"STUDY AND CHARACTERIZATION OF ALUMINIUM 7075 HYBRID COMPOSITES REINFORCED WITH B_4C AND Wc"

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Abstract - *There has been a rapid growth in the utilization of Aluminium alloys in the recent era especially in automotive and aerospace industry because of their inherent properties like high strength to weight ratio, low wear rate, etc. Hybrid MMC's are new generation advancement in composites. This project uses Al 7075 alloy as matrix metal with boron carbide and tungsten carbide as reinforcement particles. Stir casting process was used to fabricate the composites by varying the mass fractions of boron carbide (2-6wt%) and tungsten carbide being constant (4wt%). This paper investigates the mechanical property, tribological behaviour and microstructural analysis of the composites prepared as per the ASTM standards which is used to evaluate the performance of the composite. Vickers hardness test was performed and the hardness value significantly increases with increase in the percentage of boron carbide and as the hardness of composite increases the wear rate reduces. The density of the composites is similar to that of Al 7075 alloy with slightest deviations.*

Key Words: Aluminium 7075, Boron Carbide, Tungsten Carbide, Stir Casting, Mechanical property, Tribological behaviour, Microstructural analysis.

1. INTRODUCTION

Composite materials are those made from two or more constituent's material when fused together produces a material with distinguished properties difference from properties of individual material often resulting in superior product. Generally hybrid composites are those composites, which are made up of two or more reinforcement alongside matrix material the typical examples for hybrid material in nature is bone or nacre. Material technology and engineering design field requires high advanced engineering material with high end mechanical and Tribological properties. To adjust to the requirements of engineering industries, the ceramic particles like $Al_2 O_3$, sic are mostly reinforced with Aluminium metal matrix for their improved mechanical properties like hardness and low wear rate. Recent studies show that, boron carbide reinforced Aluminium metal matrix composites has attractive properties like good tensile strength, high hardness and low density than Al-SiC composites [1]. Aluminium alloys are most suitable for engineering material for automobile, aerospace and mineral processing industries for various high performing components and are being used for these diverse applications due to their low density, exceptional thermal conductivity properties[2]. Among several series of Aluminium alloys, Al7075 is ample explored due to their admirable properties. These alloys are heat treatable. Al7075 alloy are extremely resilient to corrosion and exhibits moderate strength [3]. Al7075 finds much useful in the fields of construction, automotive and marine applications. The composites made out of Aluminium alloys are of wide interest owing to their high specific strength, fracture toughness, wear resistance and stiffness [4]. Tungsten carbide is a fine dark powder which can be squeezed and framed into shapes for use in manufacturing industries, cutting devices, abrasives, defensive layer penetrating rounds, other equipments and tools [5]. Tungsten carbide is double the density of steel and is nearly two times stiffer than steel [6]. Cubic boron nitride and diamond powder wheels are used for polishing tungsten carbide which is equivalent to corundum in hardness [6]. This project consists of Aluminium 7075 as base matrix material with boron carbide and tungsten carbide as reinforcement. As known Aluminium 7075 is the hardest of the Aluminium series and boron carbide is one of the hardest material known to mankind, ranking behind diamond [7], in order to avoid the composite being brittle tungsten carbide is added to give sufficient stiffness and young's modulus to the composites. This composites yields good hardness, low density, wear resistance as per the test conducted.

2. Materials

2.1 7075 Aluminium alloy

A conceptual design of the parafoil is carried out to determine, the basic system performance and other aerodynamic parameters as well as the dynamic terms with the help of calculation procedure by J.S. Lingard [4]. The initial geometry of the parafoil was estimated with the help of the desired canopy loading, aspect ratio and other performance parameters. NASA LS (1)-0417 air foil was selected and the aerodynamic coefficients of the parafoil including the anhedral effect were estimated. Using the calculated aerodynamic coefficients, the stall velocity, glide angle and range for particular drop altitudes are estimated for a steady glide assumption. Then, the mass centre, mass moments of inertia and the apparent mass effects were calculated. To be concise, the calculations are skipped and the parameters are shown in the Table **2.1.**

Table 2.1Chemical Composition of Al 7075 alloy

Elements	Content %
Aluminium, Al	**90**
Zinc, Zn	**5.6**
Magnesium, Mg	**2.5**
Copper,Cu	**1.6**
Chromium, Cr	**0.23**

Table 2.2 Mechanical properties of Al 7075 alloy

Properties	Metric
Tensile strength	220 MPa
Yield strength	95 MPa
Shear strength	150 MPa
Fatigue strength	160 MPa
Elastic modulus	70-80 GPa
Poisson's ratio	0.33
Elongation at break	17%
Hardness	60

2.2 Boron carbide

Boron carbide (B_4C) is the reinforcement particles, it the third hardness material known, ranking behind diamond and boron nitride. It has extreme hardness good chemical resistance and low density.

Table 2.3Mechanical properties of boron carbide.

Density (g.cm^{-3})	2.52
Melting Point (°C)	2445
Hardness (Knoop 100 g) (kg.mm^{-2})	2900 - 3580
Young's Modulus (GPa)	450 - 470

2.3 Tungsten carbide.

Tungsten Carbide is often referred to as a hard metal due to it's very high **hardness** compared to other metals. Typically a Tungsten Carbide Hard Metal can have a hardness value of 1600 HV, whereas mild steel would be in the region of 160 HV a factor of 10 lower.

3. Experimentation details

3.1. Experimental Method

Stir casting process shown in Fig.1 is a simplest and cost effective liquid state fabricating method of metal matrix composites, in which boron carbide and tungsten carbide is mixed with a molten matrix i.e, (Al 7075 alloy) by means of mechanical stirring which ensures a more uniform distribution of the reinforcing particles. In this process, 7075 Aluminium alloy was superheated to 750°C and then the temperature is lowered gradually below the liquids temperature to keep the matrix material in the semi-solid state. At this temperature, the preheated boron carbide and tungsten carbide particles with different weight proportions of (2 % B_4C+4% WC, 4% B_4C + 4 % WC , 6 % B_4C + 4% WC) average size varying from 5 µm & 10 µm respectively were introduced into the slurry and mixed using a graphite and ceramic stirrer.

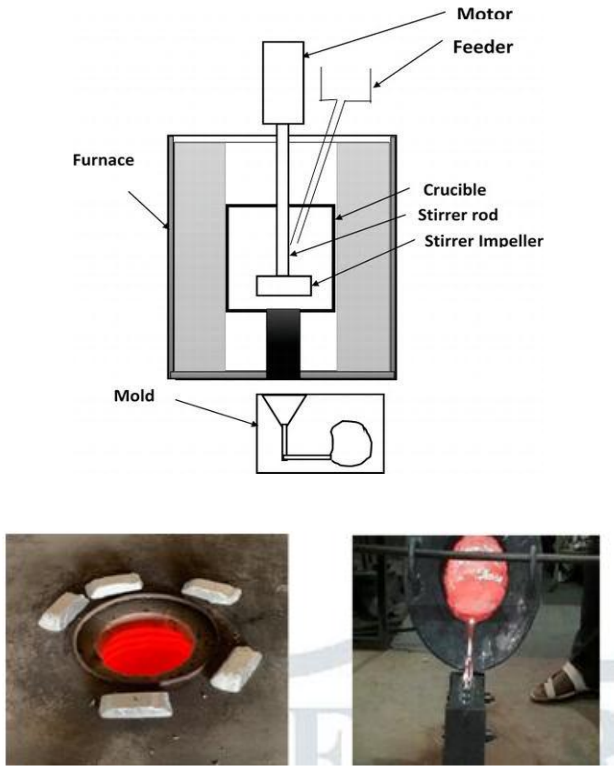

Fig. 1 Stir Casting Process

The composite slurry temperature increased to completely liquid state and automatic stirring was continued to about ten minutes at an average stirring speed of 300-350 rpm. The melted material then superheated above liquids temperature and finally poured into the permanent mould for preparing testing specimen

3.2 Experimental tests.

Density test: The common definition for density is the mass of the material per unit volume. A test conducted to determine the density of a material is detailed is ASTM standard. The density of the composites is determined using its weight in air w_a and in water w_w. The density of air is negligible and density of water ρ_w=0.9975g/cm^3 at 23°c are taken as known parameters in test composite density $\rho_c = w_a/(w_a-w_w)/\rho_w$.

Wear test: wear is defined as erosion of material mechanically or through chemical reaction i.e., corrosion. The study of wear and related process is referred to as tribology .An apparatus used for wear testing is termed as wear tester, or tribometer. The wear testing arrangements used for this project is pin-on-disc wear testing machine the test conducted to determine the wear rate of a material is detailed in the standard.

Hardness test: Hardness is defined as the ability of the material to resist plastic deformation usually penetration, indentation, abrasion under the application of load. The hardness of the material is measured by hardness tests such as Brinell; Knoop, Rockwell or Vickers hardness testing apparatus. In this project the hardness of the composites is measured using Vickers hardness apparatus. Vickers hardness test method uses diamond indenter for indenting the test material, after removal of the load the two diagonals of the indentation is measured using a microscope and their averages are calculated.

Microstructure Testing: Microstructure is the very small-scale structure of a material, defined as the structure of a prepared surface of material as revealed by a microscope above 25× magnifications. The microstructure of a material (such as metals, polymers, ceramics or composites) can strongly influence physical properties such as strength, toughness, ductility, hardness, and corrosion resistance, high/low temperature behavior or wear resistance. These properties in turn govern the application of these materials in industrial practice. Microstructure at scales smaller than can be viewed with optical microscopes is often called nanostructure, while the structure in which individual atoms are arranged is known as crystal structure.

4. Results

4.1 Density test results:

Table 3 (a) shows the density results of the different composition of specimens in air and water medium. Last column depicts the average density of the prepared composites. Fig-2 shows the graph of variation in the density of different compositions

Table 4 (a) Average density for Different compositions.

Sl. no	COMPOSITION	W1 (air) in Kg/m³	W2 (water) in Kg/m³	Density	Average Density
1	4%tungsten 2%boron	6.575	4.118	2.66	2.71
2	4%tungsten 4%boron	8.034	5.002	2.64	2.65
3	4%tungsten 6%boron	7.223	4.483	2.62	2.64
4	5%tungsten 2%boron	6.685	4.092	2.57	2.57
5	5%tungsten 4%boron	7.785	4.865	2.66	2.66
6	5%tungsten 6%boron	7.454	4.717	2.723	2.72

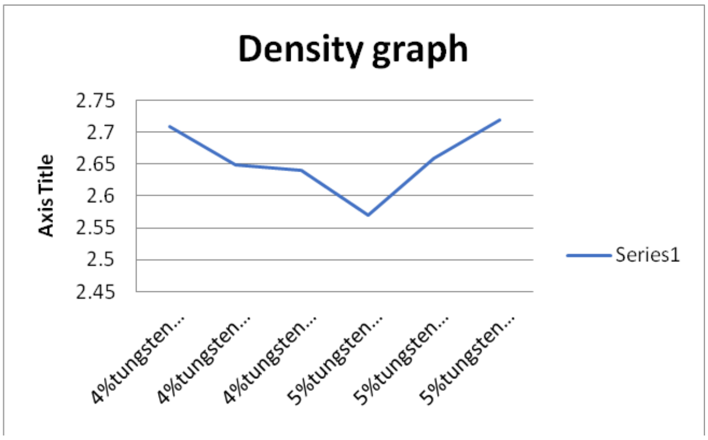

Fig-2 Graph showing the variation in the density of different compositions.

4.2. Hardness test results.

Table 4 (b) Hardness Test results for the different composition.

Sl. no	COMPOSITION	VHN			AVERAGE
		Min	Max	Mean	
1	4%tungsten 2% boron				
	Specimen 1.	99.03	120.05	111.36	
	Specimen 2.	96.00	118.00	108.00	109.02
	Specimen 3.	98.09	119.00	107.71	
2	4% tungsten 4% boron				
	Specimen 1.	88.03	114.00	98.67	
	Specimen 2.	95.07	116.00	106.69	103.81
	Specimen 3.	94.04	115.09	106.07	

3	4% tungsten 6% boron				
	Specimen 1.	108.05	124.07	118.04	107.05
	Specimen 2.	97.03	117.09	105.05	
	Specimen 3.	92.09	108.07	98.08	
4	5%tungsten 2%boron				
	Specimen 1.	95.70	121.60	108.65	
	Specimen 2.	104.50	149.20	126.85	123.00
	Specimen 3.	102.0	165	133.50	
5	5%tungsten 4%boron				
	Specimen 1.	109.90	191.80	150.85	
	Specimen 2.	97.0	125.0	111.0	157.12
	Specimen 3.	113.30	305.70	209.50	
6	5%tungsten 6%boron				
	Specimen 1.	106.80	186.70	146.75	
	Specimen 2.	100.70	129.40	115.05	161.23
	Specimen 3.	113.20	330.60	221.90	

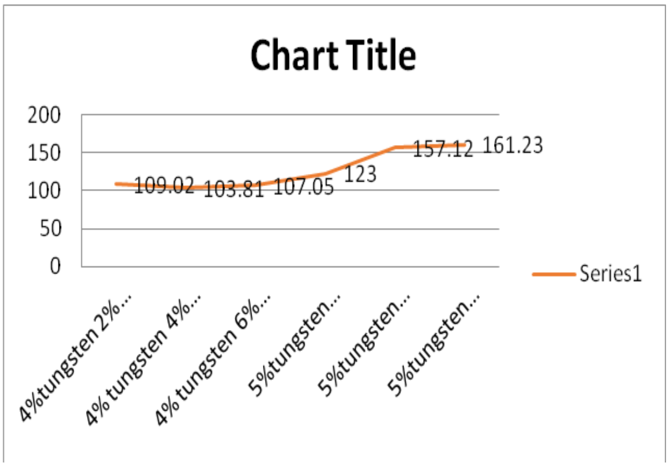

Fig 3- Graph showing the hardness numbers of different composition.

4.3 WEAR TEST RESULTS:

COMPOSITION	Load N	Initial weight in grams	Final weight in grams	Mass loss in grams	Volume loss in mm^3	Wear rate mm^3/m
4%tungsten 2% boron						
Specimen 1.	10	6.40	6.40	0.0045		1.69x
Specimen 2.	20	7.82	7.81	0.0095	1.69	10^{-3}
Specimen 3.	30	6.83	6.81	0.0198		
4% tungsten 4% boron						
Specimen 1.	10	8.00	7.97	0.0302	3.44	3.44x 10^{-3}
Specimen 2.	20	8.03	7.99	0.0341		
Specimen 3.	30	7.18	7.15	0.0369		
4% tungsten 6% boron						
Specimen 1.	10	7.21	7.18	0.0265	7.30	7.30x 10^{-3}
Specimen 2.	20	7.54	7.50	0.0423		
Specimen 3.	30	6.2	6.20	0.0581		

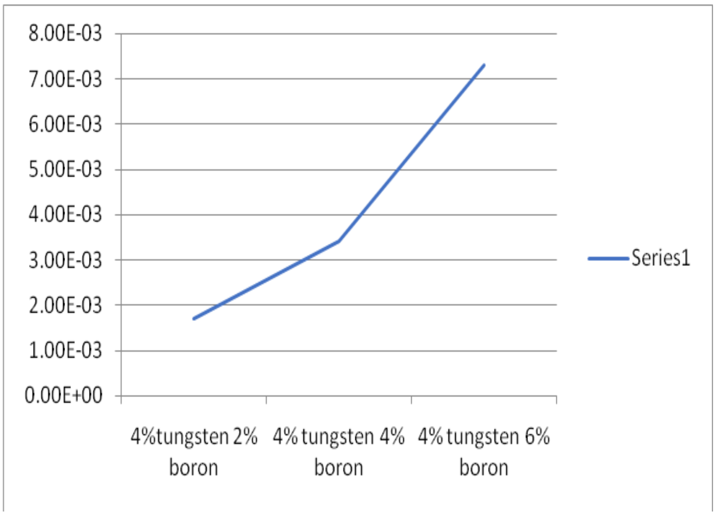

Fig-4 Graph shows the wear rate increasing with increasing reinforcements.

5. Conclusions:

- The hardness of the composites increases with the increase in the percentage of boron carbide.
- As the hardness of the composite increases the density of the specimen reduces with the increase in the percentage of boron carbide. But there is an increasing trend in the graph for 5% Wc, which indicates that density increases after adding more than 4% of Wc .

- The wear rate of the composite increases with the increase in the percentage of boron carbide as the prepared composite material turns to brittle.

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