Mechanical Properties Evaluation of Tib_2 & Nb Reinforced Aluminium 7075 For Pump Impeller Applications

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Abstract- *Aluminum composites were largely used in automobiles industries due to their light weight and corrosion free characteristics. Mechanical properties of Aluminum alloy were improved by the reinforced of TiB2. The composites were fabricated by three varying the volume percentage of TiB2 particles and Niobium. The three material matrix composites can be manufactured by stair casting method. These composites were evaluated for microstructure and mechanical property by FEA.The test results shows that overall mechanical properties of different composite samples were better than bare metal.*

Keywords- composite impeller, impeller manufacturing, SEM analysis, ansys modeling, tensile test

I. INTRODUCTION

The ever-increasing demand for light weight, fuel efficiency and comfort in automobile industries has lead to the development of advanced materials along with optimized design. The increased demand for light-weight materials with specific strength in the aerospace and automotive industry has spread the development and use of one group of composites: metal-matrix composites (MMCs). MMCs are widely used in industries, as they have excellent mechanical properties and wear resistance. MMCs have slowly replaced some of the conventional light-weight metallic alloys such as the various grades of aluminum alloys in applications where low weight and energy saving are important considerations and yet without sacrificing the strength of the components.

A metal matrix composite (MMC) can be defined as a metallic matrix (usually an alloy of Al, Cu, Fe, Mg, Ti or Pb) containing three-dimensional inclusions (usually an oxide, carbide or nitride).In these MMCs, the good ductility of the metallic alloy as the matrix material is retained while the modulus and strength of the composites are increased as a result of the reinforcement phases. By the correct combination of matrix material and reinforcements, MMCs can be tailored to give superior electrical, mechanical and even chemical properties. This is especially important in cases when monolithic metals and alloys can no longer fulfill the increasingly stringent requirements demanded by designers and engineers in newer engineering applications.

Metal-matrix composites (MMCs) exhibit the ability to withstand high tensile and compressive stresses by the transfer and distribution of the applied load from the ductile matrix to the reinforcement phase. These MMCs are fabricated by the addition of a reinforcement phase to the matrix by the use of several techniques such as powder metallurgy, liquid metallurgy and squeeze-casting. The inclusions in MMC_S can be continuous fibres, discontinuous particulate or whiskers. Particulates make excellent inclusions, because they lead to predictable isotropic behavior in the composite. In addition some particulate metal matrix composites (PMMCs) are attracting attention because of their good mechanical, thermal and tribological properties. Particulate-reinforced composites cost less than fiber-reinforced composites owing to the lower cost of fibers and manufacturing cost.

Besides their increased strength, hardness and thermal conductivity, PMMCs have been found to have better wear resistance than the unreinforced matrix metal. Among the group of hard ceramic particles considered for inclusion in aluminum based MMCs B_4C particles have been found to have an excellent compatibility with the aluminum matrix and can be obtained at low cost. Their excellent wear resistance also makes these SiC- particle-reinforced aluminum (ZrO_2/B_4C) composites important candidate materials for use in automobiles as pistons, brake rotors, calipers, connecting rods and cylinder liners. The attention has been given to aluminum PMMCs which contain particles of boron carbide (B_4C) or ES. Such materials exhibit abrasive and sliding wear rates which are substantially lower than those of the unreinforced aluminum matrix. These hard particles have been found to be of great importance at high contact loads, because the particles serve to delay the transition from mild to severe wear.

As a result of their improved wear resistance and excellent thermal conductivity, Al B_4C PMMCs have been considered for use in automobile brake rotors. Conventional material for brake rotor is gray cast iron. The volume fraction of reinforced particles or whiskers is generally within the range 10-30%. Aluminum composites are widely employed in the aerospace industry. Hyper-eutectic Al-Si based composites such as Al7075 (A1, B_4C, 0.3ES) that contain B_4C, ZrO, particles or Sic particles' are used in the fabrication of automotive engine components.

1.2 COMPOSITE

Composite material is a material composed of two or more distinct phases (matrix phase and reinforcing phase) and having bulk properties significantly different from those of any of the constituents. Many of common materials (metals, alloys, doped ceramics and polymers mixed with additives) also have a small amount of dispersed phases in their structures, however they are not considered as composite materials since their properties are similar to those of their constituents (physical property of steel are similar to those of pure iron) . Favorable properties of composites materials are high stiffness and high strength, low density, high temperature stability, high electrical and thermal conductivity, adjustable coefficient of thermal expansion, corrosion resistance, improved wear resistance etc.

II. MATRIX PHASE

1. The primary phase, having a continuous character,
2. Usually more ductile and less hard phase,
3. Holds the reinforcing phase and shares a load with it.

1.3 REINFORCING PHASE

1. Second phase (or phases) is imbedded in the matrix in a discontinuous form,
2. Usually stronger than the matrix, therefore it is sometimes called reinforcing phase. Composites as engineering materials normally refer to the material with the following characteristics:
   1. These are artificially made (thus, excluding natural material such as wood).
   2. These consist of at least two different species with a well defined interface.
   3. Their properties are influenced by the volume percentage of ingredients.
   4. These have at least one property not possessed by the individual constituents.

Performance of Composite depends on:

1. Properties of matrix and reinforcement,
2. Size and distribution of constituents,
3. Shape of constituents,
4. Nature of interface between constituents.

1.3.1CLASSIFICATION OF COMPOSITES

Composite materials are classified

a. On the basis of matrix material,
b. On the basis of filler material.

(a) On the basis of Matrix:

A. Metal Matrix Composites (MMC)

(iron, cobalt, copper) and a dispersed ceramic (oxides, carbides) or metallic (lead, tungsten, molybdenum) phase.

B. Ceramic Matrix Composites (CMC)

Ceramic Matrix Composites are composed of a ceramic matrix and imbedded fibers of other ceramic material (dispersed phase).

C. Polymer Matrix Composites (PMC)

Polymer Matrix Composites are composed of a matrix from thermoset (Unsaturated polyester (UP), Epoxy) or thermoplastic (PVC, Nylon, Polysterene) and embedded glass, carbon, steel or Kevlar fibers (dispersed phase).

(b) On the basis of Material Structure:

1. Particulate Composites
1. Particulate Composites consist of a matrix reinforced by a dispersed phase in form of particles.
2. Composites with random orientation of particles.
3. Composites with preferred orientation of particles. Dispersed phase of these materials consists of two-dimensional flat platelets (flakes), laid parallel to each other.
4. Fibrous Composites
5. Short-fiber reinforced composites. Short-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of discontinuous fibers (length < 100*diameter).
6. Composites with random orientation of fibers.
7. Composites with preferred orientation of fibers.

8. Long-fiber reinforced composites. Long-fiber reinforced composites consist of a matrix reinforced by a dispersed phase in form of continuous fibers.
9. Unidirectional orientation of fibers.
10. Bidirectional orientation of fibers (woven).
11. Laminate Composites

1.4 METAL MATRIX COMPOSITES

Automobile manufacturers are responding to demands for greater fuel efficiency through use of alternate materials such as metal matrix composites (MMCs). Parts made of MMCs offer significant weight savings while maintaining if not improving performance as compared with conventional materials. Over the last decade, MMCs have made slow but steady progress toward mainstream utilization in the automobile industry. To meet the demands of less fuel consumption, less pollution and more efficiency standards and to maintain competitiveness, automobile producers are seriously considering alternate materials in the design of their products. Advanced materials, such as metal matrix composites (MMC) appears a promising way to achieve significant improvements in performance.

1.4.1 MMC Attributes and Applications

MMCs are composed of a metal or metal alloy base (called the matrix) and a reinforcing (usually ceramic) material that is dispersed in the matrix. MMCs typically are stronger, stiffer, operate at higher temperatures, have better abrasion resistance, and have other advantages technology was first developed in the early 1960s. Since that time over $1 billion has been invested in research and development, mostly focused on military and aerospace applications, for which cost considerations are secondary to improved performance. Lower cost MMCs were developed based on this research and further R&D was undertaken by large primary aluminum producers and chemical companies to develop commercial applications. The automobile industry was targeted as an industry where suitable applications could be found and where the potential for large volumes of consumption is high.

Aluminum companies specifically targeted aluminum MMCs as a method of expanding aluminum demand.MMC properties and production costs are dependent on the type of reinforcement and the manufacturing process. The reinforcing material may be discontinuous or continuous. MMCs with continuous reinforcement have the most desirable properties. However, continuous reinforcement material is more expensive than discontinuous materials, and continuous-reinforced MMCs require costly processes to manufacture. Present production costs for the continuous-reinforced MMC exceed $200 per pound whereas costs for discontinuous-reinforced MMCs can be less than $2 per pound. The least expensive type of MMC part is the discontinuous type reinforced with particulates, which is relatively inexpensive. This type can be produced using conventional metal casting techniques. However, particulate MMCs can also produce using powder metallurgy processes that are more expensive but that produce MMCs with better physical properties.

The most promising MMCs for automobile applications are the aluminum-based types. Reinforced with particulates of silicon carbide or alumina, aluminum MMCs have been shown to be able to take the place of certain steel and cast iron parts in automobiles with weight savings in excess of 50 percent. Aluminum MMCs with particulate reinforcement appear to be practically viable for use in the automobile production process. Small amounts of aluminum MMCs are currently being used as cylinder liners and in pistons of certain Japanese automobiles.

1.4.2 Aluminum Metal Matrix Composites

Aluminum alloys are used in advanced applications because of their combination of high strength, low density, durability, machinability, availability and cost is very attractive compared to competing materials. However, the scope of these properties can be extended by using aluminum matrix composite materials. Aluminum matrix composites can be defined as follows: (1) it must be man-made. (2) It must be a combination of at least two chemically distinct materials (one being aluminum) with a distinct interface separating the constituents.(3) The separate materials must be combined three dimensionally.(4) It should create properties which could not be obtained by any of the individual constituents. The major advantages of AMCs compared to unreinforced materials are as follows:

1. Greater strength
2. Improved stiffness
3. Reduced density (weight)
4. Improved high temperature properties
5. Controlled thermal expansion coefficient
6. Thermal/heat management
7. Enhanced electrical performance
8. Improved abrasion and wear
9. Control of mass (especially in reciprocating applications)
10. Improved damping capabilities.

AMC material systems offer superior combination of properties in such a manner that today no existing monolithic material can rival. Driving force for the utilization of AMCs in automobile sector include performance, economic and environmental benefits.

The key benefits of AMCs in automobile sector are lower fuel consumption, less noise and lower airborne emissions. With increasing stringent environmental regulations and emphasis on improved fuel economy, use of AMCs in automobile sector will be inevitable and desirable in the coming years. AMCs are intended to substitute monolithic materials including aluminum alloys, ferrous alloys, titanium alloys and polymer-based composites in several applications. Moreover, by utilizing selective-reinforcement techniques AMCs can offer economically viable solutions for wide variety of commercial applications. Recent success in commercial and military applications of AMCs is based partly on such innovative changes made in the component design.

ALUMINUM ADOPTION FACTORS

1. Light-Weight

Aluminum intensive vehicles weigh 25 to 45 percent less than steel cars, achieving retention of vehicle size and passenger comfort, and improving fuel economy, vehicle performance (acceleration, braking distance, reaction time) and handling.

2. Formability

Aluminum may be alloyed relatively easily, and may be formed, fabricated, and joined by existing methods.

Light weight, heavier gauge, and strength characteristics stiffen the frame to improve car ride, handling, and safety. Process costs may be lower than those of steel, and design flexibility is high.

3. Safety

Aluminum gauge (thickness) is usually 50 percent greater than steel in equivalent frame and absorbs crash energy more effectively.

Weld-bonded aluminum structures generally perform at an equivalent level in frontal, rollover, and side intrusion crashes.

4. Cost/Price

Aluminums' cost, by weight, is several times greater than most steels, although the total value of frame is small relative to total value of auto. Price premium is declining as newer steels cost more and automakers gain experience designing with aluminum.

5. Recyclability

Both steel and aluminum are currently recycled (i.e., possess an infrastructure for recycling) and are market driven.

III. METHODOLOGY

The requirement of composite material has gained popularity in these days due to their various properties like low density, good wear resistance, good tensile strength and good surface finish. Titanium di boride and Niobium is one of the least expensive and low-density reinforcement. The Tensile strength and wear will also be taken into consideration. For the achievement of the above, an experimental set up is prepared where all the necessary inputs will be made. In this work a composite is developed by adding TiB2 & Nb in Aluminum metal by weight ratio with various percentages. The composite has to be prepared by crucible casting technique and has to be analyzed various mechanical properties.

Experimental plan

MATERIALS AND METHODS

ALUMINUM-7075

Al 7075 has a good surface finish, high corrosion resistance, is readily suited to welding and can be easily anodized. Most commonly available as T6 temper, in the T4 condition it has good formability.

CHEMICAL COMPOSITION OF ALUMINUM 7075

Typical chemical composition for aluminum alloy 7075,

ELEMENT	PERCENTAGE
Zn	5.1 to 6.1
Mg	2.1 to 2.9
Cu	1.2 to 2.0
Fe	0.50 (max)
Cr	0.18 to 0.28
Mn	0.3 (max)
Si	0.4 (max)
Ti	0.2 (max)
Al	Balance

AL 7075 ALUMINUM MECHANICAL PROPERTIES

Aluminum alloy 7075 properties

Density	2810 Kg/m^3
Melting Point	477^0C
Modulus of Elasticity	71.7Gpa
Thermal conductivity	130 to 150 W/m.K
Thermal expansion	2.36×10^{-5} /K^{-1}
Electrical resistivity	5.15×10^{-6} Ω cm

TITANIUM DIBORIDE

Titanium di boride (TiB_2) is well known as a ceramic material with relatively high strength and durability as characterized by the relatively high values of its melting point, hardness, strength to density ratio, and wear resistance. Current use of this material, however, appears to be limited to specialized applications in such areas as impact resistant armor, cutting tools, crucibles, and wear resistant coatings. An important evolving application is the use of TiB_2cathodes in the electro-chemical reduction of alumina to aluminum metal. Other applications may develop rapidly if the electrical discharge machining of TiB_2can be perfected. Broader application of this material may be inhibited by economic factors, particularly the cost of dandifying a material with a high melting point, and concerns about the variability of the material properties. The present paper addresses the latter issue by examining the physical, mechanical, and thermal properties of TiB_2 as a function of density and grain size.

NIOBIUM

Niobium is a grey, crystalline metallic element with high temperature resistance and other desirable properties for manufacturers. It is most commonly used in the creation of numerous metal alloys. Small amounts of niobium (as little as 0.1%) can significantly improve a metal's performance characteristics. Admit Inc. offers pure, alloy, and oxide niobium products in a variety of forms, including sheets, plates, rods, wires, tubes, strips, foils, and oxides.

NIOBIUM PROPERTIES

Here are some of niobium's essential properties:

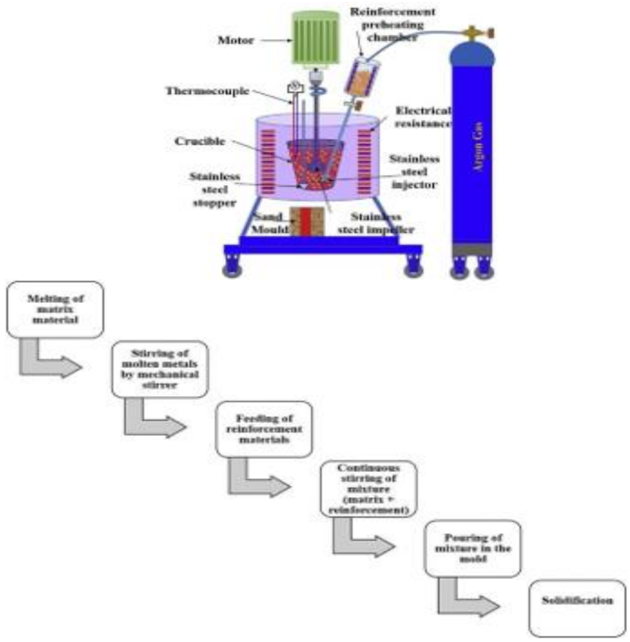
Symbol – Nb
Number – 41
Density – 8.57 g/cm3
Atomic Weight – 92.906 g/mol
Crystal Structure – Body Centered Cubic
Melting Point – 2750 K, 2477°C, 4491°F
Boiling Point – 5017 K, 4744°C, 8571°F
Electrical Resistivity – (0 °C) 152 nΩ·m
Thermal Conductivity – (300 K) 53.7 W·m−1K−1
Thermal Expansion – 7.3 µm/ (m·K).

CASTING PROCESS

The aluminum metal matrix composite materials is the combination of two or more constituents in which one is matrix and other is filler materials (reinforcements). Aluminum metal matrix may be laminated, fibers or particulates composites. These materials are usually processed through powder metallurgy route, liquid cast metal technology or by using special manufacturing process. The processing of discontinuous particulate metal matrix material involves two major processes (1) powder metallurgy route (2) liquid cast metal technology. The powder metallurgy process has its own limitation such as processing cost and size of the components. Therefore only the casting method is to be considered as the most optimum and economical route for processing of aluminum composite materials. For alloy development aluminum 7075 rod and Titanium Di Boride average particles size 200µm were purchased from local market. The aluminum rod was melted in a graphite crucible and alloyed with required quantity of reinforcements.

STIR CASTING

Stir casting is a type of casting process in which a mechanical stirrer is introduced to form vortex to mix reinforcement in the matrix material. It is a suitable process for production of metal matrix composites due to its cost effectiveness, applicability to mass production, simplicity, almost net shaping and easier control of composite structure

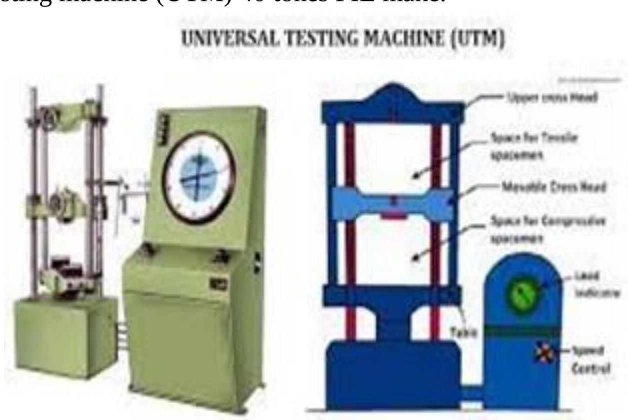


Stir casting machine set up

TENSILE TEST

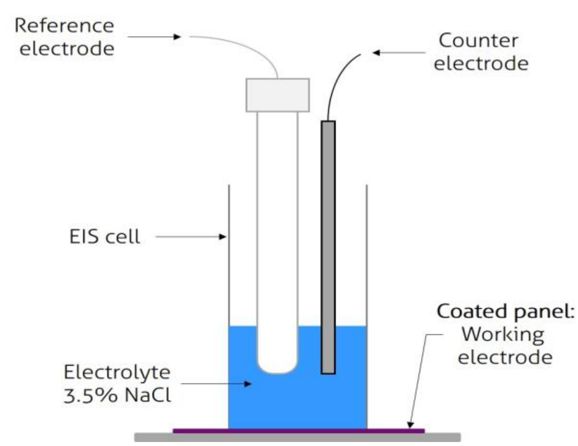
Friction processed joints are evaluated for their mechanical characteristics through tensile testing. A tensile test helps determining tensile properties such as tensile strength, yield strength, percentage of elongation, and percentage of reduction in area and modulus of elasticity.
The welding parameters were randomly chosen within the range available in the machine. The joints were made with random parameters and evaluate tensile strength and burn off. Then the joints were made and evaluate the mechanical and metallurgical characteristics.

The friction welded specimens were prepared as per the ASTM standards. The test was carried out in a universal testing machine (UTM) 40 tones FIE make.



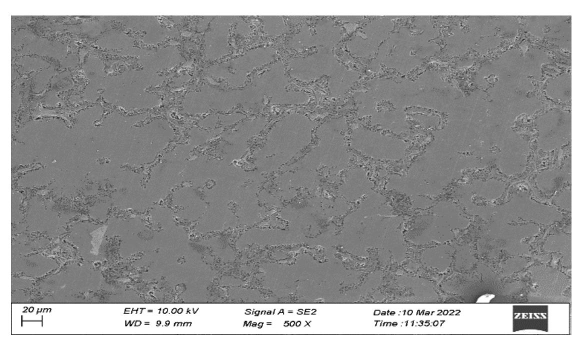
CORROSION TEST VIA ELECTROCHEMICAL IMPEDANCE SPECTROSCOPY

Electrochemical impedance spectroscopy (EIS) is a powerful technique used for the analysis of interfacial properties related to bio-recognition events occurring at the electrode surface, such as antibody–antigen recognition, substrate–enzyme interaction, or whole cell capturing. Thus, EIS could be exploited in several important biomedical diagnosis and environmental applications. However, the EIS is one of the most complex electrochemical methods, therefore, this review introduced the basic concepts and the theoretical background of the impedimetric technique along with the state of the art of the impedimetric biosensors and the impact of nanomaterials on the EIS performance. The use of nanomaterials such as nanoparticles, nanotubes, nanowires, and nanocomposites provided catalytic activity, enhanced sensing elements immobilization, promoted faster electron transfer, and increased reliability and accuracy of the reported EIS sensors. Thus, the EIS was used for the effective quantitative and qualitative detections of pathogens, DNA, cancer-associated biomarkers, etc. Through this review article, intensive literature review is provided to highlight the impact of nanomaterials on enhancing the analytical features of impedimetric biosensors.

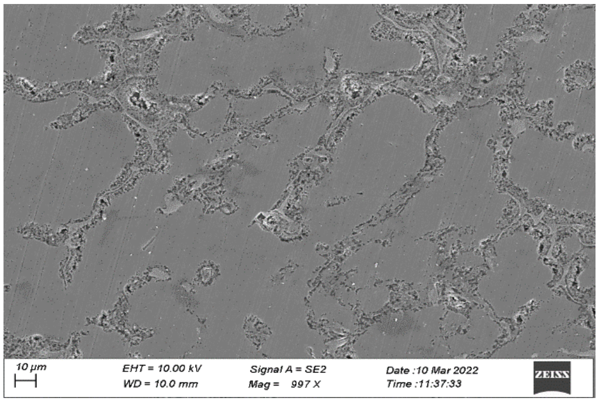


RESULT

SEM ANALYSIS TEST(FESEM)

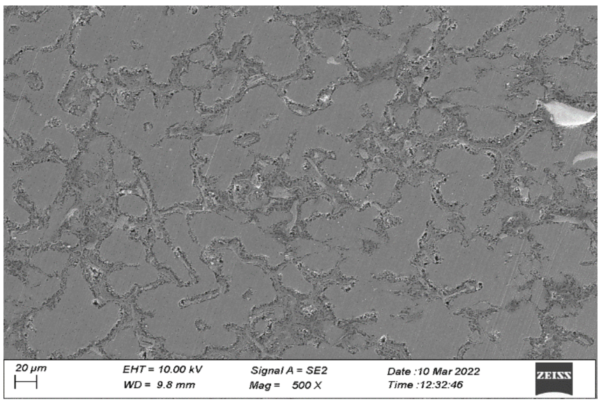


(a)

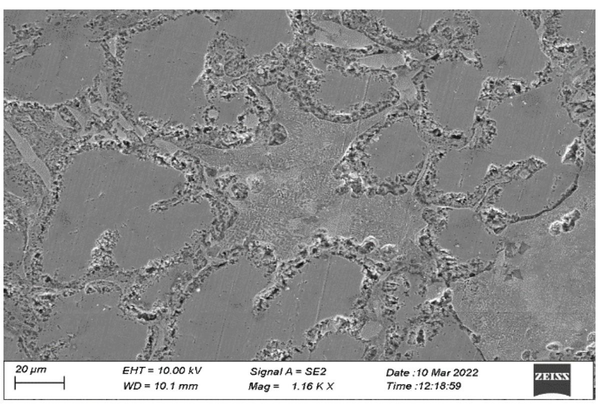


(b)

(a), (b) Al 7075+3% TiB2+2% Nb



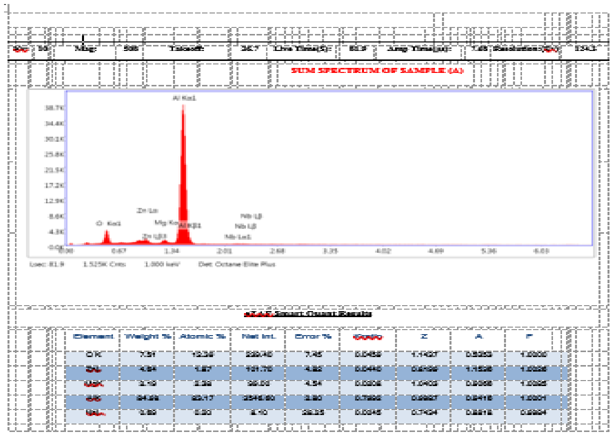
(c)

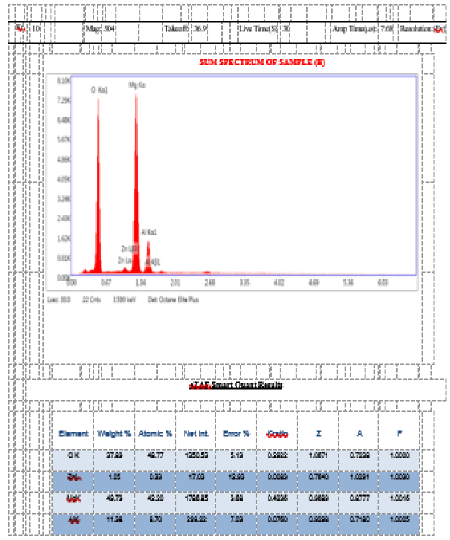


(d)

Al 7075+2% TiB2+3% Nb

EDAX



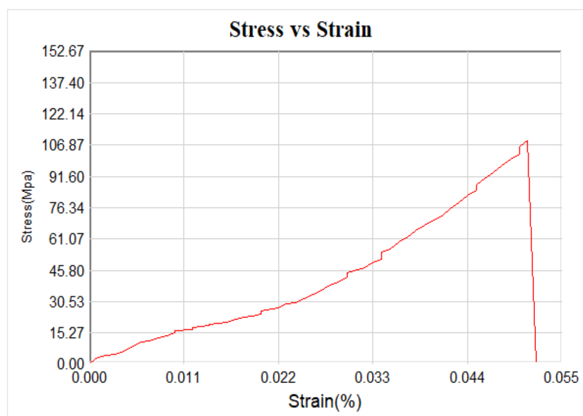


TENSILE STRENGTH VALUES

Tensile Strength

Ratio	Dia (mm)	CSA (mm^2)	YL (kN)	YS (Mpa)	TS (Mpa)	IGL (mm)	FGL (mm)	PL (kN)	MAX Displacement (mm)
A	12.2	119.83	10.38	92.346	91.09	100	101.3	2.78	4.32
B	12.5	122.72	12.63	102.916	109.19	100	101.4	2.52	5.39
C	12.9	124.31	12.94	97.508	94.17	100	101.2	3.48	4.75

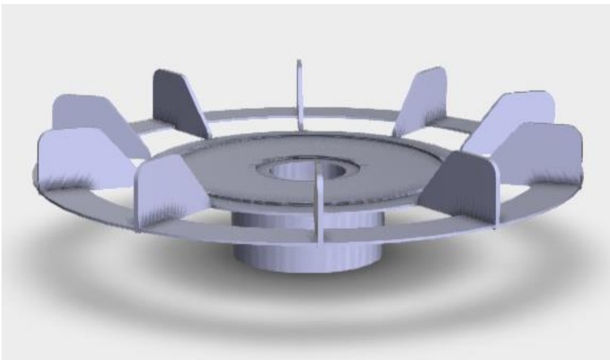
TENSILE STRENGTH GRAPH



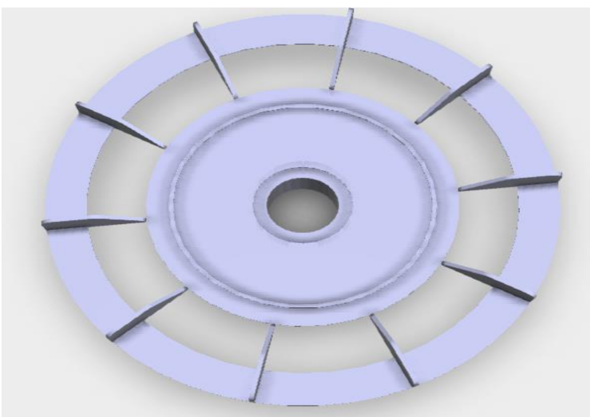
CONCLUSION OF TESILE TEST

From the investigation the mechanical property of Al 7075 metal matrix was analyzed finally found titanium di bromide reinforcement enhanced the good tensile and hardness properties. Titanium di boride shows superior strength compared than bare 7075.

MODELLING AND ANALYSIS



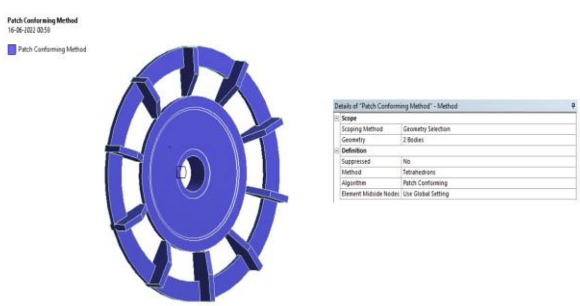
(a)



(b)

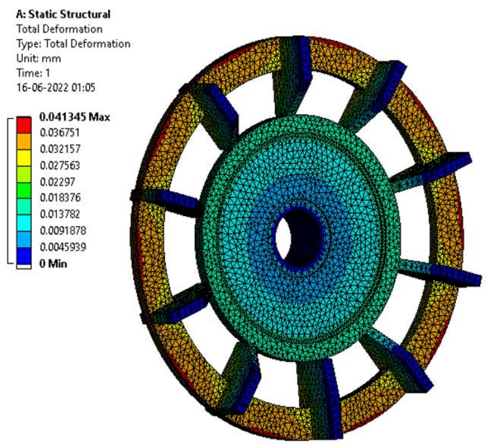
(a), (b) CATIA V5 Design of Impelle

Mesh Method – 3D – Solid -Tetrahedrons



Mesh Model

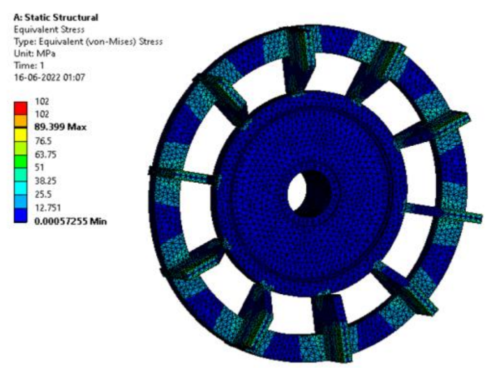
Solution - Deformation



SET VALUES

Density	: 2956 kg m^{-3}
Young's Modulus	: 1.89E+11 pa
Poisson's Ratio	: 0.33

Solution – Equivalent Stress – Von-Mises



CONCLUSION OF FEA TENSILE ANALYSIS

According to the FEA analysis we have found minimum deformation, stress and strain occurs Ratio 2 Al7075+TiB2 3% + Nb 2% is very low value compare than other ratio. So, we concluded regarding deformation and vibration character ratio 2 Al7075+TiB2 3% + Nb 2%is better than others.

IV. CONCLUSION

Composite materials especially Aluminum 7075 and Titanium di boride and Niobium composites having good mechanical properties compared with the conventional materials. It is used in various industrial applications these materials having light weight along with high hardness

REFERENCES

[1] Srisaran Venkatachalam Titanium Diboride Reinforced AluminumComposite as a Robust Material for Automobile Applications InternationalConference on Materials, Manufacturing and Machining 2019 AIP Conf.Proc. 2128, 020010-1–020010-10; Published by AIP Publishing. 978-0-7354-1870-7.
[2] M. M. Siva Analysis of Micro structural, Corrosion and MechanicalProperties of Aluminum Titanium Di boride Particles (Al-TiB2) ReinforcedMetal Matrix Composites (MMCs) Indian Journal of Science and Technology, Vol 9(43), DOI: 10.17485/ijst/2016/v9i43/100410, November 2016.
[3] N. B. Dhokey Wear Behavior and Its Correlation with MechanicalProperties of TiB2 Reinforced Aluminum-Based Composites HindawiPublishing Corporation Advances in Tribology Volume 2011,Article ID 837469, 8 pages doi:10.1155/2011/837469.
[4] C.S. Ramesh Development of Al 6063–TiB2 in situ composites Materials and Design 31 (2010) 2230–2236
[5] T.V. Christy A Comparative Study on the Microstructures and Mechanical Properties of Al 6061 Alloy and the MMC Al 6061/TiB_2/12P Journal of Minerals & Materials Characterization & Engineering,Vol. 9, No.1, pp.57-65, 2010 jmmce.org printed in the USA.
[6] S.Suresh Aluminum-Titanium Di boride (Al-TiB2) MMC Procedia Engineering 38 (2012) 89 – 97.
[7] A. R. Kennedy the microstructure and mechanical properties of TiC and TiB2-reinforced cast metal matrix Composites Journal of MaterialsScience 34 (1999) 933–940.