DEVELOPMENT OF PREDICTIVE MODELS FOR THE COALESCENCE OF FUSED DEPOSITION MODELING FIBERS

A Thesis presented to the Faculty of the Graduate School at the

University of Missouri-Columbia

In Partial Fulfillment of the Requirements for the Degree

Master of Science

---

by

QUAN HONG NGUYEN

Dr. A. Sherif El-Gizawy, Thesis Supervisor

DECEMBER 2017

The undersigned, appointed by the dean of the Graduate School, have

examined the thesis entitled

DEVELOPMENT OF A PREDICTIVE MODEL FOR COALESCENCE OF FUSED DEPOSITION MODELING FIBERS

presented by Quan Hong Nguyen,

a candidate for the degree of Master of Science,

and hereby certify that, in their opinion, it is worthy of acceptance.

Professor A. Sherif El-Gizawy

Professor Jian Lin

Professor Hani Salim

ACKNOWLEDGEMENTS

I would like to express my sincerest gratitude and warm appreciation to the following persons who had great contribution to this study

Dr. A. Sherif El-Gizawy, thesis advisor, for his constant guidance and encouragement, without which this work would not have been possible.

Dr. Yuwen Zhang, Department Chair of Mechanical and Aerospace Engineering Department, for his valuable suggestions and his great supports.

To the financial support of Ministry of Education and Training for offering me a full scholarship for graduate studies.

To my family for their encouragement which helps me in the completion of this work. To my beloved and supportive wife, Linh who was always by my side when I felt tired the most.

To all my friends and lab mates, especially to Huy Nguyen for guiding and helping me in finding the solutions for many problems that I had while conducting my research.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

Figure **Page**

Table **Page**

ABSTRACT

Fused deposition modeling (FDM) is the prominent manufacturing method for fabricating end-use parts due to the ability to build complicated structures. In order to be used confidentially in the industry requires a thorough understanding of mechanical behavior of FDM parts under working conditions. The strength of FDM parts is negatively influenced by the insufficient bond strength achieved between fibers, the weakest links in the FDM parts are the weak inter-layer bonds and intra-layer bonds. The aim of this study is to create models that can accurately predict bond length and bond strength between fibers. Analytical equations describing the sintering processes and heat transfer between FDM fibers and surrounding environment are developed and presented. By comparing the predicted value to the actual bond length, the models are found to be moderately accurate. To validate the relation between bond length and bond strength and also determine the process parameters that affect the bond strength, design of experiments (DOE) and analysis of variance (ANOVA) were applied. The result showed that the extrusion temperature to be statistically significant. Further research is recommended to take in to account more factors that could affect the cooling and sintering process that will help improve the precision of predictive models.

1. Introduction

1.1 Additive Manufacturing

There are numerous methods for fabricating components. The conventional manufacturing method constructed parts by removing material away from a solid block of material. In opposite to that, an emerging technology has been explored and become more favorable in manufacturing industry which is additive manufacturing.

Additive manufacturing(AM) has much more advantages than conventional manufacturing method. The highlight benefit of AM is the ability to build complicated geometries without any extra tools at very short time. In fact, to construct an object with complicated structure, traditional manufacturing takes days to complete, it also requires at least three cutting tools and professional machine users. In addition to that, cutting tool will be wear after limited uses that require replacement. On the other hand, AM takes hours to complete the same task, works without tooling and require no professional training to operate the machine.

Additive manufacturing builds objects by adding layer upon layer of material until the object is completely built. This can be accomplished by various methods such as SLS, SLA, FDM. Selective Laser Sintering (SLS) uses a laser beam to heat and melt thermoplastic powder into a continuous bonding layer. SLA on the other hand build object in a pool of resin. A laser beam is directed into the pool of resin, the trajectory of the beam following the same cross-section pattern of the object. Different to the other methods, fused deposition modeling (FDM) extruded melted polymer filaments through a heated extrusion