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Review of Friction Material Effect on Performance of Disc Brake

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Abstract- Brake pad & disc are most important component of an automobile braking system. For smooth retardation of vehicle it converts kinetic energy into heat energy. Due to hard or repetitive braking in steep gradient COF & wear rate, effectiveness between brake pad and disc is decreases.

In this work effect of AlTiN coating disc surface on tribological behavior of braking system are investigated by using pin on disc machine under dry condition. The AlTiN coating on disc done by PVD technology. Semi metallic & grey cast iron material considered for pin & disc. The input parameters considered for this test are load, pressure & sliding speed. This work also presents numerical analysis in FEM for analyzing COF and wear rate. Numerical & experimental results were compared in terms of wear rate & friction coefficient.

Keywords- Retardation, COF, AlTiN, PVD and Pin on Disc.

I. INTRODUCTION

Brake is most important safety system in automobile vehicle. Brake are required to stop vehicle within smallest possible distance and this is done by converting the kinetic energy into heat energy, which is dissipated into the atmosphere[1]. The maximum retarding force applied by brake at wheels depends upon coefficient of friction between road &tyre surfaces & component weight of vehicle on wheel. The effectiveness of the disc brake system depends on disc [rotor] with brake pad at their sliding interfaces. The friction force between brake pad & disc produces braking torque on the rotor, which is connected to wheel

& subsequent friction between tyre and road makes slow down car. During this process both pad & rotor worn & some of wear will become particle emission. The Proper selection of material for pad & disc at required quantities of constituents depends on experience or trial and error method. Rotors are made from variety of materials including cast iron, composite or aluminum composite. Most rotors made up of grey cast iron because high carbon content to make it hard. Pad material composed of a few elements which are used to improve friction property at low & high temperature, increase strength & rigidity, prolong life, reduce porosity and reduce noise. The elements of friction material are classified as additives, fillers, binders and reinforcement fibers. A commercial brake lining usually contains more than 10 different constituents. [10]

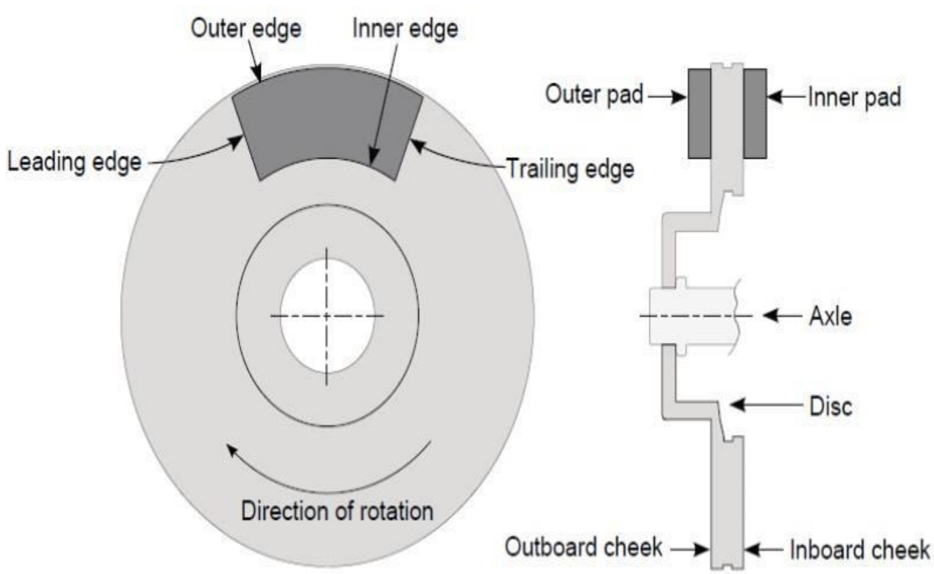

Fig.1 Disc Brake System [6]

During prolonged period of heavy braking, brake rotors and drums can absorb heat faster than it can be transferred to surrounding air. In hard braking stop temperature can increase about 50c/sec .Yet, dissipating that seconds worth of temperature increase might take 20 sec [1]. The maximum temperature can be caused by hauling heavy load, stopping from high speeds, braking in traffic and continuous downhill braking on mountain road. Due to brake related problems lining are appears more vulnerable to various braking parameter such as temperature, pressure, sliding speed & environmental condition. The coefficient of friction of brake drops with excessive temperature. This is called as brake fading. The brake fade are described into lining fade, mechanical fade and gas fade. Also due to the shape and physical properties of the brake rotor can affect brake-induced problems such as judder (vibration due to rotor warping or uneven disk thickness), fade (loss of brake effectiveness due to frictional heat) and noise [10]. This is because the physical properties of the gray iron rotor such as thermal conductivity, damping capacity, thermal expansion coefficient and specific heat change according to the phases in the gray iron. As the temperature increases beyond certain point its COF drops off requiring more pedal effort to stop vehicle. Below chart shows the COF of brake pad rise slightly as temperature rises with further temperature raises COF drops rapidly. As fade worse with addition of more heat stopping ability of radius and may disappear altogether. Change of rotor composition strongly affected both the mechanical properties of the rotor and the wear rate of brake linings and rotors, suggesting that the rotor was chemically active with the brake linings during braking.

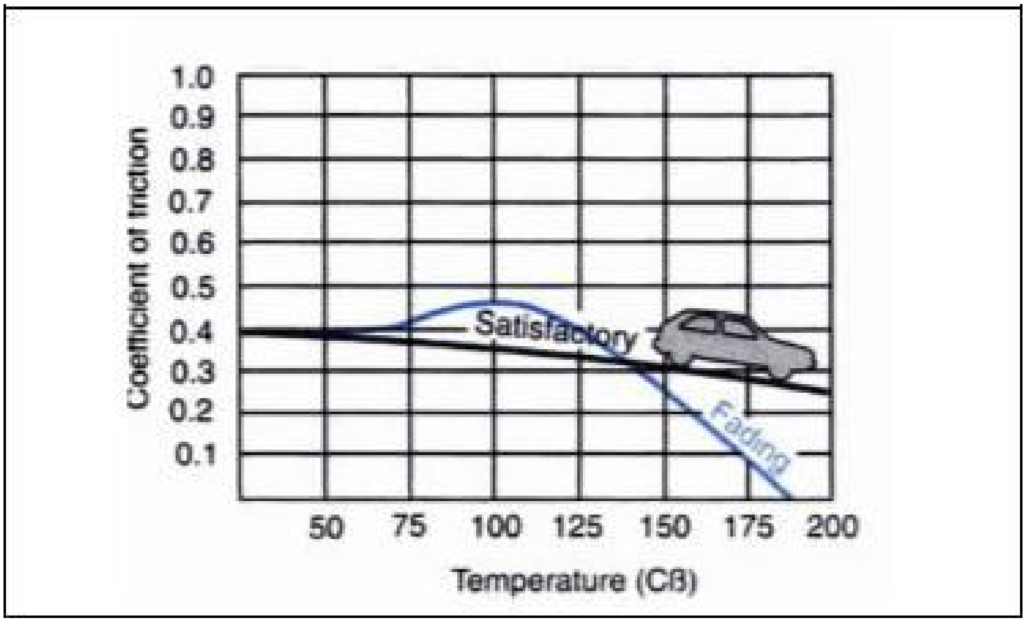

Fig. 2 Coefficient of Friction Drops as Brake Fade [1]

The mechanical brake fade occurs only in brake drum. When drum expands as temperature rises. This causes the pedal to move closer to the floor before brake apply. During extreme overheating of brake system the pads organic binding can release thin layer of hot gases. This causes the pad to hydroplane, reducing contact between pad and disc.

II. LITERATURE REVIEW

Literature regarding disc brake during the last some years was screened for systematic review. A first screening, by close reading of abstracts was independently performed by authors. A consensus of which references identified were suitable for the reviews was reached by authors. For those cites, the complete articles were accessed for eligibility. The data extracted from eligible articles were: Study design, input parameter, method/machine, outcome measures.

Author & Year	Study Design	Input Parameters	Method /Machine	Outcome Measures
Matteo Federici 2017	Pin on disc testing of low metallic friction material sliding against HVOF coated cast iron	Commercial friction material , wc-co-cr and cr3c2-nicr coating, grey cast iron of disc ,HVOF coating technology, sliding speed 1.57 m/s, pressure 1 mpa	Pin on disc machine, FEA modelling	Friction Vs. Time, Temp. Vs. Time, Wear Rate [For Coated And Uncoated Disc]
Shangwu Fan 2017	The effects of phosphate coating on fiction performance of c/c and c/sic brake material	Phosphate coating on c/c and c/sic disc, dipping method of coating under 700°c,braking speed 6100 r/min, pressure 0.68mpa,energy 3471 j	CVI, Disc on disc MM-1000 laboratory scale dynamometer	COF, Linear Wear Rate, Microscopic Morphology And 3D Profiles
Ali Belhocine 2016	FE prediction of thermal performance and stresses in an automotive disc brake system	Stainless steel and grey cast iron disc material, friction material for pad, thermo elastic properties of disc and pad	Finite element analysis in structural and transient by Ansys	Temperature And Heat Flux Distribution In Ventilated Disc, Time Vs Total Deformation, Von Misses Stresses At Different Angular Position
Jens Wahlstorm 2017	A pin on disc tribometer study of disc brake contact pairs with respect to wear and particle emissions	Three novel friction pad such titanium oxide, zinc oxide, light abrasive, three novel rotor such as lamellar cast iron, HVOF coated wccocr , nitride rotor	Pin on Disc machine with air velocity transducer	Mean COF, Disc Temperature, Flow Rate, Particle Concentration By OPS, Sp. Wear Rate of contact Pairs
D.W.Wang	Improving tribological behaviours	Two grooved graphite iron disc [t-	Pin on Disc tribometer, drag	Friction, Wear And Noise

2017	and noise performance of railway disc brake by grooved surface texturing	90 & t 45], disc rotating speed 60 rpm and normal force 100N for 30 min.	type dynamometer	Performance.
Faisal Ahmed 2017	Synthesis & characterization of Al-Ti-Cr MMC as friction material for disc brake application	Al-Ti-Cr tire inforced with SIC or B4C composite cast iron disc	Stir die casting ,EDAX analysis, Leitz Walzlar instrument	Chemical Analysis, Tensile And Compressive Strength ,Variation Of Strength and Percentage of Elongation
Ali Belhocine 2012	Thermo mechanical modelling of dry contacts in automotive disc application	Geometric dimensioning and application parameter of automotive braking, thermo elastic properties	Numerical simulation for transient field and stress field in Ansys	Stress And Deformations, Contact Pressure
N. Aranganathan 2016	Effects of aramid fiber concentration on the friction and wear characteristics of non-asbestos organic friction composites using standardized braking tests	Six composites, in the form of brake-pads of commercial vehicle [maruti alto],11 ingredients in each with varying aramid fibers by 0, 2, 4, 6, 8, 10 wt.%	Brake inertia dynamometer	Physical And Mechanical Properties, COF, Pressure Sensitivity, Speed Sensitivity
P.D. Neis 2011	Contribution to perform high temperature tests (fading) on a laboratory-scale tribometer	Two brake pads, a disk with diameter of 160 mm (12 mm thick) and inertia of 6.15 kgm2	Brake inertia dynamometer	Fading Test.Disc Temperature Vs Stop Number
Suresh R 2017	Numerical simulation and experimen study of wear depth and contact pressure distribution of aluminum mr pin on disc tribometer	Hardened steel disc and pin are casted of al6061 MMC, speed of disc 600 rpm, load 10,30,50 N, sliding velocity 3.76 m/s	Pin on disc machine, FEA modelling in Ansys	Wear Depth At 50N Load, Contact Pressure Vs Applied Load, Wear Depth Vs Applied Load
Aleksander	Influence of thermal sensitivity of	Coating Material Zro2, Steel	Laplace Transform Method,	Evolutions Of Various

Yevatushenko 2017	material on temperature and thermal stresses on the disc with thermal barrier coating	Disc, Constant Thermal Properties Of TBC And Disc	Quasi Static Normal Stress Method	Dimensionless Temperature At Various Depth Of Zro2
P.J. Blau 2003	Effects of water films and sliding speed on the frictional behavior of truck disc brake materials	Square Based Commercial Brake Pad & Disc, Pad Force 161.3 N, Pressure 1 Mpa,11 M/S.	Sub Scale Brake Testing System	Time Vs Temperature, Drag No. Vs COF, Avg. Speed Vs COF
M.Djafari 2014	Effect of humidity and corrosion on the tribological behavior of disc brake materials	Cast Iron ,Al MMC, Chromium Steel Disc, Resin Based Brake Pad Material, Normal Load 10 To 200 N, Sliding Speed 1.25 M/S, Humidity 20% To 90%,	Salt Spray Test, Pin on Disc Machine	Normal Load Vs COF, Effect of Sliding Speed on Wear Rate And COF, Effect of Humidity on Wear Rate and COF
Guangyu Biyu 2015	Friction And Surface Fracture of A Silicon Carbide Ceramic Brake Disc Tested Against A Steel Pad	Sintered Sic Ceramic Disc, Mild Steel As Brake Pad, Initial Braking Speed 4000,6500 And 9000,Sliding Speed 8.5,14 And 20 M/S, Pressure 2.1 Mpa	Laboratory Scale Dynamometer, X-Ray Spectroscopy	COF, Friction Development, Microscopy Image, Correlation COF And Stop No.
Guangyu Biyu 2016	Friction surface structure of a Cf/C-sic composite brake disc after bedding testing on a dynamometer	Carbon Ceramic Disc With Organic Pad, Frequency 100 Hz,	Laboratory Scale Dynamometer, X-Ray Spectroscopy, TEM	Microstructure And Chemical On Finished Surface, Friction Surface After Bedding
Qifei Jian 2017	Numerical and experimental analysis of transient temperature field of ventilated disc brake under the condition of hard braking	Disc HT250,Pad Resin Matrix Composites, Speed 100km/H, Rolling Radius 0.4 M	NX Software, FEA modelling in Ansys	Temperature Disrtribution Of Brake, Simulation Curve Of Temperature
A. Daoud 2010	Wear and friction behavior of sand cast brake rotor made of A359-20vol% sic particle composites sliding against automobile friction material	A395 Alloy & Sic With 5 µm For Disc, Commercial Brake Material For Pad, Loads 30 To 100 N, Pressure 0.3to 1 Mpa, Speed 3-12m/S	Stir Casting Method, Pin On Disc Machine	Effect Of Load And Speed On Wear Rate Of A359-20 Vo L% Sic Sliding Against Friction Material, Load Vs COF, Load Vs Temperature

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E.M. Bortoleto 2012	Experimental and numerical analysis of dry contact in the pin on disc test	Pin Made Of AISI4140 Steel (430hvhardness),And Discs Made Of AISIH13,Sliding Speed 1.4 M/S, Load 5to 140 N	Pin on Disc Machine, FE Modelling in Abacus, SEM	Wear Coefficient, Friction Coefficient, Micrography, Disc Mass Loss
Zmago Stadler 2007	Friction behavior of sintered metallic brake pads on a C/C–sic composite brake disc	Sintered Brake Pads, C/C-Sic Disc, Pressure 1.45 Mpa, Speed 660 Rpm	Brake Dynamometer, Vicker Micro hardness Machine, AES	Fade Cycle Vs Temperature, Fade Cycle Vs Friction, Characterization of Surfaces, Average Hardness
M. Baklouti 2014	Impact of the glass fibers addition on tribological behavior and braking performances of organic matrix composites for brake lining	Friction Lining With 7% Glass Fibre ,Stress Level 2,5 And 10 Mpa, Speed 0.1 KN/S	Pad On Disc Tribometer, TGA	Braking Performance, Wear Rate, Radiation of Disc Friction Track
Muthukannan Duraiselvama 2013	Laser surface nitrided Ti–6Al–4V for light weight automobile disk brake rotor application	Gray Cast Iron(GCI) And Ti–6Al–4V Of 10mm Thickness, Low Steel Lining Material, Velocity 2-3 M/S, Load 65 N, Sliding Distance 6000 M	DUCOM T-20 Pin On Disc Machine, Vicker Hardness ,Laser Nitrided Process	Microstructure, XRD Of Nitrided Disc, Time Vs Wear Depth, Time Vs COF, Volume Loss
Anders Söderberg 2009	Simulation of wear and contact pressure distribution at the pad-to-rotor interface in a disc brake using general purpose finite element analysis software	Passenger Car Disc Brake	Solid Modelling 185,FE Modelling in Ansys	Wear Rate Modelling And Simulation
Guido Perricone 2017	A concept for reducing pm10 emissions for car brakes by 50%	Front Left Disc Brake ,NAO Friction Material For Pad,	Pin On Disc, Dynamometer, EDXS	Temperature Vs Sp. Wear Rate, Particle Concentration Vs Friction Material, Wear Debris, Microscopy
Baijun Xiao 2018	A study of oxidation behavior of altin-and alcrn-based multilayer	Altin/Tisin And Alcrn/Tisin Multilayer Coatings, Cemented	SEM , EDX,XRD	Microstructure Analysis, Isothermal Oxidation, Time Vs

	coatings	Carbides, Speed 3.5rpm,Pressure 1× 10−3 Pa, Heated Up To 400 °C		Mass Gain
S. Anoop 2009	Analysis of factors influencing dry sliding wear behavior of Al/sicp–brake pad tribo system	Temperature 25c To 175c, Load 10 N To 20 N And Sliding Velocity 0.5 To 1.5 M/S, Aluminum Metal Matrix Composite Disc	Liquid Casting, Pin On Disc Equipment, Anova Software, SEM	Anova Wear Rate, Morphology, Time Vs Wear Rate, Effect Of Temperature Vs Velocity Interaction
I. Mutlu 2007	Boric acid effect in phenolic composites on tribological properties in brake linings	NAO Friction Pad With Boric Acid, Cast Iron Disc, Pad Pressure 1050 Kpa,675 Rpm,	Pad On Disc Machine, Brinell Hardness Machine, SEM	Wear Behavior, Effect Of Specific Wear out, Microstructure Indication
K.W. Liew 2013	Frictional performance evaluation of newly designed brake pad materials	Non-Asbestos Brake Pad (NABP) And Asbestos Brake Pad Material (ABP),Cast Iron Disc, Speed 20 M/S,1.631 Mpa,	Non-Contacting Infrared (IR) Thermometer , SEM, Pin On Disc	Coefficient Of Friction Vs Nominal Contact Pressure, Temperature Vs Nominal Contact Pressure, Wear Rate Vs Nominal Contact Pressure
Tej Singh 2014	Optimization of tribo-performance of brake friction materials: Effect of nano filler	Friction Composite With Nano Filler, Contact Pressure 2 Mpa,	Krauss Type Friction Machine	Coefficient Of Friction (M), Wear, Friction Recovery-%, Friction Fade-%, Stability Coefficient, Variability Coefficient, Friction Fluctuation& Disc Temperature Rise
F.E. Kennedy 1997	The friction and wear of Cu-based silicon carbide particulate metal matrix composites for brake applications	CUSIC MMCS and Cast Iron, Cast Iron Disc,240 And 400 Grit Wet Emery Paper, Load 27 N, Speed 1 M/S	Pin On Disc Machine, Micro hardness	Mechanical Properties Of Pmmc, COF, Wear Pmmc, influence of Interfacial Bonding Layer on Pmmc Wear
M.A.Sai Balaji 2013	Thermal and Fade Aspects of a Non Asbestos Semi Metallic Disc Brake Pad Formulation with Two Different Resins	Thermal And Fade Aspects Of A Non Asbestos Semi Metallic Disc Brake Pad Formulation With Two Different Resins	Chase Type Friction Testing Machine, Hydraulic Press Machine	Weight Loss Vs Temperature, Wear Rate, Fade Results

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III. SUMMARY

From literature survey it is seen that friction material are selected from survey are based on their properties & effect on COF & Wear rate. The COF and Wear rate of brake pad & disc depends on the load, pressure & sliding speed. In disc brake wear can contribute 50% of non-exhaust emissions from road transport & traffic. For controlling COF & Wear rate of brake pad & disc different composite material with variable percentage used for brake. Also alluminium & alluminium based composite can affect on COF & wear rate of disc because having good malleability, formability, corrosion resistance and thermal conductivity. Maximum 60% wear of disc material when brake is applied. For controlling wear of a disc coating is provided on it. Due to coating on disc effect of humidity & corrosion also reduced. In future work, we can be conducted test by considering effect of wet condition on the friction and wear. Also, considering different coating material on disc can affect wear and COF characteristics.

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