ULTRASONIC ASSISTED 3D PRINTING TO IMPROVE PRINTED PARTS SURFACE FINISH

Submitted in accordance with the requirement of the University Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Manufacturing Engineering

By

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I hereby, declared this report entitled "Ultrasonic assisted 3D printing to improve printed parts surface finish "is the results of my own research except as cited in reference.

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Name : Puteri Nurul Syaza Syahirah Binti Samsudin

Date : 22 May 2018

APPROVAL

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

Signature : …………………………

Supervisor Name : Associate Professor Dr. Shajahan Bin Maidin

Date : ………………………….

ABSTRACT

Fused Deposition Modeling (FDM) has given several benefits such as it can utilize less expensive material and has free-form design characteristic. Although, FDM had offers great opportunity to have better improvement in the future technologies, it also has several limitations such as seam lines appear between layer and the production of excess material residue on the parts surface. The implementation of ultrasound frequency had been applied in numerous traditional machining and it had given a positive result in getting better surface roughness. However, from the literature review there is no investigation that has been made on the application of ultrasonic frequency for additive manufacturing (AM). This research documented an approach to obtaining better surface finish for FDM sample by applying ultrasonic vibration. There are three input parameters that were evaluated in this research which is layer thickness, frequency and fill of density correspond to it output respond which is surface roughness, Ra. The design of expert 6.0.8 software was used to design an experimental matrix by using Response Surface Methodology (RSM) analysis. Since the experiments for the surface roughness test were conducted, the experimental designs were valid as it was investigated within the ranges and optimum value parameters can be defined. From the experimental result, it is shown that the parameter of frequency and fill of density does not give any influence towards improvement of surface roughness. However, the optimum surface roughness can be occurred at 0.2 mm layer thickness. The optimize parameters on the effects of ultrasonic assisted FDM can be used in order to achieve better surface roughness.

ABSTRAK

Pemendapan Pemodenan Terlakur (FDM),telah memberi beberapa kebaikan seperti ia menggunakan barang yang murah dan mempunyai ciri-ciri reka bentuk bebas. Walaupun FDM telah menawarkan peluang yang luas untuk teknologi di masa hadapan, namun ia juga mempunyai beberapa kelemahan seperti garis diantara lapisan sering kelihatan dan pengeluaran sisa bahan berlebihan di atas permukaan sampel. .Pengunaan frekuensi ultrbunyi telah diguna pakai dalam pelbagai proses pemesinan tradisiomal dan ia telah memberikan keputusan yang positif dalam mendapat kemasan permukaan yang lebih baik. Namun begitu, berdasarkan kajian literatur, tiada penyiasatan telah dilakukan dalam aplikasi terhadap Pembuatan Tambahan (AM). Kajian ini mempamerkan pendekatan dalam mendapat kemasan permukaan yang bagus untuk sampel FDM dengan menggunakan getaran ultrabunyi. Terdapat tiga input parameter yang dinilai dalam kajian ini iaitu ketebalan lapisan, frekuensi dan isi permukaan manakala output respon kekemasan permukaan. Perisian Design Expert 6.0.8 telah digunakan bagi mereka bentuk matriks percubaan dengan menggunkan kaedah tindak balas permukaan (RSM). Memandangkan uji kaji untuk ujian kekasaran permukaan telah dilakukan, reka bentuk eksperimen sah kerana ia diselidiki dalam julat dan parameter nilai optimum boleh ditakrifkan. Dari hasil ujikaji, ditunjukkan bahawa parameter kekerapan dan pengisian ketumpatan tidak memberikan sebarang pengaruh ke arah peningkatan kekasaran permukaan. Walau bagaimanapun, kekasaran permukaan optimum boleh berlaku pada ketebalan lapisan 0.2 mm. Parameter yang mengoptimumkan terhadap kesan ultrasonik dibantu FDM boleh digunakan untuk mencapai kekasaran permukaan yang lebih baik.

DEDICATION

In the name of Allah, the Most Gracious and the Most Merciful

I dedicated this work to;

My parents:

Samsudin Bin Hj. Baslah & Salena Binti Hj.Asan

Cherished siblings

Honorable supervisors and lecturers

Faithful friends

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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. My respected supervisor, Associate Professor Dr. Shajahan Bin Maidin from Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM) for the great mentoring and passionately guided that was given to me throughout the project. Besides that, I would like to express my gratitude to Mr. Hairuddin Bin Kanan for the kind supervision, advice and guidance as well as exposing me with meaningful experiences throughout the study and for permission using equipment‟s.

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CAD	-	Computer Aided Design
AM	-	Additive Manufacturing
RP	-	Rapid Prototyping
ABS	-	Acrylonitrile Butadiene Styrene
PLA	-	Polylactic Acid
MRR	-	Material Removal Rate
FDM	-	Fused Deposition Modeling
DOE	-	Design of Experiment
RM	-	Rapid Manufacturing
SLB	-	Selective Laser Beam
EBM	-	Electron Beam Melting
PBF	-	Metal Powder Bed Fusion
STL	-	Stereolithography
LAN	-	Local Area Network
SLS	-	Selective Laser Sintering
UV	-	Ultraviolet Light
SLA	-	Stereolithography
FFF	-	Fused Filament Fabrication
PJP	-	Plastic Jet Printing

LBMD	-	Laser-Based Metal Deposition
EB	-	Electron Beam
MRI	-	Magnetic Resonance Imaging
CT	-	Computed Tomography
UAM	-	Ultrasonic Assisted Machining
EDM	-	Electrical Discharge Machining
UEDM	-	Ultrasonic-Assisted Electrical Discharge Machining
UADG	-	Ultrasonic Assisted Dry Grinding
CDG	-	Conventional Dry Grinding
UAG	-	Ultrasonic Assisted Grinding
CG	-	Conventional Grinding
RSM	-	Response Surface Methodology
3D	-	3 Dimensions
ANOVA	-	Analysis of Variance
CCD	-	Central Composite Design

LIST OF SYMBOLS

KH_z	-	kilo hertz
KP_a	-	kilo Pascal
W	-	Watt
Mm	-	Millimeters
V_{ft}	-	Feed Speed
Mm/min	-	Millimeters per minute
V_c	-	Cutting speed
a_e	-	Depth of Cut
f	-	Frequency
A	-	Amplitude
Kg	-	Kilogram
Mm	-	Millimeters
µm	-	Micrometers
g	-	Gram

V_p	-	Peak voltage
Ω	-	Ohm
V_{p-p}	-	Peak to peak voltage
ε	-	Absolute error

CHAPTER 1

INTRODUCTION

1.1 Background

Additive manufacturing (AM) is one of amongst 3D printing innovations that manufacture an object by adding layer upon layer of the materials. The old manufacturing method is the material are being carved or shaped into the desired product by removing the part in a variety ways. However, AM works opposite from the traditional method which is the structure are made by the addition of minuscule layer which will combine later to form a product. This process involves the use of a computer and CAD software such as AutoCAD and CATIA, which it can relay the message to the printer to print the desired shape. The most advantages of using AM technologies are greater range of shape can be produced. The diversity of shape with a complex design such as hollow center or scooped still can be prepared to a single bit without need the weld or attach other separate component together.

In rapid prototyping (RP) sector industry, maintaining the quality of the product by lowering its cost is the goal for every industry in this world. Hence, an additive manufacturing (AM) process is an alternative to get a good surface finish without consume too much money on it. For the past 30 years, (AM) has come through a transformation of (RP) technologies which are continuously exhibited in the others names such as 3D printing, additive fabrication, rapid manufacturing, layered free-forming and so forth.

These variations of terminology have been used differently along the world industry due to different perspectives that appears from that industry and academic that utilizes that system. For example, in the US, a solid freeform fabrication is known as an AM term.

However, according to (Wong & Hernandez, 2012) , (AM) is a "processes take the information from a computer-aided design (CAD) file that is later converted to a stereo lithography (STL) file". In this technique, the graphics made in the CAD software is be indistinguishable to a triangles which containing a segment of information that should be set off the each layer that will be printed. The machinery used can compose a multiform shape of product without produce a lot of deformity. Fused Deposition Modeling (FDM) is an example of additive manufacture which produces parts from thermoplastic fibers such as Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid (PLA). The extended filaments are held on spools that are fills through the heated extrusion nozzle. The substances is then being heated until it become a semisolid forms and be injected through a heated nozzle layers by layers to initiate a section of certain element that are controlled by an x-y motion control. Every machine has its own pro and cons, same goes to the other machine, they also have their own advantage and disadvantage. FDM have a capability to form operative parts with a multifarious shape. However, during printing parts processing there are staircase effects which resulting in poor surface finish (Vahabli & Rahmati, 2016).

Ultrasonic assisted machining is one of mechanism in nontraditional machining that used ultrasonic actuation that are attached on the machine tool or at the sample for enhancing the better surface finishes and Material Removal Rate (MRR) of the machine. Furthermore, this ultrasonic assisted machining also are safe to use and conduct because it non-thermal, non-thermal and does not required to electrically conducted to the work piece which make it user friendly. In result, there is no formation of integrity effects, which later may lead to the formation of compressive leftover stresses on the work piece that leads to increase it fatigue strength. The objective of this project is to examine the effect of using ultrasonic-assisted technique by using low-frequency electrical energy (approximately 20 kHz) to improve the printed parts surface finish build by FDM. Ultrasonic is proven technologies that are able to increase the quality of surface finish and has been commonly used for machining (Maidin *et al.*, 2015)

The ultrasonic vibrations with piezoelectric unit that oscillate in vertical axis have been used in laser machining will produce a high degree of surface finish. The electrical signal is relayed to the transducer that converts it into mechanical vibrations that are transmitted through a 3D printer platform. The machining that assisted by ultrasonic will not produce or cause any chemical reaction which it is safe to use. Furthermore, the work piece also does not require to electrically conducting.

There are so many options about the effect of using ultrasonic in FDM machine. (Maidin *et al.*,2015) claimed that ultrasonic oscillations can condense the stairway impact during the printing which may promote better surface finish of the part model. (Friel & Harris, 2011) found that, the processes are suited to high tech metal matrix composites with high temperature and density. In this study, three important process parameters of FDM will be measured which is; (a) the frequency of ultrasonic vibration, (b) layer thickness and (c) fill of density. The measured surface roughness will be determined in the end of the printing process. In this project CATIA will be used to draw the 3D model of the part model.

1.2 Problem Statement

For the past few years an Additive manufacturing (AM) technologies had been around with theatrical improvements in order to recover its quality build. However, there are some restrictions on the printed 3D surface which is the seam lines show up amongst layers and excess material if often left as residue, which tend it to have destitute surface texture. In addition, the FDM-based AM process has the most noticeably poor surface roughness compare to the different liquid (stereolithography) and powder based material (selective laser sintering) AM process. This occurred because of the use of nozzle for material deposition, which give it higher propensity to use of higher layer thickness so that the effect of stair-stepping error and raster pattern are significant (Taufik & Jain, 2017).

Some researchers have noticed the chip discontinuity in material such as Inconel and aluminum when ultrasound frequencies are applied in the drilling process; some others did not address the chip-breaking formation either in penetrating or turning machining. The utilization of ultrasonic oscillations in various fabricating processes is well reported for more than 50 years (Pandey *et al*., 2003). Ultrasonic machining has been basically connected on delicate material, and in spite of the fact that expulsion rates are quite high, thus ultrasonic technologies has suit exceptionally to this type of material. Ultrasonic assisted machining has been demonstrated to be successful technique to moving forward the machinability of a few light materials such as aluminum (Brehl & Dow, 2008).

1.3 Objective

The objectives of the research are as follow:

i. To identify the significant term of process parameter by using Design-Expert software towards better surface roughness during 3D printing assisted ultrasonic piezoelectric transducer.

ii. To determine optimization value set of process parameter by using Design Expert software towards good surface roughness.

iii. To examine the impact of applying low frequency of ultrasonic (below 20 kHz) on 3D printed sample surface finish.

1.4 Scope of Project

This project focused on the impact of applying ultrasound frequency to develop better surface finish of 3D printed parts. The material used in this research is ABS polymers with a measurement of 1.5 cm x 1.5 cm x 1.5 cm were created by using Solidwork program. The sample model of 3D printing is fabricated by using low cost FDM machine UP Plus 2 3D printer. In addition to implement the ultrasonic assisted FDM, it is important to assess the capability of FDM process for making parameters such as layer thickness; frequency of piezoelectric transducer and fill of density. In ultrasonic state, the standard piezoelectric transducer were working in a flat mode were designed, manufactured and securely mounted to the perfboard of FDM machine. The piezoelectric transducer was settled so that the vibration was transmitted equally through the platform of FDM machine. A power generator which transmits the ultrasonic vibration that has frequency range between 1 until 27 KHz was used. The measurement of the nozzle is same as FDM nozzle in FDM research facility of Faculty Manufacturing Engineering, UTeM. The Mitutoyo surface roughness portable tester was used to determine the surface roughness value of the printed sample. In this project, the Design-Expert software version 6.0.8 was used to design the experimental runs of this research and analyze the response obtain by using Central Composite Design (CCD) under Response Surface Methodology (RSM) method.

1.5 Significant of study

Low frequency ultrasonic piezoelectric transducer is applied during the process of 3D printing of ABS filament. The purpose of implementation of ultrasound frequency is to reduce stair-case effect and seam lines that often appear to the surface of printed parts that may resulting in poor surface roughness. The Design of Experiment (DOE) will be applied to this research to help in analyze and obtaining the significant value of the correspond output which is surface roughness, Ra.