"I have read this report and from my reading, it meet the requirement and quality for purpose of been awarded Bachelor Degree of Mechanical (Design & Innovation)"

Signature :.....

Supervisor :.....

Date :.....

STUDY OF ACRYLONITRILE BUTADIENE STYRENE PROPERTIES BY FUSED DEPOSITION MODELING (FDM)

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The report is proposed in order to the requirement being awarded Bachelor Degree of Mechanical (Design & Innovation)

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"Hereby I would like to confess this report is completely done by myself except the articles, passages, data, and summary that I've declare the resources"

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Date : 3 JUN 2008

DEDICATION

To beloved Mother and Father :

Mr. Abu Bakar bin Abd Majid and Mrs. Fatimah bte Abdullah

My Siblings :

Mohamad Faisal bin Abu Bakar

Nur Asyikin bte Abu Bakar

Mohamad Firdaus bin Abu Bakar

Muhammad Faiz bin Abu Bakar

Nur Adibah bte Abu Bakar

To all my friends and others

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ABSTRAK

Kajian adalah penyelidikan mengenai mendapatkan kekuatan optimum bahan *Acrylonitrile-Butadiene-Styrene (ABS)* yang dihasilkan sebagai prototaip atau spesimen melalui mesin *Fused Deposition Machine (FDM)*. *FDM* ialah salah satu mesin berteknologi *Rapid Prototyping (RP)* yang menggunakan aplikasi penerobosan. Menjelang hari ini teknologi ini telah digunakan secara meluas di serata dunia di dalam pelbagai bidang. Tujuan penggunaan *ABS* ialah kerana ianya termoplastik dan hanya termoplastik yang boleh digunakan dengan aplikasi penerobosan. Selain faktor itu, *ABS* juga mempunyai kelebihan sifat-sifat mekanikal yang tahan tehadap kesan hentaman, menyerap hentakan dengan baik dan ianya jauh lebih ringan dari besi. Dalam penyelidikan ini parameter-parameter yang terdapat pada mesin *FDM* digunakan dan dimanipulasi untuk menghasilkan kekuatan spesimen atau prototaip yang optimum. Spesimen atau prototaip yang terhasil akan diuji kekuatan melalui *Universal Testing Machine (UTM)*. Logiknya spesimen yang mempunyai kekuatan optimum akan mengambil paling lama untuk ditarik kerana kekuatan tegangan yang dikenakan berkadar langsung dengan masa, semakin lama masa diambil semakin tinggi kekuatan tegangan yang dikenakan terhadap spesimen .

ABSTRACT

Nowadays Rapid Prototyping (RP) is widely used around the world such as in engineering, medical, industrial and etc. Beginning in the early 80's somewhere in Europe and U.S, their engineer had developed a technology that called as time compression technology (TCT) where this technology is developed to compress product or parts time to market. As the time goes by and the RP technology grows rapidly it now can be divided into 3 categories which are Solid based RP, Liquid based RP, and Powder based RP. This research is concerning about Fused Deposition Modeling (FDM) which is in Solid Base RP category. Generally information, FDM used Acrylonitrile-Butadiene-Styrene (ABS) as its material to form prototype. The purpose of using ABS as the material FDM technology is because ABS offering the best mechanical properties and suitable with FDM processes compared to other thermoplastics. For an example, ABS is offering a good impact strength, good shock absorbance, and lighter than metal. The general properties of ABS have been determined a long time ago by chemist for that reason determining the greatest strength of ABS material after been fabricated through FDM is the main priority in the research. Taken into account is FDM machine parameter as manipulate variable such as extrusion head speed, temperature, bead width, raster orientation, air gap, and model plane of extrusion.

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CHAPTER 1

INTRODUCTION

1.0 Research Background

The study is about study the ABS mechanical strength which is the material is fabricated through the Fused Deposition Modeling (FDM) to form a specimen. Generally mechanical strength can be defined as compression strength, impact resistant strength and etc. In this study, only tensile strength of the material will be test and study.

Generally, FDM is one of the Rapid Prototyping (RP) or Time Compression Technology (TCT) in manufacturing any product in shorter time but in return gives good quality of product or prototype. RP are globally applying in industrial field to fulfill customer requirement, therefore many types and categories of RP technology are developed. For FDM technology, it is categorized under solid-base RP system because from the first stage the material used is in spool form which is solid form and will remain as solid at the final stage. The technique used in this technology is extrusion method where the raw material will be extruded through the extrusion nozzle in semi-liquid form and built up the prototype layer by layer. Any further information about this system or technology will be discussed in chapter 2.

ABS is the material that will be used in this research to find out the mechanical properties. The type of material that will be used is P400 ABS that specialized made for the FDM prototyping machine. For a common knowledge ABS is widely used in industrials field, it is not only for production but also for making prototyping because the mechanical is strong and the result of any mechanical testing is quite similar with the actual product. ABS offers good impact strength, high tensile strength; even it is good UV resistance. The application of ABS is always applied on automotive industry such as interior of car, wire insulation, piping, and mobile phone.

In this research, the parameter of the machine will be controlled to get variety pattern of specimen and will under go mechanical experiment. The parameters that can be controlled in this machine is the thickness of the layer, the surface of every layer weather it is very close to each other or wider, and the path width or called road for a single extruding. Further discussion for ABS also will be detailed in literature review.

1.1 Problem Statements

The problems that occur in fabricating specimen using FDM is how the strength of the specimen can be optimize to the highest level. In this issue the problems highlighted are:

1. The need for designs that are optimum with respect to a variety of possible load conditions.
2. The possible need for both discrete and continuous design variables which prevents the direct application of efficient, gradient based optimization strategies.
3. The possibility of multiple optimum processes parameter values.

1.2 Objective

The objective of this research is to predict the behavior of ABS parts of FDM. The prediction is made before the tension test is held. What is the bigger amount of load could the specimen withstand.

1.3 Scope

The scopes that has to be covered in this research are listed as below :

- Study the FDM technology, like how the operating process and what is the main concept adapt in this technology.
- Study about modeling part using Auto-Cad or Catia software.
- Controlling parameters in order to produce the high end quality specimen, especially the mechanical properties.
- Using the Universal Tensile Machine (UTM) to test the specimen's mechanical properties.

1.4 Significant Of Research

The significant of the research are stated below:

- Produce components or parts with an adequate mechanical performance like stiffness, tensile, and durability of the FDM parts.

- Produce the best quality of parts with the right control of FDM parameters.

1.5 Summary

In the fist chapter, briefly discussed about the research objective until to the significant of the research. The problem statement regarding ABS parts produced by FDM technology are actually about optimizing the strength by manipulating the variables existed in FDM itself, such as processing parameters, while in the scope stressing about the main four matters which is about the FDM technology, CAD, Controlling or processing parameters, and the UTM.

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

In literature review is going to discuss about three main topics which is consist of ABS, FDM technology and machine, and Universal Testing Machine (UTM). The discussions about those three subjects were based on past experimental or project, source from internet like general article or journal from around the world university about the related to those 3 topics. Other information or literature sources are from the local library or university library, machine manual, and lecturer.

ABS will be the first sub-topics its going to discuss in this chapter. Generally ABS is from polymer category and the letter A.B. and S could be define generally the behavior or properties. ABS is a combination of Acrylonitrile-Butadiene-Styrene which is each of the elements has its own properties as told earlier. As known, ABS is the best material to be manufactured for conceptual prototyping through design verification through direct digital manufacturing. Before this a lot of experimental about similar to this project are held and the facts from the experimental result also taken as for review.

The second topics are FDM technology also is main role to this project. The FDM actually is one of the concept or method of rapid prototyping. FDM is known from the solid base RP system and using ABS as the raw material to manufacture prototype.

FDM using the additive layer method to built product or prototype besides implementing extrusion of material known as ABS. The review is about how to control the parameters consist in the machine and study of the impact to the prototype. Furthermore FDM play an important role in this project because through this process a variety pattern of ABS specimen about to be produced. This machine only read drawing in STL format while the drawing can be made from any CAD software.

The final part which smaller role compared to FDM and ABS analysis is UTM where the specimen will undergo a tensile strength test. UTM is machine that fabricate to held variety of mechanical test with a constraint, also provided with integrated software to run this machine. The specimens that will be experience tensile test are modeled according to this machine standard specimen. Result of the experiment will be given through the software, in form of graph and from there the yield strength and other fact of ABS finally determined.

2.1 Fused Deposition Modeling Development

As discussed at the earlier chapter FDM is kind of rapid prototyping where nowadays prototypes are an important and vital to the product development process. A little history about FDM technology development, it was found in 1989 by Stratasys Inc. In the early days around 1988, Scot Cramp is the person who responsible in developing and inventing FDM in his garage. In his new developing technology, he has implemented the concept of extrusion where the material to built 3D model will be extruded through a nozzle in the machine. Extrusion process actually is a additive process known in RP technology, the additive by process will be discuss under it's topic in this chapter. Generally FDM will built 3D model layer by layer where nozzle will extrude the built material until it finish building the first layer, also in the first layer is a support structure extruded through the same nozzle. In my research, I am using FDM

prodigy plus to built ABS specimen to be test. FDM Prodigy Plus is like shown in below picture in **Figure 1.1**

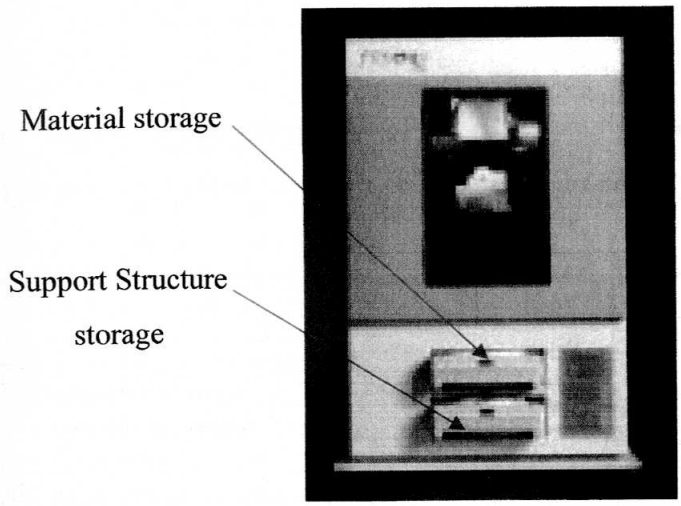

Figure 1.1 : Stratasys' FDM Prodigy Plus (Source : Stratasys Inc, 2005)

For this system, preprocessing software used to run the system is Insight where the 3D model will be read in STL format. While the drawing of model could be draw form any CAD software and it will be converted to STL format to be compatible in FDM system.

2.1.1 RP Process Chain

As described in FDM machine process chain, all RP techniques adopt the same basic approach. As such all RP systems generally have a similar sort of process chain. Such a generalized process chain is shown in **Figure 1.2**. There are a total of five steps in the chain as below (Source: RP : Principles and Applications, Chua C. K, 2003) :

- 3D modeling
- Data conversion and transmission
- Checking and preparing
- Built part
- Post processing

Depending on the quality of the model and part in Steps 3 and 5 respectively, the process may be iterated until a satisfactory model or part is achieved.

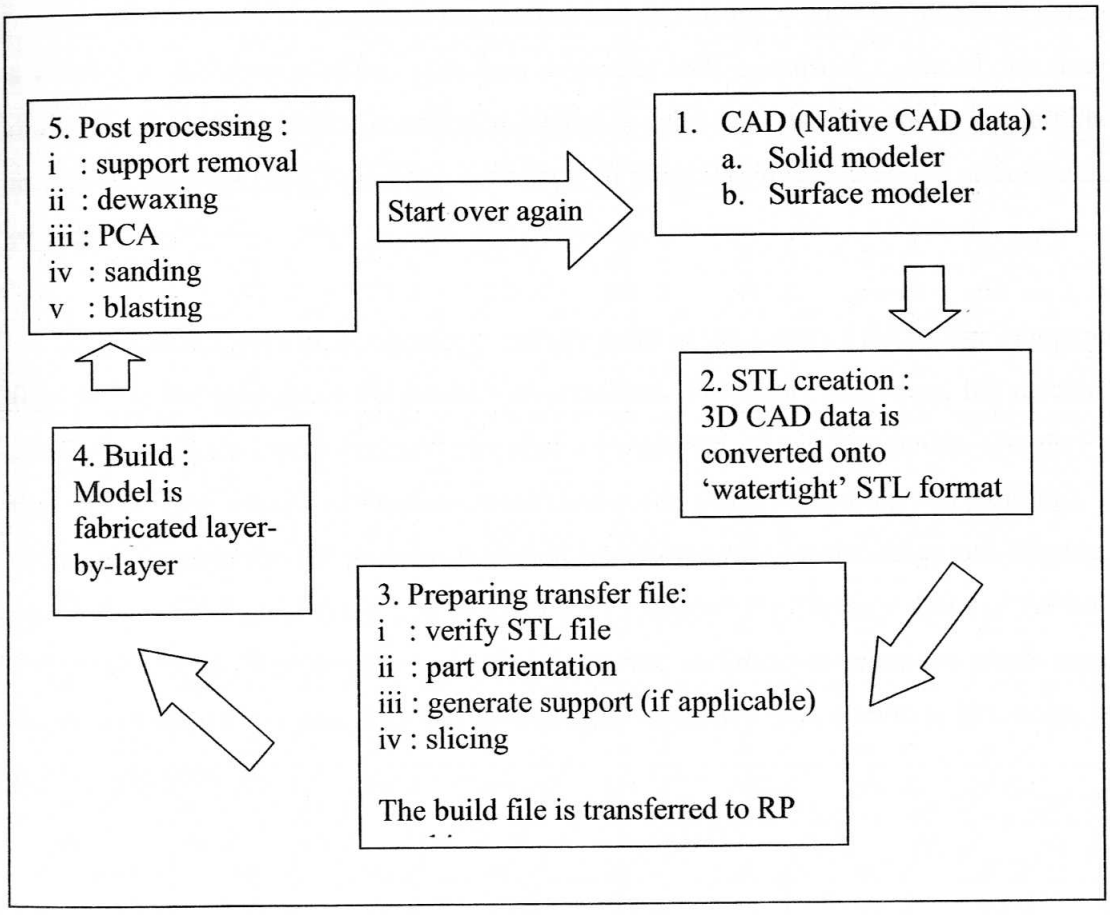

Figure 1.2 : Process chain of Rapid Prototyping

2.1.2 Additive Process

Additive RP operations all build part in layer. In order to visualize the approach used, it is beneficial to think of constructing a lot of bread by stacking individual slice on top of each other. All of the processes describe in this section build part slice by slice. The main difference between the various processes lies in the approach taken to produce the individual slice.

All additive RP operations required elaborate software. The first step is to obtain a CAD file description of the part then computer will constructs slices of the three dimensional part. Each slice is analyzed separately, and a set of instructions is compiled in order to provide the RP machine with detailed information regarding the manufacture of the part.

RP in this approach requires operation input in the setup of the proper computer files and in the ignition of the production processes. Following this stage, the machine generally operates unattended and provided a rough part after a few hours. The part is then put through a series of finishing manual operation (such as sanding and painting), in order to complete the RP process. It should be recognized that the setup and finishing operations arc very labor intensive and that the production time is only a part of the time required to obtain a prototype. In general, however, additive processes are much faster than subtractive processes; they can take as little as from a few minute to few hours to produce the part.

2.1.3 FDM Processes

In this part FDM process will be discussed in detailed. As the drawing of the model converted into STL format, justification of parameters will be done in Insight

software for FDM Prodigy Plus. The model will be sliced into layer than can be determined the thickness of the layer manually. Other parameter like an example the gap between road to road also can be manipulated for sake of cost, strength, or material usage. **Figure 1.3** shows that model is turn into slices of layer in the red color and parameters that can be decided at the side of the window.

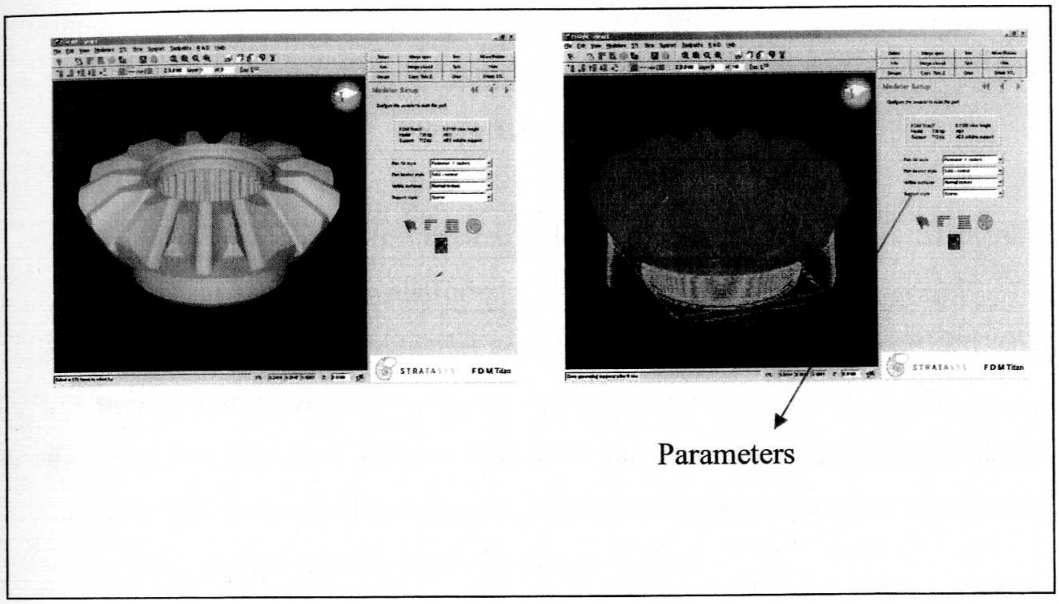

Figure 1.3: Shows the Insight is converting solid model into slices in red color and some of parameters at the right side of the window.

These are the process on FDM machine:

1) Temperature in the chamber will be get heated first, at this level there are two things will get heated. **Figure 1.4** illustrate the are that get heated :
    - Envelope area heated to 70°F
    - Extrusion head heated to 280°F