A Study Mechanical and Tribological properties of tungsten carbide reinforced with Al 7075 – T6 Alloys Composites

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Abstract

In the recent years, as the demand for the usage of high quality and lightweight materials were increased, the usage of the lightweight material like Aluminium (Al) and their Metal Matrix Composites (MMC’s) also increased, especially in aerospace and automotive industries. It has been well known that Aluminium based Metal Matrix Composites (MMC’s) offer a low thermal expansion coefficient, high specific strength, wear and heat resistance as compared to conventional aluminum alloys. Hence, it is proposed to study the properties and applications of a new Al MMC, Tungsten Carbide reinforced with wear resistance were studied by conducting experiments using X-Ray diffraction and SEM (Scanning Electron Microscope) and the test results were compared with Ductile Cast Iron. On analyzing the results, it is observed that, the addition of high strength, high modules refractory particles to a ductile metal matrix, will end up with a new material whose mechanical properties are intermediate between the matrix alloy (Al) and the ceramic reinforcement (WC).

Keywords: Aluminium, ductile cast iron, Alloy

INTRODUCTION

It is necessary to have high machinery service life, operation reliability, low friction in bearings, bushes, piston rings, brake pads, driving mechanisms, friction clutches, coupling gears and moving parts etc., The working condition of these parts differ in various aspects like sliding speeds loads environmental conditions and other parameters. No single metal can meet all the required property so it is necessary to develop a composite material that could have all combinational property satisfying all our engineering requirements. Metal Matrix Composite has enhanced mechanical properties than pure metal. Metal Matrix Composite is very attractive for automotive, aerospace, military and tribological applications. Important MMC applications in the ground transportation (auto and rail), thermal management, aerospace, industrial, recreational and infrastructure industries have been enabled by functional properties that include high structural efficiency, excellent wear resistance, and attractive thermal and electrical characteristics.

1. Composite material:

Composite material (also called composition materials or shortened to composites) are materials made from two or more constituent materials with significantly different physical or chemical properties, that when combined, produce a material with characteristics different from the individual components.

Metal matrix composite:

A metal matrix composite (MMC) is a composite material with at least two constituent parts, one being a metal. The other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite.

MMC are made by dispersing a reinforcing material into a metal matrix.

3.1: Metal Matrix Phase:

The matrix is the monolithic material into which the reinforcement is embedded, and its completely continuous. This means that this is a path through the matrix to any point in the material, unlike two materials sandwiched together.

Metal Matrix Phase: Aluminium 7070-t6:

3.2 Reinforcement Phase:

The reinforcement material is embedded into a matrix. The reinforcement does not always serve a purely structural task (reinforcing the compound),
but is also used to change physical properties such as wear resistance, friction coefficient, thermal conductivity. The reinforcement can be either continuous, or discontinuous.

**Reinforcement Phase: Tungsten Carbide:**

**Materials and properties:**

Improved corrosion resistance can be achieved by replacing 15 % to 30 % of the iron in the alloy with varying amounts of nickel, copper, or chromium.

2: Aluminium 7075-T6 Alloy:

Aluminium alloy 7075 is an aluminium alloy, with zinc as the primary alloying element. It is strong, with strength comparable to many steels, and has good fatigue strength and average mach inability, but has less resistance to corrosion than many other Al alloys. Its relatively high cost limits its use to applications where cheaper alloys are not suitable.

It is produced in many tempers, some of which are 7075-0, 7075-T6, 7075-T651.

The T6 temper is usually achieved by homogenizing the cast 7075 at 450°C for several hours, and then ageing at 120°C for 24 hours. This yields the peak strength of the 7075 alloy. The strength is derived mainly from finely dispersed eta and eta’ precipitates both within grains and along grain boundaries. 7075 alloys are often used in transport applications, including marine, automotive and aviation, due to their high strength-to-density ratio. Their strength and light weight is also desirable in other fields. Rock climbing equipment, bicycle components, inline skating-frames and hang glider airframes are commonly made from 7075 aluminium alloy. Hobby grade models commonly use 7075 and 6060 for chassis plates.

4.2.1: Composition:

<table>
<thead>
<tr>
<th>Table 4.1: Elements</th>
<th>% composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>87.1 – 91.4</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.81- 0.28</td>
</tr>
<tr>
<td>Copper</td>
<td>1.2 – 2.0</td>
</tr>
<tr>
<td>Iron</td>
<td>0.5</td>
</tr>
<tr>
<td>Magnesium</td>
<td>2.1 – 2.4</td>
</tr>
<tr>
<td>Manganese</td>
<td>0.3</td>
</tr>
<tr>
<td>Silicon</td>
<td>0.4</td>
</tr>
<tr>
<td>Titanium</td>
<td>0.2</td>
</tr>
<tr>
<td>Zinc</td>
<td>5.1 – 6.1</td>
</tr>
</tbody>
</table>

4.3: Tungsten Carbide:

Tungsten carbide (chemical formula: WC) is an inorganic chemical compound (specifically, a carbide) containing equal parts of tungsten and carbon atoms. In its most basic form, tungsten carbide is a fine gray powder, but it can be pressed and formed into shapes for use in industrial machinery, cutting tools, abrasives, amour-piercing rounds, other tools and instruments, and jewellery.

Tungsten carbide is approximately two times stiffer than steel, with a Young’s modulus of approximately 550 GPa, and is much denser than steel or titanium. It is comparable with corundum (α-Al₂O₃) or sapphire / ruby in hardness and can only be polished and finished with abrasives of superior hardness such as cubic boron nitride and diamond, in the form of powder, wheels and compounds.

2. Experimental Procedure:

3.1: Ratio Of Mmc:

<table>
<thead>
<tr>
<th>Table no. 3.1: NAME</th>
<th>TUNGSTEN CARBIDE</th>
<th>AL-7075T6 (APPROX.)</th>
<th>DUCTILE CAST IRON</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>0.830</td>
<td>0.035 (4%)</td>
<td>0.865</td>
</tr>
<tr>
<td>Sample 2</td>
<td>0.770</td>
<td>0.065 (8%)</td>
<td>0.835</td>
</tr>
<tr>
<td>Sample 3</td>
<td>0.700</td>
<td>0.100 (12.5%)</td>
<td>0.800</td>
</tr>
</tbody>
</table>

Process Involved:

1. Stir casting.
2. Surface finishing of the casted procedure.

3.2: Stir Casting Process:

The proposed aluminium metal matrix composite using AL 7075-t6 alloy and TUNGSTEN CARBIDE having the chemical composition. A batch of 2.8 KG of aluminium 7075-t6 alloy was melted at 820°C using Stir casting furnace. The melt was agitated with the mechanical stirrer (manually). Then preheated particles of tungsten carbide powder were added at constant feed into the crucible and stirring was continued which gives uniform distribution of tungsten carbide in the melt. The stirring was continued for five minutes. After stirring the mixture solidifies with uniform distribution of tungsten carbide. Then the casted composite was taken from the mould by tongs.

3.3 Surface Finish:

The composite was machined for surface finish. Here the composite produced was in cylindrical shape.
4. Hardness Test:

6.1 Hardness:
Hardness is the property of a material that enables it to resist plastic deformation, usually by penetration. However, the term hardness may also refer to resistance bending, scratching, abrasion or cutting.

4.1.1 Measurement Of Hardness:
Hardness is not an intrinsic material property dictated by precise definition in terms of fundamental units of mass, length and time. A hardness property value is the result of a defined measurement procedure.

4.1.2: The Brinell Hardness Test:
The Brinell hardness test method consists of indenting the test material with a 10 mm diameter hardened steel or carbide ball subjected to a load of 3000 kg. For softer materials the load can be reduced to 1500 kg or 500 kg to avoid excessive indentation. The full load is normally applied for 10 to 15 seconds in the case of iron and steel and for at least 30 seconds in the case of other metals. The diameter of the indentation left in the test material is measured with a low powered microscope. The Brinell hardness number is calculated by dividing the load applied by the surface area of the indentation.

The diameter of the impression is the average of two readings at right angles and the use of a Brinell hardness number table can simplify the determination of the Brinell hardness. A well-structured Brinell hardness number reveals the test conditions, and looks like this, “75 HB 10/500/30” which means that a Brinell Hardness of 75 was obtained using a 10 mm diameter hardened steel with a 500 kilogram load applied for a period of 30 seconds. On tests of extremely hard metals a tungsten carbide ball is substituted for the steel ball.

4.1.4: Hardness Process:
The Brinell hardness test method consists of indenting the test material (AL-7075-16 WITH WC REINFORCEMENT) with a 10 mm diameter hardened steel to a load of 3000 kg for at least 10-15 seconds. The diameter of the indentation left in the rest material is measured with a low powered microscope. The Brinell hardness number is calculated by dividing the load applied by the surface area of the indentation.

4.2: Scanning Electron Microscope:
A Scanning electron microscope (SEM) is a type of electron microscope that produces images of a sample by scanning it with a focused beam of electrons. The electrons interact with atoms in the sample, producing various signals that can be detected and that contain information about the sample’s surface topography and composition. The electron beam is generally scanned in a raster scan pattern, and the beam’s position is combined with the detected signal to produce an image. SEM can achieve resolution better than 1 nanometer. Specimens can be observed in high vacuum, in low vacuum, and (in environmental SEM) in wet conditions.

The most common mode of detection is by secondary electrons emitted by atoms excited by the electron beam. The number of secondary electrons is a function of the angle between the surface and the beam. On a flat surface, the plume of secondary electrons is mostly contained by the sample, but on a titled surface, the plume is partially exposed and more electrons are emitted. By scanning the sample and detecting the secondary electrons, an image displaying the tilt of the surface is created.

Sem Samples:

4.3 Xrd Process:
Required dimension of the test sample:
- Flat and square shaped
- Thickness=2mm
- Side=20mm

X-Ray Diffraction (XRD):
X-ray diffractometes consist of three basic elements:
- X-ray tube
- Sample holder
- X-ray detector

Xrd Samples:

4.4 X-Ray Tube:
X-rays are generated in a cathode ray tube by heating a filament to produce electrons, accelerating the electrons toward a target by applying a voltage, and bombarding the target material with electrons. When electrons have sufficient energy to dislodge inner shell electrons of the target material, characteristic X-ray spectra are produced. The spectra consist of several components, the most common being Kr and Kα. A detector records and processes this X-ray signal and converts the signal to a count rate which is then output to a device such as a printer or computer monitor.

The geometry of an X-ray diffractometer is such that the sample rotates in the path of the collimated X-ray beam at an angle 0 while the X-ray detector is mounted on an arm to collect the diffracted X-rays and rotates at an angle and rotates at an angle of 20. The instrument used to maintain the angle and rotate the sample is termed as goniometer. For typical powder patterns, data is collected at 20 from -5 to 70, angles that are preset in the X-ray scan.

4.5 Microstructure Of The Surface:
The surface microstructure is analysed to verify whether the tungsten carbide has been uniformly distributed over the surface.
4.5.1 Steps Involved:
1. Machining the composite to the required dimension.
2. Removing the burrs with emery sheet.
3. Buffing process.

4.5.2 Procedure:
At first the composite is machined to the required dimension as follows,
- Cylindrical shaped component
- Length = 20mm
- Diameter = 10mm

Then the composite is surface finished removing the burrs. For this the composite is removed from burrs by holding it against the emery sheet. Buffing is often used to enhance the looks of an item, prevent contamination of instruments, remove oxidation, create a reflective surface, or prevent corrosion in pipes. In metallographic, polishing is used to create a flat, defect-free surface for examination of a metal’s microstructure under a microscope. Silicon-based polishing pads or a diamond solution can be used in the polishing process.

Buffing wheels, also known as mops, are either made from cotton or wool cloth and come bleached. Specific types include: sisal, spiral sewn, loose cotton, canton flannel, do met flannel, denim, treated spiral sewn, cushion, treated vented, untreated vented, string buff, finger buff, sisal rope, mushroom, facer, tampered, scrubbing mushroom, hourglass buff, rag, “B”, climax, swans down, airflow, cool air, and bullet.

4.5.3 Cushion Type Buffs:
Used for light cutting and for colouring. A superior grade of fine cotton sheeting held together with two or more circles of lockstitch sewing. It gives a resilient, cushioned effect when in use.

4.5.4 Canton Flannel Buffs:
For use with rouge to colour gold, silver, etc. Discs of soft flannel joined by two or four circles of lockstitch sewing. Follow intricate contours easily and will not scratch.

4.5.6 Spiral Sewed Buffs:
Dependable, well-balanced, long-wearing wheels for general shop use. Carefully selected, high grade cotton sheeting assembled to give maximum cutting action continuous spiral sewing with 1/4” spacing.

4.6 Wear Test:
A tribometer is an instrument that measures tribological quantities, such as coefficient of friction, friction force, and wear volume, between two surfaces in contact. A tribometer is the general name given to a machine or device used to perform tests and simulations of wear, friction and lubrication which are the subject of the study of tribology. Often tribotesters are extremely specific in their function and are fabricated by manufacturers who desire to test and analyze the long-term performance of their products.

4.6.1 Pin On Disc:
A pin on disc tribometer consists of a stationary “pin” under an applied load in contact with a rotating disc. The pin can have any shape to simulate a specific contact, but spherical tips are often used to simplify the contact geometry. Coefficient of friction is determined by the ratio of the frictional force to the loading force on the pin.

4.6.2 Data Acquisition:
The friction coefficient signal is displayed in real time on a PC screen. Data can be viewed as it is logged for the entire specified test duration, which test files for on-line analysis. The software allows 9 different logged test files for on-line analysis/mapping. The software displays the test time turn count, linear velocity, and user defined test parameters. This data can be stored and printed along with the friction traces.

4.6.3 Purpose:
Records friction and wear in sliding contact in dry, lubricated, controlled environment and partial vacuum.

4.6.4 Application:
Fundamental wear studies wear mapping and PV diagrams, friction and wear testing of metals, ceramics, soft and hard coatings, plastics, polymers and composites, lubricants, cutting fluids, heat processed samples.

5. Results:
5.1. Tabulation For Hardness:

<table>
<thead>
<tr>
<th>Sample</th>
<th>Diameter of impression in mm</th>
<th>Brinell Hardness Number (BHN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.05</td>
<td>152.78</td>
</tr>
<tr>
<td>2</td>
<td>1.83</td>
<td>192</td>
</tr>
<tr>
<td>3</td>
<td>2.3</td>
<td>121</td>
</tr>
</tbody>
</table>

5.1.1 Comparison Of Results:
A. diameter of the impression on the samples 1 and 2 is first decreases and then it increases for sample 3 after certain limit.
B. Likewise brinell hardness number is first increasing for samples 1 and 2 then it is decreasing.
C. Hardness is increasing when WC reinforcement is upto (7 to 8%) and after that WC reinforcement decreases the hardness.
D. When the WC reinforcement is beyond 8% the hardness property decreases.
E. The samples 1 and 2 be used to replace the nodular cast iron which has a hardness of 170 BHN.

5.2 Scanning Electron Microscope (Sem) Test: Procedure For Sem Anaysis:
1. First the composite (AL 7075-T6 reinforced with WC) is machined to the required dimension as follows:
   - Cylindrical Shaped Specimen
   - Diameter= 10mm and Length= 20mm
2. Then the specimens (Samples1, 2 and 3) are analysed under SEM and their microstructure are given as follows.
3. The SEM analysis is carried out only at the surface of the samples where the wear test is performed.

7.1. Sem Images For Sample 1:

![Image of Sample 1 SEM Analysis]

7.2. Sem Images For Sample 2:

AL 7075–t6 =770gm WC =65gm (8%)

![Image of Sample 2 SEM Analysis]

5.3. Sem Images For Sample 3:

AL 7075 – t6 = 700gm WC = 100gm (12.5%)

From The Images of Sample 2, it is clear that tungsten carbide had been uniformly distributed throughout the aluminium alloy in most of the areas except few and also more amount of tungsten carbide had been distributed when compared to the sample 1 which can be identified easily.
X-Ray Diffractin Test (XRD):
X-ray Diffraction (XRD) Test Sample I:
The presence of WC is confirmed

X-ray Diffraction (XRD) Test Sample II:
The presence of Al-7075 is confirmed
The presence of WC is confirmed

Wear Test:
Result For Sample 1:

![](image1)

There exists a definite ratio between the force developed and the applied force, called the coefficient of friction. A stable and higher friction coefficient is essential for Auto motive applications.

Wear Rate Vs Time:
The wear rate for sample from the graph it can be seen that, as time increases the wear rate increases

Result For Sample 2:
Wear Rate Vs Time:

![](image2)
From the above graph it is evident that the addition of WC drastically reduces wear when compared to sample 1.

But from the above graph the wear rate is more, this is because when WC(tungsten carbide)is added beyond the limit say (>8%) the wear rate begins to increase . And thus confirming from the project that the addition of Tungsten Carbide(WC)

Beyond 8% decreases the wear resistance.

**Conclusion:**

In this project we conclude that from the results of wear and hardness tests, the sample 2 (WC8%) shows excellent wear resistance and hardness property. So we can replace ductile iron by Sample 2.

**REFERENCES**


