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Investigation into the Development of an Additive Manufacturing Technique for the Production of Fibre Composite Products

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Abstract

The advancements in manufacturing technology over recent years have made Additive Manufacturing, a breakthrough technology in the designing and manufacturing field. This paper discusses the possible applications of Additive Manufacturing (AM) techniques for the production of Carbon Fibre (CF) components without the aid of mould or plug used by traditional methods. This paper investigates the available AM designing techniques to experimentally prove the validity of the research to develop a design concept that can be embedded into an AM machine as a 3D Printer. Polylactic acid (PLA) tensile test specimens are produced with CF reinforcement using both traditional moulding and AM techniques. The preliminary mechanical testing of moulded specimens with fibres revealed a tensile strength increase of up to 73% when compared to specimens without fibres and the testing of PLA filaments produced by AM with fibres showed a performance increase of 66% when compared to filaments without fibres.

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Keywords: Additive Manufacturing; 3D Printing; Fibre Printing; Composites.

1. Introduction

In the world of manufacturing technology, there are occasional breakthroughs that have the potential to transform the industry, empowering existing products to be made faster, cheaper and better, opening up a realm of new possibilities in product development [1]. Additive Manufacturing (AM) is such a technology which is capable of

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manufacturing complex structures directly from a CAD model with less wastage of resources [2]. This paper discusses the possible applications of AM techniques for the production of Carbon Fibre (CF) composites without the aid of mould or plug used by the traditional methods. As the manufacturing industries are considering benefiting from the AM designing techniques, there has been only limited research work done on the possibilities of using fibres as a material in these techniques [1-5].

The research in this area has recently received more attention due to the popularity of user friendly 3D printers, where the users can change the machine's operating mechanisms to suit their specific purpose. Because of the complexity offered in manufacturing by AM technology and the strength to weight ratio offered by fibres such as CF, researches are working on combining these two technologies. At the Zurich Centre of Structure Technologies, researchers are working on laminating the geometrically complex manufactured AM parts with sheets of CF to increase the strength [3]. They used epoxy prepregs to bond the CF sheets, for which additional curing processes are required. Further research is also being carried out to provide efficient co-bonding of epoxy between the AM parts and the CF sheets. The thermoset composites have been in use for many years and are manufactured by traditional methods. However thermoplastic composites have many advantages over thermoset composites [2]. And they can also be altered even after the product is finished as their chemical bonding is completely reversible [4]. For this reason the matrix material preferred is a thermoplastic rather than a thermoset. It is because of these properties, thermoplastics are used in similar researches at Toyohashi University of Technology, which involve sandwiching the 3D printing parts with CF layers in a heated oven [5].

This paper investigates the available AM designing techniques to prove the potential and significance of the research in this area. The main aim of this research is to produce the CF parts at a one-time process using the AM technologies available, similar to building 3D parts from a CAD design in one go. This can be achieved by designing an extruder for a 3D printer which can extrude thermoplastic material and fibres. The printed components will be benchmarked with other AM products by conducting structural tensile tests to analyse their performance under various environmental conditions.

Nomenclature

AM	Additive Manufacturing
3D	Three dimensional
PLA	Polylactic acid
ABS	Acrylonitrile butadiene styrene

2. Methodology and Experimental Procedure

Selecting the material for the experimental work is very crucial as it determines the strength of the final parts. The most widely used thermoplastic materials are Polylactic acid (PLA) and Acrylonitrile butadiene styrene (ABS). The bonding of these materials is studied at various temperatures as this determines whether resins can be excluded from the work or not. So the behaviour of these materials as binders are studied for the proper selection of the resources required for generating the design concept. The experimental work involves producing Dumb-bell shaped specimens of thermoplastic and thermoplastic with fibres, and these specimens are tested for structural strength analysis. After considering the required criteria such as mechanical properties and the structural behaviour of the materials under various environmental temperature conditions, the working of AM machines used for the deposition of layers and building the parts are studied. Depending on the results obtained by previous studies and observations, a CAD model of the final product is designed using SolidWorks software and is tested for structural tensile and environmental failures. Once the testing of the model is finished, a physical prototype is manufactured and is embedded into the machine for part building. Based on the research done, a decision has to be made whether resins are to be used as binders or not and also whether to develop a single nozzle multi-material extruder system or multi-nozzle system to extrude the materials individually. Once the test specimens are built with carbon fibre by the modified printer, preliminary tests are done on these specimens for structural performance and case studies are developed by benchmarking them with the parts printed by the commercially available industry leading printers.