A Brief Review on Design and Development of Filament by Using Composite Material for Additive Manufacturing

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Abstract - 3D printer, nowadays, is most widely used technology in industries. However, Filament used for printing in 3D printer has very minimum range of flexibility in materials, such as ABS, PLA. Therefore, there is far more need of replaceable filament which has more strength, ductility and compactness in availability. By adding composite materials, MWCNT (Multi walled carbon nanotubes), with addition of acetone in ABS produce such characteristics which makes filament very fertile. Moreover, addition of suitable amount of MWCNT i.e 4% in the ABS granules in addition with solvent (acetone), will result into increase in conductivity, tensile strength, thermal properties and better flow rate.

Keywords: MWCNT, ABS, extruder, nano-composites, additive manufacturing.

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1.INTRODUCTION

The term additive manufacturing refers to the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies. Due to the large scope of 3D printing this technology has experienced in the recent decades a great development. The access to 3D printers is becoming easier as the prizes are going down. Nowadays both companies and regular users can develop their own parts in a relatively simple and quickly way. Moreover, the conventional process takes place by removal of material from the object, whereas additive manufacturing make materials by adding layer upon layer. That is why additive manufacturing can significantly reduce material waste, reduce the amount of production steps, inventory being held, and reduce the amount of distinct parts needed for an assembly.

In the modern plastic industry, the existing method and materials are inappropriate to meet the vast demands of manufacturing industry. The raw materials used are ABS (Acrylonitrile Butadiene Styrene) plastic is a thermoplastic polymer often used in the injection moulding process. PLA-polylactic acid and MWCNTs (Multi Wall Carbon Nano Tubes) are elongated cylindrical Nano objects made of sp^2 carbon. Their diameter is 3–30 nm and they can grow several cm long, thus their aspect ratio can vary between 10 and ten million. Kumar produced a carbon nanotube/polypropylene fiber composite material through melt spinning and found that the addition of 5% carbon nanotubes into polypropylene increased the elastic modulus and mechanical strength of the composite by 50% and 100%, respectively. [1]

Therefore, to overcome this, a new solution with improvement in materials by combining the raw materials. Some researchers have come forward to some solutions of addition of various method of carbon Nanotubes in a suitable solution and then dispersed with the polymer. The most used polymer in the additive manufacturing industry are PLA and ABS. However, PLA being widely used due to its pros like flexibility and strength. ABS with low flexibility and difficulties in composing with other polymers makes it a lower usable component as a filament. Shaffer et al. used the chemical modification method for surface modification of carbon nanotubes. The modified carbon nanotubes have static electricity, and the carbon nanotubes could be uniformly dispersed in a polyvinyl alcohol matrix, thus yielding composite materials with stable performances [2]

In this paper, the AM process of 3D printing process is used to study a MWCNTs/ABS composite materials and method to prepare it. To study the effects on the properties such as, thermal, optical, mechanical and flow

rate will be studied, and process to print the composites material are mentioned.

2. LITERATURE REVIEW ON ABS AND MWCNTS CHARECTERISTICS.

Nowadays, additive manufacturing processes applied by all industries. Composite material can give better results in these processes. Some research had done on various composite material. Research on ABS and MWCNTs is discussed in this section.

Mohammed H Al-Saleh et al. [3] researched about ABS-MWCNT composite material. They have concluded that MWCNT/ABS Nano composites filled with 0.25 wt% up to 10 wt% MWCNT were prepared by solution processing. Based on the TEM analysis, selective localization and perfect dispersion of MWCNTs within the SAN phase of the ABS polymer matrix was observed. Dielectric behaviours of the Nano composites were investigated to determine current conduction mechanisms and the development of the conductive network within the polymer matrix as a function of MWCNT concentration. For Nano composites filled with MWCNTs in the range from 0.25 to 4 wt%, conductivity might be due to tunneling in addition to direct contact between conductive nanoparticles. However, direct contact was the conduction mechanism for Nano composites filled with at least 7 wt% MWCNT. For Nano composites filled with up to 4 wt% MWCNTs, it was found that there is a critical frequency (characteristic frequency) at which the Nano composite electrical conductivity switch from frequency independent to frequency dependent. The characteristic frequency was found to increase with the increase in MWCNT concentration revealing the construction of more interconnected MWCNT pathways.

Sahil Kapoor et al. [4] discussed about Fabrication of ABS/MWCNTs Nano composite was done using solvent blending technique and the films obtained from fabrication were moulded into dog bone shaped samples using compression moulding machine for mechanical testing. The Morphological Characterization of the Nano composite films using FE-SEM show that at lower percentages of 1% MWCNTs are excellently and uniformly dispersed in ABS, at 5% dispersion is good but there are places were accumulation of MWCNTs is visible and at 10% the MWCNTs get closely entangled. From the Raman spectrum of all the percentages of ABS/MWCNTs Nano composite we could conclude the presence of MWCNTs due to presence of signature D and G peaks of MWCNTs. Results of Young's modulus shown in the table 1 and figure 5, indicate significant enhancement in Young's modulus at various compositions of MWCNTs in ABS. The following factors are responsible for the enhancement in Young's modulus of ABS/MWCNT Nano composite which are high aspect ratio (length/diameter) and high surface/volume ratio of MWCNTs. These factors improve the load transfer and reduce stress concentration zones in the Nano composite. At lower percentages of MWCNTs in ABS/MWCNTs Nano composite the improvement in the Young's modulus is more due to good dispersion of MWCNTs and which further leads to strong adhesion between MWCNTs and ABS and ensures proper transfer of stress from polymer matrix to the Nano filler, thus improving the Young's modulus of Nano composite. Finally we can conclude that incorporation of MWCNTs in ABS improves its mechanical properties and major improvement is shown at lower percentages [5-8].

Eshwar Reddy Cholleti et al. [9] had done work about ABS-MWCNT. They concluded that This work has shown that it is currently possible to synthesize MWCNT/ABS Nano-composite materials that are compatible with commercial off-the-shelf 3D printers. This work has shown that Nano-composite materials have functionality in a 3D printer and that even in ultra-high concentrations can be made into viable composites. 51 % increase in tensile strength by coating MWCNT to pure ABS filament and 25.6% increase in tensile strength by mixing MWCNT to ABS is observed. The increase in 30% of flexural strength by coating MWCNT to ABS filament is observed and the increase in 17% of flexural strength by mixing MWCNT to ABS as per the result obtained by performing the three point bend test. The study of this filaments microscopically reveals the increase is the strength is in contrast of increase in the brittleness of the filament is due to the propitiatory adhesive agent which is the herbal extract. There is a drastic decrease in the surface resistance is observed by adding or coating of MWCNT to ABS

filament, this opens avenues to the vast application of this filaments in electronic applications.

JinjieLuo et al. [10] concluded that By combining melt compounding with the FDM technology, MWCNT/PLA composite wires with different MWCNT contents were prepared. Their microstructure, electrical conductivity, mechanical properties, rheological property, and thermal properties were investigated. When the MWCNT content was less than 5 wt%, the surface of the composite wire was relatively smooth. MWCNTs as fillers significantly enhanced the conductivity and mechanical properties of the composites, and the flow rate and thermal performance of the composites were stable. The MWCNTs may have formed a stable compatible structure in the PLA matrix. Test samples obtained through 3D printing could be effectively produced in shapes such as bar, line, cylinder and cube-like geometries. In summary, the prepared MWCNT/PLA composite wire met the requirements of most 3D printers, which can significantly enable the manufacture of conductive composite products by 3D printers in the future.

Ahmad Aqel et al. [11] said that Multi-walled carbon nanotubes (MWCNTs) can be considered as a collection of concentric SWCNTs (consist of multiple layers of graphite rolled in on themselves to form a tube shape) with different diameters. The length and diameter of these structures differ a lot from those of SWCNTs and, of course, their properties are also very different (Iijima and Ichihashi, 1993). The interlayer distance in MWCNTs is close to the distance between graphene layers in graphite, approximately 3.3 A ˚. The special case of MWCNTs (double walled carbon nanotubes DWCNTs) must be emphasized here because they combine very similar morphology and properties as compared to SWCNT. DWCNT synthesis on the gram scale was first proposed in 2003 (Flahaut et al., 2003) by the chemical vapour deposition (CVD) technique, from the selective reduction of oxides solid solutions in methane and hydrogen.

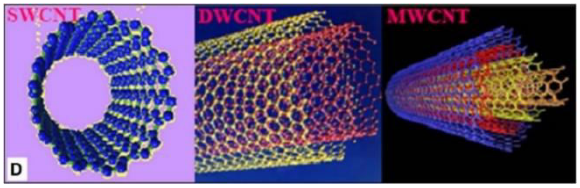

Fig 1 : showing different types of CNTs and other carbon structures: (A) Flat sheet of Graphite, (B) Partially rolled sheet of graphite, (C) SWCNT, (D) Structures of the three CNT types; SWCNT, DWCNT, and MWCNT, respectively.

S.John Alexis [12]Said that ED-x analysis of MWCNT and the strong reflection peak was found between 12o – 28o. The peak in the ED-x pattern of MWCNT shows the cylindrical nature of grapheme sheets nested together and it is in multiwall nature. AA5083 alloy added with MWCNT by compo-casting method to increase the uniform dispersion of MWCNT. Thus, the AA5083 and MWCNT mechanical interaction has been achieved. The fig. shows the surface morphology of the cast AA5083 and AA5083/MWCNT composite with a particle uniform dispersion and a minimum amount of cluster formation of MWCNT was observed in the AA5083/MWCNT composite.

PunitaKumari [13] had described that MWCNT-CNF According To Wt. % Has Been Measured And Well Grinded. Required Amount Of Epoxy Resin Has Been Taken And Put In The Homogenizer And Mixed It For 2 Minute After That Small Amount Of MWCNT-CNF Powder Has Been Added In The Resin Solution And Mixed It By Homogenizer For 10 Minute. Required Amount Of MWCNT-CNF Has Been Divided Into 6-7 The Batches Each Batch Has Been Subjected In The Resin Solution At 10 Minute Interval To Get Well Dissolve And Homogenous Resin And MWCNT-CNF Solution. The Whole Mixing Process Has Been Carried Out In Presence Of Ultra-Sonic Bath. Ultra- Sonic Bath Is A Technique To Reduce The Temperature Of The MWCNT-CNF And Resin Mixture; Which Is Overheated By Homogenizer Probe. In This Process Whole Mixing Experiment Has Been Taken Place In One Tub That Should Be Filling By Ice And The Mixture Of MWCNT-CNF, Resin Has Been Kept Between In Ice; Remember That Ice Should In Plastic Packet. Plastic Is Insulator, It Seal The Moisture Of Ice So That MWCNT-CNF Won't Affect By Any Ice Moisture. After Sonication Process Hardener Has Been Added In The Resin Mixture And Mixed It By Homogenizer For 5 Minute. Fabrication of Specimen Glass Has Been Cut Into Ten Pieces. Modified Epoxy Resin Has Been Dispersed Between 9th And 10th Layer.

Silver Paste Applied On Top And Bottom Of 10th Layer Glass Fiber Sheet For Conductivity Medium. Vacuum Resin Transfer Molding Method Is Used To Fabrication Glass Fiber Alone With Modified Epoxy Resin. All Glass Fiber Kept Together, Modified Epoxy Resin Has Been Dispersed Between 9th And 10th Layer By Roller Fabrication Area Was Closed With Bagging Material Then Vacuum Was Created Through Pump Resin And Hardener Mixture Infused By Infusing Pipe.100:12 Resin Hardener Mixtures Has Been Taken. Curing Time Is 24 Hour; Fabrication Has Been Left For 24 Hour At Room Temperature.

Table 1: *Summary of LiteratureReview.*

Author	Year	Fiber	Matrix	Measurements
Haya k al-anid*et al.* [3]	2013	CNT	ABS	Impedance characteristics.
Sahil Kapoor*et al.* [4]	2017	MWCNT	ABS	Fabrication of ABS and MWCNT.
Ian Gibson*et al.* [9]	2018	MWCNT	ABS	ABS nano composite materials.
JinjieLuo*et al.* [10]	2018	MWCNT	PLA	Research on application of MWCNTs/PLA in additive manufacturing.
Ahmad Aqel*et al.* [11]	2016	-	MWCNT	Properties of MWCNTs.

3. SCOPE OF WORK

Available filament in this area is very limited throughout the industries, hence it demands more flexible filament with high range of availability at lower price. Moreover, India has no manufacturer of composite filament, therefore this research will boost market value of composite filament in Indian industries, which do not have to rely on foreign manufacturer. Adding into it, ABS+MWCNTs is not available in international market too. However, there are many obstacles which arises during the experiment such as porosity, ductility, suitable solvent and printing of the filament.

Range of Material

There are many single polymer materials available for 3D printers. The composite materials are rarely available in the market and that too costlier than the base materials. However, the characteristics of such composite materials are much better than single polymer but composite material with MWCNTs has higher characteristics. Addition of MWCNTs in polymer conclude in high strength and better thermal properties. Mainly used polymers are ABS, PLA, polyamide and polycarbonate. Addition of MWCNTs in these polymers can give better results and better application in industries.

Printing Quality

It is very easy to print complex parts with better surface finish and dimensional accuracy with the material which have better material flow rate and easily achievable melting point. It can be achieved by ABS and MWCNTs composite material. This material has minimal change in melting point of single ABS, and it is have better and smooth flow than ABS.

Nozzle Clogging

Some composite material having fiber can clog the nozzle and it affects the life of printing nozzle. The composite material ABS and MWCNTs will have better flow of material, so the clogging of printing nozzle can be neglected by this combination. However, we can say that the life of printing nozzle is increased.

Porosity

The increase in amount of MWCNTs is resulting in increase in strength of material, but by increasing volume of MWCNTs in mixture, the porosity in the composite material is generated. The addition of MWCNTs in the mixture is limited upto 4% to achieve good results and make material with nil porosity.

Machine Constraints

Additive manufacturing has the advantage that it can print very complex part easily with better quality. But it takes more time to print an object. Some changes are needed in the technology to print object with better surface finish in minimum required time.

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