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Thermal Analysis In Disc Brake System And Crack Length Reduction For Motor Cycles

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ABSTRACT

Disc brakes mainly concern for improving the braking efficiency of the commercial vehicles is focused widely a new alternative have been developed to overcome the heat generation, service life, wear and tear. Moreover, to improve the structural, thermal and stability of the disc brake rotor working condition and the air flow through the modify weight reduction holes of brake disc rotor. The 3D geometrical model was generated by using Pro-E and thermal analysis has been carried out using ANSYS to determine its temperature distribution and heat flux generated around the holes of existing and modified disc brake systems.

INTRODUCTION

The reliable use of a road vehicle such as motor cycles necessitates the continual adjustment of its speed and distance in response to change in traffic conditions. This requirement is met by the braking system in whichthe design is an important aspect in a motor cycle which is suitable for a given application. This is achieved through the design of a system that makes use of the finite amount of traction available between the tire and the road over the range of operating conditions that are likely to bear by the vehicle during normal operation.

To evaluate the temperature distribution around the small hole of the brake disc before crack initiations. In the test of small groove machined on the disc to put the thermocouples into a neutral position in the thickness. The temperatures at 4 points of the disc were measured at 125, 130, 135 and 140mm of radial position.The crack initiation cycles of the braking under over loading condition was changed by residual stress relaxation that depended on the configuration design of weight reduction hole of disc. The crack initiation life of the brake disc was extended by slight relaxation of the compressive thermal stress. The study configuration of weight reduction hole plays decisive role in determining the design of brake disc, considered the crack initiation from the small hole in the disc rotor system.

The subject of legislation is reviewed and its importance as a tool to aid the designer of a brake system is highlighted. Both the kinematic and kinetic analyses plays major role in the braking problem to the analysis of brake proportioning, adhesion utilization and other related issues. A case study is built into this section of the chapter that illustrates the application of the theory and so reinforces understanding. The selection of appropriate materials in which to manufacture and the friction pair is reviewed and problems linked to thermo-mechanical behavior highlighted.

The initiation of small cracks which formed around small holes in the flange of one-piece disc during the amount of overloading. The thermally induced cyclic stress strongly affects the crack initiation in the brake

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discs. It showsthe temperature distribution at the flange to be measured. (Simulation of temperature distribution in Brake discs, KhongkengLeng)

The temperature distribution was analyzed by finite element method and 3D unsteady heat transfer analyses were conducted using ANSYS. The disc rotates 6 times during one braking, which means it gets heated up and cooled down 6 times in one braking (Nakatsuji, T., 2002)

During braking, the disc surface which is subjected to strains sum of two components. One is mechanical strain is caused brake torque and pad friction. The second one is the thermal strains produced by unavoidable temperature gradients present on the disc. The braking, at each disc rotation areas around holes are subjected to alternative cyclic stresses. The stress intensification factor on the hole is about 3 times the nominal stress in flange.

According to results, the deterioration on thermal cyclic strain superimposed to the mechanical strain caused by breaking torque. The work analysis by foresaid disc brakes investigating both the main causes and the evolution of its deterioration in order to find out possible solutions. Material decay is liable for starting cracks. The choice of a particular chemical composition will be demonstrated to be unfit for the purpose, produced an extremetempering of the steel as a direct result of its protracted exposure to high temperature (MengDejian, 2010)

Methodology:

- The modeling of the disc brake withinclined holes using Pro-E.
- Analyzing the parameters of disc brake model using transient thermal analysis and crack analysis using ANSYS.
- Tabulated the measured brake disc rotor temperature using infrared thermometer.
- Comparing the parametric analysis results with theoretical results.
- Comparing the heat flux values that are developed in the modified disc brake.

I. Finite Element Modelling:

The model is completed in the designing software hence the proceeding step is to analyze the model. The first step in the finite element analysis is meshing; meshing is the process of discretizing the structure into the finite elements for the accurate solution.

Modeling of the existing and inclined holes of disc brake system is designed using PRO-E and the following figures have been shown below.

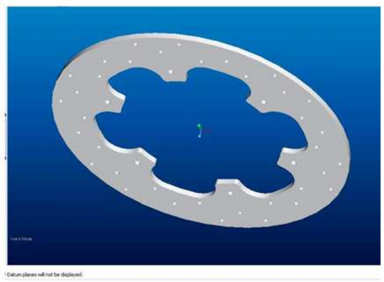

Fig. 1: Three Dimensional view of Brake Disc Rotor.

A. Elements considered for Thermal Analysis:

For carrying out thermal analysis we have chosen PLANE55 as element type, which can be used plane element or axis symmetric ring element with a 2D.Thermal conduction capability. The element has 9387 nodes with a single degree of freedom, temperature at each node. The element which is applied to a 2D steady state or transient thermal analysis and temperature element is analyzed structurally by equivalent structural element during structural analysis.

B. Geometry Boundary Conditions:

The temperature 22 degree is fixed at the disc bore grinds as the boundary condition for both existing holes of brake disc and inclined hole of brake disc motorcycles.

C. Thermal Boundary Conditions:

The heat flux is applied axis symmetrically on the rotor surface and is analyzed for 3.5 second of brake time and generate heat is going to be distributed along the surface of the existing hole of brake disc and inclined hole of brake disc motorcycles at 3.5 second to be thermal analyzed with respect to the time.

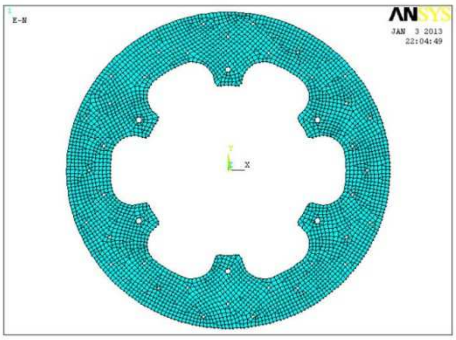

Fig. 2: Brake Disc Rotor (Meshed).

The geometric details of existing and modified brake disc system are tabulated as shown below.

Table I: Geometric Details of existing brake disc.

Object Name	Solid
State	Meshed
Definition	
Coordinate System	Default Coordinate System
Stiffness Behavior	Flexible
Reference Temperature	By Body
Reference Temperature Value	22. °C
Properties	
Volume	1.6175e-004 m^3
Mass	1.2697 kg
Centric X	-1.3646e-007 m
Centric Y	2.5e-003 m
Centric Z	1.0072e-007 m
Statistics	
Nodes	6489
Elements	776

Table II: Geometry Parts Of Inclined Holes of Brake Disc.

Object Name	Part 1
State	Meshed
Definition	
Suppressed	No
Stiffness Behavior	Flexible
Coordinate System	Default Coordinate System
Reference Temperature	By Environment
Properties	
Volume	1.6116e-004 m3
Mass	1.2651 kg
Centric X	-1.1603e-006 m
Centric Y	2.5002e-003 m
Centric Z	1.0207e-006 m
Assignment	Structural Steel
Statistics	
Nodes	9387
Elements	4257

II. Disc Brake Calculations:

A. Brake Torque Calculation:

Vehicle weight (w) = 134 kg
Initial velocity (u) = 16.67 m/s
Final velocity (v) = 0 m/s
Kinetic energy of the vehicle = ½ mv^2
= ½ *134*$(16.672)^2$

Kinetic energy of the vehicle= 18618.5 J:

Target deceleration (a) = $5 m/s^2$
Braking time (t) = (v-u)/ a
= (16.67-0)/5

Braking time (t)= 3.33 sec:
Wheel radius(r) = 0.335m
Angular initial velocity = u/r
= 16.67/0.335

Angular initial velocity= 49.75 radian/sec:
Angle through which the wheel rotates during braking = 82.83º
Braking torque (Tb) = **KE/Ø**
=18618.5/82.83

Table III Design component.

Design component	Data	Units
Co-efficient friction between the brake pad and disc plate	0.35	NIL
No. of braking faces	2	
Area of caliper piston	8.0464	m^2
Brake pad area	1825.25	mm^2
Brake disc diameter	260	mm
Braking torque at disc mean radius	408.63	Nm
Braking force at disc mean radius	4101.88	N

Required braking torque at
front wheel = 224.78 Nm

B. Braking Force Calculation:
Acceleration (a) = 0.5 m/s^2
Maximum mass of the vehicle = 264 kg
with rider and pillion
Braking force = m*a*g
= 264*0.5*9.81

Braking force = 1295 N:
Co-efficient of friction between
road and tire = 0.7
Wheel lock force (F_a) = B_f * g * μ * r
= 1295*9.81*0.7*0.335
Wheel lock force (F_a) = 2979.07 N
Brake torque (Tb) = B_f*Radius of the tire
= 1295*0.319
Brake torque (T_b) = 413.10 Nm

C. Determination of the Braking Force:
Factor of Safety:
Factor of safety = available brake torque / Required brake torque
= 408.63/224.78

Factor of safety = 1.8:
D. Brake Crack Length Calculation:
The crack length was measured by,
$K_{IC} = \sigma \sqrt{\pi a}$
Where, K_{IC}= Stress intensity factor,
σ = Applied stress,
a = crack length.
Determining da/dN to get crack growth,
Where,
da = change in crack length,
dN = change in number of cycle

RESULTS AND DISCUSSION

The calculated experimental values between the existing and inclined holes of disc rotor have been discussed and the corresponding values have been shown in tabular format and graphs are shown below in detail.

The maximum values of heat flux in existing holes of disc brake was found to be 13462 W/m^2 in 3.5 second and maximum values of heat flux in inclined holes of disc brake was found to be 32410 W/m^2 in 3.5 second.

The analysis result shows that obtained with inclined holes of brake discharging more heat flux thanthe existing holes of brake discbecause of air cooling performance.

The fig.3 for inclined hole of brake disc was crack length graduallyreduced with N no of cycle.

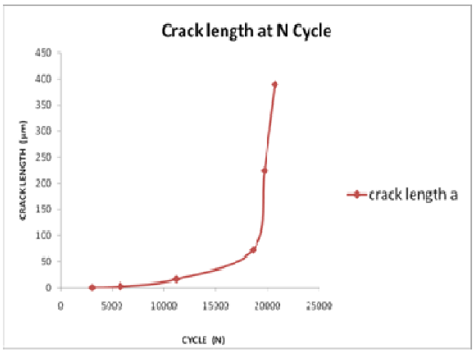

Fig. 3: Direction of crack length vs. cycle.

Table IV: Heat Flux and Time for Straight Hole.

Time [sec]	Heat flux Minimum [W/m^2]	Heat flux Maximum [W/m^2]
0.12243	-664.97	702.92
0.55304	-3579.6	3582.9
0.95304	-5267.6	5263.7
1	-5442.4	5438.9
1.54	-6989.1	6963.4
1.94	8220.9	8195.1
2	-8395.9	8370.
2.54	-9946.8	9920.2
2.94	-11090	11063
3	-11262	11234
3.5	-13522	13462

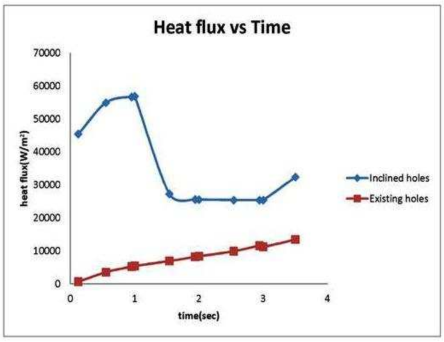

Fig. 4: Heat flux Vs Time.

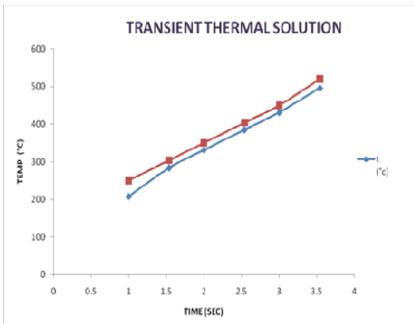

Fig. 5: Transient Thermal Analysis.

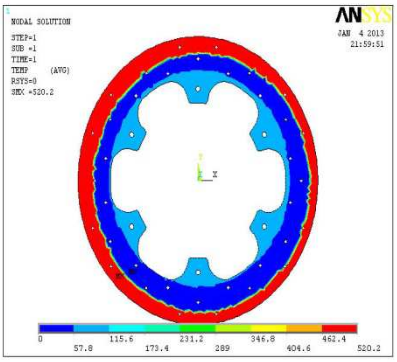

Fig. 6: Transient Thermal Analysis for 3.5 sec.

Table V: Crack Length and Cycle Values for Inclined Holes of Brake Disc for 3.5 Sec.

Cycle 'N'	Applied Stress (MPa)	Crack length ('a') (μm)
0	157	0.00249
3033	158	0.0099
5786	165	2.249
11191	196	15.98
18623	266	72.19
19735	212	224.79
20735	143	389.6

Where 'K' – Thermal conductivity in W/mk

Table VI: Transient Thermal Solution for Inclined Holes of Brake Disc.

Time (Sec)	Heat fluxMinimum (w/m^2)	Heat fluxMaximum (w/m^2)
0.1998	-54015	45459
0.5998	-79920	54972
1	-82939	56891
1.54	-39978	27263
2	-37280	25553
2.54	-37042	25407
3	-37040	25399
3.5	-47441	32410

Table VII: Comparison Results of Existing Hole And Inclined Hole of Brake Disc Rotor.

Time [sec]	Temperature minimum [°C]	Temperature maximum [°C]
0.1998	39.641	69.955
0.5998	118.91	159.95
0.8998	185.28	227.45
1.	207.7	250
1.54	283.91	304
1.94	324.98	344.
2.	331.03	350.
2.54	385.12	404.
2.94	425.13	444.
3.	431.13	450.
3.5	495.96	520.2

Conclusions:

1. The modified design parameter for disc brake system shows good results comparatively with analytical solutions.
2. The maximum and minimum heat flux values obtained by thermal analysis indicate that the less amount of heat is generated in the modified disc brake system.
3. The range of crack length values was obtained as 0.00249 μm and 389.6μm. The results of crack value is differs proportionally to the number of cycles.
4. The thermal and crack analysis in the inclined holes of brake disc shows thatmore heat flux and decreasing crack length compared to the existing brakedisc. It is the best possible solution for this modified design.

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