THERMAL BEHAVIOUR OF 3D PRINTED PART UNDER THE INFLUENCE OF NITROGEN

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This report is submitted
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DECLARATION

I declare that this project report entitled "Thermal behaviour of 3D printed part under the influence of nitrogen" is the result of my own work except as cited in the references

Signature	:	....
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Date	:	21/07/2021

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature :. ....
Name of Supervisor : ....
Date : ....

ABSTRACT

The present of oxygen during 3D printing process is expected to reduce the quality of 3D printing. The interaction between oxygen and heat during the printing caused-bubbling effect on the product surface due to-escaping of oxygen. This problem altered the product shape which can reduce the mechanical properties of the materials. Inert gases with lower ambient temperature are used by many industries to replace oxygen during 3D printing process. Therefore, this project-was carried out to study how the temperature differences would impact the mechanical properties of the 3D printing materials such as ABS and plastic PC and how can inert gases improve the printing quality thermally. ANSYS 2021 software was used to simulate 3D printing process in an enclosed environment. Different gases condition of oxygen and inert gases of nitrogen and argon were used as the convection for gases environment during the simulation to identify the thermal interaction between A5 dog bone specimen and the heat from both bed sheet and printing nozzle. It was found that the oxygen provides the highest temperature distribution during 3D printing compare to inert gases. Maximum heat flux was obtained in inert gases compared to oxygen environment because of higher temperature difference of the inert gases. The stiffness of both 3D printing materials was proven to increase when printing in inert gases environment compare to the oxygen environment. The stiffness results obtained from the simulation were verified to be precise by-the relationship between Young's Modulus equation with the Linear Thermal Expansion equation where Young's Modulus is inversely proportional to the temperature difference. Thermically, the inert gases were proven to improve the mechanical properties of the 3D printing materials.

ABSTRAK

Kehadiran oksigen semasa proses pencetakan 3D didapati dapat mengurangkan kualiti percetakan. Interaksi antara oksigen dan haba semasa pencetakan menyebabkan kesan gelembung pada permukaan produk kerana pelepasan oksigen. Masalah ini mengubah bentuk produk yang dapat mengurangkan sifat mekanikal bahan. Gas lengai dengan suhu persekitaran yang lebih rendah digunakan oleh banyak industri untuk menggantikan oksigen semasa proses pencetakan 3D. Oleh itu, projek ini dijalankan untuk mengkaji bagaimana perbezaan suhu mempengaruhi sifat mekanik bahan percetakan 3D seperti ABS dan plastic PC dan bagaimana gas lengai dapat meningkatkan kualiti pencetakan secara termal. Perisian ANSYS 2021 digunakan untuk melakukan simulasi proses percetakan 3D dalam persekitaran tertutup. Keadaan gas yang berbeza termasuk oksigen dan gas lengai nitrogen dan argon digunakan sebagai perolakan untuk persekitaran gas semasa simulasi untuk mengenal pasti interaksi termal antara spesimen tulang anjing A5 dan haba dari kedua-dua alas lapisan dan muncung percetak. Didapati bahawa oksigen memberikan taburan suhu yang lebih tinggi semasa percetakan 3D dibandingkan dengan gas lengai. Fluks haba maksimum diperolehi untuk gas lengai berbanding dengan persekitaran oksigen kerana perbezaan suhu yang lebih tinggi oleh gas lengai. Kekakuan kedua-dua bahan percetakan 3D terbukti meningkat apabila percetakan 3D di persekitaran gas lengai berbanding dengan oksigen. Hasil kekakuan yang diperoleh dari simulasi disahkan tepat melalui hubungan antara persamaan Modulus Young dengan persamaan Pengembangan Termal Linear di mana Modulus Young berkadar songsang dengan perbezaan suhu. Secara termal, gas lengai terbukti dapat meningkatkan sifat mekanikal bahan percetakan 3D.

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I would like to thank my course mates for giving me their support, patience and encouragement. Finally, I would like to thank you to family members for supporting me during the pandemic Covid-19.

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AM	Addictive Manufacturing
FDM	Fused Deposition Modelling
SLA	Stereolithography
FRF	Frequency Response Function
SLS	Selective Laser Sintering
SLM	Selective Laser Melting
EBM	Electron Beam Melting
LOM	Laminated Object Manufacturing
BJ	Binder Jetting
CAD	Computer- Aided design
ABS	Acrylonitrile butadiene styrene
PLA	Polylactic Acid
PEI	Polyetherimide
ABS-PC	Acrylonitrile butadiene styrene-Polycarbonate
ASA	Acrylonitrile Styrene Acrylate
PPSF	Polyphenylsulfone
PPMS	Physical Properties Measurement System
ASTM	American Society for Testing and Materials
NIST	National Institute of Standards and Technology
TGA	thermal gravimetric analysis
FE	Finite Element

LIST OF SYMBOLS

α_L	=	Thermal expansion coefficient
L	=	Total initial length
ΔL or dL	=	Different in length or linear thermal expansion
T or T_0	=	Initial temperature
ΔT or dT	=	Changes in temperature
A or A_0	=	Initial surface area
ΔA or dA	=	Different in area
k	=	Thermal conductivity
D	=	Distance between two points
Q	=	Amount of heat transfer
$\frac{\Delta L}{L}$	=	Different in length over initial length
$\frac{\Delta A}{A}$	=	Different in surface area over initial surface area
$\frac{\Delta V}{V}$	=	Different in volume over initial volume
σ	=	Stress
E	=	Modulus of elasticity
ε	=	Strain
Φ	=	Heat flux
dX	=	thickness

CHAPTER 1

INTRODUCTION

1.1 Background

3D printing also known as addictive manufacturing (AM) is one of the most effective ways to create a complex shape when manufacturing a product. A process of joining and solidifying deposited materials controlled by a computer to build a three - dimensional product is referred as the term of 3D printing. The materials used are varies from a single solid filament as well as a powder liquified by heating process during the printing. Figure 1.1 below shows the first 3D printer model in 1980s.

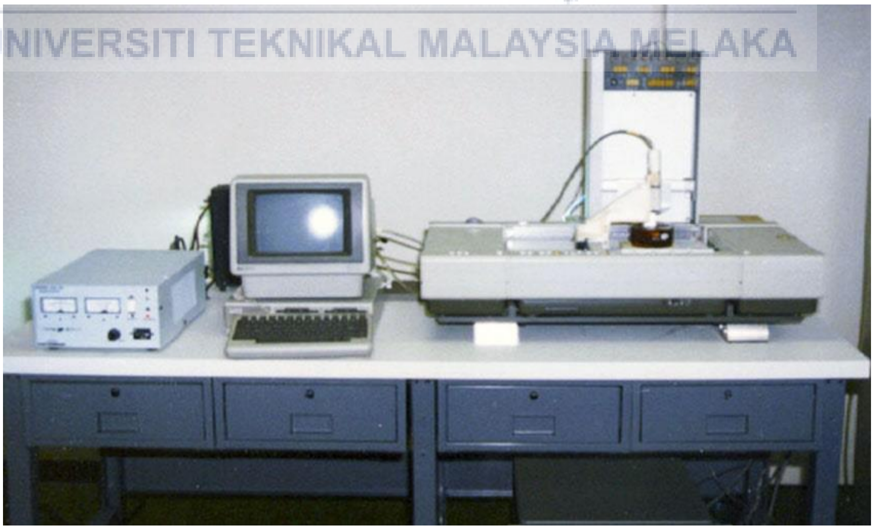

Figure 1.1: The earliest model of 3D printer in 1980s (3Dinsider.com)

The evolution of 3D printing started in early 1980s when it was considered suitable for building prototypes and functional product part. By the time the 3D printing term used is rapid prototyping which is referred to how fast the production was made. In 2019, 3D printing evolved into a more reliable and convenient industrial process. The increased of precision and accuracy of 3D printing as well as the increased of different types of materials used and repeatability of 3D printing were considered as viable as an industrial production technology.

1.2 Problem Statement

Based on the statement from the GasLab (2020), the presence of oxygen during 3D printing process can affect the strength and elastic moduli of the 3D printed part such as it can produce a void which is caused by bubble of oxygen escaping when printing. During printing process, the oxygen causing a sheet of oxidation when interacted with the printing laser. This effect can be clearly seeing when the 3D printed part had some distorted and altered finished surface. Figure 1.2 below showed the bubbling effect when deposited materials is 3D printed under oxygen's influence.

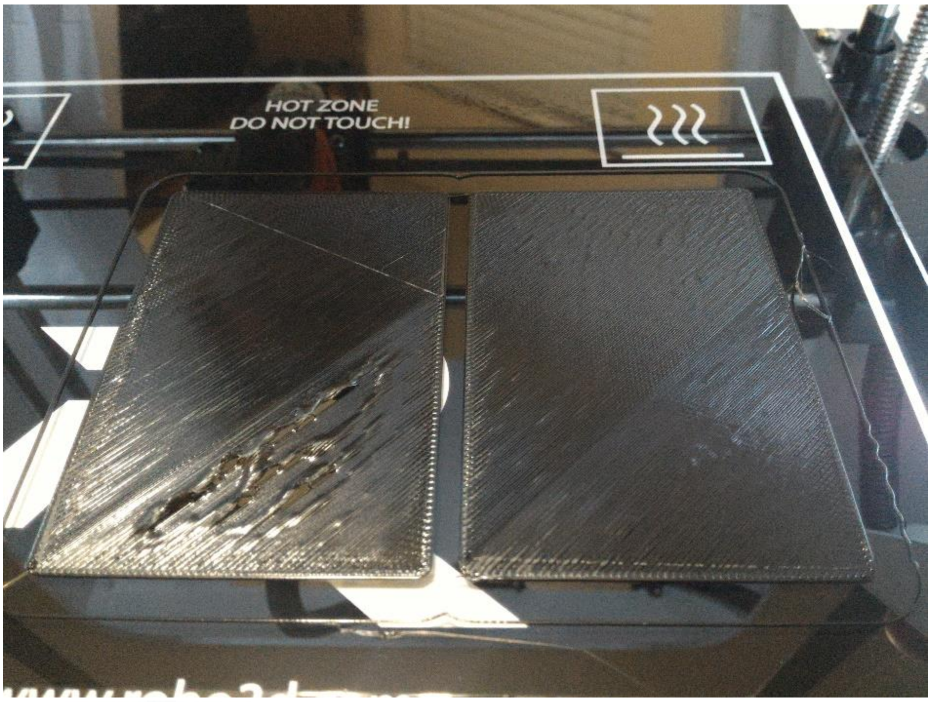

Figure 1.2: The bubbling 3D printed part (from the left) compared to the non-bubbling effect (from the right) (Williams, 2015).

According to article by Gewirtz (2019), from a marketing view, this type of error caused a great lost because the designed product did not meet the actual designed structure as well as the changes in the designed structure can affect the strength and elastic moduli of the product.

The research and study regarding the strength and elastic moduli of 3D printed part have being done by many institutes under a title of mechanical behaviour/mechanical properties of 3D printed part but not in thermal properties. Therefore, this research is conducted to analyse the thermal behaviour of 3D printed part under the influence of inert gas, nitrogen. The experiment to be conducted is based on the thermal stress and thermal strain of ABS filament when used for 3D printing.

1.3 Objective

The objectives of this research are as follows:

1. To investigate the equivalent stress and thermal strain of 3D printed part under the influence of different gas conditions.

2. To compare the stiffness and heat flux of 3D printed part under the influence of oxygen, nitrogen and argon in thermal behaviour.

1.4 Scope of Project

The scopes of this study are:

Only Fused Deposition Modelling (FDM) or Fused filament Fabrication process (FFF) is shown in this research. The study is conducted only with FDM/FFF because of the it is widely used by designers and engineers and widely in market compare to other 3D printing types. The main factor is because it is at low cost. The 3D materials printing materials are tested by using 2 type of thermoplastic filament, Acrylonitrile butadiene styrene (ABS), a common thermoplastic filament used in FDM as well as plastic Polycarbonate (PC) is used as a second manipulated variable in order to verify the data obtained from the experiment. However, due to Movement Control Order during Pandemic Covid-19, the laboratory is temporarily unavailable and the experiment study is limited to simulation using Latest ANSYS 2021 software.

1.5 General Methodology

The actions that need to be carried out to achieve the objectives in this research are listed below.

I. Literature review

Any journal, materials and article based on thermal behaviour, surface roughness of ABS 3D printed under both oxygen and nitrogen are reviewed to achieve the objectives.

II. Inspection

To achieve the objectives, the initial size before thermal expansion, initial rate of heat transfer and finished surface roughness the 3D printed part under oxygen exposure will be inspected first to identify the problem.

The thermal expansion, initial rate of heat transfer and finished surface roughness of 3D printed part under nitrogen will be inspected.

III. Comparison in Simulation

Both ABS 3D printed under oxygen and nitrogen environment are compared side by side based on their thermal behaviour and effect on mechanical properties.