International Journal of Scientific Research and Management Studies (IJSRMS)
ISSN: 23493771 **Volume 2 Issue 7, pg: 294-299**

DEPLOYING ANALYTICAL METHODOLOGY FOR EXPERIMENTAL DATA OVER WEAR RECORDED FOR BRAKE LINER WHILE ATTEMPTING OPTIMIZATION

[1]Sanjay T. Kakulate, [2]Sandip T. Chavan, [3]Swapnil S. Kulkarni
[1]PG student, Mechanical Engineering Department, Maharashra Institute of Technology, Pune
[2]Professor, Mechanical Engineering Department, Maharashra Institute of Technology, Pune
[3]Director, Ethika Engineering Solutions India Pvt. Ltd., Pune

ABSTRACT

The brake liner is susceptible to high wear due to sustained abrasive forces exerted against the disc. This is further amplified by the rise in temperature due to friction of the bearing surfaces. While choice of the material has a marked influence on the rate of wear of the liner or its effectiveness in the `Braking' action experienced by the rider, the Design Engineer also needs to look into the behavior of the material over a range of operating conditions to find an optimal setting for recommendation. This work shall focus on this aspect of research while conducting extensive experimental investigation over a standard set up of `Pin on Disc' to arrive at a correlation of wear with respect to the rpm of wheel. The data shall be treated with statistical tools like ANOVA to identify significance of the parameter/s. further analytical treatment shall be extended to include DOE using Taguchi methods to arrive at an optimal level for the given significant parameter i.e. rpm of the wheel the study shall also include determination of the Regression equation using `MiniTab', as a preferred tool for Analysis. The findings shall be evaluated to offer a crisp conclusion and / or recommendation for the industry to review the operating conditions of the braking system limited to the scope of work outlined above.

KEYWORDS: *Disc Brake, DOE, wear rate, Taguchi, ANOVA*

I. INTRODUCTION

The disc brakes on most modern passenger cars are not sealed off from the ambient air. During braking both the brake pads and rotors are worn, generating wear particles. Some of these particles are deposited on the brake hardware, and others become airborne. Most rotors used in passenger cars are made of grey cast iron. The brake pads can be made of many different materials, but are essentially of three types: non-asbestos organic (NAO) pads, semi -metallic pads, and low metallic (LM) pads. NAO brake pads exhibit relatively low brake noise and low wear rates, but lose braking capacity at high temperature. Semi-metallic brake pads have a high steel fibre and iron powder content and low wear, but are noisier than the other types. Low metallic brake pads have a relatively high abrasive content, resulting in high friction and good braking capacity at high temperatures.

When measuring airborne brake particles in field tests it can be difficult to distinguish them from particles generated from other sources such as construction, re-suspended road dust, wheel-to-rail contact, and car-to-road contact. It is therefore preferable to conduct the tests in a laboratory where the cleanness of the surrounding air can be controlled. Although several studies have focused on wear and friction at the pad-to-rotor interface in laboratory test stands (for example) only a few have focused on online measurement of airborne wear particles. The representatively of test stand measurements should be verified by comparison with field tests; however, passenger car field tests are rare. Measured number and mass concentrations of airborne particles in the field, and compared the results with those measured in dynamometer tests. Tested low metallic pads in test stands and compared the results with field testing. The objective of the work presented here is to investigate the possibilities of using the experimental set-up proposed to compare different disc brake materials. This report describes the experimental set-up and presents the result from a test series in which non-asbestos organic (NAO) pads and low metallic pads were tested against grey cast iron.

The simplest way to reduce the velocity of a railway in motion is through the friction produced between a brake shoe and the wagons' wheel tread. Cast iron (usually as a gray cast iron) has been the most used material in brake shoes. Cast iron brake shoes have the disadvantage of making the wheel-tread surface rougher during braking. Thus, a reduction in noise should be achievable through the substitution of cast iron brake shoes by other material leading to lower wheel surface roughness. In fact, over the last years, cast iron shoes have been replaced by composite synthetic brake shoes. It has been demonstrated that cast iron brake shoes make the wheel surface much rougher than a similar product made with a composite material. Replacing the cast iron shoes with a synthetic product can therefore substantially reduce the wagon noise emissions, for example, by about 10 dB for a 100 km/h freight train [6]. Nevertheless, previous experiences using a polymeric composite brake demonstrated that the organic material can be burned, coating the wheel-tread with an organic film. This film diminishes the friction between the wheel tread and rail or brake shoe. Other sintered alloys have been used as a Fe–Cu–Cr–Sn–graphite alloy. These brake shoes exhibited a better braking behavior with less wear on the tread wheel. However, premature wear has been observed in this material, being less cost-effective. The aim of this work is to study and compare the tribological properties of a gray cast iron brake and a composite sintered alloy brake (Fe–Cu–Cr–Sn–graphite). A pin-on-disc technique is proposed to analyze comparatively the friction coefficient of both materials. Other mechanical analysis and photo thermal techniques were performed to discuss the wear phenomena.

II. LITERATURE REVIEW

Friction is one of the most popular issues now a day's many researchers have investigated the different evaluation method to attempt the friction measurement. Some of the earlier research work done is as follows:

1) A pin-on-disc simulation of airborne wear particles from disc brakes

Jens Wahlstroma, Anders Soderberga,1, Lars Olanderb,2, Anders Janssonc,3, Ulf Olofssona,4 2010

A novel test method was used to study the concentration and size distribution of airborne wear particles from disc brake materials. A pin-on-disc tribometer equipped with particle counting instruments was used as test equipment. Material from four different non-asbestos organic (NAO) pads and four different low metallic (LM) pads were tested against material from grey cast iron rotors. The results indicate that the low metallic pads cause more wear to the rotor material than the NAO pads, resulting in higher concentrations of airborne wear particles. Although there are differences in the measured particle concentrations, similar size distributions were obtained. Independent of pad material,

2) Tribological study of Fe–Cu–Cr–graphite alloy and cast iron railway brake shoes by pin-on-disc technique

C. Ferrer, M. Pascual, D. Busquets, E. Rayón *2010

A new class of materials is being installed in railway brake blocks to substitute classic cast iron in order to reduce the rolling noise produced by the roughness of the tread-wheel surface. The tribological properties of cast iron and Fe–Cu–Cr–graphite sintered alloy brake shoes were analyzed. Kinetic friction coefficient (μ) and wear were monitored by means of a pin-on-disc technique. The sintered alloy brake showed an increase in μ at higher braking velocities while the cast iron brake exhibited a decrease in μ. Wear was greater on the sintered alloy, explained by its low shear strength which decreased due to its low thermal conductivity. The roughness produced by the sintered brake shoes in wheel-tread surface was 10 times lower than that produced by cast iron.

3) Effect of the pin geometry on the wear behaviour of weld-deposited hardfacing

M. Martíneza, A. Massettia, H. Svobodaa,b,* 2012

Harfacing welding is a widely used method on severe worn, corroded or oxidized surfaces to regain its functionality. For metal-to-metal sliding or rolling contact applications, in which oxidative wear, subsurface fatigue and adhesive wear are the main wear mechanisms, the materials usually selected are steels with a carbon contents between 0,1 and 0,7% and up to 20% of alloy content, such as martensitic tool steels. Among them, H13 tool steel has a great number of applications. Variables such as sliding speed, load, or contact stress may have decisive influence on wear rates. Laboratory tests like Pin-On-Disk (POD) are frequently used to evaluate the tribologic behavior of different pairs of material. The objective of this work was to study the influence of the pin geometry (flat and spherical) in a POD test on the wear resistance of a weld-deposited hard facing of H13 modified steel against low carbon steel AISI 1020 under different load and sliding speed conditions. It was observed an influence of the pin geometry on the wear rates, especially at high sliding speeds. Under light loads, the worn volume of the flat pin was greater, while under heavier loads it is the spherical pin the one with greater worn amount.

4) Experimental characterization of frictional behaviour of clutch facings using Pin-on-disk machine

M. Bezzazi a, A. Khamlichi a,*, A. Jabbouri a, P. Reis b, J.P. Davim b 2007

During the clutch engagement manoeuvre, sliding contact occurs between the pair of clutch facings mounted on the friction disk and the counter faces belonging to the flywheel and the pressure plate. The transmitted torque is proportional to the overall coefficient of friction which depends essentially on temperature, normal pressure load and relative sliding velocity. In this work, performance of the friction coefficient is investigated experimentally. Samples of a commercial clutch facings material have been tested using a Pin-on- disk apparatus. When the previous three parameters are preset constant, this machine provides automatic acquisition of friction coefficient and wear measurements. The obtained results are compared with the classical SAE J661a standard test. It is found that the actual clutch facings material has good fading resistance and a rather stable coefficient of friction once running in phase is achieved.

5) Wet clutch friction characteristics obtained from simplified pin on disc test

Pa¨ r Marklund, Roland Larsson

The frictional behavior of wet clutches in vehicle drive trains is critical for their overall behavior. During the development of new wet clutch systems there is a need to know this friction behavior. The transferred torque is normally investigated in test rigs where the friction in a sliding interface between a friction disc and separator disc is investigated. These test rigs can be designed differently, depending on the working

conditions of the investigated clutch. However, it is possible today to simulate the clutch behavior and not limit ourselves to only using measurements from test rigs for the design of the wet clutch. The torque transferred by the clutch during engagement can be roughly divided into full film torque and boundary lubrication torque. The full film regime is possible to simulate quite well, whereas the friction in the boundary regime is much more difficult to simulate due to its strong additive dependency. To obtain a good prediction of the total engagement, friction measurements in the boundary lubrication regime are still needed. These measurements should be easy to perform and fast tests are preferable. Friction coefficients for the whole range of sliding speed, interface temperature and nominal surface pressure should be measured. To use these measurements in simulations and get a better understanding of the friction behavior, it is also preferable to conduct these measurements on a small test sample, for which the temperature and sliding speed can be regarded as constant.
Here, the friction of a small sample of a wet clutch friction disc is investigated in a pin on disc test and the temperature is measured in the sample during the tests. Measurements are compared with measurements from a test rig for whole friction discs. A good correspondence between the frictional behaviors of the different measurement methods is achieved.

III. PROBLEM STATEMENT

The brake liner is subject to wear and tear as it endures the friction generated during braking. The friction causes the affected liner material to dislodge from its original state while it is homogenously intact with the surrounding bulk of material. This abrasive action is compounded by the elevated temperature on account of rubbing experienced by the mating parts. The liner material is intentionally softer than the disc of the brake to transfer the abrasive wear over the replaceable part (the liner). Although the rate of wear needs to be controlled for scheduling preventive maintenance that is less frequent.
Research needs to be done on the factors (and the levels) influencing the rate of wear. Optimal set-point for the operating conditions should be explored to bring about control over its performance. The material is sought to be changed for this work. The optimal rate of wear vis-à-vis the speed of rotation and/or the braking force to be explored using DOE. Experiments to be performed to record the performance metrics (wear) followed by analysis to find a feasible level for the significant factor identified for the case.

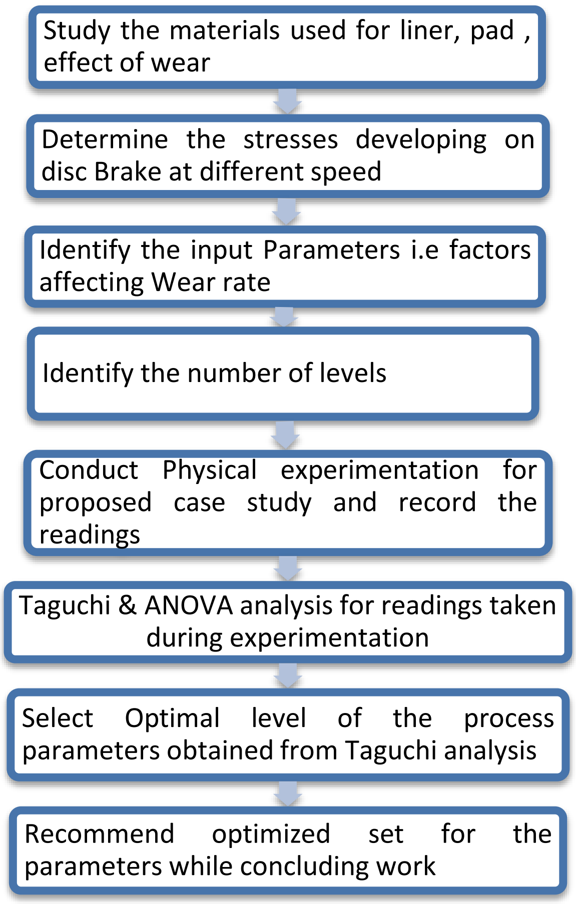
Scope of work/ Objectives

- To study the materials used for Brake shoe liner, forces acting on the liner, wear rate of the brake shoe liner
- Through literature review, identify the significant process parameters that affect the response of interest i.e. Rate of wear
- Select the levels for the parameters undertaken for this study while referring to Literature Review.
- Deploy statistical methods for analysis such as Taguchi/ Regression. Perform DOE using Taguchi method or a suitable method for Analysis
- Determine optimal levels from the Response tables and graphs vis-à-vis the wear rate
- Recommend upon review and validation

IV. METHODOLOGY

- For this case study we are using two different methodology such as Statistical Method and Experimental Method:
- In statistical method, basic problem solving techniques are used. In this work, DOE (Design of Experiments) methodology was used for optimizing Rate of wear for brake shoe liner. DOE includes following techniques
- Historical data analysis
- Taguchi analysis
- Regression Analysis
- ANOVA Analysis

Stages in Design of Experiment includes:



V. EXPERIMENTATION

Pin-on-disc machine in climate chamber

The tests were performed on a pin-on-disc machine with a horizontal rotating disc and a dead weight loaded pin (Fig. 1). The machine is a conventional tribometer used for tribological testing of various material combinations for friction and wear. The machine runs under stationary conditions with constant applied normal forces of up to 100N and constant rotational speeds of up to 440 rpm. A load cell is used to measure the tangential force acting on the pin. The coefficient of friction was calculated as the measured tangential force divided by the applied normal force.
The mass loss was measured by weighing the test samples before and after the test to the nearest 0.1mg using a Mettler H315 analytical balance. A WA/10 inductive displacement gauge from Hottinger Baldwin Measurement GMbH was used to continuously measure normal displacement of the level arm with an accuracy of ±6%. The displacement gauge gives an online measure of the total wear of both the pin and the disc sample, making it possible to observe changes in the wear rate due to running-in effects or changes in wear mechanisms.

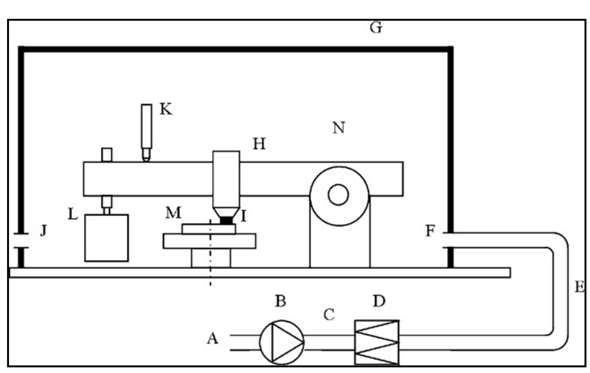


Fig1. Schematic Figure of the test setup.

Equipment's:

1. Room air
2. Fan
3. flow rate measurement
4. Filter
5. flexible tube
6. inlet for clean air, measurement point

7. pin-on-disc machine
8. pin sample
9. air outlet, measurement points
10. displacement gauge
11. dead weight
12. rotating disc sample
13. air inside chamber, well mixed.

The pin-on-disc machine is in a climate chamber, which allows testing at different temperatures and humidity levels. In these tests the climate chamber was used as a closed chamber with control of the cleanness of the incoming air. The fan (B) takes the air from the room (A) and passes it into the chamber (G) via a flow measurement system (C) and a filter (D) and through the air inlet opening (F). The connections between the fan, measurement system, filter and chamber were flexible tubes (E).

All connections from the measurement system to the chamber were sealed to prevent leakages. A leak would not disturb the tests, since the air pressure inside the tubes was higher than outside, but it would result in incorrect measurements for the airflow rate though the chamber and thus influence the particle concentration measurements. In the chamber the air was well mixed (N) due to the complicated volume of the pin-on-disc machine (H) and the high air exchange rate. This mixing was verified by the smooth particle concentrations measured during the tests. The air in the chamber transported the generated particles to the air outlet (J), where sampling points for the particle measurements were situated. The fan had a variable speed and was set to a flow rate of 7.7m3/h (2.1 L/s).

The chamber volume was 0.135m3, and the volume of the pin-on-disc machine was approximately 0.035m3, giving an approximate air change rate of 77/h (1.28/min). The measured flow rate varied somewhat during the tests, from 7.7 to 9.2m3/h. The latter value gives an air change rate of 92/h. The flow rate measurement system consisted of a straight calibrated tube with separate connections for total and static pressure, measured using an ordinary U-tube manometer. The system was calibrated in the flow interval 2–50m3/h. The filter (D) was used to ensure particle-free inlet air and was of class H13 (according to standard EN 1822) with a certified collection efficiency of 99.95% at MPPS (maximum penetrating particle size).

The particle-free inlet air was verified by monitoring it with a TSI P Trak instrument. Inside the chamber a small pneumatic tube was attached to the pin-on-disc equipment. The pressurized air was completely cleaned by a filter and was directed at the contact point with high velocity (>10 m/s) through two small nozzles. The aim was to minimize the number of particles stuck to the test materials and to simulate the air flow on the rotor in field. The air flow in these nozzles was 0.07–0.08 L/s, which increased the calculated air change for the highest air flow rate to 94/h. The air and the particles in the chamber were transported through the chamber to the outlet opening (diameter 80mm, the same as the inlet diameter) where the particle measurement sampling was done.

VI. CONCLUSION (FOR STAGE 1)

-Literature Review suggests that Load (Kg), Speed (rpm) and time (sec) have a significant effect on Wear rate, besides other factors.

-With the review of since the number of parameters and levels, the Taguchi method is found suitable for this case. The same is used to obtain optimum parameters combination for any desired rate of wear.

-The level of importance of Process parameters and their individual contributions on Wear Rate is determined using Analysis Of Variance (ANOVA).

-For Wear Rate, the setting for the response shall be “smaller is better”. The levels of significant factors which resulted in the optimum rate of wear shall be reviewed for recommendation.

VII. FUTURE SCOPE (FOR HIGHER RESEARCH WORK)

1. Investigation of the `Rate of Wear’ can be pursued using `Response Surface Methodology’ (RSM) or `Grey Relational Analysis’ (GRA).
2. Additional parameters could be identified for study which could influence the rate of wear under special circumstances
3. Analytical tools and techniques in the domain of `computational techniques’ could be explored
4. New and advanced composite materials could be experimented upon for realizing a better solution

ACKNOWLEDGEMENT

The effort for this work has been complemented with unwavering support and motivation from my college guide Prof. Dr. Sandip T. Chavan. The same has received attention and priority for analysis from the sponsoring company M/S Ethika Engineering Solutions (India) Pvt. Ltd, Pune. The experimentation could be organized and conducted with priority support from Prof P. B. Joshi (HOD Mech) at my own college. I also extend my heartful gratitude to all my fellow classmates, technical staff and contacts in the industry who have made this work enlightening for my current and future academic aspiration.

REFERENCES

[1] Jens Wahlströma*, Anders Söderberga, Lars Olanderb, Anders Janssonc, Ulf Olofssona[4]"A pin-on-disc simulation of airborne wear particles from disc brakes" Wear 268 (2010) 763–769
[2] C. Ferrer, M. Pascual, D. Busquets, E. Rayón∗ "Tribological study of Fe–Cu–Cr–graphite alloy and cast iron railway brake shoes by pin-on-disc technique" Wear 268 (2010) 784–789
[3] M. Martíneza, A. Massettia, H. Svobodaa,b,* "Effect of the pin geometry on the wear behavior of weld deposited hardfacing" Procedia Materials Science 1 (2012) 305 – 312
[4] M. Bezzazi a, A. Khamlichi a,*, A. Jabbouri a, P. Reis b, J.P. Davim b "Experimental characterization of frictional behaviour of clutch facings using Pin-on-disk machine" Materials and Design 28 (2007) 2148–2153
[5] Pa¨ r Marklund_, Roland Larsson"Wet clutch friction characteristics obtained from simplified pin on disc test" Tribology International 41 (2008) 824–830
[6] Jens Wahlström "A comparison of measured and simulated friction, wear, and particle emission of disc brakes" Tribology International 92(2015)503–511
[7] Saeed Abbasia,∗ , Anders Janssonb, Lars Olanderc, Ulf Olofssona, Ulf Sellgrena"A pin-on-disc study of the rate of airborne wear particle emissions from railway braking materials" Wear 284– 285 (2012) 18– 29
[8] J.R. Laguna-Camacho, G. Juárez-Morales, C. Calderón-Ramón, V. Velázquez-Martínez, I. Hernández-Romero, J.V. Méndez-Méndez [c], M. Vite-Torres[d] "A study of the wear mechanisms of disk and shoe brake pads" Engineering Failure Analysis 56 (2015) 348–359
[9] HiroyukiHagino*, Motoaki Oyama, Sousuke Sasaki"Airborne brake wear particle emission due to braking and accelerating"
Wear334-335(2015)44–48
[10] Piyush ChandraVerma [a], Luca Menapace [a], Andrea Bonfanti[b], Rodica Ciudin[a], Stefano Gialanella [a], Giovanni Straffelini [a,*] "Braking pad-disc system: Wear mechanisms and formation of wear fragments" Wear322-323(2015)251–258
[11] P.D.Neis [a],n, N.F.Ferreira [a], F.P.daSilva [b] "Comparison between methods for measuring wear in brake friction materials" Wear319(2014)191–199

BIOGRAPHY

Sanjay T Kakulate PG student, Mechanical Engineering Department, (M E Design Engineering) Maharashtra Institute of Technology, Pune

Sandip T Chavan is working as Professor in Mechanical Engineering in MIT Pune. He has completed his Ph.D. in Mechanical Engineering in 2010. He has completed his M.E. (Design Engineering), M.E. (Process Metallurgy) and M.B.A. from University of Pune. He has 26 years of teaching experience at under graduate and post graduate level. He is a research guide of University of Pune and six candidates are pursuing their Ph.D. under him.

Swapnil S Kulkarni Director, Ethika Engineering Solutions India Pvt. Ltd., Pune The Company offers Engineering Services and Manufacturing Solutions to Automotive OEM's and Tier I and Tier II Companies. He is a Graduate in Industrial Engineering with PG in Operations Management. With around 20 years of working experience in the domain of R&D, Product Design and Tool Engineering, he has executed projects in the Automotive, Medical and Lighting Industry. His area of interest is Research and Development in the Engineering Industry as well as the emerging sector of Renewable Energy.