ISSN 2229-5518

MACHINING CHARACTERISTICS ON SURFACE ROUGHNESS OF (ZRO2) REINFORCDED IN (AL-7075) MMC'S

CH NITHIN CHAKRAVARTHY, ASST.PROFESSOR, CMRIT

Abstract: - Metal composites posses significantly improved properties including high tensile strength, hardness, low density and good wear resistance compared to alloys or any other metals.

In this work the composite material is developed by reinforcing of Zirconium oxide Nano powder in Aluminum alloy Al7075, fabricated by Stir Casting Machine. The MMC's specimens are prepared by varying the percentage of weight fraction of the reinforced particles as 5%, 10%, 15% and 20% and the remaining aluminum alloy respectively. The characteristics that influence the surface roughness such as Feed rate, Depth of cut and cutting speed were studied. The methodology based on orthogonal array Taguchi's Analysis of Variance (ANOVA) and Signals to Noise ratio (S/N Ratio) were employed to optimize the surface roughness.

Keywords: - Surface roughness; stir casting, reinforcement of Al-7075 & Zro_2 .

CHAPTER 1
INTRODUCTION

1 COMPOSITE:-

A composite material is a macroscopic combination of two or more distinct materials, having a recognizable interface between them. Composites are used not only for their structural properties, but also for electrical, thermal, tribological, and environmental applications. Modern composite materials are usually optimized to achieve a particular balance of properties for a given range of applications. Composite is a multiphase material that exhibits a significant proportion of the properties of both constituent phases such that a better combination of properties is realized. This is termed as the principle of combined action. The term "composite" broadly refers to a material system which is composed of a discrete constituent (the reinforcement) distributed in a continuous phase (the matrix), and which derives its distinguishing characteristics from the properties of its constituents, from the geometry and architecture of the constituents, and from the properties of the boundaries (interfaces) between different constituents. Composite materials are usually classified on the

basis of the physical or chemical nature of the matrix phase, e.g., polymer matrix, metal-matrix and ceramic composites.

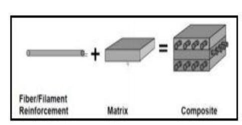


Fig 1:- Composite formation model

Aluminum is a soft, durable, lightweight, ductile and malleable metal, with appearance ranging from silvery to dull gray, depending on the surface roughness Aluminium is nonmagnetic and non-sparking. Aluminium has about one-third the density and stiffness of steel. In our time, weight for on the increase metal matrix composites for use in high performance application, have seen notably increased. Among these composites, aluminium alloy matrix composite attractive property. Various kinds of ceramic materials, e.g. Zirconium and Chromium, Al_2O_3 etc are extensively used to reinforce aluminium alloy matrices. Superior properties of these materials such as hardness, high compressive strength, wear resistance, etc. makes them suitable for use as reinforcement in matrix of composites. These composites, sometimes, are subjected to subsequent age hardening for improving mechanical properties.

Composite materials can be classified in different ways. Classification based on the geometry of a representative unit of reinforcement is convenient since it is the geometry of the reinforcement which is responsible for the mechanical properties and high performance of the composites. The two broad classes of composites are:

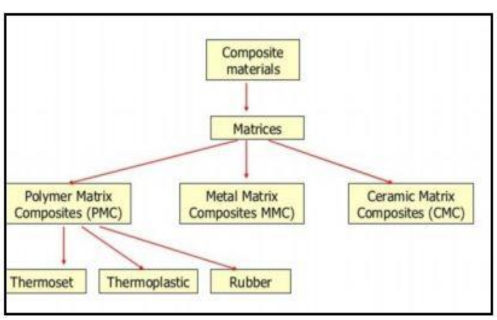


Fig 2:- Classification of composite

2 Based on Reinforcing Material Structure:-

2.1 Particulate Composites:-

Hard particles dispersed in a softer matrix increase wear and abrasion resistance. Soft dispersed particles in a harder matrix improve machinability. Composites with high electrical conductivity matrices (copper, silver) and with refractory dispersed phase (tungsten, molybdenum) work in high temperature electrical applications. When dispersed phase of these materials consists of two-dimensional flat platelets (flakes) which are laid parallel to each other, material exhibits anisotropy (dependence of the properties on the axis or plane along which they were measured.

2.2 Fibrous Composites:-

Dispersed phase in form of fibres (Fibrous Composites) improves strength, stiffness and Fracture Toughness of the material, impeding crack growth in the directions normal to the fibre. Effect of the strength increase becomes much more significant when the fibres are arranged in a particular direction (preferred orientation) and a stress is applied along the same direction.

2.3 Laminate Composites:-

Laminate composites consist of layers with different anisotropic orientations or of a matrix reinforced with a dispersed phase in form of sheets

2.4 Advantages of Composites:-

- High resistance to fatigue and corrosion degradation.
- High 'strength or stiffness to weight' ratio. As enumerated above, weight savings are

significant ranging from 25-45% of the weight of conventional metallic designs.

- Due to greater reliability, there are fewer inspections and structural repairs.
- Directional tailoring capabilities to meet the design requirements. The fibre pattern can be laid in a manner that will tailor the structure to efficiently sustain the applied loads.
- Improved dent resistance is normally achieved. Composite panels do not sustain damage as easily as thin gage sheet metals.
- It is easier to achieve smooth aerodynamic profiles for drag reduction. Complex double-curvature parts with a smooth surface finish can be made in one manufacturing operation.
- Composites offer improved tensional stiffness. This implies high whirling speeds, reduced number of intermediate bearings and supporting structural elements. The overall part count and manufacturing & assembly costs are thus reduced.
- High resistance to impact damage.

2.5 Objectives:-

The main purpose this paper is to develop the strong light weighted metal-matrix Alzro$_2$ Composite material which is useful in the industrial sectors as well as advanced machineries. The most important part of this paper is to fabricate Alzro$_2$ metal-matrix of by homogeneous stir-casting to produce High Strength Low Cost Material (HSLCM). We adopt the stir-casting method with high temperature in this project. This types of metal-matrix composite have very high specific strength, temperature resistance, fatigue resistance, abrasion resistance, corrosion resistance and stiffness properties that they are used in automotive and heavy goodsvehicle, Braking systems, piston rods, frames, piston pins, valve spring cap, brake discs, axle tubes, reinforcement blade, gear box casing, turbine blades, racing car wheels and so on.

3 Properties Of Composites:-

The following are the various properties of composites:

- ➢ Composites possess excellent Strength and Stiffness
- ➢ They are very light Materials
- ➢ They possess high resistance to corrosion, chemical and other weathering agents
- ➢ High strength to weight ratio(low density high tensile strength)
- ➢ High creep resistance
- ➢ High tensile strength at elevated temperature
- ➢ High toughness

CHAPTER 2
LITERATURE REVIEW

Aluminium (Al) As A Metal Matrix:-

Ganesh Khandoori1, Dr. K.K.S Mer and Chandraveer Singh-2015: Aluminium is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. Aluminium matrix composites (AMCs) have been widely studied since the 1920s and are now used in sporting goods, electronic packaging, armours and automotive industries. They offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix. They are usually reinforced by Al2O3, SiC, C, TiO2 but SiO2, B, BN, B4C may also be considered **[P .K. *et al*, 1988].** In addition, literature also reveals that most of the published work has considered Aluminium-based composites with their attractions of low density, wide alloy range, heat treatment capability and processing flexibility**.**

1) Zirconium (Zro2) As A Metal Matrix:-

K. L. Meena et al. [5] observed that mechanical properties of the developed ZRO_2 reinforced Al-7075 metal matrix composite material using the melt stirring technique. The experiment was performed by varying the reinforced particle size as 200 mesh, 300 mesh, 400 mesh and different weight percentage 5%, 10% of ZRO_2 particle reinforced composite material. The stirring process was conceded at 200 rpm using a graphite impeller on behalf of 15 min. A homogenous dispersion of ZRO_2 particle in the aluminium matrix was observed. Tensile strength, hardness and breaking strength improved with the enlargement in reinforced particulate size and weight percentage of ZRO_2 particles. Percentage elongation, percentage reduction area and impact strength decrease with the rise in reinforced particle size and weight percentage of ZRO_2 particles..

2) Reinforcement:-

Atul Kumar, Dr.Sudhir Kumar, Dr.Rohit Garg-2015: The selection of reinforcement depends on the type of reinforcement, its method of production and chemical compatibility with the matrix & the various aspects of the reinforcement material such as Size, Shape, Surface morphology, Structural defects, Surface chemistry, Impurities.

Even when a specific type has been selected, reinforcement inconsistency will persist because many of the aspect cited above in addition to contamination from processing equipment and feedstock may vary greatly. Rohatgi and co-workers have studied mica, alumina, silicon carbide, clay, zircon, and graphite as reinforcements in the production of composites. Numerous oxides, nitrides, borides and carbides were studied by **Zedalis *et al*.** as reinforcements for reinforcing high temperature discontinuously reinforced aluminium (HTDRA).

It has been inferred from their studies that HTDRA containing TiC TiB_2, B_4C, Al_2O_3, SiC exhibit the highest values of specific stiffness. It is proven that the ceramic particles are effective reinforcement materials in aluminium alloy to enhance the mechanical and other properties. The reinforcement in MMCs is usually of ceramic materials; these reinforcements can be divided into two major groups, continuous and discontinuous. The MMCs produced by them are called continuously (fibre) reinforced composites and discontinuously reinforced composites**.(Atul Kumar, Dr.Sudhir Kumar, Dr.Rohit Garg-2015)**

3) Metal Matrix Composites Mmcs:-

Rajeshkumar and Sudhirkumar, 2011: Metal Matrix Composites (MMCs) are one of the recent advanced materials having the properties of light weight, high specific strength, good wear resistance and a low thermal expansion coefficient. These composite materials are extensively used in structural, aerospace and automotive products such as engine piston, cylinder liner, brake disc/drum etc. MMCs are composed of metallic base material, termed as matrix, which is reinforced with hard ceramic particles like B_4C, SiC and Al_2O_3. These can be used as long fibers, short whiskers or particles either in an irregular shape or spherical shape. The properties of the resulting properties are controlled by three critical components: the matrix, the reinforcement and the interface (Hashim et al., 1999). Many of the considerations arise due to the related and interlinked processes such as fabrication, processing, and service performance of composites which occur in the interfacial region between the matrix and reinforcement. Fabrication of aluminium MMCs can be classified into: liquid state processing, semi-solid processing and powder metallurgy. Bulk fabrications of aluminium MMCs can be processed more easily and economically by the liquid state processing i.e. stir casting process. Stir casting is an attractive processing method since it is relatively inexpensive and offers wide selection of materials and processing conditions. It is able to sustain high productivity rates and allow very large size components to be fabricated. (Hashimet al 2002 a). The fabrication cost of the components using stir casting method is about one-third to one-half with that of other competitive methods; also for high volume of production it is projected that costs will fall to one-tenth. There are technical challenges associated with the 15 production of homogeneous high density composites. To achieve optimum MMC properties, the distribution of the reinforcement material in the matrix alloy must be uniform and the bonding strength between these two substances should be good. Good wetting is an essential condition for the generation of satisfactory bond between particle reinforcements and liquid aluminium metal matrix during casting. Strong bonds at the interface are required for good wetting. These bonds may be formed by mutual dissolution or reaction of the particles and metal matrix (Hashim et al 2002 b). The mechanical properties of MMCs are controlled to a large extent by the structure and properties of the reinforcement metal interface. A stronger interface permits transfer and distribution of load from the matrix to the reinforcement, resulting in an increased elastic modulus and strength. Particle distribution in the matrix material during the melt stage of casting process depend strongly on the stirring speed, heating temperature, stirring time, viscosity of slurry, particle wetting, effectiveness of mixing and minimizing gas entrapment (Balasivandha Prabu et al., 2004). The uniformity of particles dispersion in a melt before solidification is also controlled by the dynamics of particle movement in an agitated vessel. Continuous stirring of the melt with a motor driven agitator is essential to prevent the settling of particles. Stirring speed and stirring time affect the structure and grain size. A higher stirring speed and shorter duration of stirring produce smaller grains. These smaller grains results in better mechanical properties.

4) Production of Mmcs:-

Jasmi Hashim *et al*. (2007) proposed modified stir casting method to remove various deficiencies of normal stir casting process. In a normal practice of stir casting technique, cast metal matrix composites (MMC) is produced by melting the matrix material in a vessel, then the molten metal is stirred thoroughly to form a vortex and the reinforcement particles are introduced through the side of the vortex formed. From some point of view this approach has disadvantages, mainly arising from the particle addition and the stirring methods. During particle addition there is undoubtedly local solidification of the melt induced by the particles, and this increase the viscosity of the slurry. A top addition method also will introduced air into the slurry which appears as air pockets between the particles.

Rajan *et al.* (2007) studied the effect of three different stir casting techniques on the structure and properties of fly ash particles reinforced Al-Si -Mg alloy composite. Among liquid metal stir casting, compo-casting (semi-solid processing), and modified compo- 32 casting followed by squeeze casting routes were evaluated. Modified compo casting resulted in uniformly distributed and porosity-free fly ash particle-dispersed composites.

Jayaseelan *et al.* (2010) compared the extrusion characteristics of Al-SiC produced by two methods namely powder metallurgy & stir casting. Stir cast specimens exhibited finer microstructure & high hardness as compared to specimens produced by powder metallurgy. They also possessed higher strength.

Alaneme & Aluko (2012) studied the double stir-casting method to cast the Al (6063) scrap billets and silicon carbide in order to produce 3, 6, 9 and 12 % by volume of SiC reinforcements in the composite. The Al (6063) billets were charged into the furnace and melting was done till a temperature of 750°C was attained. The melt was then allowed to cool to 600°C. They found that this stage, the silicon carbide and dehydrated borax mixture was added into the melt and mixture was stirred for about 20 minutes.

CHAPTER 3
METHODOLOGY

3.1 Introduction:-

During the last two decades, metal matrix composites (MMCs) have emerged as an important class of materials for structural, wear, thermal, transportation and electrical applications. Metal matrix composites (MMCs) possess significantly improved properties including high specific strength; specific modulus, damping capacity and good wear resistance compared to unreinforced alloys. Aluminium Metal Matrix Composites (MMCs) sought over other conventional materials in the field of aerospace, automotive and marine applications owing to their excellent improved properties. These materials are of much interest to the researchers from few decades.

3.2) Metal Matrix Composite:-

Metal-matrix composite structure is generally designated purely by the term metal alloy ofThe matrix and the material in the form of the strengthening. The matrix is permeating softPart generally having excellent tensile strength, hardness, ductility and thermal conductivityWhich are set in the hard reinforcements having high toughness and low thermal expansion.For the development of metal-matrix, light metal composite materials mixed with light metalAlloys are applied as matrix materials. During the metal-matrix production, the mainContribution of special alloys is used in powder metallurgy which is used for the solidification.

Metal Matrix Composites are being increasingly used in aerospace and automobile industries owing to their enhanced properties such as elastic modulus, hardness, tensile strength at room and elevated temperatures, wear resistance combined with significant weight savings over unreinforced alloys. The commonly used metallic matrices include Al, Mg, Ti, Cu and their alloys. These alloys are preferred matrix materials for the production of MMCs. The reinforcements being used are fibers, whiskers and particulates. The advantages of particulate-reinforced composites over others are their formability with cost advantage. Further, they are inherent with heat and wear resistant properties. For MMCs SiC, Al_2O_3 and Gr are widely used particulate reinforcements.

Compositionally, MMCs have at least two components, viz. the matrix and the reinforcement. The matrix is essentially a metal, but seldom a pure one. Except sparing cases, it is generally an alloy. The most common metal alloys in use are based on Aluminium and Titanium. Both of them are low density materials and are commercially available in a wide range of alloy compositions. Other alloys are also used for specific cases, because of their own advantages and disadvantages. Beryllium is the lightest of all structural materials and has a tensile modulus greater than that of steel, but it is extremely brittle, rendering it unsuitable for general purpose use. Magnesium is light, but is highly reactive to Oxygen. Nickel and Cobalt based super alloys have also found some use, but some of the alloying elements present in the matrices have been found to have undesirable effect(promoting oxidation) on the reinforcing fibers at high temperatures.

The reinforcements for MMCs can be broadly divided into five major categories, viz. Continuous fibers, discontinuous fibers, whiskers, wires and particulates. Except the wires being metals, the reinforcements are generally ceramic; which can be oxides, carbides and nitrides which are used because of their excellent combination of specific strengths and stiffness at both ambient and elevated temperatures. MMCs offer designers benefits as they are particularly suited for applications requiring good strength at high temperature, good structural rigidity, dimensional stability and light weight. The present day trend is towards safe usage of the MMC parts in the automobile engines, which work particularly at high temperature and pressure environments. The increase in demand for lightweight, stiff and $strong materials has led to the development of MMCs reinforced with ceramic dispersions.

These MMCs possess excellent mechanical and tribological properties and are considered as potential engineering materials for various tribological applications. Several researchers have worked on sliding wear mechanism of MMCs reinforced with ceramic particulates like SiC, Al_2O_3 and garnet particles etc. and have observed improvement in wear and abrasion resistance, reviewed the world-wide upsurge in metal-matrix composite research and development activities with particular emphasis on cast metal-matrix particulate composites. Highlighted the development and processing of new generation metal matrix composites. Reported a review on fibre reinforced metal matrix composites. They studied the fabrication methods, mechanical properties, secondary working techniques and interfaces of those MMCs.

Some researchers reported on the finite element modeling of metal matrix composites. There are number of processing techniques which have been developed in recent years for processing metal matrix composites. According to the type of reinforcements, the fabrication techniques also vary considerably. The different techniques employed for metal matrix composites are powder metallurgy, spray deposition, liquid metal infiltration, squeeze casting, stir casting, etc. All of them have their own advantages and disadvantages. Among the various processing techniques available for particulate or discontinuous reinforced metal matrix composites, stir casting is the technique which is in use for large quantity commercial production.

This technique is most suitable due to its simplicity, flexibility and ease of production for large sized components. It is also the most economical among all the available processing techniques. The principle tribological parameters that control the friction and wear performances of reinforced aluminium composite can be classified into two categories. One is mechanical & physical factors and the others are material factors. The mechanical & Physical factors has been identified as sliding velocity and normal load, whereas, with regards to the material factors they are volume fraction and type of reinforcements. The volume fraction reinforcement has the strongest effect on the wear resistance and this has been studied by many researchers.

Lot of research has been carried out to prepare MMC's by different type of reinforcements. The outcome of all these findings is that wear properties are improved remarkably by introducing hard intermetallic compound in to the aluminium matrix. The present investigation has been focused on the wear behaviour of aluminium metal matrix composite (MMCs) reinforced with different composition (5% and 10% by weight of aluminium) of Magnesium Oxide (MgO) and stir casting is used to produce this composite. Roughness and wear test was performed on these MMC's.

3.3) Characteristics of Mmc's:-

Metals are extremely versatile engineering materials. The broad use of metallic alloys in engineering shows not only their strength and toughness but also the relative simplicity and low cost of fabrication of engineering components by a wide range of manufacturing processes.

The necessity of achieving better properties that those obtained in monolithic metals has allowed the development of different kinds of MMCs. However, the cost of achieving appropriate improvements remains a challenge in many potential MMC applications.

One of the main problems is focused on ensuring the optimum degree of chemical contact (or wetting) between the fibers or reinforcements and the matrix. In many systems, wetting is inhibited by oxide films or surface chemistry features of the reinforcing phase.

Composites consist of one or more discontinuous phases embedded in a continuous phase. The discontinuous phase is usually harder and stronger than the continuous phase and is called the „reinforcement, whereas the continuous phase is termed as the matrix‟.

3.4) Applications of Mmc's:-

Aluminium Matrix Composites (MMC) are used for manufacturing automotive parts (pistons, pushrods, brake components), brake rotors for high speed trains, bicycles, golf clubs, electronic substrates, cores for high voltage electrical cables, aeronautical and aerospace components.

3.5) Material Selection for Mmc's:-

The structural efficiency of metal matrix composites is directly related to the density, elastic modulus and tensile strength of the reinforcing phase. The chemical and thermal stability of the reinforcements and compatibility with the matrix phase are important not only for the end application but also during material fabrication. Concerning alloying element addition one very thing to be noted is that the added element should not form intermetallic compounds with the matrix elements and should not form highly stable compounds with the reinforcements. To get best properties in a composite system, the reinforcement and matrix should be physically and chemically compatible.

3.6) Aluminium (Al) As A Metal Matrix:-

Aluminium is the most popular matrix for the metal matrix composites (MMCs). The Al alloys are quite attractive due to their low density, their capability to be strengthened by precipitation, their good corrosion resistance, high thermal and electrical conductivity, and their high damping capacity. Aluminium matrix composites (AMCs) have been widely studied since the 1920s and are now used in sporting goods, electronic packaging, armours and automotive industries. They offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix. They are usually reinforced by Al_2O_3, SiC, C, TiO_2 but ZrO_2, MgO_2, SiO_2, B, BN, B_4C may also be considered. In addition, literature also reveals that most of the published work has considered Aluminium-based composites with their attractions of low density, wide alloy range, heat treatment capability and processing flexibility.

(a) Matrix:-

The matrix material to be used was chosen as Al7075 which is a precipitation hardened aluminium alloy, containing zinc, magnesium, copper, and chromium as its major alloying elements as indicated in Table I. It has good mechanical properties and it is strong with strength comparable to many steels, has good fatigue strength and less resistance to corrosion and many others.

Table 1:- Chemical Composition of Aluminium Al-7075

ELEMENT	%WEIGHT	ELEMENT	%WEIGHT
Si	0.4	Cr	0.28
Cu	2.0	N	-
Mg	2.9	Zn	6.1
Mn	0.3	Ti	0.2
Fe	0.5	Zr	-

Table 2:- Properties of Aluminium Al-7075

Properties	Density g/cc	Melting Point ^{0}C	Tensile Strength Mpa	Fatigue Strength Mpa	Hardness HB
Al7075	2.8	627	572	160	60

(b) Reinforcement:-

Zirconium is a very strong, malleable, ductile, lustrous silver-gray metal. Its chemical and physical properties are similar to those of titanium. Zirconium is extremely resistant to heat. and corrosion .Zirconium is lighter than steel and its hardness is similar to copper. Zirconium does not dissolve in acidsand alkalis.

Table 3:- Properties of Zirconium Zro_2

Melting point	2715
Boiling point	4300
Density	5.68g/cc

3.7) Fabrication Method of Mmc's:-

Metal matrix composite materials can be produced by many different techniques. The focus of the selection of suitable process engineering is the desired kind, quantity and distribution of the reinforcement components (particles and fibers), the matrix alloy and the application. By altering the manufacturing method, the processing and the finishing, as well as by the form of the reinforcement components it is possible to obtain different characteristic profiles, although the same composition and amounts of the components are involved. Normally the liquid-phase fabrication method is more efficient than the solid phase fabrication method because solid-phase processing requires a longer time. The certain main manufacturing processes which are used presently in laboratories as well as in industries are diffusion bonding, the powder metallurgy route, liquid-metal infiltration, squeeze casting, spray co-deposition, stir casting and compo casting.

3.8) Manufacturing And Forming Methods:-

1. **Solid state methods**:-
a) Powder metallurgy
b) Hot iso static pressing or Extrusion
2. **Liquid state methods**:-
a) Electroplating and Electroforming
b) Stir casting
c) Pressure infiltration
d) Squeeze casting
e) Spray deposition
f) Reactive processing
3. **Semi solid state methods**:-
a) Semi solid powder processing
4. **Vapour deposition**:-
a) Physical vapour deposition
5. **In-situ fabrication technique**:-
a) Eutectic alloy

3.9) Work Materials:-

❖ Matrix Material
- Aluminium (Al7075)

❖ Reinforcement Materials
- Zirconium

Table 4:- Designation and Typical Aluminium Alloys

S NO	DESIGNATION	MAJOR ALLOYING ELEMENT	CHARACTERISTICS	TYPICAL ALLOYS
1	1XXX	99% Al, No major alloying additions	Low strength, High ductility and Formability high Electrical conductivity	AA 1100 AA 1050
2	2XXX	Copper	High strength, Forming	AA 2014 AA 2024
3	3XXX	Manganese	Medium strength, High formability and Ductility	AA 3003 AA 3104
4	4XXX	Silicon	Easily welded and widely used weld filler alloys.	AA 4032

5	5XXX	Magnesium	Highest strength, Tough, Absorbing lots of energy during fracture, easily welded. Excellent resistance to atmospheric and sea water corrosion	AA 5052 AA 5454 AA 5754
6	6XXX	Magnesium and Silicon	Higher strength Excellent corrosion resistance. Good Formability, Machinability and Weldability	AA 6061 AA 6063
7	7XXX	Zinc	Highest strength and poor atmospheric corrosion resistance	AA 7075 AA 7005

3.10) Aluminium (Al7075):-

The matrix material to be used was chosen as Al7075 which is a precipitation hardened aluminium alloy, containing zinc, magnesium, copper, and chromium as its major alloying elements as indicated in Table I. It has good mechanical properties and it is strong with strength comparable to many steels, has good fatigue strength and less resistance to corrosion and many others.

Fig 3:- Aluminium alloy (Al7075)

Table 5:-Chemical Composition of Aluminium Al7075

Element	%Weight	Element	%Weight
Si	0.4	Cr	0.28
Cu	2.0	N	-
Mg	2.9	Zn	6.1
Mn	0.3	Ti	0.2
Fe	0.5	Zr	-

- **Rule of Mixtures:-**

Density: dc = dm*Vm + df*Vf

Where,

dc, dm, df – densities of the composite, matrix and dispersed phase respectively;

Vm,Vf – volume fraction of the matrix and dispersed phase respectively.

3.11) Selection of reinforcement materials

The selection of reinforcement is very important in composite fabrication. Generally the reinforcement may be of fibres or particulate, for metal matrix particles of metals such as zirconium Oxide is used. The physical, mechanical and wear properties depend on size and shape of the reinforcement used. It considered good stiffness and strength to the composite materials.

Fig 4:- zro2 nano powder

Table 6:- Nano ZRo_2 Specification

ITEM	APPERANCE	APS	Purity	SSA
EPRUI-ZR50	White powder	30-50nm	99%	15-30m^2g

3.12) Advantages of Mmc's:-

The following are the various advantages of MMCs:

- Dimensional stability
- Wear and corrosion resistance
- Reduced weigh

3.13) Disadvantages of Mmc's:-

- High production cost
- Difficult repair
- Complex fabrications methods for fibre-reinforced systems(except for casting)

3.14) Experimental Setup:-

For performing the experiment and testing of composites the following machine equipments were used:

- Weighing Machine
- Matrix (Al alloy 7075)
- Reinforcement (Magnesium Oxide, MgO)
- Digital control Muffle Furnace
- Crucible (Graphite)
- Mould (Mild Steel)
- Stirrer (Graphite)
- Power Hacksaw
- Lathe Machine
- Universal testing machine
- Salt Solution
- Corrosion and chemical testing machine

3.15) Work Plan For Experiments:-

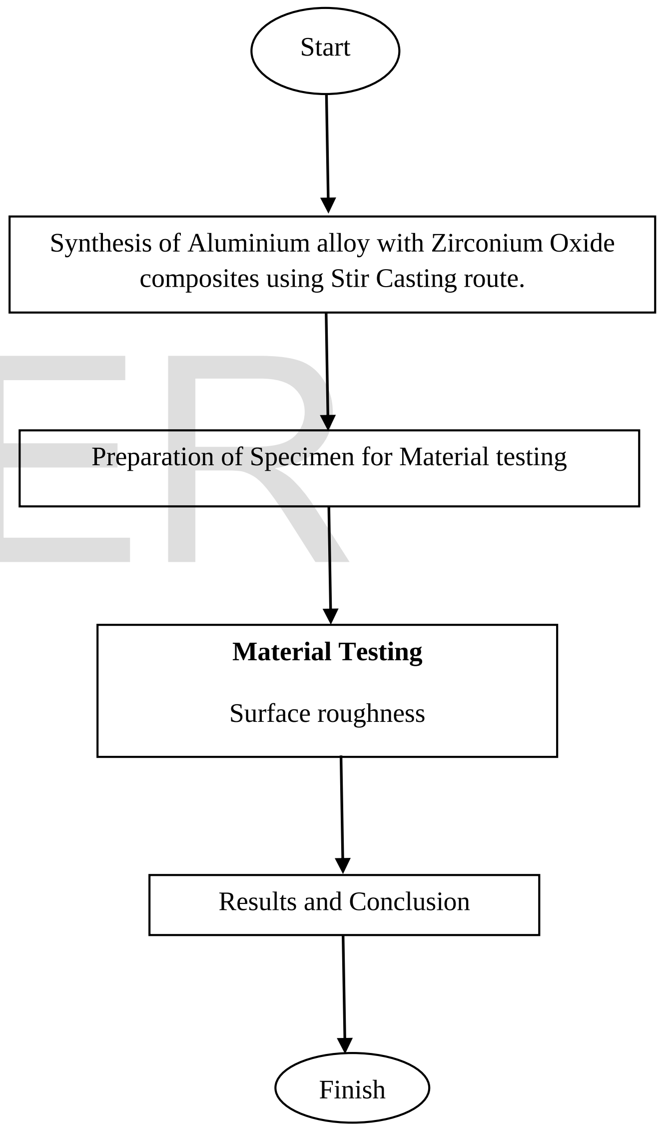


Fig 5:- Flow Chart of Work Plan for Experiments

ISSN 2229-5518

3.16) Flowchart Showing Steps Involved In Stir Casting:-

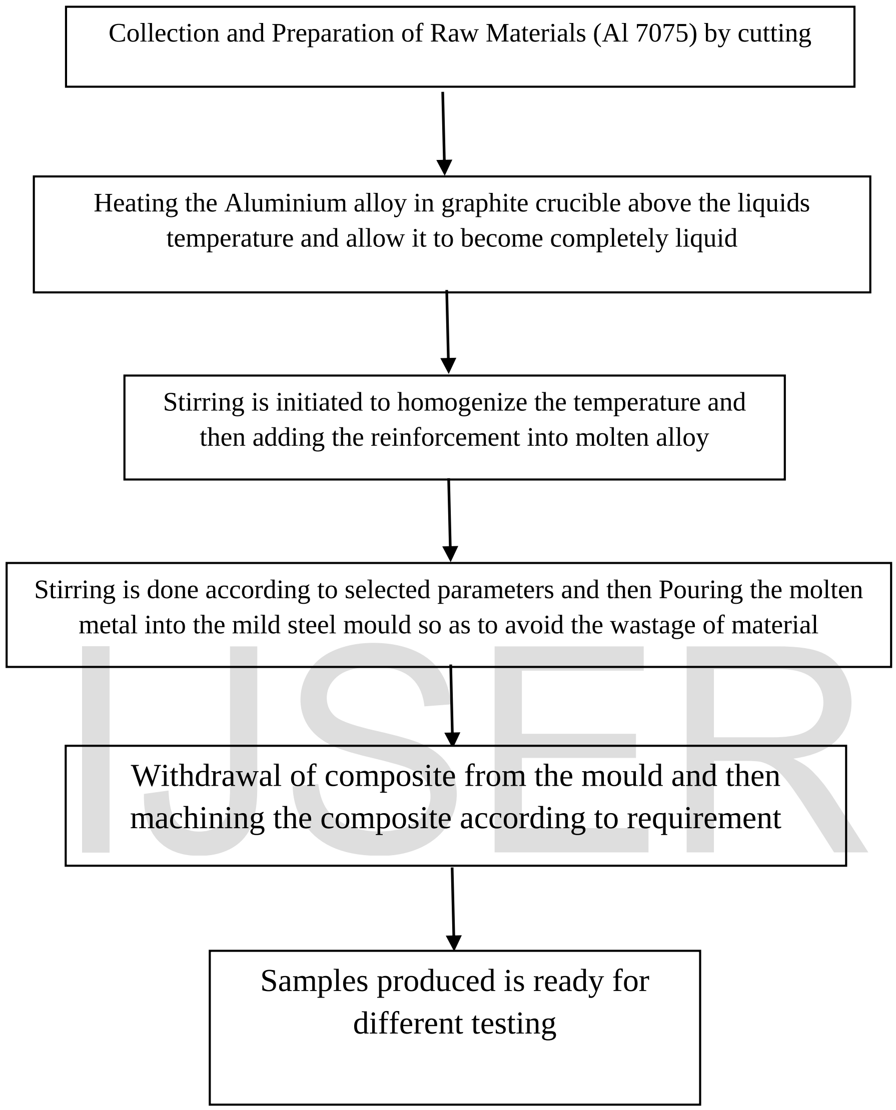


Fig 6:- Flow Chart Showing Steps Involved in Involved in Stir Casting

ISSN 2229-5518

3.17) Specimen Preparation From Base Materials To Samples (Mmcs):-

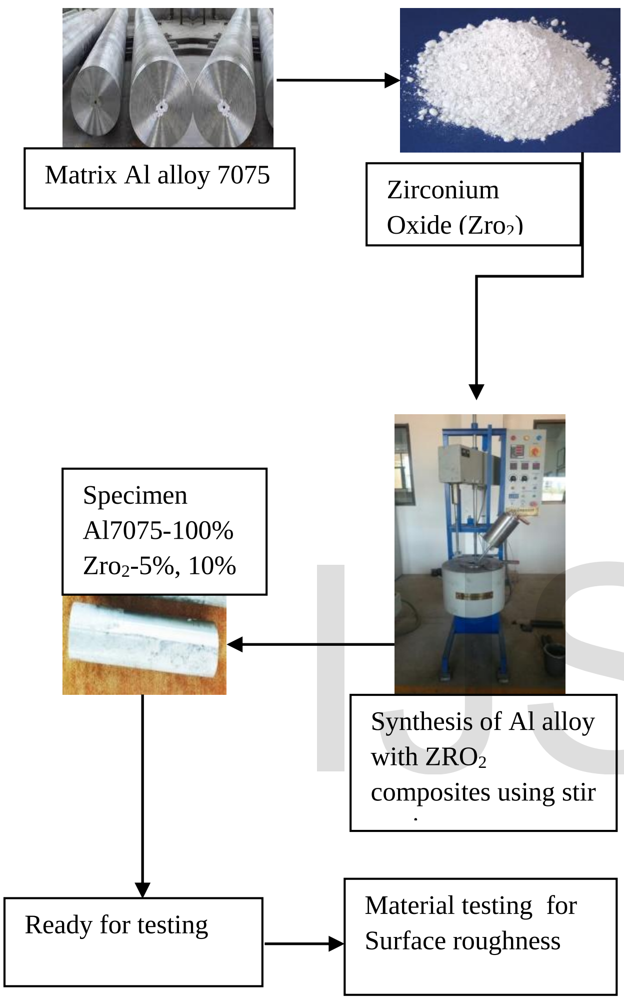


Fig 7:- Specimen preparations from base material to samples (MMC_s)

CHAPTER 4

IMPLEMENTATION

4) INTRODUCTION:-

4.1) Fabrication Method of Mmc's:-

Metal matrix composite materials can be produced by many different techniques. The focus of the selection of suitable process engineering is the desired kind, quantity and distribution of the reinforcement components (particles and fibers), the matrix alloy and the application. By altering the manufacturing method, the processing and the finishing, as well as by the form of the reinforcement components it is possible to obtain different characteristic profiles, although the same composition and amounts of the components are involved. Normally the liquid-phase fabrication method is more efficient than the solid phase fabrication method because solid-phase processing requires a longer time. The certain main manufacturing processes which are used presently in laboratories as well as in industries are diffusion bonding, the powder metallurgy route, liquid-metal infiltration, squeeze casting, spray co-deposition, stir casting and compo casting.

MMC manufacturing can be of two types: solid and liquid

4.1.1) Solid Phase Fabrication Methods:-

- **Powder blending and consolidation (powder metallurgy):** Powdered metal and discontinuous reinforcement are mixed and then bonded through a process of compaction, degassing and thermo-mechanical treatment (extrusion).
- **Foil diffusion bonding:** Layers of metal foil are sandwiched with long fibres, and then pressed through to form a matrix.

1.1)

4.1.2) Liquid Phase Fabrication Methods:-

Liquid-phase fabrication method is more efficient than the solid-phase fabrication method because solid-phase processing requires a longer time.

- **Electroplating/Electroforming:** A solution containing metal ions loaded with reinforcing particles is co-deposited forming a composite material.

- **Stircasting:** Discontinuous reinforcement is stirred into molten metal, which is allowed to solidify.

- **Squeeze casting:** Molten metal is injected into a form with fibres preplaced inside it
- **Spray deposition:** Molten metal is sprayed onto a continuous fibre substrate

1) Production And Processing Of Metal Matrix Composites:-

Metal matrix composite materials are produced by many different techniques. The selection of suitable process engineering depends upon the distribution of the reinforcement (particles/ fibre) and the cost effectiveness

Some of the production methods discussed by Karl Ulrich Kainer(2006) and Froyen et al (1994) has been discussed the different production methods of composites.

Some different production methods of composites were given below

1. Melting metallurgical processes:-

i. Infiltration of short fibre-, particle- or hybrid performs by squeeze casting, vacuum infiltration or pressure infiltration
ii. Reaction infiltration of fibre- or particle performs
iii. Processing of precursor material by stirring the particles in metallic melts, followed by sand casting, permanent mould casting or high pressure die casting.

2. Powder metallurgical processes:-

i. Pressing and sintering and/or forging of powder mixtures and composite powders
ii. Extrusion or forging of metal-powder particle mixtures
iii. Extrusion or forging of spraying compatible precursor materials

3. Hot isotactic pressing of powder mixtures

Melting metallurgy for the production of Metal Matrix Composites is at present of greater technical importance than powder metallurgy. It is more economical and has the advantage of being able to use well proven casting processes for the production of Metal Matrix Composites. There are three melting metallurgical processes for composite materials. They are

i. compo-casting or melt stirring
ii. gas pressure infiltration
iii. Squeeze casting or pressure casting.

Melt stirring is used to stir the reinforcement particles into an alloy melt. The particles often tend to form agglomerates, which can only be dissolved by intense stirring. Atmospheric gas access into the melt is avoided as it leads to unwanted porosities or reactions. To avoid dissolution of the reinforcement components attention must be paid to the dispersion of the reinforcement components, temperature of the melt and the duration of stirring, as it could lead to dissolution of the reinforcement component. Because of the lower surface to volume ratio of spherical particles, reactivity is usually less critical with stirred particle reinforcement than with fibers. The melt can be cast directly or processed with alternative procedures such as squeeze casting.

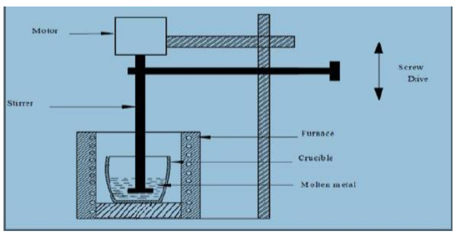


Fig8:- Stir Casting Machine

2) Stir Casting:-

Stir casting setup mainly consists of furnace and a stirring assembly as shown in figure 4.1 In general, the solidification synthesis of metal matrix composites involves a melt of the selected matrix material followed by the introduction of a reinforcement material into the melt, obtaining a suitable dispersion. The next step is the solidification of the melt containing suspended dispersions under selected conditions to obtain the desired distribution of the dispersed phase in the cast matrix. In preparing metal matrix composites by the stir casting method, there are several factors that need considerable attention, including.

- ➢ The difficulty in achieving a uniform distribution of the reinforcement material.
- ➢ Wettability between the two main substances.
- ➢ Porosity in the cast metal matrix composites.
- ➢ Chemical reactions between the reinforcement material and matrix alloy

In order to achieve the optimum properties of the metal matrix composite, the distribution of the reinforcement material in the matrix alloy must be uniform, and the wettability or bonding between these substances should be optimized. The porosity level needs to be minimized.

3) Experimental Procedure:-

Stir-casting is the simplest and most commercial method of production of MMCs. This approach involves mechanical mixing of the reinforcement particulate into a molten metal bath and transferred the mixture directly to a shaped mould prior to complete solidification. In this process, the crucial thing is to create good wetting between the particulate reinforcement and the molten metal.

Microstructure inhomogeneity can cause notably particle agglomeration and sedimentation in the melt and subsequently during solidification. Inhomogeneity in reinforcement distribution in these cast composites could also Bea problem as a result of interaction between suspended ceramic particles and moving solid liquid interface during solidification. This process has major advantage that the production costs of MMCs are very low.

Literature reveals that most of the researchers are using 7075 aluminium matrix reinforced with Magnesium particles for high corrosive properties. Aluminium alloys Al7075 were chosen as the matrix and as nano-particles, with an average diameter of 40nm, as reinforcements.

The stir casting technique was used to fabricate the composite specimen as it ensures a more uniform distribution of the reinforcing particles. This method is most economical to fabricate composites with discontinuous fibers or particulates. In this process, matrix alloy (Al 7075) was first superheated above its melting temperature. Then keep the matrix alloy in the semisolid state. At this temperature, the preheated Mg particle of 5%, 10% (by weight) were dropped into the slurry and mixed using a graphite stirrer.

The composite slurry temperature was increased to fully liquid state and automatic stirring was continued to about five minutes at an average stirring speed of 300-350 rpm under protected organ gas. The Mg particles help in distributing the particles uniformly throughout the matrix alloy. The melt was then superheated above liquids temperature and finally poured into the cast iron permanent mould for testing specimen. The size of the fabricated billet composite is100 mm length and 100 mm width and 100mm thickness.

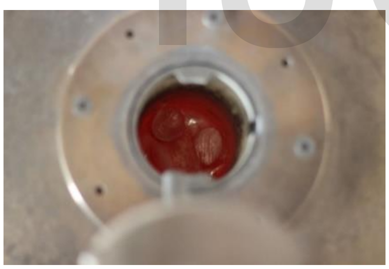


Fig 9:- Melting of Al7075 in Stir Casting

Base material: Aluminium AA7075
Nano particle: Magnesium
Nano particle size: 40nm.
Fabrication method: stir casting (at atmospheric condition.

4) Important Parameters Used In Stir Casting:-

Synthesis of composite was done by stir casting route. The parameters used in this word were stirrer design, preheating temperature for particulate and stirring speed and time. These parameters are discussed below:

1) Particulate Preheating Temperature:-

Preheating of particulate is necessary to avoid moisture from the particulate otherwise chances of agglomeration of particulate occurs due moisture and gases. The preheated temperature in a furnace is made up to 800^0C and maintained at that temperature before mixing with Aluminium melt. Along this MgO particles were heated to form a oxide layer on the MgO particles which make it chemically more stable and by the oxide layer formation wet ability will increase so particles will effectively embedded in aluminium matrix and will result in less number of porosities in casting.

2) Stirring Speed:-

In stir casting process stirring speed is very important parameter for consideration. In the process stirring speed was 500 rpm which was effectively producing vortex without any spattering. Stirring speed is decided by fluidity of metal if metal having more fluidity then stirring speed will be low. It is also found that at less speed, dispersion of particulates is not proper because of ineffective vortex.

3) Stirrer Design:-

It is also one of the important parameters for stir casting process. It is essentially requires for vortex formation for the uniformly dispersion of particles. There is no uniform dispersion of particles in case of no vortex formation

5) Steps Involved In Preparation of Mmc Casting:-

5.1) Melting Process:-

It is done by using Stir Casting Machine as shown in figure 4.3 Al7075 is taken the form of ingots for the trails. Temperature about 740 to 800ºc is set in an open hearth furnace and a cleaned metal ingot is placed inside the crucible and for trial 1 kg of alloy is used.

The graphite crucible containing ingots now placed inside the furnace and it is heated until reaches its melting point, once the metal reaches into the liquid state the slag formed on the surface will be removed slowly. And the particulate of reinforcements (MgO) are added in small quantity and the molten metal is stirred continuously at a constant speed.

Fig 10:- Stir Casting Machine

5.2) Pouring:-

After complete mixing of Graphite particulate with aluminium alloy which is inside the crucible the molten mixture is taken outside the furnace and poured into the die as shown in figure 4.4. Simple vice die sets are used as mould cavity. The die sets are made by good strengthened and temperature resisted materials. Initially die sets are correctly positioned and locked using screw clamp arrangement after clamping molten metal will be poured inside the mold cavity. The composite metal after been ejected from the mold is then cooled. After moulding process casted pieces will be machined. Depending upon the type of test conducted machining shape will be varied.

Fig11:- pouring molten metal into mould cavity

5.3) Solidification:-

While the molten metal mixture of Al and particulate is poured into the die after some few minutes it gets solidified, and slowly remove the cast product as shown in figure 11.

100% Al pure

5% Zr

10% Zr

Fig 12:- Solidified specimens after removed from the die.

CHAPTER 5

PREPARATION OFCOMPOSITEMATERIALS

5.1) Preparation:-

There are various types of metal-matrix composite materials fabrication techniques in Engineering field like, Metallurgical melting method, Gas or Pressure infiltration method, Finishing by machining method, Pressing and sintering method, Forging and extrusion Method, Squeeze or pressure casting method, Compo-casting method, vortex and Stircasting Method.

Matrix selected is Al-7075 which is procured in the form of Ingots. Ingots are melted using electrical resistance furnace. And the stirrer is inserted into molten metal and rotated to create vortex. Zro2 particulates are added to vortex and stirring composite was taken out of furnace and poured in to sand moulds hybrid composite. Hybrid composite is obtained by adding equal quantities of AL-7075 and ZRO_2 into the vortex. 100% Al 7075 alloy is prepared without adding zro2 into the vortex.

In the preparation process of this method, stirring has been carried out in graphite crucible in Coal-fired furnace with continuous stirring of the molten metal-matrix gives homogeneous Mixture of composites and instantaneously poured in to the sand mould to get solidify. Coalis used as a fuel for preparation. The working diagram of the coal-fired furnace is given in the Experimental figure.

5.2) Experimentation:-

The experimental arrangement has been assembled by the coupling gear-box motor and mild steel four blade stirrer is used. The melting of the aluminium (100%) scraps and zirconium nano powder (Zro_2 – 50nm size) is carried out in the graphite crucible into the coal-fired furnace. First the scraps of aluminium were preheated for 2 to 3 hours at 450°C and Zro2powderalso heated with 800°C and both the preheated mixtures is then mechanically mixed with each other below their melting points. This metal-matrix $Alzro_2$ is then poured into the graphite crucible and put in to the coal-fired furnace at 830°C temperature.

The furnace temperature was first increases above the composites completely melt the scraps of aluminium and then cooled down just below the components temperature and keep it in a semi-solid state. At this stage the preheated Zro_2 were added with manually mixed with each other. It is very difficult to mix by machine or stirrer when metal-matrix composites are in semi molten state with manual mixing taking place. When the manual mixing is complete then automatic stirring will carried out for ten minutes with normal 400 rpm of stirring rate The temperature rate of the coal-fired furnace should be controlled at 760 ± 10°C in final mixing process. After completing the process the slurry has been taken into the sand mouldwithin thirty seconds allow it to solidify. Tests should be taken of solidified samples like hardness and impact tests. This experiment should repeatedly conducted by varying the compositions of the composite powder of Zro_2 (5%, 10%), weight of aluminium scraps in grams plus weight in grams of Zro_2 powder as shown in the following chart. For each composition variation a total 2 kg (2000 gms) material mix is used forecasting the test samples.

Table 7:- Weight in grams for composition of $AlZro_2$ Casting

Percentage	Alcp-100%	Zro2-50nm size
100	**100**	**0**
95	**95**	**5**
90	**90**	**10**

Finally we prepared the six types varying samples including rounded bars as shown in the given fig.6.

Fig 13:- Ready Samples for Testing

These final samples are now ready for further testing processes of machining characteristics on surface roughness of $AlZr0_2$ composition.

5.3) Introduction to Machining:-

Metal matrix composites (MMC) are materials that are fabricated by the combination of a tough metal matrix with reinforcement of hard ceramic particulate material. Generally incorporation of carbide particles enhances the properties like hardness, adhesiveness, abrasiveness, diffusion wear resistance, thermal properties, and stiffness. By choosing the particle shape, size and distribution the mechanical properties can be fine-tuned to the requirement. Hybrid composites are unique materials manufactured by two or more reinforcing elements of different properties in to the base alloy to improve the thermal and mechanical properties. For the past few years the usage of Al-Carbide composites have been increased in the industries of aerospace, automobile and advanced arm systems such as satellite bearing, inertia navigation system, and laser reflector. Due to the addition of reinforcing materials, which are normally harder and stiffer than matrix, machining of these MMC become significantly more difficult than those of conventional materials. Despite their higher specific properties the non-homogeneous and anisotropic nature combined with the abrasive reinforcements render their machining difficult. The work piece may get damaged and the cutting tools experience high wear rates, which may lead to an uneconomical machining. The machinability of a particular material can be evaluated by assessing any one of the following five parameters:

(i) Surface finish of test specimen
(ii) Tool life or tool wear
(iii) Cutting force requirement
(iv) Electrical power requirement
(v) Cutting temperature

Among different cutting tool materials like HSS, carbide tool, PCD tool 'open' literature survey proves that poly-crystalline diamond (PCD) tool is more suited and has significant effect on cutting performance.

5.4) Turning:-

Turning is a machining process used to obtain the desired dimension of round metal. The main objective in present industrial era is to produce low cost quality product with required dimensions in an optimum time. Therefore the optimum cutting parameters are to be recognized first. In turning, the metal is in rotational motion and a cutting tool is used to shear away the unwanted metals. This process requires lathe or turning machine, cutting tool, work piece and fixture. The work piece is fixed in the fixture and is rotated in high speed. The cutting tool is fed in parallel to the axis of rotation as shown in Fig. During this process the cutting parameters highly depends upon the work piece, cutting tool material, etc. These are determined by experience or machine hand book.

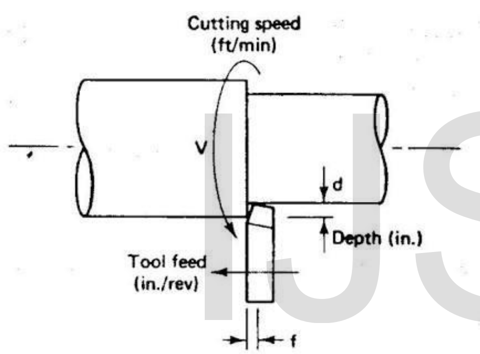


Fig14 Cutting Conditions For Turning Operations

Fig.15:- Before Machining The Alzro$_2$ Pieces

Fig.16:- After Machining The Alzro$_2$ Pieces

These are the samples of aluminium composites of length 100mm and diameter of 25mm.

5.5) Machining Characteristics:-

1) Material Removal:-

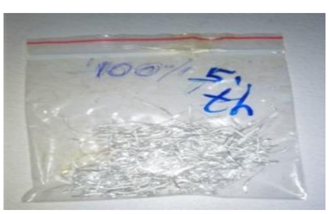
Mechanism of Chip formation in metal matrix composites look like, the behavior of monolithic materials. Joshi et al. highlighted that the most efficient and economical ways of studying the machining characteristics of any material is to study its chip formation details. It was stated that as the volume fraction of the reinforcement particles increases, the number of circles that the chips form before breaking decreases also explained the observation based on decreasing strain at failure of the chip curls. Hence, number of chip curls is directly related to material strain at failure. Ductility of the composite reduces as the increased volume fraction of the hard reinforcements reduces, supporting chip breakage. Tool rake angle affect the chips curl in case of the unreinforced aluminum alloy however composite chip curls remain unaffected. Fundamentally, chip curling depends on the ratio of plastic contact length to total contact length between the chip and the tool face. With increase in this ratio Flatness also increases. Therefore, as the rake angle decreases, chips turn out flatter (chips having greater diameter). At lower cutting speeds, shear strength of the alloy remains high, enabling chip breakage at smaller lengths. But, the same does not happen in case of composites as their low ductility produces much smaller chips. However, it was observed that chip morphology of composites depend on the volume fraction of reinforcements. The chips showed a tendency to stick to the tool face, restricting their

ISSN 2229-5518

movement for lower volume fractions, resulting in longer chips of larger diameters. Joshi et al. have worked on a combined chip breaking criterion that is based on two conditions given by Nakayama and Zhang. Chip breaks when its strain reaches a certain limit, while the latter expressed this limit of strain on chip based on mechanical properties and chip breaker geometry. Comparison with obtained experimental results shows similarity with the model given by Nakayama. Gallab and Sklad also found continuous chips being formed at lower feed rates, which are difficult and hazardous in handling. Lin et al. observed that cutting with sharp tool resulted in the formation of long, helical chips. As the tool became blunt, chips turned to short, helical shapes. It was explained by the researchers as due to lowered ductility of aluminum matrix due to chip breaking action by the built up edges developed on the progressively blunt tool nose.

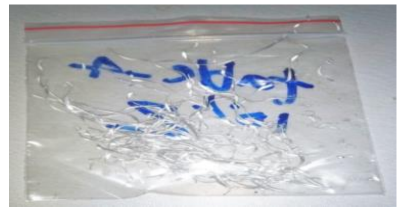
These are the various chip formations while machining the $AlZro_2$ samples of weight percentage of 5%, 10%..

After Turning Process



100% Pure Al-7075

5% Zro2 Powder



10% Zro_2 Powder

2) Surface Roughness:-

Gradually increased with cutting distance at lower cutting speeds (50 m/min) with HSS tools machining $AlZro_2$ MMCs, surface roughness (Ra). This was due to the supremacy of adhesion in high speed cutting. The hard work material diffused to the tool surface and then abraded against the work surface itself, at high cutting speeds. Later, it detached back from the tool to the machined surface and thus induced a many of surface defects such as debris, grooves etc. with increasing Ra value. Use of coolant somewhat controlled the diffusion effect, and helped improve surface quality. Notch wear on the tool translated into replication of the ridges on the machined surface also observed at lower speeds, imparting higher surface roughness. Much better surface quality to the machined surface was imparted due to use of tools with higher notch wear resistance due to higher abrasion hardness. Lin et al. reported that the surface finish improved with increasing cutting speeds at constant feed rate. Better surface finish was obtained with a slightly worn tool due to stabilization of the nose radius. And at constant speeds, with rising feed rates surface finish deteriorated. Similar results were obtained about inverse relationship of surface finish with feed while machining Al/Zro_2 (20p) MMCs by Venkatesh et al. During turning of LM 10 Al/Zro_2 MMC, Arokiadass et al. observed feed to be the most significant parameter affecting surface roughness, followed by spindle speed and weight percentage of particle reinforcement. Muthukrishnan and Davin observed that in turning of Al/Zro_2 (20p) MMC with coarse grade HSS insert, feed rate has maximum influence on surface roughness, followed by depth of cut and cutting speed.

5.6) Talysurf Instrument:-

The instrument which measures the surface roughness we have used is TALYSURF ROUGHNESS TESTER which shows the Ra values of machined work pieces.

Fig17 Surface roughness tester

5.7) Machine, Tool Used, And Material And Experimental Methods:-

1) Machine:-

The dry turning operation is carried out using a medium duty lathe of following specifications:

- Distance between centres:
- Main spindle power:
- Feed type: Cross and longitudinal
- Drive system: Gear
- Head stock: 3 jaw chuck

➢ **Cutting Tool Inserts:-**

After doing a quick review (Table 3) over different grades of the HSS tool, for the dry turning of hybrid MMC material, HSS is chosen.

Table 8:- Specification of the tool holder and HSS insert

CHARACTERISTICS	SPECIFICATIONS
Substrate	**High speed steel**
Insert HSS	
Nose radius	**2mm – 4mm**
Shank size	**1.5**
Tool holder specification	
Product name	

➢ **Material**:-

The work material used for the present investigation is aluminium alloy (Al-7075) with particle reinforcements of Zro_2 5% and 10%. The grain size varies from 20 nm to 50 nm. This composite material is fabricated in the form of cylindrical rods of diameter 25 mm and length 100 mm. The rod is manufactured in house by stir-casting process. The chemical composition of the base material used in this work is given in Table 4. The microstructure of the specimen is shown in Fig. 1.

2) Experimental Method:-

In this paper the experiment is designed by Taguchi method. The optimization of cutting parameters in machining of hybrid MMC is done by Signal-to-Noise ratio also called as (S/N) ratio method which is very

ISSN 2229-5518

attractive and effective method to deal with responses influenced by number of variables. In this method, main parameters are assumed to have influence on process results, which are located at different rows in a designed orthogonal array (L-10). This method is useful for studying the interactions between the parameters and it also is a powerful design of experiments tool, which provides a simple, efficient and systematic approach to determine optimal cutting parameters. Compared to the conventional approach of experimentation, this method reduces drastically the number of experiments that are required to model the response functions. Once the levels of each design parameter have been identified, analysis of the influence of machining parameters on surface roughness has been performed using the response table for S/N ratios, which indicates the response at each level of control factors. The optimum level of cutting parameters can be found from its corresponding S/N ratios. The analysis of variance is performed to find the significant parameters.

3) Experimental Details:-

Using Taguchi's orthogonal array the experiments are planned in the design of experiments (DoE), which helps in reducing the number of experiments. The experiments were conducted according to orthogonal array L10. In the present investigation the three cutting parameters are selected as cutting speed (v), feed (f) and depth of cut (d). Since the considered factors are multi-level variables and their outcome effects are not linearly related, it has been decided to use three level tests (Table 7) for each factor. Taguchi's orthogonal array of L10 is most suitable for this experiment as shown in Table 8 and the S/N ratio results and analysis as shown in Tables 9,10 and 11.

Table 9:- Chemical composition of aluminium alloy (Al-7075) T6511 matrix

ELEMENT	%WEIGHT	ELEMENT	%WEIGHT
Si	0.4	Cr	0.28
Cu	2.0	N	-
Mg	2.9	Zn	6.1
Mn	0.3	Ti	0.2
Fe	0.5	Zr	-

Table 10:- Machining parameters and their levels

CONTROL PARAMETERS	UNIT	SYMBOL	LEVELS		
			1	2	3
Cutting speed	mm/min	v	19	30	47
Feed rate	mm/rev	f	0.53	0.58	064
Depth of cut	mm	d	0.3	0.6	0.9

CHAPTER-6

RESULTS AND ANALYSIS

6.1) Results:-

Study of the surface roughness characteristics of Aluminium metal matrix composites require more analysis due to the presence of abrasive phase in the reinforcing Zro_2 particles. The presence of these nano particles in the metal matrix increases hardness and strength. When it is machined, discontinuous chips are produced, resulting in different machining characteristics.

6.1.1) Effect of Control Parameters on Surface Roughness:-

In Taguchi method, the term 'signal' represents the desirable value and 'noise' represents the undesirable value. The objective of using S/N ratio is a measure of performance to develop products and processes insensitive to noise factors. The S/N ratio is calculated using the formula, S/N = –10 log10 {1/3 x (R1 2 + R2 2 + R3 2)} where 3 indicates the number of trials and R1, R2, R3 are the observed values on those trials. The S/N ratio indicates the degree of the predictable performance of a product or process in the presence of noise factors. Process parameter settings with the highest S/N ratio always yield the optimum quality with minimum variance. The S/N ratio for each parameter level is calculated by averaging the S/N ratios obtained when the parameter is maintained at that level. Table 9 shows the S/N ratios obtained. And also the response characteristics are found out using average surface roughness values at all the three levels as shown in Table 10. As shown in Table 9 & 10 and Figs. 11, 12 the feed is a dominant parameter on the surface roughness followed by cutting speed. The depth of cut had a lower effect on the surface roughness. Lower surface roughness is always preferred. The quality characteristic considered in the investigation is lower-the-better characteristics. The surface roughness observed at lower cutting speed is more than the surface roughness observed at higher cutting speed. In the present investigation, when the cutting speed is set at m/min, the surface roughness is minimized. From the experimental results, it is observed that at low depth of cut the surface roughness is minimal. Contrary to the cutting speed and depth of cut, the maximum S/N ratios, which were the values of minimum surface roughness, were obtained at the lowest level for feed. This is the fact that, the increase in feed increases the heat generation and tool wear, which results in higher surface roughness. The increase in feed also increases the chatter, and it produces incomplete machining of work piece, which leads to higher surface roughness. The results proved that the roughness of the machined surface is highly influenced by the feed. Based on the above discussions and also evident from Figs. 11, 12 and the Tables 9, 10 the optimum conditions for the surface roughness could be established.

6.1.2) Taguchi's Method For Dry Turning:-

Table 11:- Responsible table for S-N ratios

LEVELS	CUTTING SPEED	FEED RATE	DEPTH OF CUT	MATERIAL %
1	-6.908	-7.168	-5.848	-8.240
2	-6.798	-7.149	-7.170	-7.821
3	-7.994	-7.383	-8.682	-5.639
Delta	1.197	0.234	2.834	2.602
Rank	3	4	1	2

Table 12:- Response table for means of surface roughness (Ra)

LEVELS	CUTTING SPEED	FEED RATE	DEPTH OF CUT	MATERIAL
1	2.063	5.360	2.440	2.287
2	2.423	2.250	2.483	5.757
3	5.617	2.493	5.180	2.060
Delta	3.553	3.110	2.740	3.697
Rank	2	3	4	1

Table 13:- Analysis of variance for Ra values

SOURCE	DEGREE OF FREEDOM	SEQ SS	ADJ SS	ADJ MS	F	P
Cutting speed	2	0.19902	0.199022	0.099511	*	*
Feed rate	2	0.01869	0.018689	0.009344	*	*
Depth of cut	2	0.89669	0.896689	0.448344	*	*
Material %	2	0.77362	0.773622	0.386811	*	*
Residual error	0	*	*	*		
Total	8	1.88802				

6.1.3) Taguchi's Method For Wet Turning:-

Table 14:- Responsible table for S-N ratios

LEVELS	CUTTING SPEED	FEED RATE	DEPTH OF CUT	MATERIAL %
1	2.293	2.377	1.990	2.597
2	2.193	2.280	2.287	2.503
3	2.547	2.377	2.757	1.933
Delta	0.353	0.097	0.767	0.663
Rank	3	4	1	2

Table 15:- Response table for means of surface roughness (Ra)

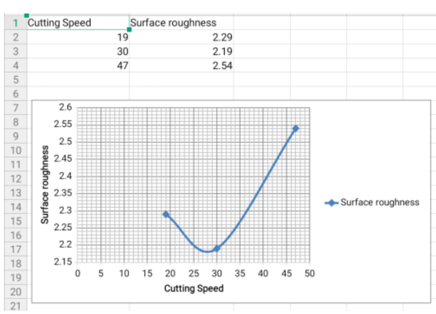
LEVELS	CUTTING SPEED	FEED RATE	DEPTH OF CUT	MATERIAL %
1	-6.217	-11.477	-7.566	-7.124
2	-7.503	-6.954	-7.899	-12.933
3	-12.500	-7.789	-10.755	-6.162
Delta	6.283	4.523	3.189	6.771
Rank	2	3	4	1

Table 16:- Analysis of variance for S/N ratios

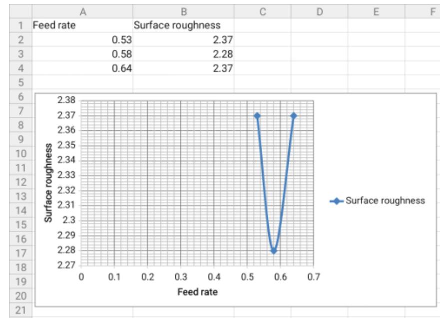
SOURCE	DEGREE OF FREEDOM	SEQ SS	ADJ SS	ADJ MS	F	P
Cutting speed	2	2.6248	2.6248	1.31241	*	*
Feed rate	2	0.1013	0.1013	0.05067	*	*
Depth of cut	2	12.0692	12.0692	6.03460	*	*
Material %	2	11.7088	11.7088	5.85439	*	*
Residual error	0	*	*	*		
Total	8	26.5041				

6.1.4) Graphs Based On Dry Turning:-

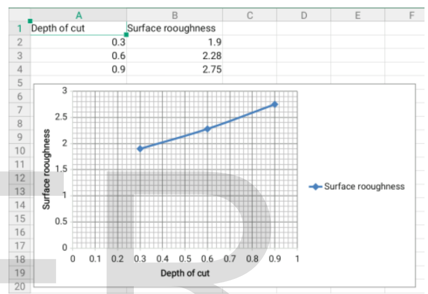
1) Cutting Speed Vs Surface Roughness Values:-



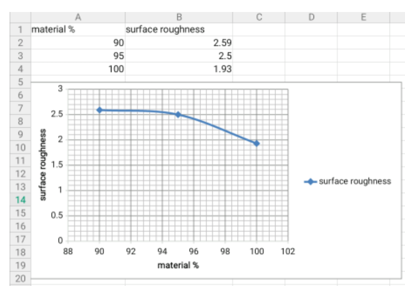
2) Feed Rate Vs Surface Roughness Values:-



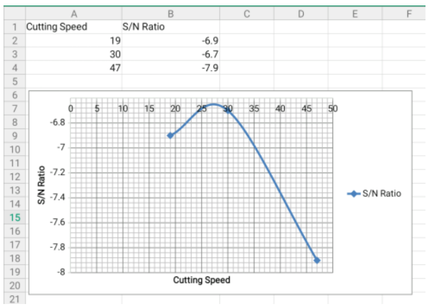
3) Depth of Cut Vs Surface Roughness Values:-



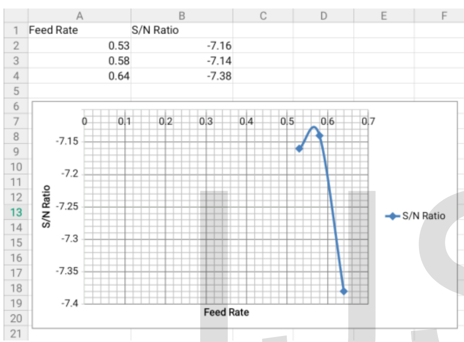
4) Material % Vs Surface Roughness Values:-



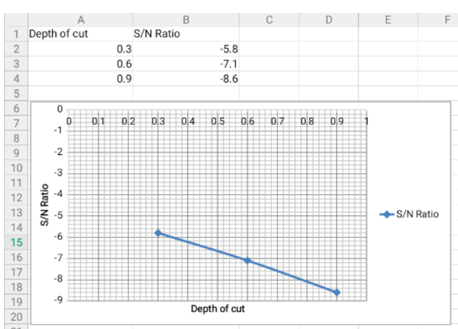
5) Cutting Speed Vs S/N Ratio Values:-



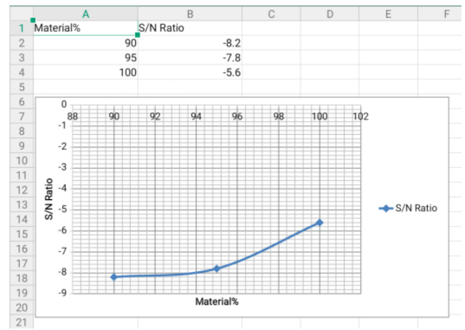
6) Feed Rate Vs S/N Ratio Values:-



7) Depth of Cut Vs S/N Ratio Values:-

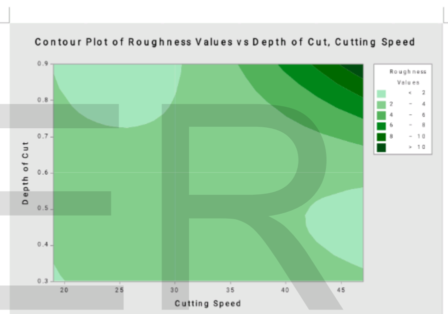


8) Material % Vs S/N Ratio Values:-

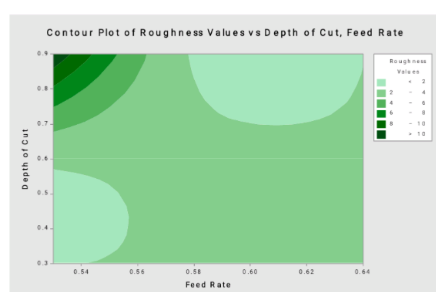


6.1.5) Contour Plots Of Dry Turning:-

1) Roughness values vs depth of cut, cutting speed

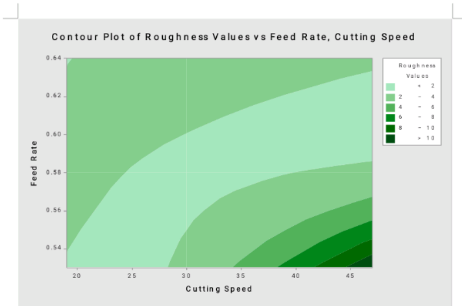


2) Roughness values vs depth of cut, feed rate



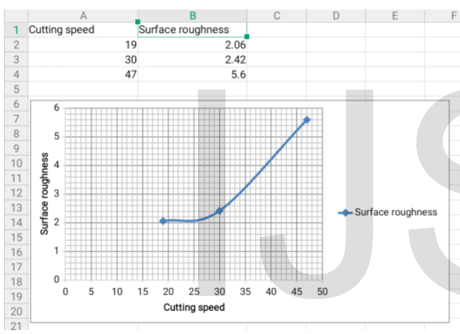
ISSN 2229-5518

3) Roughness values vs feed rate, cutting speed

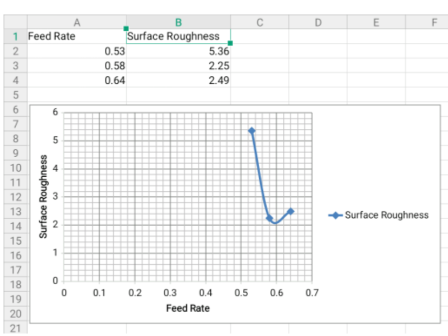


6.1.6) Graphs Based On Wet Turning:-

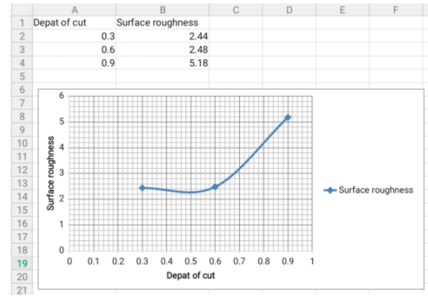
1) Cutting Speed Vs Surface Roughness Values:-



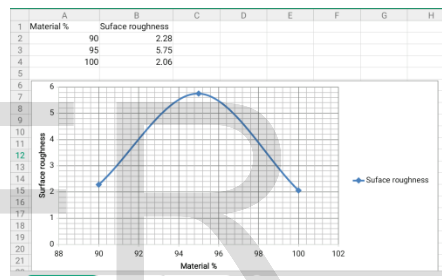
2) Feed Rate Vs Surface Roughness Values:-



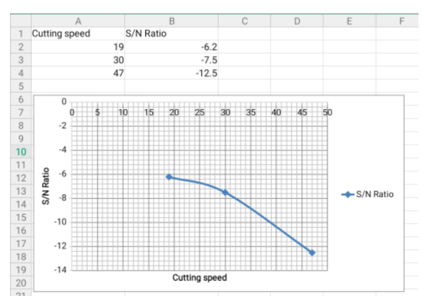
3) Depth of Cut Vs Surface Roughness Values:-



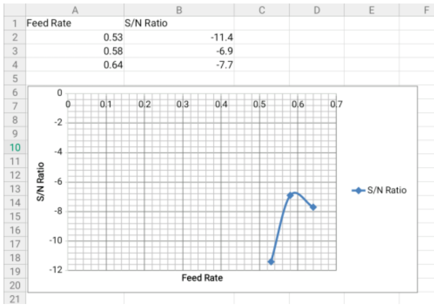
4) Material % Vs Surface Roughness Values:-



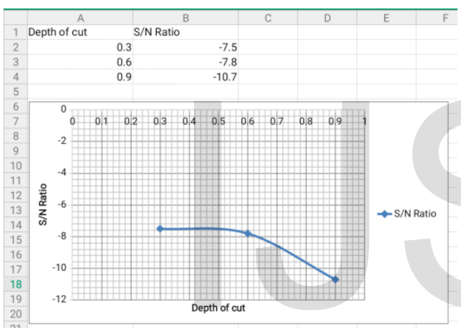
5) Cutting Speed Vs S/N Ratio Values:-



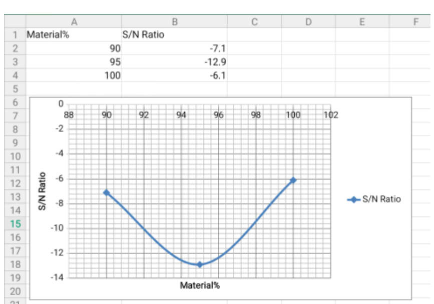
6) Feed Rate Vs S/N Ratio Values:-



7) Depth of Cut Vs S/N Ratio Values:-

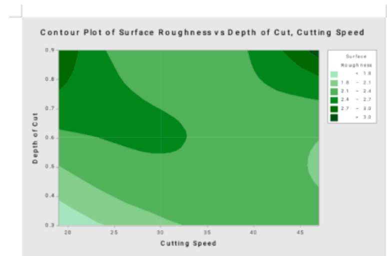


8) Material % Vs S/N Ratio Values:-

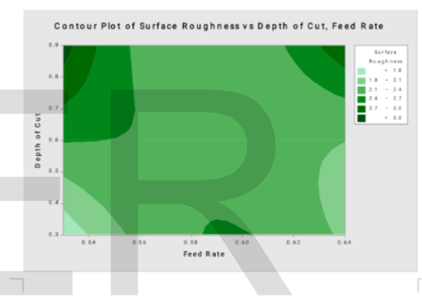


6.1.7) Contour Plots Of Wet Turning:-

1. Roughness values vs depth of cut, cutting speed



2) Roughness values vs depth of cut, feed rate



3) Roughness values vs feed rate, cutting speed

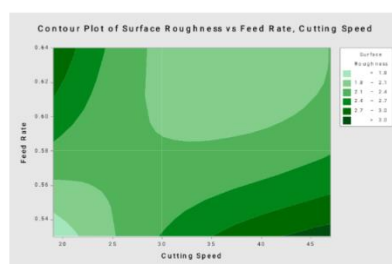


Table 17:- Machining Values By Using Dry Turning

CUTTING SPEED	FEED RATE	DEPTH OF CUT	MATERIAL %	ROUGHNESS VALUES	S/N RATIOS	MEAN VALUES
19	0.	0.3	100	1.56	-	1.56

	53				3.8624	
19	0.58	0.6	95	2.33	-7.3471	2.33
19	0.64	0.9	90	2.99	-9.5134	2.99
30	0.53	0.6	90	2.42	-7.6763	2.42
30	0.58	0.9	100	2.13	-6.5675	2.13
30	0.64	0.3	95	2.03	-6.1499	2.03
47	0.53	0.9	95	3.15	-9.9662	3.15
47	0.58	0.3	90	2.38	-7.5315	2.38
47	0.64	0.6	100	2.11	-6.4856	2.11

Table 18:- Machining Values By Using Wet Turning

CUTTING SPEED	FEED RATE	DEPTH OF CUT	MATERIAL%	ROUGHNESS VALUES	S/N RATIOS	MEAN VALUES
19	0.53	0.3	100	1.82	-5.2014	1.82
19	0.58	0.6	95	2.45	-7.7833	2.45
19	0.64	0.9	90	1.92	-5.6660	1.92
30	0.53	0.6	90	2.45	-7.7833	2.45
30	0.58	0.9	100	1.81	-5.1535	1.81
30	0.64	0.3	95	3.01	-9.5713	3.01
47	0.53	0.9	95	11.81	-21.444	11.81
47	0.58	0.3	90	2.49	-7.9239	2.49
47	0.64	0.6	100	2.55	-8.1308	2.55

CHAPTER 7

CONCLUSION

The surface roughness in the turning process has been investigated for machining of aluminium (Al-7075) MMC with reinforcements of nano particles with 5%,10% Zro_2 under different cutting conditions with a HSS tool of 1600 grade using Taguchi's orthogonal array. Based on the experimental and analytical results, the following conclusions are drawn:

a) With the help of Taguchi method the effect of machining parameters on the surface roughness has been evaluated and optimal machining conditions would be arrived at to minimize the surface roughness.

b) It is found that the feed rate is the dominant parameter for surface roughness followed by the cutting speed. Compared to other parameters the depth of cut shows minimal effect on surface roughness.

c) The results of the analysis of variance revealed that minimal surface roughness could be arrived at significantly for hybrid composite turning operations through the specified machining conditions: v = 19 m/min, f = 0.53 mm/rev and d = 0.3 mm.

The optimal cutting parameters and the percentage contribution may be established as follows:-

Cutting speed (v): 19 m/min & Percentage contribution: 15.694%

Feed rate (f) : 0.53 mm/rev. & Percentage contribution: 80.379%

Depth of cut (d): 0.3 mm & Percentage contribution: 1.375%

CONFLICT OF INTEREST:-

On behalf of all authors, the corresponding author states that there is no conflict of interest.

ACKNOWLEDGEMENT:-

Has a glad to completing this work with success is being supported by the project guide P.CHINNA SRINIVAS RAO I must be thankful for this great extent of project.

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