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FAILURE OF FRICTION BRAKE PAD AGAINST RAPID BRAKING AND IT'S LIFE ENHANCEMENT

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Abstract - This Disc brake have evolved to be a reliable method of decelerating and stopping a vehicle. There have been different designs of disc brake systems for different applications. This review describes different aspects of the components and the materials used in a disc brake system. Despite all the improvements, there are still many operational issues related to disc brakes that need to be understood in greater detail and resolved. The basic principle used in braking systems is to convert the kinetic energy of a vehicle into some other form of energy. During a braking operation not all the kinetic energy is converted into the desired form, some energy might be dissipated in the form of heat and vibrations. Graphene is still a very new material, especially in friction brake compounds. Due to its unique properties and years of testing, we were able to develop a friction material like no other. In the automotive industry, where every major car maker has already filed several patent applications for friction compounds containing graphene, it's clear to see that it is the future of braking pads. New regulations which start from 2025 will prohibit the use of copper powder in disc pads. Graphene is not only an excellent substitute for copper, but a major upgrade in terms of performance.

Key Words: Friction Brakes, Disc Brakes, Braking Systems, Brake pads, Heat Transfer, Heat Management, Wear Testing , Wear modeling, Material Doping, Pin on Disc, etc.

1. INTRODUCTION

The advancement of technology to achieve braking systems, with improved performance continues, to ensure safe and stable braking. Such improvement has been brought to the disk braking system by the addition of disks of ferrite magnets, reducing both the time and the braking distance, resulting in safe and smooth braking even at high velocities [1].

Several studies and research have been performed to improve the braking system performance of motor vehicles [2,3] through:

- materials used, in particular, for those of contact surfaces;
- design of the whole assembly of the braking system including the parts
- braking system behavior over time, assessed using simulations and field testing
- drive type of the braking system: mechanical, electric, electro-mechanical regenerative, magnetic, hydraulic, pneumatic, or vacuum.

A braking system is essential for the proper operation in road traffic conditions and the safety of a vehicle. Over time, the reliability and efficiency of braking systems have been continuously improved [4]. The braking couple represents the main feature of these systems, and its reliability and durability, or other braking system components, ensure a reliable braking function, without interruptions or defects [3].

Velocity control is the brake's main function, and the energy dissipation rate defines the deceleration rate of the vehicle. The braking system elements must increase the force exerted on the brake pads by the driver's foot. As a result, supplementary control and assistance systems were added to the basic equipment of the braking system, to help the driver in difficult and critical situations and to provide increased comfort in traffic conditions [5].

1.1 Classification of Braking System:

Braking systems are defined on the following basis:

- On a Power Source Basis
- On a Frictional Contact Basis
- On Application Basis
- On Brake Force Distribution Basis

On Frictional Contact Basis:

There are 2 types of frictional contact to decelerate or stops vehicle given below:

1.1.3.1. Drum Brake or the Internal Expand Brake

1.1.3.2. Disc Brake or the External Contract Brake

In a disc brake system, a set of pads is pressed against a rotating disc and due to friction, heat is generated at the disc-pad interface. This heat ultimately transfers to the vehicle and environment and the disc cools down. A simplified disc brake is shown in Figure 7 with the terminology that is in common use. The pad which is nearer to the center of the vehicle is called the inboard pad while the one that is away is called the outboard pad. Similarly friction surface of the disc that faces toward the vehicle is called the inboard cheek and the one that faces away is called the outboard cheek. The edge of the pad that comes into contact with a point on the disc surface first is called the leading edge while the edge that touches that point last is called the trailing edge. The edge of the pad with a smaller radius is called the inner edge while the one with a larger radius is called the outer edge [6].

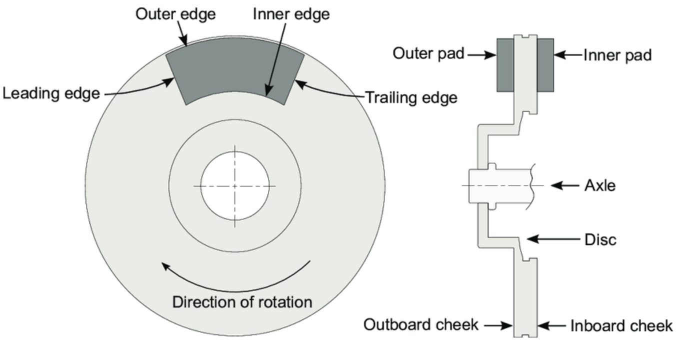


Figure 7: Disc Brake components [6]

A disc brake assembly consists of the following major components: brake disc, pad, underlayer, back plate, shim, and caliper. Now these components will be described in more detail.

1.1.3.2.1 Brake disc:

The brake disc, also called the brake rotor, is fixed to the axle, so it rotates at the same speed as the wheel. The braking power of a disc brake is determined by the rate at which kinetic energy is converted into heat due to frictional forces between the pad and the disc. For an efficient brake design, it is also important that heat is dissipated as quickly as possible otherwise the temperature of a disc might rise and affect the performance of a disc brake. So to get optimum performance in demanding applications, ventilation is introduced in the brake discs which increases the cooling rate.

1.1.3.2.2 Brake pad

A brake pad consists of a friction material that is attached to a stiff back plate. Figure 11 shows a brake pad attached to a back plate. Sometimes the friction material and back plate together are called a brake pad. A brake pad usually incorporates slots on its face and chamfers at the ends. A pad can have more than one slot and it could be arranged in different orientations. One purpose of incorporating chamfers and slots is to reduce squeal noise [7, 8, 9]. Relatively higher temperatures at the pad surface than the interior will result in convex bending of the pad [10, 11]. A slot will allow the material to bend and help avoid cracks. Furthermore, it facilitates cleaning the dust collected between disc and pad surfaces by offering an escape.

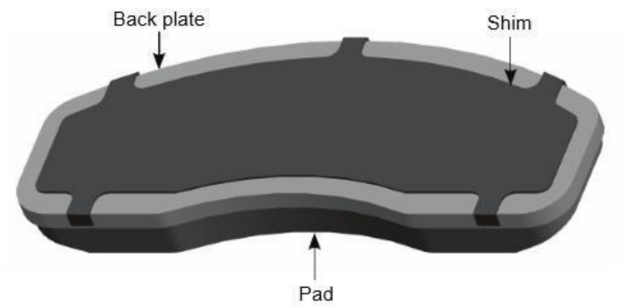


Figure 11: An assembly of pad, back plate, and shim [6].

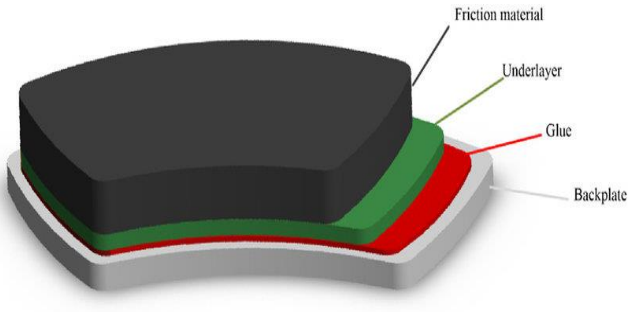


Figure 12: Schematic representation of different parts that make up a pad assembly [6].

Under layer

Sometimes an additional layer of material, called under layer or substrate, is placed between the friction material and the back plate as shown in Figure 12. Its main purpose is to damp vibrations originating at the disc-pad interface [12,13,14].

Backplate

A back plate is used to support the friction material and transmit the actuation force. The friction material is mostly attached to the back plate in two ways, adhesive bonding and mechanical retention. Mechanical retention can be achieved in different ways. One way is to weld studs to the back plate that protrude into the friction material as shown in Figure 10a. Another way (patented [15]) is to gouge hooks on the surface of the backplate as shown in Figure 10b. In a similar way (patented [16]) undercuts are created in the back plate which mechanically engages the friction material. Adhesive bonding can delaminate during service so mechanical retention systems are preferred.

Shims

Shims are laminates of metal and viscoelastic materials. They are placed between a back plate and a piston or caliper housing (in the case of a floating caliper). Their purpose is to dampen the vibrations in the disc-pad system [17]. They are usually attached to the back plate with an adhesive or assembled mechanically. Shims can be constructed in various ways and materials e.g. steel core with viscoelastic material on both sides or viscoelastic material core with steel on both sides.

1.1.3.2.3 Brake caliper

A brake caliper is an assembly that houses the brake pads. In addition, it also houses the pistons and provides the channels for the brake fluid which actuates the pistons. There are two types of calipers, fixed and floating. A fixed caliper does not move relative to the brake disc and houses the pistons on both sides of the disc as shown in figure 13. When pressure is exerted both pistons move and push the brake pads. A floating caliper houses the piston only on one side of the disc. When pressure is exerted, the piston moves and pushes the inner brake pad. When the pad contacts the disc surface, the caliper moves in the opposite direction so that the outer pad also contacts the disc surface. In this design, the inboard pad is also called a piston-side pad, and the outboard one is called a finger-side pad. In general, the inner and outer pads show different contact pressure distributions and wear behaviors [18] due to different support and actuation systems and differences in thermal deformations of the inboard and outboard cheeks of a disc.

1.2 Causes of Brake Failure

Manufacturers are required by law to design and engineer cars that meet a minimum safety standard. While advancements are being made every day to improve the safety and efficiency of automobiles on the road, problems with the design and functionality of the cars themselves sometimes referred to as product liability are one of the top causes of car accidents on the road. Even with safety standards and extensive testing on every automobile manufactured, there are a significant amount of defective cars on the road. [19].

Three main types of failure may occur:

1.1.1 Failure in Brake Pad

1.1.2 Failure in Disc or Rotor

1.1.3 Failure in the Brake Line

1.4.1 Failure in Brake Pad

1.4.1.1 Friction lining comes loose from the base plate

The friction lining has come loose from the lining's base plate, either in full or in part.

Causes:

- Thermal or mechanical overload
- Subsurface corrosion between the lining and base plate
- Insufficient fitting accuracy of the brake pads
- Damage to the brake pad due to incorrect handling or installation
- Non-compliant brake pad

1.4.1.2 Thermal overload

The brake pad has been damaged due to overheating. The binder in the pad has been destroyed and the pad material is breaking down. The surface is porous and glazed in parts.

Causes:

- Sticking or tight guide sleeves
- The brake piston stuck within the brake caliper
- Extreme driving conditions or sustained braking
- Sticking brake pad

1.4.1.3 Grooves in the friction lining

The pad surface has a deep groove and wear edges.

Causes:

- New pads have been installed on the old, worn brake discs
- Foreign bodies between the brake pad and disc
- Environmental influences (salt, dirt, etc.).

1.4.1.4 Material and edge chunking on the friction lining

The friction lining is damaged. The lining material has broken off at the edges

Causes:

- Incorrect installation
- Incorrect, non-compliant brake pads
- Lack of freedom of movement for the brake caliper
- Mechanical overload
- Thermal overload

1.4.1.5 Excessive wear

Brake pads are heavily worn and have worn down to the base plate in some cases.

Causes:

- Deficient maintenance
- Exceeding the inspection intervals
- Sustained braking during downhill driving
- Sticking or tight guide sleeves

- The brake piston stuck within the brake caliper
- Extreme driving conditions or sustained braking
- Sticking brake pad

1.4.1.6 Uneven lining wear

The brake pads on one side of the wheel brake have been worn down unevenly.

Causes:

- Sticking or tight guide bolts or caliper guides on the brake caliper
- The brake piston stuck within the brake caliper or brake pad wedged in the caliper slot

1.4.1.7 Glazing of the friction lining

The friction lining has a hard, smooth, polished-looking surface that reflects incident light and is similar to a glass surface. This defect generally occurs on new brake pads with minimal time in service

Causes:

- Overload of the brake pads in the bed-in phase
- Repetitive high-temperature change on the brake pad at short intervals
- Long braking phases with low pedal pressure

1.4.1.8 Contamination of the friction lining surface

The brake pad has been contaminated by grease, oil, or other foreign substances.

Causes:

- Deficient maintenance work
- Defective drive shaft joints
- Leak in hydraulic brake system

1.3 Lifespan of Your Brake Pads

Many car manufacturers estimate that a braking pad can last anywhere from 20,000 to 70,000 miles. However, on average, most car owners replace their brake pads after about 40,000 miles. Back in the 1950s and 60s, the asbestos pad was the go-to option for disc brake pads. Unfortunately, asbestos pads had severe environmental and public health consequences, leading to their discontinuation [20].

1.3.1 The Organic Brake Pad: Your Affordable

Organic brake pads are made of brake material like glass, fiber, carbon, rubber, and kevlar mixed with resins. They have the lowest lifespan of about 30,000 miles for all three types of brake pads and are easily subject to brake fade.

1.3.2 The Semi-Metallic Brake Pad

Semi-metallic pads (metallic brake pads) are made for performance with extended durability and a much better braking response than organic pads. You can expect a semi-metallic pad to last for about 50,000 miles.

1.3.3 The Ceramic Brake Pad

Ceramic pad car brake systems are found on luxury cars and are meant for comfortable braking. Carbon ceramic brakes aren’t meant for use in high-performance conditions but have a long lifespan of about 70,000 miles.

2. LITERATURE REVIEW

Andrzej Borawski et al. (2022) The braking system is one of the most important components in any motor vehicle. Its proper function in emergencies may save road users' lives. Today, as vehicles have more and more power at their disposal, leading to increased acceleration and maximum speed, the issue of effective braking is particularly important. It must also be noted that brakes are used in harsh conditions (water and salt, especially during winter), and must provide appropriate durability (on average, circa 30,000 km). For these reasons, many institutions conduct research aimed, among other things, at minimizing fading. However, this study looked into a different matter, focusing on how the operating conditions mentioned above, including the lifespan of brakes, impact the tribological properties of the friction pair. To achieve this, samples from brake pads were obtained (both brand new and used). Next, using a pin-on-disc tribological test, it was shown that the pads have lower coefficients of friction and abrasive wear rates. The results indicated that both parameters change in a manner that is dependent on how long the brake system has been in use [21].

Filip Ilie et al. (2022) For road safety, braking system performance has become a very important require

ment for car vehicle manufacturers and passengers. To this end, vehicle designers must understand the characteristics of tribological behavior and the causes of their variation in properties. This paper analyzes the tribological behavior (at friction and wear) of the most recent material couples of the braking disk-pad system affected by their structural change through the implications on the braking system stability, reliability, and suitable characterizations. Obtaining information to design a very efficient braking system and assessing the influence of the material's structural changes on its stability has become a necessity. This has been made possible by using several methods of testing a brake disk-pad couple on various devices intended for this purpose. The materials of the contact surface disk-brake pad with their tribological performance (friction, wear), especially the friction coefficient, present particular importance. Also, system components' reliability, heat transfer, and the noise and vibration of the brake disk-pad couple are vital to the correct operation of the braking system and should be given special attention. The test results obtained define the friction patterns and the influence of structural changes and other environmental factors that can be used in computer analysis. [22]

Mufti Reza Aulia Putra et al. (2021) In general, the braking system used a friction principle. The friction appears between the disk pad and the disk rotor. The friction on the disk pad and disk will cause damage to the surface of the braking components. The use of a friction-based braking system requires regular maintenance. The treatment is used to maintain the performance of brake components. In general, the brakes wear on the rapid braking process. The friction will affect heat generation, and heat generated will be released to the environment. But, in a rapid braking process, the heat dissipation capability will decrease. The overheating disk will increase the risk of disk damage. The damage is caused by the braking behavior and the selection of materials used as brake components. Material changes will help improve braking performance. A good braking performance can be found when it is capable of high heat dissipation and wear resistance. A better material selection will change heat dissipation capability and has high wear resistance is very necessary. Besides the materials, the design of the brake components is also important. The use of a ventilated brake design with an additional heat pipe can reduce temperatures by up to 10% compared to conventional ventilated disks [23].

Kumar N. et al. (2021) Today, in the fast-moving world, the focus of all automobile companies is to increase the speed of vehicles to reduce travel time. With an increase in the speed of vehicles, there is an urgent need for the development of friction materials suitable for high-speed braking applications. A historical review of various materials used to date for making brake pads and brake drums/discs is done in the present work. Asbestos was the most suitable and widely used brake lining material, but its carcinogenic nature has forced the health and environment agencies to ban it. Ban on the use of asbestos has forced researchers to develop asbestos-free brake friction materials. Today, the non-asbestos organic type of brake pads are the most widely used. However, non-asbestos organic type brake pads wear out rapidly and generate lots of wear debris. Wear debris generated from braking materials is a cause of concern to health and environmental agencies. So, researchers are working on developing environment-friendly brake friction materials for all-weather high-speed braking applications. Natural fiber or agricultural waste-based brake pads are considered the future material for brake pads. At the same time, cast iron was the most commonly used material for brake discs or drums. Today, various materials such as aluminum matrix composites, carbon-carbon composites, and ceramic-based materials are used to make brake discs or drums. However, the use of cast iron is still preferred. Aluminum matrix composite is considered the future material for brake discs or brake drums because of its low density and improved braking stability [24].

Andrzej Borawski (2020) The brake system must be reliable and display unchanging action throughout its use, as it guards the health and life of many people. Properly matched friction pair, a disc, and a brake pad (in disc brakes) have a great impact on these factors. In most cases, the disc is made of grey cast iron. The brake pads are far more complex components. New technologies make it possible to develop materials with various compositions and different proportions and connect them permanently in fully controllable processes. This elaboration shows that all these factors have a greater or lesser impact on the coefficient of friction, resistance to friction wear and high temperature, and the brake pad's operating life. This review collects the most important, the most interesting, and the most unconventional materials used in the production of brake pads, and characterizes their impact on the tribological properties of pads [25].

Kartik Bhasin (2019) Mechanical brakes all act by generating resistance forces, as 2 surfaces rub against one another. The stopping power or capacity of a brake depends more on the surface area of frictional surfaces as well as on the actual force applied. The friction and wear encountered by the operating surfaces square measure severe. Thus, the durability of a brake or service life between maintenance depends heavily on the type of material used to line the brake shoe or pads. They use levers or linkages to transmit force from one purpose to a different Most brakes unremarkably use friction between a pair of surfaces smooth on to convert the energy of the moving object into heat, though other methods of energy conversion may be employed.

The anti-braking system has gone through several changes since its invention all the changes are aimed at improving its performance and safety. The advancement in technology has had a lot of contributions towards the improvement or implementation of the automobile braking system. For instance, the production of anti-braking systems is a huge step towards improving the safety of automobile braking systems. The opposed braking systems are created in such a way that they will sense associate degrees and avoid associate degree-at-hand collision with an obstacle with no input from the driving force [26].

Ali Mohammadnejad et al. (2019) This paper investigated a failure in a ventilated disc brake in an automobile. The failed brake disc had been in service for approximately 10 years. The observed failure was in the form of radial cracks that appeared to have initiated at the outer edge of the disc brake. The cracks were rather straight with no branching. An optical microscope, scanning electron microscope (SEM), and energy-dispersive X-ray spectroscopy (EDS) were used to study the microstructure of the failed disc. Vickers microhardness test was also used to evaluate the hardness of the samples. Results showed that the root cause of crack formation, in this case, was related to the excessive wear in the brake disc. Different wear mechanisms, namely abrasive and adhesive wear, were recognized in the failed specimen. Moreover, the worn surface in some areas was covered with fine oxide particles. These particles appeared to have a significant contribution toward abrasion. To further understand the wear mechanisms, pin-on-disc experiments were also conducted on the samples. The results of the pin-on-disc experiments were compared and correlated to the results obtained from the failed brake disc [27].

Edward Nule Bohr et al. (2018) Reliability analysis of the brake system of a forklift automobile inspired by the forklift of Bouygues Construction Company was conducted in this study. The operations of a braking system in the automobile process and the reasons for failure in the brake's system operation were investigated; the various causes of failure in a brake system such as oil in the friction plate, failure of the caliper piston to home, lack of braking action and failure of the oil valve were examined for failure that can lead to its maintenance and improvement in its performance. The reliability results of a brake system to improve the performance of the forklift automobile were articulated and a flowchart of the brake system replacement model was constructed. The descriptive statistics of the reliability indices were employed in the analysis and the mean mile to failures and availability indices were determined. Reliability analysis of the brake system of the forklift was conducted using an exponential reliability model and broad-based results revealed that the brake system was established according to the structure and failure reason of the brake system of the forklift automobile. Weibull distribution parameters of failure reasons of the brake system were estimated using the maximum-likelihood estimation method. Reliability analysis of brake system which was carried out based on real-time value, and parameter estimation such as failure rate, reliability, unreliability, availability, and maintainability. The reliability of the brake system has progressed between 2014 and 2017. Conclusions and recommendations were made to improve the performance of the forklift automobile as the failure caused probability of brake system was different under different reliability [28].

Anant W. Nemade et al. (2018) Road accidents are an outcome of the interplay of various factors, some of which are the length of the road network, vehicle population, human population and adherence/enforcement of road safety regulations, vehicle component failure, etc. of which some parameters are difficult to control or can be controlled by external factors such as strict traffic norms, rigorous driving tests for a license, traffic separation, etc. But accidents due to failure of vehicle brakes are a prime responsibility of vehicle manufacturer, the brakes must work properly without failure of any component in its assembly. Road accident causes injuries, fatalities, disabilities, and hospitalization with severe socio-economic costs across the country. Consequently, road safety has become an issue of concern both at the national and international levels. The United Nations has rightly proclaimed 2011-20 as the Decade of Action on Road Safety. India is also a signatory to the Brasilia Declaration and is committed to reducing the number of road accidents and fatalities by 50 percent by 2020 [29].

Asim Rashid (2017) Disc brakes have evolved to be a reliable method of decelerating and stopping a vehicle. There have been different designs of disc brake systems for different applications. This review gives a detailed description of the different geometries of the components and the materials used in a disc brake system. Despite all the improvements, there are still many operational issues related to disc brakes that need to be understood in greater detail and resolved. There has been a lot of research going on about these issues and at the same time different methods are being proposed to eliminate or reduce them. There has also been intensive fundamental research going on about the evolution of the tribological interface of the disc-pad system. One major purpose of the present paper is to give a comprehensive overview of all such developments [30].

Problem Statement:

If the temperatures reached in braking become too high, deterioration in braking may result, and in extreme conditions, complete failure of the braking system can occur. It can be difficult to attribute thermal brake failure to motor vehicle accidents as normal braking operations may return to the vehicle when the temperatures return to below their critical level.

1. Brake Fade

2. Excessive Component Wear

3. Thermal Judder

Objective of the Project:

1. Wear modeling of brake pad and Doping with Graphene matrix for improving behavior.
2. Reduce brake fade.

3. RESEARCH METHODOLOGY

3.1 Materials Used for Brake Pad or Brake Lining

The brake pad is the stationary friction material rubbed against the rotating brake disc or brake drum. Some of the properties required in a brake pad are lightweight, corrosion resistance, low wear rate, low noise, long life, and low cost [31]. Over the years, many materials have been used for making brake pads. Some of the brake pad/lining materials are given in Table 1 with an approximate year of first use. Asbestos is one of the most suitable materials for brake drums, but asbestos has some health issues [32-35]. There are mainly two types of asbestos, serpentine asbestos (chrysotile) and amphibole asbestos (crocidolite). It was found that wear-out particles of chrysotile asbestos brake pads have a high carcinogenic effect on the car mechanics who replace brake pads [36]. Hence, the use of asbestos-based brake

The evolution of brake friction materials: a review of 801 pads was banned by the Environment Protection Agency in 1986. So, it becomes a challenge for research communities to develop asbestos-free brake pads. Bernstein et al. have done a comparative study on health issues caused by two types of asbestos (chrysotile and crocidolite) [37]. An opposing result to previous studies was found. It was observed that the chrysotile asbestos does not cause lung infection on inhalation for a short period. In contrast, crocidolite asbestos had a half-life of more than 1000 days and caused a severe inflammatory response. The release of other heavy metals such as copper, iron, antimony, etc., from brake pads, is also harmful to the environment [38,39,40]. So, researchers are working on the development of eco-friendly brake pads.

Table1. History of brake pad/lining materials [41, 42]

Brake Pad or Brake Lining Material	Approximate Year of First Use
Cast iron or steel	Before 1870
Cotton or hair belting	1897
Asbestos	1908
Molded materials to replace steel or cast iron	1930
Flexible organic materials	1930
Semi-metallic materials	1950
Non-asbestos organic	1960
Carbon fibers	1991

There are four types of brake pads used widely, metallic or semi-metallic brake pads, Non-asbestos Organic (NAO) brake pads, Metal Matrix Composite (MMC) brake pads, and ceramic or carbon-carbon brake pads [43]. It can be observed that non-asbestos organic brake pads are most widely used today because of their low cost and environment-friendly nature.

3.2 Test Specimens and Sample Preparation

3.2.1 Materials—This test method may be applied to a variety of materials. The only requirement is that specimens having the specified dimensions can be prepared and that they will withstand the stresses imposed during the test without failure or excessive flexure. The materials being tested shall be described by dimensions, surface finish, material type, form, composition, microstructure, processing treatments, and indentation hardness (if appropriate).

3.2.2 Test Specimens—The typical pin sample is cylindrical or spherical. Typical cylindrical or spherical pin sample diameters range from 2 to 10 mm. The typical disk specimen diameters range from 30 to 100 mm and have a thickness in the range of 2 to 10 mm. Specimen dimensions used in an inter-laboratory test with pin-on-disk systems are given below

L = 25 mm

A= 10*10 mm^2

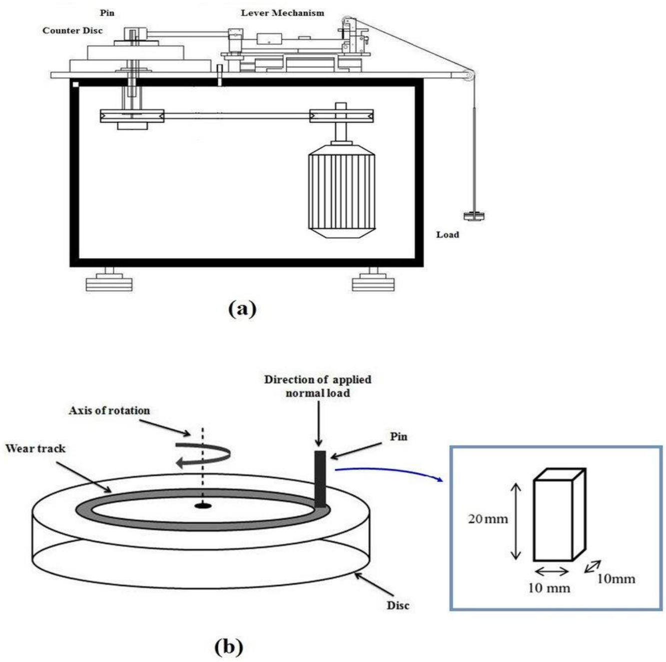
3.3.3 Surface Finish—A ground surface roughness of 0.8 µm (32 µin.) arithmetic average or less is usually recommended.

3.3 Procedure

3.3.1 Wear Testing On Pin Disc Apparatus

- For the pin-on-disk wear test of sample 1, two specimens are required. One, a pin with a square face, is positioned perpendicular to the other, usually a flat circular disk. The test machine causes either the disk specimen or the pin specimen to revolve about the disk center.

- The pin specimen is pressed against the disk at a specified load usually using an arm or lever and attached weights. Other loading methods have been used, such as, hydraulic or pneumatic.
- Wear results are reported as volume loss in cubic millimeters for the pin and the disk separately. When two different samples are tested, it is recommended that each sample be tested in both the pin and disk positions.
- The amount of wear is determined by measuring the appropriate linear dimensions of both samples before and after the test, or by weighing both specimens before and after the test. If linear measures of wear are used, the length change or shape change of the pin and the depth or shape change of the disk wear track (in millimeters) are determined by any suitable metrological technique, such as electronic distance gauging or stylus profiling.
- Wear results are usually obtained by conducting a test for a selected sliding distance and for selected values of load and speed.
- Wear results may in some cases be reported as plots of wear volume versus sliding distance using different samples for different distances. Such plots may display non-linear relationships between wear volume and distance over certain portions of the total sliding distance, and linear relationships over other portions.



3.3.2 Coating of Graphene Powder

Another sample of the failed component Brake Pad was heated at elevated temperature along with graphene powder and coolant inside the muffle furnace. In such a way a thin layer of Graphene powder is imposed on the surface of sample 2.

Then wear test is performed on the pin disc apparatus on the same test conditions which shows improved characteristics.

3.3.3 Coating Material: Graphene

Graphene was properly isolated and characterized in 2004 by Andre Geim and Konstantin Novoselov at the University of Manchester.[13][14] They pulled graphene layers from graphite with a common adhesive tape in a process called either micromechanical cleavage or the Scotch tape technique. This work resulted in the two winnings the Nobel Prize in Physics in 2010 "for groundbreaking experiments regarding the two-dimensional material grapheme".

Rice University and GIT in 2014 Graphene is also relatively Brittle with a fracture toughness of about 4 MPa. This indicates that imperfect Graphene is likely to crack in a Brittle manner like ceramic material. Later 2014 research said Graphene has a greater ability to distribute force from an impact than any known material ten times of steel per unit of impact. The force was transmitted 22.2 km /s.

Graphene is an allotrope of carbon consisting of a single layer of atoms arranged in a hexagonal lattice nanostructure. The name is derived from "graphite" and the suffix -ene, reflecting the fact that the graphite allotrope of carbon contains numerous double bonds. Graphene is the thinnest 2D material in the world. Single-layer material or 2D materials refers to crystalline solids consisting of a single layer of atoms. Generally carry suffix "ene".

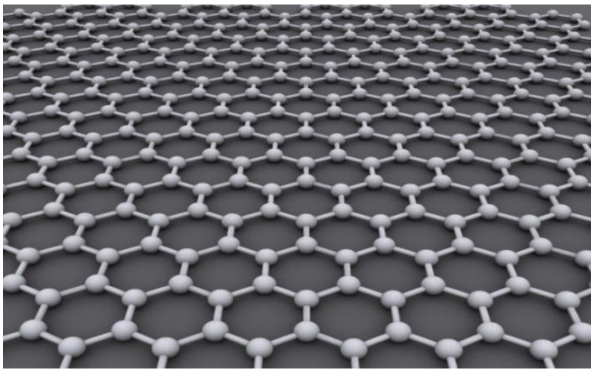


Figure: Graphene Hexagonal lattice (source Wikipedia)

4. RESULT AND ANALYSIS

4.1 Calculation and Reporting

4.1.1 The wear measurements should be reported as the volume loss in cubic millimeters for the pin and disk, separately.

- Use the following equations for calculating volume losses when the pin has initially a spherical end shape of radius R and the disk is initially flat, under the conditions that only one of the two members wears significantly:

$$\text{Volume loss}(mm^3) = \frac{\pi\,(\text{wear scar diameter, } mm^4)}{64\,(\text{sphere radius, } mm)}$$

- Calculation of wear volumes for pin shapes of other geometries uses the appropriate geometric relations, recognizing that assumptions regarding the wear of each member may be required to justify the assumed final geometry.
- Wear scar measurements should be done at least at two representative locations on the pin surfaces and disk surfaces, and the final results averaged.
- In situations where both the pin and the disk wear significantly, it will be necessary to measure the wear depth profile of both members. A suitable method uses stylus profiling. Profiling is the only approach to determine the exact final shape of the wear surfaces and thereby calculate the volume

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of material lost due to wear. In the case of disk wear, the average wear track profile can be integrated to obtain the track cross-section area, and multiplied by the average track length to obtain disk wear volume. In the case of pin wear, the wear scar profile can be measured in two orthogonal directions, the profile results are averaged and used in a figure-of-revolution calculated for pin wear volume.

- While mass loss results may be used internally in laboratories to compare materials of equivalent densities, this test method reports wear as volume loss so that there is no confusion caused by variations in density. Take care to use and report the best available density value for the materials tested when calculating volume loss from measured mass loss.
- Use the following equation for the conversion of mass loss to volume loss.

$$\text{Volume Loss (mm}^3) = \frac{\text{Mass loss (g)}}{\text{Density (g/cm}^3)}$$

4.1.2 If the materials being tested exhibit considerable transfer between specimens without loss from the system, volume loss may not adequately reflect the actual amount or severity of wear. In these cases, this test method for reporting wear should not be used.

4.1.3 Friction coefficient (defined in Terminology G 40) should be reported when available. Describe the conditions associated with the friction measurements, for example, initial, steady-state, etc.

4.1.4 Adequate specification of the materials tested is important. As a minimum, the report should specify the material type, form, processing treatments, surface finish, and specimen preparation procedures. If appropriate, indentation hardness should be reported.

4.2 Wear result of Samples:

Time(sec.)	S1	S2
10	9.736064	26.17684
50	150.4842	30.32015
100	183.8038	110.8776
150	250.6316	148.3149
200	290.8781	167.0913
250	320.9396	181.3918
300	376.7083	192.8981
350	399.4477	202.0787
400	442.1875	212.1195
450	462.2982	203.047
500	470.7163	214.5133
550	476.8743	219.132
600	483.0957	221.6242
650	495.2827	227.0017
700	501.0052	230.5343

750	512.599	234.392
800	517.9886	231.6131
850	522.9397	228.23
900	520.8882	233.5043
950	525.56	228.174
1000	535.0654	235.4265
1050	542.2364	233.2548
1100	558.4074	245.5874
1150	551.5784	256.92
1200	572.7494	250.2154
1250	595.2827	265.6131
1300	595.0052	263.23
1350	605.599	266.5043
1400	621.9886	274.174
1450	631.9397	273.4265
1500	644.8882	273.2548
1550	650.5148	280.5874
1600	662.0654	282.92
1650	679.2364	280.2154
1700	675.4074	293.2548
1750	680.5784	290.5874
1800	688.7494	292.92
1850	691.0654	280.2154
1900	691.2244	287.2548
1950	692.4074	290.5874
2000	690.5784	294.92

	S1	**S2**
weight loss	74.578 4	13.106
weight loss	74.578 4	13.106

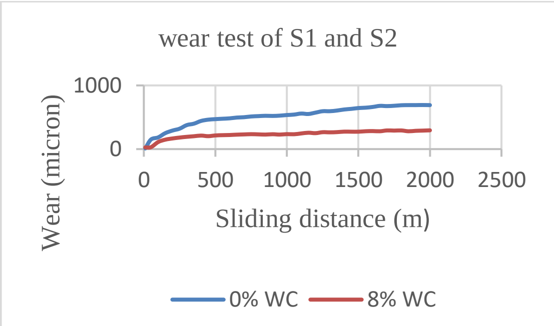

Figure: Wear of Sample1 & sample2

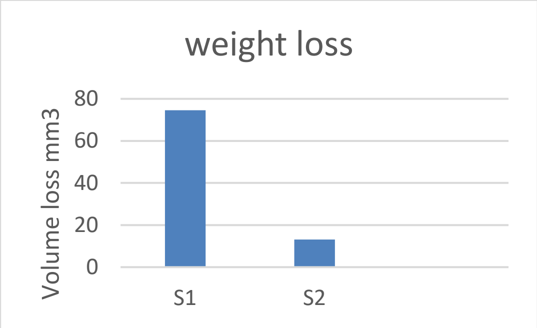

Figure: Volume loss of S1 & S2

4.3 Coefficient of friction of samples S1 and S2

Time(sec.)	S1	S2
10	0.142778	0.153084
50	0.219336	0.280467
100	0.206272	0.314072
150	0.20617	0.381991
200	0.203994	0.380736
250	0.207271	0.380626
300	0.204726	0.408193
350	0.205009	0.399198
400	0.206558	0.398809
450	0.207313	0.397903
500	0.209929	0.398231
550	0.191538	0.398251
600	0.192588	0.418475
650	0.199456	0.41171
700	0.21198	0.392764
750	0.227856	0.393904
800	0.213455	0.394896
850	0.224893	0.394558
900	0.238951	0.397421
950	0.232324	0.395918
1000	0.202522	0.39937
1050	0.222139	0.402187
1100	0.22641	0.416574
1150	0.220643	0.414008
1200	0.208232	0.421184
1250	0.192588	0.418475
1300	0.199456	0.41171
1350	0.21198	0.392764
1400	0.227856	0.393904
1450	0.211909	0.394896
1500	0.214893	0.394558
1550	0.238951	0.397421
1600	0.232324	0.395918
1650	0.202522	0.39937
1700	0.222139	0.402187
1750	0.22641	0.416574
1800	0.220643	0.414008

1850	0.218232	0.421184
1900	0.222324	0.395918
1950	0.212522	0.39937
2000	0.212139	0.402187

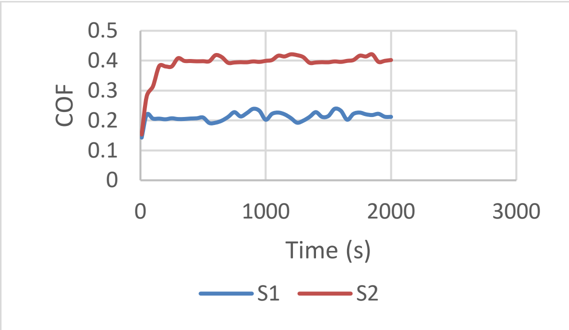

Figure: COF of S1 & S2

5. CONCLUSION

Braking is a very vital component in a vehicle. The use of a good braking system requires adjustment in terms of dimensions and design to be used in various conditions of braking scenarios. The scenario that often occurs is braking which occurs repeatedly this causes high wear of disc brake pads so analyzing the braking design the material to be used needs to be considered.

Traditional brake pads have a higher wear rate at higher temperatures at sudden braking conditions. By using graphene coating on brake pads we have achieved improved performance in braking. Graphene has minimum or almost zero wear and its very thin layer is capable of transmitting load at a higher rate. Graphene is also relatively Brittle with a fracture toughness of about 4 MPa. Graphene has a greater ability to distribute force from an impact than any known material ten times of steel per unit of impact. The force was transmitted 22.2 km /s.

Future scope: Graphene pad has a good ability to transmit load equally in all directions but introducing graphene coating on brake pad increases the cost of brake pad. We can research these and other methods of implementing graphene matrix on Brake pads so that we can reduce the cost.

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