Evaluation of Tribological And Thermal Behavior of Cast Iron With Titanium Brake Disc Rotor Used In Automobiledisc Brake

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Abstract- *The braking system is a vital safety component of ground based transportation systems, and the structural materials used in brakes have to fulfill a combination of functions. They must be dependable, durable, corrosion resistant, structurally sound, and economically viable. The aim of this research is to find out the best combination of parameters for braking material at the point of view friction and wear. In this work a pin on disc tribometer is used to carry wear test. In this work three discs are prepared, one is gray cast iron and another two are its composite with varying percentage of titanium (0.5% and 1%) used as a brake disc rotor material with the existing brake pad (bagasse as a pin) material. The optimization of different parameters is done by using Taguchi Approach. In this experiment L9 orthogonal array is used with three controllable factors like Load, Speed and material with varying percentage of filler with three levels of each to find out optimum level of parameters for minimization of wear. The ANOVA results used to find out significant factor and percentage contribution of individual factor. In this thermal analysis are carried out using ansys workbench then results are found that there isnot much variation in temperature and total heat flux are increases by using titanium*

Keywords- Disc Brake, Brake Pad, Cast Iron, Heat Flux, Thermal Conductivity

I. INTRODUCTION

One of the most important active safety features of the car is a disc brake set is located on the front axle. The rotor brake disc is the main component of the disc brake system. For safe driving, the braking system must be good enough to provide a safe and repeatable stop. Brake pads that are made up of friction materials are hydraulically pressed against the rotor disk on both sides with the device clamp. When the friction pads are pressed against the disc, the kinetic energy of the vehicle is converted to heat and the vehicle slows down. The generated heat is dissipated into the environment. Braking systems work on the principle of converting the kinetic energy of the vehicle to heat through the friction between the pads and the rotor. Therefore, the effectiveness of the braking system depends on the amount of friction between the pads and the rotor and how the generated heat is dissipated in the environment failure which can lead to the failure of the braking system due to the overheating and thermal stresses developed by it. The entire braking system includes components such as clamps, piston and cylinder, pads and rotor.

Brakes are an energy conversion mechanism that converts vehicle movement into heat by blocking wheel rotation. All braking systems are designed to slow down and stop a moving vehicle as desired by the remote driver in case of an emergency. This is causing friction in the wheels. There are two basic types of friction that explain how braking systems work: kinetics, or motion, and static or fixed. The amount of friction produced is proportional to the applied pressure between two objects, the type of contact material and the smoothness of the friction surfaces. Friction converts kinetic energy into heat. The higher the pressure applied to the objects, the more friction and heat being produced, and the first vehicle stops

Kinetic friction acts on brakes and static friction between the tire and the road to slow down the vehicle. When the brakes are applied, the weights of the vehicle is transferred to the front wheels and the exhaust rear wheels plus exposed air surfaces and then dissipate the heat more efficiently. They are also resistant to water fading due to rotor rotation tends to get rid of moisture.

II. LITERATURE SURVEY

Ting-Long Ho et al. (1974), the effect of friction heat on the material brake (airplane) has been studied. The result has shown that the most significant factors affecting surface temperature. When there are restrictions on size and weight, specific heat and maintaining the contact area, a criterion is suggested to determine the number and thickness of the brake disks within the limited space available on a wheel. Friction changes at high temperatures could be due to three different softening phenomena of the material, formation of oxides and surface fusion. The metallographic study approach has been used here. It was found that the minimum surface temperature is obtained in a material with a minimum value (1 / ρc) and (1 / kρc), when there is a maximum contact area and use the lower load friction of the system.

Masahiro Kubota et al. (2000) studied the development of a light braking rotor is a design approach to achieve optimal thermal balance, vibration and weight. This work demonstrated a parametric study based on an analysis of air flow through the ventilation holes, and a thermal stress analysis and vibration analysis during braking. Based on the ratio between rotor weight, shape and performance requirements, a method is presented for the design of a rotor light. Computational Fluid Dynamics (CFD) analysis method has been used to visualize the actual process. A wrap arrangement used short form and shaped pumpkin and the results verified the anti-chirp performance and substantial weight reduction with respect to the shape of the rotor base without causing improved cooling performance and heat resistance deterioration. [2]

Choi and Lee (2004) studied the analysis of finite elements of transient brake disc braking behavior. A transient analysis of the problem of thermo elastic disc brakes contact with abrasion temperature group is made using the finite element method. To analyze the thermo elastic phenomenon occurring in disk brakes, coupled heat conduction and elastic equations (cylindrical coordinates) with contact problem are resolved. The material is made up of carbon and it is assumed that wear is negligible. Numerical simulation of the thermo-elastic behavior of the disc brake is achieved in the repeated braking condition. Computational results are existing for weight and heat distributions on each roughness surface among the contact frames. It should be noted that orthotropic disc brakes can provide better braking concert of the isotope due to the unbroken distribution of smooth pressure. [3]

Jiang Lan et al. (2011), studied thermal analysis for the Sci / 6061 Al brake disc. The CRH3 co-continuous alloy alloys during an emergency braking, taking into account the cooling air flow [4]. Thermal and stress of the SiCN / Al brake disc brake during an emergency braking at a speed of 300 km / h. Considering that the cooling air flow was studied by methods of finite element (FE) and computational fluid dynamics (CFD). The three modes of heat transfer were analyzed. The highest temperature after emergency braking was 461 ° C and 359 ° C without cooling and air flow, respectively. Equivalent stress could reach 269 MPa and 164 MPa and without considering the cooling air flow, respectively. The air flow through and around the brake disc was analyzed using the Solidwork2012 simulation software package. The results suggest that high convection coefficients obtained with the cooling air stream not only reduce the maximum braking temperature, but also reduce thermal gradients, as heat is removed more quickly from the hot parts of the disk.

Oder G. et al. (2009), model and analysis of space loads and discovery exploration. The analysis is carried out in such a way as to protect; In the first case, consider the remade paradox; The case Segundo considers the remainder in a china and maintaining a constant speed. Ambassadors are able to keep in touch with the heat fluid and the braking surfaces and combustion of the traction sheave.. If you used the component finishing method (FEM), the 3D model was used for analysis. Red-Red Graphite Brake Disc E Material; The scan speed is 250 km / h and the environment and the disc begin at room temperature and 50 ° C. The temperature and voltage levels in the batches are different. The results are compared to the results of the experiments. [5]

Talati and Jalalifar (2009), Studied Analysis of heat conduction in a disk brake system. In this paper, the governing heat calculations for the disk and the pad are extracted in the form of transient heat calculations with heat generation that is needy to time and space. In the derivation of the heat equations, parameters such as the period of braking, vehicle speed, geometries and the sizes of the brake mechanisms, resources of the disk brake rotor and the pad and contact pressure distribution have been taken in to explanation. The difficulty is solved systematically using Green's function approach. It is concluded that the heat generated due to friction between the disk and the pad should be ideally degenerate to the environment to avoid decreasing the friction coefficient between the disk and the pad and to avoid the temperature rise of various brake components and brake fluid vaporization due to excessive heating the pad should be ideally dissipated to the environment to avoid decreasing the friction coefficient between the disk and the pad and to avoid the temperature rise of various brake components and brake fluid vaporization due to excessive heating.[6]

Zaid, et al. (2009) investigated disc brake rotor by Finite element analysis. In this paper, the author has conducted a study on ventilated disc brake rotor of regular traveler vehicle with full load of ability. The study is more expected concern of heat and temperature distribution off disc brake rotor. In this study, the method for final concluding analysis if it has a cabin with the window for the distribution of temperature and presentation of the hard disk rotor and transient response Modeling is done in CATIA & ABAQUS/CAE has been used as finite elements software to perform the thermal analysis on transient response. Material used is Grey cast iron, with maximum permissible temperature 550 C. For load analysis 10 cycles of breaking and 10 cycles without breaking (idle) operation is considered total of 350 seconds. Result provided during 1 st , 5th and during 10th cycle. Thus, this sure study provide well understanding on the thermal characteristic of disc brake rotor and promotion the locomotive industry in developing best and current disc brake rotor.[7]

Haripal Singh and HarshdeepShergill (2012), Studied thermal Analysis of Disc Brake Using Comsol, In this paper Finite element analysis techniques is used to predict the temperature distribution and identify the critical temperature of brake disc. Considering all three modes of heat transfer (conduction, convection and radiation) for three different materials of rotor disc are been used (cast iron, aluminum and ceramics). If you have to conclude, you must use the hard disk in such a way that an integration system can be reasonable at temperature and compare with others. Ceramics has good cooling characteristics but it is costly, can be used in racing cars where high temperature is produced.[8]

III. OBJECTIVE

1. To do comparative study about the friction and wear behaviour of Gray cast iron and its composites with varying percentage titanium (0.5% and 1%) as a brake disc rotor material (used as a disc material) with Bagasse brake pad material (used as a pin material) on pin on disc apparatus.
2. To study effect of temperature on wear, coefficient of friction for tested materials.
3. To conduct wear test by varying normal load, speed, Different disc material as per design of experiment in Minitab software.
4. To suggest optimum level of parameters for minimization of wear by using Taguchi and ANOVA analysis.

IV. EXPERIMENTATION

5.1 Design of Experiment

Dr. Genichi Taguchi is viewed as the preeminent defender of hearty parameter plan, which is a building technique for item or process outline that spotlights on limiting variety as well as affectability to commotion. At the point when utilized appropriately, Taguchi plans give an intense and effective technique for planning items that work reliably and ideally finished an assortment of conditions. Minitab is a measurable instrument utilized for investigation and elucidation of test information. In industry outlined trials can be utilized to methodically research the procedure or item factors that impact item quality. After you distinguish the procedure conditions and item parts that impact item quality, you can guide change endeavors to upgrade an item's manufacturability, dependability, quality, and field execution

5.2 No of Experiment

Number of Experiments to is decided with the help of Taguchi Method using Minitab-16 Software. Three factors (Load, speed and material) at 3 levels each are as follows:

Table 1. Level of Experimental Parameters

Control Factors	Units	Type	Levels	Level		
				I	II	III
Load	N	Numeric	3	10	20	30
Speed	Rpm	Numeric	3	200	400	600
Material	Type	Text	3	Gray cast iron	Gray cast iron + 0.5% titanium	Gray cast iron + 1% titanium

5.3 Calculations and Measured parameter

5.3.1 Calculation of Load

1. Disc Brake Standard

Rotor disc dimension = 240 mm. (240×10-3 m)
Rotor disc material = Cast iron with titanium
Pad brake area = 2000 mm2 (2000×10-6 m2)
Pad brake material = Asbestos
Coefficient of friction (Wet) = 0.07-0.13
Coefficient of friction (Dry) = 0.3-0.5
Maximum temperature = 350 ºC
Maximum pressure = 1MPa (106 Pa)

2. Tangential force between pad and rotor (Inner face), FTRI

   1. FTRI = μ1.FRI

Where, FTRI = Normal force between pad brake and Rotor (Inner)
μ1 = Coefficient of friction = 0.5
FRI = P max / 2 × A pad brake area
Pressure from master cylinder Pmax= 106 N/m2
Area of brake pad =2000×10-6 m2
So, FTRI = μ1.FRI
FTRI = (0.5)*(0.5)*(1×106 N/m2) *(2000×10-6 m2)
FTRI = 500 N.

Tangential force between pad and rotor (outer face), FTRO.
In this FTRO equal FTRI because same normal force and same material

3. Calculation of Load
Load on Disc Due to Pin = (Load due to Brake Disc/ Area of Pad)* Area on Pin

$$= \frac{500}{2000} * \frac{\pi}{4} * 122$$

$$= 28.24\ N \cong 30N$$

5.3.2 Speed of Brake disc

1. Assume vehicle travel speed = 100 km/hr

$V=r^{\omega}$
Radius of wheel = 431.8
(100 *1000)/(60)= .431 * 2*π*n
N = 614.308 rpm

2. Assume vehicle travel speed = 60 km/hr

$V=r^{\omega}$
Radius of wheel = 431.8
(60 *1000)/(60)= .431 * 2*π*n
N = 368 rpm

3. Assume vehicle travel speed

= 30 km/hr
$V=r^{\omega}$
Radius of wheel = 431.8
(30 *1000)/(60)= .431 * 2*π*n
N = 184.63 rpm

5.3.3 Measured Parameters

1. Friction Measurements

The lever transmits a signal through a load cell for determining frictional force. Load cell is connected to digital panel, which displays the frictional force and also connected to PC where it is recorded. The readings are recorded manually for every 5 minutes of interval.

2. Wear Measurement

Electronic LVDT wear measurement is used for permanently recording wear. The readings are recorded manually for every 5 minutes of interval.

3. Test Time

Digital timer/controller for automatic shut off.

4. Cycle Counter

Panel mounted cycle counter gives the RPM of the rotating disc

Table 2.Combination of Parameters using Taguchi method & Result

Run	Factor 1 Load (N)	Factor 2 Speed (rpm)	Factor 3 Material	Wear (micron)	Coefficient of Friction
1	10	200	0.0	110	0.43
2	10	400	0.5	97	0.39
3	10	600	1.0	105	0.44
4	20	200	0.5	110	0.31
5	20	400	1.0	121	0.35
6	20	600	0.0	160	0.37
7	30	200	1.0	77	0.36
8	30	400	0.0	89	0.35
9	30	600	0.5	82	0.40

V. RESULTS AND DISSCUSSION

5.1 Analysis of Wear

5.1.1 S/N Ratio for Wear

The Signal to Noise (S/N) Ratio for Surface roughness is calculated by using Smaller the Better characteristic.
Smaller the better,

$$\text{S/N Ratio} = -10\log\left[\frac{1}{n}\sum_{i=1}^{n}(Y_{i}2)\right] \quad (1)$$

Table 3.SN ratio for Wear.

Run	Factor 1 Load (N)	Factor 2 Speed (rpm)	Factor 3 Material	S/N Ratio Wear
1	10	200	0.0	-40.82
2	10	400	0.5	-39.73
3	10	600	1.0	-40.42
4	20	200	0.5	-40.82
5	20	400	1.0	-41.65
6	20	600	0.0	-44.08
7	30	200	1.0	-37.73
8	30	400	0.0	-38.99
9	30	600	0.5	-38.28

5.2 Main effect plot for S/N Ratio

Fig 1 shows the main effect for S/N Ratio of wear. From fig. 1 the optimum level of parameters are obtained at

Load of 30 N, speed of 200 rpm and 0.5% of filler content. From analysis it is also found that Load is the most influencing parameter for wear followed by speed and filler content

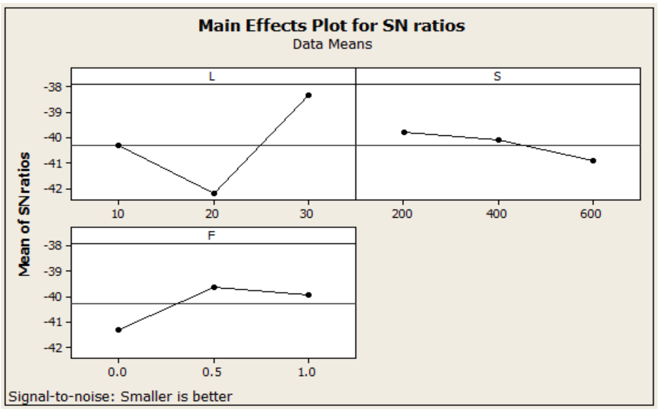

Fig.1 Main effect plot for S/N ratio of Wear

5.3.Thermal Analysis of Cast iron Brake disc

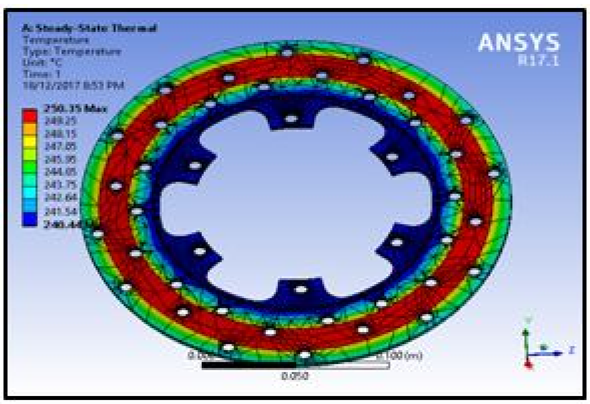

Fig 2. Steady State Temperature distribution for temperature

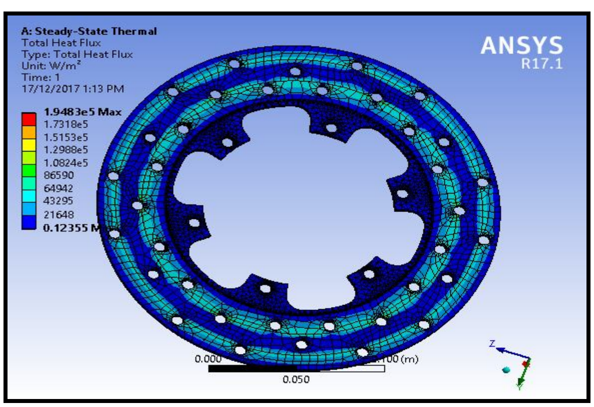

Fig 3. Total Heat Flux for Brake Disc

5.4.Thermal Analysis of CI Brake disc with Titanium (0.5 %)

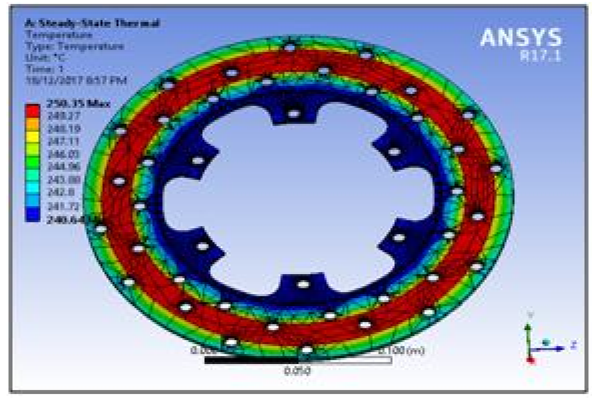

Fig 4. Steady State Temperature distribution for temperature

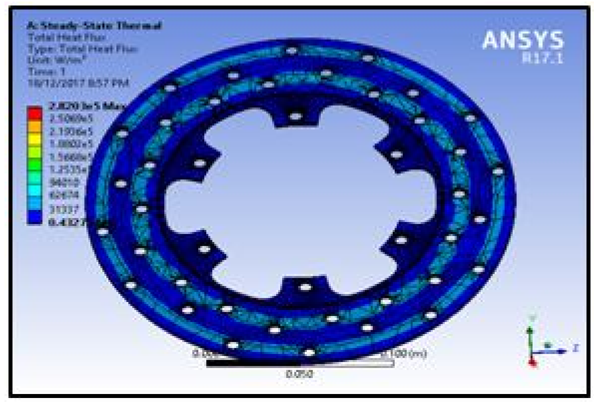

Fig 5. Total Heat Flux for Brake Disc

5.5.Thermal Analysis of CI Brake disc with Titanium (1 %)

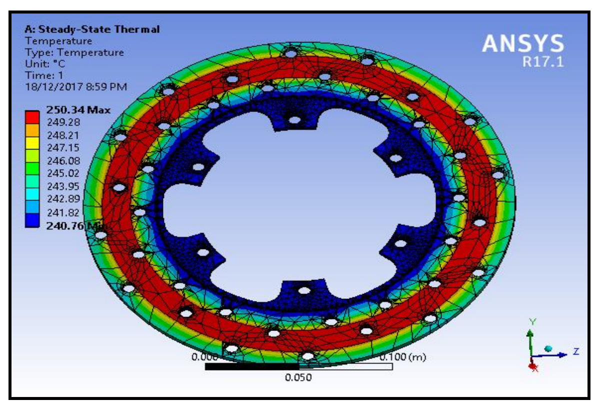

Fig 6.Steady State Temperature distribution for temperature

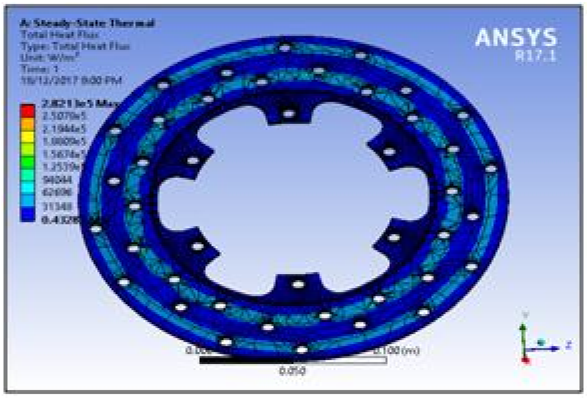

Fig 7. Total Fig 7.Heat Flux for Brake Disc

VI. CONCLUSION

In this work nine experiments were conducted with three levels of each parameter on pin on disc tribometer. Influence of load, speed and filler content investigated by using taguchi and ANOVA analysis. From analysis the following conclusions are drawn:

1. From ANOVA analysis it is found that load is most contributing factor for wear with contribution of 75.8%.
2. The optimum parameters level setting for wear is found at load of 30N, speed of 200 rpm and 0.5% of filler content.
3. From ANOVA analysis it is found that speed and filler content have less contribution for wear
4. Gray cast iron with 1% titanium shows less wear as compared to other tested material followed by load.
5. Also Gray cast iron with 0.5% titanium shows less C.O.F. as compared to other tested material followed by load.
6. Gray cast iron with 1% titanium shows less wear as compared to other tested material followed by speed.
7. Also Gray cast iron with 0.5% titanium shows less C.O.F. as compared to other tested material followed by speed
8. The thermal analysis of the disk brake rotor is conducted using Ansys Work bench and the results obtained are given in the table.

Results

Material	Temperature ^0C		Total Heat Flux(W/mm²)	
	Min	Max	Min	Max.
CI	240.44	250.35	0.12355e5	0.12355
CI-.5 % Ti	240.64	250.35	2.82e5	0.4327
CI- 1% Ti	240.74	250.34	2.8213e5	0.4328

9. Effect of titanium not affect too much in temperatures distribution. The temperature distribution on the cylindrical surface of the disk brake is shown in the table. It is found that the temperature is less in case of Cast iron with the TI - 0.5, Ti – 1% Composite compared to Grey Cast Iron. By replacing by Ti Composite the value of the temperature is less as compared to Grey Cast Iron

REFERENCES

[1] Ting-Long Ho., 1974. “Effect of frictional heating on brake materials”, Wear, 30(1974) 73-91

[2] Masahiro Kubota., 2000. “Development of lightweight brake disc rotor: A design approach for achieving an optimum thermal, vibration and weight balance.” JASE review 21 (2000) 349-355

[3] Choi and Lee, “Finite element analysis of transient thermo elastic behaviors in disc brakes‟, Vehicle Noise and Vibration, I Mech E Conference Transactions. -1998

[4] Jiang Lan et al. “ Thermal analysis for brake disk of Sci/6061 Al. Alloy co-continuous composite for CRH3 during emergency braking considering air flow cooling” 2012

[5] Oder G. “Modeling and analysis of thermal and stress loads in train disc brakes. (2009) ,ISSN: 1846-5900.

[6] Faramarztalati, 2009. “Analysis of heat conduction in a disk brake system”,Spinger-Velag- 2009

[7] Zaid, et al, “ Disc brake rotor by Finite element analysis” 2009

[8] Harpal Singh, 2012. “Thermal Analysis of disk brake using COMSOL”, International journal on Engineering technologies ISSN No. 2249-3255

[9] Koetniyom. S "Thermal stress Analysis of Automotive Brake Rotors." International Journal of Current Engineering and Technology. - 2014. - 3. - pp. 129-132.

[10] Mr. V.A.Nehete, Prof. R.B.Barjibhe, Analysis of various brake lining Material used for Disc Brake of Bajaj Pulsar 150CC by using FEA, Indian Research Transaction Vol. 5, No.2 , Apr-June 2015

[11] G. Babukanth & M. Vimal Teja, Transient Analysis of Disk Brake By using Ansys Software, International Journal of Mechanical and Industrial Engineering (IJMIE), ISSN No. 2231 –6477, Vol-2, Issue-1, 2012.

[12] Stefan Voloaca, Gheorghe Fratila, Theoretical and Experimental Researches of Brake Discs Thermal Stress, 15th WSEAS International Conference on Automatic Control, Modelling& Simulation (ACMOS’13), Brasov, Romania, June 1-3, 2013.

[13] SaeedAbbasi, ShahabTeimourimanesh, Tore Vernersson, Ulf Sellgren, Ulf Olofsson, Roger Lundén, Temperature

and thermoelastic instability at tread braking using cast iron friction material, Wear 2014.

[14] Mr. Milind H. Pendkar, Prof. S. P. Gaikwad and Mr. Vinil N. Kongari, Thermal Analysis Of 150 Cc Pulsar Disc Brake, International Journal of Application or Innovation in Engineering & Management (IJAIEM)Volume 3, Issue 6, June (2014) 63-67.

[15] Swapnil R. Abhang, D.P.Bhaskar, Design and Analysis of Disc Brake, International Journal of Engineering Trends and Technology (IJETT) – Volume 8 Number 4- Feb 2014 Page 165-167.

[16] P.K.Zaware, R.J.Patil, P.R.SonawaneDesign Modification &Optimisation Of Disc Brake Rotor, IJREAT International Journal of Research in Engineering & Advanced Technology, Volume 2, Issue 3, June-July, 2014.

[17] YaojungShiao, Quang-Anh Nguyen, Structural Analysis and Validation of the Multi-pole Magnetorheological Brake for Motorcycles, Procedia Engineering 76 (2014) 24 – 34.

[18] R. S. Kajabe, R.R.Navthar, S.P.Neharkar, Design & Implementation of Disc Brake Rotor By using Modified Shapes, IJISET International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 3, March 2015 444-449.

[19] Madu. Gowrisankar, Kanduladeepthi, Design and Analysis of a Vented Disc brake Rotor, International Journal of Computational Engineering Research (IJCER), Vol, 05 Issue,02 February-2015 Page 68-73.