



Development of Experimental Set up for Temperature Measurement on the Brake Disc of Pulsar 150 cc Motorcycle

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ABSTRACT

From the standpoint of safety, the braking system is an essential part of the motorcycle. The capacity of the brake disc composition to endure excessive frictional and durability to wear rate is the most crucial factor to take into account. Tolerating the maximum temperature that developed as a result of friction is also needed. Hence to increase the performance of brake disc we need to improve the thermal performance of brake disc. Thermal performance of brake disc is depending on the kind of material utilized for manufacturing of brake discs. As we know, brake disc assembly is rotating and moving from one place to another place in the actual application. Hence it is challenging task to do thermal analysis of brake disc experimentally. In this present study experimental setup is proposed for measuring the brake disc's surface temperature which can be useful to do the thermal analysis of the brake disc.

Keywords:- Brake disc, Thermal analysis, Experimental Set up, motor cycle.

1. INTRODUCTION

Vehicles are an important part of our day-to-day life. We all use the motorcycle for transportation from one place to another place. As we know, we need to change the speed of the vehicle while traveling by vehicle. Sometimes we need to slow down the speed or stop the vehicle to adjust to the road conditions and traffic. For this purpose, we use a brake system. Vehicle manufacturing companies are using two types of brakes namely drum brakes and disc brakes. Though the cost of disc brakes are more than drum brake, disc brakes are preferred over drum brake in automobile applications.

Disc brakes are having advantages over the drum brake as good efficiency, lightweight, good heat dissipation, good braking power, and an openness to the atmosphere that prevents them from retaining any undesired material, which prevents corrosion and performance decline. But still, there are some adverse effects when disk brakes are used for braking in automobile applications. To minimize the adverse effects we need to improve the performance of the brake disc. By lowering the highest temperature that develops on the brake disc's surface when activating the brake, efficiency may be enhanced. We can achieve the minimum temperature by replacing the brake disc made up of material which is having good thermal



properties than existing material. Cast Iron is generally used as material for the brake disc or rotor. We can increase the performance of brake discs by replacing good material which is having good thermal properties required for the application of brake discs [1]. Also, higher thermal conductivity is one of the important properties required by the brake disc [2]. The potential and kinetic energy of the vehicle is transformed into thermal energy by friction brakes [3]. While braking, the temperature has an impact on the coefficient of friction between the brake disc as well as the brake pads. [4]

Following adverse effects are observed during the braking application in the automobile sector.

- Macroscopic cracks [5]
- Thermal cracks [6] [22]
- Wear [7]
- Brake fade [8]
- Disc thickness variation [9]
- Permanent damage [10]

2. LITERATURE REVIEWED

Soojin Park et al. [11] have studied that by ensuring structural stability and confirming it with bench tests, the thermodynamic performance of a vented brake disc was enhanced. In order to retain structural performance while improving heat dissipation, disc forms were developed. A prototype was made to evaluate the viability of the optimization using a dynamometer, allowing comparison and verification between the original model and the improved model.

Rahim Jafari et al. [12] have studied the effectiveness of the vented brake disc's overall cooling system. In order to evaluate the temperature at various locations inside the brake disc, they conducted their experiment using a brake dynamometer that is available from FIAT. In terms of cooling the brake disc, the ventilation gap width was the most efficient variable. The gap from 8 mm to 14 mm was extended, which ultimately improved the heat transfer from the disc by increasing the quantity of airflow and the cooling surface.

Ioan Feier et al. [13] have provided a method to systematically forecast brake temperatures and friction performance by integrating dynamometer testing, numerical thermal models, and bicycle tests. For bicycle disc brakes, they have supplied information on the thermal behavior and brake friction performance.

Ms. A. J. Padwal et al. [14] found that the perimeter brake system is subject to far fewer strains and temperatures, in comparison to the traditional disc brake system. The results of the trial indicate that using a perimeter disc requires significantly less time and effort than using a standard braking system to stop the wheel.

R. S. Kajabe et al. [15] have provided Experimental setup to study the effect of different shapes of brake discs on the performance of the brake disc.

A.K.Matta et al., [16] have examined the experimental set-up that was specifically designed to investigate the impact of thermal loads on the brake rotor. The brake rotor's thermal loads and static strength are analyzed using the finite element method (FEM). The findings



demonstrate that the disc's deformation, which results in ineffective braking, is mostly caused by the disc's temperature.

P. K. Zaware et al., [17] have studied the temperature of disc can be measured using infrared sensor, which is non-contact type of sensor. ANSYS has been used as finite element software to perform thermal analysis of Gray cast iron disc brake rotor of Bajaj pulsar 150. The experimental setup to determine the temperature distribution in the rotor is provided. Experimental and software results are compared with each other to find the modified shape of rotor.

Borchate Sourabh Shivaji et al., [18] have proposed methodology and Layout of experiment set up to determine the 'Thermal Distribution' of the disk brake application.

D. Murali Mohan Rao et al., [19] have measured heat generated on the rotating disc with the help of an Infrared Thermometer. Fabricated Experimental Setup and ANSYS software is studied to do structural analysis and thermal analysis of brake disc of gray cast iron.

Karthik Ravi et al., [20] have studied and provided fabrication of experimental test rig for temperature measurement of brake. This rig is used to simulate working cycle of a vehicle & heat dissipated by the brake during this cycle.

2.1 Literature Gap Identified:-

From above Literature review it is found that different researcher suggested various experimental set up to determine the temperature distribution on the surface of the brake disc. But Details like procedure, specification and design of each component of experimental set up and whole assembly is found less in the Literature.

Hence the aim of this paper is to provide the details like design calculation, specifications about all the components of experimental set up required to determine the temperature distribution on the surface of the brake disc.

We cannot take measurements on the vehicle which is moving on the road. Hence for doing the thermal analysis, we should have a proper experimental setup that can be used as a real-time scenario instead of an actual vehicle. Fig 2.1 shows the brake disc of the motorcycle Bajaj 150 CC Pulsar. The present study is related to developing the experimental setup for the measurement of temperature on the brake disc.

3. PROPOSED EXPERIMENTAL SET UP:-

The brake disc has rotary as well as linear motion, so in this case, we are unable to monitor the temperature of the brake disc surface. Hence there is a need to arrange a rotating wheel but stationary set up to take the readings. The goal would be to measure the disc brake rotor's temperature as it rotates. The disc is mounted on a stationary frame with a motorized drive to rotate the disc at the required speed. A hydraulic brake arrangement with a caliper set on the disc brake rotor is provided.

The experimental setup for taking temperature measurements on the surfaces of different braking discs is schematically shown in Fig. 3.1.



Table 3.1 lists the different parts used in the experimental setup for determining the surface temperature of brake discs.

Sr.No.	Part Name
1	AC Induction Motors and Flywheel
2	Pulleys
3	Bearing
4	Shaft
5	Caliper and Hydraulic Brake Arrangement
6	Brake Discs (Original and Modified)
7	Base Frame
8	Non-Contact Type Infrared Thermometer
9	Contact Type Digital Tachometer

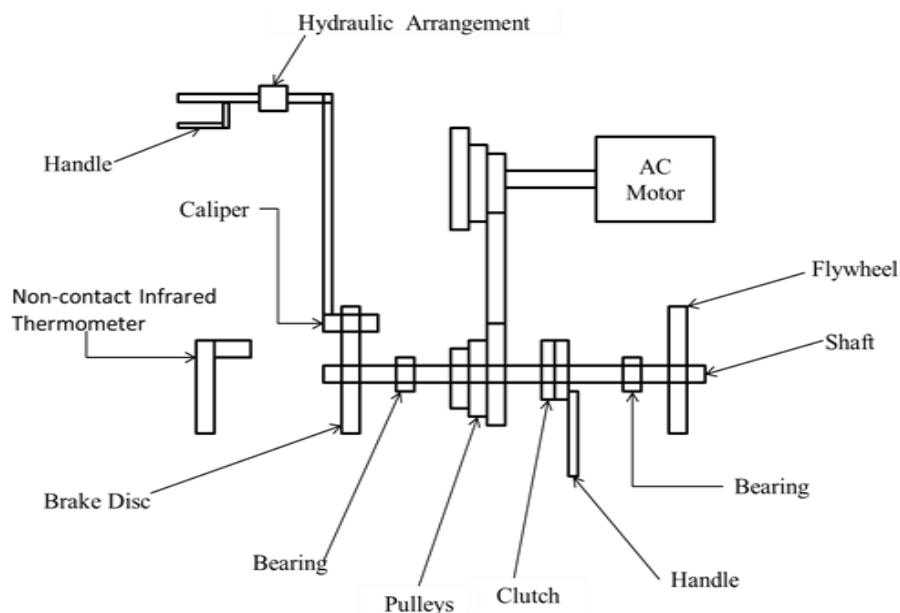


Fig 3.1: Schematic Layout of Experimental Set up

3.1 AC Induction Motor and Flywheel:-

The majority of industrial control systems and conventional household appliances for motion employ AC induction motors. The key benefits of AC induction motors include their straightforward and durable construction, relatively inexpensive, low maintenance



requirements, and connection directly to an AC power supply. There are several different kinds of AC induction motors. For various purposes, several motors are appropriate.

Motor Selection:

Weight= 130 kg

Disc brake diameter= 240 mm

So if above mentioned bike is moving at 60 Kmph (11.11m/s) its kinetic energy (K.E.) will be stated by

$$\begin{aligned} \text{K.E.} &= 1/2 mv^2 \\ &= 1/2 \times 130 \times 11.11^2 \\ &= 8023.08 \text{ kg-m}^2/\text{s}^2 \text{ (Joule)} \end{aligned}$$

Thus, the study of heat transfer in disc brakes can be done in two ways:

1. By generating 8023.08 joule of K.E by using flywheel and using interpolation and extrapolation.
2. By using wheel-disc assembly and then using interpolation and extrapolation to predict the temperature at required energy levels.

Kinetic energy of flywheel is given by (Neglecting mass of disc)

$$\text{K.E} = \frac{1}{2} \times I \times W^2 = 8023.08 \quad (\text{where } W=314\text{rad/sec motor output speed})$$

$$I = 8023.08 \times 2 / W^2$$

$$I = 8023.08 \times 2 / 314^2$$

$$\begin{aligned} \text{But } I &= \frac{1}{2} \times MR^2 = 8023.08 \times 2 / 314^2 = 0.16 \\ &= \frac{1}{2} \times MR^2 = 0.16 \end{aligned}$$

Mass of flywheel = 20kg, Radius = 0.12 m = 120 mm

In our experiment since we have to gain maximum 8023.08 joule K.E and then cut the power supply from motor. Also torque required is very less as we only need to overcome friction between shaft and bearings.

Calculation of frictional torque and frictional power lost:

Mass of system = 25 kg approx.

u = 0.2 (coefficient of friction)

Radius of shaft = 20 mm = r

$$\begin{aligned} \text{Frictional torque} &= F \times r \\ &= umg \times r \\ &= 0.2 \times 25 \times 10 \times 0.020 \end{aligned}$$

$$\text{Frictional torque} = 1.0 \text{ N-m approx.} \text{-----(1)}$$

$$\begin{aligned} \text{Frictional power lost} &= TW \\ &= 1 \times 314 \\ &= 314 \text{ watts} \text{-----(2)} \end{aligned}$$

Hence a motor with torque and power ratings as more than those given in eq. 1 and 2 can be used. We have to conduct the experiment at different speeds hence a variable speed motor with voltage/frequency drives will be suitable. The speed changes can be made using a pulley and belt arrangement also. Hence, the specifications of the motor selected are as follows.

3-phase induction motor AC

Power = 0.75 KW

Speed= 1440 rpm



The motor's specification that can be employed as the primary drive in the testing method for determining the surface temperature of the braking discs are shown in Table 3.1.1

Table 3.1.1 Specification of Motor

Sr. No.	Parameter	Values
1	Power	1 HP
2	Rpm	1440
3	Volts	415
4	Hertz	50
5	Phase	Three

3.2 Selection of Pulleys

Generally, braking is required in the range of the speed of the vehicle 40 to 90 Km per hour. At this time the speed of the shaft is in the range of 800 rpm to 2000 rpm. So for experimental setup shaft speed is maintained between 800 to 2000 rpm by means of a stepped pulley. The speed of the motor is 1440 rpm.

Calculations for different diameters of Pulleys is as follows:-

- 1) First Speed reduction
 $N_1 \times D_1 = N_5 \times D_5$
 $D_5 = N_1 \times D_1 / N_5$
 $D_2 = 1440 \times 0.03770 / 800$
 $D_2 = 0.0845\text{m}$
- 2) Second Speed reduction
 $N_2 \times D_2 = N_6 \times D_6$
 $D_6 = N_2 \times D_2 / N_6$
 $D_6 = 1440 \times 0.05450 / 1200$
 $D_6 = 0.06945\text{ m}$
- 3) Third Speed increment
 $N_3 \times D_3 = N_7 \times D_7$
 $D_7 = N_3 \times D_3 / N_7$
 $D_7 = 1440 \times 0.06950 / 1600$
 $D_7 = 0.0556\text{ m}$
- 4) Fourth Speed increment
 $N_4 \times D_4 = N_8 \times D_8$
 $D_8 = 1440 \times 0.08450 / 2000$
 $D_8 = 0.0380\text{ m}$

Table 3.2.1 shows diameters of pulleys used for getting different speeds of brake discs in experimental set up.



Table 3.2.1 Sizes of Pulleys

Sr No.	First Set	Second Set
1	D1=0.03770 m	D5=0.0845 m
2	D2=0.0545m	D6=0.06945 m
3	D3=0.06950 m	D7=0.0556 m
4	D4=0.08450 m	D8=0.0380 m

3.3 Bearing

Bearing is a mechanical element that supports two machine parts and permits relative motion between them with minimum friction. In the experimental setup, two bearings of 6204 designations were used. Ball bearings are frequently employed in numerous with low to moderate stresses. In situations where forces are greater, roller bearings are employed. Deep groove ball bearings are capable of the fastest speeds when the only loads present are radial ones. Deep groove ball bearings have the following advantages such as great for fast speed, have a decent radial load capacity, have a respectable axial load capacity in both directions produces little noise when operating, and require low maintenance. Hence deep groove ball bearing is used in the experimental setup. The diameter of the shaft is 20 mm, hence bearing with a bore diameter of 20 mm is selected for the arrangement for a test. Table 3.3.1 shows the specification of bearings used in the arrangement for a test.

Table 3.3.1 Specification of Bearing

Bearing Designation	Type of rolling contact bearing		Series of bearing		Bore diameter	
	No.	Type of bearing	No.	Series of bearing	No	Bore diameter in mm
6204	6	Single row deep groove ball bearing	2	Light	4	5xNo.=20

3.4 Shaft

The shaft is stepped with a maximum diameter in the middle portion i.e 25 mm and a minimum diameter at two ends i.e. 20 mm, where bearings are mounted. The length of the shaft is 320 mm and the step of the shaft provides shoulders for positioning transmission elements like pulleys and bearings. The material used for the shaft is 40C8. Fig. 3.4.1 shows a drawing of the shaft used in the experimental setup as follows.

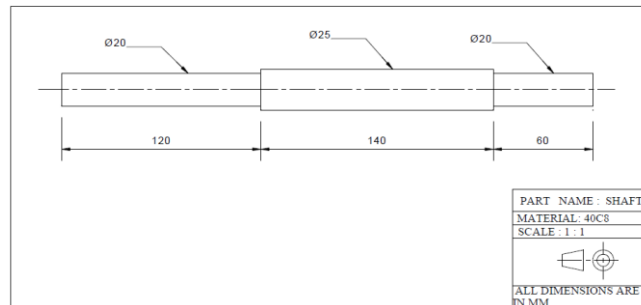


Fig. 3.4.1 Shaft Drawing

3.5 Caliper and Hydraulic Brake Arrangement

The two major components of a disc brake are the braking disc and the caliper-carrier assembly. A disc brake is created by mounting a brake disc to the wheel. The calliper is made of two pieces, one of which has a piston, and is connected to a permanent part of the vehicle. With the aid of L angles that are weld to the frame, the calliper is positioned on the disc. A tandem master cylinder, entirely separate hydraulic circuit, controls the braking system. Fig. 3.5.1 shows tandem master cylinder used to provide hydraulic pressure to the brake disc in the experimental set up [21].

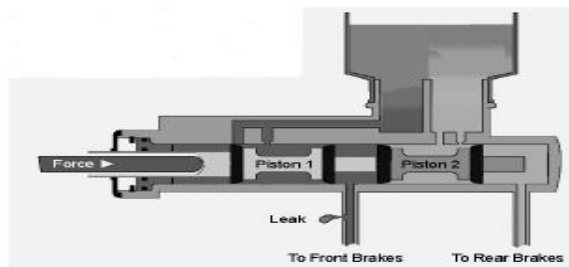


Fig. 3.5.1 Tandem Master Cylinder [21]

3.6 Non-Contact Type Infrared Thermometer

A direct connection to the thermocouple input terminal of the temperature controller is possible thanks to the non-contact type infrared temperature sensor's electromotive output, which is equivalent to that of a thermocouple. Food manufacturing, packaging, and the electronics sectors, among others, can measure temperature precisely thanks to the IR Series' outstanding linearity in any of the possible temperature ranges. A fast reaction time of 500 ms and repeatability of ± 1 or $\pm 1^\circ\text{C}$ provide high-accuracy temperature measurement. As the sensing does not decay over a period like thermocouples do, consistent and actual temperature management is possible.

Fig 3.6.1 shows a non-contact type infrared thermometer used to measure temperature over both the brake discs in the experimental testing.



Fig.3.6.1 Non-Contact Type Infrared Thermometer

Table 3.6.1 shows the specification of a non-contact type infrared thermometer employed in the experimental testing to monitor the surface temperatures of the brake disc.

Table 3.6.1 Specification of Non Contact Type Infrared Thermometer

Sr.No.	Parameters	Values
1	Temperature Range	-50 °C to 600 °C (-58 °F to 1112 °F)
2	Accuracy	± 1.5 % of measured value or 1.5 °C whichever greater
3	Sensing Distance	1500 mm
4	Distance Spot Ratio	12: 1
5	Response time	500 ms

3.7 Contact Type Digital Tachometer

The speed of motor shaft and disc shaft are measured with the help of contact type digital tachometer. The range of tachometer is 60 to 20000 rpm which is sufficient for our testing. Range = 60 to 20000 rpm. The fig. 3.7.1 shows photo of contact type digital tachometer used for speed measurement of brake discs in experimental testing.



Fig 3.7.1: Digital Tachometer

4. EXPERIMENTAL TESTING

It is impossible to keep track of the disc temperature installed on the bike. Thus, it is necessary to create a setup that represents a bike in its genuine condition.

The constructed experimental setup consists of an electric motor with a multiple pulley fastened to the main shaft and another pulley with the identical size attached on the output shaft. Power is transferred through a belt from the driving pulley to the driven pulley. The brake disc is connected to the motor through the clutch. The brake calliper and disc are attached to the frame. According to the need, the disc is stopped by applying the brake. During braking, heat produced in the disc is dispersed via conduction and also convection mode of heat transfer and the radiative heat flow is not particularly considerable.

We can use the following steps to take measure the brake disc's surface temperature

- i. Install the brake disc on the setup, then test the arrangement to ensure good operation.
- ii. In order to accelerate the pulleys attached to the motor shaft, start the prime mover.
- iii. In order to transfer power from the main shaft to the output shaft the clutch should engage.
- iv. Use a tachometer to determine the speed of the braking disc.
- v. After that, release the clutch and use the brakes instantly and simultaneously using a sensor, taking a temperature reading produced on a specific area of the brake disc.

We should Allow the disc to recover its usual temperature before taking another one. The same process can be carried out at various speeds and brake discs made by different materials so that we can analyze the performance experimentally. The schematic layout of experimental set up is shown in the figure 3.1.

5. CONCLUSION:-

- i. The experiment can be carried out to study the thermal Analysis of brake discs by using the proposed experimental setup.
- ii. We should study the material properties required by the brake disc application.
- iii. Depending upon the properties required, we can propose good material for brake disc application and can manufacture the brake disc of that suitable material.
- iv. We can do thermal analysis by using suitable software like ANSYS.
- v. We can perform experimental testing by using the proposed setup in this paper fig 3.1 to determine the thermal performances of different brake discs.



- vi. We can compare the results obtained by analysis software and experimental results for validation.
- vii. Based on the thermal performance, we can find a suitable material for the brake disc application.
- viii. By increasing thermal performance, we can minimize the adverse effects produced during braking applications.

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