OPTIMIZATION OF MECHANICAL PROPERTIES OF ALUMINUM METAL MATRIX COMPOSITE USING SILICON CARBIDE

Submitted by

Abdullah	**16ME03**
Ansari Iqbal	**16ME07**
Ansari Danish	**16ME09**
Ansari Obaidullah	**16ME11**
Chaudhary Shahid	**16ME14**
Khan Mohd sameer	**16ME32**
Mahaldar Safeer	**17DME124**

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PROF. Khan Jalal

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Certificate

This is to certify that the project report titled, "**OPTIMIZATION OF MECHANICAL PROPERTIES OF METAL MATRIX COMPOSITE USING SILICON CARBIDE (SiC) "** submitted to Anjum-i-islam's KALSEKAR TECHNICAL CAMPUS,PANVEL submitted by , **ABDULLAH, IQBAL, DANISH, OBAIDULLAH, SHAHID, SAMEER , SAFEER** in MECHANICAL ENGINEERING is the bonafide record of project work done by them under our supervision. The contents of this report, in full or in parts, have not been submitted to any other institute or university for the award of any degree or diploma.

PROF. KHAN JALAL (PROJECT GUIDE)
Professor of Mechanical Department

Project Report Approval for B. E.

This Project report entitled **Optimization of mechanical properties of aluminum metal matrix composite using silicon carbide** by **Ansari Abdullah , Ansari Iqbal , Ansari Danish , Ansari Obaidullah , Chaudhary Shahid , khan Sameer , Mahaldar Safeer** is approved for the degree of **Bachelor of Mechanical Engineering, Mumbai University.**

Examiners

1.______________________________

2.______________________________

Date:20 Sep 2020
Place: Mumbai

Declaration

I declare that this written submission represents my ideas in my own words and where other's ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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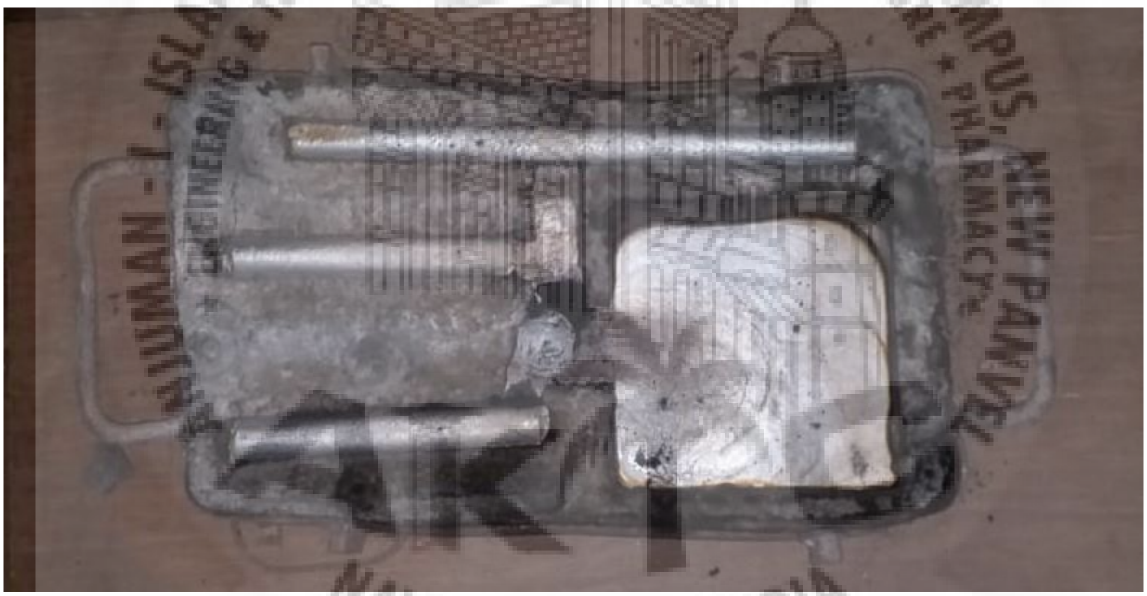
(Name of student)

Actual Picture of the Project

Stirrer motor and speed regulator

Coal furnace with stirrer motor

Sand mould of sample



Prepared sample

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CHAPTER 1

INTRODUCTION

1.1 Definition Of Aluminum Alloy
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1.1 Definition of aluminum alloy:

The unique combination of properties provided by aluminum and its alloys make aluminum one of the most versatile , economical and attractive metallic material for a broad range of uses – from soft , highly ductile wrapping foil to the most demanding engineering application .Aluminum alloys are second only to steels in use as structural metals. Aluminum is nonferromagnetic , a property of importance in the electrical and electronics industries. It is nonpyrophoric, which is important in applications involving inflammable or explosive-materials handling or exposure. Aluminum is also non-toxic and is routinely used in containers for food and beverages. It has an attractive appearance in its natural finish, which can be soft and lustrous or bright and shiny. It can be virtually any color or texture.

The reinforcements should be stable in the given working temperature and non-reactive too. The most commonly used reinforcements are Silicon Carbide (SiC) and Aluminum Oxide (Al2O3). SiC reinforcement increases the tensile strength, hardness, density and wear resistance of Al and its alloys . The particle distribution plays a very vital role in the properties of the Al MMC and is improved by intensive shearing. Al2O3 reinforcement has good compressive strength and wear resistance. Boron Carbide is one of hardest known elements. It has high elastic modulus and fracture toughness. The addition of Boron Carbide (B4C) in Al matrix increases the hardness, but does not improve the wear resistance significantly . Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired. Zircon is usually used as a hybrid reinforcement. It increases the wear resistance significantly .

Alloy Categories: It is convenient to divide aluminum alloys into two major categories: wrought compositions and cast compositions. A further differentiation for each category is based on the primary mechanism of property development. Many alloys respond to thermal treatment based on phase solubility. These treatments include solution heat treatment, quenching, and precipitation, or age, hardening. These alloys are referred to as work hardening. Some casting alloys are essentially not heat treatable and are used only in as-cast or in thermally modified conditions unrelated to solution or precipitation effect . the alloy are classified into different families listed below,

•1 xxx: Controlled unalloyed (pure) composition, used primarily in the electrical and chemical industries

•2 xxx: Alloys in which copper is the principal alloying element, although other elements , notably magnesium , may be specified. 2xxxseries alloys are widely used in aircraft where their high strength (yield strengths as high as 455 MPa, or 66 ksi) is valued.

•3 xxx: Alloys in which manganese is the principal alloying element, used as general-purpose alloys for architectural applications and various products

•4 xxx:Alloys in which silicon is the principal alloying element ,used in welding rods and brazing sheet

•5 xxx: Alloys in which magnesium is the principal alloying element, used in boat hulls, gangplanks, and other products exposed to marine environments

•6 xxx:Alloys in which magnesium and silicon are the principal alloying elements, commonly used for architectural extrusions and automotive components

•7 xxx:Alloys in which zinc is the principal alloying element (although other elements,such as copper,magnesium,chromium,and zirconium, may be specified), used in aircraft structural components and other high-strength applications. The 7xxxseries are the strongest aluminum alloys, with yield strengths ≥500 MPa (≥73 ksi) possible.

•8 xxx:Alloys characterizing miscellaneous compositions. The 8xxxseries alloys may contain appreciable amounts of tin,lithium,and/or iron.

•9 xxx: Reserved for future use.

1.1.1 Application of aluminum alloy:

Alloy	Description and selected application	Alloy	Description and selected application
1100	Commercially pure aluminum highly resistant to chemical attack and weathering. Low cost, ductile for deep drawing and easy to weld, used for high-purity application such as chemical processing equipment.	3105	Residential sliding, mobile homes, min-carrying goods, sheet metal work, appliance parts, building products, electronic, fin stock, furniture, hospital and medical equipment, kitchen equipment.
1350	Electrical conductors	2017	Truck frames, aircraft structure, automotive, cylinders and piston, machine parts.
7075	For aircraft and other application requiring highest strength. Alclad 7075 combines the strength advantages of 7075with the corrosion-resisting properties of commercially pure aluminum-clad surface. Also used in in machine parts and ordnance.	6063	Used in pipe railing, furniture, architectural extrusions, appliance parts and trim, automotive parts, building products, electrical and electronic part, machine parts, rail road parts, recreation equipment, recreation vehicles, trucks and trailers.
5056	Cable sheathing, rivets for magnetic, screen wire, zippers, automotive application, fence wire, fasteners.	5052	Strong than 3003 yet readily formable in the intermediate tempers. Good weldability and resistance to corrosion. Uses include pressure vessels, fan blades, electronic panels, electronic chassis.
6061	Good formability, weldability , corrosion resistance, and marine application, parts.	5083	For all type of welded assemblies, marine components, and tanks requiring high weld efficiency and maximum joint strength.
6065	Aircraft structure, automotive, cylinders and piston, machine parts commercially pure aluminum highly resistant to chemical attack and weathering. Low cost, ductile for deep drawing and easy to weld.	7073	tanks requiring high weld efficiency and maximum joint strength good weldability and resistance to corrosion. Uses include pressure vessels, fan blades, electronic panels, electronic chassis.
3003	Most popular general purpose alloy stronger than 1100 with same good formability and including sheet metal work, stamping fuel tanks, chemical equipment, agriculture application, appliance application, parts and trim.	2219	Structural uses at high temperature (to 315 C or 600F). high strength weldments.

1.2 Aluminum metal matrix composite :

AMMC (Aluminum metal matrix composites) are metals reinforced with other metal, ceramic or organic compounds. They are made by dispersing the reinforcements in the metal matrix. Reinforcements are usually done to improve the properties of the base metal like strength, stiffness, conductivity, etc. Aluminium and its alloys have attracted most attention as base metal in metal matrix composites . Aluminium MMCs are widely used in aircraft, aerospace, automobiles and various other fields . The reinforcements should be stable in the given working temperature and non-reactive too. The most commonly used reinforcements are Silicon Carbide (SiC) and Aluminium Oxide (Al2O3). SiC reinforcement increases the tensile strength, hardness, density and wear resistance of Al and its alloys . The particle distribution plays a very vital role in the properties of the Al MMC and is improved by intensive shearing. Al2O3 reinforcement has good compressive strength and wear resistance. Boron Carbide is one of hardest known elements. It has high elastic modulus and fracture toughness. The addition of Boron Carbide (B4C) in Al matrix increases the hardness, but does not improve the wear resistance significantly . Fibers are the important class of reinforcements, as they satisfy the desired conditions and transfer strength to the matrix constituent influencing and enhancing their properties as desired. Zircon is usually used as a hybrid reinforcement. It increases the wear resistance significantly . In the last decade, the use of fly ash reinforcements has been increased due to their low cost and availability as waste by-product in thermal power plants. It increases the electromagnetic shielding effect of the Al MMC. Based on the stated potential benefits of MMC this paper examine the various factors like (a) effect of various reinforcement (b) mechanical behaviour like strength, wear ,fatigue behaviour, etc. (c) processing methodology and its effects.(d) application of the speciality AMC were discussed.

1.3 Mechanical testing :

1.3.1 Tensile strength :

tensile strength is a measurement of the forces required to pull something such as rope, wire, or a structural beam to the point where it breaks.
The tensile strength of a material is the maximum amount of tensile stress that it can take before failure, for example breaking.

There are three typical definition of tensile strength:

- Yield strength - The stress a material can withstand without permanent deformation . This is not a sharply defined point. Yield strength is the stress which will cause a permanent deformation of 0.2% of the original dimension.
- Ultimate strength - The maximum stress a material can withstand.
- Breaking strength - The stress coordinate on the stress-strain curve at the point of rupture.

Tensile testing might have a variety of purposes, such as:

- Select a material or item for an application
- Predict how a material will perform in use: normal and extreme forces.
- Determine if, or verify that, the requirements of a specification, regulation, or contract are met
- Decide if a new product development program is on track
- Demonstrate proof of concept
- Demonstrate the utility of a proposed patent
- Provide standard data for other scientific, engineering, and quality assurance functions
- Provide a basis for Technical communication
- Provide a technical means of comparison of several options
- Provide evidence in legal proceedings

Tensile specimen

The preparation of test specimens depends on the purposes of testing and on the governing test method or specification. A tensile specimen is usually a standardized sample cross-section. It has two shoulders and a gage (section) in between. The shoulders are large so they can be readily gripped, whereas the gauge section has a smaller cross-section so that the deformation and failure can occur in this area.

The shoulders of the test specimen can be manufactured in various ways to mate to various grips in the testing machine (see the image below). Each system has advantages and disadvantages; for example, shoulders designed for serrated grips are easy and cheap to manufacture, but the alignment of the specimen is dependent on the skill of the technician. On the other hand, a pinned grip assures good alignment. Threaded shoulders and grips also assure good alignment, but the technician must know to thread each shoulder into the grip at least one diameter's length, otherwise the threads can strip before the specimen fractures.

In large castings and forgings it is common to add extra material, which is designed to be removed from the casting so that test specimens can be made from it. These specimens may not be exact representation of the whole work piece because the grain structure may be different throughout. In smaller work pieces or when critical parts of the casting must be tested, a work piece may be sacrificed to make the test specimens. For work pieces that are machined from bar stock, the test specimen can be made from the same piece as the bar stock.

1.3.2 Compressive test :

Compressive strength or **compression strength** is the capacity of a material or structure to withstand loads tending to reduce size, as opposed to which withstands loads tending to elongate. In other words, compressive strength resists being pushed together, whereas tensile strength resists tension (being pulled apart). In the study of strength of materials, tensile strength, compressive strength, and shear strength can be analyzed independently.

Some materials fracture at their compressive strength limit; others deform irreversibly, so a given amount of deformation may be considered as the limit for compressive load. Compressive strength is a key value for design of structures.

Compressive strength is often measured on a universal testing machine. Measurements of compressive strength are affected by the specific test method and conditions of measurement. Compressive strengths are usually reported in relationship to a specific technical standard.

1.3.3 Hardness testing :

Hardness is a measure of the resistance to localized plastic deformation induced by either mechanical indentation or abrasion. Some materials (e.g. metals) are harder than others (e.g. plastics, wood). Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behavior of solid materials under force is complex. Mainly Rockwell hardness testing is used for metal. Sometime brinell hardness testing is also used. The Rockwell scale is a hardness scale based on indentation hardness of a material. The Rockwell test measuring the depth of penetration of an indenter under a large load (major load) compared to the penetration made by a preload (minor load). There are different scales, denoted by a single letter, that use different loads or indenters. The result is a dimensionless number noted as HRA, HRB, HRC, etc., where the last letter is the respective Rockwell scale (see below). When testing metals, indentation hardness correlates linearly with tensile strength.

Fig: Rockwell hardness tester

1.3.4 Microstructure testing :

Microstructure is the very small scale structure of a material, defined as the structure of a prepared surface of material as revealed by an optical microscope above 25× magnification. The microstructure of a material (such as metals, polymers, ceramics or composites) can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behaviour or wear resistance. These properties in turn govern the application of these materials in industrial practice.

Microstructure at scales smaller than can be viewed with optical microscopes is often called nanostructure, while the structure in which individual atoms are arranged is known as crystal structure. The nanostructure of biological specimens is referred to as ultrastructure. A microstructure's influence on the mechanical and physical properties of a material is primarily governed by the different defects present or absent of the structure. These defects can take many forms but the primary ones are the pores. Even if those pores play a very important role in the definition of the characteristics of a material, so does its composition. In fact, for many materials, different phases can exist at the same time. These phases have different properties and if managed correctly, can prevent the fracture of the material.

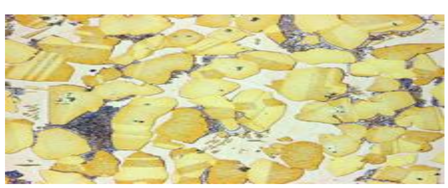


Fig : Microstructure of aluminium and slicon

1.3.5 Bending testing :

In applied mechanics, **bending** (also known as **flexure**) characterizes the behavior of a slender structural element subjected to an external load applied perpendicularly to a longitudinal axis of the element.
The structural element is assumed to be such that at least one of its dimensions is a small fraction, typically 1/10 or less, of the other two.[1] When the length is considerably longer than the width and the thickness, the element is called a beam. For example, a closet rod sagging under the weight of clothes on clothes hangers is an example of a beam experiencing bending. On the other hand, a shell is a structure of any geometric form where the length and the width are of the same order of magnitude but the thickness of the structure (known as the 'wall') is considerably smaller. A large diameter, but thin-walled, short tube supported at its ends and loaded laterally is an example of a shell experiencing bending.

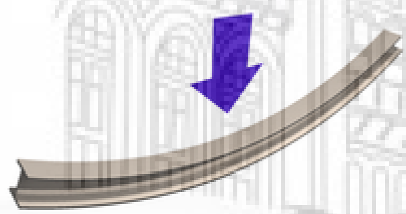


Fig : Bending of metal

1.4 Objective :

1. We will test mechanical property and study of micro structure by taguchi method which predicts the best possible experiments to give the optimized result.
2. To extend a knowledge of application and selection of different composite in consideration of the properties an characteristics.
3. To prepare and analyse a hybrid composite material test and comparing its properties with normal sample material.
4. Testing as per the ASTM (American society for testing and material) standards.

CHAPTER 2

LITERATURE REVIEW

2.1: LETERATURE SURVEY ON PAPERS

TOPIC NAME	JOURNAL	YEAR OF PUBLICATION	OBSERVATION
Assement of mechanical properties of silicon carbide and graphene reinforced aluminium composite	Materials Today	2019	1.The SEM micrographs revealed that presence of SiC(10%) and graphene (6%) weight fraction led to homogeneous dispersion. 2.The Aluminium 7075 reinfoprced by SiC composites posted the highest hardness value of 222BHV. 3.The reinforcement of SiC microparticles increased the tensile strength of Al MMC to 200 Mpa .
Preparation and evaluation of mechanical properties of 6061 Al Al2O3 metal matrix composite by stir casting process	Materials Today	2019	1.Hardness of Al6061 alloy increased with increasing weight fraction of aluminium oxide particles. 2.Ultimate tensile strength improved by the addition of Al2O3 particles in 6061Alloy. 3.Compression strength of samples inreased with increment in weight% of Al2O3 particles in 6061.
Fabrication and investigation on mechanical properties of AA7075/Cr3C2 MMC	Materials Today	2019	1.Composite containing 3.52 micrometre sized Cr3C2 particulates 2.5,5 and7.5 % are succcesfully fabricated using stir casting method. 2.No voids or discontinuities were present in the composite due to even distribution of Cr3C2 in composite 3.The agglomeration was observed in the case of 7.5 % of Cr3C2 composite.
Experimental investigations on mechanical and tribological properties of extruded Aluminium A356 Al2O3 stir cast MMC	Materials Today	2018	1.The micrograph reveal the precipitation Silicon phase in acicular form at grain boundries of the alloy structure 2.Tensile strength of composite sample increased but the elongation of decreased with decreasing size of particulates.

TOPIC NAME	JOURNAL	YEAR OF PUBLICATION	OBSERVATION
Production and investigation on mechanical properties of TiC reinforced Al7075 MMC	Materials Today	2018	1.Stir Casting are successfully adopted in the preparation of Al7075 TiC composite 2.The micro structural examination revealed the uniform distribution of particles in the matrix of the system
Aluminium composites fabrication technique and effect of improvement in their mechanical properties	Materials Today	2017	1.The advantages of stir casting process are flexibility, simplicity, cost effective & applicability to mass production 2.For enhanced machine ability prperties of composites, reinforement should be <10%.
Material selection of aluminium hybrid MMC	Materials Today	2017	1.The hardness property is the most influential criteria in 7XXX series material selection having 0.3871 as priority value 2.The aluminium alloy 7075 is obtained as best alternative having the highest priority level of 55.14%, therefore it is most suitable alternative amongst the 7XXX series
Combined effecct of reinforcement fraction and porosity on ultrasonic velocity in SiC Al MMC	Materials Today	2017	1.The specimens investigated had the weight fraction of 3.82 to 15.5% and the porosity content practically upto 4.7% that was maximal for the maximum SiC fration.

TOPIC NAME	JOURNAL	YEAR OF PUBLICATION	OBSERVATION
Optimization of mehanical properties of silica gel reinforced AlMMC by using Taguhi method	Materials Today	2015	1.The tensile and flexural strength of silica gel reinforced AlMMC was estimated with the variati on of % filler content and speed 2.Optmization of tensile strength and flexural were performed by Taguchi technique. It can be validated by ANOVA which gives percentage of filler content most affeted the tensile as well as flexural strength at 95% confidence level.
Aluminium metal matrix composites review	Materials Today	2014	1.SiC reinforced AlMMC have higher wear strength than Al2O3 reinforced composite 2.The wear resistance of SiC reinforced MMC is higher than B4C reinforced MMC 3.The wear resistance and compressive strength of MMC inreases with the addition of Zr particles.
Statistical analysis dry sliding wear behaviour of graphite reinforced MMC Design and fabrication of stir casting furnace Set-p	Materials Today	2014 2015	1.Based on ANOVA result it is observed that the sliding distance has highest significant effect on wear volume loss followed by sliding velocity, contact stress and reinforcement %. Aluminium scrap was melted successfully using The furnace and casting of the molten aluminum was done
Aluminium and aluminium alloys	ASM international	2001	1.Introduction of aluminium and aluminium alloys 2.effect of alloying elements 3.effect of alloying on processing a)Forming b)Forging c)Machining d)Welding

2.2: Literature gap :

1.No study was found to improve porosity of aluminium metal metrix composite with the help of heat treatment process.

2.there is no studies done on variation of percentage of silicon carbide in Al7075

3.Any binding agent was not mentioned in any of the studies.

4.there is no studies done considering speed as variable factor

5.the dimension of blade was not mentioned in any of the studies.

6.there are many researches in which Taguchi method is not implemented while it gives optimized results for varying different parameter.

2.3 Problem statement :

After a rigorous literature survey, we found various gaps as listed below

1) Varying the different minor parameter, mechanical property get changed, like weight percentage of reinforcement, size of the particle, change in reinforcement, speed of the rod, change in alloy etc.

2) Porosity can be improved in (AA7075/Silicon carbide) MMC with the help of forging process and heating process.

3) Speed can be varied in (AA7075/Silicon carbide) MMC then the material can be tested

4)There are many research in which Taguchi method is not implemented while it gives optimize result for varying different parameter.

5).Manufacturing of aluminium 7075 / Silicon carbide metal matrix composite with variation percentage reinforcement , speed variation and partical size.

CHAPTER 3

METHODOLOGY

3.1: SELECTION OF MATERIAL AND THEIR PROPERTIES

The material selected for the experiment is Al7075 and the reinforcement used is SiC.

PROPERTIES OF REINFORCEMENT AND ALLOY

Elements	Properties		cost in RS
Matrix 7075	Density (g/cc) Hardness (Kg/mm3) Melting point (degree celcius) Tensile strength(Mpa)	2.81 175 477-635 230	750/Kg
Reinforcement -SiC	Density (g/cc) Hardness (Kg/mm3) Melting point (degree celcius) Elastic modulous(Gpa)	3.1 2800 2830 410	1/g

3.2: CONTROL FACTORS

The control factor selected for the testing are

PROCESS PARAMETER	LEVEL 1	LEVEL 2	LEVEL 3	REMARK
Speed	700	800	900	based on research paper
Weight %	3%	4%	5%	based on research paper
Size	16	17	18	based on research paper

3.3) TAGUCHI METHOD :

There are different control factor and the number of specimen to be tested to much larger therefore Taguchi method is implemented to find the result . Taguchi method minimize the number of specimen to be tested with the help of ANOVA analysis therefore Taguchi method is very beneficial in cost reduction and work reduction. There are three step in Taguchi method

3.3.1) ARRAY SELECTOR

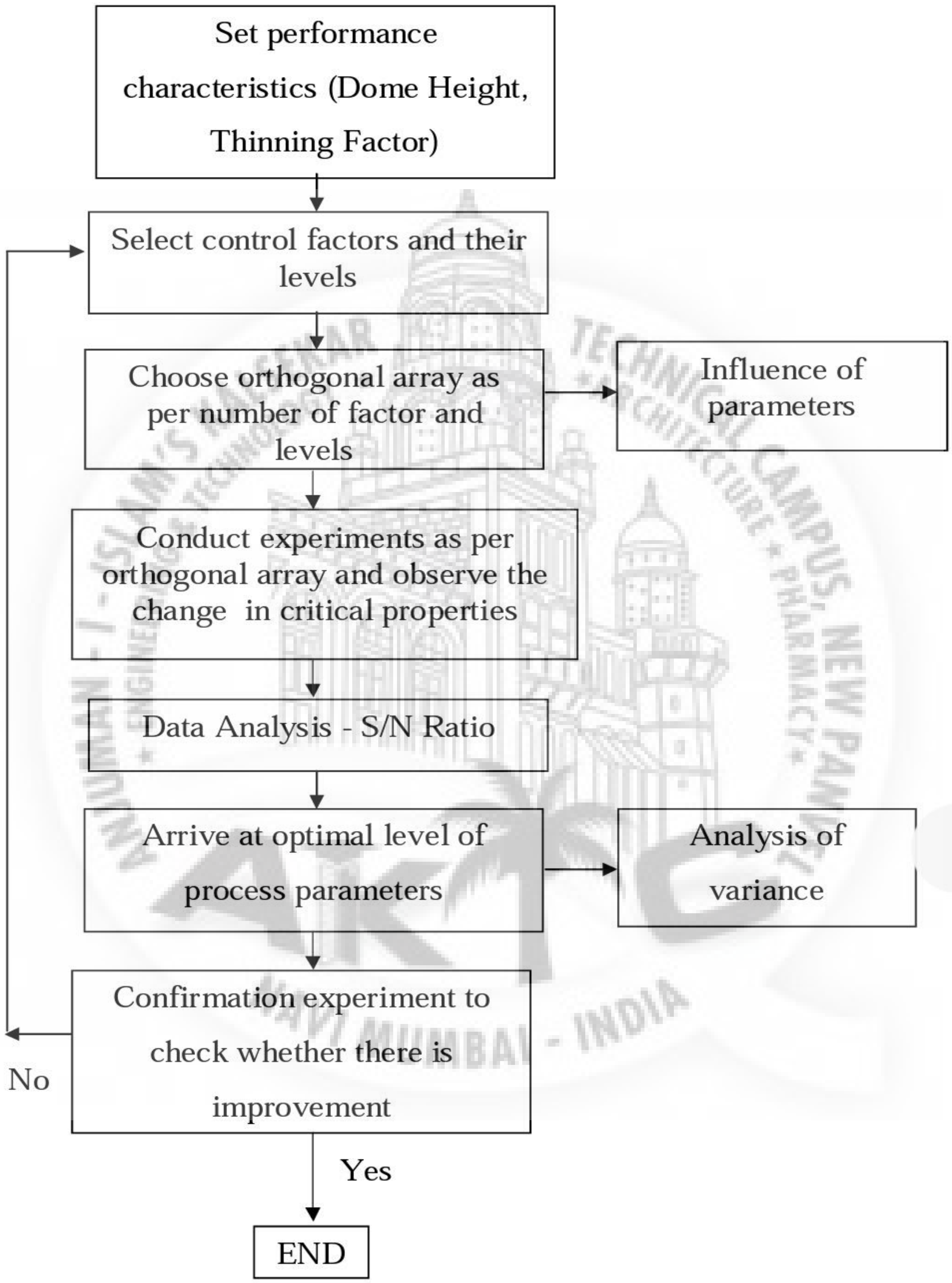
	PARAMETERS											
LEVELS		2	3	4	5	6	7	8	9	10	11	12
	2	L4	L4	L8	L8	L8	L8	L12	L12	L12	L12	L16
	3	L9	L9	L9	L18	L18	L18	L18	L27	L27	L27	L27
	4	L16	L16	L16	L16	L32	L32	L32	L32	L32		
	5	L25	L25	L25	L25	L25	L50	L50	L50	L50	L50	L50

There are 3 levels and 3 parameter in our experiment therefore we are selecting L9 from Array selector

3.3.2) ORTHOGONAL ARRAY: (Selecting L9)

EXPERIMENT NO	SPEED(RPM)	WEIGHT%	SIZE(MICROMETER)
1	700	3	16
2	700	4	17
3	700	5	18
4	800	3	16
5	800	4	18
6	800	5	16
7	900	3	18
8	900	4	16
9	900	5	17

3.3.3) TAGUCHI METHODOLOGY:



3.4: TESTING

1) comparing porosity in (AA7075) & casted (AA7075/ Silicon carbide) MMC by after forging process and heating process.

2) Comparing hardness from base alloy.

3) tensile strength, compressive strength on Universal testing Machine from the base metal. .

4) Microstructure testing on SEM & TEM.

5)Using Taguchi method, will get optimizing result.

CHAPTER 4

CASTING PROCESS

4.1 Preparation Of Coal Furnace
4.2 Preparation Of Stirrer Arrangement
4.3 Casting Process
4.4 Annealing

4.1: Preparation of coal furnace:

Several specialised furnaces are used to heat the metal. Furnaces are refractory-lined vessels that contain the material to be melted and provide the energy to melt it. Modern furnace types include electric arc furnaces (EAF), induction furnaces, cupolas, reverberatory, and crucible furnaces. Furnace choice is dependent on the alloy system quantities produced. For ferrous materials EAFs, cupolas, and induction furnaces are commonly used. Reverberatory and crucible furnaces are common for producing aluminium, bronze, and brass castings.

Furnace design is a complex process, and the design can be optimized based on multiple factors. Furnaces in foundries can be any size, ranging from small ones used to melt precious metals to furnaces weighing several tons, designed to melt hundreds of pounds of scrap at one time. They are designed according to the type of metals that are to be melted. Furnaces must also be designed based on the fuel being used to produce the desired temperature. For low temperature melting point alloys, such as zinc or tin, melting furnaces may reach around 500 °C (932 °F). Electricity, propane, or natural gas are usually used to achieve these temperatures. For high melting point alloys such as steel or nickel-based alloys, the furnace must be designed for temperatures over 1,600 °C (2,910 °F). The fuel used to reach these high temperatures can be electricity (as employed in electric arc furnaces) or coke. The majority of foundries specialize in a particular metal and have furnaces dedicated to these metals. For example, an iron foundry (for cast iron) may use a cupola, induction furnace, or EAF, while a steel foundry will use an EAF or induction furnace. Bronze or brass foundries use crucible furnaces or induction furnaces. Most aluminium foundries use either electric resistance or gas heated crucible furnaces or reverberatory furnaces.

Design of furnace elements

While considering the design of stir casting furnace several important elements of the furnace come to mind. They are:

1) Body frame

2) Walls

3) Insulating materials

4) Pot/Container

5) Crucible

6) Stirrer

7) Thermocouples / Temperature sensors

8) Cover Plate

9) Control Panel

1) Body frame :

The furnace body is of the dimension 46×46×46 cm3 and rises to a height of 16 cm on four legs made of angle section mild steel bars. The frame is made with the same angle section mild steel bars as the legs and is weld joined. The sides are made of galvanized plates of steel and the top side is made with mild steel plate which is bolted to the frame and has a circular opening on top.

2) Walls :

The walls are made with refractory bricks (Fig 1) that are cut into the same shape as that of the furnace and are joined with a paste made up of ceramic powder and glue after the gaps in between are covered by pieces of ceramic blanket.

Fig 1 Refractory Bricks

3) Insulating material:

The insulating material used in the furnace is Ceramic blankets . Ceramic blankets are very high heat resistive material used in high temperature applications to avoid heat leakage and fire hazards. These have very low value of thermal conductivity and highly flexible and can be easily cut and used as insulating material. An important parameter associated with the use of ceramic blankets is critical thickness of insulation. The critical thickness of insulation is the minimum thickness that must be provided so that the heat loss could be minimized and for cylindrical surfaces its value is twice that of its thermal conductivity. Ceramic blankets are produced from exceptionally pure oxides of alumina and silica using the spinning process.

4) Pot / container :

The pot/container is made of the ceramic clay shaped into a cylinder of diameter 10cm and height 15cm. The working temperature of the pot is approximately 1400oC

5) Crucible:

Crucible is the container in which the metal is melted and then poured into a mould to perform casting. The material of the mould should have very high melting point, high strength and should be a very good conductor of heat so that heat loss should be less.There are several materials available for this purpose like silicon-carbide, cast steel and graphite. For our requirements the siliconcarbide crucible is best suited, however the cost is very high so can’t be afforded. We have taken here a graphite crucible which serves to our purposes as its melting temperature is about 2700°C which is far above our operating temperature.The crucible is made in a shape of a cylinder with decreasing diameter so that the upper portion remains a cylinder however the bottom part takes the shape of a hemisphere. A handle is attached to the side of the crucible to hold it while placing it inside the furnace and while pouring hot metal into the mould cavity.It can withstand very high temperatures and is used for metal, glass, and pigment production as well as a number of modern laboratory processes.

Fig:Crucible

6) Stirrer:

The method used in fabrication of MMC requires the dispersed phase that is the ceramic particles (SiC) to be mixed in solid state in the liquid metal. So for uniform mixing of the ceramic particles in the liquid metal it is needed that the mixture be stirred well. So, a stirrer is required which can withstand the high temperature and doesn't affect the purity of the composite. The stirrer is made of a stainless steel rod whose front end is attached with a graphite fan. It is driven by a ½ HP AC motor and rotates at about 400 rpm. The stirrer is inserted vertically into the crucible about one third of its height after adding the ceramic particles. Here we have provided ways for stirring through external mediums that can be attached to the furnace at any point through the top.

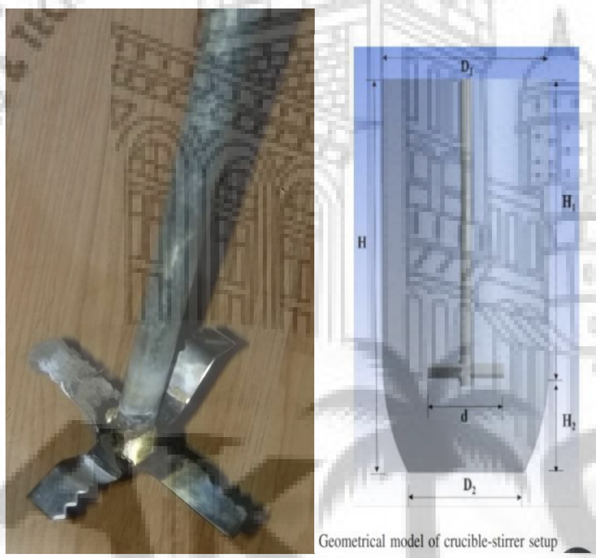


Fig : Stirrer

7) Thermocouple:

Thermocouples are temperature sensing devices used to measure temperature. These are highly effective, accurate, highly sensitive and cheaper. Here we are using a copper-constantan thermocouple. It is required to know the temperature of the liquid metal at all points i.e. why thermocouples are used. The thermocouple used here is the Iron-Constantan and Chromel-Alumel (K type) whose maximum range of operation is 1200ºC.

8)Cover plate :

The cover plate of the furnace is made up of Mild Steel of dimension 46cm×46cm. A portion of circular cross-section of about 6 inch diameter was cut at the centre of the cover plate. Another hollow cubical cover made up of galvanized plate was clamped to the mild steel cover plate which is fixed to the furnace top permanently with the help of bolts. The hollow cover was filled with ceramic blanket. In order to lift the cover, two handles made up of Bakelite were attached.

9) Control panel :

The control panel has following parts

Body , Fan , Ammeter , Voltmeter ,Temperature controller , Energy regulator Energy meter , Selector switch , Limit switch , Contactor , Guerter circuit (AC to DC converter) , Transformer ,Connectors (both Porcelain

Fig: Control panel

4.2 Preparation of stirrer arrangement :

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

Stir casting setup as shown in Figure 1, consist of a furnace, reinforcement feeder and mechanical stirrer. The furnace is used to heating and melting of the materials. The bottom poring 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 the crucible. The mechanical stirrer is used to form the vortex which leads the mixing of the reinforcement material which are introduced in the melt. Stirrer consist of the stirring rod and the impeller blade. The impeller blade may be of, various geometry and various number of blades. Flat blade with three number are the preferred as it leads to axial flow pattern in the crucible with less power consumption. This stirrer is connected to the variable speed motors, the rotation speed of the stirrer is controlled by the regulator attached with the motor. Further, the feeder is attached with the furnace and used to feed the reinforcement powder in the melt. A permanent mold, sand mold or a lost-wax mold can be used for pouring the mixed slurry.

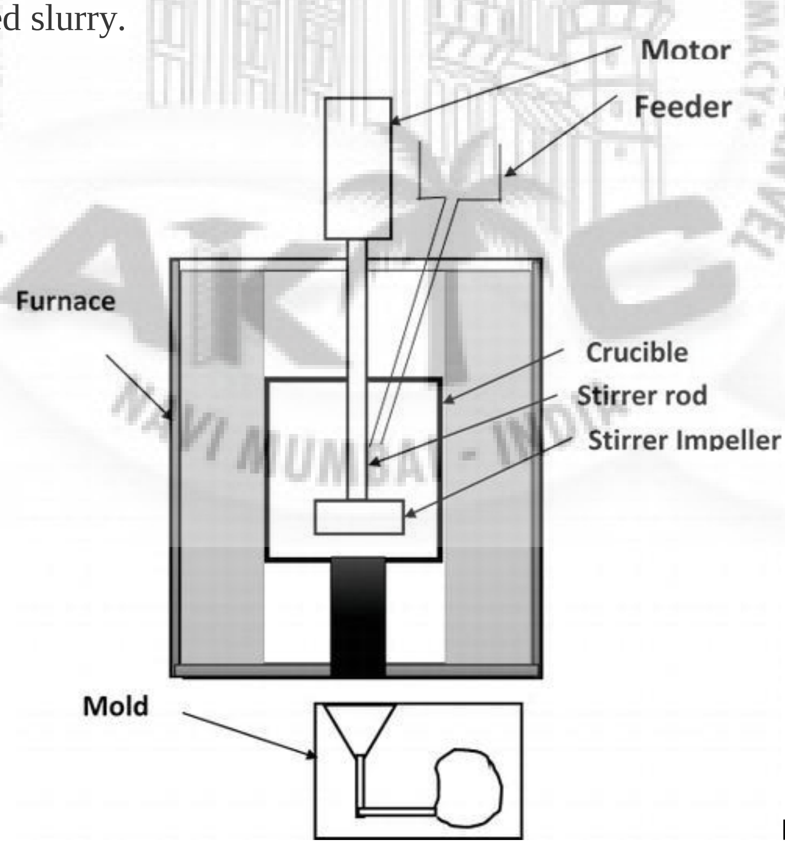
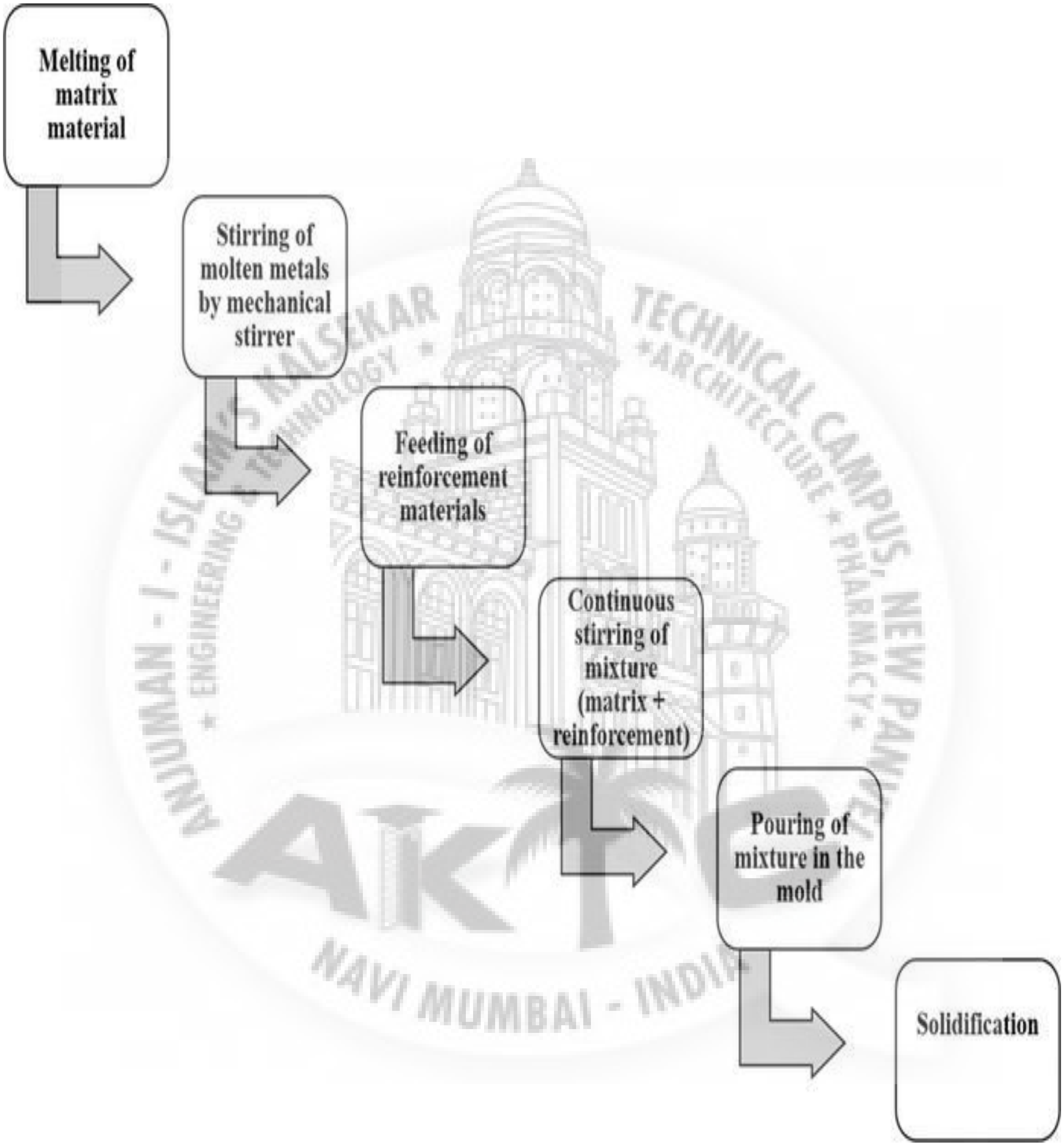


Figure 1

Various steps involved in stir casting process is shown in . In this process, the matrix material are kept in the bottom pouring furnace for melting. Simultaneously, reinforcements are preheated in a different furnace at certain temperature to remove moisture, impurities etc. After melting the matrix material at certain temperature the mechanical stirring is started to form vortex for certain time period then reinforcements particles are poured by the feeder provided in the setup at constant feed rate at the center of the vortex, the stirring process is continued for certain time period after complete feeding of reinforcements particles. The molten mixture is then poured in preheated mold and kept for natural cooling and solidification. Further, post casting process such as heat treatment, machining, testing, inspection etc. has been done. There are various impeller blade geometry are available. Melting of the matrix material is very first step that has been done during this process.

Fig:STIR CASTING ARRANGEMENT

4.2.1: Different Processes Of Stir Casting:

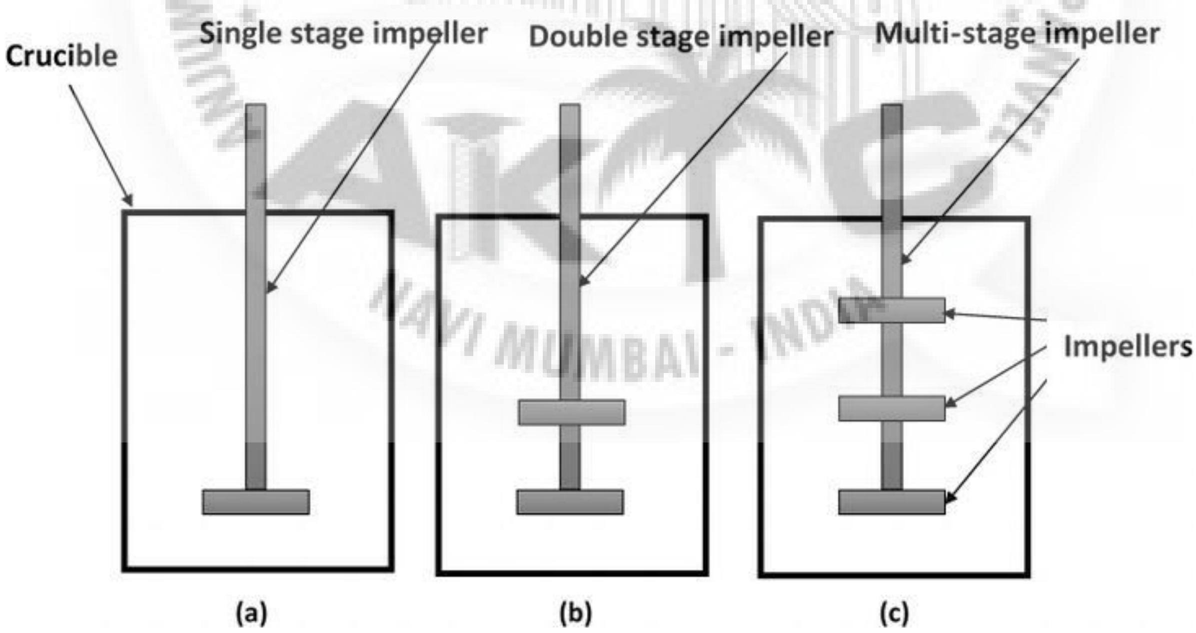


4.2.2 : Melting Of Matrix Material:

Out of various furnaces, bottom pouring furnace is suitable for fabrication of metal matrix composites in stir casting route, this type of furnace consist of automatic bottom pouring technique which provides instant pouring of the melt mix (matrix and reinforcement). Automatic bottom pouring is mainly used in investment casting industry. In this technique, a hole is created in the base of melting crucible to provide bottom pouring and was shielded by a cylinder-shaped shell of metals. 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.

4.2.3 : Mechanical Stirring:

In stir casting process, the mechanical stirrer is coupled with the varying speed motor to control the speed of the stirrer. There are various stages of impeller stirrer i.e. single stage, double stage and multistage impeller. Double stage and multi stage stirrer are mainly used in chemical industries whereas single stage impeller stirrer is commonly used for fabrication of AMCs and HAMCs due flexibility and to avoid excessive vortex flow [12, 13]. Figure shows various stages of impeller stirrer.



(a) Single stage impeller stirrer, (b) double stage impeller stirrer, (c) multistage impeller stirrer.

Stirring plays a vital role over the final microstructure and mechanical properties of the casted composites as it controls the distribution of reinforcements within the matrix. Optimum mechanical properties can be attained by the uniform distribution of reinforcement and this problem is a common to most of processing techniques, including stir casting . This problem can be solved by optimal selection of stirring parameters.

Researcher has provided a range of stirring parameters based on the properties of the matrix, reinforcement, wettability and oxidation factors for various combination of material .The parameters selected by various authors for the fabrications of aluminum matrix composites and aluminum hybrid matrix composites. These parameters are type of matrix material, percentage of reinforcements, stirring speed, stirring time and feed rate. The range of certain stirring parameters has been used by the authors such as the stirring speed should be in the range of 450–700 rpm, stirring time in between 5 and 15 min federate in the range of 0.9–1.5 g/s for different percentage of reinforcements.Mechanical properties of AMCs and HAMCs mainly depends on the dispersion of the reinforcements throughout the composite. The dispersion of reinforcements is governed by stirring parameters. Hence, performing experiment with selecting random stirring parameters may not provide homogeneous dispersion of reinforcement particle which leads to lower mechanical properties. Therefore, understanding of effect of stirring parameters and selection of optimal stirring process parameters is crucial. The effect of various stirring parameters with suggested optimal values of this parameters is discussed further.

Fig: Stirer process

4.2.3 : Effect And Optimization Of Stirring Process Parameter:

There are some significant stirring process parameters which affect the distribution of reinforcement at most. These parameters are stirring speed, stirring time, blade angle, stirrer size, position of the stirrer and feed rate of reinforcements. The main purpose of introducing stirrer is to form vortex in melt which transfers the reinforcement particles in the matrix melt and maintain them in suspension. There are various types of stirrer are existing for this purpose but for minimizing the power requirement stirrer are designed such that it provide high degree of axial flow.

4.2.3.1 : Stirring Speed:

Stirring speed is a significant parameters which affect the distribution of the reinforcement particles within the matrix material. Prabu et al. investigated the effect of stirring speed and stirring time on the hardness of casted silicon carbide reinforced aluminum matrix composite, in which the stirring speed were selected 700, 800 and 900 rpm and the stirring time was taken as 5, 10 and 15 min. The experimental study concluded 600 rpm and 10 min is the best combination of stirring speed and stirring time for uniform hardness value through the composite which confirms the uniform distribution of SiC particles over the aluminum matrix. Further, Design of impeller i.e. impeller blade angle plays a vital role over the flow characteristic and power consumption by the stirring motors.

Process parameter	Level (1)	Level (2)	Level (3)	Remark
SPEED(rpm)	700	800	900	Based on research paper
WEIGHT % OF REINFORCEMENT (gm)	3%	4%	5%	Based on research paper
SIZE OF REINFORCEME (μm)	16	17	18	Based on research paper

4.2.3.2 : Impeller Blade Angle:

The vortex formed by the stirring on solid-liquid mixing transfers reinforcements particles into the melt from the liquid surface whereas shearing action assist to break the accumulation formed by the reinforcement particles and lead to uniform distribution. Therefore, selection of a suitable blade angle is crucial to acquire good level of axial flow and shearing action.

To investigate the effect of impeller blade angle, researchers used water model and CFD model. They selected blade angle as 15, 30, 45, 60 and 90°. In a water model Ravi et al. investigated the effect of impeller blade angle over the distribution of solid particles in the liquid. They found at low angle (α = 15°) particles are dispersed below the stirrer. Impeller with blade angle (α = 30°) performed well and shows uniform dispersion without concentration of particles. Whereas, impeller with high blade angle (α > 30°), most of the solid particles concentrate at just below the tip of the impeller blade which results more radial variation. Thus, 30° was concluded as optimal value of blade angle with respect to stirrer axis which is in good agreement with FEM Model by Sahu and Sahu and Lu and Lu. They attempted to reduce stagnant and dead zones in the flow pattern with blade angle 30, 45, 60 and 90° with respect to the impeller axis. Inactive zone in the cylindrical portion and bottom portion of the crucible are said stagnant zone and dead zone respectively. High blade angle (α > 90°) lead to high level of shearing flow and consume high power as well. Shearing action ensure the solid particle suspension in the melt but without axial suction pressure it is difficult to suck solid particles into the melt. The axial flow can be increased by decreasing the blade angle and significant axial flow was seen close to the liquid surface when the blade angle decreased to 30° [2, 12, 13] . Moreover, stirring time plays an important role over the distribution of solid particles and power consumption by the stirring motor.

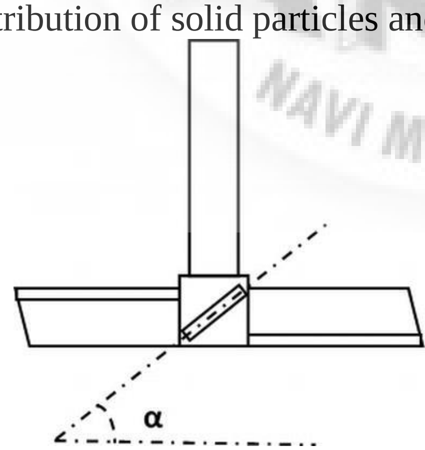


Fig : Impeller blade

4.2.3.3 : Stirring Time:

Stirring time is a significant process parameter in stir casting process. Lower stirring time may lead to clustering of particle reinforcements and results non-homogeneous distribution of reinforcement particles. Whereas, higher stirring time may lead to the deformation of the stainless steel stirrer impeller blade at very high working temperature. The working temperature of some reinforcement such as boron carbide with aluminum matrix are very high. This temperature range is 850–950°C, which may deform the stirrer impeller. Moreover, unwanted high stirring time also consumes more power which leads to rise in fabrication cost of composite. Therefore, optimal value of stirring time is essential. Prabu et al. studied effect of stirring time on microstructure and hardness of Al/SiC composite has been investigated and suggested 10 min as optimal value of stirring to achieve better distribution of reinforcements and uniform value of hardness throughout the composite. Apart from stirring time, the position of stirrer is important and discussed further.

4.2.3.4 : Impeller Position:

The position of the impeller should not be more than 30% of the height of the fluid from base of the crucible to avoid agglomeration of reinforcements particles at the bottom of the crucible. Figure 5 shows the position of stirrer impeller. In which height of impeller (h) from the bottom of the crucible is given in Equation. $h>0.3H0$

Where h is the position of the impeller from the bottom of crucible and H0 is the height of the fluid.

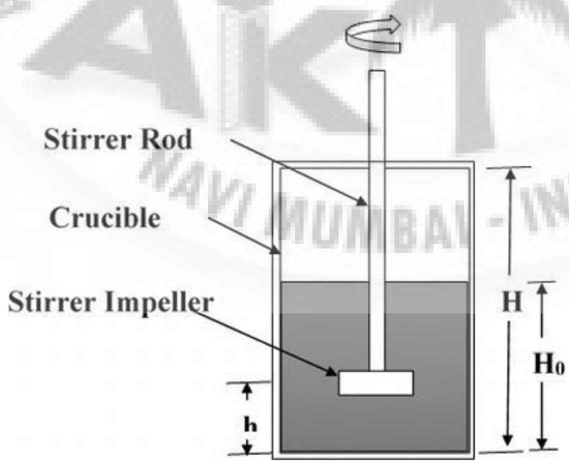


Fig : position of stirrer

4.2.3.5 : Impeller Blade Size:

The impeller blade size is the diameter of the impeller blade which is given in term of the diameter of the crucible. The size of impeller plays a substantial role over the distribution of particles. If the size impeller is too small then the reinforcement particles persist suspended at the periphery of the crucible which cause lack of suspension of particles at the center. Whereas if the impeller size is too large then the reinforcements particles concentrated at the center of the crucible bottom. Hence, optimal size of impeller is that size which provides distributed particle in both center as well as the periphery of the crucible at the similar speed. So the optimal diameter of the impeller d, is 0.5 times of D, the diameter of crucible for flat base crucible single stage stirring at 550 rpm , and 0.55 times of D, the diameter of crucible for semispherical base crucible and multistage stirring at 1000 rpm . Whereas the blade width b is equal to 0.1–0.2 times of D, the crucible diameter.

Fig : Size of stirrer blade

4.2.3.6 : Feed Rate:

Mechanical stirrer forms vortex and reinforcements particles are feed in the center of the vortex. Feeder should be designed in such a manner that it allows continuous flow of particles. High feed rate results particles accumulation in the composite and low federate is difficult to achieve due to the formation of lumps of small solid particles. Thus, selection of optimal rate of feeding is crucial. Less than 0.8 g/s is very difficult to achieve and greater than 1.5 g/s results particle accumulation, hence the optimal rate of feeding is in the range of 0.8–1.5 g/s to avoid the accumulation of reinforcements in the composite and achieve homogeneous dispersion of reinforcement particles throughout the composite [11, 18, 22].

Fabrication of AMCs and HAMCs by stir casting method with optimal combination of above stated
stirring process parameters govern the mechanical properties of the composites and discussed further.

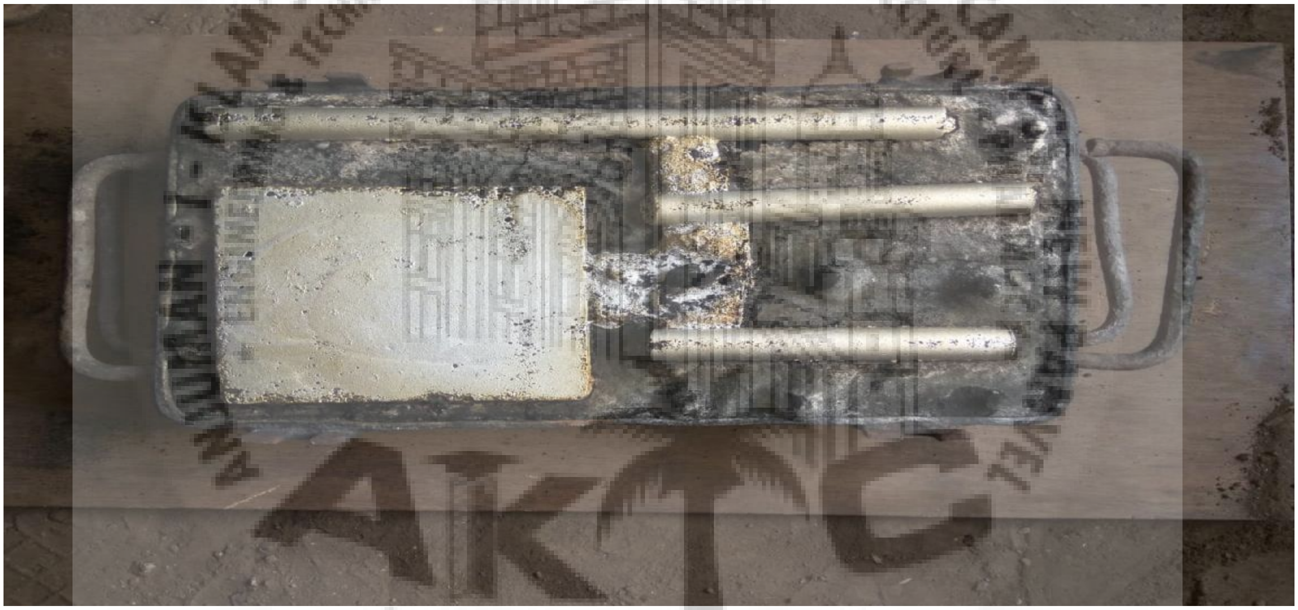
Fig : Speed regulator

Based on extensive review on stirring parameters the position of the stirrer is advised as 25–30% of the height of the melt height from the bottom of the crucible to avoid the dead zone, which is the reason of the agglomeration of reinforcements at the bottom of the crucible. In case of water model, if the impeller blade angle was taken less than 30° then the solid particle dispersed below the stirrer. Impeller with 30° blade angle displays homogeneous distribution without concentration of particles. While, for impeller blade angle more than 30°, most of the solid particles concentrated at just below the tip of the impeller blade. In case of FEM Model, angle ($\alpha < 30°$) showed good axial flow but less shearing action, whereas ($\alpha > 30°$) showed good shearing action but less axial flow. Blade angle as 30° provides good level of axial flow and shearing action to such the solid particles into the melt from the melt surface and break the accumulation of mixing particles. Thus impeller blade angle 30° is suggested as optimal value to achieve homogeneous dispersion of reinforcements particles in the melt. Stirrer size ($d < 0.5$ D) cause lack of suspension of particles at the center while stirrer size ($d > 0.55$ D) results particles concentrated at the center of the crucible base. Thus optimal diameter is 0.5 D at 550 rpm for single stage stirring and 0.55 at 1000 rpm for multistage stirring.

4.3 Casting process :

4.3.1 Introduction:

Casting is a manufacturing process in which a liquid material is usually poured into a mold, 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 mold to complete the process. Casting materials are usually metals or various time setting materials that cure after mixing two or more components together; examples are epoxy, concrete, plaster and clay. Casting is most often used for making complex shapes that would be otherwise difficult or uneconomical to make by other methods. Heavy equipment like machine tool beds, ships' propellers, etc. can be cast easily in the required size, rather than fabricating by joining several small pieces.



4.3.2 : Types Of Casting :

Metal :

In metalworking, metal is heated until it becomes liquid and is then poured into a mold. The mold is a hollow cavity that includes the desired shape, but the mold also includes runners and risers that enable the metal to fill the mold. The mold and the metal are then cooled until the metal solidifies. The solidified part (the casting) is then recovered from the mold. Subsequent operations remove excess material caused by the casting process (such as the runners and risers).

The Metal Casting or just Casting process may be divided into two groups:

Hot Forming Process :

Examples are Centrifugal casting, Extrusion, Forging, Full mold casting, Investment casting, Permanent or Gravity Die casting, Plaster mold casting, Sand Casting, Shell Mold casting. The method to be used depends upon the nature of the products to be cast.

Cold Forming Process :

Examples are Squeeze casting, Pressure die casting, Gravity die casting, Burnishing, Coining, Cold forging, Hubbing, Impact Extrusion, Peening, Sizing, Thread rolling.

Selecting the Right Metal Casting Process :

For any Metal Casting Process, selection of right alloy, size, shape, thickness, tolerance, texture, and weight, is very vital.

Special requirements such as, magnetism, corrosion, stress distribution also influence the choice of the Metal Casting Process.

4.3.3 Working :

1) Patternmaking :

A replica of the part to be cast is made using a suitable material such as wood, metal plastic or plaster.

Fig : Pattern of sample

2) Mould making :

Mould making is a multi-step process in which patterns and cores are used to create a mould. The type and how the moulds are made would vary depending on the type of metal casting.

For example, sand casting uses sand inside a flask to create moulds and die casting uses hardened tool steel moulds.

Fig : Mould of sample

3) Metal melting & pouring –

Liquid is then melted and poured into the mould cavity either by gravity or by high pressure. Then the cast is allowed to solidify before the cast parts are removed from the mould. Again, the cast part removal will vary depending on the type of metal casting

Fig : Melting of Aluminium

4) Post processing –

In this final step, the cast metal object is removed from the mould and then fettled. During the fettling, the object is cleaned of any moulding material, and rough edges are removed.

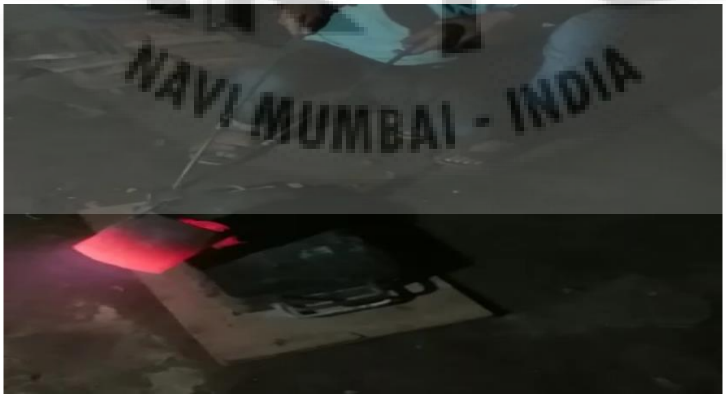


Fig : pouring into mould

4.3.4:Advantages, Disadvantages and Applications Of Sand Casting Method :

Sand Casting		
Advantages	**Disadvantages**	**Recommended Application**
Least Expensive in small quantities (less than 100) Ferrous and non - ferrous metals may be cast Possible to cast very large parts. Least expensive tooling	Dimensional accuracy inferior to other processes, requires larger tolerances Castings usually exceed calculated weight Surface finish of ferrous castings usually exceeds 125 RMS	Use when strength/weight ratio permits Tolerances, surface finish and low machining cost does not warrant a more expensive process

4.4 : Annealing of Aluminium alloy

Heat treating (or **heat treatment**) is a group of industrial, thermal and metalworking processes used to alter the physical, and sometimes chemical, properties of a material. The most common application is metallurgical. Heat treatments are also used in the manufacture of many other materials, such as glass. Heat treatment involves the use of heating or chilling, normally to extreme temperatures, to achieve the desired result such as hardening or softening of a material.the following are the various heat treatment techniques:

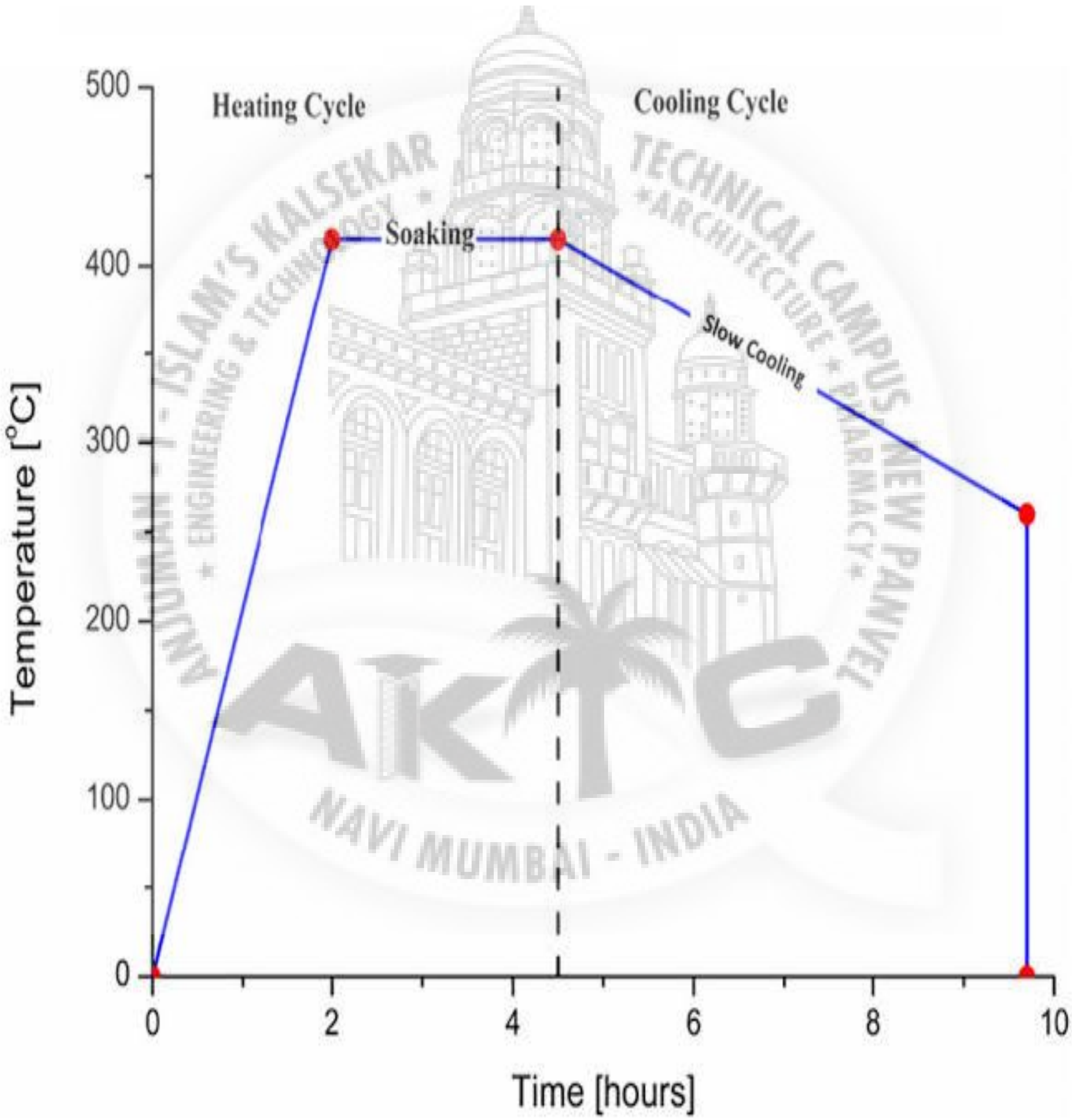
1. Annealing
2. Case hardening
3. Precipitation strengthening
4. Tempering
5. Carburizing
6. Normalizing
7. Strengthening
8. Quenching

Although the term *heat treatment* applies only to processes where the heating and cooling are done for the specific purpose of altering properties intentionally, heating and cooling often occur incidentally during other manufacturing processes such as hot forming or welding.

The heat treatment method which we used is Annealing.**annealing** is a heat treatment that alters the physical and sometimes chemical properties of a material to increase its ductility and reduce its hardness, making it more workable. It involves heating a material above its recrystallization temperature, maintaining a suitable temperature for an appropriate amount of time and then cooling.

In annealing, atoms migrate in the crystal lattice and the number of dislocations decreases, leading to a change in ductility and hardness. As the material cools it recrystallizes. For many alloys, including carbon steel, the crystal grain size and phase composition, which ultimately determine the material properties, are dependent on the heating rate and cooling rate. Hot working or cold working after the annealing process alters the metal structure, so further heat treatments may be used to achieve the properties required. With knowledge of the composition and phase diagram, heat treatment can be used to adjust from harder and more brittle to softer and more ductile.

In the case of ferrous metals, such as steel, annealing is performed by heating the material (generally until glowing) for a while and then slowly letting it cool to room temperature in still air. Copper, silver and brass can be either cooled slowly in air, or quickly by quenching in water.[1] In this fashion, the metal is softened and prepared for further work such as shaping, stamping, or forming.



The steps followed for Annealing the MMC specimens were as follows:

- Cleaning and surface finishing the specimens very well.
- Keeping the specimens in the electric furnace.
- Raising temperature of the furnace to 416°c.
- Holding at this temperature of one hour.
- Reducing the temperature by 20°c and holding at that temperature for one hour.
- Repeating the process until the temperature comes upto 250°c.
- Cooling the specimens at room temperature.
- Cleaning the black coating on the specimens.

This is how the heat treatment of the MMC specimens was done for testing purpose.

Fig : Annealing of Aluminium composite

CHAPTER 5

EXPERIMENTAL TESTING, RESULT & CONCLUSION

The preparation of the specimen was done. The heat treatment of the specimens was done.

But ufortunately, due to the pandemic, we were not able test the specimens.

Hence,results of the specimens were not produced yet

CHAPTER 6

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