Tribological Behaviour Of Passenger Vehicle Brake Pad Material

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Abstract - *The braking system of an automobile is one of the most significant mechanical devices. It's a device that slows or stops the spinning of a wheel. Because the primary goal of the braking system is to manage a vehicle's speed, it is necessary to investigate the tribological characteristics of automobile brake pads and braking systems for passenger vehicles. As a result, the coefficient of friction and frictional force for braking should be as high as possible. However, excessive braking causes the production of hot spots and brake pad material deterioration. This leads to the investigation and development of metal matrix composite as an alternative to brake pad material. The most often utilised composites are metal matrix composites. Under dry sliding conditions, optimization of disc break by tribological behaviour of LM13 cast Al alloy, stir cast composite, and semi-metallic lining material (brake pad) sliding against grey cast iron disc with chemical composition and surface roughness value similar to that of disc used in actual passenger vehicle.*

Key Words: *rotation , brake pad, frictional force, metal matrix, tribological, LM 13.*

1.INTRODUCTION

Friction material in the form of brake pads is pressed on both sides of the disc mechanically, hydraulically or pneumatically or electromagnetically in automobiles for stopping purposes. The disc brake and the associated wheel slow or halt as a result of friction. Because the disc is more easily cooled and disc brakes recover more quickly from immersion, disc brakes provide better stopping performance than drum brakes. Disc brakes are commonly utilised in light vehicles nowadays. The production of surface cracks and a substantial amount of plastic deformation in the brake rotor occurs at high temperatures. Excessive braking traps brake pad wear particles in the gap between the brake pad and the disc, causing brake pad wear. When sliding on vehicle friction material under equal conditions, metal matrix composites have significantly superior wear resistance than conventional grey cast iron. The normal force (FN) to lateral or tangential force ratio is a common way to measure friction. There are various types of friction, but this research will concentrate on dry friction, often known as Coulomb friction. The resistance to relative motion between two solid surfaces in contact at rest or in motion is known as dry friction. The objective of friction brakes is to decelerate a vehicle by converting the vehicle's kinetic energy to heat and distributing that heat into the environment. Brake materials have extra requirements as part of a commercial vehicle or automobile, such as corrosion resistance, light weight, long life, low noise, stable friction, low wear rate, and an acceptable cost versus performance ratio. Drum/shoe brakes and disc/pad brakes are the two most prevalent forms of friction brakes. Heat flow, dependability, noise characteristics, and ease of maintenance are all influenced by the brake design.

1.1 Problem Staement

Long repetitive braking leads to brake failure & cause severe wear of brake pad. Due to heavy braking there is formation of hot spots on brake disc and formation of grooves on brake pads and excessive wear leading to failure of brake system. In order to optimize existing grey cast iron material used in passenger cars the study of tribological behavior of LM-13 composite under various load and sliding velocities will be performed.

1.2 Objectives

1.The goal of this project is to assess the fabrication and development of brake pad material for passenger vehicles.

2. The project's goals are to use the Taguchi method to design performance characteristics for a L9 orthogonal array.

3. Determine the material's wear and friction behaviour, as well as the impact of various sliding speeds, loads, sliding distances, and materials.

4. Identifying the significant control factors' contributions, interactions, and influence on the composites' wear rate using ANOVA techniques.

5. Using regression analysis, develop a mathematical model to predict wear for various conditions.

1.3 Methodology

In order to measure tribological behaviour, wear characteristics must be obtained. The pin-on-disc equipment is employed. A pin on disc wear test apparatus consists of a stationary pin in contact with a revolving disc under an applied load. To imitate a specific contact, the pin can be any form, but spherical tips are commonly utilised to simplify the contact geometry. The pin on disc test determines the friction and sliding wear qualities of a variety of bulk materials and coatings on dry or lubricated surfaces. The pin on disc tester pits a revolving disc of the material to be tested against a stationary pin, which is commonly constructed of cemented carbide.

The pin surface can also be examined for wear and friction. Prior to the pin on disc test, the user must specify the typical load, rotating speed, and worn track diameter. For the experimental verification of wear characteristics, both alternative and conventional materials are used as samples.

1. LM13 composite as an alternative disc material.

2. Semi-metallic is the traditional disc material.

2. Literature Review

In “Optimization of Friction and Wear Behaviour in Hybrid Metal Matrix Composites Using Taguchi Technique” V. C. Uvaraja1 and N. Natarajan fabricated Al-7075 alloy-base matrix, reinforced with mixtures of silicon carbide (SiC) and boron carbide (B4C) particles, known as hybrid composites by stir casting technique (liquid metallurgy route) and optimized at different parameters like sliding speed, applied load, sliding time, and percentage of reinforcement by Taguchi method. The specimens were examined by Rockwell hardness test machine, Pin on Disc, Scanning Electron Microscope (SEM) and Optical Microscope. A plan of experiment generated through Taguchi’s technique is used to conduct experiments based on L9orthogonalarray. The developed ANOVA and the regression equations were used to find the optimum wear as well as coefficient of friction under the influence of sliding speed, applied load, sliding time and percentage of rein-forcement. The dry sliding wear resistance was analyzed on the basis of “smaller the best”. Finally, confirmation tests were carried out to verify the experimental results. They found the wear rate is dominated by the order of percentage of reinforcement, applied load, sliding speed, and sliding time. ANOVA test concluded that as percentage of reinforcement increases the wear rate also decreases significantly and Coefficient of friction is dominated by different parameters in the order of percentage of reinforcement, sliding speed, applied load, and sliding time.

V.D. Londhe, Prof. M.S. Mhaske, Prof. R.A. Kapgate experimented that for semi-metallic lining material there is transfer of material on disc & leads to formation of transfer layer, but at higher load & sliding velocity there is generation of high temperature & destruction of transfer layer which leads to increase in wear. The coefficient of friction for semi-metallic lining material is high but wear is also maximum. For LM13 cast Al alloy the wear & frictional force increases with increase in load & sliding velocities. For LM13-10SiC composite material wear is negative & coefficient of friction is high at lower load as compared to semi-metallic lining material. For composite material at 1250 C temperature of pin material wear is negative & frictional force, coefficient of friction is high as compared to composite material at room temperature. Development of LM13-10SiC composite material by using stir casting technique is more economical & beneficial than any other manufacturing process.

From study named Tribological properties of Aluminium Metal Matrix Composites (AA7075 Reinforced with Titanium Carbide (SiC) Particles) [3] the direction for project I have been taking is that the matrix metal and Titanium carbide (SiC) particles (2-10%) with an average particulate size of 2µm as reinforced material were processed by stir casting route. Computerized pin on disc wear tester was used for wear test with counter surface as EN32 steel disc (58-60 HRC) and cylindrical pin as the composite specimens. The wear rate in terms of weight loss per unit sliding distance, coefficient of friction and volume loss were obtained for the matrix metal and composites. The results of composite shows better wear resistance than matrix metal. The microstructural characterization of worn surface was investigated using SEM. Weight loss of samples was calculated and the variation of cumulative wear loss with sliding distance has been found to be uniform for both the matrix metal and the composites. It was also observed that the wear rate is low for composites compared to matrix metal.

In study of “Dry Sliding Wear Behavior of Aluminium/Be3Al2(SiO3)6 Composite Using Taguchi Method” H. B. Bhaskar and Abdul Sharief [4] shown the investigation relating to the influence of wear parameters like sliding speed, applied load and sliding distance on the dry sliding wear of aluminium metal matrix composites. The design of experiment approach was employed to acquire data in controlled way using Taguchi method. A pin-on-disc apparatus was used to conduct the dry sliding wear test. An orthogonal array, signal-to-noise ratio and analysis of variance were employed to investigate the wear behavior of aluminium and it’s composite.

The mathematical model was obtained to determine the wear rate of the aluminium and it’s composite. The confirmation tests were conducted to verify the experimental results. The incorporation of Al2 (SiO3)6 as reinforcement material in aluminium matrix material improves the tribological characteristics. It showed that DOE technique is successfully used to study the dry sliding wear of aluminium and aluminium composite.

Phool Kumar, A.M. Azad, Vinod [5] introduces an attempt to increase the mechanical and tribological property of Al6061 alloy by adding SiC particulates as reinforcements in “Frictional and Wear Characteristics of Stir-Cast Hybrid Composite Aluminium Al6061Reinforced with SiC Particulates”. The particle size of SiC particles is 400µm. Hybrid metal matrix composite is prepared by Stir casting route and Friction and wear test is done by pin-on-disc method. Al6061T6 hybrid composites are used in automobile components for reliable, long life and high performance. Experiments were conducted based on the plan of experiments generated through Taguchi’s technique. A L9 Orthogonal array was selected for analysis of the data. Results show that sliding distance has the highest influence on wear rate followed by sliding speed and load. Sliding distance has the highest influence on wear rate followed by load and sliding speed. In this project they proposed the regression equations for Coefficient of friction (Al6061/20%SiC MMC) implies that Coefficient of friction is directly proportional to applied load and sliding speed and inversely proportional to sliding distance.

The investigation is in regard shows that the MMCs have considerable higher wear resistance than conventional grey cast iron while sliding against automobile friction material under identical conditions. A gradual reduction of friction coefficient with increase of applied load is observed for both cast iron and Al MMC materials. However, in all the tests it is observed that the friction coefficient of Al MMC is 25% more than the cast iron while sliding under identical conditions. The wear of the lining material has been observed more when sliding against MMC disc because of the ploughing of the lining material by the silicon carbide particles. It is concluded that the friction coefficient of the MMC is found to be 20% more than that of cast iron which will enhance the braking performance.

Chetan T. Jadav [8] in paper "An Approach to Optimize the Disc Brake of a MotorCycle" depicts about a disc brake is a wheel brake which slows rotation of the wheel by the friction caused by pushing brake pads against a brake disc with a set of calipers. To stop the vehicle, friction material in the form of brake pads is forced mechanically, hydraulically, pneumatically or electromagnetically against both sides of the disc. Friction causes the disc brake and attached wheel to slow or stop. Compared to drum brakes, disc brakes offer better stopping performance, because the disc is more readily cooled and disc brakes recover more quickly from immersion.

Case study of "Wear resistance of cast irons used in brake disc rotors" by G. Cueva, A. Sinatora, W.L. Guesser, A.P. Tschiptschin [10] took experiment related to the wear resistance of three different types of gray cast iron (gray iron grade 250, high carbongray iron and titanium alloyed gray iron), used in brake disc rotors, was studied and compared with the results obtained with a compact graphite iron (CGI). The wear tests were carried out in a pin-on-disc wear-testing machine, the pin being manufactured from friction material usually used in light truck brake pads. The rotating discs (500rpm) were subjected to cyclical pressures of 0.7, 2 and 4MPa and forced cooled. The results showed that compact graphite iron reached higher maximum temperatures and friction forces as well as greater mass losses than the three gray irons at any pressure applied. However, when compact graphite iron was tested with lower applied pressures and same friction forces sustained by the gray iron rotors, CGI presented the same performance, as did the gray cast iron.

3. Manufacturing Method

To begin the experimental process, we must first choose a material, a matrix, and a reinforcing material. There are several factors to consider when choosing a material:

1. Availability
2. Design adaptability
3. Price per unit
4. Aspects of performance
5. Aspects of regulation
6. Biocompatibility
7. Aesthetics and ease of use
8. Efficiency in manufacturing

3.1 Matrix Material Selection

The matrix is a monolithic substance in which the reinforcement is usually embedded and must be dispersed uniformly throughout. As matrix materials, aluminium, magnesium, nickel, titanium, and cobalt can be employed. Aluminum and its alloys drew the greatest attention as a matrix material in MMCs in most engineering applications due to its outstanding mechanical qualities, superior ductility, and good corrosion resistance. Consumers are imposing increasingly stringent fuel economy requirements on the car industry, as well as demands for better comfort and safety.

As a result, we choose Aluminum as the metal matrix. Aluminum MMCs are appealing because they allow for property combinations that are not possible with monolithic materials, as well as significant service benefits and a great degree of design freedom.

3.2 Material Selection for Reinforcing

Different types of reinforcing material are used, including powder, fibres (continuous and discontinuous, aligned and random), and laminates embedded in the matrix. Stiffness, hardness, fracture toughness, thermal shock resistance, wear resistance, friction coefficient, and thermal conductivity are some of the matrix qualities that can be improved using it. An aluminium matrix composite reinforced with silicon carbide is one type of MMC (Al-SiC). In terms of the aerospace sector, the most important attribute of aluminium-silicon carbide is its strength-to-weight ratio, which is three times that of mild steel. Furthermore, when compared to many other materials, composites comprising SiC (reinforcing material) and Al (matrix) offer higher modulus, strength, wear resistance, high thermal stability, reduced weight, and a higher effective load carrying capacity. Because silicon carbide creates a protective covering of silicon oxide at 1,200°C and, as previously noted, aluminium also exhibits a similar reaction, this composite is expected to have good corrosion and oxidation properties. As a result, it is clear that this material has significant benefits for the aerospace sector, particularly in applications that demand excellent thermal and tensile qualities.

3.3 Fabrication Method for Stir Casting

The Stir casting procedure was chosen for this project. Metal matrix composites can be made using a variety of materials and production processes. Stir casting was chosen as one of the processes because it is a promising technique that is now being used commercially. The flexibility, simplicity, and application of the stir casting technique are all advantages. This method is also used in large-scale production. The LM13 alloy was chosen as the basis matrix in this study. Two reinforcing materials were used SiC with 0wt%, 5wt%, and 10wt%, respectively.

Stir casting is a method in which the melt is continuously stirred, exposing the melt surface to the atmosphere and causing continuous oxidation of the aluminium melt. Stir casting is a sort of casting method in which a mechanical stirrer is used to create a vortex in the matrix material to combine reinforcement. Due to its cost effectiveness, mass production suitability, simplicity, nearly net shaping, and easier control of composite structure, it is a good process for the manufacturing of metal matrix composites.

In this project Stir casting process was selected. Among the various material manufacturing process available for metal matrix composites. Among this stir casting process selected because this process generally use as a promising route, currently practiced commercially. Stir casting process have some advantage like its flexibility, simplicity and applicability. This process also use for large quantity production.In the present work LM13 alloy was selected as the base matrix. and two reinforcing materials were token SiC with 0wt%, 5wt%, 10wt% respectively. Stir casting process involves stirring of melt, in which the melt is stirred continuously which exposes the melt surface to the atmosphere which tend to continuous oxidation of aluminum melt.

Stir casting is a type of casting process in which a mechanical stirrer is introduced to form vortex to mix reinforcement in the matrix material. It is a suitable process for production of metal matrix composites due to its cost effectiveness, applicability to mass production, simplicity, almost net shaping and easier control of composite structure.

4. Therotical Analysis

4.1 Taguchi Method

The Taguchi approach entails using a robust design of tests to reduce variation in a process. Genichi Taguchi is the creator of the Taguchi technique. He devised a method for conducting experiments to see how different parameters affect the mean and variance of a process performance metric, which indicates how effectively the process is working. Taguchi's experimental design entails organising the parameters impacting the process and the levels at which they should be altered using orthogonal arrays. The Taguchi technique, rather than testing all potential combinations like the factorial design does, tests pairs of possibilities. This enables the collecting of critical data to discover which aspects have the most impact on product quality with the least amount of trial, saving time and resources. When there are an intermediate number of variables (3 to 50), minimal interactions between variables, and only a few variables contribute significantly, the Taguchi technique is the best choice.

4.2 Pin On Disc Apparatus

A stationary pin is generally loaded against a rotating disc in a pin on disc tribometer. To imitate a specific contact, the pin can be any form, but spherical tips are commonly utilised to simplify the contact geometry. The ratio of the frictional force to the loading force on the pin determines the coefficient of friction. The pin on disc test has proven to be an effective way to test low friction coatings for wear and friction. The Pin on disc device is used to obtain wear parameters for tribological behaviour assessment.

For the experimental evaluation of wear properties (coefficient of friction and frictional force), both alternative and conventional materials are used as samples. This results in a point contact between the pin and the disc at the start of the test, which grows in size as the test progresses. A ball can also be used to replace the pin (ball-on-disk). Unlike the ring-on-disc test, there is no reversing motion and no disruption of the lubricating layer between the worn components during the pin-on-disc test. As a result, pure sliding friction between the friction components can be assumed in an ideal situation.

The normal load, the sliding velocity, the initial temperature of the test medium, and the sliding distance between the worn couplings constitute the loading condition in the pin-on disc test. The wear volume in the pin-on-disc test can be determined either by changing the specimen geometry (shortening the pin and determining the volume of the on the disc) or by reducing the wear track mass of the specimens.

4.3 Test Procedure

1) Standard hand polishing with 320 emery paper was used to polish the samples.

2) Insert pin into jaw holder, check that it is firmly seated, and tighten two jaws to secure pin in place while also tightening jaw to specimen holder.

3) Turn on the controller and wait 5 minutes for the display to normalise.

4) After setting the time on the timer display, press the TEST START push button on the controller, twist the speed knob to the appropriate speed, confirm the speed is steady, and then click the STOP button. Do not change the position of the speed knob.

5) On the controller, press the usual load, frictional force, and wear zero buttons.

6) On the PC, open the software, create a new file, input a test parameter and sample ID on the screen, and then press the START icon to activate the screen to accept data.

7) If necessary, add dead weight to the loading pan to apply a normal load.

8) Set the timer according to the situation.

9) Press the START button to begin the test.

10) The test comes to an end when the time limit is reached.

11) Take note of the wear and frictional force measurements on the controller display.

12) Remove the specimen and use polish paper to wipe the disc surface.

14) Determine the volume loss and friction coefficient.

5. Conclusion

Pin-on-disc equipment is used to do experiments on Semi-Metallic material, LM13 Alloy, and LM13+10 percent SiC. The following are the outcomes of this project:

1. The stir casting method was used to successfully cast the LM13+SiC 10% composite material.

2. The DOE method was used to investigate the dry sliding wear of brake pads made of conventional and alternative materials.

3. According to the analysis of variance, Sliding Velocity (41.73%) and Sliding Distance (18.89%) have a significant impact on LM13 Alloy wear.

4. The analysis of variance reveals that Sliding Velocity (42.60%) and Sliding Distance (19.28%) have a significant impact on Semi-Metallic material wear.

5. When compared to conventional materials, LM13 with 10% SiC has a lower wear forming tendency. As a result of its great wear resistance, it can be employed as a brake disc pad. The material's wear is related to the load and the sliding speed, but not to the sliding distance.

6. The experimental observation and the prediction are in good agreement. Errors of fewer than 10% have been found, which is significant.

7. This represents a significant cost and time savings for the industry, allowing it to build more general and specific databases of material properties.

8. A confirmation test demonstrates that the Taguchi L9 orthogonal array model is satisfactory and adequate. As a result, the model produced by both parties may be utilised to successfully forecast the sliding wear behaviour of diverse situations.

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