Investigating The Effect of Mechanical Properties on Al7075 Hybrid Composite with Bn and Al_2o_3

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Abstract—

Aluminum matrix composites (AMCs) become choice for automobile and aerospace industries due to its tunable mechanical properties such as very high strengthto weight ratio, superior wear resistance, greater stiffness, better fatigue resistance, controlled co-efficient of thermal expansion and good stability at temperatures. Nowadays Al7075 having high priority in aircrafts, rock climbing and cycle industries. The present work study is focused on hybrid metal matrix composition of Al7075 with Boran nitride (BN) as 0.5% constant throughout the composites and Aluminium Oxide (Al2O3) as 1%, 2%, 3%, 4%. Stir casting is highly used in industries for hybrid composites. Aluminium will be converted into molten phase and add the reinforcement materials by using mechanical stirrer as per proposed composition and then pour the molten metal into the required patterned die. That fully developed cylindrical bars are tested to find out the mechanical properties of desired composites to compare with pure Al7075. By examining all the results tested on different composition of specimens, the specimen of 3%Al_2O_3 have the efficient mechanical properties than compared with pure aluminium, 1%, 2%, 4% .

Material History

Material science has shaped the development of civilizations since the dawn of mankind. Better materials for tools and weapons have allowed mankind to spread and conquer, and advancements in material processing like steel and aluminum production continue to impact society today. The history of materials science is the study of how different materials were used and developed through the history of Earth and how those materials affected the culture of the peoples of the Earth.

Classification of Materials

There are thousands of materials available for use in engineering applications. Most materials fall into one of three classes that are based on the atomic bonding forces of aparticular material. These three classifications are metallic, ceramic and polymeric. Additionally, different materials can be combined to create a composite material. Composite materials are often grouped by the types of materials combined or the waythe materials are arranged together. Solid materials have been conveniently grouped into three basic classifications: metals, ceramics, and polymers. In addition, there are the composites, combinations of two or more of the above three basic material classes.

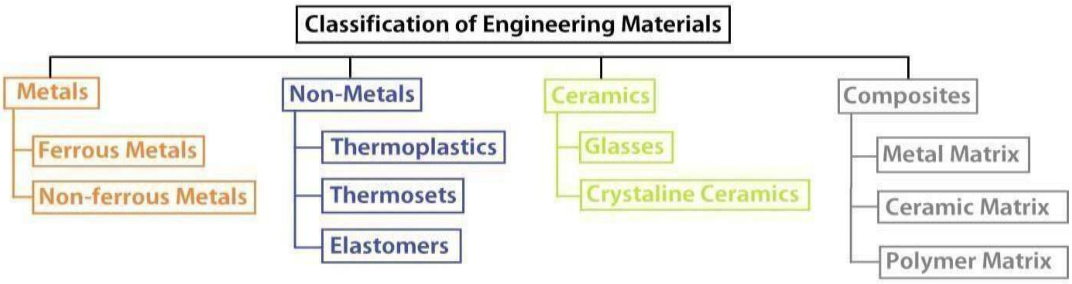


Fig 1: classification of materials

TYPES OF ALLOYS

There are two types of alloys Casted Alloy and Wrought Alloy

Cast Alloy

Casting is a manufacturing process in which a liquid material is usually poured into a mould, which contains a hollow cavity of the desired shape, and then allowed to solidify. The solidified part is also known as a casting, which is ejected or broken out of the mould to complete the process. Casting materials are usually metals or various cold setting materials that cure after mixing two or more components together, examples are epoxy, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods.

A. *Wrought Alloy*

Wrought alloys contain low percentages of elements; that is, alloying elements total isless than about 4 percent. Casting alloys contain the same elements as wrought, but ingreater amounts; for example, the silicon content in cast alloys can range up to 22 percent.

ALUMINIU ALLOYS

Aluminium alloys are alloys in which aluminum (Al) is the predominant metal. The typical alloying elements are copper, magnesium, manganese, silicon, tin and zinc. There are two principal classifications, namely casting alloys and wrought alloys, Alloys composed mostly of aluminium have been very important in aerospace manufacturing since the introduction of metal-skinned aircraft. Aluminium- magnesium alloys are both lighter than other aluminium alloys and much less flammable than alloys that contain a very high percentage of magnesium.

(i) PROPERTIES OF ALUMINIUM

- It has low density of approximately 2.7 g/cc.
- High mechanical strength achieved by suitable alloying and heat treatment and it has high ductility and resultant low working cost.
- High corrosion resistance of the pure metal, high thermal and electrical

conductance.

- It is relatively soft metal with yield strength of only 34.5 N/mm^2 (5000 lb/in^2)

(ii) APPLICATIONS AEROSPACE

ALLOYS

This has two beneficial effects the precipitated Al_3Sc forms smaller crystals than are formed in other aluminum alloys and the width of precipitate- free zones that normally exist at the grain boundaries of age-harden able aluminum alloys is reduced. Scandium is also a potent grain refiner in cast aluminum alloys, and atom for atom, the most potent strengthener in aluminum.

NEED OF COMPOSITES

The 2024 aluminum and 2008 aluminum alloy are extensively used for external automotive body panels, with 5083 and 5754 used for inner body panels. Bonnets have been manufactured from 2036, 6016, and 6111 alloys. Truck and trailer body panels have used 5456 aluminum. Automobile frames often use 5182 aluminum or 5754 aluminum formed sheets, 6061 or 6063 extrusions. Wheels have been cast from A356.0 aluminum or formed 5xxx sheet. Cylinder blocks and crankcases are often cast made of aluminum alloys. The most popular aluminum alloys used for cylinder blocks are A356, 319 and to a minor extend 242.

CLASSIFICATION OF COMPOSITES

In general, composites are classified according to the type of matrix material and thenature of reinforcement at two distinct levels. The first classification includes organic-matrix composites (OMCs), metal matrix composites (MMCs) and ceramic- matrix composites (CMCs). The term “organic-matrix composite” is generally assumed to include two classes of composites: polymer matrix composites (PMCs) and carbon-matrix composites.

COMPOSITES can be classified into:

A. Polymer Matrix Composites (PMCs)

B. Ceramic Matrix Composites (CMCs)

C. Metal Matrix Composites (MMCs)

METAL MATRIX COMPOSITES

Metal matrix composites have been able to full fill all the desired conceptions of the component designers in order to cater the specific demands of different engineering applications. In metal matrix composites, the hard reinforcements are infused into thesoft metal matrix to achieve a combination of enhanced physical, mechanical and electrical properties. For development of metal matrix composites, various metals used are titanium, magnesium, copper, nickel and aluminum. But the most widely used base metal is aluminum due to its light weight, strength, excellent thermal and electrical properties, good reflective properties, impermeability and cost effectiveness.

B. Base Metal

The matrix is the monolithic material into which the reinforcement is embedded, andis completely continuous. This means that there is a path through the matrix to any point in the material, unlike two materials sandwiched together. In structural applications, the matrix is usually a lighter metal such as aluminum, magnesium, or titanium, and provides a compliant support for the reinforcement. In high- temperature applications, cobalt and cobalt–nickel alloy matrices are common.

C. Reinforcement

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, or thermal conductivity. The reinforcement can be either continuous, or discontinuous.

D. Stir Casting

Stir casting is currently the most popular commercial method of producing aluminum-based composites. Fabrication of aluminum and its alloys-based casting composite materials via stir casting is one of the prominent and economical technique for development and processing of MMCs and widely used for applications that required high strength.

Bottom pouring type stir casting machine

OBJECTIVE OF THE PROJECT

The main objective of the project is to prepare hybrid composites and to study the behavior of the base metal Al7075 when it is pure and when reinforcement is added to it. This change can be observed thoroughly under microstructure examination. The main purpose of the project survives with the completion of investigation on mechanical properties of Al7075 in pure state and as a composite and obtain the optimum values of cutting speed, feed, depth of cut for MRR and Ra by using Optimization of process parameters

METHODOLOGY:

SELECTION OF MATERIALS

SELECTION OF MATRIX MATERIAL

The matrix material used in the present study is **Al7075**. Al7075 alloys are alloys where in aluminium (Al) is the major metal. The distinctive alloying elements are copper, magnesium, manganese, silicon and zinc. It has a wide field of application in the automotive and avionics industries.

(i) Chemical Composition of Al7075alloy

Table No.1 Chemical Composition of Al7075

Alloy	%Zn	%Mg	%Cu	%Mn	%Fe	%Cr	%Al
Al7075	6.05	2.32	1.36	0.01	0.02	0.18	Bal

(ii) Mechanical Properties ofAl7075

Mechanical Properties of Al7075 based metal matrix composite are depended on its microstructure, grain size, volume and size of second phase etc.

Table No.2 mechanical properties of Al7075

S.No	**Mechanical properties**	**Values**
1	Density	2.81g/cc
2	Hardness, Brinell	175
3	Tensile strength, Ultimate	572 MPa
4	Tensile strength, Yield	503 MPa
5	Modules of Elasticity	71.7GPa
6	Poisson Ratio	0.33
7	Melting Point	477-635℃

(iii) Applications ofAl7075

It is commonly used in transportation applications are aerospace, aviation, marine and automobile due to their good mechanical properties and low density and high strength to density ratio

SELECTION OF REINFORCEMENTMATERIAL

(iv) Boron Nitride(BC): They are effectively used for lubricating the surface operating at higher temperature and pressure. They have a high thermal conductivity which makes them applicable where the application involves rapid heat removal rate.

Boron Nitride

(v) Aluminium oxide(Al_2O_3): Aluminium oxide, normally remarked as aluminum oxide, possesses robust ionic put down atomic bonding giving rise to its fascinating material characteristics. It will exist in many crystalline parts that all revert to the foremost stable polygon alpha phase at elevated temperatures.

Aluminium oxide

Stir casting

Stir casting is a type of casting process which is suitable 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.

(a).Description of Experimental setup

A Bottom Pouring Type Stir casting equipment is used for the production of composites. Stir casting setup consist of a furnace, reinforcement feeder and mechanical stirrer. The furnace is used to heating and melting of the materials. The bottom pouring furnace is more suitable for the stir casting as after stirring of the mixed slurry instant poring is required to avoid the settling of the solid particles in the bottom of the crucible.

a) (b).Melting of matrix material

Out of various furnaces, bottom pouring furnace is suitable for fabrication of metal matrix composites in stir casting route, this type of furnace consists of automatic bottom pouring technique which provides instant pouring of the melt mix (matrix and reinforcement). In stir casting process, the matrix material is melted and maintained a certain temperature for 2–3 h in this furnace. Simultaneously, reinforcements are preheated in a different furnace. After melting of the matrix material, the stirring process has been started to form the vortex.

b) (c).Mechanical stirring

In stir casting process, the mechanical stirrer is coupled with the varying speed motor to control the speed of the stirrer. Stirring plays a vital role over the final microstructure and mechanical properties of the casted composites as it controls the Distribution of reinforcements with in the matrix

Composite Casting

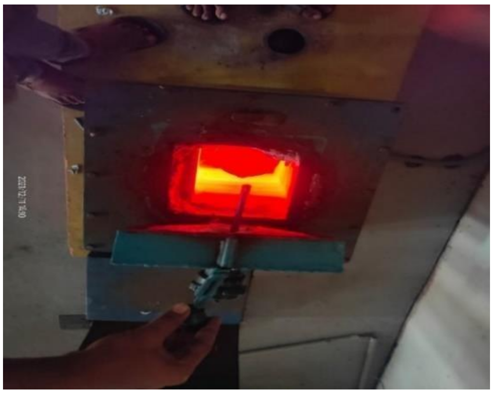
Heating of base metal: Small size ingots of base metal Al7075 was used for preparing composite. These base metal ingots were made into small pieces and dropped into the furnace and heated up to 750^{O} C. The molten metal was stirred by a zirconium coated stainless steel stirrer at 350rpm**.**

Pre heating of Reinforcement: The reinforcements were preheated up to 250^{O}C in the heater provided beside the furnace. After heating for certain period of time the reinforcements were slowly added to the melt.

Stirring: Stirring plays a very important role in the fabrication of composites. Proper stirring is to be provided for the melt not to be solidified. For this purpose, a stirrer is provided which is connected to the motor. Now the melt is ready to pour into the die .

Pre heating of die: A two fingered die is used for the fabrication of composites. Before pouring the molten metal in to the die it is heated up to 400^0 C to prevent the melt from solidification. The desired hybrid composite of Al7075 alloy with different wt.% (1%, 2%, 3%,4%) were produced.

Melting of Aluminium in Furnace



Specimen after Casting

Homogenization: Heat treatments can be used to homogenize cast metal alloys to improve their hot workability during hot and cold processing operations, or to alter their microstructure in such a way as to achieve the desired mechanical properties by reducing the residual stresses. During homogenization process the casted composite materials are heated in a furnace (Muffle Furnace) at 220^{0}C for five hours and annealed for 24 hours.

Fig 8: Muffle Furnace

In the present chapter the methodology used for obtaining better response parameters is briefly discussed. In modern industrial environment a numerous kinds of Investigations havebeen done for the improvement of product quality in the field of manufacturing. Some have few factors to be considered, some have many. While there are others, that demand factors to have mixed levels. A vast majority of experiments however fall in the categorywhere all factors possess the same number of levels. In the conventional technique of varying one factor at a time, lot of experimental data can be obtained. This way of experimentation not only consumes lot of time but also poses a challenge to the investigator for deriving appropriate conclusion from the huge experimental data. Design of Experiments (DOE) is at ever rescue for planningsystematic experimentation and arriving at meaningful conclusion without being inundated inhuge set of experimental data. DOE is an experimental strategy in which effects of multiple factors are studied simultaneously by running tests at various levels of factors.

3.1 *Methodology*

- Selection of process parameters and their levels
- Conduct the experiments as per the Taguchi Design of Experiments
- Measure the selected quality characteristics

- Conclude the results.
- Analyze the results with taguchi method
- Determine the optimal setting of process parameters for optimum utility
- Conduct ANOVA for finding the significance of the factors
- Run the confirmation experiment and compare the predicted optimal values with the actual ones.

3.1.1 Design Of Experiments (DOE)

Design of Experiments is a powerful statistical technique introduces by R.A**.** Fisher inEngland in the 1920's to study the effect of multiple variables simultaneously. The DOE using Taguchi approach can be economically satisfy the needs of problem solving and product/process design optimization projects. DOE is a technique of defining and investigatingall possible combinations in an experiment involving multiple factors and to identify the best combination. In this different factors and their levels are identified. Design of Experiments is also useful to combine the factors at appropriate levels, each with the respective acceptable range, to produce the best results and yet exhibit minimum variation around the optimum results. Therefore, the objective of a carefully planned designed experiment is to understand which set of variables in a process affects the performance most and then determine the best levels for these variables to obtain satisfactory output functional performance in products.

E. Advantages of Design of Experiments (DOE)

- Number of trails is significantly reduced.
- Important decision variables which control and improve the performance of the productor the process can be identified.
- Optimal setting of the parameters can be found out.
- Qualitative estimation of parameters can be made.
- Experimental errors can be estimated.
- The effect of parameters on the characteristics of the process can be found out.

F. The DOE techniques used for process parameter optimization

- Full factorial technique
- Fractional factorial technique
- Taguchi orthogonal array

- Response surface method (central composite design).

(i) *Full Factorial*

In statistics and experimental design, a full factorial design is a design in which all possible combinations of factor levels are included in the experiment. In other words, a full factorial design includes all possible combinations of the levels of each factor.

A full factorial design with 3 factors, each with 3 levels, would involve testing all possible combinations of the factor levels. This would result in a total of 3^3 = 27 experimental conditions.

To describe this design, we often use a shorthand notation that lists the levels of each factor. For example, the notation (-1, 0, +1) might be used to represent a factor with 3 levels, where -1 represents the low level, 0 represents the medium level, and +1 represents the high level.Using this notation, a full factorial design with 3 factors, each with 3 levels, can be described as a 3x3x3 design, or a 3^3 design. The shorthand notation for this design would be (-1, 0, +1)^3.To illustrate how this design works in practice, consider an experiment that investigates the effects of 3 different types of fertilizer on plant growth. The 3 factors in this experiment are fertilizer type (A, B, or C), fertilizer amount (low, medium, or high), and fertilizer frequency (once a week, twice a week, or three times a week). To conduct a full factorial design with this setup, the experimenters would test all 27 possible combinations of the factor levels. For example, they would test plants that received fertilizer A at a low amount and once a week, plants that received fertilizer B at a medium amount and twice a week, and so on. By analyzing the results of these 27 experimental conditions, the experimenters can determine the main effects of each factor (the effect of fertilizer type, amount, and frequency on plant growth), as well as any interactions between the factors (such as whether the effect of fertilizer type depends on the amount or frequency of application).

(ii) *Analysis of Variance*

Analysis of variance, or ANOVA, is a strong statistical technique that is used to show the difference between two or more means or components through significance tests. It also shows us a way to make multiple comparisons of several populations means. The ANOVA test is performed by comparing two types of variation, the variation between the sample means, as well as the variation within each of the samples.

ANOVA is to study the significance of process parameters on the output characteristics. In this method, first the total sum of the square's SST, sum of the squares within the group and sum of the squares between the group.

sum of the squares within the group (SSW) = $\sum_{j=1}^{k} \sum_{j=1}^{l} (x - \overline{x_j})^2$

sum of the squares between the group (SSB) = $\sum_{j=1}^{k} (\bar{x}_j - \bar{x})^2$

total sum of the squares (SST) = $\sum_{j=1}^{n} (\bar{x}_j - \bar{x})^2$

Where 'n' is number of experiments in orthogonal array and 'k' is the levels of factor or number of observations.

Degrees of freedom will be calculating as

Degrees of freedom for within the group (df_w) = k-1

Degrees of freedom for between the group (df_b) =n-k Total

Degrees of freedom (df_t) = n-1

Mean square values will be calculated as

Mean Sum of squares between the groups (MSB) = $\frac{SSB}{df_b}$

Mean Sum of squares within the groups (MSW) = $\frac{SSW}{df_w}$

For calculating F test value

$$F\ value = \frac{MSB}{MSW}$$

The percentage contribution p can be calculated as:

$$P = \frac{SSW}{SST}$$

The P value gives the percentage that each process parameter is contributed for the response characteristi EXPERIMENTATION AND RESULTS

TESTING OF COMPOSITE

Different tests are conducted on the specimen to find out variousmechanical properties of the composite specimen

4.1.1 COMPRESSION TEST

Compression strength is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tendingto elongate. In other words, compressive strength resists compression (being pushed together), whereas tensile strength resists tension (being pulled apart). Generally, weuse UTM for compression test.

a) Universal testing machine (UTM)

A universal testing machine (UTM), also known as a universal tester, materials testing machine or materials test frame, is used to test the tensile strength and compressive strength of materials.

Compression Testing Machine is operated hydraulically. Driving is performed with the help of electric motor. Depending upon the size of the specimen the C. T. M. canbe set into two ranges C. T. M. consists of two units (a) Loading & (b) Control Unit.The specimen is tested upon the loading unit and the corresponding readings are takenfrom the dial fitted to the control unit. Hydraulic cylinder is fitted in the center of thebase and the piston slides in the cylinder when the machine is in operated. A lower table is rigidly connected to an upper crosshead by two straight columns. This assembly moves up and down. Compression test is conducted by putting the specimenin between lower table and upper crosshead.

The control panel consists the two valves one is at right side and the another one at left side. These valves control the flow of oil in the hydraulic system. The right-side valve controls pressure flow and left side valve allow the oil from cylinder to goback in to the tank. Control panel consists of dynamometer, which measures and indicates the load on the specimen

Fig 9: Universal testing machine

Fig10

Compression test Specimen dimensions

Fig 11

Compression Pieces after testing

Table No.3: Compression Test

Sample	Composite	Compressive Strength(N/mm^2)
C1	Al7075	336
C2	Al7075+BN(0.5%)+ Al_2O_3 (1%)	353
C3	Al7075+BN(0.5%)+ Al_2O_3 (2%)	365
C4	Al7075+BN(0.5%)+ Al_2O_3 (3%)	375
C5	Al7075+BN(0.5%)+ Al_2O_3 (4%)	380

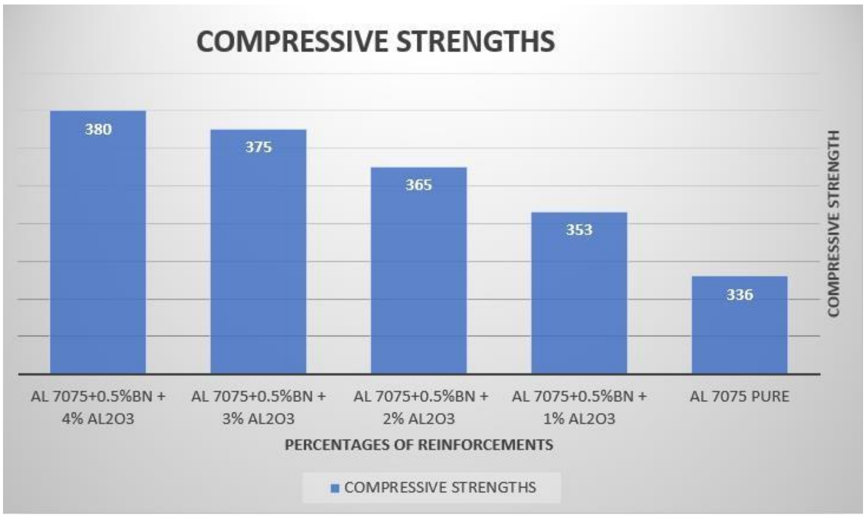


Fig 12: Compression Strength Vs Metal Matrix composites By adding reinforcement compression strength is increased.

4.1.2 *Micro Hardness Test*

The Vickers hardness test was developed in 1921 by Robert L. Smith and George E.Sandland at Vickers Ltd as an alternative to the Brinell method to measure the hardness of materials. The Vickers test is often easier to use than other hardness testssince the required calculations are independent of the size of the indenter, and the intender can be used for all materials irrespective of hardness. The basic principle, aswith all common measures of hardness, is to observe materials ability to resist plasticdeformation from a standard source. The Vickers test can be used for all metals and has one of the widest scales among hardness test. The unit of hardness given by test is known as the Vickers Pyramid Number (HV) or Diamond

Pyramid Hardness (DPH). The hardness number can be converted into unit pascals, but should not confused with pressure, which uses the same units. The hardness number is determined by the load over the surface area of the indentation and not the area normalto the force, and is therefore not pressure.

Fig 13: Hardness test Specimens after testing

Fig 14: Vicker's Hardness testing equipment

Table No.4: Hardness Test

Sample	Composite	Vickers Hardness Value
C1	Al7075	137.39
C2	Al7075+BN(0.5%)+ Al_2O_3 (1%)	142.76
C3	Al7075+BN(0.5%)+ Al_2O_3 (2%)	143.76
C4	Al7075+BN(0.5%)+ Al_2O_3 (3%)	152.53
C5	Al7075+BN(0.5%)+ Al_2O_3 (4%)	167.82

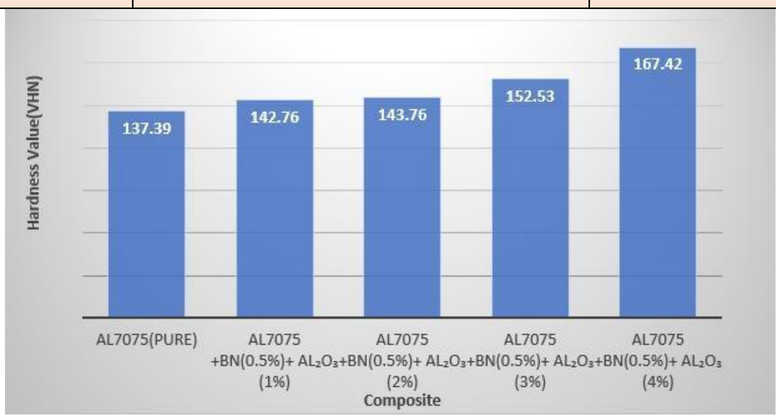


Fig 15: Hardness values Vs Metal Matrix composites
By adding reinforcement Hardness is increased.

Density Test

The particle density of Al_2O_3 determined was 3.428g/cm^3 while the density of the Al7075 alloy was 2.81g/cm^3. Since Al_2O_3 has high density than Al7075 alloy, its addition to the produce composite will make the density of the composite to be higher than that of the alloy.

$$\rho = (w/w - W_1)*\rho_w$$

W is weight of sample in air

W_1 is weight of sample in water ρ_w

is density of water

Fig 16: Digital weighing machine

Fig 17: Test specimen for density test

Table No.5 : Density Test

Sample	Composite	Density(g/cm^3)
C1	Al7075	2.81
C2	Al7075+BN(0.5%)+ Al_2O_3 (1%)	3.173
C3	Al7075+BN(0.5%)+ Al_2O_3 (2%)	3.540
C4	Al7075+BN(0.5%)+ Al_2O_3 (3%)	3.907
C5	Al7075+BN(0.5%)+ Al_2O_3 (4%)	4.274

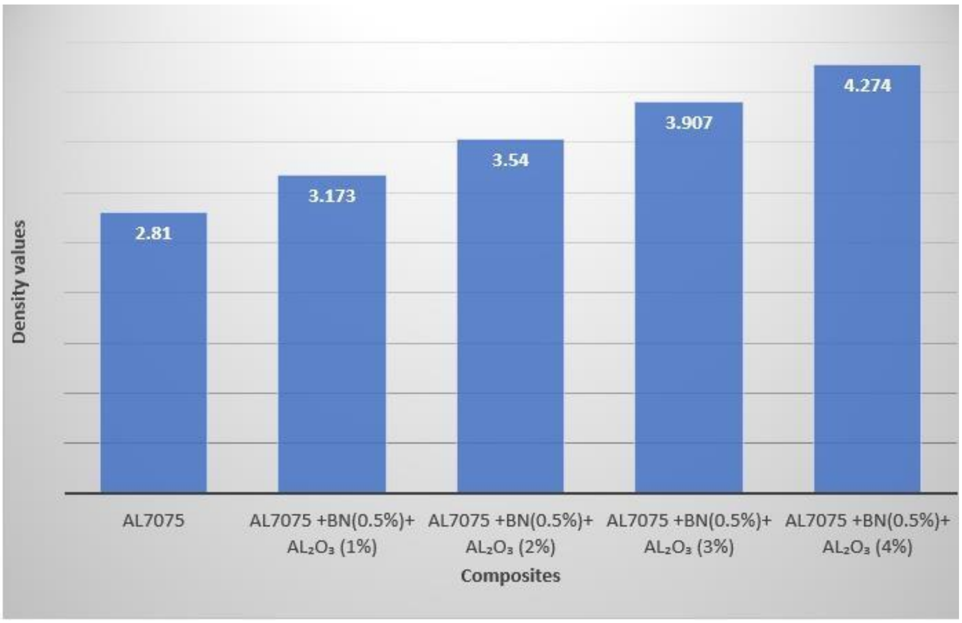


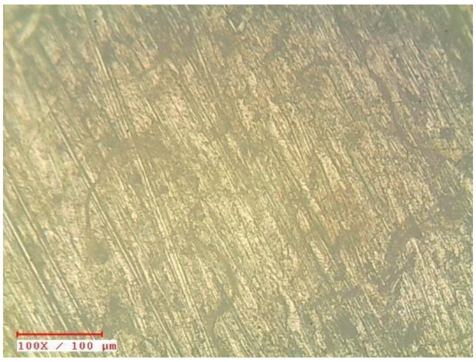
Fig 18:Density values Vs Metal Matrix composites By adding reinforcement density is increased.

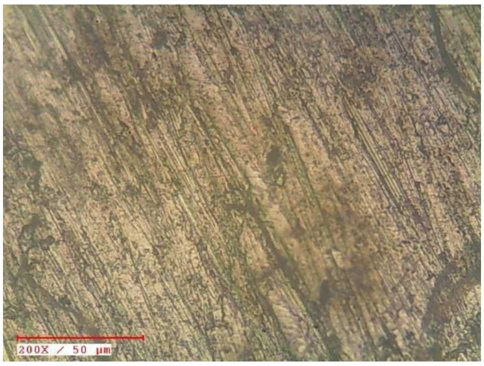
4.1.3 Microstructure

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 25x magnification. The microstructure of a material can strongly influences physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior or wear resistance. The testing process is going to done with Computer AidedMicroscope.

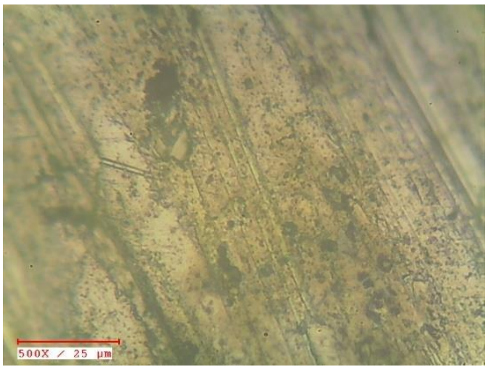
b) (a). Specimen Preparation

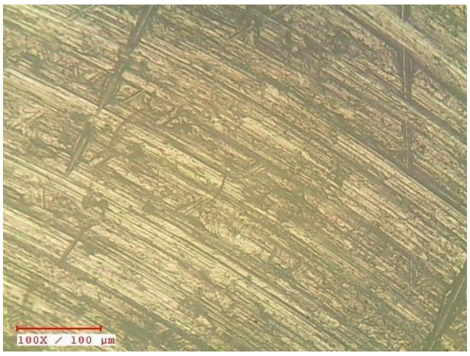
By using lathe operation length of the specimen and diameter are maintained at 20mm 18 mm. Initially rough polishing is done with the help of belt grinder and later with the help of emery papers of 220, 320, 400, 600 and 800 polishing is done. Then smooth polishing done with the double disc polisher.





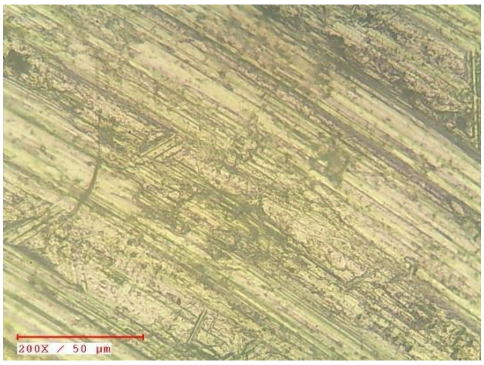
Pure Al7075 100X Pure Al7075 200X

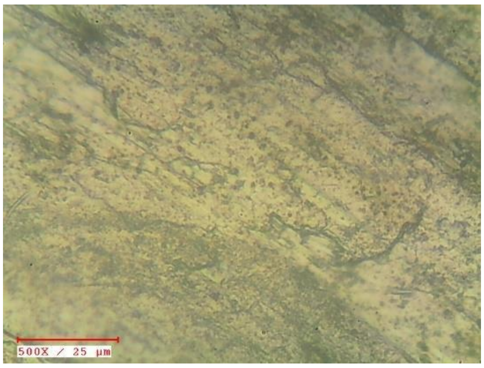




Pure Al7075 500X

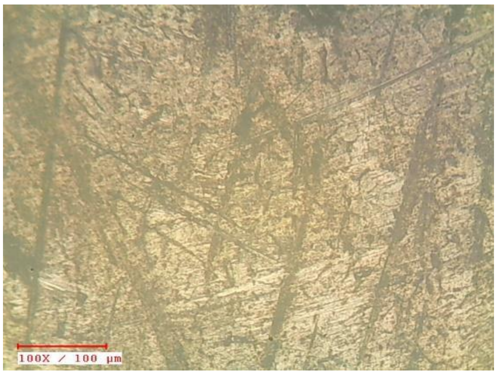
Al7075 +BN(0.5%)+ Al_2O_3 (1%) 100X

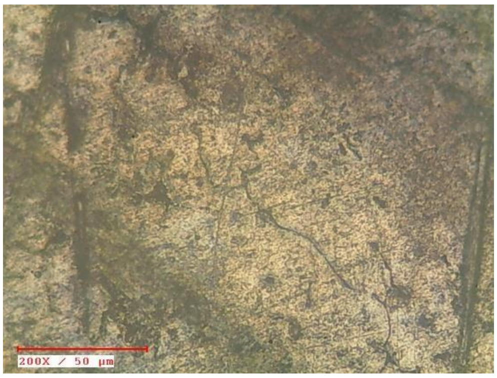




Al7075 +BN(0.5%)+ Al_2O_3 (1%) 200X

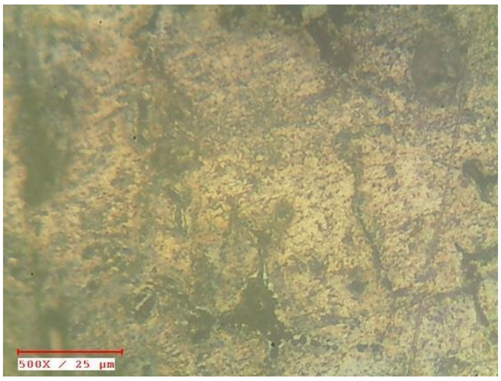
Al7075 +BN(0.5%)+ Al_2O_3(1%) 500X



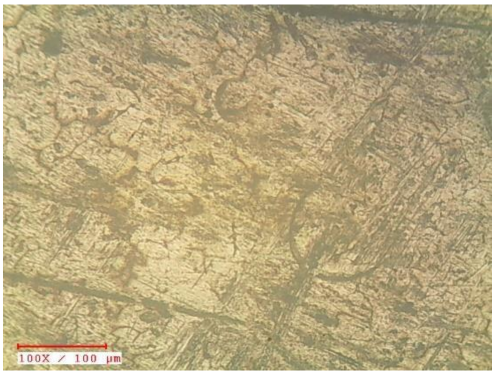


Al7075 +BN(0.5%)+ Al_2O_3 (2%) 100X

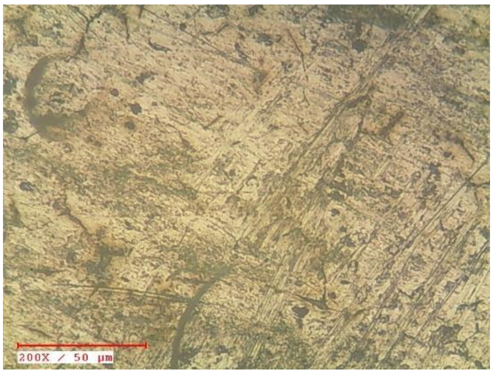
Al7075 +BN(0.5%)+ Al_2O_3 (2%) 200X



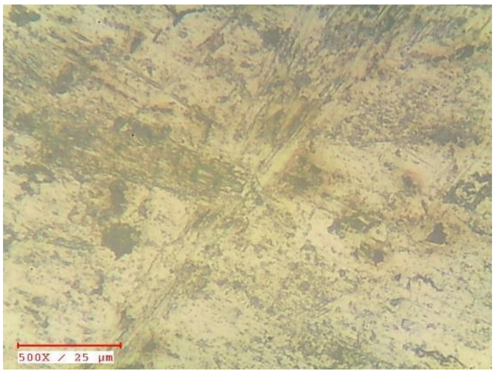
Al7075 +BN(0.5%)+ Al_2O_3 (2%) 500X



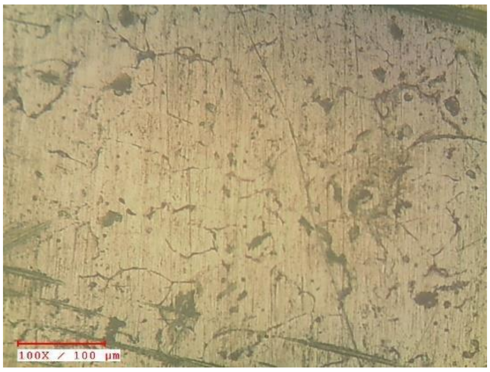
Al7075 +BN(0.5%)+ Al_2O_3 (3%) 100X



Al7075 +BN(0.5%)+ Al_2O_3 (3%) 200X



Al7075 +BN(0.5%)+ Al_2O_3 (3%) 500X



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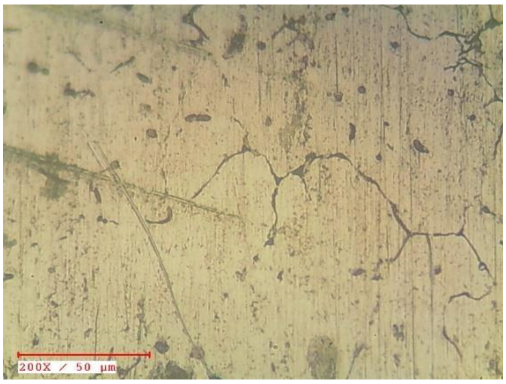
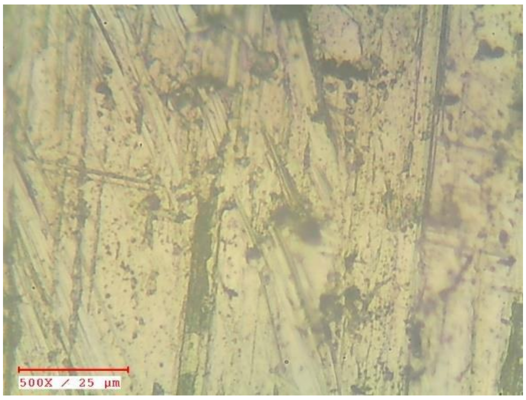


Al7075 +BN(0.5%)+ Al_2O_3 (4%) 200X



Al7075 +BN(0.5%)+ Al_2O_3 (4%) 500X

Fig 19: Microstructues

4.1.4 Charpy Impact Test

The principle of the test differs from that of the Izod test in that the test piece is tested as a beam supported at each end; a notch is cut across the middle of one face, and the striker hits the oppositeface directly behind the notch.

Fig20 : Impact Testing Machine

G. Description:

The machine consists of a swinging pendulum that has an arm and head. For this test the dimensionsof standard specimen are 55 mm x 10 mm x 10mm. It is a simple supported beam. Swinging Head strikes other side of the specimen notch. Pendulum falls from 1.457 m height or from an angle of 140 degrees. The weight swinging hammer is 20.932 kg or 250 N. The specimen struck exactly at its center i.e. 27.5mm.

The machine also has a pedal operated brake, to stop the hammer after the specimen is struck.

Table No.6 : Impact Strength

Sample	Composite	Impact Strength (J)
C1	Al7075	17
C2	Al7075+BN(0.5%)+ Al_2O_3 (1%)	18.5
C3	Al7075+BN(0.5%)+ Al_2O_3 (2%)	19.4
C4	Al7075+BN(0.5%)+ Al_2O_3 (3%)	20.6
C5	Al7075+BN(0.5%)+ Al_2O_3 (4%)	21.3

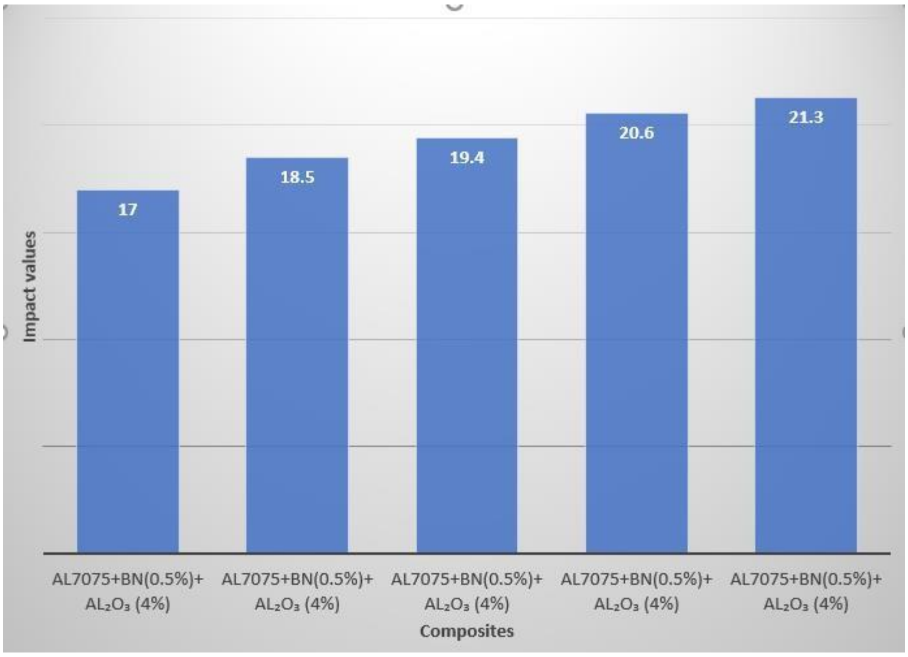


Fig 21: Impact values Vs Metal Matrix Values

By adding reinforcement Impact strength is increased.

4.1.5 Tensile Test

The Tension test which is conducted on a universal testing machine at room temperature is a commonmethod to evaluate strength and ductility under static load conditions. The tension test is carried outby loading a standard specimen gripped at both ends and measuring the resultant elongation of the specimens at various increments of loads.

H. Procedure:

1. Measure the diameter of the given mild steel specimen at three different places with the help of verniercalipers and determine the average diameter of the specimen and gauge length.
2. Mount the specimen in the grip of the movable and fixed cross head
3. Adjust the load stabilizer, start the machine and open the inlet valve slightly. When the load indicator just shows reading, it indicates that the load is held caught between the grips, and then adjusts the digital meter toread zero.
4. Apply the load at a steady uniform rate and until specimen breaks.
5. After some time the load showing drops slowly from higher to lower. At this stage, a neck is formed in thespecimen, which breaks. Note the position of actual pointer during breaking. Record the maximum load as “Breaking load”.
6. Press the freeze button and then print to get the graph between load vs displacement.
7. Repeat the procedure for another specimen.

Fig 22: Specimens After Testing

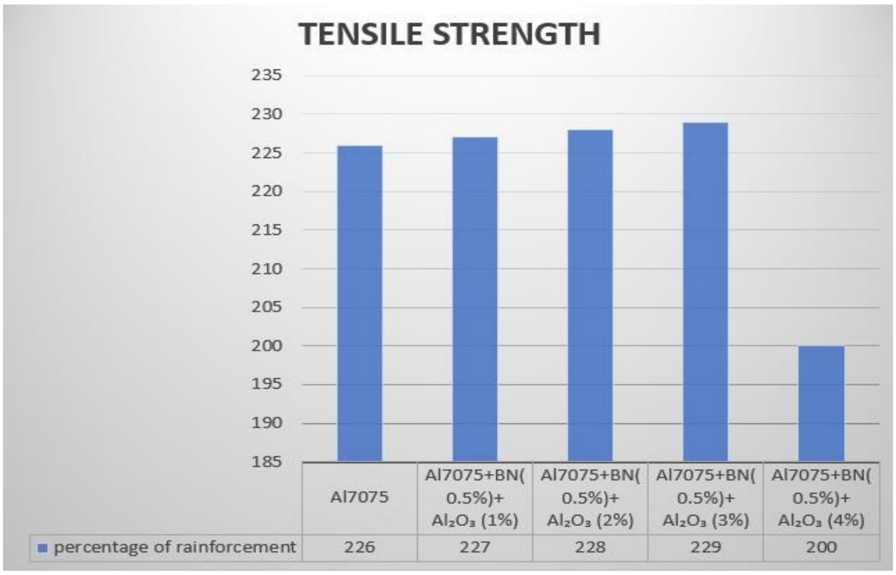
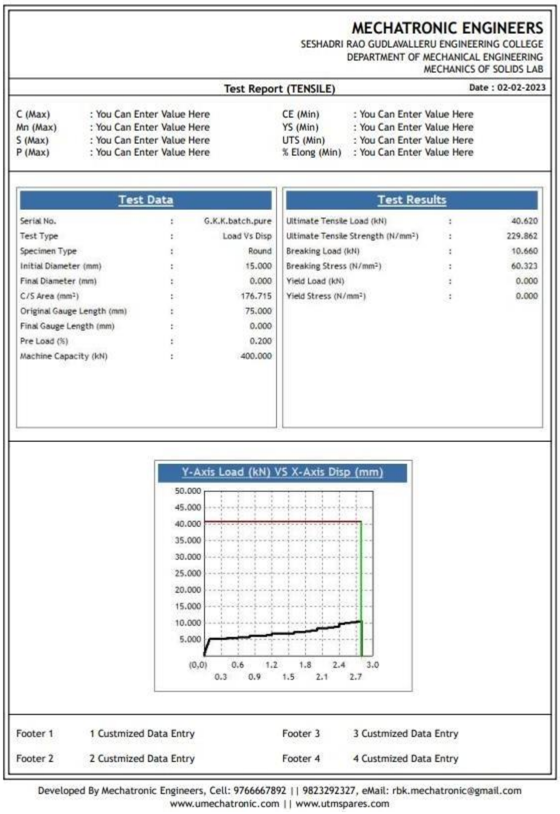


Fig 23: Tension Values Vs Metal Matrix Composites By

adding reinforcement Tensile strength is increased.



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Test Report (TENSILE) Date : 02-02-2023

C (Max)	: You Can Enter Value Here	CE (Min)	: You Can Enter Value Here
Mn (Max)	: You Can Enter Value Here	YS (Min)	: You Can Enter Value Here
S (Max)	: You Can Enter Value Here	UTS (Min)	: You Can Enter Value Here
P (Max)	: You Can Enter Value Here	% Elong (Min)	: You Can Enter Value Here

Test Data

Serial No.	:	G.K.K.batch.pure
Test Type	:	Load Vs Disp
Specimen Type	:	Round
Initial Diameter (mm)	:	15.000
Final Diameter (mm)	:	0.000
C/S Area (mm²)	:	176.715
Original Gauge Length (mm)	:	75.000
Final Gauge Length (mm)	:	0.000
Pre Load (%)	:	0.200
Machine Capacity (kN)	:	400.000

Test Results

Ultimate Tensile Load (kN)	:	40.620
Ultimate Tensile Strength (N/mm²)	:	229.862
Breaking Load (kN)	:	10.660
Breaking Stress (N/mm²)	:	60.323
Yield Load (kN)	:	0.000
Yield Stress (N/mm²)	:	0.000

Y-Axis Load (kN) VS X-Axis Disp (mm)

Footer 1	1 Custmized Data Entry	Footer 3	3 Custmized Data Entry
Footer 2	2 Custmized Data Entry	Footer 4	4 Custmized Data Entry

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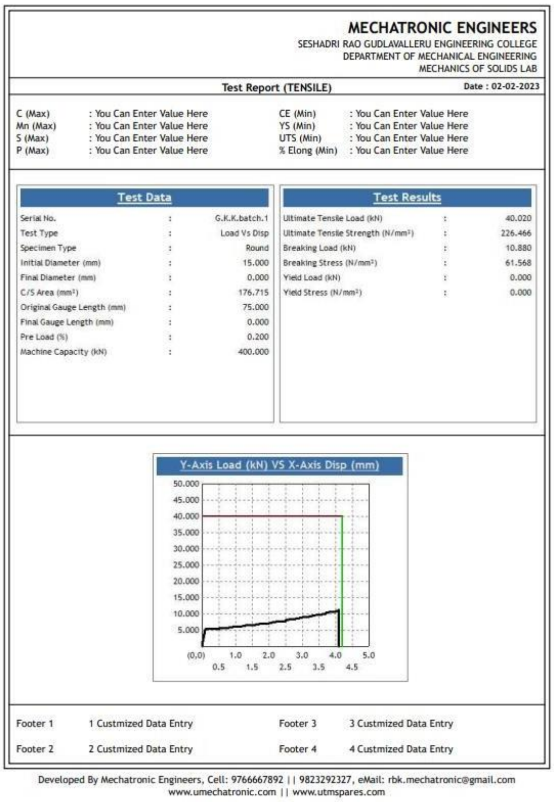

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S (Max)	: You Can Enter Value Here	UTS (Min)	: You Can Enter Value Here
P (Max)	: You Can Enter Value Here	% Elong (Min)	: You Can Enter Value Here

Test Data

Serial No.	:	G.K.K.batch.1
Test Type	:	Load Vs Disp
Specimen Type	:	Round
Initial Diameter (mm)	:	15.000
Final Diameter (mm)	:	0.000
C/S Area (mm²)	:	176.715
Original Gauge Length (mm)	:	75.000
Final Gauge Length (mm)	:	0.000
Pre Load (%)	:	0.200
Machine Capacity (kN)	:	400.000

Test Results

Ultimate Tensile Load (kN)	:	40.020
Ultimate Tensile Strength (N/mm²)	:	226.466
Breaking Load (kN)	:	10.880
Breaking Stress (N/mm²)	:	61.568
Yield Load (kN)	:	0.000
Yield Stress (N/mm²)	:	0.000

Footer 1	1 Custmized Data Entry	Footer 3	3 Custmized Data Entry
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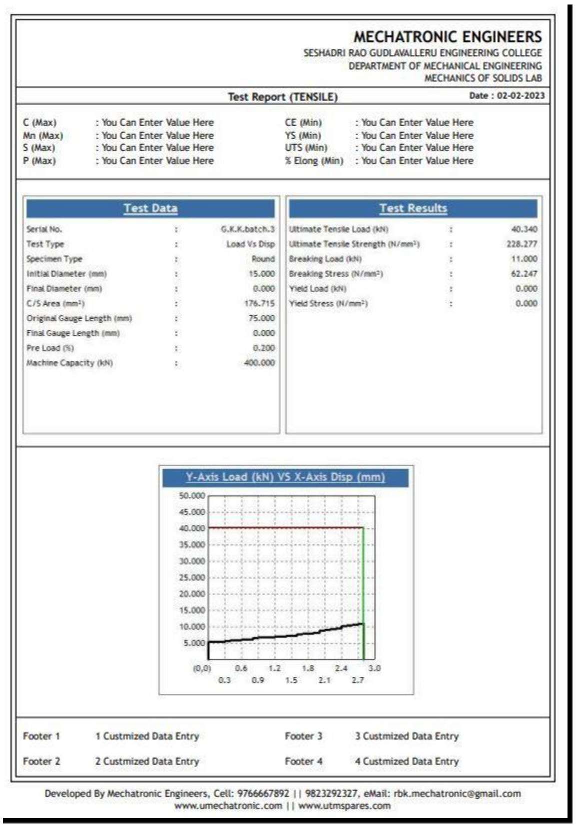

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S (Max)	: You Can Enter Value Here	UTS (Min)	: You Can Enter Value Here
P (Max)	: You Can Enter Value Here	% Elong (Min)	: You Can Enter Value Here

Test Data

Serial No.	:	G.K.K.batch.3
Test Type	:	Load Vs Disp
Specimen Type	:	Round
Initial Diameter (mm)	:	15.000
Final Diameter (mm)	:	0.000
C/S Area (mm²)	:	176.715
Original Gauge Length (mm)	:	75.000
Final Gauge Length (mm)	:	0.000
Pre Load (%)	:	0.200
Machine Capacity (kN)	:	400.000

Test Results

Ultimate Tensile Load (kN)	:	40.340
Ultimate Tensile Strength (N/mm²)	:	228.277
Breaking Load (kN)	:	11.000
Breaking Stress (N/mm²)	:	62.247
Yield Load (kN)	:	0.000
Yield Stress (N/mm²)	:	0.000

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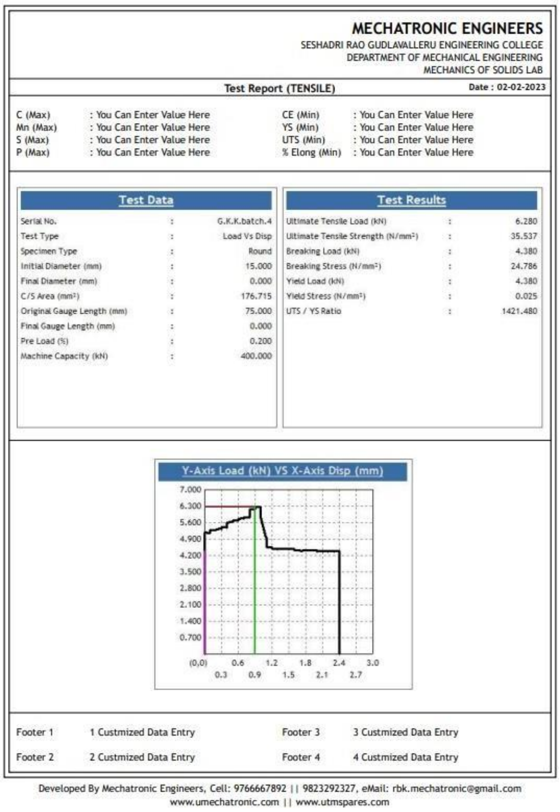

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Mn (Max)	: You Can Enter Value Here	YS (Min)	: You Can Enter Value Here
S (Max)	: You Can Enter Value Here	UTS (Min)	: You Can Enter Value Here
P (Max)	: You Can Enter Value Here	% Elong (Min)	: You Can Enter Value Here

Test Data		Test Results	
Serial No.	G.K.K.batch.4	Ultimate Tensile Load (kN)	6.280
Test Type	Load Vs Disp	Ultimate Tensile Strength (N/mm²)	35.537
Specimen Type	Round	Breaking Load (kN)	4.380
Initial Diameter (mm)	15.000	Breaking Stress (N/mm²)	24.786
Final Diameter (mm)	0.000	Yield Load (kN)	4.380
C/S Area (mm²)	176.715	Yield Stress (N/mm²)	0.025
Original Gauge Length (mm)	75.000	UTS / YS Ratio	1421.480
Final Gauge Length (mm)	0.000		
Pre Load (%)	0.200		
Machine Capacity (kN)	400.000		

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Fig 24 : Stress strain diagram

4.2 *Optimization of Process Parameters:*

- Optimization of machining parameters is one of the most important elements inany process planning of metal parts.
- In this study, the optimization of process parameters is performed on CNC turning operation.
- On conducting different mechanical properties tests on the specimens, the specimen with acomposition of 3% Al_2O_3 and 0.5% BN gave the best results.
- Hence, we decided to perform optimization on the specimen which gave us the best results.
- The parameters that are considered for the work are
  - Cutting speed
  - Feed rate
  - Depth of cut

I. *Cutting Speed:*

- It is the most important cutting parameter that provides necessary cutting motion.

- It can be imparted either on the cutting tool or on workpiece by either rotating it orreciprocating it.
- In case of either rotating tool (such as milling, drilling, grinding) or rotating workpiece (suchas turning), the peripheral velocity of cutter or workpiece is considered as the cutting velocity.

J. Feed Rate:

- Feed rate is the distance which the cutting tool travels during one spindle revolution.
- It is also defined as the velocity at which the cutter is advanced against the workpiece.
- It is measured in either inch per revolution or millimetres per revolution (ipr or mpr) forturning and boring processes.
- However, machinists use the inches per minute or millimetres per minute (ipm or mpm) formilling processes.

K. Depth of Cut:

- The third parameter that provides necessary depth of material that is required to remove by machining.
- In general cutting speed, feed and depth of cut usually act in mutually perpendicular directions.

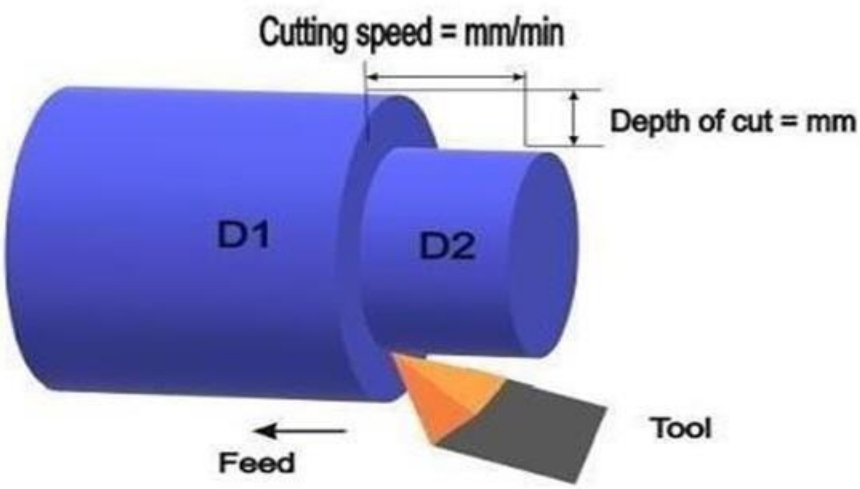

Fig 25: Working Principle

4.2.1 *Design Of Experiments (DOE)*

Design of Experiments is a powerful statistical technique introduces by R.A**.** Fisher in England in the 1920's to study the effect of multiple variables simultaneously. The DOE using Taguchi approach can be economically satisfy the needs of problem solving and product/process design optimization projects.

DOE is a technique of defining and investigating all possible combinations in an experimentinvolving multiple factors and to identify the best combination. In this different factor and their levels are identified. Design of Experiments is also useful to combine the factors at appropriate levels, each with the respective acceptable range, to produce the best results and yet exhibit minimum variation around the optimum results. Therefore, the objective of a carefully planned designed experiment is to understand which set of variables in a process affects the performance most and then determine the best levels for these variables to obtain satisfactory output functionalperformance in products.

L. Advantages of Design of Experiments (DOE)

- Number of trails is significantly reduced.
- Important decision variables which control and improve the performance of the product or theprocess can be identified.
- Optimal setting of the parameters can be found out.
- Qualitative estimation of parameters can be made.
- Experimental errors can be estimated.
- The effect of parameters on the characteristics of the process can be found out.

M. The DOE techniques used for process parameter optimization

- Full factorial technique
- Fractional factorial technique
- Taguchi orthogonal array
- Response surface method (central composite design).

4.2.2 *Full Factorial*

In statistics and experimental design, a full factorial design is a design in which all possible combinations of factor levels are included in the experiment. In other words, a full factorial design includes all possible combinations of the levels of each factor.

A full factorial design with 3 factors, each with 3 levels, would involve testing all possible combinations of the factor levels. This would result in a total of 3^3 = 27 experimental conditions.

To describe this design, we often use a shorthand notation that lists the levels of each factor. For example, the notation (-1, 0, +1) might be used to represent a factor with 3 levels, where -1 represents the low level, 0 represents the medium level, and +1 represents the high level. Using this notation, a full factorial design with 3 factors, each with 3 levels, can be described as a 3x3x3 design, or a 3^3 design. The shorthand notation for this design would be (-1, 0, +1) ^3. To illustrate how this design works in practice, consider an experiment that investigates the effects of 3 different types of fertilizer on plant growth. The 3 factors in this experiment are fertilizer type (A, B, or C), fertilizer amount (low, medium, or high), and fertilizer frequency (once a week, twice a week, or three times a week). To conduct a full factorial design with this setup, the experimenters would test all 27 possible combinations of the factor levels. For example, they would test plants that received fertilizer A at a low amount and once a week, plants that received fertilizer B at a medium amount and twice a week, and so on. By analyzing the results of these 27 experimental conditions, the experimenters can determine the main effects of each factor (the effect of fertilizer type, amount, and frequency on plant growth), as well as any interactions between the factors (such as whether the effect of fertilizer type depends on the amount or frequency of application).

Fig 26: CNC Lathe Machine

a) Table No.7 : Process parameters and levels

Parameter	Levels		
	1	2	3
Cutting Speed(RPM)	400	800	1200
Feed(mm/rev)	0.1	0.15	0.2
Depth of Cut(mm)	0.2	0.4	0.6

Fig 27: Roughness Gauge SJ-210

N. Mini tab

Minitab is statistical analysis software. It can be used for learning about statistics as well as statistical research. Statistical analysis computer applications have the advantage of being accurate, reliable, and generally faster than computing statistics and drawing graphs by hand.

O. Taguchi method

Taguchi Method is a process/product optimization method that is based on 8-steps of planning, conducting and evaluating results of matrix experiments to determine the bestlevels of control factors. The primary goal is to keep the variance in the output very loweven in the presence of noise inputs. Thus, the processes/products are made ROBUST against all variations.

Generally, a process to be optimized has several control factors which directly decide thetarget or desired value of the output. The optimization then involves determining the bestcontrol factor levels so that the output is at the target value. Such a problem is called as a "STATIC PROBLEM".

Table No.8 : Responses

S.No.	MRR	Ra	Rq	Rz
1.	1.1080	1.836	2.454	10.246
2.	4.4560	0.770	1.070	6.518
3.	10.4000	0.730	0.874	3.812
4.	1.2000	1.281	1.613	7.571
5.	6.6660	1.459	1.755	7.989
6.	15.5630	1.378	1.706	7.889
7.	2.3500	1.415	1.763	8.163
8.	9.3080	1.597	2.037	9.395
9.	19.5300	2.249	2.767	11.539
10.	2.3270	0.804	1.008	5.047
11.	8.8700	0.834	1.091	5.502
12.	19.7600	0.680	0.912	5.258
13.	3.3010	0.961	1.202	5.542
14.	12.5660	2.453	2.754	9.327
15.	29.1480	1.181	1.485	6.857
16.	4.3830	1.679	2.039	8.837
17.	17.6700	0.518	0.655	3.173
18.	44.4680	0.983	1.205	5.117
19.	3.2720	0.855	1.005	4.333
20.	12.9990	0.961	1.237	6.384
21.	29.1123	0.750	0.966	5.037
22.	5.6180	0.927	1.132	5.217
23.	19.9460	0.691	0.856	4.400
24.	49.3870	0.851	1.068	5.460
25.	7.2350	0.702	0.863	4.034
26.	28.9430	1.473	1.797	8.126

27.	65.1230	1.451	1.736	7.558

CONCLUSION:

The summary of effect of Al_2O_3 and BN on the mechanical properties of Aluminium Hybrid composite is as follows:

1. The compressive strength increases with increase in composition of Al_2O_3
2. The density of the composite increases with increase in composition of Al_2O_3
3. The hardness of the composite increases with increase in composition of Al_2O_3
4. The microstructure of the composites is observed under the microscope
5. The tensile strength increases with increase in composition of Al_2O_3

- The optimum combination of process parameters for material removal rate is obtained at

  Speed: 1200 RPM,

  Feed: 0.2 mm/rev

  Depth of cut: 0.6 mm respectively.

- The optimum combination of process parameters for surface roughness of Ra, Rq and Rz are obtained at

  Speed: 400 RPM,

  Feed: 0.2 mm/rev

  Depth of cut: 0.4 mm respecti

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