Study and Comparison of Mechanical Properties of Brake Rotors Made of Steel Based Hybrid Metal Matrix Composite and Grey Cast Iron

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ABSTRACT

Replacing automobile components with the composite materials is a healthy trend in the recent decades due to their enhanced mechanical properties. Grey Cast Iron (GCI) is the existing material widely used in automobile brake rotor application as it has advantages like high hardness and wear resistance. Even though GCI has few benefits, it also has major drawbacks like high specific weight, low mechanical properties (tensile strength, impact and shock resistance) and low corrosion resistance. In order to overcome these issues and to enhance the wear resistance of brake rotor material, the present research work aims to find an alternate for the GCI with a based metal matrix composite. Among other material steel alloys offers better physical, mechanical and thermal properties, so present work attempts to fabricate a metal composite with Steel based hybrid composite. The fabricated composite is tested. The results are compared with existing Grey cast iron. Similarly, composite materials are tested for friction and wear behaviour. Wear test is carried over drum wear test machine, this could be an alternate for existing Grey Cast Iron (GCI) material used in automobile brake rotor application.

Keywords: Grey Cast Iron, thermal properties, metal composite, hybrid composite

1. INTRODUCTION

Recent advancements in the fields of automotive and aerospace require special materials having combined properties to perform one or more functions. One among those materials is „COMPOSITE MATERIAL’ and it can be defined as „a material produced by two or more constituents with dissimilar physical or chemical properties that produce a combined characteristic which is different from the individual materials”. Composite materials are preferred due to its distinctive properties that are not possible by conventional monolithic materials. Generally, composites have two phases, one is the „Matrix’, and other one is the “Reinforcement’. The properties of composites are mostly decided by type of reinforcements and their particle size, geometry, volume percentage, and orientation (Chawla 2012). Researchers and engineers show interest in designing composite materials to enhance its properties like hardness, tensile strength, compressive strength, stiffness, toughness, wear resistance, corrosion resistance etc., Lina F. Kadhim has explained about her research work on the corrosion behaviour and wear resistance of grey cast iron and published her research work. In her work she has focused mainly on Grey cast iron...
which has many applications as pipes, pumps and valve bodies where it has influenced by heat and contact with other solutions. This research has studied the corrosion behaviour and Vickers hardness of grey cast iron by immersion in four strong alkaline solutions with three concentrations of each solution. Dry sliding wear has carried out before and after the heat treatments. S Vijayarajan’s research on aluminium metal matrix Composite for automotive brake Drum applications was published in International society for scientific research and development journal which mainly focuses on the application of Metal Matrix Composites MMCs as new brake drum materials to brake components has been receiving worldwide attention because of their light weight superior mechanical properties high thermal conductivity specific heat and better wear resistance than cast iron. Since the brake drum represents part of the unsprung rotating masses the reduction in their mass will help in increasing the vehicle dynamics and ride comfort. Vijayakumar S journal on the Fabrication of aluminium metal matrix composites and their wear behavior focuses mainly on developing new structural materials with higher strength to weight ratio. It is one of the biggest challenges in the transportation and aerospace industry. Properties like high specific strength, stiffness, better wear resistance and improved elevated temperature properties compared to the conventional metals and alloys. He has also discussed about the various existing and recent fabrication techniques of Aluminium based MMC. Vishal asokan, Arshad Mohammed Gani, Vimal and Mohammed nooh muballigh’s journal on the Design and analysis of reinforced Composite matrix disc brake was available in the journal “International Journal of Engineering Research and General Science”. It mainly tells about the practical use of C-SiC composite material which produces much effective braking compared to steel disc brakes. They also experimentally show the stress accumulated on the composite is much less, which proves the wear resistance, rigid and stable braking during high speeds. S.Mohankumar, R.Deivasigamani, ’s Study on Wear and Friction Characteristics of Brake Rotor made of A359- B4CP Composites mainly tells about the alternate materials for automobile brake disc applications with special consideration to Aluminium and Boron carbide MMC. Amit Pal, Abhishek Verma’s research on Stir Casting of Metal Matrix Composites is also a significant reference. Stir casting process appears a more wide and promising technique for production of metal matrix composite. This paper provides a literature review on MMCs and various effecting parameters like densities of reinforcements and metal matrices, stir speed, time of stirring, angle of stirrer and a wide range of research options which can be used and can be of vital importance for MMCs.

Fig.1. Proposed flow direction

2. CLASSIFICATION OF COMPOSITES

A composite fabricated with reinforcements in the form of particles are known as particle reinforced composites. They are broadly used for various applications, owing to its isotropic property, cost effectiveness, and good interfacial bonding. Significant reasons to use particulates in matrix phase are, low density, improved hardness,
enhanced wear resistance and low cost. Fibers used in fiber-reinforced composites, may be of continuous or discontinuous form. FRCs have high specific strength, stiffness (Mandal et al. 2004) and structural potential so, inherently, they are widely used in industrial and structural applications. The fibers are load-bearing members in FRCs, while the matrix phase is to keep fibers in required places and orientation. Generally, structural composites are of two types, one is laminar and the other is sandwich panels. The consecutively layered panels or sheets form a sandwich panel, whose strength is mainly depending on the orientation and the direction of panels or sheets. In a sandwich panel, the outward sheets are supposed to withstand various stresses while loading, so, they should be made with robust and firm materials like titanium, steel, and aluminum alloys.

3. CLASSIFICATION OF COMPOSITES BASED ON MATRIX

Polymer matrix composites comprise polymer resins (e.g. epoxy, polyesters, vinyl esters, PEEK) as matrix, and fibers (e.g. E-glass, aramid or carbon) as the reinforcements. A polymer can be of large molecule, which is a collection of several subunits. A fiber can be fillers that bares the actual load. Floorings in industries, plastic pipes, automotive parts, and storage containers are the possible applications of Glass fiber Reinforced Polymer (GFRP) composites. Carbon Fiber Reinforced Polymer (CFRP) composites are widely preferred for ultra tech applications like rocket parts, aircraft components, space shuttle quantities. Ceramic matrix composites have ceramic material as matrix phase and ceramic particles, fibers or whiskers as reinforcements. CMC finds their application in engines of aircraft turbine and automobile, as it reveals enhanced creep and thermal behavior. CMC tools made up of alumina composites reinforced with SiC, finds application in CNCs to machine hard metals. Metal Matrix Composites possess metals like Ferrous, Chromium, Molybdenum, Brass, magnesium, etc are as reinforcement in the form of particles, whiskers, short fiber and continuous fiber. As MMCs have more strength, electrical properties, mechanical and corrosion properties.

4. EXPERIMENTAL DETAILS WITH MMC

Among many ferrous based material, stainless steel materials are better wear and corrosion resistant. These properties are attend due to presence of Chromium, vanadium, Molybdenum, Silicon and nickel. So, we decide to get matrix composite which as these material in higher composition. Material investigates in S.B.B alloys, telugupalayam and purchased with higher composition.

Table 1.0. Chemical composition

<table>
<thead>
<tr>
<th>Base Fibre/Metal</th>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>Cr</th>
<th>Ni</th>
<th>Nb</th>
<th>Mo</th>
<th>Fe</th>
<th>Cu</th>
<th>Zr</th>
<th>Al</th>
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<tbody>
<tr>
<td>AISI 304</td>
<td>0.11</td>
<td>0.25</td>
<td>0.48</td>
<td>0.08</td>
<td>0.64</td>
<td>0.32</td>
<td>Bal</td>
<td>0.16</td>
<td>1.08</td>
<td>0.31</td>
<td></td>
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<tr>
<td>AISI 316</td>
<td>0.05</td>
<td>0.14</td>
<td>0.07</td>
<td>0.67</td>
<td>0.17</td>
<td>0.17</td>
<td>Bal</td>
<td>0.23</td>
<td>9.35</td>
<td>2.01</td>
<td></td>
</tr>
<tr>
<td>HRNG-3</td>
<td>0.12</td>
<td>0.11</td>
<td>0.31</td>
<td>2.33</td>
<td>Bal</td>
<td>2.6</td>
<td>0.3</td>
<td>0.95</td>
<td>22.85</td>
<td>70.65</td>
<td>0.20</td>
</tr>
<tr>
<td>HRNG-2</td>
<td>0.12</td>
<td>0.15</td>
<td>0.17</td>
<td>2.33</td>
<td>0.32</td>
<td>Bal</td>
<td>2.6</td>
<td>0.3</td>
<td>18.86</td>
<td>53.39</td>
<td>1.36</td>
</tr>
</tbody>
</table>
5. HARDNESS TEST

One of the most popular hardness testing methods, Brinell Hardness Number is obtained using a perfectly spherical hardened steel ball of 10 mm pressed against the test surface using a static force of 3000 kg (≈29.42 kilo Newton) for at least 10 seconds for steel and measuring the diameters of the indentation left on the surface by means of a graduated low power microscope.

Brinell Test Method All Brinell tests use a carbide ball indenter. The test procedure is as follows: i. The indenter is pressed into the sample by an accurately controlled test force. ii. The force is maintained for a specific dwell time, normally 10 - 15 seconds. iii. After the dwell time is complete, the indenter is removed leaving a round indent in the sample. iv. The size of the indent is determined optically by measuring two diagonals of the round indent using either a portable microscope or one that is integrated with the load application device as shown in Figure 1.11. v. The Brinell hardness number is a function of the test force divided by the curved surface area of the indent. The indentation is considered to be spherical with a radius equal to half the diameter of the ball. The average of the two diagonals is used in the following formula to calculate the Brinell hardness number:

\[ H_B = \frac{2 \times F}{\pi \times d^2} \]
hardness. The Brinell number, which normally ranges from HB 50 to HB 750 for metals, will increase as the sample gets harder. Tables are available to make the calculation simple. Tensile testing, also known as tension testing, is a fundamental materials science and engineering test in which a sample is subjected to a controlled tension until failure. Properties that are directly measured via a tensile test are ultimate tensile strength, breaking strength, maximum elongation and reduction in area. From these measurements the following properties can also be determined: Young’s modulus, Poisson’s ratio, yield strength, and strain-hardening characteristics. Uniaxial tensile testing is the most commonly used for obtaining the mechanical characteristics of isotropic materials. Some materials use biaxial tensile testing. Material strength testing, using the tensile or tension test method, involves applying an ever-increasing load to a test sample up to the point of failure. The process creates a stress/strain curve showing how the material reacts throughout the tensile test. The data generated during tensile testing is used to determine mechanical properties of materials and provides the following quantitative measurements: Tensile strength, also known as Ultimate Tensile Strength (UTS), is the maximum tensile stress carried by the specimen, defined as the maximum load divided by the original cross-sectional area of the test sample. Yield strength is the stress at which time permanent (plastic) deformation or yielding is observed to begin. Ductility measurements are typically elongation, defined as the strain at, or after, the point of fracture, and reduction of area after the fracture of the test sample.

The test sample is securely held by top and bottom grips attached to the tensile or universal testing machine. During the tension test, the grips are moved apart at a constant rate to pull and stretch the specimen. The force on the specimen and its displacement is continuously monitored and plotted on a stress-strain curve until failure. The measurements, tensile strength, yield strength and ductility, are calculated by the technician after the tensile test specimen has broken. The test specimen is put back together to measure the final length, then this measurement is compared to the pre-test or original length to obtain elongation. The original cross section measurement is also compared to the final cross section to obtain reduction in area.
6. CORROSION TEST (salt spray test)

The salt spray (or salt fog) test is a standardized and popular corrosion test method, used to check corrosion resistance of materials and surface coatings. Usually, the materials to be tested are metallic (although stone, ceramics, and polymers may also be tested) and finished with a surface coating which is intended to provide a degree of corrosion protection to the underlying metal. Salt spray testing is an accelerated corrosion test that produces a corrosive attack to coated samples in order to evaluate (mostly comparatively) the suitability of the coating for use as a protective finish. The appearance of corrosion products (rust or other oxides) is evaluated after a pre-determined period of time. Test duration depends on the corrosion resistance of the coating; generally, the more corrosion resistant the coating is, the longer the period of testing before the appearance of corrosion/rust. The salt spray test is one of the most widespread and long-established corrosion tests. ASTM B117 was the first internationally recognized salt spray standard, originally published in 1939. Other important relevant standards are ISO9227, JIS Z 2371 and ASTM G85.

Fig. 9. Specimen after Tensile test

Fig. 10. Salt spray test machine

Fig. 11. Corrosion test report
8. CONCLUSION

The main objective of the present research work is to proof MMC is more suitable for replace automobile disc plate. The material S105 composition is proved that this is unique material which cannot purchase locally. Experimental results are compared detailed and absorbed all results properly. 17.7% Chromium content made the material to fight against corrosion even in salt condition. Presence of chromium also makes the component aesthetically fair and smooth. 2.16% Molybdenum has high melting point and heat dissipation in nature, but due to unavailability of technology this research paper not proof it. 9.51% Nickel, usually Nickel stronger than higher. Thus, nickel makes this material rigid.

REFERENCES


