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AN INVESTIGATION INTO 3D PRINTING OF FIBER REINFORCED THERMOPLASTIC COMPOSITES

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ABSTRACT:

Three-dimensional (3D) printing has been successfully applied for the fabrication of polymer components ranging from prototypes to final products. An issue, however, is that the resulting 3D printed parts exhibit inferior mechanical performance to parts fabricated using conventional polymer processing technologies, such as compression moulding. The addition of fibres and other materials into the polymer matrix to form a composite can yield a significant enhancement in the structural strength of printed polymer parts. The printing is done layer by layer (Additive manufacturing) using plastic, metal, nylon, and over a hundred other materials. 3D printing has been found to be useful in sectors such as manufacturing, industrial design, jewellery, footwear, architecture, engineering and construction, automotive, aerospace, dental and medical industries, education, geographic information systems, civil engineering, and many others. It has been found to be a fast and cost effective solution in whichever field of use. The applications of 3D printing are ever increasing and it’s proving to be a very exciting technology to look out for. In this paper we seek to explore how it works and the current and future applications of 3D printing.

Keywords: 3D printing, Additive manufacturing, metal, polymer.

I. INTRODUCTION:

3D printing or additive manufacturing (AM) is a process for making a 3D object of any shape from a 3D model or other electronic data sources through additive processes in which successive layers of material are laid down under computer controls. [1]Hideo Kodama of Nayoga Municipal Industrial Research Institute is generally regarded to have printed the first solid object from a digital design. However, the credit for the first 3D printer generally goes to Charles Hull, who in 1984 designed it while working for the company he founded, 3D Systems Corp. Charles a

Hull was a pioneer of the solid imaging process known as stereo lithography and the STL (stereo lithographic) file format which is still the most widely used format used today in 3D printing. He is also regarded to have started commercial rapid prototyping that was concurrent with his development of 3D printing. He initially used photopolymers heated by ultraviolet light to achieve the melting and solidification effect. [2]Since 1984, when the first 3D printer was designed and realized by Charles W. Hull from 3D Systems Corp., the technology has evolved and these machines have become more and more useful, while their price points lowered, thus becoming more affordable. Additive manufacturing techniques, such as FFF, commonly known as 3D printing, have an underappreciated similarity to those of traditional composite materials, as both are inherently based on stacking a series of discrete layers. It is therefore reasonable to suggest that successful adaptation of 3D printing technologies to composite materials could enable a simple composite manufacturing method with lower production cost and a high degree of automation. As reinforcements can be accurately placed, the laminated structure of composite parts can be further optimised in each layer, allowing for an increase in design freedom and mechanical performance. While still a relatively undeveloped avenue of research, there is at least one company developing commercial 3D printers capable of processing continuous fibre reinforced composite materials: Mark Forged [2]. The Mark One and Mark Two printers developed by Mark Forged print continuous carbon fibre reinforced Nylon with mechanical properties an order of magnitude higher than common 3D printers, and open new applications in both the personal fabrication market and in the manufacture of lightweight parts for industry.

MAIN OBJECTIVE:

Interestingly, the cost of acquiring 3D printers has been decreasing with the advancement of technology. Domestic usage of 3D printers has been on the rise with the average cost ranging from a few hundreds of dollars going up. However, one major drawback is that it requires expertise to print 3D objects. The traced pattern hardened into a layer, thanks to the laser, and that was how you built an object out of plastic. Since then tremendous progress has been made in additive manufacturing such that material extrusion is now used. By this method, an object is built out of matter that is pushed from a mechanical head like the way an inkjet printers extrudes ink onto paper.

II. RELATED STUDY:

Nowadays, rapid prototyping has a wide range of applications in various fields of human activity: research, engineering, medical industry, military, construction, architecture, fashion, education, the computer industry and many others. In 1990, the plastic extrusion technology most widely associated with the term "3D printing" was invented by Stratasys by name fused deposition modeling (FDM). After the start of the 21st century, there has been a large growth in the sales of 3D printing machines and their price has been dropped gradually. By the early 2010s, the terms 3D printing and additive manufacturing evolved senses in which they were alternate umbrella terms for AM technologies, one being used in popular vernacular by consumer - maker communities and the media, and the other used officially by industrial AM end use part producers, AM machine manufacturers, and global technical standards organizations. Both terms reflect the simple fact that the technologies all share the common theme of sequential-layer material addition/joining throughout a 3D work envelope under automated control. Other terms that had been used as AM synonyms included desktop manufacturing, rapid manufacturing, and agile tooling on-demand manufacturing. The 2010s were the first decade in which metal end use parts such as engine brackets and large nuts would be grown (either before or instead of machining) in job production rather than obligatory being machined from bar stock or plate. Material extrusion based 3D printing techniques, such as FFF and Fused Deposition Modelling (FDM), are manufacturing processes where a solid thermoplastic material is extruded through a hot nozzle. The viscous material solidifies on the build plate which allows build-up of a part with dimensional accuracies typically in the order of 100 µm [4]. The most commonly used thermoplastics for this process are acrylonitrile butadiene styrene (ABS) and polylactic acid (PLA), with typical bulk strengths between 30–100

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MPa and elastic moduli in the range of 1.3–3.6 GPa [5]. Mechanical properties of 3D printed parts, however, can deviate significantly from the material bulk properties due to the specifics of how a structure is formed on the meso-scale during printing [6]. To maximise the mechanical performance of printed parts, the key elements of the printing process and how they affect final print quality must be understood (Fig. 1). Turner et al. [4,7] provide an extensive review on FFF process modelling, including the flow and thermal dynamics of the melt, the extrusion process and the bonding process between successive layers of material. Temperature, viscosity and surface energy of the melt play an important role in how the material flows through the nozzle and more importantly, how the final interface between the beads is formed.

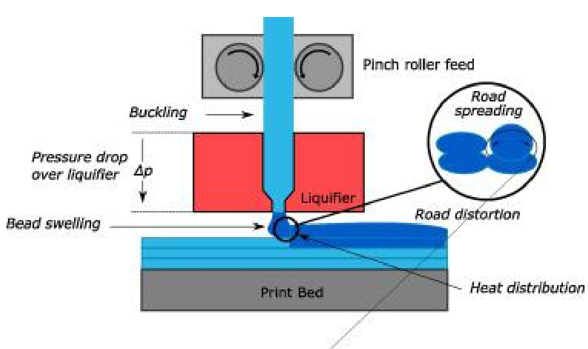

Fig.1.3D printing model.

III. PROPOSED METHODOLOGY

Design model:

3D printable models can be created with the help of CAD design packages or via 3D scanner. The manual modeling process of preparing geometric data for 3D computer graphics is similar to method sculpting. 3D modeling is a process of analyzing and collecting data on the shape and appearance of an object. Based on this data, 3D models of the scanned object can be produced. Both manual and automatic creations of 3D printed models are very difficult for average consumers. That is why several market-places have emerged over the last years among the world. The most popular are Shape ways, Thing verse, My Mini Factory, and Threading.

Manufacturing:

3D printing has introduced an era of rapid manufacturing. The prototyping phase is now able to be skipped and go straight to the end product. Car and aeroplane parts are being printed using 3D printing technology. The printing of parts is being done in a fast and efficient manner thus contributing immensely to the value chain. Customised products are able to be manufactured as customers can edit the digital design file and send to the manufacturer for productions. Nokia Company has taken the lead in manufacturing in this area by releasing 3D design files of its case to its end users so they can customise it to their specifications and get the case 3D printed.

3D Printing of Continuous Fibre-Reinforced Composite:

The incorporation of short fibre reinforcement can usually increase the stiffness of the resulting composite; however, the part strength is often only marginally increased. This is due to reliance on the matrix material to transfer loads between fibres. In contrast, a continuous fibre reinforcement transfers and retains primary loads within unbroken strands of fibre, and this results in a significantly lower load transfer through the polymer and allows for a load-bearing capacity orders of magnitude higher than that which short reinforcement is capable of achieving. In the case of continuous fibre composites, the polymer serves to transfer off-axis loads between fibres, such as shear forces.

Two main categories of continuous fibre printing have been described in the literature, these being “in-situ fusion”, and “ex-situ prepreg”. The in-situ systems utilise two input materials, typically a dry fibre feedstock (the reinforcing fibre) and a neat polymer (the matrix polymer), which are combined together during the printing process. One of the most widely used techniques is known as “in-nozzle impregnation”. In this process, the dry fibre is typically pre-threaded through the printer nozzle prior to printing, and the fibre is also preheated using a coil heater or IR lamps, so as not to excessively cool the molten polymer during printing. The polymer is fed by a motor-driven hobbed gear into the melt zone of the hot-end, and the preheated fibre and melted polymer converge in this melt zone where they are pushed together by the feeding polymer filament.

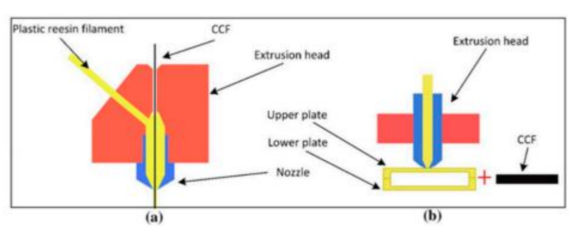

Fig.2. Schematics of in-situ fusion techniques.

The “ex-situ prepreg” systems separate the manufacturing of the

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filament and the printing of the composite into two separate steps. This allows for greater control over the individual processes. As with in-situ systems, the method utilises two input materials (a fibre tow and polymer); however, these are combined together prior to printing into a pre-impregnated filament (prepreg), via a separate extrusion process.

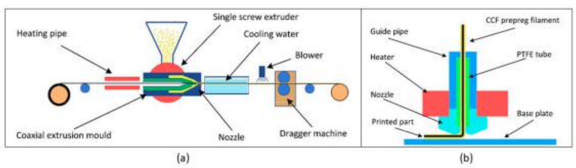

Fig.3. Schematics of ex-situ prepreg.

5. CONCLUSION:

This paper provided an overview of the use of the fused filament fabrication technique for the manufacture of both short and continuous fibre-reinforced polymeric materials, along with details of the mechanical properties of the resulting composites. The most widely reported short fibres in the literature are those of carbon and glass fibres, which is primarily due to the application focus within aerospace and automotive. Several other reinforcement fibres, including basalt, aramid and jute (and other natural fibres), are also reported, and have also been shown to improve the mechanical properties of polymer composites. d multi-input print heads for proper polymer–fibre infusion. Two primary methods of continuous composite printing have been highlighted. "In-situ fusion" shows great promise for the rapid manufacturing of composite parts, with potential to produce variable volume fraction parts with a single manufacturing process. This technique, however, typically produces inferior quality parts due to entrained air contents and poor polymer permeation. "Ex-situ prepreg" provides superior quality parts with lower air contents and excellent polymer infusion, at the expense of a more complex multi-stage manufacturing process.

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