WEAR & THERMAL ANALYSIS OF DISC BRAKE ROTOR FOR DIFFERENT MATERIALS

Mr. Harshal Suresh Shinde[1]
1: PG Student, Department of Mechanical Engineering, SVCET, Rajuri, Pune, Maharashtra, India

ABSTRACT

Brake is an essential component of moving vehicle, in which break is used for stopping or slowing down the vehicle. In vehicle various kinds of braking systems are used such as drum brake, disc brake, band brake which is operated by Pneumatically, Hydraulically, electrically, mechanically or by either combination of two means. The disc brake is loaded with various stresses, wear & squeal, in this study we are going to find the wear rate of disc brake rotor for different materials to find the best suitable alternative material. We are performing experimentation on disc brake rotor to obtain the Results for five different material, the wear rate are tested by using pin-on-disc machine. And temperature produces at surface is obtain from the test setup available. Then same disc modelled by using Catia & analyzed for each parameter by using Ansys. And then results are compared to obtain the results.

Keywords – *Disc Brake Rotor, Temperature analysis, Wear Analysis, Squeal.*

NOMENCLATURE

E_c= Total Kinetic Energy of vehicle

v_o= Initial speed of vehicle

m=Mass of Vehicle

E= Distributed Kinetic Energy of vehicle on each axle.

q =Heat flux produced

E_d =Energy produced in disc

s_d =Friction contact area of disc & Pad

ϕ_o =Initial angle of contact

σ =Heat partition coefficient

μ =Coefficient of friction

P = Pressure applied on disc pad

r =Radius of surface contact

ω =Angular velocity of disc

ξ =Thermal effusivity of material

K =Thermal Conductivity of Material

ρ =Mass density of material

ς =Specific heat of material

I. INTRODUCTION

The disc is the component of a disc brake against which the brake pads are applied. The material is typically grey iron. The design of the disc are simply solid, or hollowed with fins or vanes joining disc's two contact surfaces The weight and power of the vehicle determines the need for ventilated discs. Ventilated disc helps to dissipate the generated heat and is commonly used on the more heavily loaded.

In this project we are working on the wear of disc rotor due to friction between friction pad & disc material. In this we are selecting five different materials to obtain the wear rate at the pressure applied on friction pad, speed of vehicle (velocity), & disc rotor material properties, temperature of disc. And then we are finding the best suitable material for disc brake rotor. Then this results are compared with Ansys results to obtain final results.

II. LITERATURE SURVEY

Ali Belhocine have been study that the temperature distribution in disc brake rotor is fully depend on the type of material & friction between the rotor & Pad. They have been presented numerical simulation of thermal behavior of three different material for determining a braking mode, which shows the radial ventilation is very significant in cooling of rotor in braking phase. [6]

C. Radhakrishnan have been study a Cast Iron, Aluminium Composite Matrix for reducing a wear with Hexagonal, Circular & Square patterns cut along a disc profile to optimize the disc rotor, By investigation they found that the Aluminium composite with square pattern is best for heat dissipation. [1]

Hui Lu have been study an uncertain optimization method to reduce the brake squeal, the parameters of frictional coefficient, material properties and the thicknesses of wearing components are treated as uncertain parameters, which are described as interval variables. After that they proposed that this can improve the stability of brake system effectively. [7]

Mr. N. Suryanarayana have been study about high carbon steel, grey cast iron & Manganese to find the optimum results of all this material. They find out structural parameters displacement, Stress, Strain which compare theoretically and find out optimum material as a grey cast iron. To validate this they modelled disc rotor in Pro-E and analysis is done using Ansys. [3]

Jared Feist have been study a mechanical & Tribological properties of disc brake rotor. To study friction properties a modern technique scanning electron microscopy method is used. By reviewing this he suggest that breaking materials chosen on mechanical properties with oxidation properties also considered. Also he suggest the future work in mechanism of braking friction and further development in new pad & rotor materials. [2]

III. PROBLEM DEFINITION

In Breaking system there are various problems occurred such as a response of stopping of vehicle, Heating of Brake shoe which causes thermal stresses in brake shoe, Friction & wear of surfaces which causes the worn out of friction surfaces. To overcome such a problem in conventional breaking system disc brake system is developed. Which gives better breaking effect, stopping response but other than this advantages some disadvantages also occurred

In disc brake system due to friction which produces squeal, thermal stresses, & worn out of rotor surfaces so braking efficiency will be affected. So in to avoid this we have to find some material which gives less wear than now a day's rotor & also which produces a less temperature and best alternative to conventional one.

By studying various literatures available with us we found that the change in material of disc brake is possible to reduce the wear & temperature.

IV. OBJECTIVES

1. Find the wear rate of disc brake rotor surface.
2. Find the temperature distribution along the surface of disc brake.
3. Find the best alternative possible material for disc brake rotor.
4. Study and analyzed the temperature profile along the disc brake surface in steady state thermal analysis.

V. EXPERIMENTAL METHODOLOGY

First by literature survey and available data we have find five material as per the strength & properties of material which required for the disc brake rotor. So by various studies we have decided

1. Grey Cast Iron (GCI)
2. Aluminium (Al)
3. Ti Alloy (Ti-2)
4. Ti Alloy (Ti-5)
5. Al-Cu alloy (Al-Cu)

Table-1: Standard Properties of Material

Material	**GCI**	**Al**	**Ti-2**	**Ti-5**	**Al-Cu**
Thermal Conductivity (w/mK)	58	237	16.3	7.3	399
Mass Density (Kg/m^3)	7800	2700	4510	4420	8906
Specific Heat (KJ/Kg/K)	460	910	540	570	390

Coefficient of Friction (μ)	0.4	1.10	0.32	0.28	0.29

Then the variable for taguchi design is decided the variable are Speed of Vehicle, Breaking Force & Time of stopping the vehicle. No of experiments trial are find by performing Design of Experiments (DOE) by using Taguchi Method Which we get total 80 trial (16 for each material) for L4×4 level factors. Then we find the wear rate & friction force of material by using pin-on-Disc Machine. [7] The same disc is modelled using catia-V5R21 & then its thermal Stresses is analysed by using Ansys Package.

VI. EXPERIMENTATION

The trial is carried out for four different speeds and four different applied force. This are decided by considering the operation condition of vehicle at which maximum time break is applied. This speed and combination of braking forces is given below. [8]

Table-2: Variables Decided for trials & Experimentation

Sr. No.	1	2	3	4
Speed of Vehicle *(KM/hr)*	20	30	40	50
Pressure Applied on brake lever *(Bar)*	0.1	0.2	0.3	0.4

The trials are carried out on Pin-On-Disc Machine, where the trial time decided is 10 Min (In which 05 min is with constant contact & then applied the decided force). And all the observations where recorded. This tests are carried out under dry condition.

Figure-1: Set-up of pin-on-disc Tribometer (TR-20LE)

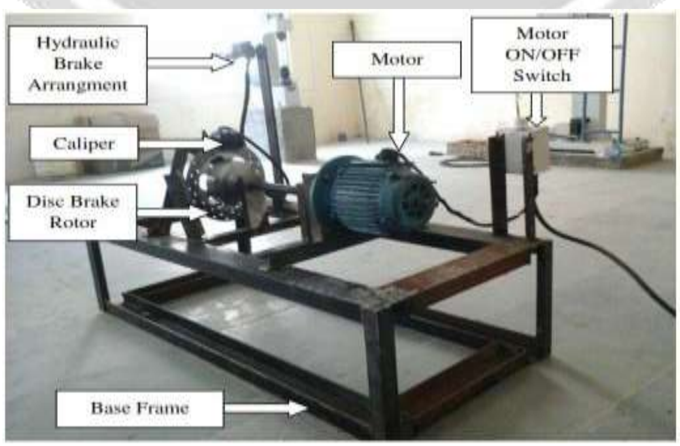


Figure-2: Set-up of Disc Rotor Temperature test.

Then the temperature tests are carried out on the setup of actual disc brake operation model which is available in Al-

Ameen Institute of Allied Sciences & Engineering Technology. Where the temperature is recorded for the same test speed and applied

VII. MODELLING & ANALYSIS

The disc is modelled using CATIA-V5R21 for Hyundai I20 Model. This Model is analyzed using Ansys for selected material properties.

The heat flux produced and heat generated due to friction is calculated by using following formulas.

$E_c = \frac{1}{2} m {v_o}^2$ *(Equation-1)*

$E = 0.5 \times E_c$ *(Equation-2)*

$q_{at\,r} = \frac{dE_d}{dS_d}$ *(Equation3)*

$q_{at\,r} = \frac{\phi_o}{2\pi} \sigma \mu P r \omega$ *(Equation-4)*

$\sigma = \frac{\xi_d S_d}{\xi_d S_d + \xi_P S_P}$ *(Equation-5)*

$\xi = \sqrt{K \rho \varsigma}$ *(Equation-6)*

By using equation 1 & 2 we find out the heat flow due to friction which is $E = 48226.08\ Joule$

And from equation 4, 5 & 6 we find the heat flux produced at the friction surface at the time of braking which is given below for all materials.

Table-3: Heat Flux produced

Material	GCI	Al	Ti-2	Ti-5	Al-Cu
Heat Flux *(w/m^2)*	2939.73	9003.28	1744.45	1259.35	2531.38

Figure 2 shows the modelled disc brake rotor by CATIA &Figure 3, 4, 5, 6, 7 shows the temperature profile formed at the time of braking for different material which is obtained from Ansys.

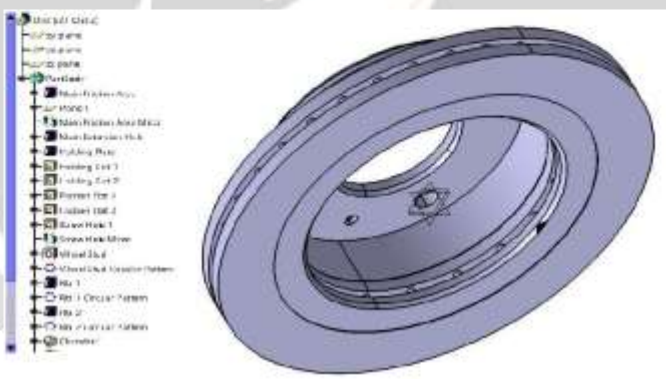


Figure-3: Model of Disc Brake Rotor (Using CATIA-V5R21)

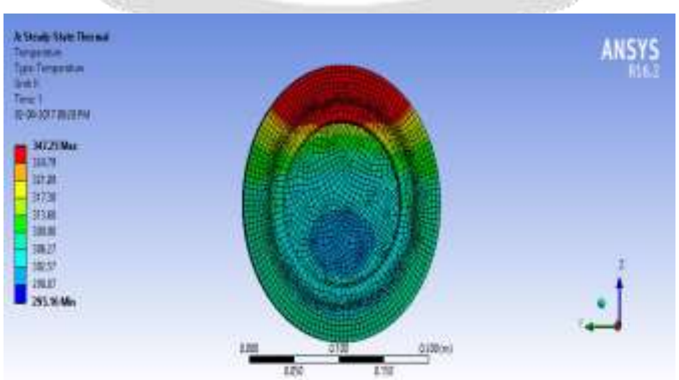


Figure-4: Ansys Temp Profile (Material: GCI)

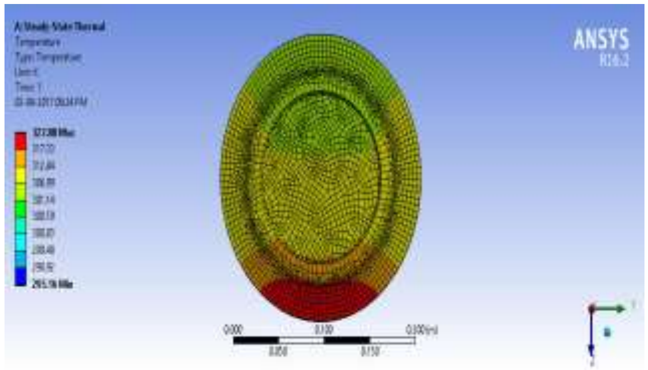


Figure-5: Ansys Temp Profile (Material: Al-Cu Alloy)

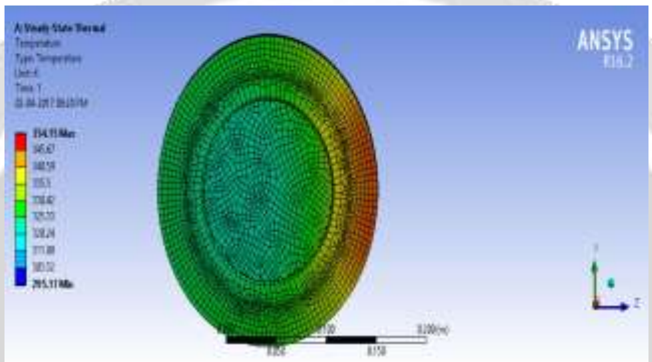


Figure-6: Ansys Temp Profile (Material: Aluminum)

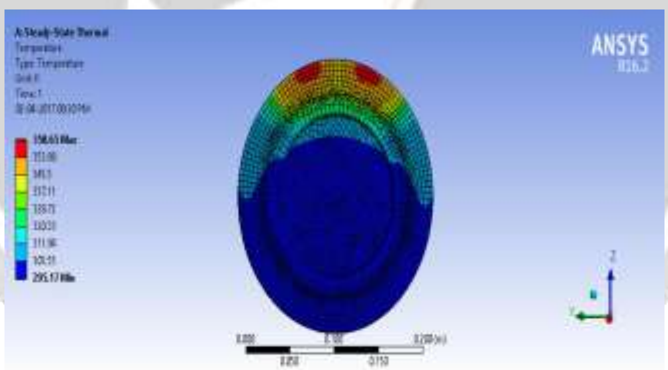


Figure-7: Ansys Temp Profile (Material: Ti-2)

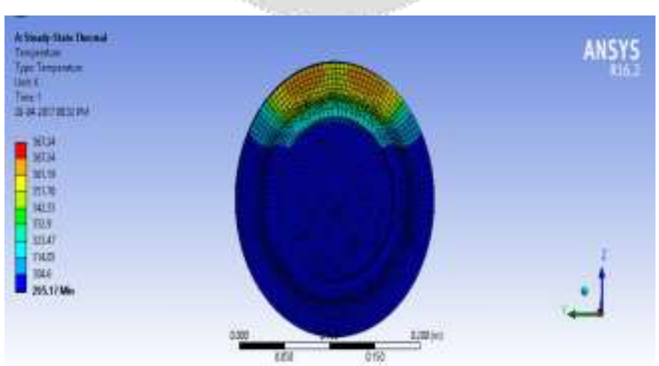


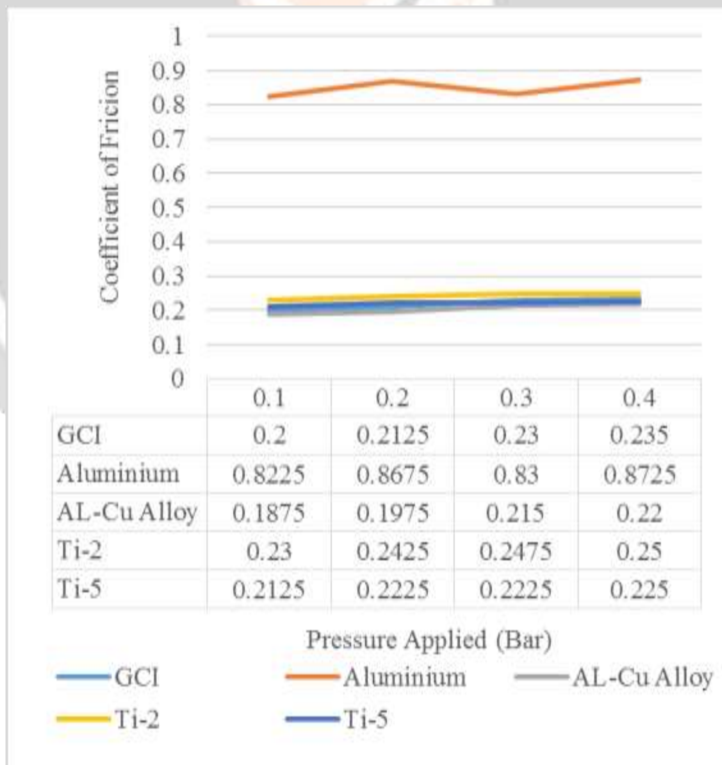
Figure-8: Ansys Temp Profile (Material: Ti-5)

VIII. RESULTS & DISCUSSION

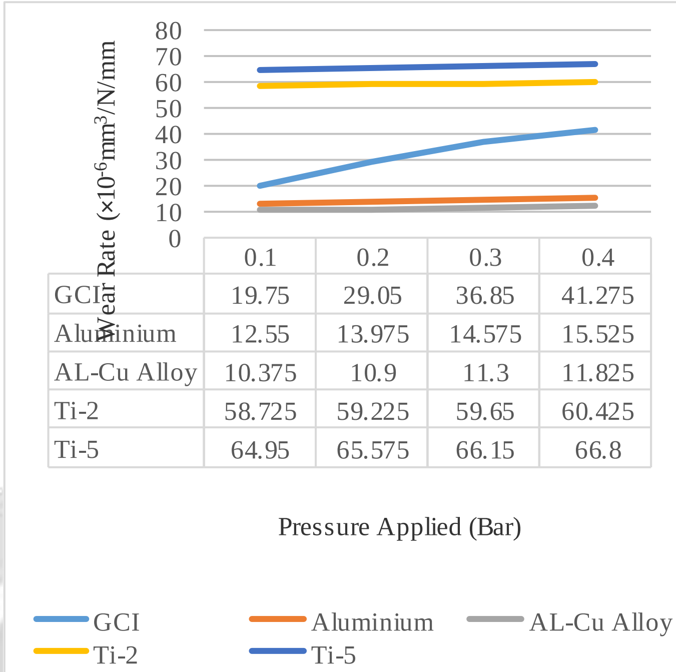
The table-4 shows the Design of experiments obtained from taguchi method to carry out the trial experiment on pin on disc tribometer and the experimental test rig.

Table-4: Sets of Trials decided using Taguchi Method

Set	Speed of Vehicle **(KM/hr)**	Pressure Applied on brake lever **(Bar)**
S1	20	0.1
S2	20	0.2
S3	20	0.3
S4	20	0.4
S5	30	0.1
S6	30	0.2
S7	30	0.3
S8	30	0.4
S9	40	0.1
S10	40	0.2
S11	40	0.3
S12	40	0.4
S13	50	0.1
S14	50	0.2
S15	50	0.3
S16	50	0.4

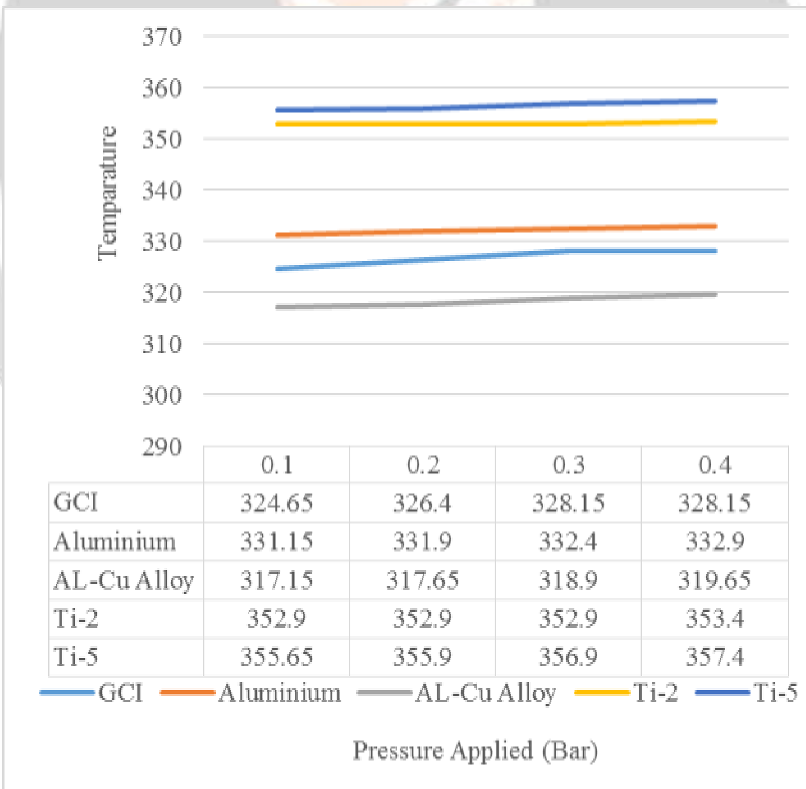


Graph-1: Mean Speed & force Vs Coefficient of Friction



	0.1	0.2	0.3	0.4
GCI	19.75	29.05	36.85	41.275
Aluminium	12.55	13.975	14.575	15.525
AL-Cu Alloy	10.375	10.9	11.3	11.825
Ti-2	58.725	59.225	59.65	60.425
Ti-5	64.95	65.575	66.15	66.8

Graph-2: Mean Speed & force Vs Wear Rate



	0.1	0.2	0.3	0.4
GCI	324.65	326.4	328.15	328.15
Aluminium	331.15	331.9	332.4	332.9
AL-Cu Alloy	317.15	317.65	318.9	319.65
Ti-2	352.9	352.9	352.9	353.4
Ti-5	355.65	355.9	356.9	357.4

Graph-3: Mean Speed & force Vs Temperature Profile

Table-4 shows the average values of all readings obtained from experimentation. By the considering the disc brake requirements we get that the Al-Cu Alloy is suitable for disc brake rotor application.

Table-5: Average values of all observations

Parameter	Coefficient of friction	Wear Rate	Temperature
CGI	0.219	31.731	326.83
Aluminium	0.848	14.156	332.08
Ti-2	0.243	59.506	353.02
Ti-5	0.221	65.868	356.46
Al-Cu	0.205	11.1	318.33

IX. CONCLUSION

From the experiments performed for different material we found that the wear rate of AL-Cu alloy is less among the all material tested

The heat flux generated in friction is less in Ti-2 material but the temperature produced at the friction surface in Al-Cu alloy is less among all material tested

Also the coefficient of friction obtained in experimentation we get that the Coefficient of friction of Al-Cu alloy is less as compared to all material.

The variation of obtained result in the experimental work and result of analysis is approximately 15% which is within limit of acceptable that is 19%. [10]

The best suitable option for Gray cast Iron disc brake is Aluminum Copper Alloy disc. Where the less wear rate is resent and temperature at the time of braking is also less compared to GCI.

REFERANCES

[1] C. Radhakrishnan, Yokeswaran. K, Naveen Kumar M., Sarath kumar B, Gopinath M, Inbasekar. B, *Design and Optimization of Ventilated Disc Brake for Heat Dissipation*, IJISET, Vol. 2, Issue 3, March 2015, PP-692-694.

[2] Jared Feist, *Tribological Investigation on Automotive Disc Brakes*, 6960 Friction Wear and Lubrication, Sep 2013.

[3] Mr. N. Suryanarayana, Mr. S. Chandrasekhar Reddy, *Design and Material Optimization of air Disk brake of Volvo Trucks*, IJMETMR, Volume No: 1(2014), Issue No: 9 (September), PP-45-49.

[4] G. Cueva, A. Sinatora, W.L. Guesser, A.P. T schiptschin, *Wear resistance of cast irons used in brake disc rotors*, Wear 255 (2003), PP-1256–1260.

[5] Yathish K.O, Arun L.R, Kuldeep B, Muthanna K.P, *Performance Analysis And Material Optimization of Disc Brake Using MMC*, IJIRSET, Vol. 2, Issue 8, August 2013, PP-4101-4108.

[6] Ali Belhocine, Mostefa Bouchetara, *Thermomechanical modelling of dry contacts in automotive disc brake*, International Journal of Thermal Sciences, 60, (2012), PP-161-170.

[7] Hui Lu, Dejie Yu, *Brake squeal reduction of vehicle disc brake system with interval parameters by uncertain optimization*, Journal of Sound and Vibration 333, (2014), PP-7313–7325.

[8] Promit Choudhury, Rahul Kumar Singh, Pritish Panda, *Thermal and Structural Analysis of A Ceramic Coated FSAE Brake Rotor Using 3d Finite Element Method for Wear Resistance and Design Optimisation*, IOSR Journal of Mechanical and Civil Engineering, Volume 11, Issue 2 Ver. VII (Mar- Apr. 2014), PP-143-149.

[9] Dieter G E, Engineering Design. 3rd ed. USA: McGraw-Hill; 2000.

[10] Ali Belhocine, Mostefa Bouchetara, *Investigation of temperature and thermal stress in ventilated disc brake based on 3D thermomechanical coupling model*, Ain Shams Engineering Journal (2013) 4, 475–483,