PERFORMANCE EVALUATION OF FDM WATERWORKS SYSTEM FOR ABS PART

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To my loving wife , Elmy Johana Mohamad and sons, Muhammad Hafiy Darwis and Muhammad Harris Haikal , my family and friends.….

"My Success Is Yours Too"

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ABSTRACT

Fused Deposition Modeling(FDM) is one of the Rapid Prototyping(RP) Technologies to produces plastic prototypes from acrylonitrile butadiene styrene(ABS) which has control over numerous processing variables that will impact the quality of the fabricated part . The ability to select the optimal process parameters has been a major concern for part quality improvement. This work was undertaken to determine parameters which influence the part quality for FDM Waterworks Soluble Support(WSS) system .The effect of these factors on FDM performance or response were investigated and the optimum conditions of those responses were established. Design Of Experiments (DOE) was used to perform the experiments. Experimental results were analysed by using Minitab software to obtain the significant parameters and to optimize the setting. Pareto Chart, Analysis of Variance(ANOVA), Main Effect plot and Regression were employed to determine the significant parameters and to generates recommendations of process variables setting and the associated predict build outcomes for FDM process . Finally, validation tests were conducted to verify the model of each responses against the actual results.

ABSTRAK

Fused Deposition Modeling(FDM) merupakan salah satu daripada Teknologi Pembuatan Deras untuk menghasilkan prototaip plastik daripada acrylonitrile butadiene styrene(ABS) di mana terdapat pelbagai proses pembolehubah perlu dikawal yang akan memberi kesan terhadap kualiti produk. Kemampuan untuk memilih parameter yang optimum telah menjadi penting untuk memperbaiki kualiti sesuatu produk. Kajian ini dijalankan untuk mengenalpasti parameter-parameter yang memberi kesan terhadap kualiti produk untuk FDM Waterworks Soluble Support(WSS) sistem. Faktor atau respon yang memberi kesan terhadap prestasi FDM dikaji dan keadaan optimum dapat ditentukan untuk setiap respon tersebut. Design Of Experiments(DOE) digunakan untuk menjalankan kerja eksperimen. Keputusan kajian dianalisis menggunakan perisian Minitab dimana untuk mendapatkan parameter-parameter yang penting dan meramal keadaan yang optimum. Rajah Pareto, Analysis of Variance(ANOVA),Main Effect Plot dan Analisis Regression digunakan untuk memperolehi parameter penting dan memberi rekomen dan ramalan terhadap produk yang dihasilkan di dalam proses FDM. Akhirnya , ujian pengesahan dijalankan untuk mengesahkan di antara model setiap respon dan keputusan sebenar.

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LIST OF SYMBOLS & ABBREVIATIONS

%	Percent
μm	Micro Meter
^{o}C	Degree Celsius
Ø	Diameter
ABS	Acrylonitrile Butadiene Styrene
ANOVA	Analysis Of Variance
BASS	Breakaway Support System
BT	Built Time
CAD	Computer-Aided Design
cm	Centimeters
CMM	Coordinate Measuring Machine
DOE	Design Of Experiment
DA	Dimensional Accuracy
DF	Defect
FDM	Fused Deposition Modeling
LM	Layered Manufacturing
LOM	Laminated Object Manufacturing
m	Meters
mm	Millimeters
RM	Rapid Manufacturing
RP	Rapid Prototyping
RP&M	Rapid Prototyping and Manufacturing
RT	Rapid Tooling

RTV	Room Temperature Vulcanizing
SFM	Solid Free-Form Manufacturing
SGC	Solid Ground Curing
SL	Stereolithography
SLA	Stereolithography Apparatus
SLS	Selective Laser Sintering
Std.	Standard
.STL	Stereolithography File
UG	Unigraphics
WSS	Water Soluble Support System

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CHAPTER I

PROJECT BACKGROUND

1.1 Introduction

Rapid prototyping (RP) is a process in which a part is produced using layer by layer deposition of material. It is an important technology as it has the potential of reducing 30 to 50 % of the manufacturing lead time of the product even the product complexity is very high (D.T. Pham and S.S. Demov., 2001). The RP cycle consists of creation of geometric model using a solid modeler, determination of suitable deposition orientation, slicing, generation of material deposition paths, part deposition and the post processing operations. Most of the steps in RP are automatically driven; however part deposition orientation is selected manually among the few options provided by the RP software. Orientation for a part deposition on RP machine platform has a significant effect on many key characteristics which will determine the final quality and cost of the prototype (P.Alexander, et al., 1998).

Fused Deposition Modeling (FDM) is one of the major technique in developing rapid prototypes or models. The FDM machine builds the part by extruding a semi-molten filament through a heated nozzle in a prescribed pattern onto a platform. A second nozzle may extrude a second material usually the support material if required. When the first layer is completed, the platform move downwards by one layer thickness and the building process repeats all over again. Once completed, the build model is removed from the platform and removal of the support materials is done to obtain the final part.

Recently , there are profoundly numerous possible parameters that can affect the final quality of part using FDM. Altering the parameters will affects the character of the resulting part. Determination of the proper significant parameters and optimum condition has been a subject of research in the FDM area for a some time . Bharath, et al. (2000), found the orientation and layer thickness as a significant parameters influence to surface finish quality. Anitha, et al. (2001), concluded the layer thickness has been proved influenced to surface roughness. Azanizawati, et al.(2003), have studied optimization for build time and surface finish. They found that the layer thickness and orientation influence to build time and orientation was the significant parameter affect to surface roughness.

It is observed that most of previous work on produce better part quality has been related to FDM BSS(Breakaway Support System).Not much work about orientation has been directed to the FDM WSS system. Therefore , continue evaluation on performance of part deposition orientation is a very essential as it effects build time, surface finish, dimensional accuracy and defect occurrence. In this project, Design Of Experiments (DOE) technique were used to study the influence of numerous parameters setting , optimum setting condition and predict the part quality outcomes .

1.2 Background Of Problems

Evaluation of part surface quality, geometrical accuracy and reduction in build time is a major concern in RP technologies. Very few attempts (Nur Fazidah and Safian Sharif, 2003) (D.T. Pham and S.S. Demov., 2001)(S.H. Masood, et al., 2001) (K.Thrimurthulu, et al., 2004) have been conducted to evaluate performance of FDM process which is more dominant as compared to Stereolithography(SL). Current support removal system using BSS(Breakaway Support System) where the predecessor to WSS(Waterworks Soluble Support) system that requires manual stripping of support from the part surface seems to be less efficient as compared to WSS system in obtaining optimum part quality within FDM technology .However in WSS system there are lack of information settings and optimum parameters used on producing acceptable part quality. Research on the FDM WSS system more limited as compared to Breakaway Support System (BASS) where the WSS is the latest invention in FDM technology .

Currently, it was reported that most of FDM users use the default settings of the various of parameters and others rely on the supplier recommendation or use trial and error methods (Azanizawati, et al., 2003). These practices created waste of material and time in achieving the optimum part quality . Furthermore, there are various methods in determining significant parameters and to predict optimum condition of settings including Adaptive Slicing, Classical Method and DOE(Design Of Experiment). A study on suitable method is required .

Hence there is a need to determine and produce a new prototype model for identifying significant parameters and optimum settings within WSS system based on various design criteria of responses through a suitable method . In addition optimizing process parameters is one of the major concern in FDM research areas. Once the parameters of the model have been determined experimentally, the model should be able to give reliable predictions under various final part quality requirements.

1.3 Research Questions?

(i) Can the identification and evaluation of significant parameters in the FDM WSS process in building a compliant prototype using suitable method which influence the part quality?

(ii) Can the analysis of the significant parameters result in optimised settings for predicting and influencing part quality, based on criteria of responses?

1.4 Objectives of the Project

The main objectives of the study are as follows:

(i) To analyse significant parameters of FDM-WSS (Waterworks Soluble Support within Fused Deposition Modeling) system which give influence to the responses of the build part quality, based on Design of Experiment(DOE) and Classical Analysis methods.

(ii) To determine and analyse optimum settings from the significant parameters for each criteria of response by using DOE approach which result in improved part quality.

(iii) To validate the optimum part quality using a predicted regression model and actual conditions.

1.5 Scope of the Project

Experimental investigation will be carried on the FDM Stratasyss Prodigy Plus waterworks system using P400 ABS as the part material. Experiments will be carried out based on Design of Experiment(DOE) approach and all related parameters and responses will be analysed using Minitab Software. The 3D model of the part will be created using the Unigraphics package. InSight software will be used to provide the necessary information on the FDM process. The response that will be investigated and evaluated are build time, surface roughness, dimensional accuracy and part defects.

1.6 Importance of the Project

Identifying the significant factors in the FDM process will eventually assist in building a quality prototype. Quality prototype possess good surface quality, high dimensional accuracy , low cost and less defects. Since FDM is a complex technology which involves many different process parameters, continuous improvement of the prototype quality are particularly important. By determining the significant parameter which effect to the part quality, the optimum process condition can be obtained and predicted for future part development .

CHAPTER II

LITERATURE REVIEW

Layered Manufacturing(LM) or RP is a process which automatically generates a physical 3D object through layer by layer deposition of raw material. The 3D solid model can be created in a solid modeler packages such as Unigraphics, Ideas, ProE etc. It's now become imperative for manufacturer to use the RP technology during their product development to enhance the ability of the product or model to be produced. Currently, the diverse nature of RP processes leads to a wide variation of product quality characteristics. However, all processes have a common problem of stair stepping which will have a significant effect on final the product quality. It is often desirable for an RP model to have lower surface roughness, good accuracy and lower build time..

Today, FDM is the second most common commercial layered manufacturing system (Justin, et al. 1999). There are several attempts to produce better product using FDM. These attempts were intended to obtain product which best surface finish, lowest build time and high geometrical accuracy. It has becomes a big challenge for a RP user to minimize the adverse effects through appropriate orientation of the model during building. Currently, there is no systematic methodology or software to aid this process

(R.I. Campbell, et al. 2002). For optimum selection orientation, the user must have some indication of the product quality. Most of the FDM users use the default setting of the various parameters available in the system when building a model. Others rely on the supplier recommendation or use trial and error methods in order to obtain a good quality model within a very short time (Azanizawati, et al. 2003).

Todd Grimm et al. (2003), explained that there were two reasons. First , FDM brings forth a new set of evaluation criteria since the technology has different parameter set than other RP technologies . Second , while it is widely used , the technology is most often applied to internal use rather than service bureau operations , which limits the availability of hands on data .

2.1 Introduction To Rapid Prototyping

Rapid Prototyping (RP) can be defined as a group of techniques used to quickly fabricate a scale model of a part or assembly using three-dimensional computer-aided design (CAD) data (Hilton, et al. 2000) . It is also refers to the physical modeling of a design based on a special class of machine technology (Wohlers and T., 2003). The capability of RP in directly generating physical objects from graphical computer data enable the transition from basic research and design work into finished products faster, with higher quality, and at lower cost.

RP has also been referred to as solid free-form manufacturing (SFM), computer automated manufacturing, and layered manufacturing. Solid is used because while the initial state may be liquid, powder, individual pallets or laminates, the end result is a

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