

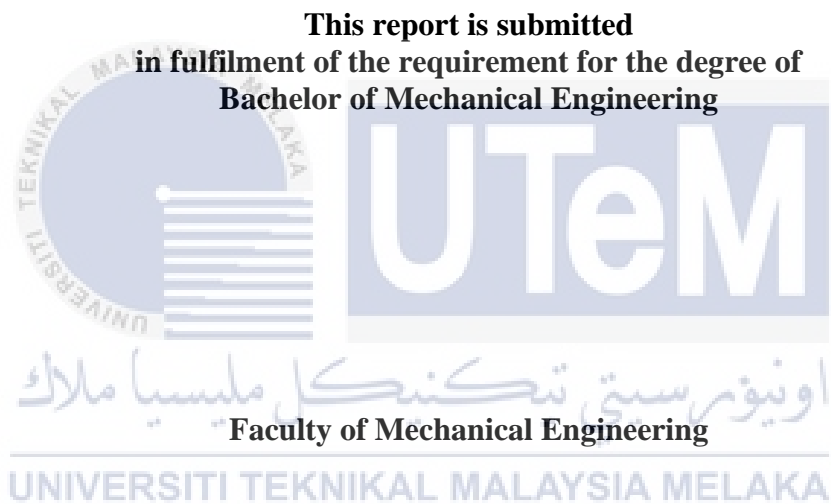
THERMAL BEHAVIOUR OF 3D PRINTED PART UNDER THE INFLUENCE OF NITROGEN



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

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 : 
Name : Mohammad Adib Bin Ramli
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 presence of oxygen during the 3D printing process is expected to reduce the quality of 3D printing. The interaction between oxygen and heat during the printing caused a bubbling effect on the product surface due to the 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 the 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 inert gases can improve the printing quality thermally. ANSYS 2021 software was used to simulate the 3D printing process in an enclosed environment. Different gas conditions of oxygen and inert gases of nitrogen and argon were used as the convection for the gas environment during the simulation to identify the thermal interaction between the A5 dog bone specimen and the heat from both the bed sheet and the printing nozzle. It was found that oxygen provides the highest temperature distribution during 3D printing compared to inert gases. Maximum heat flux was obtained in inert gases compared to an oxygen environment because of the higher temperature difference of the inert gases. The stiffness of both 3D printing materials was proven to increase when printing in an inert gas environment compared 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. Thermally, inert gases were proven to improve the mechanical properties of the 3D printing materials.

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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 diperolehi 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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ACKNOWLEDGEMENT

Praise to Allah S.W.T for His guidance and His protection as well as giving me opportunities to finish the Final Year Project report. I would like to express my deepest appreciation to my supervisor Dr. Faiz Rezda Bin Ramli for giving me this opportunity to do final year project with him. He never hesitated to give me advice and guidance whenever I confronted problems. I am thankful for his patience and advice while leading me in this project.

Secondly, I would like to thank a senior named Arif and Hanafi for spending his time to guide me. They would share their knowledge with me and guide me to do finish the simulation.

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.



CONTENT

CHAPTER	CONTENT	PAGE
	SUPERVISOR'S DECLARATION	ii
	ABSTRACT	v
	ACKNOWLEDGEMENT	vi
	TABLE OF CONTENT	vii
	LIST OF FIGURES	x
	LIST OF TABLES	xv
	LIST OF ABBREVIATIONS	xvii
	LIST OF SYMBOLS	xviii
CHAPTER 1	INTRODUCTION	1
	1.1 Background	1
	1.2 Problem Statement	2
	1.3 Objective	4
	1.4 Scope of Project	4
	1.5 General Methodology	5
CHAPTER 2	LITERATURE REVIEW	7
	2.1 Addictive manufacturing	7
	2.2 Fused Fabrication Modelling	10
	2.3 Thermoplastic Materials	11
	2.3.1 Acrylonitrile butadiene styrene	11
	2.3.2 Application of ABS	14
	2.3.3 Thermal Degradation of ABS	15
	2.3.4 Thermogravimetric analysis of ABS	18
	2.4 Inert Gas	20
	2.4.1 Argon the Noble Gas	21

2.4.2	Nitrogen	23
2.4.3	Comparison between Argon and Nitrogen	25
2.4.4	Nitrogen in Addictive Manufacturing	26
2.5	Heat Transfer	27
2.5.1	Heat Conduction	29
2.5.2	Heat Convection	29
2.5.3	Heat Radiation	29
2.6	Thermal Expansion	30
2.7	Thermal Expansion of Thermoplastic Filament ABS	31
2.8	Tensile Strength	32
CHAPTER 3	METHODOLOGY	35
3.1	Introduction	35
3.2	FDM 3D Printing Experiment Setup	37
3.2.1	The isolation of Oxygen in FDM	37
3.2.2	Printing Parameters	41
3.3	Preliminary Result	41
3.3.1	Thermal expansion graph	42
3.3.2	Comparison of Tensile Strength	44
CHAPTER 4	RESULT AND DISCUSSION	47
4.1	ANSYS Simulation	48
4.2	Temperature distribution	54
4.2.1	ABS temperature distribution	54
4.2.2	Plastic PC temperature distribution	56
4.3	Total Heat Flux distribution	60
4.3.1	ABS Heat Flux distribution	60
4.3.2	Plastic PC Heat Flux distribution	62
4.4	Equivalent Stress and Thermal Strain	66
4.4.1	Stress and Thermal Strain of ABS	66
4.4.2	Stress and Thermal Strain of Plastic PC	67

4.5	Analysis on Temperature distribution and Total Heat flux	69
4.5.1	Temperature distribution Analysis	69
4.5.2	Total Heat Flux analysis	71
4.6	Stress Vs. thermal Strain graph	73
CHAPTER 5	CONCLUSION AND FUTURE RESEARCH	84
5.1	Conclusion	84
5.2	Future Research	85
	REFERENCE	86



LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	The earliest model of 3D printer in 1980s (3Dinsider.com)	1
1.2	The bubbling 3D printed part (from the left) compared to the non-bubbling effect (from the right) (Williams, 2015)	3
2.1	The FDM schematic (Mazzanti <i>et al</i> , 2019)	11
2.2	The composition of ABS polymer (“Acrylonitrile Butadiene Styrene (ABS plastic): Uses, Properties & Structure,” 2021)	13
2.3	Appliances made using ABS materials (“Acrylonitrile Butadiene Styrene (ABS plastic): Uses, Properties & Structure,” 2021)	15
2.4	The ABS specimens in impact testing (Ramli <i>et al</i> , 2018)	16
2.5	Graph of impact energy against time (Ramli <i>et al</i> , 2018)	17
2.6	Graph of absorbed energy against time (Ramli <i>et al</i> , 2018)	17
2.7	The block diagrams of TGA’s schematic (Suresh Selvaraj ,2015)	18
2.8	Graph of weight of ABS and ABS/CF against temperature (Billah <i>et al</i> , 2019)	19
2.9	Periodic Table of element (Periodic Table – Ptable, 2020)	20

2.10	The argon phase diagram (“Argon - Thermophysical Properties,” 2021)	21
2.11	Nitrogen in stable state with triple bond (GSCE-Chemistry, 2015)	23
2.12	The Parker Nitrogen Generator; 1) compressor, 2) Air receiver, 3) water separator, 4) Clean dry Air system, 5) Buffer Vessel, 6) Nitrogen Generator, 7) Low-pressure storage, 8) Addictive Manufacturing Machine. (Green, 2019)	27
2.13	Transfer of heat during boiling water under direct heat. (Jesrinn, 2018)	28
2.14	The types of thermal expansion. (Physictutorials.org)	31
2.15	The stress vs strain of yield tensile strength, ultimate tensile strength and breaking tensile strength (Ashish, 2017)	34
3.1	The flow chart of the experiment	36
3.2	The FDM’s schematic in controlled environment (Mazlan <i>et al</i> , 2018)	38
3.3	The ANSYS schematic for the 3D printing simulation.	39
3.4	The boundary condition for steady state thermal analysis	40
3.5	The boundary condition for static structural analysis	40
3.6	Thermal expansion of ABS and Verowhite against temperature	43

3.7	The thermal conductivity of ABS and Verowhite against temperature (Weiss <i>et al</i> , 2015)	43
3.8	Averaged load–strain curves of plates made of ABS, nylon copolymer at air and under nitrogen atmosphere (Lederle <i>et al</i> , 2016)	44
3.9	Load v/s displacement graph of tensile specimen and Stress v/s Strain graph of tensile specimen (Anoosha <i>et al</i> , 2018)	45
3.10	The tensile test resulted of different ABS properties (Jayanth <i>et al</i> , 2018)	46
4.1	The FE mesh for 3D printed materials simulation in different gases	48
4.2	Bulk ambient temperature for all gases	54
4.3	ABS's temperature distribution 3D printed under oxygen environment	55
4.4	ABS's temperature distribution 3D printed under nitrogen environment	55
4.5	ABS's temperature distribution 3D printed under argon environment	56
4.6	Plastic PC's temperature distribution printed under oxygen environment	56
4.7	Plastic PC's temperature distribution printed under nitrogen environment	57

4.8	Plastic PC's temperature distribution printed under argon environment	57
4.9	The bar chart of Temperature distribution of ABS in different gas environment	59
4.10	The Temperature distribution of plastic PC in different gas environment	60
4.11	ABS Heat flux 3D printed under oxygen environment	61
4.12	ABS Heat flux 3D printed under nitrogen environment	61
4.13	ABS Heat flux 3D printed under argon environment	62
4.14	Plastic PC heat flux 3D printed under oxygen environment	62
4.15	Plastic PC heat flux 3D printed under nitrogen environment	63
4.16	Plastic PC heat flux 3D printed under argon environment	63
4.17	The Total Heat flux of ABS 3D printed in different gas environment	64
4.18	The Total Heat flux of plastic PC 3D printed in different gas environment	65
4.19	From the right, ABS Equivalent Stress and thermal strain 3D printed in oxygen environment	66
4.20	From the right, ABS Equivalent Stress and thermal strain 3D printed in nitrogen environment	66

4.21	From the right, ABS Equivalent Stress and thermal strain 3D printed in argon environment	67
4.22	From the right, plastic PC Equivalent Stress and thermal strain 3D printed in oxygen environment	67
4.23	From the right, plastic PC Equivalent Stress and thermal strain 3D printed in nitrogen environment	68
4.24	From the right, plastic PC Equivalent Stress and thermal strain 3D printed in argon environment	68
4.25	The bar chart for minimum temperature distribution for ABS and plastic PC in different gas environment	69
4.26	The maximum total heat flux of ABS and plastic PC in different gases environment	71
4.27	The stress vs strain graph for ABS 3D printed in different gas environment	76
4.28	The stress vs strain graph for plastic PC 3D printed in different gas environment	77
4.29	The Bar chart of Young Modulus of ABS and plastic PC in different gases environment	81

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	The additive manufacturing process and description on how the materials is fused. (Shah <i>et al</i> , 2016)	9
2.2	Mechanical properties of ABS (Dielectric Manufacturing, 2019)	14
2.3	Thermal properties of ABS (Dielectric Manufacturing, 2019)	14
2.4	The Argon Properties (“Argon - Thermophysical Properties,” 2021)	22
2.5	The properties of liquid nitrogen (Sanderson, 2021)	24
3.1	The 3D printing parameter setting for the test specimen. (Jayanth <i>et al</i> , 2018)	41
4.1	The temperature for 3D printing nozzle and bed sheet for different material filament	49
4.2	The materials properties defined during the steady state thermal analysis	50
4.3	The thermal and physical properties for different gases	51
4.4	The heat transfer coefficient for the all type of gases.	53

4.5	The maximum and minimum temperature value for ABS materials in different printing environment	58
4.6	The maximum and minimum temperature value for plastic PC materials in different printing environment	59
4.7	The maximum and minimum total heat flux for ABS materials in different printing environment	64
4.8	The maximum and minimum total heat flux of plastic PC in different printing environment	65
4.9	The temperature different for each gas environment	71
4.10	The maximum stress and maximum strain of ABS 3D printed in different gas environment.	74
4.11	The maximum stress and maximum strain of plastic PC 3D printed in different gas environment.	75
4.12	The Young's Modulus for both ABS and plastic PC 3D printed in all environments	81

LIST OF ABBREVIATIONS

AM	Additive 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 additive 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.

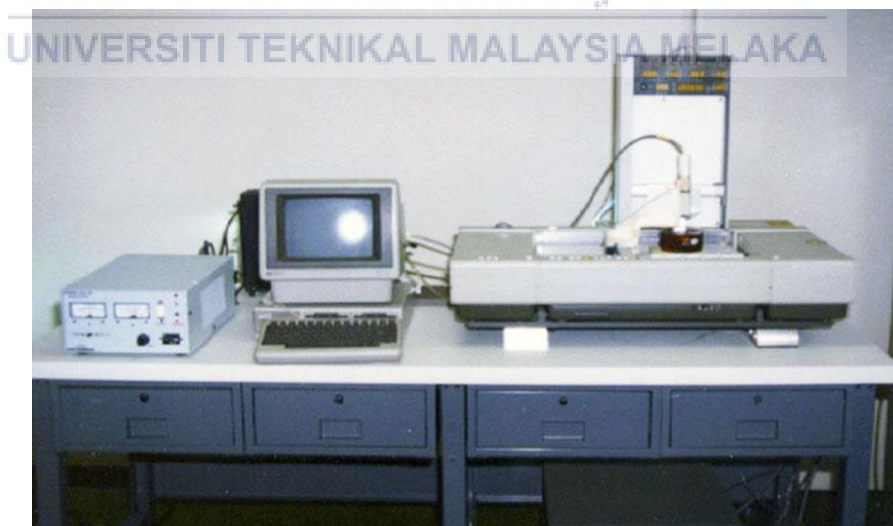


Figure 1.1: The earliest model of 3D printer in 1980s (3Dinsider.com)

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.

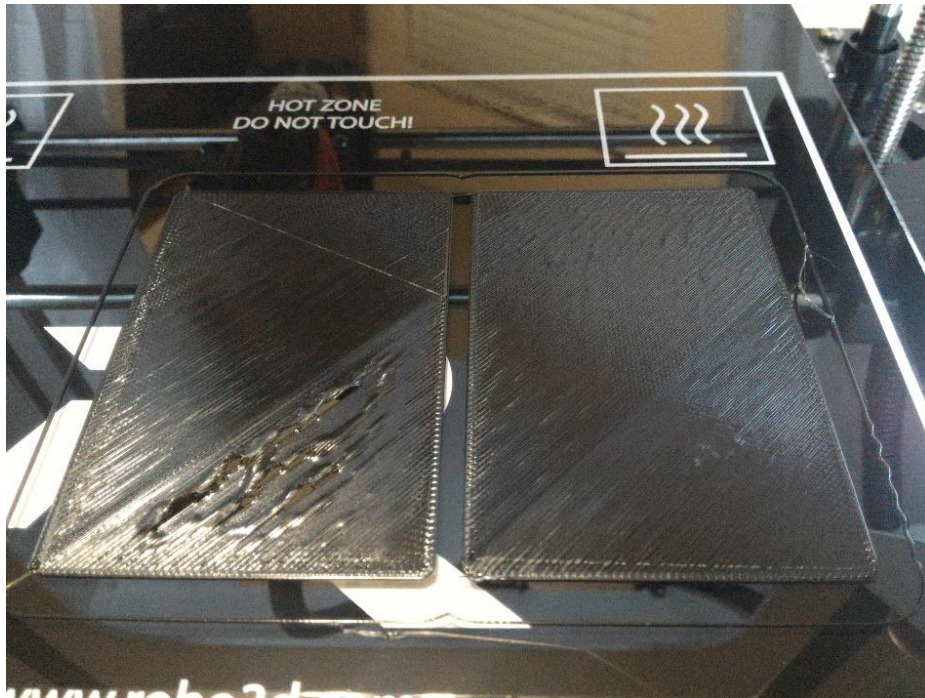


Figure 1.2: The bubbling 3D printed part (from the left) compared to the non-bubbling effect (from the right) (Williams, 2015).

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.

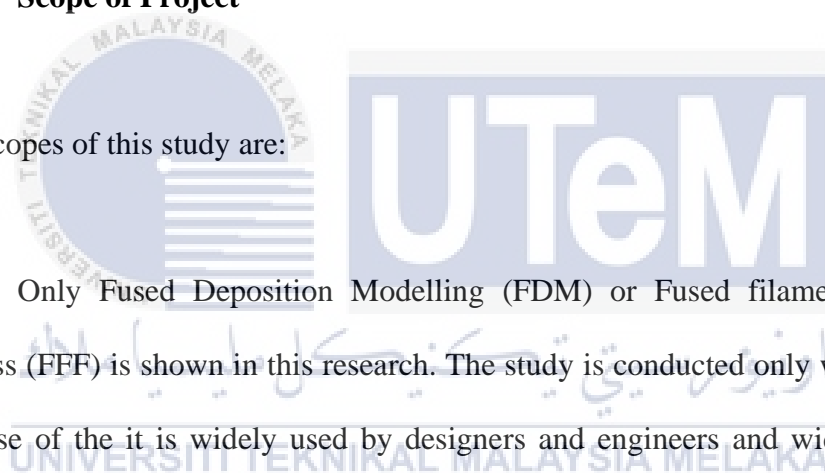
1.3 Objective

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.