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Design and Development of a Disc Brake Test Rig for Experimental Investigation of a Disc Brake Temperature under Repeated Braking Cycles.

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ABSTRACT: *The brakes are one of the most important aspects of a vehicle, since it fulfills all the stopping functions and requirements. Disc brake thermal analysis is techniques to find out new disc design. The findings of this research provide a useful design tool to improve the brake performance of disc brake system. In this paper provides modelling of rotor discs using CATIA software followed by finite elements analysis of rotor discussing ANSYS to determine whole field temperature distribution, thermal gradients, stress distribution and whole field deformation.*

This paper present design and development of a physical device for determination of temperature distribution on the disc surface during repetitive braking operation.finding an experimental set-up requirement, design/development and testing details related to estimated field results based on experimental results in laboratory.

(Keywords : Disc brake,Temperature distribution,Test rig,Selection of Component,)

1. INTRODUCTION TO DISC BRAKES

A **disc brake** is a type of brake that uses calipers to squeeze pairs of pads against a disc in order to create friction that retards the rotation of a shaft, such as a vehicle axle either to reduce its rotational speed or to hold it stationary. The energy of motion is converted into waste heat which must be dispersed.

Compared to drum brakes, disc brakes offer better stopping performance because the disc is more readily cooled. As a consequence discs are less prone to the brake fade caused when brake components overheat. Disc brakes also recover more quickly from immersion (wet brakes are less effective than dry ones).

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Close-up of a disc brake on a car | On automobiles, disc brakes are often located within the wheel. | A drilled motorcycle brake disc

Fig. 1.1 Disk Brakes

2 CHARACTERISTICS OF DISC BRAKE

The following information forbids the usually expected characteristics of a well-designed disc brake.

1) Peak force – The peak force is the maximum decelerating effect that can be obtained. The peak force is often greater than the traction limit of the tires, in which case the brake can cause a wheel skid.
2) Continuous power dissipation – Brakes typically get hot in use, and fail when the temperature gets too high. The greatest amount of power (energy per unit time) that can be dissipated through the brake without failure is the continuous power dissipation. Continuous power dissipation often depends on e.g., the temperature and speed of ambient cooling air.
3) Fade – As a brake heats, it may become less effective, called brake fade. Some designs are inherently prone to fade, while other designs are relatively immune. Cooling has intense big effect on fade.
4) Smoothness – A brake that is grabby, pulses, has chatter, or otherwise exerts varying brake force may lead to skids. For example, railroad wheels have little traction, and friction brakes without an anti-skid mechanism often lead to skids, which increases maintenance costs and leads to a "thump " feeling for riders inside.
5) Power – Brakes are often described as "powerful" when a small human application force leads to a braking force that is higher than typical for other brakes in the same class.
6) The meaning of the term "powerful" does not relate to continuous power dissipation, and may be confusing in that a brake may be "powerful" and brake strongly with a gentle brake application, yet have lower (worse) peak force than a less "powerful" brake.
7) Pedal feel – Brake pedal feel encompasses subjective perception of brake power output as a function of pedal travel. Pedal travel is influenced by the fluid displacement of the brake and other factors.
8) Drag – Brakes have varied amount of drag in the off-brake condition depending on design of the system to accommodate total system compliance and deformation that exists under braking with ability to retract friction material from the rubbing surface in the off-brake condition.
9) Durability – Friction brakes have wear surfaces that must be renewed periodically. Wear surfaces include the brake shoes or pads, and also the brake disc or drum. There may be tradeoffs, for example a wear surface that generates high peak force may also wear quickly.
10) Weight – Brakes are often "added weight" in that they serve no other function. Further, brakes are often mounted on wheels, and unsprung weight can significantly hurt traction in some circumstances. "Weight" may mean the brake itself, or may include additional support structure.
11) Noise – Brakes usually create some minor noise when applied, but often create squeal or grinding noises that are quite loud

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3 OBJECTIVES OF THE PROPOSED WORK

1) To design and develop of brake disc test rig for analysing the conditions of disc brake rotor experimentally in laboratory environment.
2) To analyse given set of disc brake rotors for load, stress and thermal effect using ANSYS and select the best one on the basis of ANSYS results.
3) To design and develop new disc brake rotor and analyse the same for load, stress and thermal condition.
4) To compare the performance of transient thermal analysis of selected disc rotor and new disc brake rotor.
5) To investigate performance of new designed brake disc experimentally on developed brake disc test rig under frequent braking and un-braking conditions.
6) To compare the performance of experimental results in relation to ANSYS analysis to show physical agreement of the approach.

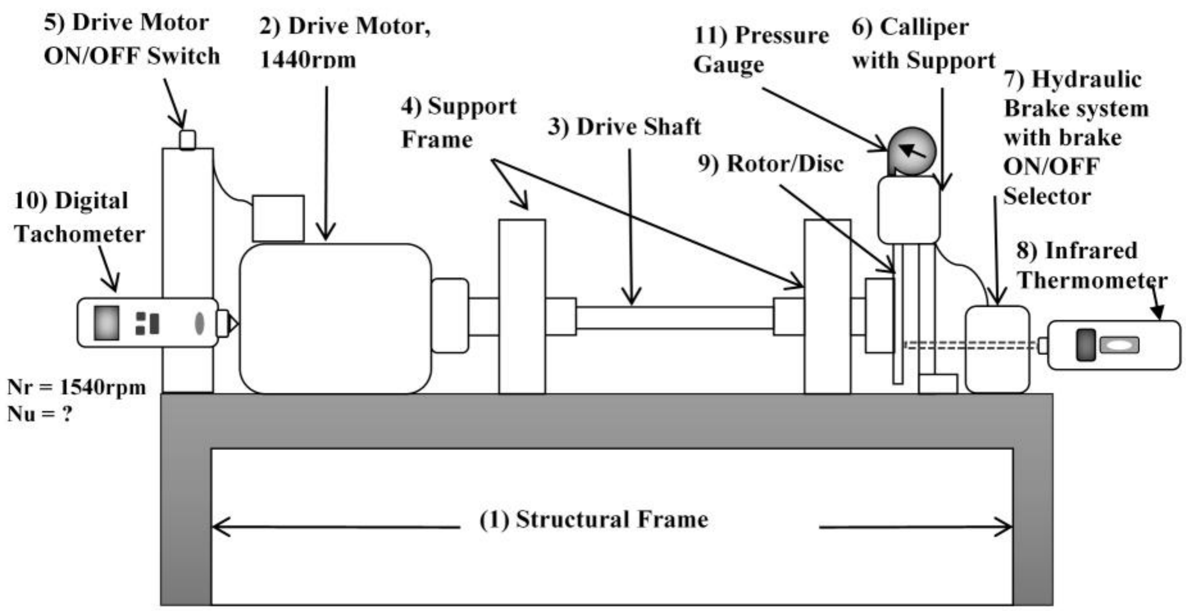
3.1 Test Rig Design-

Friction characterization test systems have a dual-purpose function, in which they can be used for quality inspection or for material development. Experiment setup is expected to develop physical working condition in laboratory. Figure 4.1 shows a schematic diagram of such a laboratory disc brake test system.

The test set up is designed for physical measurement in disc breaking pad surface temperature during repeated braking operation i.e. 2 sec braking followed by 2 sec release (data provided by the project sponsoring company).

The design includes power calculations, selecting of electric drive set up ,disc brake working system including the required temperature and force applied measurement system in dynamic conditions.

Fig.3.1 Schematic of disc brake test rig



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1. Structural frame	2. Drive motor	3. Drive shaft	4. Support bearing with stands	5. Drive motor On/Off switch
6. Caliper assembly with support structure	7. Hydraulic brake operating system	8. Infrared thermometer	9. Disc/Rotor for testing	10. Tachometer (Digital)

4. BASIC STEPS IN DESIGN OF CONFIGURATION

It is proposed to design, develop and test a brake disc testing system on a laboratory scale, where braking force and the braking/unbraking time setting can be adjusted. This configuration will represent braking operation in the field.

The followings are the parameters used for such a design process.

m= 189 kg (mass supported by the front wheel: 70% of the full mass)

rt= 0.320 m

m_1 = 0.95541 kg

A= 2000 x 10^{-6} m^2

rd= 0.120m

C_p= 586 J/kg.K

t = 2 Sec+ 2 sec

4.1 Basic calculations

The system based on repeated braking / un breaking cycle can be designed using the basic steps as follows for a two wheeler (Bajaj Pulsar 150cc) .

Step 1. Kinetic energy needed to develop braking operation to reduce the vehicle velocity $v_f$tou$_f$ is given as

K.E.=0.5 m (v_f^2-u_f^2)

The front wheel plays important role and is supported to carry 70% braking load 30% load will be supported by the real wheel.

K.E = 0.7 x 0.5 m (v_f^2-u_f^2)

Step 2. The kinetic energy described above is absorbed at the interfacing surface of the disc and the brake pads and converted in to heat i.e.

K.E.= 0.35 m (v_f^2-u_f^2) = m_1 $c_p\Delta t$

Step 3. The heat balance is as follows..

0.35 m (v_f^2-u_f^2) = 2 (μ x F)rb (2 π(Nv_f -Nu_f)

Step 4.the field condition and laboratory conditions are compared as follows…

i.e.

$$K = \frac{0.3\ \ m\,(v_f{}^2 - u_f{}^2)}{P\ \ \ n\ \ \ i\ \ l} = \frac{(\ \ m_1\,C_p\Delta t)f}{(\ \ m_1 C_p\Delta t)l} = \frac{2\,(\mu\ \ F)\,r\ \ \ 2\pi(N\ \ -N\ \ )f}{2\,(\mu\ \ F)\,r\ \ \ 2\pi(N\ \ -N\ \ )l}$$

where K is the ratio for conditions in field and in laboratory.

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In both the cases the common parameters are μ, rb, m_1 and C_p .

$$K = \frac{0.3\ \ m\,(v_f^2 - u_f^2)}{P\ \ \ n\ \ \ \ i\ l} = \frac{(\Delta t)f}{(\Delta t)l} = \frac{(N\ \ -N\ \ )f}{(N\ \ -N\ \ )l}$$

The initial and final velocities of the two wheeler are $v_f = 80\frac{k}{h}(22.22\ m/s)$and $u_f = 40\frac{k}{h}(11.11\ m/s)$ respectively.

The Table4.1 shows the calculated values in Step 1 to Step 4 and confirmation of K

		K
$0.35\ m\,(v_f^2 - u_f^2)$	Watts	$K=\frac{1\ \ \ \ .5}{1} = 10.94$
Power needed in lab	Lab reading 1.5hp (1118 Watts)	
$(\Delta t)f$	43.77 ^{0}C	$K=\frac{4\ \ .7}{4} = 10.94$
$(\Delta t)l$	4.00 ^{0}C	
$(Nv\ - Nu)f$	5.05 rps	$K=\frac{5.0}{0.4} = 10.94$
$(Nv\ - Nu)l$	0.46 rps	
F_f	4020.75 N	$K=\frac{4\ \ \ .7}{3\ \ .5} = 10.94$
F_l	367.52 N	
Estimation of temperatureT_{maxf} in field….		
T_{maxf}	71.77 ^{0} C(Estimation in the Field)	$T_{maxf} = (K_{Tmax})\,(T_{maxl})$ Where $K_{Tmax}=\frac{7\ \ .7}{3} = 2.24$
T_{maxl}	32 ^{0} C (measurement in laboratory)	

Table 4.1 Field and laboratory parameter relationship constant K and Estimation of temperature T_{maxf} in field.

5 EXPERIMENTAL INVESTIGATION

5.1 Introduction

The developed experimental test set-up is prepared for physical experimentation for collection of experimental data. The test procedure followed is as follows.

5.2 Test Procedure

The following steps are followed to perform the designed experiments,

1) Brake test setup is well checked for its proper operation and initial adjustments are made like as brake disc fitting, speed of motor, braking time arrangement, etc.

2) The selected brake disc in Chapter 3 is tested for the temperature rise with a braking cycle i.e. 2 sec braking / 2 sec unbraking cycle for different periods and observed temperatures measured are recorded.

3) Operation is performed for entire hour at selected steps and temperature measurement is taken after every 10 minutes for one hour and the measurements are properly recorded. Temperature of the disc is measured by infrared sensor, which is non-contact type of sensor.

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5.3 Test Results and Discussion

Table 5.1 represents the recorded information regarding the disc temperatures measured using infrared digital temperature indicator.

The Tabulated results are used for estimating the field temperatures.

Table 5.1 Test Results

Time (seconds)	Lab Testing			Estimated results in field condition		
	Min Temp in ºC	Max Temp in ºC	$(\Delta T)_l$ ^{0}C	$(\Delta T)_f$ = (2.24) $(\Delta T)_l$ ^{0} C	Min Temp in ºC	Max Temp in ºC
0 To 600	23.15	23.90	0.75	1.68	23.15	24.83
600 To 1200	23.90	31.10	7.2	16.12	24.83	40.95
1200 To 1800	31.10	36.95	5.85	13.10	40.95	54.054
1800 To 2400	36.95	45.10	8.15	18.256	54.054	72.31
2400 To 3000	45.10	52.15	7.05	15.792	72.31	88.102
3000 To 3600	52.15	58.13	5.98	13.39	88.102	101.49

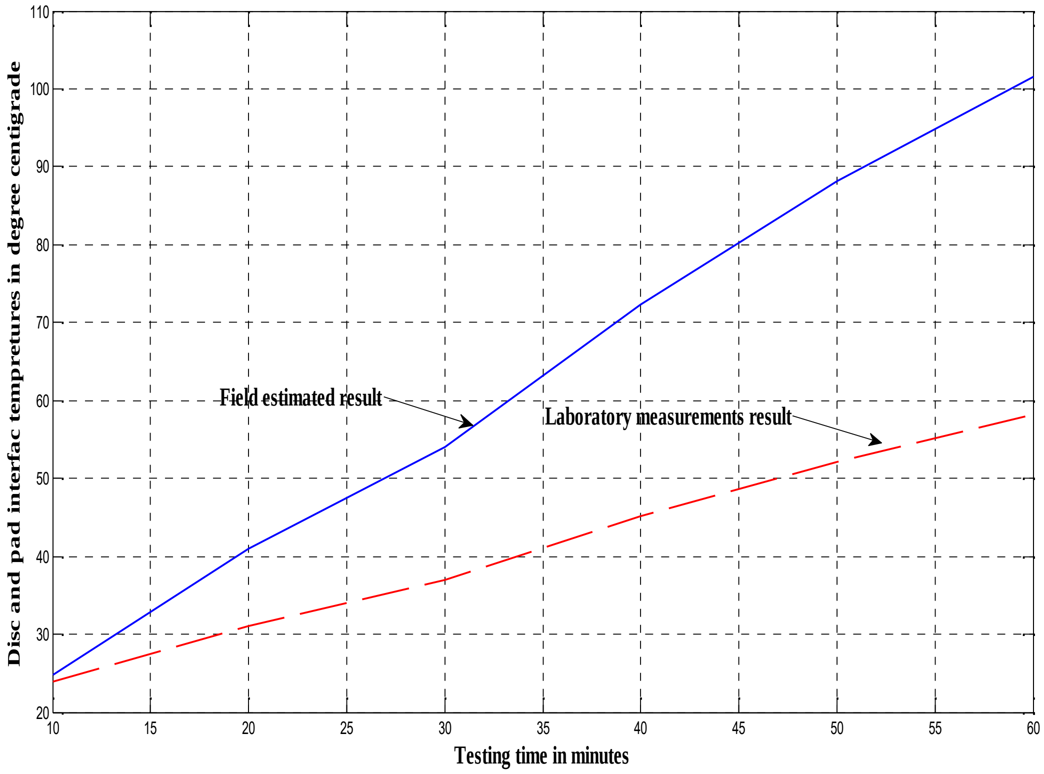

Figure 5.1 shows the results obtained using the developed test rig and estimated field readings for better

understanding of the process.

Chapter 6 provides discussions on conclusion and future scope.

6.CONCLUSION AND FUTURE SCOPE

6.1 Introduction

The experimental investigation, when observed carefully the following conclusions are developed.

1) In this process it is assumed that the coefficient of friction μ in both the states is constant, however it may vary due to the variations in the disc temperature and affect the result.
2) The heat developed during testing in laboratory and at the field is dissipated to surroundings due to air flow velocity this fact is not considered, hence it may affect the results.
3) For structural analysis, result of both computational and experimental analysis of the brake discussed for testing evidences the safer design.
4) Compared to the ANSYS simulation, experimental investigation in laboratory used for estimated results in field are in fair agreement.

6.2 Future Scope

1) The same test rig can be used for testing the brake systems of light four wheeler with few modifications.
2) The real time data can be collected by in laboratory using data acquisition systems and can be used for display, recording and animations.
3) The current investigation may be done by varying operating speed of the vehicle.

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