Faculty of Manufacturing Engineering

EMBEDDED COMPONENTS DESIGN STRATEGY FRAMEWORK FOR FUSE DEPOSITION MODELING SYSTEM

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DECLARATION

I declare that this report entitled "Embedded Components Design Strategies Framework for Fuse Deposition Modeling System" is the result of my own research except as cited in the references. The report has not been accepted for any master and is not concurrently submitted in candidature of any other master.

Signature :

Name : HENG KHIM HIONG

Date : 17/8/2023

APPROVAL

I hereby declare that I have read this report and in my opinion this report is sufficient in terms of scope and quality for the award of Master of Manufacturing Engineering in Manufacturing System Engineering.

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Date : 17/8/2023

DEDICATION

To my beloved Parents and Family Members.

ABSTRACT

The aim of this project is to develop a framework to guide the process of 3D printing embedded products specifically by using fused deposition modeling (FDM) printing process. Furthermore, to meet the environmental sustainability, the framework also focusses on the material use to create product which allow the user to recycle the products. In this project, the framework was used as a technique to improve the design of the product by lowering the number of components and assemblies. The framework was developed in four-layered design criteria to overcome the difficulties of embedded products design which includes Design Process Flow, Design Knowledge, Key Enabling Technologies, and Design Application. Three case study were used which are Electric Shaver, Remote Control and Nintendo Switch to compare the robustness and the effectivenss of the framework. Based on first case study, it was able to design a product with integration for blade interchangeable. While for the second case study, the compatibility to change the cover with similar size which allow it to be reusable. In third case study, it shows the flexibility of the design which every single part is interchangeable with various looks and design that allow the user to independently change to the desired pattern without the help from the external that will lead to cost incur. In other words, there are disadvantages in the development after using the framework. First case study shows that the design is too bulky and difficulty to monitor on the blade life span. As for the second case study, the development was not able to create a water-resistant product and also the battery indicator of batter life span. Third case study, shows that the pixel resolution during usage of the product is not satisfactory. The framework gives many advantages than disadvantages to the development whereby time constraint, cost and resources are reduced significantly. Lastly, this project shows a simplified study of the FDM process which aids in minimizing waste and difference of current market design with the new design by using framework.

ABSTRAK

Matlamat projek ini adalah untuk membangunkan rangka kerja untuk membimbing proses pencetakan 3D produk terbenam secara khusus dengan menggunakan proses pencetakan pemodelan pemendapan bersatu (FDM). Tambahan pula, untuk memenuhi kemampanan alam sekitar, rangka kerja ini juga memberi tumpuan kepada penggunaan bahan untuk mencipta produk yang membolehkan pengguna mengitar semula produk. Dalam projek ini, rangka kerja digunakan sebagai teknik untuk menambah baik reka bentuk produk dengan mengurangkan bilangan komponen dan pemasangan. Rangka kerja ini dibangunkan dalam kriteria reka bentuk empat lapisan untuk mengatasi kesukaran reka bentuk produk terbenam yang merangkumi Aliran Proses Reka Bentuk, Pengetahuan Reka Bentuk, Teknologi Pemboleh Utama dan Aplikasi Reka Bentuk. Tiga kajian kes telah digunakan iaitu Pencukur Elektrik, Kawalan Jauh dan Nintendo Switch untuk membandingkan kekukuhan dan keberkesanan rangka kerja. Berdasarkan kajian kes pertama, ia dapat mereka bentuk produk dengan penyepaduan untuk bilah yang boleh ditukar ganti. Manakala untuk kajian kes kedua, keserasian untuk menukar penutup dengan saiz yang sama yang membolehkan ia boleh digunakan semula. Dalam kajian kes ketiga, ia menunjukkan fleksibiliti reka bentuk yang mana setiap bahagian boleh ditukar ganti dengan pelbagai rupa dan reka bentuk yang membolehkan pengguna menukar secara bebas kepada corak yang diingini tanpa bantuan daripada luaran yang akan menyebabkan kos ditanggung. Dengan kata lain, terdapat kelemahan dalam pembangunan selepas menggunakan rangka kerja. Kajian kes pertama menunjukkan bahawa reka bentuk terlalu besar dan sukar untuk dipantau pada jangka hayat bilah. Bagi kajian kes kedua pula, pembangunan tidak dapat menghasilkan produk kalis air dan juga penunjuk bateri jangka hayat adunan. Kajian kes ketiga, menunjukkan bahawa resolusi piksel semasa penggunaan produk adalah tidak memuaskan. Rangka kerja ini memberikan banyak kelebihan berbanding keburukan kepada pembangunan di mana kekangan masa, kos dan sumber dikurangkan dengan ketara. Akhir sekali, projek ini menunjukkan kajian ringkas proses FDM yang membantu dalam meminimumkan pembaziran dan perbezaan reka bentuk pasaran semasa dengan reka bentuk baharu dengan menggunakan rangka kerja.

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CHAPTER 1

INTRODUCTION

1.1 Background

Additive Manufacturing (AM) began in the 1980s with the invention of Chuck Hull on solid imaging process known as stereolithography which now referred to as 3D printing. During he discovered the approach that was employed with UV lasers to construct the 3D objects layer by layer and it is crimped with the extended manufacturing timelines of prototypes. In other words, this method of producing a real product by stacking elements one by one from a computer model. In contrast to subtractive manufacturing, which generates the finished object by eliminating material. Therefore, this triggered the next generation of production methods and in 1986s, he was successful in patenting his innovation on the 3D printing and eventually becoming the father of 3D printing (Albar et al., 2019).

Each of the numerous advantanges of AM has a degree of waste reduction and energy saving in common. Therefore, the advantages can be seen in AM are customization, expedited prototyping, energy savings, environmental advantages, inventory stock reduction, legacy components, manufacturing and assembly, material waste reduction, part flexibility, part dependability, production flexibility, and supply chain improvements are all possible. These advantages can help to let the parts to withstand on the pressure taken for the parts especially on the aerospace parts (Elhajjar, 2017). It also can be considered to be used by the Medical product as AM gives environmental free which can meet the requirement (Zhu et al., 2021). While the drawbacks of AM include the high cost of entrance, production costs, extra materials, slowness, and post-processing.

Most of the AM are suitable for the aerospace, consumer products, energy, medical and transportation as they need a reliable parts to be used on their application. For example, the Aerospace needed a reliable product because of the vacuum and pressure needed to be considered in the application (Elhajjar, 2017). As a result, AM is the best option since it enables the delivery of complicated, integrated components with increased strength, which in need to the industry. All consolidated designs demand least material and total weight rebate, which is critical in the aircraft sector.

AM has a great potential by reduces energy and can cut waste and materials compared to traditional manufacturing methods. This is very important because with minor exceptions which there has been minimal research towards identifying and improving the wear characteristics of AM parts. Furthermore, this technology has the potential to increase energy production which grant for more design flexibility and shorter manufacturing times. This also help to figuring out and enhancing the wear characteristics through AM parts. Objects with integrated components and multi-material assemblies exacerbate the problem since they are difficult to deconstruct for recycling and disposal (Kudryashova et al., 2021).

AM is a method of manufacturing that use additives to produce goods. These AM processes are used to build items from computer-generated CAD models (Liu & Rosen, 2010). This approach allows to depend on the type of 3D printer utilised, material is deposited, powder is melted and fused, and liquid photopolymer is finally cured to create components. Lastly, the final 3D products need changes such as polishing, and finishing would be essential before they are ready to be used.

AM can be distinguished into a few categories which are binder jetting, directed energy deposition, material extrusion, powder bed fusion, sheet lamination, vat polymerisation and directed energy deposition-arc (DED-arc). AM is crucial for generating lighter, more complex designs that would be too difficult or costly to produce using traditional manufacturing procedures. As a result, moulds, milling, and machining are obsolete. As a result, AM provides a number of advantages for both prototype and production.

Additionally, 3D printing is the umbrella term for the layer-by-layer manufacturing technology known as AM, of which material extrusion [commonly referred to by its commercial name fused deposition modeling (FDM) has been widely embraced by a wide range of businesses (Kim et al., 2018). Theoretically, As an additive process category, material extrusion (ME) may meet demanding industrial criteria. Fused Layer Modeling (FLM) is the only established ME process, despite the fact that other others exist. Establishing pellet-based methods could circumvent ME limits. Although there are numerous cost estimates for AM, there is no transparent mechanism for comparing the profitability different ME procedures (Kampker et al., 2019).

Adding electrical functionality during AM is a promising new application area. Various methods for merging 3D dispensing (3DD), an extrusion-based AM process, with the embedding of electrical components are explored and compared. Among six distinct strategies, the optimal one is selected based on factors such as the final surface quality and overall accuracy. To further validate and confirm the selection, long-term reliability tests [humidity and thermal shock testing (TST)] were done, with an emphasis on the electrical contacts between the printed tracks and the embedded electronic components. The embedding approach and cavity design were demonstrated to have no effect on the long-term qualities of the printed electrical tracks. Finally, an acceleration sensor is integrated in a three-dimensional housing to demonstrate real-world use.

Finally, in the coming era, AM will be used to replace the subtractive manufacturing in order to reduce the high wastage created and able to increase the speed at which single part created as faster pace (Kampker et al., 2019). Because of the time required to build or generate parts, AM is unlikely to completely replace traditional manufacturing or subtractive manufacturing. Traditional manufacturing or subtractive manufacturing is still used for basic and easy-to-manufacture things, but additive manufacturing is becoming the preferred approach for producing smaller bathes of more complicated parts.

This project will investigate the embedded components design strategies framework for Fuse Deposition Modeling (FDM) Systems. The main focus will be improving the design strategies with the assists of framework to address and overcome these limitations that must be developed in the future. Therefore, material used to meet the requirement of the application is used to prevent the reliability of the reduction of the part. Moreover, the pieces created using

FDM need to be made of lightweight material, enabling the features to be easily a replacement part for the application used to avoid wastage of the module. However, the designs will come with advantages and disadvantages.

1.2 Problem Statement

AM emphasized the advantages of embedded components and printed assemblies. Printed assemblies, on the other hand, are typically not disassembled for periodic maintenance or repair. This raises the expense and waste associated with the product over the course of its useful life. This is especially significant because, with a few exceptions, minimal work is being done to determine and improve the wear qualities of AM parts. Objects with embedded components and multi-material assemblies exacerbate the problem because they are difficult to disassemble for recycling and disposal.

One of the most challenging aspects of employing embedded components is their implementation in design tools. Because most CAD tools are in 2D, precisely designing with integrated components and modelling the correct connection type may be challenging and time-consuming. Often, a large amount of documentation must be supplied for manufacturing suppliers to avoid mistakes and ensure that the boards are manufactured as planned. The intelligent and successful application of embedded components begins with the product planning.

The purpose of this project was to study the benefits of AM towards the embedded components and printed assemblies from the framework. This allows chances of recycling of the waste materials and cost avoidance on the disassembled products by using AM as a replacement. Moreover, this also helps to design strategies to address and overcome these limitations that must be developed in the future.

1.3 Project Objectives

Objectives of the project are:

1. To establish a framework for embedded components design strategies for FDM system.
2. To evaluates the effectiveness of the proposed framework on selected case studies.
3. To validate the framework by comparing current design and new proposed design.

1.4 Project Scope

The purpose of this project is to investigate the embedded components design strategies for FDM AM systems. In order to design an excellent framework for embedded components, three case studies will be studied and analyzed which are Electric Shaver, Remote Control and Nintendo Switch. The case study involve integrated embedded design that build together with the use of FDM with assists from the framework and the effectiveness of reducing waste material by exchanging the parts including the embedded design.

1.5 Organization Of The Report

The organization of this report is divided into five chapters:

Chapter 1: This chapter is the introduction, and it comprises the background study, problem statements of the investigation, aims of this research, and the scope of inquiry.

Chapter 2: This chapter outlines the literature and theory linked to the topic and any previous research that can support this project.

Chapter 3: Outlines the approaches, methods, and stages employed to conduct the study.

Chapter 4: Result and Discussion concentrates on the result and explores the outcome.

Chapter 5: Conclusion in this chapter, the test findings are summarised, and comments and recommendations for further research are made.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

A literature study is being carried out to understand the topic further and examine the research objectives. The fundamental study on material extrusion will help reduce the wastage of the embedded component, whereby AM can replace the parts without any obstacles for the product to be thrown away. Moreover, this project will also discuss the challenges and obstacles that AM is facing.

AM is a promising technique for optimising the supply chain for spare components. In addition to its techno-economic feasibility, a full examination of whether it is desirable to convert to this technology for spare parts management should include a thorough study of its sustainability. There have been general analysis of the economic, environmental, and social consequences of AM, however assessments of the sustainability effects of additive manufacturing in the spare parts industry are restricted to certain industries (Angela et al., 2022).

There are seven types of AM that can help to represent or replace the obsolete or spare parts for the products as shown in Figure 1.

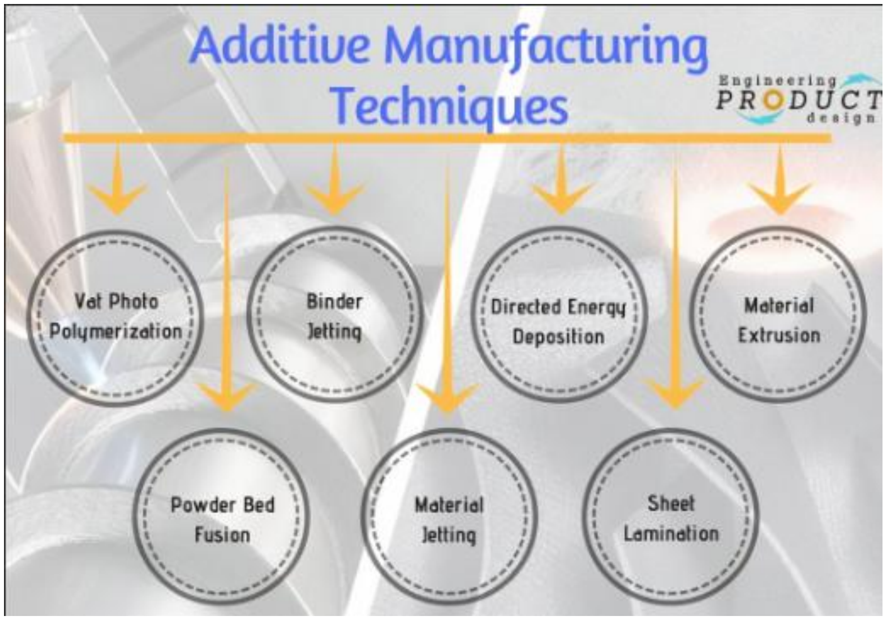

Figure 1: Types of AM (Kudryashova et al., 2021)

2.1 AM Techniques

2.1.1 Material Extrusion (ME)

In terms of affordability and dependability, ME was the first and most widely used additive manufacturing process for a wide variety of items. ME is a process that permits the inventive manufacture of metal, ceramic, and cermet components (Spiller et al., 2022). ME is a 3D inkjet printing procedure that requires feeding the material via nozzle or jetting. This operating concept is mostly used by low-cost 3D printers. Materials used to make objects must be adequate to thrust out the material through the nozzle. To "draw" two-dimensional cross-sections of a given 3D model, any pasty material (sometimes warmed) can be utilised.

There are several process under consideration in creating screening printing for pyrotechnic purposes and Doctor Blade Casting are two examples of flat constructions. The Doctor Blade technique is appropriate for coating substrates with varying wet film thicknesses from 20 to a few hundred microns, at speeds up to several metres per minute (Lerner, 2021). Using a knife with a certain gap, the substrate is treated with a HEM suspension containing a dissolved binder. as shown in Figure 2.

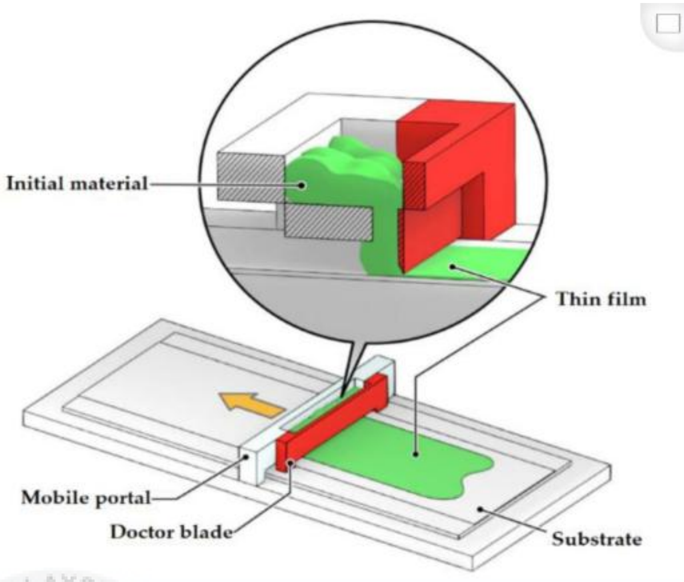

Figure 2: Material Extrusion (Lerner, 2021)

Extrusion is also utilised to create more complicated three-dimensional constructions.

To do this, "ink" added layer by layer via hole in the 3D printer head (Figure 3). DIW is the name given to the related 3D printing technology (Direct Ink Writing). Due to solvent evaporation or binder deposition, liquid ink initially harden on the substrate, resulting in a volumetric product structure. Printed structures can have a minimum size of less than one micron, by susceptible on the size of nozzle tip and the physicochemical properties in the ink.

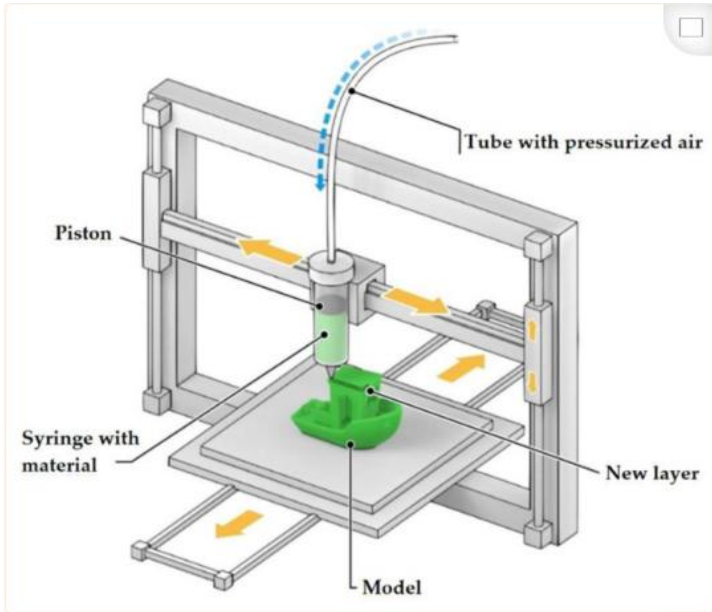

Figure 3: Direct Printing Method (Lerner, 2021)

The syringe is loaded with ink, and compressed air drives the extrusion process. The management of printing speed and the setup of printing technology in accordance with ink viscosity is made possible by the manipulation of air pressure. Simulations demonstrate that higher on yield stress produces prints with fewer deformations, whereas a higher plastic in viscosity produces prints with more deformations in the deposited layers (Mollah et al., 2021).

FDM is a prevalent AM technique. It works by depositing layers of plastic filament onto a substrate using a heated extruder (Figure 4). FDM typically achieves spatial resolutions within the range of hundered to five hundred meter (Cader & Kiński, 2022).