heat generated on the interface of the rotor and the pads can cause high temperature and this temperature so generated has to be conducted and dispersed across the disc rotor cross section. Particularly, the temperature may exceed the critical value for a given material, which leads to undesirable effects, such as brake fade phenomenon that is Brakes convert 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.

Thermal stresses due to high temperatures may induce a number of un favorable conditions such as surface cracks and permanent distortions. Frictional heating, thermal deformation. Hot spots can cause material damage and thermal crack, and induce an undesirable frictional vibration known as “hot judder”. Long repetitive braking also leads to temperature rise of various brake components of the vehicle that reduces the performance of the brake system. Long repetitive braking, such as one which occurs during a mountain descent, will result in a brake fluid temperature rise and may cause brake fluid vaporization. High temperature during braking also leads for premature wear, bearing failure, thermal cracks, and thermally excited vibration, thermal shock that generates surface cracks; and/or large amounts of plastic deformation in the brake rotor. Due to repetitive use of brake temperature of disk rotor within fraction of seconds reach to max level that leads to change in mechanical and chemical properties of the disk rotor material. Thus, to gain a safe braking system performance, the brake must be sufficiently designed to be able to dissipate the heat generated from the braking process adequately, so that the brake surface temperature is kept within the brake material in acceptable operating range. Therefore, it is important to predict the temperature rise of a given brake system and assess its thermal performance in the early design stage [8].

In this paper analytical method is proposed for calculation influence of heat flux and by that heat flux temperature find out on rotor.

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II. DESIGN OF ROTOR

CAD model of disc brake rotor was done in CATIA V5 dimensions of rotor are mention in Table 1. Material used is Cast Iron because it is relatively hard and resist wear, cheaper than steel, it absorbs and dissipates heat as well.

Table 1 Material properties and data used in analysis.

Item		
Mass density (kg/m3)	7228	2595
Specific heat (J/kg oc)	419	1465
Thermal conductivity		

Atmospheric temperature (oC) - 2
Sliding length during braking (mm Convection
film coefficient (w/m2 oC) - 30
Initial velocity (m/sec) - 27.78
Coefficient of friction µ - 0.25
Effective radius of rotor) - 60

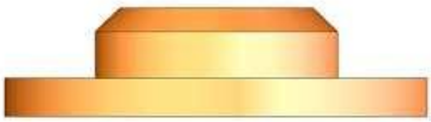

Fig. 1 CAD model of Rotor

Pressure and angular velocity readings are taken from dynamometer test bench for each second.

Table 2 Pressure and Angular velocity variation for solid rotor.

Sr. No	**Time t (sec)**	**Hydraulic pressure p (Mpa)**	**Angular velocity ω (rad/sec)**
1	0	0	89
2	1.0	2.10	79
3	2.0	2.60	56
4	3.0	2.72	32
5	4.0	3.17	7

III. ANALYTIAC METHOD FOR HEAT FLUX CALCULATION

Using these pressure and angular velocity values from Table 2, heat flux for each second time steps are calculated from eq. (1) which is derived by C H Gao et al as follows Heat flux entering in to the disc.

$$q_d(r,t) = \gamma\mu p(r,t) v(r,t) = \gamma\mu p(t) w(t) r$$

IV. THERMAL BOUNDARY CONDITION

After formulation of the heat flux thermal boundary conditions they are applied on the FE model to obtain an estimate of the temperature distribution in the disc rotor. The thermal boundary conditions on the rotor are as follows Initial temperature on the rotor is set to 20 ^{0}C. Convection is applied on those surfaces of rotor which is not in contact with the pad, with the film coefficient of 30 w/m^2 ^{0}C Heat flux at each second time steps is applied on the respective contact region.

V. ANALYSIS OF ROTOR

A Transient Thermal Analysis

After application of appropriate thermal boundary conditions, a transient thermal analysis is performed over an interval of 4 seconds in second time steps in the analysis software i.e. ANSYS. The temperatures contour plots showing the temperature distribution in the disc rotor at each one second time step are as shown in figure 2. It shows that maximum temperature at the end of 4 seconds is 343.805 ^{0}C

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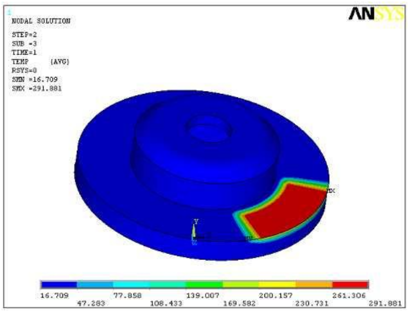
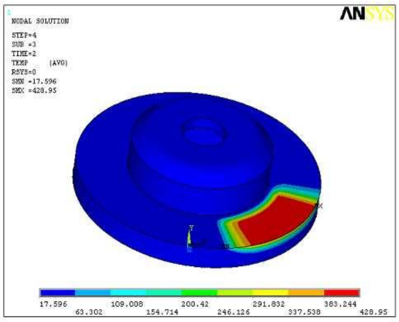


Where,

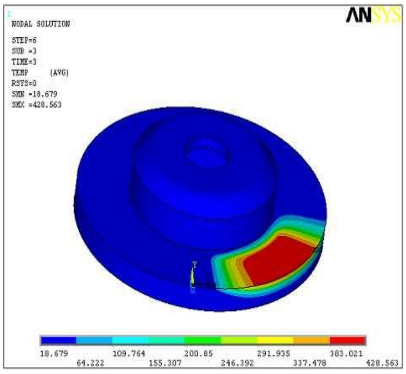
$$\frac{1}{1+\sqrt{\frac{\rho_p c_{p*} k_p}{\rho_{d*} c_d k_d}}}\gamma =$$

Using the values from Table. 1
(1)

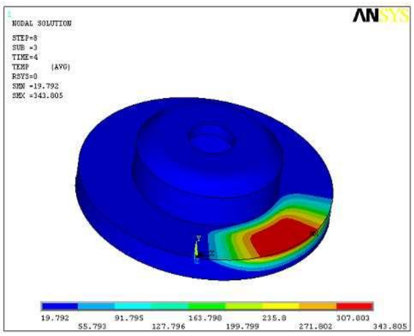
At t = 1.0 sec, T_{max} = 291.881 ^{0}C



At t = 2.0 sec, T_{max} = 428.95 ^{0}C



At t = 3.0 sec, T_{max} = 428.563 ^{0}C



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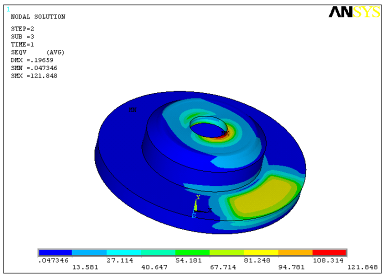
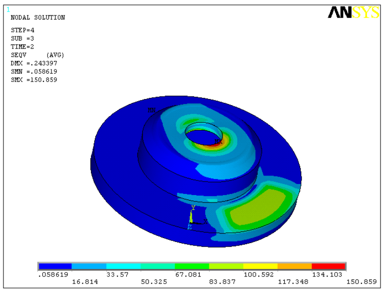
The pressure values are applied for the disc / rotor at each second time steps from table 2.
The hub region of the rotor is constrained in all degree of freedom.
The thermal load is applied from the result file jobname.rth, which is generated after solving the thermal analysis.

After applying boundary conditions, transient structural analysis is performed over an interval of 4 seconds. von Mises stress distribution plot for each one second time step for C.I. FG 260 are as shown in figure 3.It shows that maximum von Mises stress at the end 4 seconds is 193.582 MPa , which is less than the tensile strength 260 MPa of the material C.I. FG 260 . So, rotor is safe against loading conditions.

At t = 1 sec, Max von Mises stress = 121.848 MPa



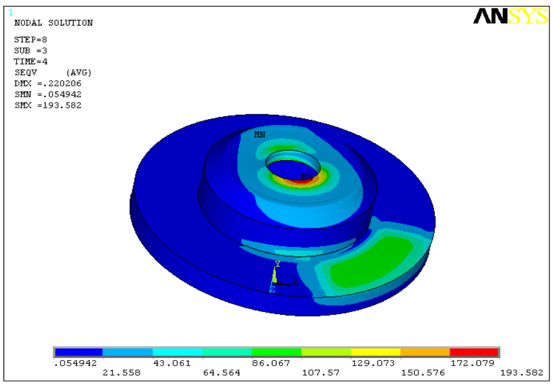


At t = 4.0 sec, T_{max} = 343.805 ^{0}C
Fig. 2 Temperature contour plots for C.I. solid disc
At t = 2 sec, Max von Mises stress = 150.859 MPa

B Transient Structural Analysis
The materials properties of disc rotor used for the analysis are as follows:

Thermal conductivity - 48.46 w/m0c Specific heat - 41.9 J/kg Mass density - 28 kg/m3
Elastic limit - 128 GPa
Poisson's ratio - 0.26
Coefficient of thermal expansion - 12.1 e- 6/0C
Tensile strength -260 N/mm2

The boundary conditions applied on the finite element model are described below.
At t = 3 sec, Max von Mises stress = 157.762 MPa



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At t = 4 sec, Max von Mises stress = 193.582 MPa

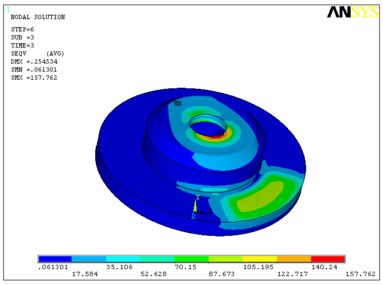

Fig. 5.11 Von Mises stress contour plot for C.I. Solid disc

VI. RESULT AND DISCUSSION

Results from transient analysis are often more desirable in predicting the actual performance of the disc during operation. The transient thermal and structural 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.

Table 2. result for solid rotor

Sr No	**Method**	**Von-misses stress Mpa**	**Temperature ^{0}C max at the end of 4 sec**	**Allowable stress CI FG**
1	ANSYS	193.582	343.805	260

VII. CONCLUSION

The present study can provide a useful design tool and improve the brake performance of Disc brake system. it is concluded that 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.

VIII. FEATURE SCOPE OF PROJECT

As future work a complicated model of slotted or cross drilled rotor can be taken it account. Also Suitable hybrid composite material which is lighter than cast iron is use for rotor.

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