UNIVERSITI TEKNIKAL MALAYSIA MELAKA

SURFACE FINISH IMPROVEMENT USING RETRACTION METHOD FOR FUSED DEPOSITION MODELING

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTEM) for the bachelor degree of Manufacturing Engineering (Manufacturing Design) (Hons.)

By

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DECLARATION

I hereby, declared this report entitled "Surface Finish Improvement using Retraction Method for Fused Deposition Modeling " is the results of my own research except as cited in the references.

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Date: 31 MAY 2017

APPROVAL

This report is submitted to the Faculty of Manufacturing Engineering of Universiti Teknikal Malaysia Melaka as a partial fulfillment of the requirements for the degree of Bachelor of Manufacturing Engineering (Manufacturing Design) (Hons.). The member of the supervisory is as follow:

……………………………….

(DR. SHAJAHAN BIN MAIDIN)

ABSTRAK

Kaedah penarikkan balik ialah parameter dalam perisian Repetier yang dihubungkan dengan Pencetak 3D yang diperkenalkan untuk pengoptimuman kualiti produk atau proses. Produk yang dihasilkan oleh ABS Fused Deposition Model (FDM) mempunyai hasil yang tersendiri yang berbeza dengan perubahan parameter proses mesin seperti nilai z-lift, kelajuan dan panjang. Prestasi bahagian yang dihasilkan melalui mesin Folgertech diukur untuk kekasaran permukaan. Dalam usaha untuk mencapai prestasi optimum bahagian yang dihasilkan, reka bentuk eksperimen telah digunakan. Dalam projek ini, yang ortogon mudah 27 keping sampel telah ditentukan untuk 3 parameter iaitu: z-lift, kelajuan dan panjang dengan 3 nilai yang berbeza setiap satu. sampel telah direka menggunakan SolidWorks 2013 dan direka menggunakan mesin pencetak Folgertech 3D. Sampel telah diuji untuk kekasaran permukaan menggunakan Mitutoyo Surftest SJ 301. Keputusan telah diperolehi dan data dianalisis. Data menunjukkan bahawa sampel 11 dengan kombinasi parameter z-lift 1mm, kelajuan 20mm/s dan panjang 1mm memberi nilai purata paling rendah manakala data yang menunjukkan bahawa sampel 23 dengan kombinasi parameter z-lift 2mm, kelajuan 40mm/s dan panjang 5mm mencapai kekasaran permukaan purata yang paling tinggi mengikuti nilai Ra masing-masing. Oleh itu, keputusan ini menunjukkan bahawa ciri-ciri produk yang dihasilkan menggunakan Stratasys FDM 400 MC berbeza dengan kombinasi yang berbeza parameter proses dan kaedah penarikan balik menyediakan penyelesaian untuk menentukan kombinasi yang optimum dengan jumlah minimum eksperimen.

ABSTRACT

Retraction Method is a parameter in the Repetier software which connected to the 3D Printer introduced for the optimization of a product or process quality. The ABS product produced by Fused Deposition Modeling (FDM) has its own unique result which varies with the changes of the process parameters of the machine such as the value of z-lift, speed and length. The performance of the part produced via Folgertech machines was measured for surface roughness. In order to achieve the optimum performance of the produced part, the design of experiment was employed. In this project, an orthogonal array 27 pieces of samples were determined for 3 parameters namely: z-lift, speed and length with 3 different value each. The sample was designed using SolidWorks 2013 and fabricated using Folgertech 3D printer machines. The samples were tested for surface roughness using Mitutoyo Surftest SJ 301. The results were obtained and data was analysed. The data shows that the samples 11 with parameters combination of z-lift of 1mm, speed of 20mm/s and length of 1mm give the lowest average Ra value which is 1.33 µm while the data shows that the samples 23 with parameters combination of z-lift of 2mm, speed of 40mm/s and length of 5mm give the has the highest average Ra value which is 5.93 µm, Hence, this results show that the properties of the product produced using Folgertech 3D printer vary with the different combination of process parameters and the Retraction Method provides the solution of determining the optimum combination parameter with minimum number of experiment.

DEDICATION

Only

My beloved father, Abdul Rahman

My appreciated mother, Jamilah Maiden

My adored brothers, Hafiz and Mikhail

For giving me moral support, money, cooperation,

encouragement and also understandings

Thank You So Much & Love You All Forever

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In the name of ALLAH, the most gracious, the most merciful, with the highest praise to Allah that I manage to complete this final year project successfully without difficulty.

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TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS, SYMBOLS AND NOMENCLATURE

ABS	-	Acrylonitrile butadiene styrene
AM	-	Additive manufacturing
AMC	-	Advanced Manufacturing Center
ANOVA	-	Analysis of Variance
BS	-	British Standard
CAD	-	Computer-aided Design
CAM	-	Computer-aided Manufacturing
CNC	-	Computer Numerical Control
DOE	-	Design of Experiment
FDM	-	Fused Deposition Modeling
FKP	-	Fakulti Kejuruteraan Pembuatan
GA	-	Genetic Algorithm
ISO	-	International Standard Organization
OA	-	Orthogonal Array
PC-ABS	-	Polycarbonate-Acrylonitrile butadiene styrene
PC-ISO	-	Polycarbonate ISO
PPSF	-	Polyphenylsulfone
Ra	-	Roughness Average
SOP	-	Standard Operating Procedure
STL	-	Stereolithography
US	-	Unites States
UTeM	-	Universiti Teknikal Malaysia Melaka
3D	-	3 Dimension

CHAPTER 1

INTRODUCTION

1.1 Background

According to American Society for Testing and Material (ASTM), Additive Manufacturing (AM) is defined as a "The process of joining some materials from 3D model data to make an objects, and commonly the process occurs layer by layer, as opposed to subtractive manufacturing methodologies, such as traditional machining". Other names for AM are direct-digital-manufacture, generative manufacture or 3D Printing and producing parts layer by layers of material rather than removing material, as is the case with conventional machining.

Fused deposition modeling (FDM) is a technology in additive manufacturing commonly used for modeling, prototyping, and production applications. It is one of the techniques used for 3D printing. Surface finish, surface texture or surface topography give the same meaning, which it is the nature of a surface and texture of the manufactured surface in manufacturing field. This project investigate the optimize parameter using retraction method to give improvement on the surface finished when using FDM. The project will run a design of experiment (DOE) to find the optimize parameter of the retraction setting. For retraction setting, the parameter that has been adjusted is retraction length, retraction speed, and the retraction z-lift. These combination had been analysed using design of experiment (DOE) by which it can be able to determine every possible combination of experiment using a design matrix table. From here, it be able to get until 27 specimen using matrix 3 x 3 combinations.

All the 27 test specimen were test their surface roughness using surface roughness tester. From that test, analysis was done, which parameter in the retraction give the best surface finished.

1.2 Problem statement

According Ranveer (2004) problems such as oozing and stringing is very common problem occurred in FDM machine. Oozing and stringing cause undesirable surface finish and require post processing processes. This study aims to improve surface finish through several factors such as retraction length, z-lift speed, extra length on restart and minimum travel after retraction. Due to this problem, the surface finished must be considered using retraction method. This is to make sure to have the improvement on the surface finished.

1.3 Objectives

1. To design and print the test specimens to investigate the 3D printed surface finish improvement technique.

2. To study the surface finish quality of the 3D printed test specimens through several factor such as retraction length, z-lift and speed of printing.

3. To investigate the optimize retraction parameters for the best quality of 3D printed surface finish.

1.4 Scope and limitation

When using FDM, it is better to use the best retraction setting. This is because there is a lot of misinformation about how much retraction that it should have.

Common recommendation given is from 1mm until up to 20mm only. The acceptable amount is when minimum amount required to reduce the stringing and oozing on the printed part. Some of the machines are hot ends and require more retraction than others, and each material also has different requirements. In general, it shouldn"t need more than 5mm or less than 1mm.

There are a few other important settings on the retraction that affect oozing/stringing on parts, which is z-lift, speed and retraction length. The process of adjusting the machine retraction parameter to get the least amount of oozing possible, but to start out with a properly calibrated extruder is very critically important. In this project a Folger technologies, llc 2020- will be used as the 3D printer. These 3D printer is very good in terms of performance and their stability during the printing process occur. It has extruded aluminum rails which make it strong as well as aesthetically pleasing of the printed part. Next, Acrylonitrile butadiene styrene (ABS) were choosed as the material of this project. ABS is a common thermoplastic polymer that been used in this 3D printing industry. This material is very light in terms of weight, impact-resistant and heat-resistant.

CHAPTER 2

LITERATURE REVIEW

2.1 Definition of AM

According to the American Society for Testing and Material (ASTM) the AM can define as "the process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies, such as traditional machining". Subtracting material process is removing material from the stock such drilling, lathe, and milling out to material by Gosselin *et* al.(2005). Figure 2.1 shows the different between subtractive and additive manufacturing. According on Rosen (2007), "AM technologies, informally called rapid prototyping, enable the fabrication of parts and devices that are geometrically complex, have graded material compositions, and can be customized". Beside the name of AM, this process also known as additive fabrication, three dimensional printing, solid freeform fabrication, direct digital manufacturing and layered manufacturing by Hague *et* al. (2004).

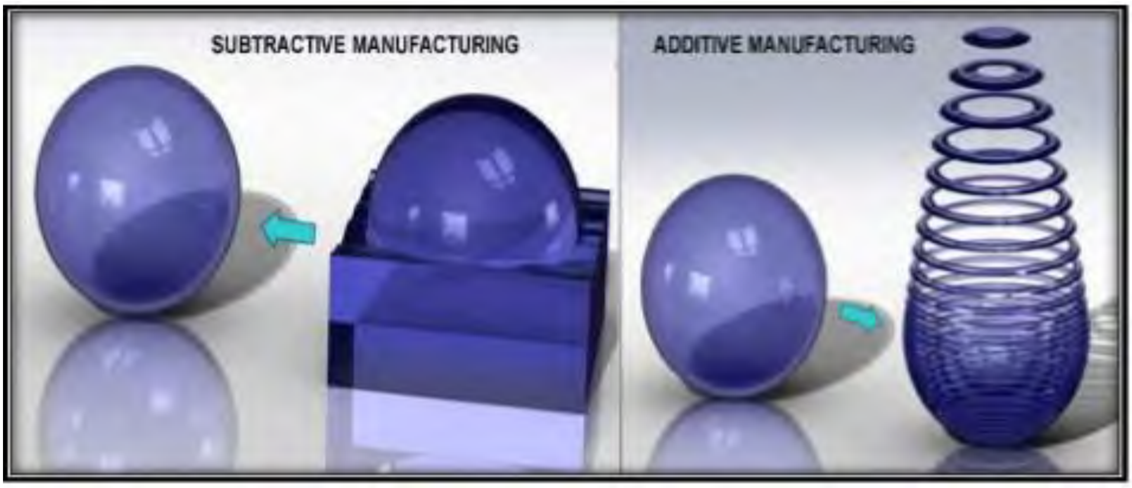

Figure 2.1: The different between subtracting and AM

(Source: <http://www.ciri.org.nz/nzrma/technologies.html> 08/11/16)

2.2 Eight Generic AM Processes

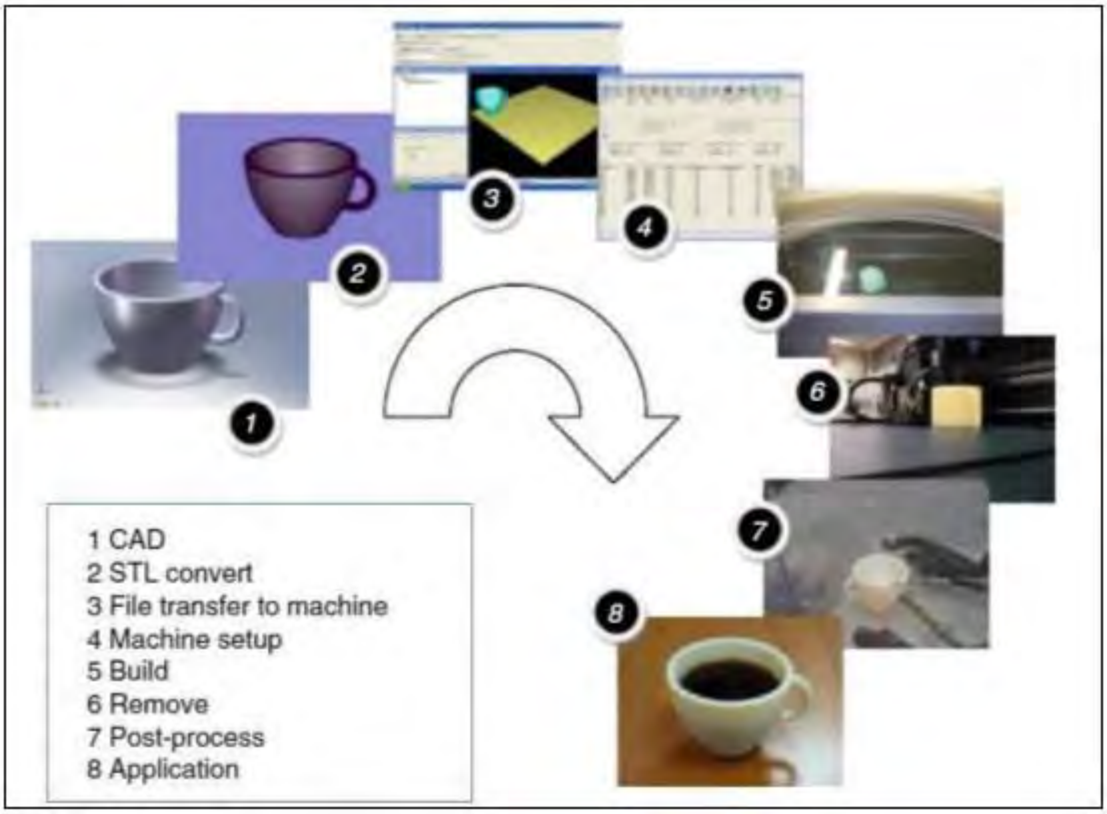

Figure 2.2: Eight Generic AM Processes (Gibson *et* al., 2010)

From the Figure 2.2, it is clearly shown that there are eight steps needed to produce a part for FDM machine.

a) Step 1: Data Creation

A 3D CAD model of the product or part is created using any CAD solid modeling software or reverse engineering equipment using laser scanning equipment. Wozny (1997) has emphasized that the CAD model must be defined in a closed 3D volume with the absence of any holes (Gibson *et* al., 2010).

b) Step 2: Data Export

Almost every AM machines support STL file format. Thus, when the CAD data is converted into STL file format, they are sliced into thin cross-sectional layers (Gibson *et* al., 2010).

c) Step 3: Transfer to AM machine and STL file manipulation

The part can be sent to the AM machine to generate the part after the STL file format is created. However, there will be some modifications to be made to ensure the part is in correct size, position and build orientation (Gibson *et* al., 2010).

d) Step 4: Machine Setup

Process parameters such as material constraints, energy source and layer thickness are set up according to the part requirement (Gibson *et* al., 2010).

e) Step 5: Fabrication of the part

Fabrication of the part is an automated process but the machine needs to be supervised to prevent power failure or running out of materials throughout the FDM process (Gibson *et* al., 2010).

f) Step 6: Removal of Part

The part must be removed once the FDM process is completed. Some of the part produced only can be removed with the aid of tools. Usually, this stage involves the removal of the support structures and excess material contained on the part (Gibson *et* al., 2010).

g) Step 7: Post processing

After the part is removed, they may require some finishing of the parts before they are ready to be used. Polishing, sandpapering, paintings and application of coatings are carried out to give a good surface finish (Gibson *et* al., 2010).

h) Step 8: Applications

The part generated is ready to be used but additional treatment processes have to be carried out if the surface finish is very demanding (Gibson *et* al., 2010).

2.3 AM Process

Although several AM techniques exist, all employ the same basic five-step process. Figure 2.3 are step to step of AM process. The steps are:

Figure 2.3: Step of AM process (Campbell *et* al. 2011)

a) Create a CAD model of the design Firstly, the object to be built is modeled using Computer-Aided Design (CAD) software such as Solidwork, Catia, AutoCAD, and etc. that represent 3D objects more accurate compare wire-frame modelers and give yield better results (Palm, 2002). The model to be built must be representing as closed surface (Chua *et* al., 2003).

b) Convert the CAD model to STL format In the second step, the solid or surface model to create is converted into a dubbed the STL and the STL file format approximates the surface of the model polygon using tiny triangle. Because STL files use planar elements, they cannot represent curved surfaces exactly. Increasing the number of triangles improves the approximation. (Chua *et* al., 2003). Figure 2.4 shows the CAD data are transferred to STL data using Google SketchUp.

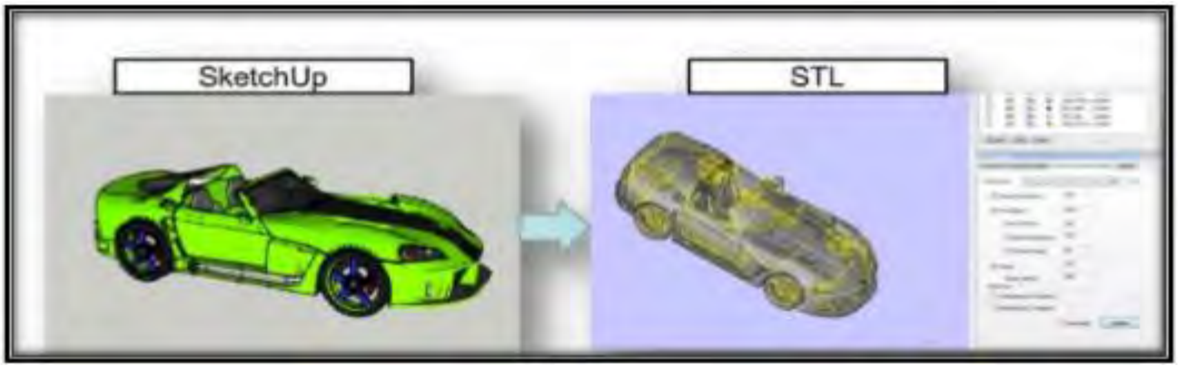

Figure 2.4: CAD data are transferred to STL

(Source: < Source: http://objet.com/3d-printers/software/cad-to-stl> 5/10/16)

c) Slice the STL file into thin cross-sectional layers In this step, it allows the user to adjust the size, location and orientation of the model (Chua *et* al., 2003). Build orientation is important because to determine the amount of time required building the model. The shorter dimension should put on z direction (Palm, 2002). Figure 2.5 shows the example of the model from STL file to be slide.

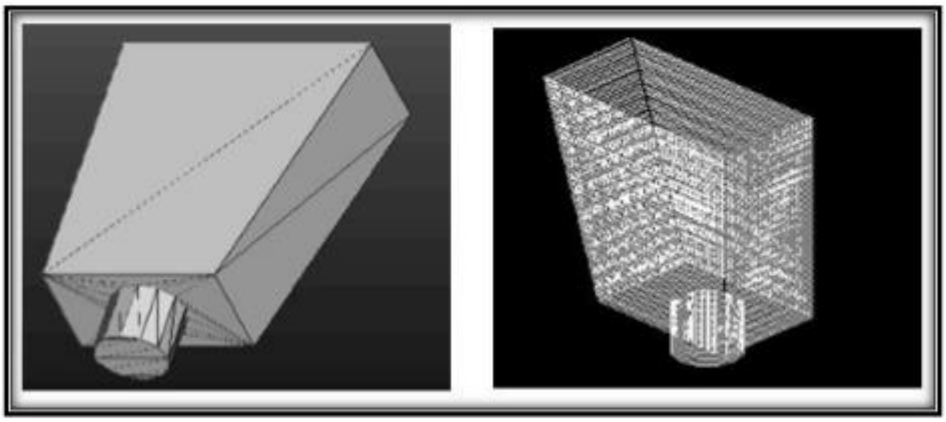

Figure 2.5: Model from STL file to be slide.

(Source: <http://www.intechopen.com/source/html/6601/media/image56.png> 2/10/16)

d) Construct the model one layer on another layer This process is actual construction of the part. Most machines are fairly autonomous. The building process may take up to several hour depend the size and the number of part requirement (Chua *et* al., 2003). Figure 2.6 illustrated the model construction layer by layer.

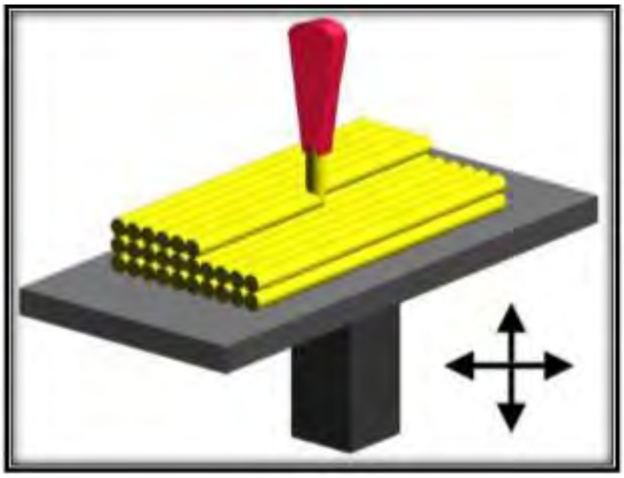

Figure 2.6: Model construction layer by layer.

(Source: < http://en.wikipedia.org/wiki/File:FDM_by_Zureks.png> 5/10/16)

e) Clean and finish the model The final step is post-processing. This involves removing the prototype from the machine and removing any supports. Products may also require minor cleaning and surface treatment. Sanding, sealing, and/or painting the model will improve its appearance and durability (Chua *et* al., 2003). Figure 2.7 are illustrating a cleaning-post of product by AM process.

Figure 2.7: Post Processing

(Source: < http://pricinginsider.carsdirect.com/2011/08/15/gm%E2%80%99s-unbelievably-slickrapid-prototyping-machine/> 2/10/16)

2.4 Advantages and Disadvantages of AM

2.4.1 Advantages

Based on (Campbell *et* al., 2011), AM offers some of benefits over traditional manufacturing techniques (e.g., injection molding, casting, stamping, machining). The advantages of AM such as:-

a) Increased Part Complexity AM process allows designers to create shapes impossible to be thought, has made possible the realization of details never seen before. Figure 2.8 is example of curving internal cooling channels. Besides that, the designer also can take inspiration from nature such as coral, wood, flora and bone to apply in their design (Campbell *et* al., 2011).
   Figure 2.8 shows Dahlia Wall Light from Freedom of Creation by inspired of nature and arrangement of flower petals.

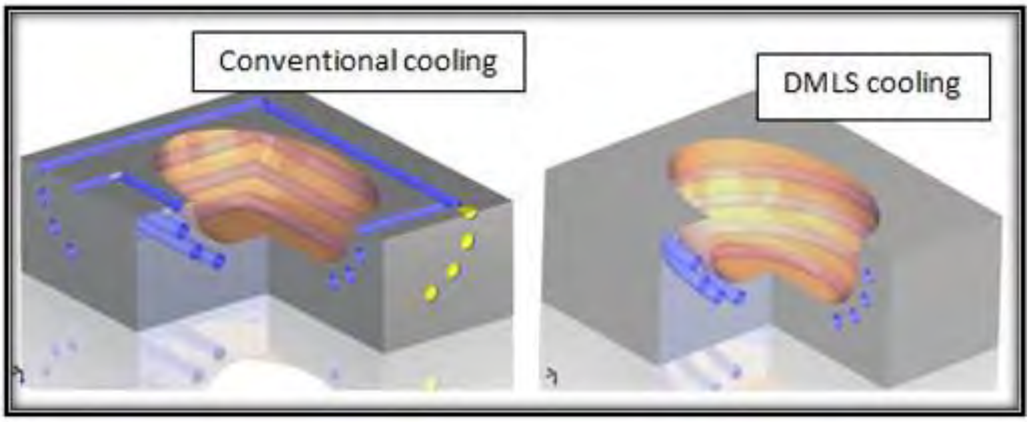

Figure 2.8: Conventional and DMLS curving internal cooling channels (Source:<http://www.metal-powder.net/view/4030/channelling-quality-for-moulded-partsusing-fast-manufacturing/”> 28/10/16)