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Effect of Temperature on Wear Rate and Coefficient of Friction of Railway Brake Block

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ABSTRACT

Braking is a very complex process in overall railway assembly, braking system has a great importance and contribution towards the safety. During braking a number of phenomenon occurred like mechanical, thermal, electrical etc. which led to the high forces act on the brake blocks of railway results in thermal cracks, reduced life of blocks. It is estimated that a minimum of 60 brake shoes or brake blocks are used in the railway wagons which have to be changed within a month. In our study, author investigated and analyzed the braking tribology characteristics i.e. to determine the wear rate and coefficient of friction at a constant frequency at different temperature by keeping the stroke length constant. The experiment reveals the rate of wear and coefficient of friction varying at ambient and in summers during to continuous exposure of brake block for a fixed distance moved. The experiment is performed on the liner reciprocating tribometer by using stainless steel pin without any aid of lubricating material.

Keywords: *Wear rate; Coefficient of friction; Railway brake block..*

1.0 Introduction

A railway brake is a type of brake used to de-acceleration, control the acceleration at time of uphill or downhill or to stop for the wagons of the railway trains. The basic principle of railway braking is same as vehicles running on the road while the operational features are more complex because of multiple linked carriage system and also effectively used to stop at the same time.

In the earliest days of railway, braking technology was primitive. The first train had brakes operative on the locomotive tender and they were called as potters or brakeman to stop the train. Some railways fitted a special deep-noted brake whistle to locomotives to indicate to the porters the necessity to apply the brakes. At this stage, all the brakes were applied by operation using the screw and linkage to brakes. The braking effort achievable here was limited and also unreliable as it was fully dependent on the listening on the brakeman.

Nowadays we use a frictional type of brake in which a fixed surface (shoe block) is brought into contact with moving parts to slow down or stop the vehicle named as railway brake shoes or railway brake pads. The process is known as shoe braking (or treads brake) .Brake shoe is a device for braking the moving group of cars and other type of rolling stock. In addition to the main task of braking the cars, the shoes are used to prevent the cars to move freely.

Shoe braking is obtained by direct pressure of brake blocks on the wheel tread. It is typical for freight trains and frequent for metro and suburban trains, either as unique braking system or coupled with other ones. Shoes braking power is limited and only applied when the speed is below 120km/hr.The application of shoe brake is raised in recent years due to its environment friendly coritents.

In shoe braking, brake block is pressed against the steel rim by the application of pneumatic pressure. During braking it is taken into consideration to employ continuous, constant (unfluctuating) and exact pressure so that brake remains into contact during operation.

Braking is a complex tribological phenomenon which occurs due to interaction of moving surfaces (i.e. brake block and steel rim). Brake block is a composite material which is employed to proper

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manveuring of the train. In braking, braking material (i.e. brake block) is pressed against the moving member by means of linkages or other means (like hydraulic or pneumatic). During braking, stationary member forces the moving member to stop by dissipating the kinetic energy (of moving member) into the atmosphere in the form of heat. During braking an extreme high temperature is reached at the shoe-tread interface which increases the chances of nucleation of surface cracks on the wheel and altering local and global stress-strain distribution. Braking effectiveness of shoe depends upon-

(i) wear rate (ii) coefficient of friction (iii) working temperature (iv) heat dissipating constant (v) application of constant pressure, etc.

A desired brake must possess rigidity, flexible to accommodate, heat conducting, wear behavior (also wear of counterface material), environment friendly, economical etc.

From Designing to application of braking material, different parameters affects its efficiency like material used, binder resin, manufacturing process employed, resins, load, pressure (contact force), velocity, conditions of applications (temperature), attack angle, cooling medium used (wet), etching brake block, cast iron is used which produced noise during braking, in order to reduce rolling noise produced by the roughness of the tread wheel surface. To reduce the noise Fe-Cu-Cr-graphite sintered alloy is used. Investigation unfold that sintered alloy has constant and 1.8 times the coefficient of friction compared to the cast iron brake block moreover friction coefficient in cast iron shoe decreases while friction coefficient increases in sintered alloy with increase in sliding friction velocity[1-2] Investigated that phosphorous cast iron with different graphite form doesn't affect the wear rate and coefficient of friction, with increase in sliding velocity rate of wear of cast iron increases up to a point then decreases significantly. With increase of both sliding velocity and contact pressure friction coefficient drops significantly at first, and then tends to be stable. Compacted graphite phosphorous cast iron has maximum coefficient of friction and minimum wear loss compared to grey phosphorous cast iron (both maximum wear rate and friction coefficient) and nodular phosphorous cast iron (good wear resistance but worst friction coefficient) [3]. Studied wear with silicon modified phenolic resin, straight phenol resin, boron phosphorus modified phenolic resin. Author investigation revealed variation of coefficient of friction with temperature due to thermal decomposition of binder resin. Friction materials with heat resistant pulp found to be with improved wear resistant and wear resistance is more pronounced at high temperature above the thermal decomposition temperature. At high temperature above critical temperature the thermal decomposition of resin of resin had a major impact on the abrasion rate, which contains random chain separation and carbonization.

During application of brake, wearing of brake block takes place but the amount of wear also depends upon friction coefficient, velocity and pressure. On further investigation it was found that with increase in pressure and velocity interface temperature also rises, which expedite the wearing of the brake block [4]. As the high temperature is reached, this causes damage to the wheel. The different method by which damage to the surface of the wheel takes place is ratcheting, surface crack nucleation and wear. The mechanism of substance transfer in tread damage plays a key role, in fact a "third body "layer is created. When the applied brake liner is released, it also includes the steel substrate, which probably promotes surface breakage. In addition, the abrasive waste produced produces advanced abrasive wear. The cracks thus formed can move above if the deposited fluid pierce through the opening (cracks) and under pressure of load, which results into breaking into smaller pieces or fragments [5-6].

Braking can be assisted with liquids for dissipation of heat generated at the interface of contacting surface so that life of shoe can be increased, chances of abrasive wear, adhesion wear can reduced to the minimal but the results were opposite. It was found that the coefficient of friction between the steel wheel and brake shoe in the wet state shows a significant decrease compared to the dry low speed position and the rate of decline is around 30%.Friction properties at high speed doesn't show much difference at high speed in dry and wet condition [7]. The water film reconstructs an instantaneous velocity of about .30m/s for poor water flow and .45m/s for strong water flow. Cultivated water in the gap produces a part of surface hypertension which causes serious gas damage to the brake shoes (pitting wear/damage) .A powerful water flow leads to greater wear loss and lower interface temperature at high speed (6.70-13.40m/s) [7]. Also with increase in speed, attack angle and axle load resulted in the wheel/rail adhesion coefficient being significantly reduced. Water lubricants can have a significant impact on the adhesive behavior of the wheel/rail. The addition of water to the wheel/rail surface would significantly reduce the coefficient of adhesion. Under water conditions, the adhesion coefficient would decrease with an increase in velocity and angle of attack [8].

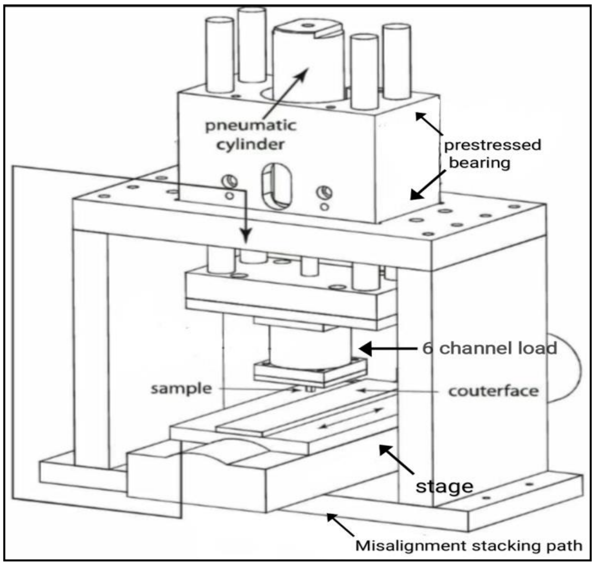
2.0 Experimental Methodology

The linear reciprocating tribometer is a floor standing model used for determining the frictional force and coefficient of friction to estimate the wear rate of a sample material. It is designed in such a way that it allows user to characterized Tribological performance of the material and lubricants in a wide range of operating conditions ranging from fretting wear to large amplitude linear sliding conditions. It can accommodate a variety of sample geometry to create point, line and area contact. It is connected with pc for sequence control and data acquisition with software. The linear movement is provided by the oscillatory movement of servo motor which is mounted vertically below base plate with its shaft projecting above it, also a crank is fastened to the shaft. The reciprocating rod is a long shaft having a specimen holding arm at middle supported; the upper specimen pin is clamped between jaws of holder. The bottom specimen 50✕50✕5mm is seated with in a holder; the holder is in the form of shallow bath having capacity to hold 20ml of oil. The specimen is clamped above a flexure with a heater block below it; heater block has a hole for temperature sensor used to measure temperature of lower specimen. After this the load is applied by dead weights on loading pan which pulls the shaft down to press the upper specimen against lower specimen.

The frequency of linear reciprocating tribometer may vary from 1Hz TO 50Hz depending upon the stroke length which also varies from 1mm to 20mm.the normal load can vary from 5N TO 50N in steps of 5N.the piezo sensor is used to measure the frictional force with a least count of 0.01N.

Author performed the experiment as shown in the figure. The experiments are held on the linear reciprocating tribometer to find the coefficient of friction and wear rate of the railway brake shoes at different temperatures. For Performing the experiment author prepared a piece of 25mm✕25mm from railway brake block and placed it into the cabinet of the size 30mm.

Figure 1: Experimental Test Bench



Authors also used a stainless steel pin having same composition to the railway wheel of 15mm stroke length holds at upper space of tribometer. The load is applied by upper space to the horizontal flat specimen. Here the load of 30N is applied at 15mm stroke length having frequency 10Hz.For first specimen we set the ambient temperature and time duration in the software and started the machine, upper specimen moves at a fixed stroke length on the specimen surface. The frictional force are measured by the sensors and displayed on the screen. After test the dimensional changes for both ball and specimen are used to measure the wear rate. Here we measure the weight of specimen before and after the test, there are some differences in their weight which we weigh by using the digital weighing machine having least count of 0.0001g and use to find the wear rate of brake shoes.

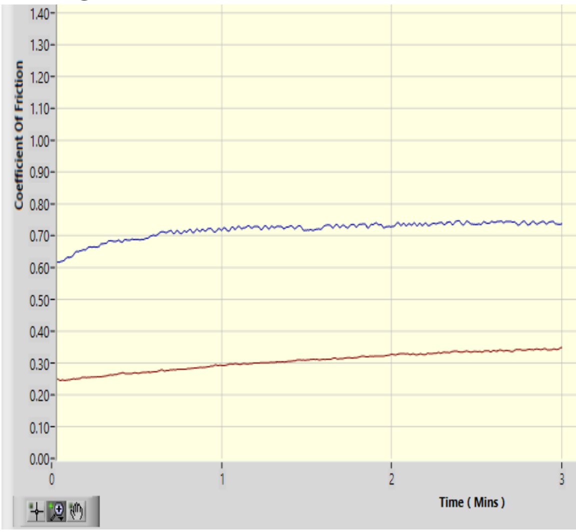
A similar phenomenon is used for the second specimen but with only difference is that the author set the temperature 45 degrees with the help of activating the inbuilt heater at the same load , stroke length and frequency. After the test we again weigh our piece as described above and determine its wear rate. We obtain some data in both the cases so we put these data in the software to get the graph and try to compare it.

Figure 2: Brake Shoe Surface Before Test

Figure 3: Brake Shoe Surface After Test

3.0 Result and Discussion

Figure 4: Coefficient of Friction v/s Time



As earlier author specified that they take two specimen for the test, weight of first specimen is 10.0022g while weight of second specimen is 10.5522g and after the test on the linear reciprocating tribometer for fixed time of 180 seconds their weight become 10.0012g and 10.5494g respectively. So by this the wear of the brake shoe first specimen is 0.0010g while other is 0.0028g.

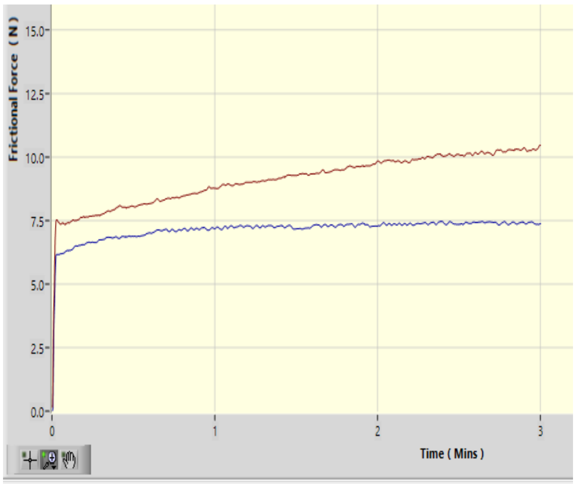
As per the graph (i), the following points were noted as follows:-

1. In case of first specimen(red) which is tested at room temperature coefficient of friction varies in range of 0.25 to 0.35.While in case of second specimen(blue) which is tested at the 45 degree Celsius, the coefficient of friction varies from the range 0.61 to 0.74 which is much higher as compared to the first specimen.
2. During 0-1 min, in specimen first the coefficient of friction significantly increases from 0.25 to 0.30 with a difference of 0.05 while in specimen second here too the coefficient of friction rapidly increases from 0.61 to 0.72 with a difference of 0.11 which is again much higher as compared to specimen first.
3. During elapsed time 1min to 2min, In first specimen there is no appreciable change in coefficient of friction as slope is much less dominating (0min to 1min) during this coefficient of friction varies from 0.30 to 0.32. While in case of specimen second, the coefficient of friction varies from 0.72 to 0.735 and again the slope is not as dominating as in the case of 0-1 min.
4. During elapsed time 2min to 3min, as in first specimen the coefficient of friction varies from 0.32 to 0.35 and has an observable slope as compared to 1min to 2min. While in case of specimen second coefficient of friction is not so much very and its slope look like constant, during this the coefficient of friction varies from 0.735 to 0.74 with a difference of 0.005 which is lower as compared to specimen first on their difference.

As per the graph (ii), the following points were noted as follows:-

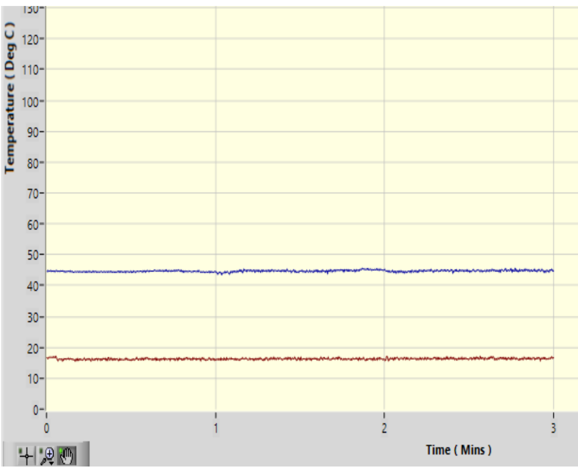
Frictional force directly depends upon (i) coefficient of friction and (ii) normal force in case of dry friction. There are two types of frictional force (i) static friction and (ii) kinetic friction. Static friction is the resistance offered by the object before coming into motion and kinetic friction is the resistance offered during motion. Static friction is always greater than kinetic friction. Static friction force can be calculated as the product of coefficient of friction and normal force acting on the body.

Figure 5: Frictional Force vs Time



From the graph, frictional force vs time for two specimen shows that kinetic friction is less than static friction in both the cases. Moreover, it is evident that static friction is more at lower temperature than at high temperature. In specimen 1(red) static friction is more even though the coefficient of friction (0.25) is less it means that static friction is more at lower temperature and the rate at which friction force increases during 0-1 minute is comparatively significant and large as compared to others time elapse and in case of high temperature static friction is less even though the coefficient of friction is more at high temperature and increases more rapidly than at ambient temperature.

Figure 6: Temperature vs Time



Friction force nearly becomes constant after some time as their is no appreciable change in friction force during 1-3 minute. As wear rate is more in 2nd specimen it shows that high temperature influence the wear rate, even though the frictional force is greater at lower temperature wear rate is also low.

From above graph, it is clear that there is no appreciable changes in temperature of the cavity on which thermocouple were embedded to measure the temperature. Test pieces after proper sizing were seated in the cavity, if during experiment temperature rises due to rubbing between test piece and pin, that would have caused some fluctuation in the temperature which would be recorded by the embedded thermocouple but co- incidentally there wasn't .It means heat generated during the experiment at interface was efficiently distributed and diffused in the atmosphere and hence there was no appreciable damage to piece which increases the operational life of the brake block.

4.0 Conclusions

From above discussion we found the following results are as follows:-

1. The coefficient of friction is much higher as compared to coefficient of friction at lab temperature.
2. It is found that coefficient of friction is found to start with high initial value and rise rapidly during 0-1min but in the rest of the time span there is no appreciable rate of change in friction coefficient with time in case of high temperature application while in case of lab temperature , coefficient of friction starts initially with lower value and progresses with nearly high constant rate during 0-1min as compared to the rest of time and attains a final value which is much lesser than the initial value at high temperature.
3. From graph 2, it is clear that frictional force is greater at low temperature as compared to high temperature even though friction coefficient is low for same parameter and maximum value attained at high temperature is lower than minimum value during low temperature. Both static and kinetic friction is greater in case of low temperature as compared to other, that means braking are more efficient at lower temperature.

4. The weight of pin remains unchanged during testing of 1st specimen and only the weight of the specimen reduces(i.e 0.0010g wear) it means that at lab temperature(18 degree celsius) wear of the wheel will be minimum which will increase the life of the wheel. But at high temperature there is wear in both pin and specimen (i.e wear of 0.0028g in specimen and 0.0002g in pin) which means at higher temperature wheel will wear along with the brake block and hence both the materials will wear resulting in net increase in operational cost of railway during operation at high temperature.

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