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EXPERIMENTAL INVESTIGATION ON MECHANICAL PROPERTIES OF TIB2 & NB REINFORCED ALUMINIUM 7075 FOR PUMP IMPELLER APPLICATION

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Abstract

The main aim of this project is to create corrosion free light weight pump impeller with composite materials. Due to light weight and corrosion-free qualities, aluminium composites were widely used in the automotive industry. When TiB_2 is being reinforcement with aluminium alloy it increases mechanical characteristics of the material. So here in our project we are going to use aluminium 7075 as a base material and reinforcing it with titanium di boride to increase its strength and also adding niobium which forms oxide layer which restricts the occurrence of corrosion. The stir casting method is being used to create three composites made of different materials. After manufacturing three different samples of composites, we are going to make three different tests like tensile test to check the ultimate tensile strength of the material and impact test to check the toughness behavior of the material and microhardness test to check the hardness of the material. The test findings demonstrate the different composite samples and their overall mechanical characteristics. Finally, by comparing three different test results we are going to choose the material composition which possess higher mechanical properties.

Keywords: Composite impeller, impeller manufacturing, tensile test, Impact test, Microhardness test.

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1. INTRODUCTION

Continuous demands for comfort, fuel efficiency, and lightweight in the automotive industry has led to the development of better materials and optimised design. Due to increasing demands for materials that are lightweight with specific capabilities in the aerospace and automotive sectors, metal-matrix composites (MMCs) have gained prominence. MMCs are often used in industries because of their excellent mechanical properties and wear resistance. In areas on which low weight and energy savings are critical factors without sacrificing the strength of the components, MMCs have increasingly replaced some of the conventional light-weight metallic alloys, like the various grades of aluminium alloys. By transferring and distributing the force being applied through the ductile matrix towards the reinforcing phase, Metal-matrix Composites (MMCs) show the capacity to withstand significant tensile and compressive stresses[1]. By adding a reinforcing phase to the matrix using several techniques, including powder metallurgy, liquid metallurgy, and squeeze-casting, these MMCs are manufactured. MMCS may include whiskers, continuous filaments, and discontinuous particles[2] .Particles are good additives due to their capacity to provide consistent isotropic behaviors in a combination Due to their ability for providing predictable isotropic behaviors in a combination, particles are good additives[3]. Several particulate metal matrix composites (PMMCs) have become increasingly popular as a result of their advantageous mechanical, thermal characteristics. Due to low manufacturing and fibre costs, particle-reinforced composites tend to be less costly than fiber-reinforced composites. Compared to unreinforced matrix metal, PMMCs have been demonstrated to have higher wear resistance in addition to strength, hardness, and thermal conductivity[4]. Within the category of hard ceramic particles that are being studied for inclusion in aluminum-based MMCs, B4C particles are known to have excellent compatibility in the aluminium matrix and can be made at a reasonable cost. Due to their excellent wear resistance, this SiC-particle-reinforced aluminium (ZrO2/B4C) composites were prime candidate materials for applications in cars as pistons, brake rotors, callipers, connecting rods and cylinder liners. Aluminium PMMCs with ES or boron carbide (B4C) particles have drawn attention. Comparing these materials to aluminium matrix without reinforcement, they have much reduced rough and sliding wear rates. Because they help to postpone the transition from moderate to severe wear, these hard particles are being discovered to be extremely important at high contact loads. Due to its enhanced wear resistance and superior thermal conductivity, Al B4C PMMCs were given consideration for application in brake rotors for vehicles. Brake rotors are frequently made of grey cast iron[5]. The ratio of volume to the number of reinforced particles, also known as whiskers, typically varies from 10% to 30%. Aluminium alloys are frequently employed by aerospace firms. Hyper-eutectic Al-Si related alloys like A6082 (A1, B4C, 0.3ES), that include B4C, ZrO, or Sic particles, are used to make components for automobile engines. Aluminium 7075 is a material that is commonly employed for applications in the automotive, aerospace, and marine sectors due to its excellent strength-to-weight ratio, remarkable corrosion resistance, and good fatigue qualities. Meanwhile, by adding ceramic reinforcements like TiB2 and Nb, its limitations in the areas of resistance to wear and strength may be addressed[6]. The mechanical characteristics of aluminium 7075 reinforced with TiB2 and Nb for pump impeller applications were examined in this work. The impeller, a crucial component of a centrifugal pump, experiences heavy stresses and deteriorates with time. Use of a material with robust mechanical characteristics and the capacity to survive these circumstances is essential[7].

Impellers

Impellers are essential parts of centrifugal pumps, vacuum pumps, and other pumping systems. Pump impellers work on the basis of Bernoulli's principle, which stipulates that a rise in a fluid velocity is linked with a drop in pressure or potential energy (advisers). When fluid or gas media reaches an impeller pump, it gets caught in the impeller vanes and the pump wall, increasing in velocity as it goes from the impeller eye (centre) to the impeller's outer diameter. When the media reaches a specific point near the outer diameter, its velocity abruptly falls and pressure increases (according to Bernoulli's principle). As the media is expelled through the impeller and through the pump opening, it gets even more pressurised. Based on these operating principles, it is clear that the rotational speed (which affects velocity) and vane height (which affects pressure and the possibility of a vacuum) of a pump impeller greatly influence the pump's output pressure and flow.

2. Material And methodology

Due to the numerous charactertics, including low density, strong wear resistance, good tensile strength, and outstanding surface quality, composite materials are more in demand than ever. Niobium and titanium di boride are two of the least expensive types of low-density reinforcement. Wear and Tensile strength will also be taken into account. An experimental setup with all the required inputs is set up to achieve the aforementioned goals. In this study, TiB2 and Nb are added to aluminium metal in various weight ratios to create a composite. The composite must be created using the stir casting technique, and its various mechanical properties must be examined through the testing process.

ALUMINUM-7075

Al 7075 is easily weldable, anodizable, and has a nice surface quality. It also has great corrosion resistance. The T4 conditon has good formability and is most frequently available in T6 temper.

Experimental plan

AL 7075 ALUMINUM MECHANICAL PROPERTIES

1.	Density	2810kg/m^3
2.	Melting point	477^{0}C
3.	Electrical Resistivity	5.15*10^{-5}/K^{-1}
4.	Thermal Conductivity	130 to 150 W/m.K
5.	Thermal Expansion	2.36*10^{-5}/K^{-1}
6.	Modulus of Elasticity	71.7Gpa

TITANIUM DI BORIDE

The ceramic substance titanium di boride (TiB2) is well known for having a high melting point, hardness, strength to density ratio, and wear resistance, as well as a comparatively high strength and durability. However, it appears that this material's current uses are restricted to a small number of specialized industries, including impact-resistant armor, cutting tools, crucibles, and wear-resistant coatings. Utilizing TiB2 cathodes in the electro-chemical reduction of alumina to aluminium metal is a significant emerging application. If TiB2 can be machined using electrical discharge, it may be possible for further uses to emerge quickly. Economic factors, in particular the cost of dandifying a material with a high melting point, and worries about the material's variable qualities, may prevent this material from being used more widely. The latter problem is addressed in this study by examining the relationship between TiB2's physical, mechanical, and thermal characteristics and its density and grain size.

NIOBIUM

Niobium is a metallic element that is grey, crystalline, and has other qualities that make it valuable to manufacturers, including excellent temperature resistance. It is most frequently used to make a variety of metal alloys. Niobium, even in trace levels (as little as 0.1%), can considerably enhance a metal's performance properties. Niobium goods from Admit Inc. are available in a number of shapes and sizes, including sheets, plates, rods, wires,tubes, strips, foils, and oxides.

NIOBIUM PROPERTIES

1.	Density	8.57 g/cm^3
2.	Atmoic Weigth	92.906g/mol
3.	Melting point	2750 K, 2477°C, 4491°F
4.	Boilling Point	5017 K, 4744°C, 8571°F
5.	Electrical Resistivity	(0 °C) 152 nΩ.m
6.	Thermal Conductivity	(300 K) 53.7 W.m^{-1}K^{-1}
7.	Thermal Expansion	7.3 µm/ (m.K).

2.1 CASTING PROCESS

Aluminium metal matrix composite materials (Reinforcements) are formed by the combination of two or more elements, one of which is the matrix and the other is filler material. Fibers or particle composites may be layered on top of an aluminium metal matrix. These materials are often treated utilizing liquid cast metal technology, powder metallurgy, or specialized manufacturing techniques. Powder metallurgy and liquid cast metal technology are the two main methods used to process discontinuous particulate metal matrix material. The powder metallurgy method has some inherent limitations, such as high processing costs and small component sizes. Therefore, the sole technique to be taken into account as the most ideal and cost-effective approach for processing aluminium composite materials is casting. Aluminium 7075 rod and Titanium Di Boride with an average particle size of 200 m were bought from the local market for the alloy development. The needed quantities of reinforcements were alloyed with the molten aluminium rod in a crucible made of graphite.

2.2 STIR CASTING

In the stir casting process, a mechanical stirrer is utilised to produce a vortex that joins the reinforcement with the matrix material. It is an excellent technology for creating metal matrix composites due to its low cost, adaptability for production in larger quantities, simplicity, near net shaping, and ease of composite structure management.

Figure.No.1 Creating Mould using stir casting method

2.3 TENSILE TEST

The mechanical characteristics of friction-treated joints are evaluated using tensile testing. Tensile testing may detect tensile properties such as tensile strength, yield strength, percentage of elongation, percentage of area reduction, and elastic modulus. Within the parameters that the equipment could handle, the welding settings were picked at random. The joints' tensile strength and burn off were tested while using random parameters to create them. Following the creation of the joints, the mechanical and metallurgical properties were assessed. The friction-welded samples were made in accordance with ASTM specifications. A universal testing machine (UTM) with 40 tonnes of FIE manufacture was used for the test.

Figure.No.2. Universal Tensile Testing machine

2.4 IMPACT TEST

The impact test is a technique employed to find the mechanics of a material when it is subjected to a sudden load which leads the object to deform, fracture, or break entirely. A known weight falls from a given height, often but not at all times in what appears to be of a pendulum, and impacts the sample with an abrupt force. The kind of test determines the shape and position of the holding fixture. The contact between the weight and the specimen destroys the specimen in most cases, but the passing of energy between the two is utilized for evaluate the fracture mechanics of the material.

The objective of the impact test:

The purpose of impact testing is to determine if a material can absorbs the energy effectively during a collision. This energy may be used to evaluate the material's toughness, impact strength, fracture resistance, impact resistance, or fracture resistance, depending on the test and the characteristic to be evaluated. These considerations are critical for selecting materials for the usages like as automobile collisions, in which the material must endure a very rapid loading process.

Impact test types:

The three most common impact test types which includes the Charpy V-notch test, the Izod test, and the Tensile Impact test. These three tests essentially find the same material properties but vary in the position of the test sample, causing the specimen to be stressed in various directions, and includes an identified weight released from a specified height hitting with the sample in its test fixture. All of these tests can help you figure out the impact mechanics of your test specimen.

Figure.No.3. Impact Test

2.5 MICRO-HARDNESS TEST

Methods for testing hardness involve pushing an indenter probe into a surface while applying a certain load. Usually, the dwell time of the indentation is set. Hardness is often assessed by mechanical testing by measuring the size or depth of the indentation. There are two types of hardness testing and they are

- Macrohardness
- Microhardness.

Microhardness testing with applied stresses of 10 N is routinely performed on thin specimens, plated surfaces, thin films, and tiny samples. Vickers and Knoop tests are used to determine microhardness.

MICROHARDNESS

Microhardness testing must take sample size, preparation, and environment into consideration for more exact and reproducible findings. Samples must be square to the indenter tip and fit inside the sample stage. An exceptionally rough surface may cause indentation data to be less accurate; polishing samples using a tried-and-true procedure is advised. Vibrations must be separated from the microhardness testing. Statistics are necessary for samples with different phases or grain sizes.

Traditional microhardness test techniques optically analyse the indented imprint, confounding results with operator bias. Unlike the Vickers or Knoop hardness test procedures, instrumented indentation employs a three-sided pyramidal (Berkovich) indenter. This form enables the edge to be theoretically tailored to an atomic point. Utilising the high load nano-indenter for microhardness testing with forces ranging up to 1 Newton (N), instrumented indentation with an array of indents using dynamic measurements delivers unmatched accurate and consistent microhardness data with no operator bias.

VICKERS HARDNESS

A Vickers indenter is being used to press into a surface to a specific force in order to perform the Vickers hardness test. It is typical to hold the force for 10 seconds. The finished indentation is examined visually to measure the diagonal lengths to calculate the size of the impression.

3. RESULT

3.1. ENSILE TEST

Table1: Tensile strength

Material	Sample No	CS Area[mm]^2	Peak Load[N]	%Elongation	UTS[N/mm^2]	Mean UTS[N/mm^2]
Pure AL 7075	1	36.00	2408.630	1.120	66.904	111.121
	2	36.00	4357.837	2.090	121.055	
	3	36.00	5234.557	3.150	145.404	
AL 7075=80gm Niobium=24gm TiB2=16gm	4	36.00	4465.061	2.210	124.028	82.721
	5	36.00	2817.324	1.330	78.254	
	6	36.00	1651.661	1.120	45.881	
AL 7075=80gm TiB2=24gm Niobium=16gm	7	36.00	6282.707	3.970	174.520	162.156
	8	36.00	5629.233	5.060	156.371	
	9	36.00	5600.607	2.850	155.577	

From the Table1: Tensile strength, we can able to understand that the composition AL7075=800 gm, TiB2=24gm and Niobium=16 gm possesses higher ultimate tensile strength when compared with other two compositions.[8]

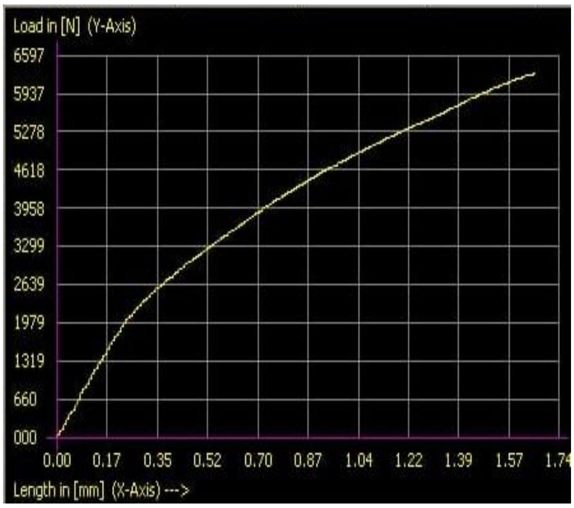

Figure.No.4 Load vs Length

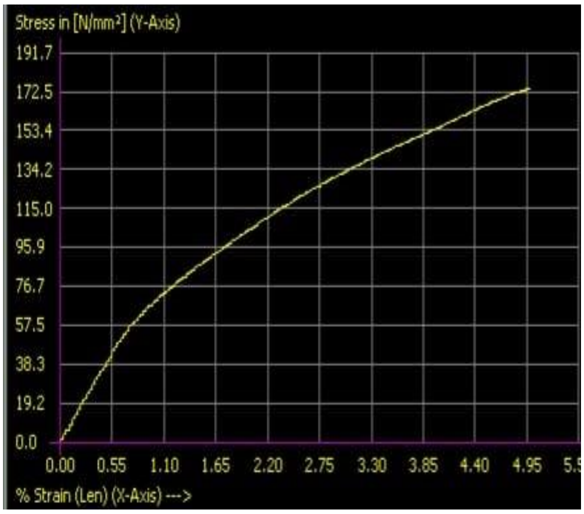

Figure.No.5 Stress vs Strain

Figure.No.4 and Figure.No.5 shows us the output Graph for load VS length and Stress vs Strain relation for the Peak load 6282.707N.

3.2 IMPACT TEST

Table 2: Impact test

S.NO	IZOD IMPACT VALUE IN J FOR GIVEN THICKNESS
1	1.25
2	0.85
3	1.00
4	1.50
5	1.60
6	1.20
7	1.10
8	1.80
9	1.70

From Table 2: Impact test, we can able to say that the sample 8,9 which is of the material composition AL7075=800 gm, TiB2=24gm and Niobium=16 gm possesses high impact strength and toughness when compared with other two composition.

3.3 MICRO-HARDNESS TEST

Table 3: Vickers Hardness Test

S.NO	TEST LOAD	DURATION TIME[Sec]	H LENGTH	V LENGTH	AVERAGE LENGTH	HARDNESS (HV)	MEAN HARDNESS (HV)
1	HV0.1 (980.7mN)	10	35.2388	35.4293	35.334	148.539	152.422
2	HV0.1 (980.7mN)	10	35.2388	33.334	34.2864	157.755	
3	HV0.1 (980.7mN)	10	33.715	36.3817	35.0483	150.971	
4	HV0.1 (980.7mN)	10	35.8102	36.1912	36.0007	143.089	

							141.224
5	HV0.1 (980.7mN)	10	35.6198	35.6198	35.6198	146.166	
6	HV0.1 (980.7mN)	10	37.1436	37.1436	37.1436	134.419	
7	HV0.1 (980.7mN)	10	38.096	32.953	35.5245	146.951	154.176
8	HV0.1 (980.7mN)	10	35.0483	32.953	34.0007	160.418	
9	HV0.1 (980.7mN)	10	36.1912	32.953	34.5721	155.159	

From Table 3: Microhardness test, we can able to say that the sample 8,9 which belongs to the material composition AL7075=800 gm, TiB2=24gm and Niobium=16 gm possesses high hardness when compared with other two composition.

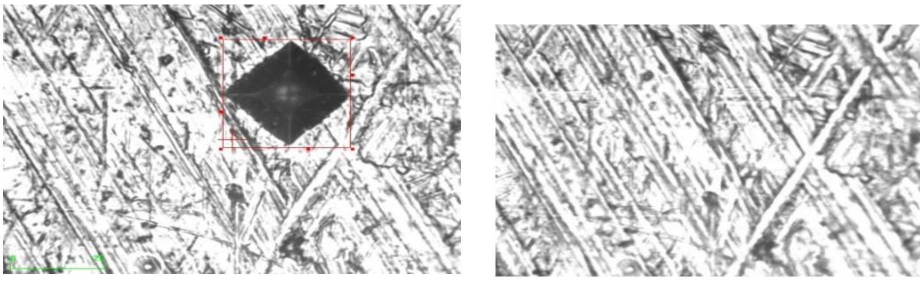

Figure.No.6 Vickers Hardness

Figure.No.6 Shows the Vickers Hardness test result of the composition AL7075=800 gm, TiB2=24gm and Niobium=16 gm.

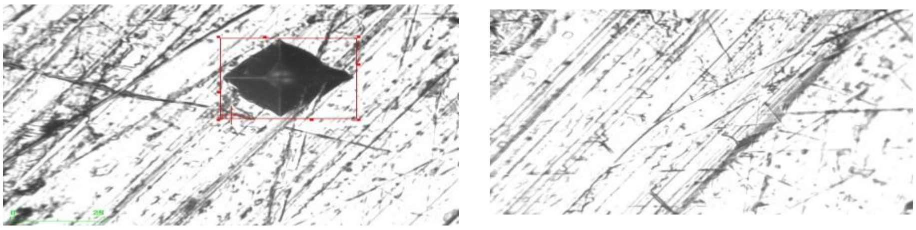

Figure.No.7 Vickers Hardness

Figure.No.7 Shows the Vickers Hardness test result of the composition AL7075=800 gm, TiB2=16 gm and Niobium=24 gm.

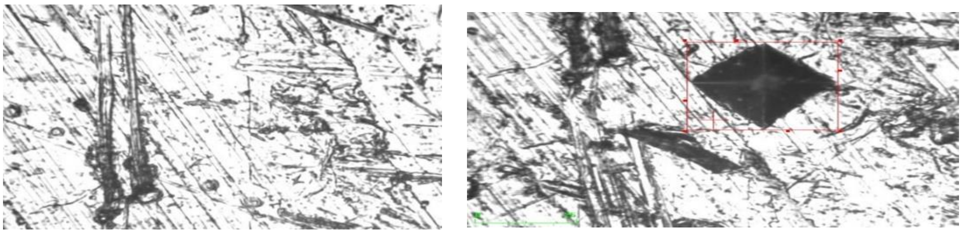

Figure.No.8 Vickers Hardness

Figure.No.8 Shows the Vickers Hardness test result of the composition AL7075=800 gm

4. CONCLUSION

When compared to traditional materials, composite materials, particularly aluminium 7075, titanium diboride, and niobium composites, have superior mechanical qualities. Because of their low weight and excellent toughness, these materials can be employed in a variety of industrial applications. The mechanical properties of the Al7075 metal matrix were investigated and finally, we discovered that AL7075=800 gm, TiB2=24gm and Niobium=16gm is better than other composites and bare Al7075.

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