EFFECT OF LAYER THICKNESS AND FILL ANGLE ON FLEXURAL PROPERTIES OF CARBON FIBRE REINFORCED ABS PRINTED PART

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DECLARATION

"I hereby declare that the work in this report is my own except for summaries and quotations which have been duly acknowledged."

Signature: ....

Author : AMIRAH DIYANA BT AHMAD AZAN

Date : ....

SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature :..................................

Name of Supervisor : DR. MOHD NIZAM BIN SUDIN

Date :..................................

DEDICATION

For my beloved parents

for raising me to believe everything is possible!

and

my family

ABSTRACT

Fused deposition modelling (FDM) is a rapidly growing 3D printing technology. However, printing materials are restricted to acrylonitrile butadiene styrene (ABS) or polylactic acid (PLA) in most Fused deposition modelling (FDM) equipment. Here, this project on a new high-performance printing material, Carbon Fibre reinforced ABS, which could surmount these shortcomings. This project is dedicated to studying the influence of layer thickness and fill angle on the mechanical properties of 3D-printed specimens. Specimens with three different layer thicknesses (0.18mm, 0.25mm and 0.31mm) and fill angles (30º, 45º and 90º) were built using a 3D printing system and their flexural strengths were tested. The optimal mechanical properties of ABS specimens were found at a layer thickness of 0.25mm and a fill angle of 45° and for Carbon Fibre reinforced ABS obtained 0.18mm layer thickness and 45° fill angle. To evaluate the flexural properties of Carbon Fibre reinforced ABS specimens, a comparison was made between the mechanical properties of 3D-printed Carbon Fibre reinforced ABS and acrylonitrile butadiene styrene (ABS) parts.

ABSTRAK

Pemodelan Pemendapan Bersatu (FDM) adalah teknologi percetakan 3D berkembang pesat. Walau bagaimanapun, bahan-bahan percetakan adalah terhad kepada styrene acrylonitrile butadiene (ABS) atau asid polylactic (PLA) dalam kebanyakan terlakur pemodelan pemendapan (FDM) peralatan. Di sini, melaporkan pada bahan cetak yang berprestasi tinggi yang baru, gentian karbon bertetulang ABS, yang boleh mengatasi kelemahan ini. Kertas ini adalah khusus untuk mengkaji pengaruh ketebalan lapisan dan mengisi sudut atas sifat mekanik spesimen 3D bercetak. Spesimen dengan tiga ketebalan lapisan (0.18mm, 0.25mm dan 0.31mm) dan mengisi sudut (30º, 45º dan 90º) telah dibina menggunakan sistem percetakan 3D dan kekuatan lenturan mereka telah diuji. Sifat-sifat mekanikal yang optimum spesimen ABS ditemui pada ketebalan lapisan 0.25 mm dan sudut mengisi 45 ° dan untuk serat karbon bertetulang ABS diperolehi 0.18mm ketebalan lapisan dan 45 ° mengisi sudut. Untuk menilai sifat-sifat lenturan gentian karbon bertetulang spesimen ABS, perbandingan yang telah dibuat di antara sifat-sifat mekanikal 3D bercetak Fiber Carbon bertetulang ABS dan acrylonitrile butadiene styrene (ABS) bahagian.

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LIST OF ABBEREVATIONS

ABS	Acrylonitrile Butadiene Styrene
PLA	Polylactic acid
3D	3 Dimensional
ASTM	American Society for Testing and Materials
FDM	Fused-Deposition Modelling
CAD	Computer Aided Design

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LIST OF SYMBOL

C = Celcius

mm = Milimeter

CHAPTER 1

INTRODUCTION

1.1 Background

The material extrusion additive manufacturing (AM) process, commonly known as fused deposition modeling (FDM) is well known for its use in producing prototypes for concept modeling, pre-surgical models in medical applications, and various other uses. Fused deposition modeling (FDM) is such a layered manufacturing technology that produces parts with complex geometries by the layering of extruded materials, such as durable acrylonitrile butadiene styrene (ABS) plastic. In this process, the build material is initially in the raw form of a flexible filament. The feedstock filament is then partially melted and extruded though a heated nozzle within a temperature controlled build environment. According to Sun (2008), the material is extruded in a thin layer onto the previously built model layer on the build platform in the form of a prescribed two-dimensional (x-y) layer pattern. The deposited material cools, solidifies, and bonds with adjoining material. After an entire layer is deposited, the build platform moves downward along the z-axis by an increment equal to the filament height (layer thickness) and the next layer is deposited on top of it.

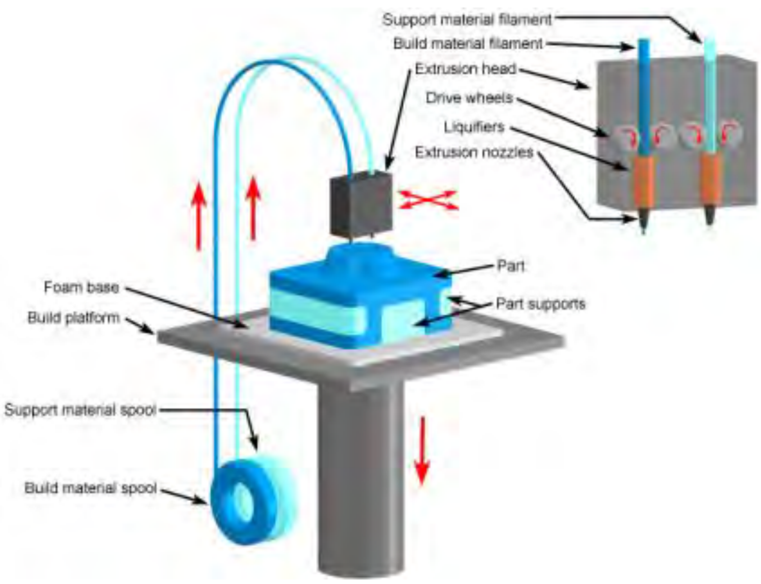

Figure 1.1: Schematic of the FDM process

Now days, there has been an ever-increasing study in composite materials for many types of industry in the world such as automotive industry and in many other fields (A.S Singha, 2009). Acrylonitrile-Butadiene-Styrene (ABS) currently used in making the filament. It is a rubber toughened thermoplastic, characterized by its notch insensitivity and low cost. Other than that, the disadvantages of ABS are poor flame and chemical resistance, and low thermal stability (L.A Utracki, 2002).

This paper presents the flexural test are carried out to determine the flexural properties of carbon fiber reinforced abs printed parts. By verifying the effect of layer thickness (0.18mm, 0.25mm and 0.31mm) and fill angle (30º, 45º and 90º) for the printed parts.

1.2 Problem Statement

Printed part layer by layer by using ABS material reported brittle due to the flexural strength and studies on ABS reinforced with carbon fiber have received less attention. The previous studies mainly usually focus on ABS only. The present study will focus on the effect of adding carbon fiber into ABS. The effect of adding certain percent of carbon into ABS has not yet been reported. This proposed study hopefully will contribute to further the knowledge in the area of carbon fiber reinforced ABS printed part.

1.3 Objective

The objectives of this project are as follows:

1. Comparing and evaluating the effect of layer thickness and fill angle on flexural properties of carbon fibre reinforced ABS.

1.4 Scope of Project

The scopes of this project are:

1. Flexural test carried out to determine effect of layer thickness and fill angle.
2. Preparing the specimen by using 3D printing technique with specific dimension and composition (pure ABS and 15% carbon).

CHAPTER 2

LITERATURE REVIEW

2.1 Acrylonitrile Butadiene Styrene (ABS)

2.1.1 Introduction

Acrylonitrile Butadiene Styrene (ABS) is a common end-use engineering material that allows to perform functional tests on sample parts in FDM. ABS is the combination of three different monomers Acrylonitrile, Butadiene, and Styrene to form a single polymer as shown in Figure 2.1(a). Acrylonitrile primarily offers chemical resistance and heat stability; butadiene delivers toughness and impact strength; and the styrene component provides ABS with balance of clarity, rigidity, and ease of processing (Svec, 1990). ABS has the highest use for thermoplastic in worldwide due to the characteristic itself.

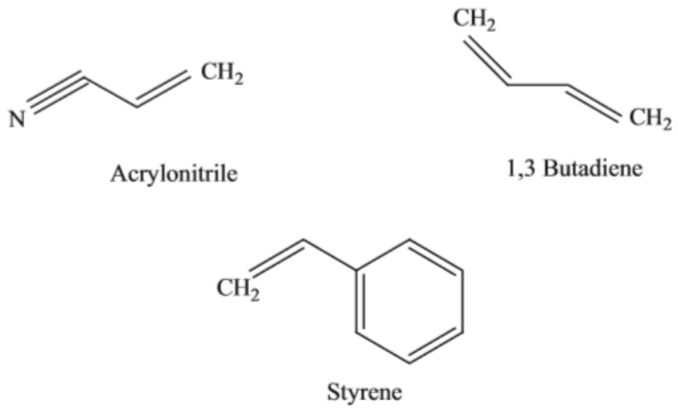

Figure 2.1(a): Monomers unit of ABS

As stated by Norbert (1971), the important characteristic of ABS in engineering thermoplastics is their stress-strain behaviour in flexure. Such measurements are usually made using a simple supported beam test specimen loaded at mid-span according to ASTM D790. The flexural strength at yield and flexural modulus can be used to determine the resistance of a product to short-term loadings. They are also useful in comparing the strength and rigidity of the many ABS products. According to Sharon (2016), ABS polymers exhibit high toughness (even in cold conditions), adequate rigidity, good thermal stability, and high resistance to chemical attack and environmental stress cracking. Other significant properties of ABS include cheapness, durability, and low coefficient of thermal expansion. This high impact ABS marks the boundary in price and performance between commodity and engineering thermoplastics (Fried, 2009). The common properties of ABS are it have a good resistance to heat and high toughness. Properties of ABS determined by morphological parameters and molecular parameter.

Acrylonitrile butadiene styrene (ABS) is one of the most widely used of the rubber toughened commercial plastics. A blend of polybutadiene rubber phase and styrene acrylonitrile copolymer (SAN) rigid phase are the phases of ABS. ABS is found in an extensive range of applications because of its excellent balance of mechanical properties, processing latitude, recyclability and economics. It can be further blended with other materials, thus the scope of possible applications is broadened (Jin, D. W. H, 1998).

2.1.2 Uses

ABS usually used in many technology industry such as automotive industry as shown in Figure 2.1(b). This is because of the price is cheap compared to other polymers. The performance ratio is a high rank. For interior injection molded application, high heat, general purpose, and low-gloss grade have been developed for application (Shahrir, 2006). Other manufacturers also use ABS to their product to product better quality of product. It is a commonly and extremely used thermoplastic that is used to manufacture appliance housings, shoe heels, pipes, chairs, insulated wires, automotive parts and pump impellers for 8 washing machines. Some notable properties of ABS are excellent impact strength and high rigidity, very good chemical and heat resistance properties, good creep resistance under heavy load and very low moisture absorption (Basdekis, C. H., 1964).

Figure 2.1(b): Example components in automotive industry

2.1.3 3D filament

When ABS act as 3D filament in Figure 2.1(c), printing with ABS usually operates with hot end nozzle and bed in the certain temperature. The melt temperature for ABS is about 200ºC to 250ºC. Furthermore, ABS have difficulty during moulding process because of low thermal conductivity. Thermal properties of ABS depends on their glass transition temperature, T_g. When the temperature of T_g increase, the flexural strength will decrease.

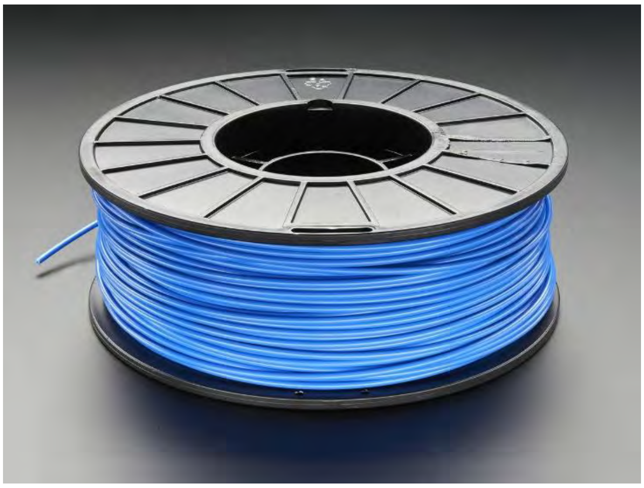

Figure 2.1(c): 3D Filament

A research of Sood (2009), study on parameter orientation layer thickness, raster angle, air gap and raster width effect on mechanical strengths, like tensile, flexural and impact strength. The surface plot is analysed to distortion between layers.

At the University of Texas at El Paso, Torrado et al. tested the hypothesis that varying additives in ABS reduces the change in effects between orientations. In this experiment, ABS was combined with plant fibers, metal oxides and other polymers creating four different blends. ABS was also mixed with two different ratios of styrene ethylene butadiene styrene (SEBS). In addition two combinations of ABS, SEBS, and ultra-high molecular weight polyethylene (UHMWPE) were tested. Each polymer combination was tested at two layer orientations; horizontal (XYZ) and vertical (ZXY). The experiment concluded that the polymer blend of ABS, SEBS, and UHMWPE was the most successful at reducing anisotropy of ultimate tensile strength due to a lower complex velocity above the glass transition temperature, creating stronger layer to layer bond. As a result, failure did not happen between layers, but rather occurred within layers.

2.1.4 Advantages and Disadvantages

ABS is good at toughness, cheap in price and high strength of impact. Shahrir (2006) state that in his study, the dimensional stability is good; it replaces die-cast metal components and can be electroplated for ABS. Also, properties for balancing by ABS are the best among the other polymers. Besides that, ABS have disadvantages which are the polymer is resistant to solar radiation and precipitation.

2.2 Composite Material

2.2.1 Introduction

A composite material can be defined as a combination of two or more materials that results in better properties than those of the individual components used alone (F.C Cambell, 2010). Now days, composite material becomes high demand on produce a product. The reinforcement can be in layers, but also as yarn or woven or as short fibres without specific organisation (Johannesson, 2013)

The advantages of composite materials are high strength, relatively low weight, and corrosion resistance. While, it also high raw material costs and usually high fabrication and assembly costs. For carbon composites, basically carbon composites is from carbon fibres and polymetric resins. It is very stiff and strong material.

2.2.2 Fibres

Fibre have high quality of strength behaviour. Fibre composites commonly consist of many layers, and the fibres in continuous-fibre composites laminated materials are normally oriented in directions that will enhance the strength in the primary load direction (Campbell, 2010). Orientation is one of the influence factor for strength. Unidirectional laminates fibre reinforced polymers have a fibre orientation of 0° and is very tough and stiff compared to 90° are very weak in the direction as the load must be carried by the polymer matrix that is much weaker (Campbell, 2010).

Fibres-reinforced composites are composed of two or more materials which, when properly combined, form a different material with properties not available from the ingredients alone. Depending on the ingredients chosen and the method of combining them, a large spectrum of material properties can be achieved. A brittle material can be made more ductile (flexible) by adding a softer material; conversely a soft material can be made stiffer. Wood is a good example of a composite. The cellulose fibers provide the strength and are held together by the resin (Scoot Roben, 2002).

Modern composites or FRP (Fiber reinforced polymers, or plastics) are the newest addition to the structural engineers toolbox. Although the materials have been available for decades, a reduction in cost, combined with newer understanding of the versatility and benefits of the material properties, has allowed composites to move into mainstream construction.