SYNTHESIS AND CHARACTERIZATION OF MECHANICAL PROPERTIES OF CARBON NANOTUBES REINFORCED ALUMINIUM COMPOSITE

Dissertation-II

Submitted in partial fulfillment of the requirement for the award of degree

Of

Master of Technology

IN

MECHANICAL ENGINEERING

By

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Under the guidance of

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DEPARTMENT OF MECHANICAL ENGINEERING

LOVELY PROFESSIONAL UNIVERSITY

PUNJAB

TOPIC APPROVAL PERFORMA

School of Mechanical Engineering

Program:P17L: M.Tech. (Manufacturing Engineering) [Full Time]

COURSE CODE: MEC604 **REGULAR/BACKLOG:**Regular **GROUP NUMBER:** MERGD0006

Supervisor Name: Dr. Sumit Sharma **UID:** 18724 **Designation:** Assistant Professor
Qualification:________________________ **Research Experience:** ________________________

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SPECIALIZATION AREA: Materials Engineering **Supervisor Signature:** ___________________

PROPOSED TOPIC: Mechanical properties of carbon nanotube reinforced aluminum composites

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Sr. No.	**Parameter**	**Rating (out of 10)**
1	Project Novelty: Potential of the project to create new knowledge	7.00
2	Project Feasibility: Project can be timely carried out in-house with low-cost and available resources in the University by the students.	5.00
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Final Topic Approved by PAC: **Synthesis and characterization of mechanical properties of carbon nanotube reinforced aluminium composite**

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled **"Synthesis and characterization of mechanical properties of carbon nanotubes reinforced aluminum composite"** in partial fulfillment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of (Dr. Sumit Sharma, Assistant Professor) Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

(25-11-2017) (Sunil Kumar Tiwari)

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ACKNOWLEDGEMENT

"A theory can be proved by experiments;
But no path leads from experiment to the birth of theory"

-Albert Einstein

I feel a very immense pleasure in expressing my gratitude to my thesis supervisor Dr. Sumit Sharma whose inspiring guidance and support has helped me a lot in carrying on my research work. I feel very thankful to him for sharing his inspirational thoughts, motivations and giving me too much of time for my study and help.

Moreover, explanations and discussions with my mentor and other faculties of lovely professional university, conferences and inspirations from my friends, seniors and paper presenters have motivated me to take an initiative for this study. I would like to thank my mentor and corresponding author Dr. Sumit Sharma for his helpful support and discussions at every stage of my study.

I would like to thank my parents who have supported me for carrying on my studies and research work in this field. I am very obliged to them because without their support and motivation it would not be possible for me to reach at this extent.

(Sunil Kumar Tiwari)

ABSTRACT

This study emphases to study the fabrication of Al-CNTs composites through stir casting process along with the synthesis and characterization of its mechanical properties. In view of the manufacturing and fabrication of Al-CNT composites, different approaches have been surveyed by researchers in last few years. Few researchers have successfully fabricated Al-CNT composites but they have confronted common challenges in their fabrication approaches like non-homogeneous distribution of CNTs in Al matrix, agglomeration of CNTs, damaging of structure of CNTs, CNTs coming out of Al matrix while fabrication. In this study we are mixing MWCNT in aluminum matrix in different ratio with wt%. CNT is either coated or mixed with paraffin oil to increase its density so as to prevent non-homogeneous distribution of CNT in Al matrix.

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LIST OF ABBREVIATIONS

AFM	Atomic force microscopy
CFRP	Carbon fiber reinforced polymer
CNT	Carbon nanotube
ECAP	Equal channel angular pressing
EMI-SE	Electromagnetic interference shielding effectiveness
FE	Forward extrusion
FEM	Finite element method
FRP	Fiber reinforced polymers
FSP	Friction stir processing
HIP	Hot Isotactic pressing
MMA	Methyl methacrylate
MWCNT	Multi walled carbon nanotube
NDM	Nano dispersion method
NSD	Nano scale dispersion
PIE	Polyethyleneimine
PM	Powder metallurgy
PMMA	Poly methyl methacrylate
PSF	Plasma spray forming
RMS	Root mean relationship
SEM	Scanning electron microscopy
SiC	Silicon carbide
SPP	Semi solid powder pressing
SWCNT	Single walled carbon nanotube
TEM	Transmission electron microscopy
UTM	Universal testing machine
VGCF	Vapor grown carbon fiber
VHP	Vacuum hot pressing

1. INTRODUCTION

The idea of composite material came into the mind of people in 1500 B.C when people started making their housed with mud, straw, bricks, stones and wood. A composite material is made up of two or more than two materials having dissimilar properties when combined, gives a different material with different features from that of the discrete component, while the individual constituent remains separate and distinct. The modern era of composites started with light materials like plastics because these products were very light and had high strength. Then the idea of reinforcement came into the mind of people to increase the strength of these plastic materials so that they could be used for structured applications. These plastic composites provided good strength and durability but failed in the conditions of high temperature environment. Then people started using metallic products and then they started reinforcing those products with different reinforcements. These products were quite good to use in high temperature environment but people again started feeling problems because of their heavy weight. Scientists started reinforcing light metallic materials like aluminum, copper, zinc etc. In recent years light metal matrix composites are used in aerospace industries for making planes, flights, missiles, rockets etc. In most of the space crafts, aluminum is used because of its excellent properties, most commonly because of its light weight. Researchers have reinforced aluminum with different reinforcements but in recent years CNTs have been in the eyes of researchers because of their extraordinary thermal electrical and chemical characteristics, stability, virtuous elastic modulus (1 ~TPa), high aspect ratio (50-500), strength (~100GPa), high stiffness and low density (~1.2g/cm^3 to ~1.8g/cm^3). Researchers have paid their attention towards the fabrication of Al-CNT composite because of the light weight and also because of non-corrosive properties of aluminum and excellent properties of CNTs and they also consider this composite to be the next generation material to be used in aerospace and automobile industries. Focusing at the excellent properties of Al-CNT composite, researchers have gone through different approaches of fabrication like Nano scale dispersion method, ECAP, stir casting, powder metallurgy, spraying processes and many more. However, in all these processes they have faced the common problem of the non-uniform dispersion weak interfacial bonding of CNTs in Al matrix and structural damages. Due to the low density of CNTs as compared to Al matrix, CNTs comes out of the matrix and floats on molten aluminum while casting. To get rid of this challenge, they have gone through coating of CNTs or mixing of paraffin oil in CNTs before fabrication so as to increase the density of CNTs or CNTs were spread in elastomer matrix and then elastomer was banished by Al. Literature studies have revealed that the strengthening in Al-CNT composite highly depends on dispersion of CNTs in Al matrix, and their degree of orientation as well as their aspect ratio. Solid state fabrication processes (powder and spraying) have been used for making of large samples of composite so they are less suitable for mass production. Liquid state fabrication processes (stir, die and squeeze-casting) have been anticipated for mass production. Though every fabrication processes have resulted in better outcomes, but still the underlying strengthening mechanism is unstated.

1.1. Problems detected

Fabrication of Al-CNT composite has been done by different methods by different researchers as per their convenience in handling and expenses. Every researcher has almost successfully fabricated the Al-CNT composite in their way but they all faced some problems in their methodology of fabrication. The common problem that they faced was the non-uniform distribution of CNTs in Al matrix. Some other problems that faced have been stated below

- Low wettability of CNTs, non-uniform distribution of CNTs in Al matrix, coming out of CNT from the molten matrix on the surface of matrix due to low Density of CNT, agglomeration, and the formation of clusters in case of stir casting process.
- Disentanglement of CNT in Al matrix in case of ECAP and NSD.
- Formation of defects on the surface of sample in ECAP process when back pressure is applied and formation of cracks due to increased number of ECAP passes.
- Kim et al (2011) found fracture with ductile nature along with dimples at high temperature (640ºC) while fabricating Al-CNT composite through semi solid powder processing.

2. OBJECTIVE OF STUDY

Researchers have been working on the Al-CNT composites for last fifteen years and they have found that these composites are the most dominant materials which can be used instead of traditionally used materials. It can be seen that the volume and the market of the Al-CNT composite have grown to a large extent because of their excellent properties. The main objective of this study is to examine the characteristics and properties of Aluminum composite reinforced by MWCNT as well as to introduce a new composite. The well-known characteristics and properties helps to find the areas of their applications and the improvement required in them. In today's scenario researchers have a challenge to make these composites a cost effective. Some of the major objectives to conduct study on Al-CNT composite materials are:

I. To examine the properties and characteristics of the Al-CNT composites and their areas of application.
II. To enhance the properties and morphologies by using new techniques and other reinforcing materials.
III. Introduction of new composite materials in market.
IV. Recycling of composites.

3. REVIEW OF LITERATURE

Iwahashi et al., (1995) studied the principle of ECAP for the processing of ultra-fine-grained materials (≤100nm) which resulted in grain size reduction up to 100 to 200 nm. It was found that there were some changes in the properties of material (moduli of elasticity and the deby and curie temperature) after ECAP process. Earlier there were some problems in determining the strain induced in the sample but in this paper authors have calculated the condition based on the principle by mathematical expressions. For the manufacture of materials with ultrafine grain size, ECAP was declared as the attractive technique. For calculating the executed strain (ε) after pressing sequences a mathematical relationship was derived [41].

Iwahashi et al., (1997) conducted an experiment to examine the growth of ultrafine grain size while performing equal channel angular pressing (ECAP) of high purity aluminum (99.99%) formed by ingot metallurgy with a primary grain size of 1.0 mm. Ingot was rolled in the form of plates and tiny parts at the room temperature having dimensions 14×14 mm^2 with length about 80 mm. surface of longitudinal faces were polished on 800 grades SiC paper to get smooth surface finish. The sample was removed from die in route A without any spinning and the other sample was spin at an angle of 180° in route C and then the pressing was repeated. In both the routes, pressings were repeated on distinct samples from minimum of 1 to maximum of 10. Authors concluded from the experiment that aluminum particle which had grain size of 1.0mm were reduced to 4µm and Vickers hardness was improved by (>2) times when 1st pressing was done as shown in fig 1. The microstructure of the material had parallel bands of sub-grains which were distributed by grain boundaries which had disorientation with very low angles. It was determined that 4 pressings with rotation by 180° resulted in optimum microstructural condition.

Iwahashi et al., (1997) studied the method and process of equal channel angular pressing (ECAP) for the refinement of grains of high purity aluminum (99.99%). 1 to 4 pressings were carried out and then microstructural examinations were sectioned in all the three mutually perpendicular directions. In the samples, shearing patterns induced during the processing with the help of which authors explained the results. Iwahashi et al failed to make available the information regarding microstructure and shearing direction in their earlier studies. ECAP was carried at a pressing speed of 19mm/sec at the room temperature in which MoS_2 was used for coating sample and was used as lubricant too. Hitachi (H-8100) and TEM were used to examine the specimen. Authors found that after the single pressing sub-grains bands were visible on the parallel segments of the sample which were at 45° to the top and bottom faces and the size of the grains was in range of 0.5 to 1.5µm.

Nardelli et al., (1998) studied the ductile and brittle behavior of carbon nanotubes (CNTs) using large scale molecular dynamics and the effect of external conditions and tube symmetry on CNTs. Authors had focused on the existence of mechanical failure in CNTs under the tensile loading which leads to the appearance of novel un-foreseen patterns in plasticity and breakage. Completely different scenarios were observed because of different orientations of carbon-bonds with respect to the axis of strain; behaviors (ductile and brittle) were observed in nanotubes with different symmetry under the same applied conditions. Authors found that under low temperature and high strain all tubes were brittle in nature. They concluded that if the plastic flow was favored by external conditions tubes were completely ductile while larger tubes were brittle because of their symmetry.

Nemoto et al., (1999) deliberated the evolution of microstructure for super-plasticity through equal channel angular pressing (ECAP) because it was able to present ultrafine grain size into bulk material. In the experiment, authors performed ECAP with Al-1420 alloy having alloying element Al-5.5%Mg-2.2%Li-0.12%Zr with grain size of 400µm. 8 passes were performed at a temperature of 673k and 4 passes at a temperature of 473k which gave the strain of 12. After the experiment was over, writers showed that the grain size was refined up to the level of 1µm or may be smaller. They have explained the principle of ECAP along with their processing routes while the shearing characteristics were also included.

Looney et al., (1999) studied the stir casting method for the preparation of metal matrix composites. In this paper the authors have evaluated different methods for distribution of reinforcing element but they found that the stir casting method was the most cost-efficient method for the production of metal matrix composite. They have made a composite of silicon aluminum alloy metal matrix composite using stir casting method and they have well explained the steps used in it. They have concluded that the homogeneous mixing of the component depends upon the holding temperature, stirring speed, shape and size and position of impellor and by controlling over these parameters we can easily prepare metal matrix composite with uniform distribution.

Cong et al., (2002) studied the production of composite made up of Nano aluminum reinforced by carbon nanotubes (CNTs). Going through the different studies for the manufacturing of composites through carbon nanotubes, it was found that the change in mechanical properties was not satisfactory as expected. The reason behind this was presence of impurities like graphite particles and carbon. Authors conducted this study for making of composite consisting of single wall carbon nanotubes (SWCNTs) and aluminum matrix for the consideration of its properties and morphology. They used hydrogen arc discharge process for production of SWCNTs while H_2 plasma evaporation method was used for producing the Nano Al particles [27]. TEM and SEM showed that SWCNTs were 90% pure.

0.5wt% SWCNTs were mixed with Al particles and drenched in alcohol and stirred for about half an hour by ultra-sonication and dried. The resultant product was almost spherical in shape having Al_2O_3 on its outer layer. Furthermore, the mixture was compressed in a disc (diameter 8 and 1.2mm) under a pressure of 1.50 GPa. Finally, the disc was consolidated for half an hour under a pressure and temperature of 1.0 GPa and 260 to 480°C respectively. Authors declared that the uppermost hardness value of SWCNT/Nano composite was 2.89 GPa about 20 times greater than course grained Al.

Noguchi et al., (2004) developed a new method for the uniform dispersion of CNTs in Al matrix; they called it as Nano-scale dispersion method (NSD). The method was followed by two steps. In the first step, a precursor in which CNTs were uniformly dispersed in an elastomer matrix was prepared; and in second step, the elastomer matrix was displaced by Al. They used MWCNTs with average diameter of 13 nm and length was reported to be 10-50 µm. MWCNTs powder mixed into a precursor was of either 10g or 20g, which turned out to be 0.8vol% or 1.6vol% of MWCNT/Al composites when pure Al (99.85% purity, 30mm × 40mm × 10mm) was heated in a furnace in a nitrogen atmosphere when the temperature was gradually raised and kept at 800°C for one hour and then cooled. The composite was investigated by an optical microscope (Metal Microscope EPIPHOT TME300, Nikon Corporation) and a scanning microscope (FE-SEM S-4700, Hitachi Ltd.) under an acceleration voltage of 3 KV. The authors also found the metallic luster on the cross section of composite.

Agarwal et al., (2004) studied the synthesis and description of the Al-nanostructured composite reinforced by CNTs as a second phase element through PSF method. SEM, XRD, and TEM optical microscopy were used for the compressive evaluation of Al-CNT composite formed by PSF method. Matrix used was Al-23wt%Si powder (10 wt%) and CNTs as reinforcement (95% purity) and were blended and balled milled for 48 hours for their consistent distribution. SG gun was used for spraying plasma over the blended powders mandrel [44]. Authors confirmed the chemical stability of CNTs throughout spray forming and they also found that the density of the prepared composite was more than the theoretical expectations. They made it confirm that addition of CNTs increased the hardness of the composite.

Sun et al., (2004) predicted the stiffness and strength of single walled carbon nanotubes (SWCNTs) by the method of molecular mechanics based finite element approach under tensile load along nanotubes diameter. Thickness of the nanotube was selected as 0.34 nm, which was equal to the graphite layer spacing. From the results, the authors found that the tensile stiffness of SWCNTs was around 0.4 TPa and the tensile strength varied from 77 to 101 GPa. Authors found that the tensile stiffness was independent of both the nanotube diameter and the nanotube helicity. Poisons ratio varied from 0.31 to 0.35 which decreased when diameter of nanotube was increased. They declared that Arm-chair nanotube had biggest tensile strength.

Danaf et al., (2006) surveyed the improvement in mechanical properties and grain dimension improvement of commercial purity Aluminum-1050 (having purity of 99.5%) processed by ECAP. Cylinder-shaped samples of Al-1050 (diameter 12mm) were machined equivalent/parallel to the rolling direction and then were annealed (at a temperature of 500°C) for 24 hours generating a grain extent of 300µm. Graphite was used to lubricate the samples and pressed in the ECAP die at a speed of 10mm/min using an Instron machine and processed up to eight passes. Two routes of ECAP; route C (sample was rotated by 180°) and route B (sample was rotated by 180°) were adopted. After 8 ECAP passes authors found that the average grain size was 1.1µm for route B and 2.9 for route C. They found that the hardness for route B and C increased by a factor of 3.5 and 3.3 respectively (fig 2) and the yield strength for route B and C increased by a factor of 4.2 and 3.8 respectively. This accredited to somewhat smaller average grain size and a little higher disorientation developed in route B.

Kim et al., (2011) for the first time studied the fabrication of semisolid powder pressing SPP for Al6061-CNT. Effect of different temperatures (600°C, 620°C, and 640°C) on the mechanical behavior of the composite was examined. Authors used SPEX 8000M mixer for mixing Al6061 powder with 1.0wt%CNTs and after mixing the mixture was compacted under a pressure of 100 MPa [33]. Al6061 underway melting when 50 MPa pressure was applied at 580°C. Authors made it confirm that there was a complete dispersion of CNTs in Al6061 matrix after applying mechanical alloying method. High relative density (99%) was achieved when consolidating in liquid medium and the maximum hardness value of 87.5 HV was attained at 620°C. Fracture surface was seen (ductile dimples) at a temperature of 640°C.

Sasaki et al., (2011) studied the deformation dependence of thermal conductivity Aluminum built high thermal conductive composites containing CNT and vapor growth carbon fiber VGCF. The composite material was produced by powder metallurgical process. Pure Al powder added 10wt% and Al-12%Si was chosen as matrix. Authors conducted tensile tests to elucidate the strength of composite at different temperatures. Thermal conductivity was measured before and after the tensile tests to elucidate the deformation happening due to the thermal conductivity. The tensile test temperature was kept at 293k, 373k, 473k, 573k, 673k using electrical furnace. For thermal conductivity test 30vol% and 60vol% VGCF were used. The authors found that the interfacial strength between fiber and matrix was improved at high temperature (573k). The internal damage of internal structure of the composite decreased thermal conductivity of the composite however it can be increased by precise control of VGCF orientation.

Ke et al., (2012) simulated the mechanical properties of multi-walled carbon nanotubes (MWCNTs) reinforced in aluminum matrix. The authors carried out the experiment by fabricating the MWCNTs-AL matrix by friction stir processing, and interference between aluminum matrix and MWCNTs was examined. They examined the distribution of MWCNTs using transmission electron microscopy (TEM). Fracture surface was observed by means of scanning electron microscopy (SEM). After the completion of the experiment authors found a 50% to 55% improvement in hardness of matrix after incorporating MWCNTs by FSP. Ultimate tensile strength reached up to 190.2 MPa when 6% of MWCNTs were added. Though the tensile strength of the final material was not stated but the material became brittle.

Park et al., (2014) examined the influence of multi-walled carbon nanotubes (1-18 wt.%) by the method of electromagnetic interference shielding effectiveness (EMI-SE) of highly dense polyethylene (HDPE). Authors prepared the composite by melt compounding process using an interior mixer at 180ºC for 1.5 h. The prepared mixture was then hot pressed at the same temperature for 5 min under 8 MPa to prepare a sheet of 3 mm. EMI-SE of the composite was measured using EMI shielding tester according to ASTM D4935-89 in the frequency range of 0.5-1.5 GHz. After the investigation, it was determined that EMI-SE plus conductivity was improved with intensification in MWCNTs where as volume resistivity of the composite declined with rise in MWCNTs. With the rise in amount of MWCNTs (Wt %), the shielding effectiveness was also enhanced as shown in fig 3.

Arab et al., (2014) implemented the equal channel angular pressing (ECAP) process for refining SiC reinforced in Al- SiC composites (commercial Al 99.84% pure). Al-SiC (55µm) composite with 5 vol% and 10 vol% were fabricated by Stir casting. The SiC were heated at 900°C for 1 hour so as to clean the surface and form oxide layer which improves wettability. The Al was melted in a furnace and stirred using a speed of 300 rpm. When the vortex appeared, SiC powder was added in uniform rate. Composite of cylindrical shape of diameter 15mm and length of 85mm were prepared after machining the cylindrical rod for ECAP process. Authors carried out tensile and compressive tests according to ASTM standards ASTM:E8/E8M and ASTM:E9-09 using LR 300 universal testing machine and predicted that strength was increased but ductility was decreased. More rupture of SiC was found in composite wealthier in reinforcing particles so as to SiC reached approximately 1µm in the Al-10vol%SiC_p after 8 ECAP passes and 4µm in AL-5vol%SiC after 12 ECAP passes.

Simoes et al., (2015) deliberated the effect of dispersion time on the mechanical properties of aluminum carbon nanotubes (Al-CNTs) Nano composites. Aluminum powder having grain size of 22±11µm and 99.99% pure were used with 0.75wt% MWCNTs to create Nano composites. Authors conducted ultra-sonication process in isopropanol (10 to 40 minutes) for the dispersion of MWCNTs with Al powders. Now the mixture of Al particles and carbon nanotubes were pressed uni-axially at 300 MPa followed by sintering at a temperature of 640°C for 1½ hours a furnace (vertical) in a vacuum of 10^{-2} Pa. Microstructural features were achieved by (SEM). Writers showed that the perfect dispersion time for consolidating the aluminum matrix with CNTs was 15 minutes. Furthermore, growth of 50% in the hardness along with growth of 200% in the tensile strength was found when the final composite was compared with pure aluminum under the same conditions.

Lee et al., (2015) clarified the underlying strengthening mechanism together with load allocation, generation of dislocations because of thermal misalliance and Orowan looping method to elucidate the improved mechanical properties of CNT- Al composite. Authors prepared the samples by unusual casting procedure for dispersion of CNTs in Al matrix. The complete procedure involved powder metallurgy, wetting, mixing and then drying at 500°C, after then de-oiling and sintering was carried out at 580°C along with melt blending, casting and then lastly extrusion. They found that the pulverization of Al particles in oil (paraffin) stops the oxidation of Al. The yield strength plus tensile strength of Al-CNT composite was enhanced by 60% and 23%, respectively, with the addition of 0.2 wt% CNTs.

Jahedi et al., (2016) examined the hardness and the microstructure of carbon nanotubes in aluminum matrix (CNTs-Al) composite after reinforcing the CNTs (2 vol %) in Al matrix. Authors were able to get homogeneous distribution of CNTs within Al matrix when they used ultra-sonication process. Authors used B_c equal-channel angular pressing (ECAP) for the synthesizing of CNTs-Al composites. ECAP process comprised of forward extrusion and torsional extrusion. 8 ECAP passes were carried out in this experiment. Authors found that the dispersed CNTs inhibited propagation of dislocations accordingly improved the strength of the composite. Composite which contained (2 vol %) CNTs in Al matrix exhibited 20% rise in hardness relative to all Al samples.

4. RESEARCH METHODOLOGY

The research methodology started with detecting problem and converting that problem in research oriented work. In stir casting process, parameters like rpm of stirrer, pouring conditions, temperature of the molten metal has vital role in homogeneous distribution of MWCNT in Al matrix.

In this study we have to design stirrer keeping in mind the volume of the molten metal in the crucible. The stirrer is to be made up of graphite and cast iron.

4.1 Equipment, materials, and experimental setup

Equipment used for stir casting are furnace (electrical) for melting aluminum 7075 shown in fig 5, crucible of graphite of diameter 12 cm, stirrer for stirring when MWCNT is mixed in molten aluminum in the crucible shown in fig 4, mold of graphite for casting, temperature detector and electronic motor to run the stirrer.

Aluminum alloy

Aluminum is extracted from Bauxite through Bayer process. The most important property of aluminum is its light weight and non-corrosive nature. They are the best replacements of steel in industries. Materials used in this research work are Al 7075 T651 whose compositions and properties have been discussed in table 2 and table 3 respectively.

Property	Value
Atomic number	13
Atomic weight (g/mol)	29.98
Valency	3
Crystal structure	FCC
Melting point	660ºC
Boiling point	2480ºC

Carbon Nano tubes

We are using MWCNTs for reinforcing the molten aluminum. CNT is first mixed with paraffin oil so as to increase its density to avoid agglomeration and floating of MWCNT on the molten aluminum.

The whole set up consists of furnace, motor for rotating stirrer and temperature detector for detecting the temperature fig 5 and fig 4 shows the set up for this work.

6. PROPOSED PLAN

Weeks/Months	September	October	November
Week 1	N/A	Modified the problem to a particular research oriented work and studied about the effectiveness of stir casting	Selected materials for the work. Discussed about the properties to be investigated. Taken Al 7075-T651 as metal matrix and MWCNT as a reinforcement.
Week 2	Discussed with mentor	Literature review	Process study at IIT Ropar and finalized the parameters of the work, prepared crucible for melting aluminum.
Week 3	Searched problems in field of material science and metallurgy.	Literature review	Designed stirrer for stirring the MWCNTY in molten aluminum for homogeneous distribution of MWCNT in aluminum matrix.
Week 4	Finalized the problems and decided the way to work on it, that is stir casting.	Studied about the mold making, mold material, and prepared a mold of graphite of desired shape and dimensions.	Waiting for the schedule to be fixed in IIT Ropar for the work.

Table 1: Materials categorized **by their molecular properties**				
Reinforcing Material/Material under consideration	**Writers**	**Processes involved**	**Matrix material**	**Properties studied**
Single wall carbon nanotubes (SWCNTs)	Cong et al., (2002)	Hydrogen arc discharge process, Stirring and ultra-sonication	Nano aluminum	Hardness
	Sun et al., (2004)	Finite element approach	-	Stiffness and strength of SWCNTs were studied
	Jahedi et al., (2016)	ECAP	Aluminum	Hardness of the composite was studied
Multiwall carbon nanotubes (MWCNTs)	Noguchi et al., (2004)	Nano dispersion method (NDM)	Purity aluminum	Dispersion of CNTs in Al matrix was explained
	Agarwal et al., (2004)	Plasma spray forming technique	Al-23wt%Si	Chemical stability, density and hardness
	Kim et al., (2011)	Semi solid powder processing (SPP)	Al6061	Hardness and distribution of CNTs in matrix
	Ke et al., (2012)	Friction stir processing (FSP)	Aluminum	Mechanical behavior, tensile strength and hardness of composite were studied
	Park et al., (2014)	Diode sputtering technique	dense polyethylene	Conductivity and volume resistivity
	Hee lee et al., (2015)	Powder metallurgy and thermal spray method	-	Yield strength and tensile strength
	Zhang et al., (2015)	Controlled program synthesis	$Fe_3O_4@SiO_2$	Adsorption property of composite was studied
	Bai et al., (2016)	Finite element method	Cu	Strength, ductility and thermal conductivity
	Iwahashi et al., (1997)	ECAP	-	Grain refinement in the composite was studied

Purity Aluminum	Nemoto et al., (1999)	ECAP	Al-1420	Grain refinement and shearing features of Al-1420 alloy
	Danaf et al., (2006)	ECAP using routes B_c and C	Al-1050	Hardness and grain size refinement of the composite
	Paydar et al., (2008)	FE-ECAP	Al particles	Mechanical properties and density of 6061 Al particles

Table 2: Composition of Al 7075-t651 in wt%

Element	**Amount in wt%**
Aluminum (Al)	87.1 to 91.4
Chromium (Cr)	0.18 to 0.28
Copper (Cu)	1.2 to 2
Iron (Fe)	Maximum 0.5
Magnesium (Mg)	2.1 to 2.9
Manganese (Mn)	Maximum 0.3
Silicon (Si)	Maximum 0.4
Titanium (Ti)	Maximum 0.2
Zink (Zn)	5.1 to 6.1
Other (each)	0.05
Other (total)	Maximum 0.15

Table 3: Properties of Al 7075-t651

Physical	Density	2.81 gram/cc
Mechanical	Hardness (V)	175
	Hardness (B)	150
	Ultimate tensile strength	572 MPa
	Yield strength (Tensile)	503 MPa
	Modulus of elasticity	71.7GPa
	Poisons ratio	0.33
	Strength (Fatigue)	159 MPa
	Fracture toughness	20 MPa-m$^{1/2}$ in S-L direction
	Fracture toughness	25 MPa-m$^{1/2}$ in T-L direction
	Fracture toughness	29 MPa-m$^{1/2}$ in L-T direction
	Machinability	70%
	Shear modulus	26.9 GPa

	Strength (shear)	331 MPa
Electrical	Electrical resistivity	23.6µm/m-ºC
Thermal	Specific heat capacity	0.96 J/g-ºC
	Thermal conductivity	130 W/m-K
	Melting point	477-635ºC
Processing	Annealing temperature	413ºC
	Solution temperature	466-482ºC
	Aging temperature	121ºC

7. CONCLUSION AND SCOPE OF STUDY

The study presents the results of reinforcing the Al matrix with MWCNT through stir casting process. After reinforcing the material, we are going to examine several properties and behavior like, yield strength, hardness, coefficient of friction, bonding of grains, grain refinement, chemical stability, ultimate strength, thermal stability, brittle behavior, tensile stiffness, Vickers hardness etc. Homogeneous distribution of the reinforcements in the matrices was a great challenge for the researchers for which they have gone through different methods of fabrication of composites (ECAP, ECAE, FE-ECAP, Stir casting, Plasma spraying, Molecular level mixing, NSD, and NDM). However some experiments have shown that the ECAP has resulted in good homogeneous distribution of reinforcements in the matrices, but we need to concentrate on the number of passes, routes employed and the working temperature and pressure. In this study we are going to mix MWCNT in Al matrix homogeneously through stir casting process. It has been seen that reinforcement of materials have resulted in good will of the composites, so there is a good scope of research in this domain over different materials as there is a great need of composites and Nano composites in the field of science and technology, medical science, aerospace and other different research oriented works.

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FIGURES

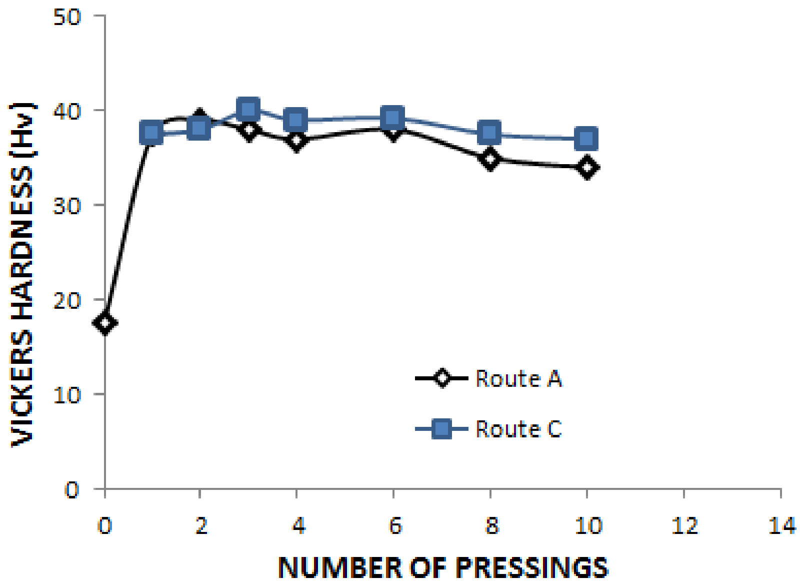

Fig 1: Effect on hardness by increasing the number of Pressings taken Through route A and C, adapted from Iwahashi et al., (1997)

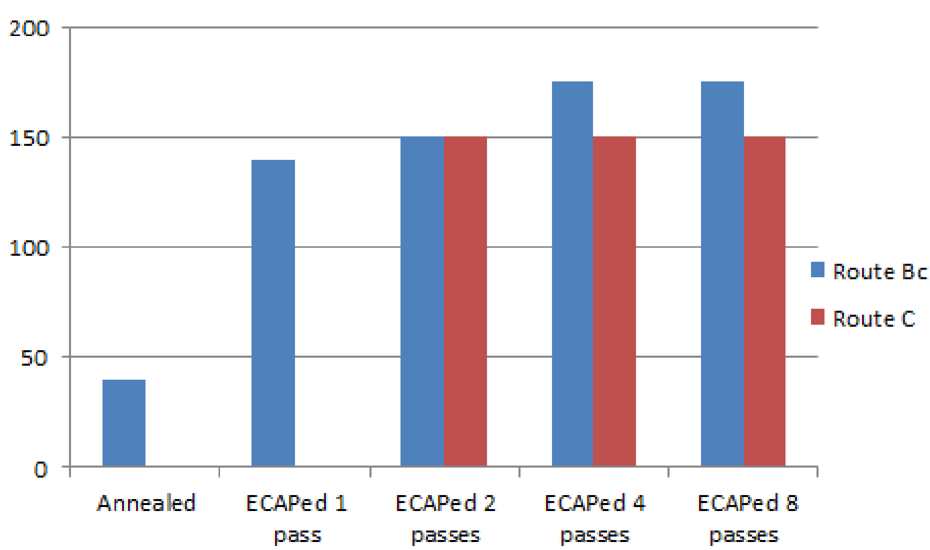

Fig 2: Disparity of yield strength with number of passes for Route C and B_c. Adapted from Danaf et al., (2006)

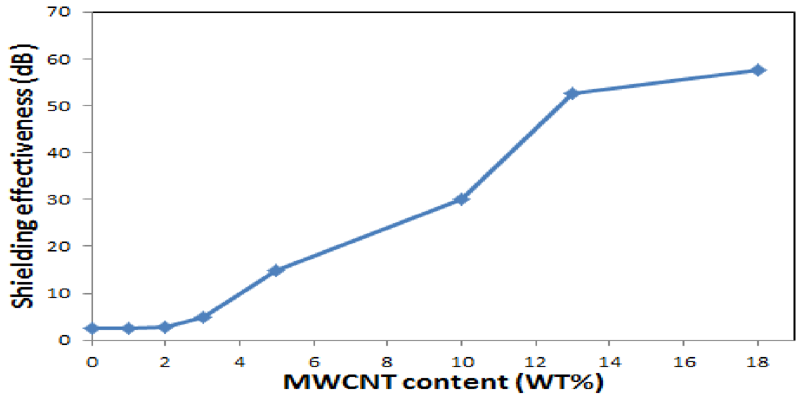

Fig 3: Electromagnetic shielding effectiveness of MWCNTs adapted from Park et al., (2014)


Fig 4: Stirrer used for mixing CNT in Al matrix


Fig 5: Electrical furnace for melting Aluminum