PERFORMANCE OF A NAO FRICTION MATERIAL FOR DISC BRAKE

Pradnya Kosbe[1], Chittaranjan More [2]

[1]Department of Mechanical Engineering, Pune University, Jayawantrao Sawant College of Engineering, Pune, India.
[2]Indira College of Engineering and management, Parandwadi Pune,India.
Email: [1]pradnyakosbe@gmail.com

Abstract

The purpose of brake is to decelerate a vehicle by transforming the kinetic energy of the vehicle to heat via friction and dissipating that heat to the surroundings. As a part of an automobile, brake materials have additional requirements like resistance to corrosion, light weight, long life, low noise, stable friction, low wear rate and acceptable cost versus performance. Selection of the material is often based on experience or a trial and error method. This paper deals with the performance of a NAO(Non asbestos organic) disc brake friction material for a four wheeled vehicle. There are different friction performance properties such as base line check, average coefficient of friction. The physical properties are studied according to Indian standards. The results are discussed and correlated to the observed friction phenomenon.

Keywords: Coefficient of friction, speed, disc brake, NAO.

I. INTRODUCTION

The friction materials used in brakes are required to provide a stable coefficient of friction and a lower wear rate at various operating speeds, pressures, temperatures and environmental conditions. These friction materials must also be compatible with the rotor material in order to reduce its extensive wear, vibration and noise during braking.

First brake lining material was invented in 1897. It was a cotton-based material impregnated with bitumen solution and was used for wagon wheels as well as early automobiles. This invention led to the founding of the Ferodo Company, a firm that still supplies break friction materials today. The first brake lining materials were woven but in the 1920's these were replaced with moulded materials that contained crysotile asbestos fibres, a plentiful mineral [3]. Resin-bonded metallic linings were introduced in the 1950's and by the 1960's so-called 'semi-metallic material' were developed. These contain a higher amount of metal additives [5].

In the past 20 years, rapid developments in the automotive industry have been accompanied by increase of speed, loads and engine power. A commercial brake lining usually contains more than 25 different constituents. Selection of the constituents is often based on experience or a trial and error method to make a new formulation [6].

A. Brake Pad Assembly

Disc brake pads consist of steel backing plate to which the pad is riveted or bonded. Brake pad materials are made of either asbestos (asbestos fibre filled), semi metallic (metal particle filled) and non asbestos organic friction material. Many new vehicles, especially those with front-wheel drive use NAO disc brake friction material.

Friction materials can be considered as composite materials which Anderson classified as organic, carbon-based and metallic. According to Bergman et al. and Jacko et al., there can be up to 25 components of an organic brake pad which are collectively termed the friction material. These components can be divided into five categories:

- A matrix, which is composed of a binder and other materials
- Fibres
- Abrasives which include metallic articulates
- Mineral fillers which serve to improve manufacturability
- Solid lubricants

The binder is usually composed of a thermosetting polymer with some possible additions of rubber and cashew nut resin. Pertaining to the fibres, Anderson notes that there are three types which are used: asbestos, non-asbestos organic and resin bonded metallic (semi met or semi-metallic) [1]. Due to health issues and public awareness, substantial attention has been recently focused on friction materials with non-asbestos organic fibres. The metallic particulates serve to control the wear and thermal properties of the friction material and the solid lubricants serve as stabilizers for the friction coefficient [3]. The precise mixture of the five components employed in a friction material depends on the wear, thermal range of operation and friction coefficient required [1]. The operating temperature range discussed in the literature is usually from 0 to 500°C. At the upper extremes of this range, the wear rate of the friction material increases exponentially [1].

B. Regulations and the current use of asbestos in brakes

Medical research showed that asbestos fibres can lodge in the lungs and induce adverse respiratory conditions. In 1986 the Environmental Protection Agency (EPA) announced a proposed ban on asbestos. The ban would have required all new vehicles to have non-asbestos brakes by September 1993 and the aftermarket would have had until 1996 to convert to non-asbestos. The EPA's proposed ban was overturned in federal court but it resulted in a major shift away from asbestos by most friction material suppliers and vehicle manufacturers [3].

The selection of the ingredients and composition in the formulation have been largely depend on experience. Recently several methodologies for optimization of the multicomponent friction material have been reported. However analysis of the physical properties, friction material ingredients, performance and wear characteristics is still very limited partly due to proprietary reasons and also because of difficulties in obtaining unambiguous conclusions from the complicated material system.

C. Non asbestos organic brake linings

Both low metallic and non-metallic brake linings are frequently called non-asbestos organic (NAO) brake linings. A typical NAO pad consists of a polymer/ ceramic/ metallic fibres, binders, fillers, abrasives and solid lubricants. The fibrous reinforcement provides strength, stiffness, thermal stability, wear resistance and stable frictional properties to the lining. The fillers are inert materials whose primary role is to adjust the relative volume fractions of other constituents. The binder is generally a thermosetting phenolic resin. Abrasives are used to generate friction. The lubrication provides friction stability and controls lining and rotor wear [3].

D. Constitution of non asbestos organic friction material

The constituents of this is given as follows

1. Binding agent

The binding agent or resin system forms the major organic portion of all modern non asbestos organic friction material formulation, usually anywhere between 25 to 40% of the component by weight [2]. Friction material formulation currently represents about 1% of the world wide consumption of phenolic resin. A great verities of phenolics exists e.g. modified resin, cashew nut shell liquid modified resin, epoxy modified resin etc. are used in non asbestos friction lining material [1].

2. Abrasives

Abrasive particulates may be added to a friction material formulation in order to attain an increased level of dynamic friction. So that such materials are capable of generating an increase in the friction level when coupled with grey cast iron. Abrasive particulates also serve to clean up the disc. Their abrading action ensures homogeneity (both in nature and in thickness) of the crucial third body layer. There is considerable influence on the wear rate of both triboelements which may be either beneficial or deleterious demonstrating the importance of their careful control [2].

Although abrasive friction modifiers exhibit many common properties e.g. they are all virtually insoluble and exhibit high hardness to elevated temperature. These additions are critical and being extremely sensitive to chemical nature, hardness, toughness, size, morphology and distribution [2].

Commonly used abrasives include alumina (Al_2O_3), silica (SiO_2), magnesia (MgO), magnetite (Fe_3O_4), chromia (Cr_2O_3), silicon carbide (SiC – carborundum) and zirconium silicate ($ZrSiO_4$) etc. Despite repeated references to mineral grades, abrasive friction modifiers must usually be of a highly pure form [2], [3].

3. Solid lubricants

Solid lubricants are a distinct class of friction modifier that aid in the formation of the third body layer (T.B.L.) acting at the friction interface and in particular on the surface of the cast iron counter member. They provide friction stability over given ranges of interfacial temperature. They reduce the wear of the friction material component and enable the minimization of slip-stick interactions. Individual lubricants remains effective over specific temperature ranges so that high energy pads usually contain a combination that selectively maintains their effects throughout the permissible operating regime [2].

In the brake lining, solid lubricants are added in relatively small amounts but strongly affect various brake performance such as wear resistance, stopping distance, friction stability and noise propensity [7]. The effectiveness of solid lubricants is strongly affected by temperature, pressure, speed and environmental conditions. Metal sulphides are known to modify and stabilize the coefficient of friction. Commercial sulphides available in the market are Antimony trisulfide (Sb_2S_3), Copper sulphide (CuS), Zinc sulphide (ZnS), Cu_2S [3], [9].

4. Fillers

Fillers represent the major constituent of non asbestos organic brake pad materials. It is generally a combination of relatively inexpensive minerals and fibres [2]. The most important of which being described as follows Steel Wool, Potassium titanate and aramid pulp, Barytes ($BaSO_4$), Calcium Carbonate ($CaCo_3$), Calcium Hydroxide $(CaOH)_2$.

II. EXPERIMENTS

In this work we focused on the study of physical properties and brake performance of commercial NAO disc brake pad material. Numbers of characterization methods are applied to disc brake pad materials.

The vehicle under consideration is a four wheeled, fitted with disc brakes for the front wheels and shoe brakes for the rear wheels. It is a rear wheel drive vehicle. Commercial brake pad material is used for the brake assembly of specified vehicle. The behaviour of this material was studied under different conditions.

A. Physical properties

Heat swell was obtained by measuring the blank thickness at different five different points equally spaced along the length and at the centre along the width. The thickness was measured at ambient temperature and after soaking in a muffle furnace for 30 minutes at 300°C.It is the average difference in thickness as measured at ambient and at 300°C.The average difference in thickness is the heat swell. Water swell was found out for checking the absorption of water by the material. It is the average difference in thickness of specimen (50 mm $\times$ 25 mm) measured along the length at five points and at the centre point of the specimen width before and after soaking in water for 30 minutes. Hardness of the disc brake friction material was measured using a Rockwell hardness tester with R scale. Density was measured using CONTECH (CA 123) digital density meter.

B. Brake performance characteristics

To evaluate the brake performance characteristics of disc brake pad assembly intended for specified vehicle, four wheeler inertia brake dynamometer as shown in Fig.1 and brake pad assembly were used.

The inertia for this test is 90 kg.m^2. The fixture of calliper disc brake pad assembly is mounted on the tail stock end of dynamometer. The disc is mounted. The disc pad assembly is positioned properly onto the calliper. Different tests are conducted as mentioned in Table 1 to determine friction characteristics.

1. Motor, 2. Flywheels, 3. Brake disc, 4. Caliper, 5. Power transfer axle 6. Loadcell

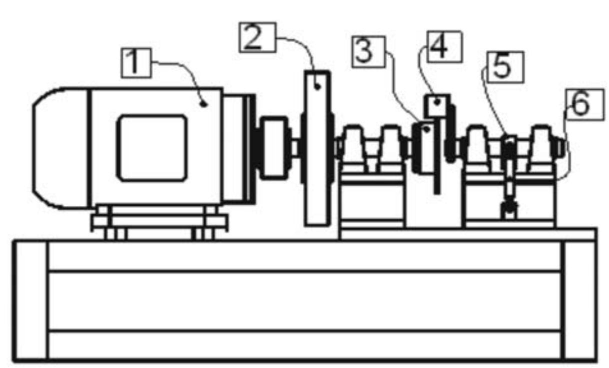

Fig. 1 Block diagram of inertia dynamometer

Table 1. performance characteristics tests parameters

Test	Parameter
Preburnishing	Number of stops:20 Speed:80 km/hr Pressure:45 bar Initial brake temperature(IBT): 90°C
Bedding in test	Number of stops:50 Speed:50 km/hr Pressure:45 bar IBT: 90°C
Performance at different speeds	Speed:30, 50, 80, 100, 120, 140 km/hr Pressure:20 to 120 bar IBT: 90°C Note: Increment of pressure is 20 bar at each speed

III. RESULTS AND DISCUSSION

A. Physical properties

The measured values of physical properties are given in Table 2.

Table 2. Physical properties

Physical Property	Value
Heat swell at 300°C	Less than 0.05 mm
Water swell test	Less than 0.02 mm
Density	3.38 gm/cc
Rockwell Hardness (R scale)	90 to 95

B. Brake performance characteristicsx

The dynamometer test started with preburnishing or prebedding. This test was carried out for initial checking of the dynamometer and brakes functioning. The friction material was new at this stage so there was not a proper contact between friction material and rotor. Due to this at the initial stage the coefficient of friction (μ) was low. The value of prebedded μ for this pad grade is given in Table 3. After prebedding test bedding in test was done.

When the proper contact was achieved between rotor and disc pad, the stable friction film formation was achieved between the two triboelements [10]. The braking effectiveness was almost stable and it gave the stable μ for the tested pad grade during bedding in cycles.

Table 3. performance characteristics

Parameter	Value
Prebedded μ	0.422
Bedding in μ	0.422
Min. μ	0.352
Max. μ	0.482
Average μ	0.403

C. Effect of pressure and speed

The performance of disc brake system was carried out at different pressures and speeds. It was observed during the braking effectiveness test, friction material (Ref. Fig. 2 and Fig. 3) gave high coefficient of friction for 80 kmph.

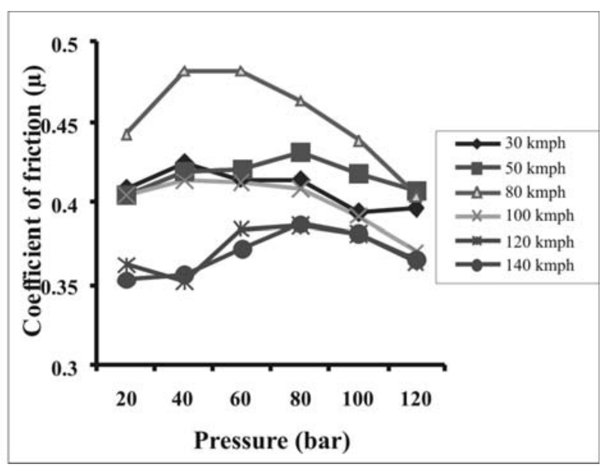

Fig. 2. Effect of pressure on coefficient of friction

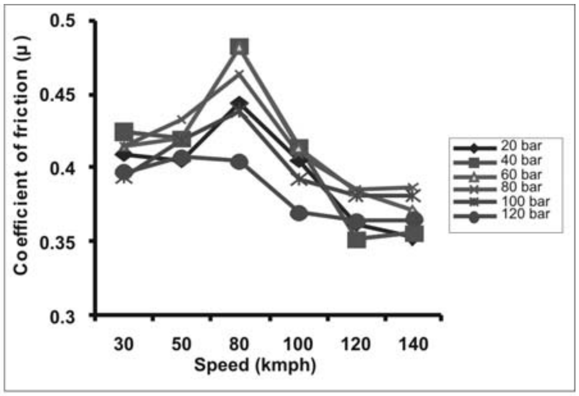

Fig. 3. Effect of speed on coefficient of friction

IV. CONCLUSION

The coefficient of friction variation is determined at various speeds and pressures. The coefficient of friction increased with increase in speed from 20 kmph to 80 kmph and then continuously decreased from 80 kmph to 140 kmph. The maximum coefficient of friction was observed at 80 kmph. This material gave almost stable coefficient of friction.

REFERENCES

[1] Bijwe J., Nidhi, Mujumdar N., Satapathy B.K., "Influence of modified phenolic resin on the fade and recovery behavior of friction materials", Wear 259(2005)1068-1078.

[2] Eggleston D. (Technical Manager)-Precision disc castings ltd., "EURAC-Technical bulletin 00010433" (2000).

[3] Peter J. Blau, "Compositions, functions and testing of friction brake materials and their additives", prepared for U.S. Department of Energy under contract DE-AC5OOOR22725.

[4] Ho S.C., Chern Lin J.H., Ju C.P., "Effect of fiber addition on mechanical and tribological properties of a copper/phenolic based friction material", Wear 258 (2005)861-869.

[5] Boz M., Kurt A., "The effect of Al2O3 on the friction performance of automotive brake friction materials", Tribology International 40(2007)1161-1169.

[6] Hee K.W., Filp P., "Performance of ceramic enhanced phenolic matrix brake lining materials for automotive brake lining", Wear 259(2005)1088-1096.

[7] Ling Han, Li Huang, Jinsheng Zhang, Yafei Lu, "Optimization of ceramic friction materials", "Composites, Science and Technology" 66 (2006) 2895-2906.

[8] Disc brake assembly", Construction Mechanic Basic Volume 02 - Construction methods and practices.

[9] Min Hyung Cho, Seong Jin Kim, Keun Hyung Cho, Ho Jang, " Complementary effects of solid lubricants in the automotive brake lining", Tribology International 22 (2006).

[10] Kim J., Cho M.H., Lim D., Jang H., "Synergistic effects of aramid pulp and potassium titanate whiskers in the automotive friction material", Wear 251 (2001) 1484–1491.