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Experimental Investigation of Mechanical Characterization of Semi Solid Aluminium 7075 Alloy

S.Venkata Narasimha Rao, Research scholar, Dept of mechanical engineering,jntuh,sugursnr@gmail.com

Dr.S. Rajesham, professor, Dept of mechanical engineering,rajesham_s20@rediffmail.com

Dr.M.Manzoor Hussain, Registrar, Jntuh, Dept of mechanical engineering, manzoorjntu@gmail.com

ABSTRACT

The goal of this work is to improve the heat processing parameters for extruded 7075 alloy, which are important to achieve the thixoforging spheroidal grain structure. The compound and the base alloy casted into a steel mould were studied side by side in the microstructure and the mechanical behaviour of the composite. The present work describes the synthesis of Al7075 semi solid metal matrix composite reinforced with graphene and the characterization of their microstructure and mechanical properties. Graphene is added to aluminium-7075 and samples are prepared both with stirring and without stirring at varying temperatures. The samples are prepared at 6800c, 7100c, 7400c, 7700c, 8000c, 8300c, 8600c, 8900c, 9200c.These samples were additionally pressed in a special tooling by which tensile test samples were obtained. The implementation of the composite casting approach led to a dendritic transformation into a dendritic base alloy structure. The mechanical properties of the composite are improved in relation to the base alloy.

Keywords

Aluminum-7075, Graphene, Furnace, Die, Crucible, Semi Solid Processing, Mechanical Characterization, Specimens

INTRODUCTION

A composite material is a combination macroscopic with a recognisable interface between two or more separate materials. Composite is a multi-stage material with a large proportion of all product phases' properties in order to produce a perfect mix of properties. This is considered the combined action theory. Due to its low specific gravity, strong strength-to-weight ratios, high wear resistance and a high reflectivity, decent heat and electric conductivity, low melting point, aluminium (Al) alloys are used on a wide range of applications in the automotive, maritime or space industries, The insignificant gas solubility, outstanding cast capacity and good corrosion strength (except for hydrogen). In general, aluminium alloys can be classified as casting alloys and wrought alloys. The cast alloys are a category of cast materials which are secondary in tonnage to ferrous castings. [1] Mainly because aluminium casting alloys are one of the most flexible casting alloys. Furthermore, many aluminium alloys are very free of hot, short cracking or tearing patterns and at the same time offer a good surface finish with little or no defects. [2]Fine homogenous spheroidal-grain equiaxed structures sufficient to shape half-solid alloys without the development of

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tears or cracks because of high fluidity resistance to dendritic structures [13], and spheroidal microstructures have better mechanical characteristics than dendritic microstructures [14]. SIMA (Strain Inducted Melt Activated) is one of the methods for obtaining this microstructure. This alloy is ideal for the semi-solide formation application with a wide freezing range from 7075 alloy between 477 and 635 ◦C. The evolution of the liquid volume fraction in an increasing temperature alloy 7075 is demonstrated according to Fu et al.[16]..

LITERATURE SURVEY

Misra and Oswalt have studied The aging feature of the alloy is replicated here with its findings. Ti Al-Mg-Si alloys are made up of two various precipitates, namely TiAl2 and Mg2Si platelets. When the structure is completely made of Mg2Si, the substance has optimum resistance The alloys are typically artificially ageed to reach an acceptable tensile strength combination and an acceptable expansion. Specimen treated with the solution only contain TiAl2, which is acting as a nuclear agent. During the precipitation phase, TiAl2 density continually diminishes as the Mg2Si platelet density increases. When just Mg2Si breaks, the microstructure is the best duration available, with peak strengths. In combination with low dendrite arm spacing, the highest possible tensile characteristics are given.

Hanliang Zhu, JingjieGuo, and Jun Jiain their work In a number of ageing conditions, the mechanical properties, microstructures and deformation activity of the A357 casting alloy Al-7Si-Mg cast was studied. The mixture of intensity and elongation was found to differ with ageing parameters. Aging at 1650C offers the optimal balance between power and ductility. The observation of the TEM (transmission electron microscopy) reveals that regions of Guinier-Preston (GP) are formed under old conditions. Planar slip bands and slip band coarsening with aging temperature were seen. His tests have shown that overage therapy can enhance the overall tensile properties.

WitthayaEidhed In their studies, they find optimum microstructure durability with limited solution time from 4 to 6 hours, in comparison to solution time effects on microstructure and stiffness of Al-12Si-1.2Cu-1.1Ni alloy made by permanent mould casts.. The chosen solvent was 520°C with 0.5, 1,1.5, 2, 4, 6, 8 and 10h holding periods. Water was quenched and aged for 15 hours at 175oC.

Hanliang Zhu, et.al Experiments on the mechanical and metallurgical characteristics of Al-7Si-Mg cast alloys under various ageing conditions were performed in his paper. The attributes differ with aging. It was found. Aging at 165 °C provides the best balance between strength and ductility. TEM was shown to be planar bands and (GP) areas. Coarse slip bands are increasing as the temperature or time of aging increases. They used ageing to increase the efficiency of the tensile.

Daniel H. Herring In their recent research, Double Aging suggested improving processing techniques, shortening cycle times, and lowering costs without sacrificing the quality of production.

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Chirita et.al studied the hypo and hyper eutectic Al-Si alloys mechanical properties produced by centrifugal and gravity die casting processes. The centrifugal castings showed better rupture strength, % elongation and modulus of elasticity than die cast specimen.

Erhard Ogris He studied new ductile Al-Si-Mg alloys of semi-solid metal during his PhD thesis. Theoretically and experimentally described were silicone spheroidisation and its influence on mechanical properties. Modelling and experimental silicon spheroidization studies show well-modified silicone spheroidizes between 500°C and 540°C in minutes of soaking time. This silicone spheroidization (SST) treatment has resulted in excellent fracture elongation values at a high yield resistance (~230MPa) of up to 18 per cent to formed thixo components. Even for components which have particularly variable wall thicknesses, FEM simulations of short high-temperature heat treatment confirm the short time for a successful sST.

H. Moller et.al studied High pressure die casting (HPDC) of semi-solid metal (SSM), newly developed heat-treatment cycles and conventional heat-treatment cycles indicate similar hardness values may be achieved by significantly shortening heat-treatment cycles. Compaid with those produced by gravity die-casting were the tensile properties obtained for SSM-HPDC. The change in the microstructure (globulary or dendrite) does not have a significant effect for the response to heat treatment, which means that dendritic liquid A356 casts can also successfully be used with short heat treatment cycles initially developed for the worldwide SSM-HPDC A356 casting.

M.WESSÉN, et.al In its work, a thick-walled section (approximately 45 mm × 43 mm) of the arheocast component examined the micro structure and tensile properties. Longer solidification periods can lead to gross eutectic Al-Si. A modification has been made to minimise the coarseness of eutectic sodium. They have prepared a 1) As cast, 2) Na modified cast and 3) modified melt cast 30 minutes after Na added. The material has been studied as cast and in condition T6. The results show that Na adds a refined Al-Si eutectic even after a decline of 30 minutes. But no change in yield reduced by more than 30%.

M. Hitchcock, et.al Studied Al–7Si–0,6Mg slurry consolidification behaviour and rheo die casting effect on the microstructure studied By metallographic research, they have characterised the 2017 aerospace aluminium alloy. For the 2017 alloy precipitation, solution treatment reinforcement was conducted in processes of 550^{o}C and age hardening heat treatment. The microstructure of the samples was uniformly spread in the aluminium alloy matrix, which enabled the aluminium alloy to be aluminium alloy in 2017 by means of precipitations and age hardening heat-treatment processes.

METHADOLOGY

The specimens are casted in a die box setup to form a cylindrical shape as shown below. The below processes show the casted specimens at different temperatures and the mutability of the specimen.

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Die Box Setup

A Die is a specialised tool for material forming in manufacturing industries. The die used here is hollow cylinder shape. It consists of two hollow cylinder shaped in which the casting material is to be poured into the two hollow cylinders. With this a specimen of length 23cms and diameter of 2.5 cm can be produced. Die cost is low design and manufacturing is easy.

Fig 1.1 Die used in casting process

Crucible

The crucible we used is made of clay and graphite and it having thickness of 15mm.The material has to be placed in the crucible and is inside the furnace and is heated up to our desired temperature. The heating of charge is due to conduction of heat through walls of crucible.

Fig 1.2 crucible placed in furnace

Furnace

The material Al7075 and Graphene are heated to required temperature and melted in furnace. The furnace consists of a temperature indicator by which we can heat to required temperature. To this furnace a stirrer is attached and is controlled automatically with motor. The RPM to which the stirrer has to rotate is to be adjusted.

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MATERIAL

Aluminium – 7075

For the present study, aluminum-7075 is taken. Aluminum alloy mainly contains zinc as alloying element. 7075 alloy is composed of 90.0% Zn, 2.5% Mg, 0.23% Cr and 1.21% Cu. The aluminium alloy is one of the strongest. It is mainly used in aerospace applications. It can be further improved by reinforcing with other material.

Fig 1.3 Casted Aluminium Specimens

The below table gives the chemical composition of Al 7075 alloy that is used for the examination of different mechanical properties with different samples.

Table 1. Chemical composition of 7075 alloy examined in the tests (%)

Al	Zn	Mg	Cu	Fe	Si	Cr
90.3	5.08	1.97	1.21	0.5	0.26	0.23

Mn	Zr	Ni	Ti	Pb	Sn
0.21	0.04	0.04	0.02	0.02	0.018

Graphene

Graphene is a carbon allotropic in the shape of a single atomic sheet in a hexagonal two dimension grid. It's about 100 times stronger than steel. They effectively move heat and energy and are almost translucent. It is used mostly in anti-corrosion coatings.

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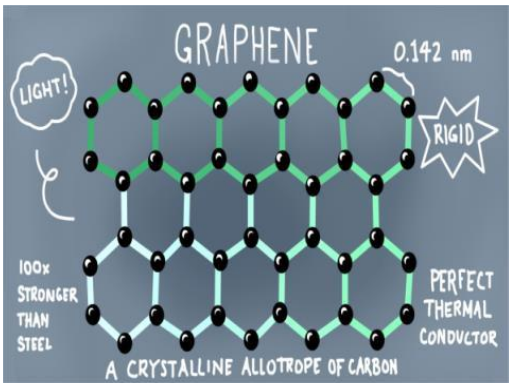
(a)



(b)

Fig 1.4 (a) Graphene powder (b) graphene Structure

In current higher Zn, Fe and Cu levels, the energy-dispersive continuum occurs as white zones (point 2) and higher concentrations of Mg, Zn, Si and Cu as black zone (Point 3). The solid grains are composed of al and minimal quantities of zn and mg (point 1) and, as a result of micro-separation at the grain borders, are deprived of si and cu. The separation of Cu and Si raises the melting temperature of the solid grains and reduces the temperature of melting at grain limits and allows liquid phases to form around the mass grain. The rectangled Al–Fe–Cr intermetallic continuum energy-distribution spectrum at the grain limit is depicted in (Point 4) theme Spheroidal cereals started to develop from 20 min at 620 ◦C. At 25 minutes thin films at the seed limits extended as solid grains began to melt around grains in 35–40 minutes and the volume of liquid phase increased with increased time. The longer isothermal thermal treatment length makes the kernels more spheroidal and decreases the grain dispersion but the mean size of the spheroidal kernels increases. The key mechanism used for grain growth during isothermal heat processing is thought to be coalescence.. The liquid intra-granular trap in solid particles has also coarsened over time. Bolori [20] states that the chemical in alloy homogeneities results in these liquid phases. Next to each other, small intergranular phases eventually converge by coalesce and some move through the Ostwald mating process to greater liquid regions.

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FABRICATION OF METAL MATRIX COMPOSITE

The process for producing metal composite (MMC) from Babbitt-ilmenite is Stir casting. The explanation is that production costs are low and therefore a safer way to achieve dispersion in low time and expense. Heating process of the die is also part of the production process. We used a cast iron die here that makes two forms of cavities possible.

Pre-Heating of Metal Die

Metal die is used for casting of the required work piece. The key benefits of using a metal die are the reusable mould, a strong surface finish, high dimensional precision and high output speeds. A metal mould results in a fine grain structure than sand casting by the quick cooling rate. The process continues with the lubricating oil surrounding the hole, which stops the casting from sticking to the mould and increases the service life. The die is then pre-heated to 150°C, which decreases flow and heat impact.

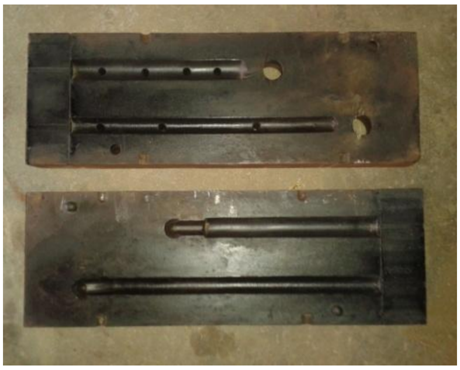	
Fig 1.5 Metal Die	Fig 1.6 Pre – heating

Matrix Phase

Babbitt was selected as the most common Tin-based alloy for a composite. In certain fields such as the automobile and shipboard markets, Babbitt finds its use. Because of their compact weight and hardness properties, Babbitt uses high tin content in high speed and low pressure applications.

Fig 1.7Tin Base Material (Babbit)

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Melting and Casting Of Test Specimen

The weighted quantities of Babbitt were melted to desired heating temperature of 450°Cin steel crucible. The electric furnace is used for melting. Ilmenite powder in requisite quantity is pre-heated in a furnace to 400°Cbefore being introduced into the molten metal. Stirring is done while the powder is added. Stirring improves the dispersion of the Ilmenite material within the alloy to form a better particulate matrix.

EXPERIMENTATION

Semi solid Aluminium MMC was prepared both with stirring and without stirring. In this study Aluminum7075 is used as metal matrix and graphene is used as reinforcement material. Different samples are to be prepared at varying temperatures and same percentage of graphene. The samples are prepared without stirring and with stir casting processes. The below image show the flow chart of the experimentation process of different samples.

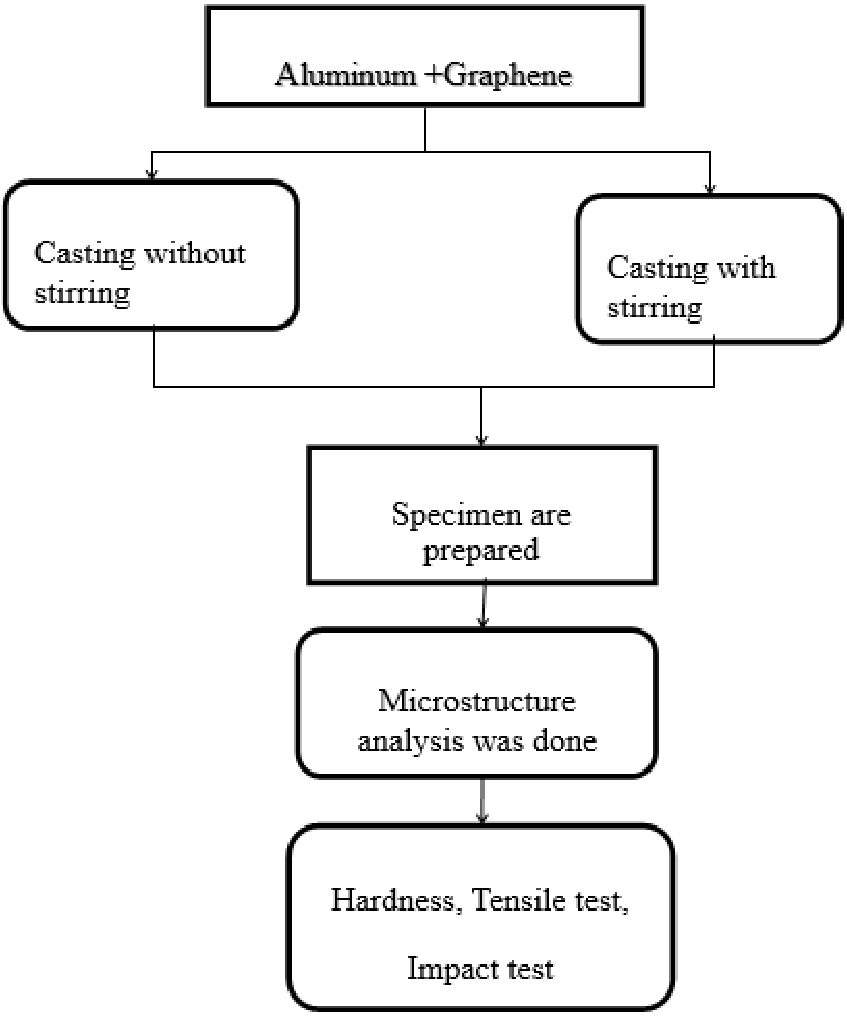

Fig 1.8Flowchart of Experimentation

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Specimen Dimensions

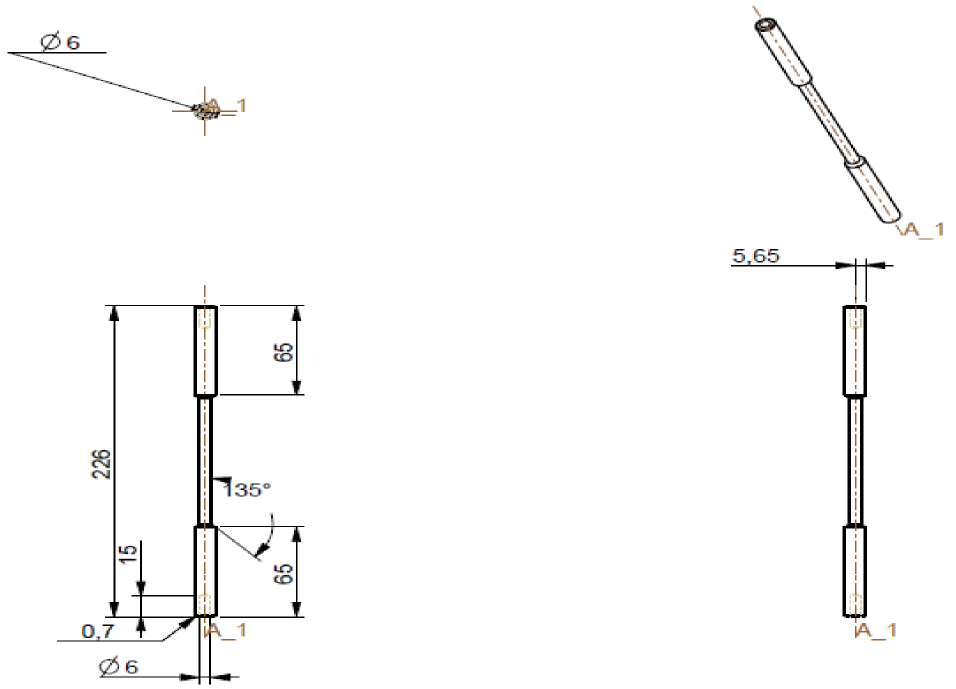

Fig 1.9 Specimens Dimensions

HARDNESS TEST

Hardness is a material's property to survive permanent indentation. Since a variety of measuring hardness methods exist, the hardness of a substance is often defined in reference to the particular test used to calculate this value. Any types of testing are Rockwell, Vickers, or Brinell. Rockwell hardness tests are popular in industrial applications, since the Rockwell measuring system works rapidly and efficiently and can also minimise operator errors. The indentation depth defines the values of hardness. Two types of fillers are available: brale and steel ball fillers.

The Braleindentor is an angle cone of 120 degrees and a heavy steel ball with lengths from 1.6 to 12.7 mm, respectively. The braleindentor is an inclined angle cone. During the hardness tests of various materials, different combinations of indenters and loads are available.

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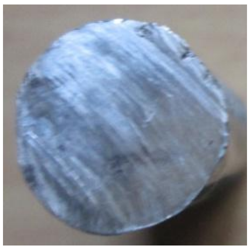
Fig 1.10Hardness Test Equipment

Here the suggested diameter of the indenter steel is 10 mm, the load of 100 kg is constant for 5 seconds.

Specimens Before and After Testing Rockwell Hardness

RHN	BEFORE:	AFTER:
Specimen A1: Pure Tin Alloy (Babbitt)		
Specimen A2: Speed: 300 RPM Time: 10 Min		
Specimen A3: Speed: 400 RPM Time: 10 Min		

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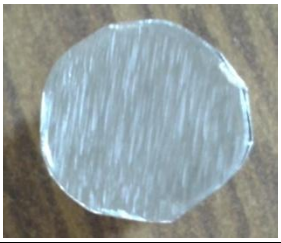
Specimen A4: Speed: 400 RPM Time: 5 Min		
Specimen A5: Speed: 300 RPM Time: 5 Min		

TENSION TEST

Tension testing is a fundamental material science test where a sample is tensioned until it is broken. The test results are typically used to choose a material for an operation, to monitor the consistency and to decide how a material responds to other forces. The characteristics which are calculated directly by a tensile test are ultimate strength, overall length and area reduction. The following features can also be calculated from these measurements. Young modulus, the ratio of Poisson, yield strength and the hardening properties of strain. Uniaxial tensile testing is the most widely used process for the mechanical features of isotropic materials. Biaxial tensile testing is important in the case of anisotropic materials, such as composites and textiles.

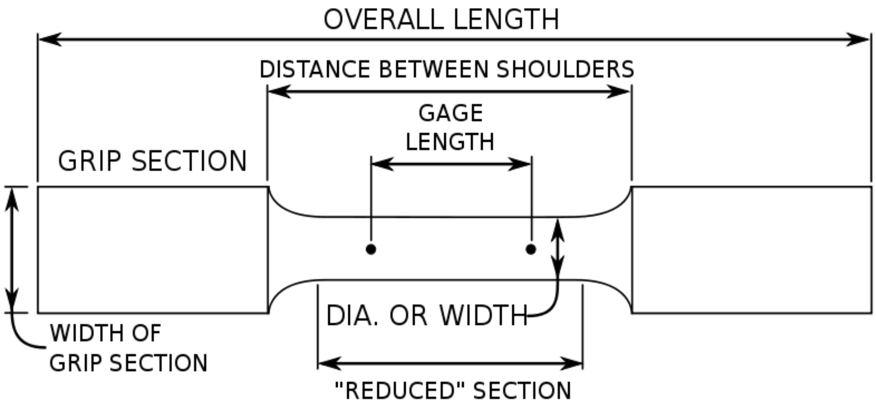


Fig 2.0 Standard Tensile Test Designation

The below image shows the specimen after the tensile loading is done. Where the specimen is broke into two parts with random particle distribution and with cracks in the body. The below table is shown for the time taken for cooling at different temperature to produce the specimen.

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Fig 2.1 Specimen after the Tension Test

RESULTS & DISCUSSIONS

The foundry's mechanical properties, including the nature of hardness and tensile properties, have been experimentally investigated. Brinnel hardness testing is evaluated, where a steel ball indenter is employed with 300 N for 15 s load. The tensile properties of a screw-driven type screw machine of 100 KN are controlated at room temperature. The test specimens have been built on the ASTM B557 basis.

HARDNESS TEST

The hardness test is done by using Rockwell hardness tester. The red ball indenter used is 1/16 and the specimen is placed. A load of 100N is to be applied and the corresponding hardness number is to be noted and the hardness number at different positions on specimen is to be taken. The hardness value of other samples is calculated in the same manner and compared.

Fig 2.2 Rockwell hardness testing machine

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Fig 2.3 (a) Specimen before hardness testing	Fig 2.3 (b) Specimen after hardness testing

Table 2. Table showing hardness number

S.No	Temperature (°C)	Without stirring (Hardness Number)	With stirring(Hardness Number)
1	680	55	58
2	710	51	55
3	740	49	54
4	770	48	53
5	800	48	52
6	830	47	53
7	860	46	53
8	890	46	52
9	920	44	51

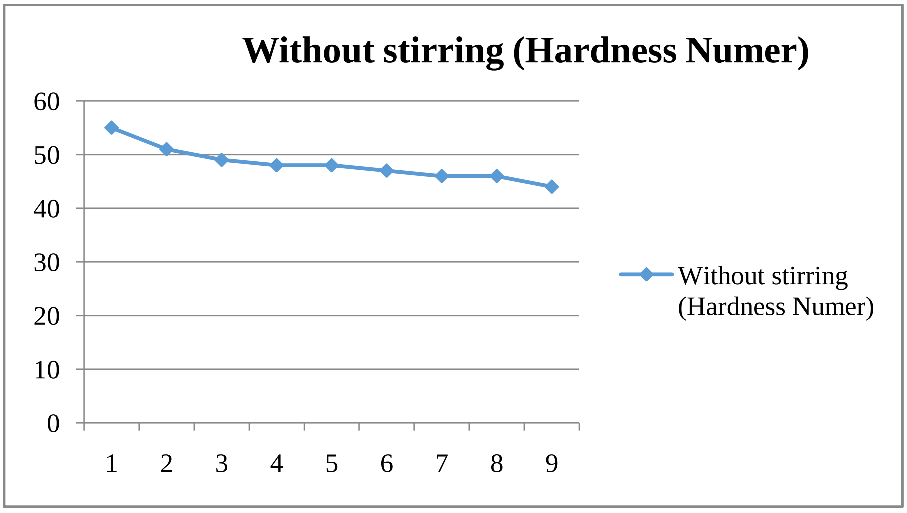

Fig 2.4. Graph showing hardness number

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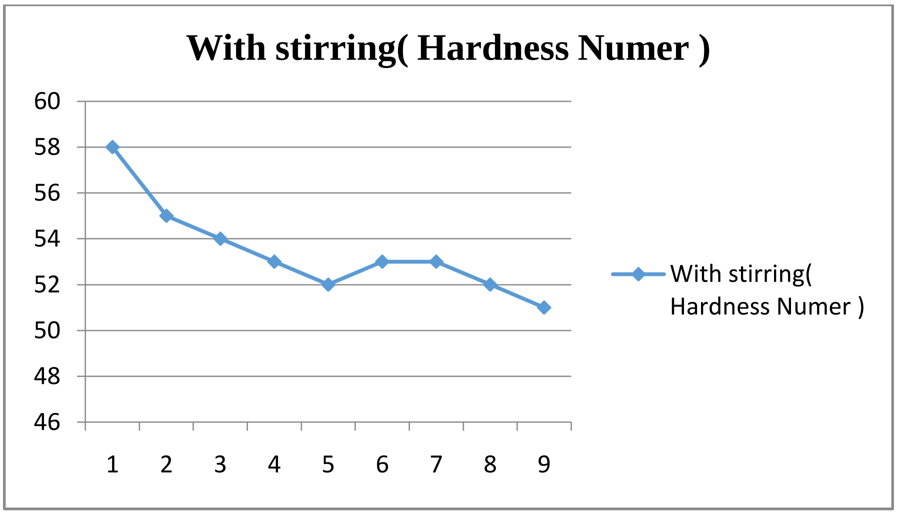

Fig 2.5. Graph showing hardness number for stirring process

IMPACT TEST

The charpy impact test is also known as the V-notch carbon test that determines the energy consumption in the material. The test specimen is made in accordance with ASTM A370, the test specimen is processed with a knot in a square form. The specimen is clamped horizontally on the anvil and hammer is released. The impact strength value is calculated. The same procedure is repeated and value is to be calculated.

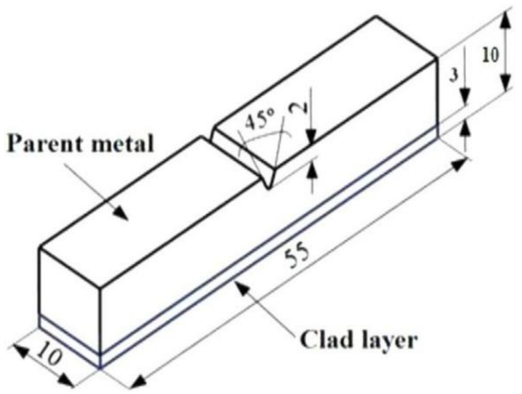

Fig 2.6 (a) specimen according to ASTM standard

Fig 2.6 (b)specimen after testing

Table 3. Impact Test Readings

S.No	Temperature (^{o}C)	Without stirring (Impact Strength) J	With stirring (Impact Strength)J
1	680	1.2	2
2	710	1.5	3
3	740	2.7	6
4	770	6	20

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5	800	8	26
6	830	16	40
7	860	18	48
8	890	24	50
9	920	31	54

TENSILE TEST

A pulling force is applied to a material by a tensile test. This test determines the strength and length of a material. Examples are to be prepared and tensile checked in accordance with ASTM E8 standards. The tensile test was carried out using a Universal Test Machine. It should be noted the computerised values. The specimen is to be placed in the UTM machine and load is applied. The specimen fractures at some point of load. Tensile test for different samples is done and values are to be compared.

Table 4.Tensile Test Readings

S.No	Temperature (^{o}C)	Without stirring (Tensile Strength) MPa	With stirring(Tensile Strength)MPa
1	680	142	210
2	710	138	196
3	740	125	185
4	770	109	115
5	800	104	107.4
6	830	98	105
7	860	97	102
8	890	94	98.9
9	920	94	97

COMPRESSION TEST

Tests of compression are used to assess how a product or material reacts when it is compressed or crushed and the compression load specimen is used. The specimen is to be prepared according to ASTM standards. Compression test is done using UTM machine. The specimen is placed and load is applied. The specimen gets compressed by the load. The compression strength value is noted and compared with other specimens.

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Fig 2.7 (a) specimen during compression testing	Fig 2.7 (b) specimen after compression testing

We observe that different tests are conducted for different specimen at various temperature. Tests like hardness, tensile, compression tests are conducted for these samples. We notify that as the temperature increases the hardness, tensile, compression test values are decreasing. This decrease in these values is due to the amount ash formed during casting increases with rise in temperature and this effects the hardness, tensile strength. The maximum values are found at low temperature. The below table shows the compression strength at different temperatures.

Table 5. Compression Strength Readings

S.No	**Temperature (^oC)**	**Without stirring (Compression Strength) MPa**	**With stirring(Compression Strength)MPa**
1	680	224.17	392.74
2	710	220.38	387.45
3	740	198.72	374.52
4	770	188.53	361.78
5	800	162.74	344.82
6	830	159.23	331.21
7	860	156.63	324.73
8	890	149.72	321.57
9	920	147.59	319.19

CONCLUSIONS

Al 7075 reinforced with graphene was successfully produced with stir casting and without stirring process. Based on the experimental studies, the following conclusions were drawn:

a) Different samples are produced with varying temperatures both with stirring and without stirring process.

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b) The casting of these samples is done and specimens are prepared according to ASTM standards.
c) Different tests like hardness, tensile and compression test are carried out, it was found that these values are decreasing with increasing temperature.
d) The maximum tensile strength was found at low temperature, hardness number and compression strength was increased by reinforcing with graphene.

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