Investigation and prediction of Braking Performance of disc brake by changing the Brake Rotor profile

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Abstract— Braking is a process which converts the kinetic energy of the vehicle into mechanical energy which must be dissipated in the form of heat. During the braking phase, the frictional heat generated at the interface disc-pads can lead to high temperatures. This high temperature rise of the rotor decreases the coefficient of friction between the rotor and pad, Brake fluid vaporization problem arises, component wear will be higher at higher temperature. So to remove the heat from rotor we use vented rotor now days, in vented rotor number of vanes have effect on mass flow rate through vented rotor. For this paper have taken one rotor with simple vane design and second having higher number of vanes with some design change considered after literature review.

Keywords: disc brake rotor,36 and 42 vane no. rotor, heat removal.

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 to the surrounding atmosphere. Excessive thermal loading can result in surface cracking, judder and high wear of the rubbing surfaces. High temperatures can also lead to overheating of brake fluid, seals and other components. Based on the design configurations, vehicle friction brakes can be grouped into drum and disc brakes. The drum brakes use brake shoes that are pushed in a radial direction against a brake drum. The disc brakes use pads that are pressed axially against a rotor or disc. Under extreme conditions, such as descending a steep hill with a heavy load, or repeated high speed decelerations, drum brakes would often fade and lose effectiveness. Compared with their counterpart, disc brakes would operate with less fade under the same conditions. An additional advantage of disc brakes is their linear relationship between brake torque and pad/rotor friction coefficient. Advantages of disc brakes over drum brakes have led to their universal use on passenger-car and light-truck front axles, many rear axles, and medium-weight trucks on both axles.

II. PROBLEMS ASSOCIATED WITH OVERHEATING BRAKES

If the temperatures reached in braking become too high, deterioration in braking may result, and in extreme conditions complete failure of the braking system can occur. It can be difficult to attribute thermal brake failure to motor vehicle accidents as normal braking operation may return to the vehicle when the temperatures return to below their critical level One of the most common problems caused by high temperatures is brake fade; other problems that may occur are excessive component wear, rotor deterioration, and thermally excited vibration (brake judder). Heat conduction to surrounding components can also lead to damaged seals, brake fluid vaporization, as well as wheel bearing damage, while heat radiated to the tyre can cause damage at tyre temperatures as low as 200°F (93°C).

III. DISSIPATION OF HEAT FROM DISC BRAKE

The rise in temperature of the brake disc in any braking operation will depend on a number of factors including the mass of the vehicle, the rate of retardation, and the duration of the braking event. In the case of short duration brake applications with low retardation, the rotor and friction material may absorb all of the thermal energy generated. As a result very little heat dissipation occurs as the temperature rise in the rotor is minimal. In extreme braking operations such as steep descents or repeated high speed brake applications, sufficient heat dissipation becomes critical to ensure reliable continued braking. As the rotor temperature rises it begins to dissipate heat, at steady-state conditions heat generated through braking equals heat dissipation and not further heating occurs. If the heat generation is greater than the dissipation then the temperature will rise, the rate of this rise will depend of the relative quantities of each. If sufficient heat dissipation does not occur the temperature of the rotor and friction material can reach critical levels and brake failure may occur. Heat dissipation from the brake disc will occur via conduction through the brake assembly and hub, radiation to nearby components and convection to the atmosphere. At high temperatures heat may create chemical reactions in the friction material, which may dissipate some of the braking energy.

However research conducted by Day and Newcomb (1984) indicated this to be less than two per cent of the total energy dissipated. While conduction is an effective mode of heat transfer it can have adverse effects on nearby components. Such effects include damaged seals, brake fluid vaporization, as well as wheel bearing damage. Radiation heat transfer from the rotor will have its greatest effect at higher temperatures but must be controlled to prevent beading of the tyre. It is estimated that the amount of heat dissipation through radiation under normal braking conditions is less than 5% of the total heat dissipated.

IV. INFLUENCE OF VENTILATED BRAKE ROTOR AERODYNAMICS

The aerodynamics of a ventilated brake rotor is complex and highly dependent on the geometry of both the brake rotor and its surrounding environment. As we have understood that ventilated rotor behaves as a centrifugal fan, drawing cool air from the inboard side, passing through the rotor passages and exhausting at the outer diameter, researcher have studied the aerodynamics of conventional centrifugal impellers extensively from pumping performance and efficiency point of view . Earlier work was measuring of the rotor exit airflow using pressure probes for velocity profile and calculation of the rotor mass flow.

Barigozzi[7] is one of the few previous workers who used hot -wire anemometry (HWA) to examine the unsteady rotor exit flow field for two disk geometries featuring a)backward curved vanes and a b)pedestal arrangement.

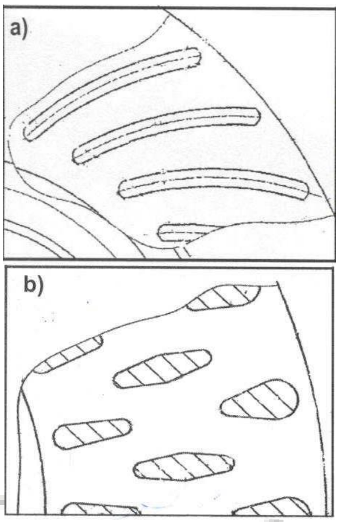

Fig. 1: A) Backward Curved Vanes & B) Pedestal Arrangement.

He showed that the pedestal configuration increased both the non - dimensional mass flow as well as the reported turbulence intensity.

Johnson [6] used two -component PIV system and revealed a large area of separated flow within passages where the air changes route from both axial to radial and also tangential to radial.. Other workers have shown that both local geometry modifications to the rotor inlet and cross drilled holes can have a beneficial effect on the cooling performance.

V. EXPERIMENTAL SETUP

Fig. 2: Experimental setup

In experimental setup to rotate the shaft on which disk rotor will be bolted, we have used the pulsar motorcycle engine which is mounted on the table as seen in the above picture. Power is transmitted through the chain drive for which I have even bolted a sprocket to flange which is welded to the rotating shaft. On one side of the chain sprocket is inertia weight and on another is the brake rotor and caliper arrangement.

For the experiment I have used the two rotors having the different number of vanes and also some geometry changes. Radial blades were considered for the analysis and this also reduces the manufacturing cost due to symmetry of the model.

- Rotor 1 have 36 number of vanes and from no onward it will be written as Rotor36
- Rotor 2 have 12 number of vanes and from no onward it will be written as Rotor42

Outer diameter and inner diameter of both the rotor is same. But there is different in the number of vanes and its geometry.

Fig. 3: vane rotor geometry

Fig. 4: No. vane rotor geometry

It is clearly visible from the above two images that Rotor42 vanes have rounded and Rotor36 doesn't. Other difference is that Rotor36 vanes run till the outer diameter but In case of Rotor42 there is 4 mm gap between the outer diameter and the outer ends of the vane.

Fig. 5: Rotor42 have long length and short length vanes.

Johnson et al. used PIV(particle image velocimetry) and found large flow separation in the internal vane-to-vane passage on the suction side surfaces, which would lead to poor heat transfer conditions and also restrict the flow of air. To reduce such effect second rotor which has 42 no. of vanes, have combination of one short length and one long length, the difference in the length is 5 mm that too at inside diameter of rotor only. Purpose of this short-long length vane combination is to allow the more air to enter in to the rotor. Lesser the obstruction area for the air, higher the mass flow rate of air through the rotor.

Air velocity measurement

Fig. 5: Digital Anemometer

For the measurement of the air velocity I used the Microprocessor Digital Anemometer (LT AM-4201). It is capable of measuring the 0.1 to 25.0 m/s air velocity speed. Air velocity is measured at the exit of the rotor buy keeping Anemometer vane housing cabinet very close to the vanes exit of rotor.

VI. RESULT ANALYSIS:

Air velocity reading for both the rotor is taken at four speeds and then it is used to find out the mass flow rate of air through rotor. For the mass flow rate calculation density of air is taken 1.2 kg/m3.

Calculation:-

Mass flow rate = ρa*A*V

Where, ρa = density of air. A = Outlet cross section area. V = Exit air velocity.

- Outlet cross section area of the single passage in the Rotor36 is 82.5 mm2 and total is 2970 mm2.
- Outlet cross section area of the single passage in the Rotor42 is 66.0 mm2 and total is 2772 mm2.

Experimental value of the Air velocity and calculated Mass flow rate value at different speed.

Table. 1: Experimental and calculated value

Speed		Air velocity (m/s)		Mass flow rate (g/s)	
RPM	Km/hr	Rotor36	Rotor42	Rotor36	Rotor42
600	60	3.5	3.3	12.474	10.977
500	50	2.3	2.1	8.197	6.985
400	40	1.5	1.3	5.346	4.324
300	30	1.1	1	3.92	3.326

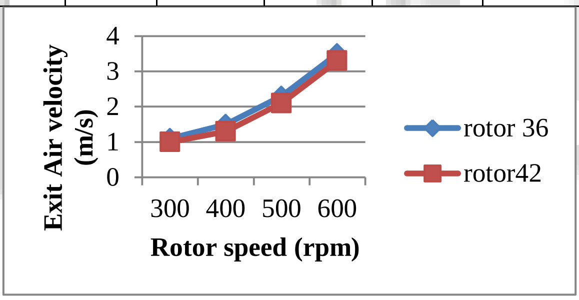

Fig.6 Exit air velocity at different rpm for both the rotor

It is clear from the graph that exit air velocity increases with increasing the rotor speed and exit air velocity of the Rotor36 is higher than the exit air velocity of the Rotor42. As exit velocity is higher mass flow rate through Rotor36 is also higher which helps in carrying the heat from the rotor.

VII. CONCLUSION

In experimental investigation of two different rotors, one is having the 36 number of vanes and other having 42 numbers of vanes with different design. Different design in 42 vane rotor is that, for reducing the obstruction to the air at the inlet, one long length vane and one 10 mm shorter vane combination is used.

It is found that, as the number of vanes increases exit air velocity and air mass flow rate through rotor decrease. But one advantage of increasing the number of vane is that it increases the surface area for the heat convection increase. This experiment was conducted in still air but in actual condition higher surface area will help in removing the more heat from rotor, so further experiment can be carried by casting a two disc from same material but having the different number of vanes in the experimental setup and temperature rise can be recorded and can be compared.

REFERENCE

[1] "Cooling Analysis of Disc Brake Rotors", Limpert, R., 1975, SAE Paper No.751014.
[2] "Thermal analysis of vented brake rotors", Sisson, A.E. (1978), SAE Paper 780352.
[3] "Analysis of automotive disc brake cooling characteristics", Voller, G.P., Tirovic, M., Gibbens, P. (2003) , D11902 © IMechE 2003
[4] "Structural and Thermal Analysis of Disc Brake in Automobiles" , Daniel Das.A, Christo Reegan Raj.V, Preethy.S, Ramya Bharani.G , IJLTET Vol. 2 Issue 3 May 2013. Preethy.S, Ramya Bharani.G , IJLTET Vol. 2 Issue 3 May 2013.
[5] "Analysis of heat conduction in a disk brake system", Faramarz Talati, Salman Jalalifar,
[6] "Thermal Performance Analysis and Geometrical Optimization of Automotive Brake Rotors", Zhongzhe Chi, July 2008.
[7] "Thermal analysis of a solid brake disc", Ali Belhocine, Mostefa Bouchetara, Applied Thermal Engineering 32 (2012) 59-67.
[8] "Analysis of the Flow Through a Vented Automotive Brake Rotor", David A. Johnson, Bryan A. Sperandei, Ross Gilbert, Journal of Fluids Engineering, November 2003, Vol. 125 / 979.

