WEAR BEHAVIOUR OF 3D PRINTED PART OF CARBON FIBRE REINFORCED ABS COMPOSITE

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Report

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DECLARATION

I declare that this project report entitled "Wear Behavior of FDM Printed Part of Carbon Fibre Reinforced ABS Composite" is the result of my own work except as cited in the references

Signature	:	....
Name	:	MOHAMAD SAFEI BIN SANI
Date	:	....

SUPERVISOR'S DECLARATION

I have checked this report and the report can now be submitted to JK-PSM to be delivered back to supervisor and to the second examiner.

Signature: ……………………………………………

Name of supervisor: DR. MOHD NIZAM BIN SUDIN

Date: ……………………………………………………

ABSTRACT

The main idea of this study is to investigate the wear behavior of 3D printed part of carbon fibre reinforced ABS (acrylonitrile butadiene styrene) and compare the result with the pure ABS that will be printed the same way. The 3D printer used was a FDM (fused deposition modeling) type. The tests were performed on a pin on disk machine according to ASTM G 99 standard under dry sliding condition. The parameters used were 5,10,15,20 and 25 N of applied load and 0.6 m/s or 286 RPM sliding speed for the duration of 3 minutes and 5 minutes. The results of the tests showed that there are two main wear mechanisms that influenced the results of the tests which are abrasive and adhesive. The results also shown that the varied parameters chosen which are applied load and run time duration could affect the wear rate, rate of volume loss, friction force and friction coefficient of the test samples. Carbon fibre reinforced ABS specimens showed a better wear resistance and durability properties than ABS specimens when operating with high load and long time duration. This research could be useful to the wear resistant industries in the future as it could develop a better wear resistance component for various field of applications.

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LIST OF ABBREVIATIONS

FDM	-	Fused deposition modelling
ABS	-	Acrylonitrile butadiene styrene
3D	-	Three dimensional
FFF	-	Fused filament fabrication
RP	-	Rapid prototyping
CAD	-	Computer aided design
AM	-	Additive manufacturing
STL	-	Stereolithoghraphy
LOM	-	Laminated object manufacturing
SLS	-	Selective laser sintering
LENS	-	Laminated engineering net shaping
EBM	-	Electron beam melting
CAE	-	Computer aided engineering
CAM	-	Computer aided manufacturing
CATIA	-	Computer aided three dimensional interactive application

CHAPTER 1

INTRODUCTION

1.1 Background of study

The purpose of this study will focus on the wear behaviour of fused deposition modelling (FDM) printed parts of carbon fibre reinforced acrylonitrile butadiene styrene (ABS) composite. FDM is one of the techniques used for 3D printing. FDM also included in additive manufacturing technology commonly used for modelling, prototyping, and production application. FDM produces parts of complex geometry by layering the extruded materials, such as acrylonitrile butadiene styrene (ABS) plastic. The ABS material is initially in the raw form of a flexible filament which is then moderately melted and extruded through a heated nozzle in a specified parallel road pattern onto a platform layer by layer at room temperature. In the late 1980s, S. Scott Crump developed the FDM technology which is later commercialized by Stratasys in 1990. FDM also known as fused filament fabrication (FFF).

In this study, ABS and carbon particles will be combined to produce a composite material. Only 15% of carbon fibre with 250 micron particle size will be extruded along the ABS particles with the same size to produce filament. Acrylonitrile butadiene styrene (ABS) is one of a common thermoplastic polymer. The glass transition temperature of ABS is approximately 105 °C. ABS is useful in manufacturing products such as musical instruments, automotive trim components, automotive bumper bars, and toys because of its light weight and ability to be extruded.

In 1493, Da Vinci identified the laws of friction in a notebook. He stated that the frictional resistance was the same for two different objects of the same weight but making contacts over different widths and lengths. He also found that the force needed to overcome friction doubles when the weight doubles. Charles Hatchet carried out the first reliable test on frictional wear using a simple reciprocating machine to evaluate wear on gold coins in which he discovered that mated coins with grits between them wore at a faster rate than the self-mated coins. The wear test of this study will be performed as recommended by ASTM G 99 standard at room temperature under dry sliding conditions. ASTM international and respective subcommittees such as Committee G-2 define the standard result review for wear tests, should be expressed as loss of material during wear in terms of volume.

In this present research, the purpose is to investigate the effect of dry sliding wear characteristic of FDM printed parts of carbon fibre reinforced ABS composite. In addition, the discussion of numerous wear mechanisms will be made.

1.2 Problem Statement

Wear is erosion or sideways displacement of material from its original position on a solid surface performed by the action of another solid surface. Wear could cause many unexpected things such as slip while walking and road accidents. In other to overcome those problems, the evolution of superior wear resistance components for various field applications should be executed. The potential of this study is to produce FDM parts by using carbon fibre reinforced acrylonitrile butadiene styrene (ABS) composite to meet the needs of wear resistant industrial components.

1.3 Objectives

The objectives of this project are:

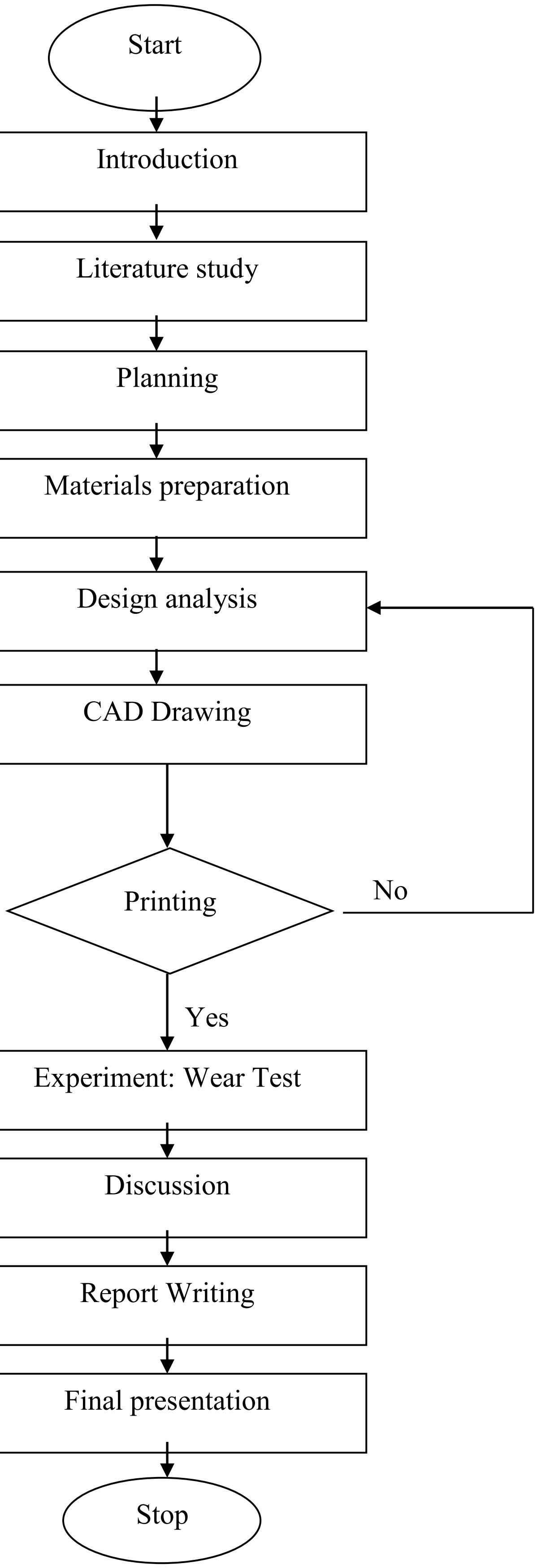
1. To fabricate carbon fibre reinforced ABS printed part by using FDM machine.
2. To study the wear behaviour of the 3D printed part of carbon fibre reinforced ABS composite.

1.4 Scope

The scopes of this study are:

1. Wear behaviour of carbon fibre reinforced ABS printed specimen will be compared with pure ABS printed specimen.
2. Default FDM parameter will be used for the specimens.
3. Based on previous research by Rupinder et al. (2016), The test will be conducted by applying load of 5, 10, 15, 20 and 25 N with sliding velocity of 0.6 m/s for the duration of 3 and 5 minutes at room temperature.
4. The results may be different in practical applications due to different operating conditions.

1.5 General Methodology



CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of this chapter is to collect all related information from journals, internet articles and previous research notes regarding this study. New technologies for part fabrication were introduced due to increased competitiveness and fast changing customer demand in marketplace. One of the technologies is rapid prototyping (RP) technologies (Bernarand, A. 2002). Fused deposition modelling (FDM) is deemed as best process for RP because it is easy to operate, less expensive and produces durable built parts (Levy et al. 2003). Currently, industrial application of FDM process biggest issue is the quality of parts produced by the process. Hence, it is important to understand the performance of FDM built parts. Previous studies mainly focus on characterization of mechanical strength, improvement of surface roughness and dimensional accuracy of the processed part. Wear is one of the essential features for the durability of part but the research done to study the wear behaviour of RP built part is very little. Thus, the current study is subjected to comparative analysis of wear characteristic between FDM parts fabricated by ABS (acrylonitrile butadiene styrene) pure material and carbon fibre reinforced ABS composite material.

2.2 Rapid Prototyping

Rapid prototyping (RP) is defined as a group of techniques used to quickly create a scale model of a part or assembly using three dimensional computer aided design (CAD) data. RP was developed in the 1980's for fabricating models and prototype parts. RP also one of the first additive manufacturing (AM) processes. There are many crucial benefits that this process delivered to product development such as the time and cost reduction and the possibility to fabricate complex shape design that could be very demanding to machine (Ashley, S. 1991). Figure 2.1 shows all the steps involved in product development using rapid prototyping. RP decreases development time by allowing corrections to a product to be made early in the process.

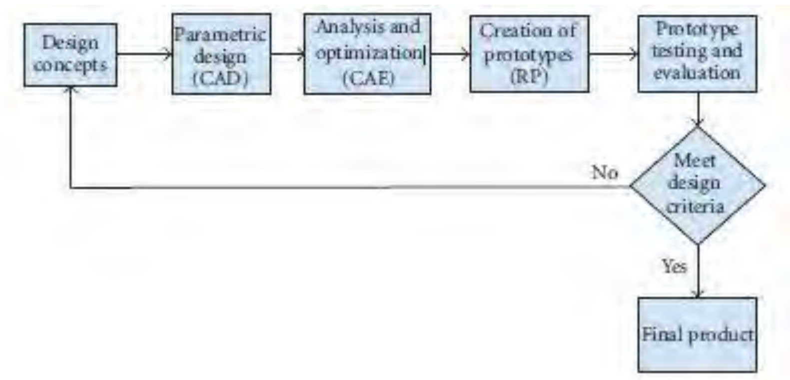


Figure 2.1: The steps involved in product development using rapid tooling (Hernandez et al. (2012))

In Figure 2.3, there is an analysis of the different additive manufacturing processes that are going to be further considered. Here in this figure adapted from Kruth (1991), the processes are classified into liquid base, solid based, and powder based. The processes included in this review are considered the most applicable in the past, and promising for the future of the industry. The processes considered are stereolithography (SL), Polyjet, fused deposition modelling (FDM), laminated object manufacturing (LOM), Prometal, selective laser sintering (SLS), laminated engineered net shaping (LENS), and electron beam melting (EBM). The liquid-and powder-based processes seem more promising than solid-based processes of which LOM is the predominant one today.

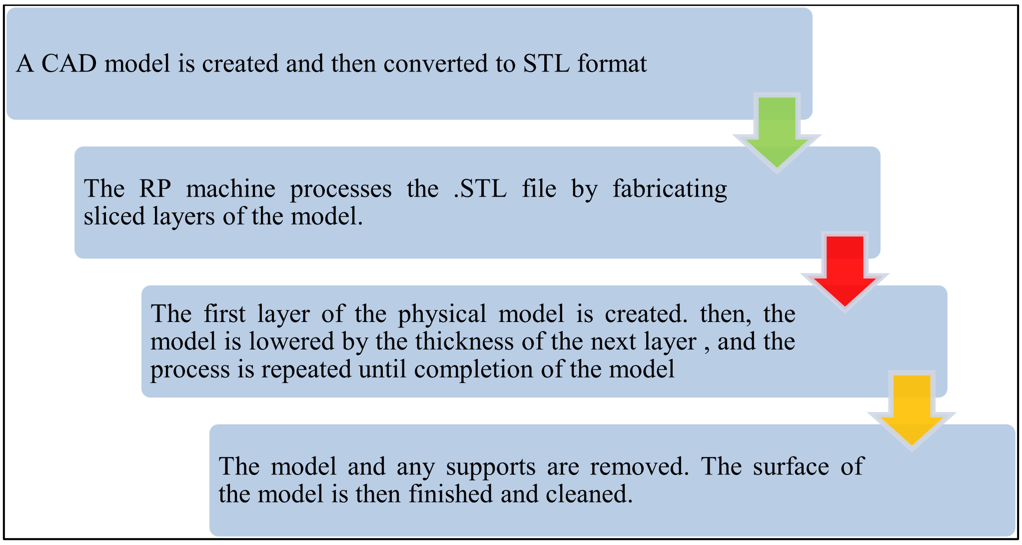


Figure 2.2: Basic methodology for rapid protyping

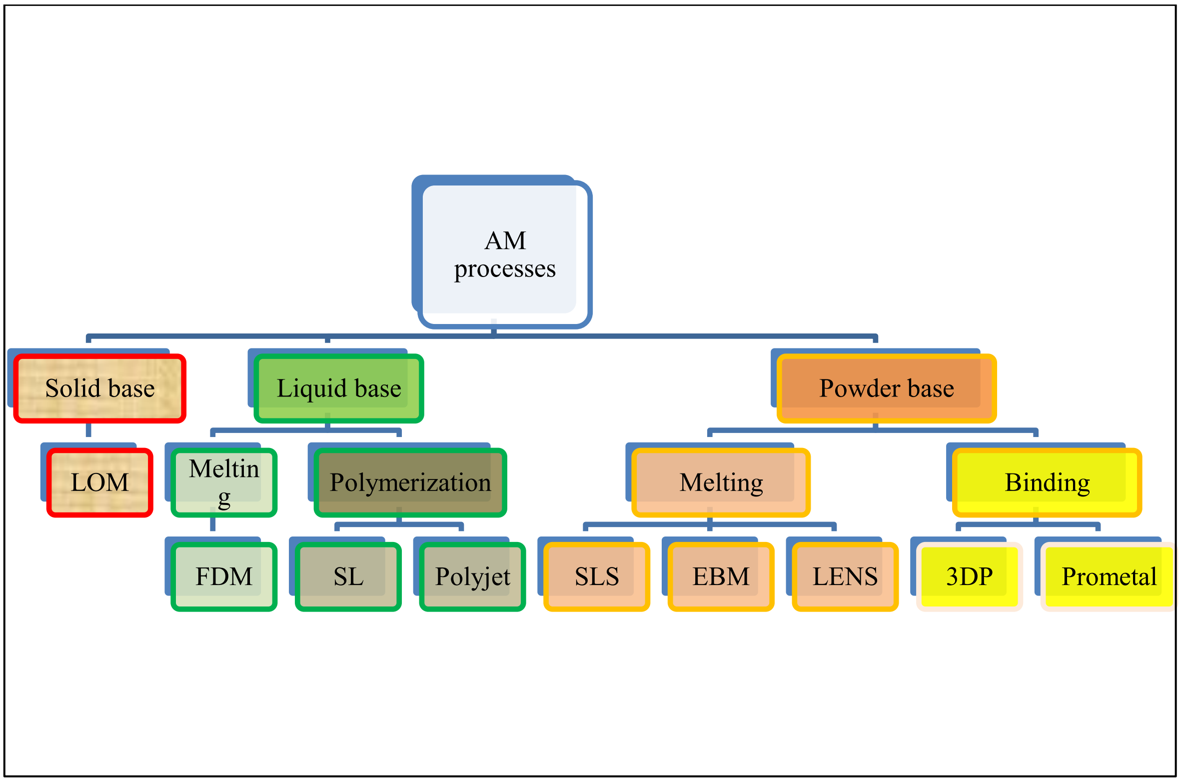


Figure 2.3: Different additive manufacturing processes
(Hernandez et al. (2012))

2.2.1 Fused Deposition Modelling (FDM)

Lee et al. (2005) stated that fused deposition modelling (FDM) is one of the RP systems that created prototype from plastic materials by lying tracks of semi molten plastic filament on to a platform in a layer wise manner from bottom to top. The first step in producing an FDM part is to create a three dimensional solid model by using commonly available CAD softwares such as CATIA V5R20. Next, the 3D solid model will be converted to stereolithography (STL) format and exported to the FDM slicer software. Most CAD systems are compatible to STL format. Once the STL file has been transferred to slicer software, STL file is horizontally divided into many thin sections after it has been transferred to slicer software. FDM process will generate the two-dimensional contours that these sections represent. The two dimensional contours will closely resemble the original three dimensional part when they are stacked upon one another. Basically, all present RP processes are familiar with the sectioning approach. Clearly, the part will be more accurate when the sections are thinner. Next, the FDM machine's hardware is controlled by the process scheme that had been created by the software.

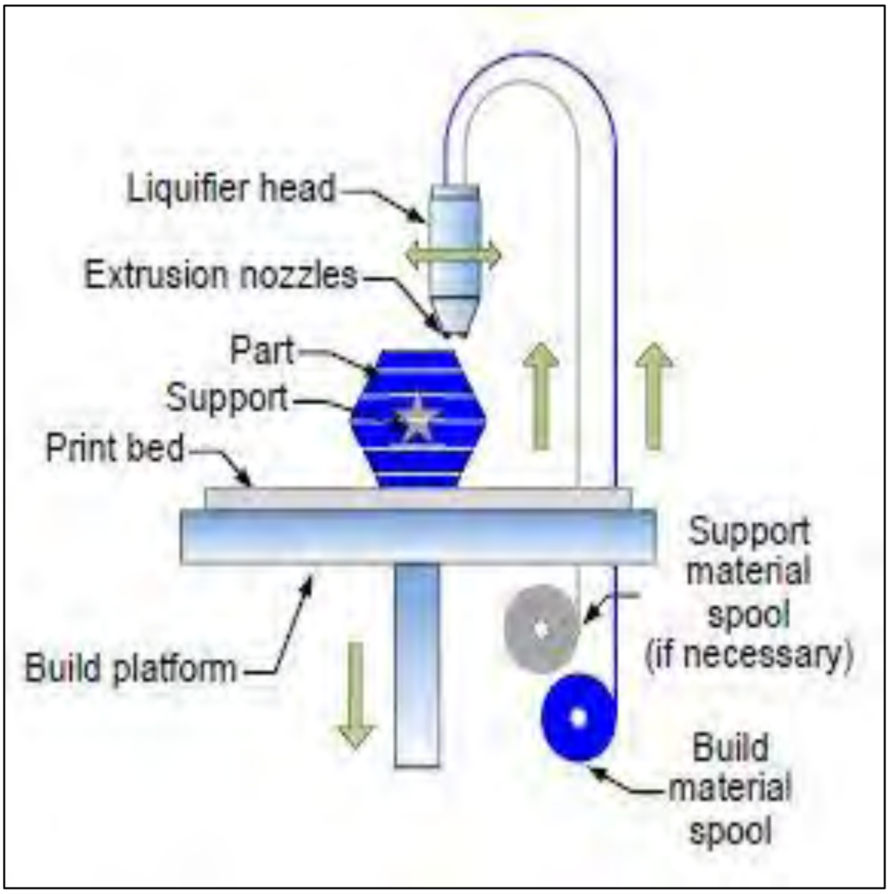


Figure 2.4: FDM apparatus set up
(Fahraz et al. (2014))

The concept of FDM is that its filament is fed through a heating element or liquefier head, which heats it to a semi-molten state. After that, the filament is fed through an extrusion nozzle and deposited onto the partially constructed part. Since the material is extruded in a semi-molten state, it merges with the material around it that has already been deposited. Then the head is moved around the X-Y plane and deposits material as specified to the part requirements from the STL file. After the previous layer is completed, the head is then moved vertically in the Z plane to begin depositing a new layer. After a period of time, normally several hours, the head will finish the deposition of a full physical representation of the original CAD file. This procedure may require a support structure to be created below the sections. The FDM machine has a second nozzle that extrudes support material. The support material is identical to the model material, but it is more brittle so that it can be easily extracted after the model is finished. Generally, the FDM machine fabricates support for any structure that has an overhang angle of less than 45° from horizontal as the default. As an example, if the angle is less than 45°, more than one half of one bead is overhanging the contour below it, and therefore is likely to fall (Montero, M. 2001).

2.2.2 Laminated Object Manufacturing (LOM)

Figure 2.4 demonstrates a common type of the laminated object manufacturing (LOM) process. As in other additive manufacturing, LOM process is conducted by layered manufacturing. Three main components of the LOM machine are a feed mechanism, a heated roller and a cutting tool. Chua et al. (2010) stated that stacking, bonding and cutting layers of adhesive-coated sheet material on top of the previous one are the processes involved in LOM part production. A cutting tool cuts the outline of the part into each layer according to prepared CAD data. After each cut is completed and another sheet is loaded on top of the earlier accumulated layers, the platform is lowered by a depth equal to the sheet thickness. After that, the platform is rises slightly, and the heated roller applies pressure to bond the new layer. The cutting tool cuts the outline, and the process is repeated until the last layer.

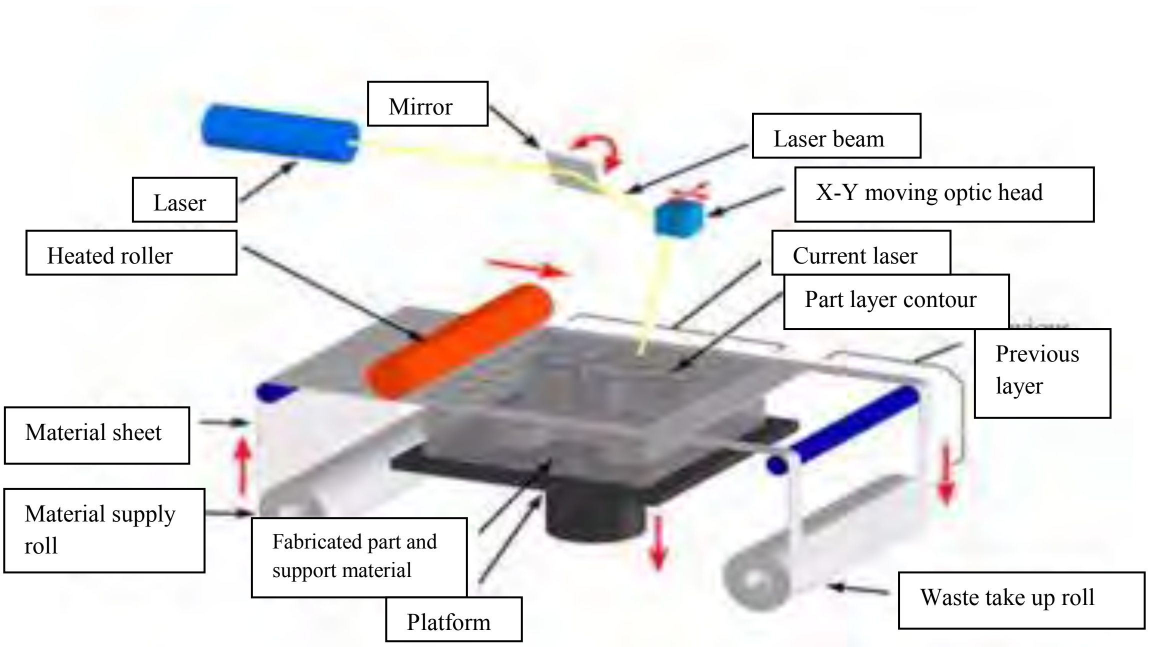


Figure 2.5: Example of LOM mechanism
(Chua et al. (2014))

2.2.3 Selective Laser Sintering (SLS)

Selective laser sintering (SLS) is one of the most common additive manufacturing processes that emerged in the last decades (Levy et al., 2003 and Kruth, J. 1991). SLS enables the fabrication of three dimensional polymer components with complicated shapes according to CAD data instantly out of powdery material without the need of tooling and setup. Hence parts are built layer by layer. Hopkinson et al. (2005) stated that three steps are repeated for each layer:

1. Firstly, the platform is lowered by the thickness of one layer.
2. Next, powder is deposited on the building platform using a moving roller or blade device and preheated to a temperature close to the material melting point.
3. After that, laser beam scans the powder layer with arbitrary trajectories in order to melt specific powder layer areas.

These steps are applied from time to time until the part is finished. Before the parts can be removed from the machine, consistent cooling has to occur while the viscose melted polymer crystallizes with minimal distortions.