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Wear Test on Brake Rotor Using Pin on Disc Apparatus

S. R. Durairajua[1], S. Deepak kumar[2], S. Deeraj kumar[3], D. Gokul[4]
[1]*Assistant Professor, Dept. of Mechanical Engg., Sri Ramakrishna Engineering college, Coimbatore, India*
[2,3,4]*UG Student, Dept. of Mechanical Engg., Sri Ramakrishna Engineering college, Coimbatore, India*

***Abstract*—With weight reduction and component reliability being the top priority while designing automobile components, the selection and use of materials of a high strength to-weight ratio is of vital importance. Less weight ensures low fuel consumption and hence low emissions thus having a great impact on the environment on a large scale. This study focuses on the use of abrasive particle (SiC)-reinforced aluminum metal matrix composite material for brake rotors which is expected to generate less heat during braking (due to friction) and also reduces the mass of the vehicle resulting in better handling and increases the fuel efficiency.**

***Index Terms*—wear test, brake rotor**

I. Introduction

Brake rotors are one of the most important components in an automobile, which is used in stopping the vehicle by converting the kinetic energy of the moving vehicle into heat energy by means of friction. Heat is then dissipated through exchange mainly with the environment and during braking, temperature may even rise tremendously in the contact region. However at higher temperatues the wear rate is high. The commercial brake rotor material used is cast iron. In the place of cast iron in brake rotor, we use aluminium. Aluminium which is a white silvery metal, is about 8% on earth's surface is used in many application as it has unique properties than other metals. Using the Aluminium as the material for the brake rotor the main advantage is the reduction of weight of the brake rotor. The reduction in the weight of the brake rotor reduces the weight of the total vehicle so that the fuel consumption by the vehicle reduces. With increase in the applied load in the brake rotor, the wear rate of the brake material increases. This study focuses on the use of aluminum metal matrix composite material for brake rotors which is expected to produce less heat during the brake is applied and also reduces the mass of the vehicle resulting in better handling.

The material used for brake systems should have stable, reliable frictional and wear properties under varying conditions of load, velocity, temperature, and environment and high durability. There are some factors which are to be considered while selecting the brake rotor material. Some of the factors are mentioned below. 1) The most important condition is the ability of the brake rotor material to withstand high temperatures generated in the action of applying load when the brake is applied. 2) Resistance to abrasive wear. 3) Thermal resistance. The widely used brake rotor material is cast iron. Based on the survey of patents and literature, it is found that there are reports about carbon disc rotor, steel rotor coated with ceramic; and titanium rotors which are light in weight is mostly used in racing cars but it is not widely used because of its high cost. Different types of fibre are mixed with aluminium to get correct mixture to use in brake rotor. Here we consider about the effects of mixture of aluminium and silicon carbide i.e (SiC) reinforced aluminium metal matrix composite

II. Aluminium Matrix Composites

Composite materials are usually classified based on the physical or chemical nature of the matrix phase, e.g., polymer matrix, metal-matrix, and ceramic composites. Aluminium metal matrix refer to the class of lightweight high performance aluminium centric material systems. The major advantages of Aluminium metal matrix compared to unreinforced materials are a greater strength, improved stiffness, reduced weight, improved high-temperature properties, controlled thermal expansion coefficient, and improved abrasion and wear resistance. Aluminum and silicon carbide have very different mechanical properties: Young's moduli of 70 and 240 GPa; coefficient of thermal expansion of 24×10^{-6} and7×10^{-6} per °C; and yield strengths of 35 and 600 MPa, respectively. By combining these materials, e.g., Al6061/SiCT6 condition, an MMC with a Young's modulus of 99.6 GPa and a yield strength of 510 MPa can be produced.

With the increase in weight percentage of SiCup to 25%, increases both hardness and impact strength of the composite is observed. Beyond this weight fraction, the hardness starts to decrease as SiC particles interact with each other leading to the clustering of particles and consequently settling down.

Al6061, an alloy of aluminium , magnesium and silicon is chosen because of its mechanical and thermal stability and less cost.An in-depth investigation of literature shows that 20%SiC-reinforced aluminum alloy exhibits a significant reduction in the wear compared to other volumetric fraction of SiC in the aluminum matrix. The composite material also has lower thermal expansion than the matrix material due to the presence of SiC particles.

III. Brake Rotor

In this study, a commercially available two-wheeler having a rear wheel disc brake system was selected. The outer profile is necessary in order to facilitate degassing of the brake pad during braking. The thickness of brake rotor is found to be 4mm and the holes are introduced in the brake rotor because of heat reduction process i.e radiation process.

The performance of braking is affected by rise of temperature during application of load in braking. High temperatures during braking may cause brake fade, premature wear, brake fluid vaporization, bearing failure, thermal cracks, and thermally excited vibration.

Therefore it is important to consider the thermal performance of a brake material during the design stage. While applying load by the brake pad, a compressive force is developed which makes the brake rotor to deflect. Hence the maximum deflection has to be considered to ensure the good and safe working of the brake rotor in service.

IV. Fabrication Process of the Composite Brake Rotor

- Stir casting is generally accepted as a particularly promising route. Its advantages lie in its simplicity, flexibility, and applicability to a large quantity of production and less investment compared to squeeze casting and powder metallurgy, and hence, stir casting method is chosen.
- In stir casting, stirrer blades are used to stir the molten metal matrix phase. The stirrer blades are attached to the motor.
- In order to achieve the optimum properties, the distribution must be uniform. The porosity levels need to be minimized, and chemical reactions between the reinforcement materials and the matrix alloy must be avoided.
- The assembly holes and the outer profile of the brake rotor were machined in a vertical machining center (VMC).
- The heat treatment of the composite is necessary to increase its strength and hardness, therefore increasing the hardness increases its wear resistance.
- The heat treatment involves the following three stages heat treatment, quenching and age hardening.

V. Results and Discussion

A. Structural Analysis

The maximum deflection of the composite brake rotor is found to be 0.277x10^-4 m. The maximum stress and the Von-Misesstress is found to be 2.076 N/mm^2and 7.124 N/mm^2 respectively.

B. Thermal Analysis

The maximum temperature occurs at the contact surface of the brake rotor and the brake pad, which is equal to 180.88 °C. The minimum temperature of the brake rotor is obtained as 108.91°C

The thermal analysis for gray cast iron brake rotor yielded a maximum temperature of 497.35 °C and a minimum temperature of 341.5 °C.

C. Metallurgical Characteristics

The microstructure analysis indicate that the cast Al-SiC brake rotor is having normal microstructure and is suitable for performance testing of brake disc.

Brinell hardness tests were carried out for the as-cast and age-hardened SiC-reinforced Al matrix composite.

Higher hardness would result in greater resistance to abrasive wear, which is the most important characteristic required for brake discs.

D. Wear Analysis

The wear behavior of AMC was tested using a pin on disc tribo meter.

During the test, the pin was pressed against a rotatingEN32 steel disc with hardness 65 HRC by applying the load.

A strain-gauged friction-detecting arm holds and loads the pin specimen vertically into a rotating hardened steel disc.

VI. Conclusion

- Brake rotor with the 20% silicon carbide-reinforced Al 6061 metal matrix composite was cast and machined and the stir casting is used to mix the aluminium and the silicon carbide particles which is economical.
- The mechanical and thermal properties were considered for the above composite i.e the aluminium with silicon carbide particles.
- The higher content of the hard particles on the frictional surface of the brake rotor enhances the heat resistance of the brake rotor.
- Both the wear rate and friction coefficient vary with the applied normal load and the sliding speed. The formation of tribo-layer can have a significant role to play in wear behavior of tribological couple made of Al–Si/SiCp MMC and brake pad during the service.
- It is found that the weight of the above composite material is found to be 56% less than the brake rotor made of cast iron.

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