NETAJI SUBHAS INSTITUTE OF TECHNOLOGY

A Project Report on

Mechanical Properties of Fused Deposition Modelling

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CONTENTS

Mechanical Properties of Fused Deposition Modelling

Generative production techniques have the advantage of manufacturing parts via an additive process without needing a forming tool. One of these additive manufacturing technologies is “Fused Deposition Modeling” (FDM). It is one of the most used additive manufacturing processes to produce prototypes and end- use parts [1]. From a 3D-CAD data set, components and assemblies are manufactured out of thermoplastic material in only a few working steps. Native software automatically slices the data, calculates the support structures, and creates toolpaths. The parts then are built up layer by layer by means of an additive process. An extrusion head deposits the molten thermoplastic filament to create each layer with a particular toolpath. Due to the thermal fusion the material bonds with the layer beneath and solidifies. Thus a permanent bonding of two layers is formed [2].

This technology began as a process for creating prototype parts; recently it has found new utility in the production of manufacturing tools and as a manufacturing process for end-use parts.

In order to be used as a part for serial production, the components must possess the required mechanical properties. To this end, not only is the chosen material relevant, but a correct process control is also necessary. An interesting material for the aircraft and automotive industry is the material PEI with the trade name Ultem*9085. This material should typically be used on FDM-machines for the manufacturing of end products. The aim of the research is to determine the present mechanical data based on the process control and the toolpath generation.

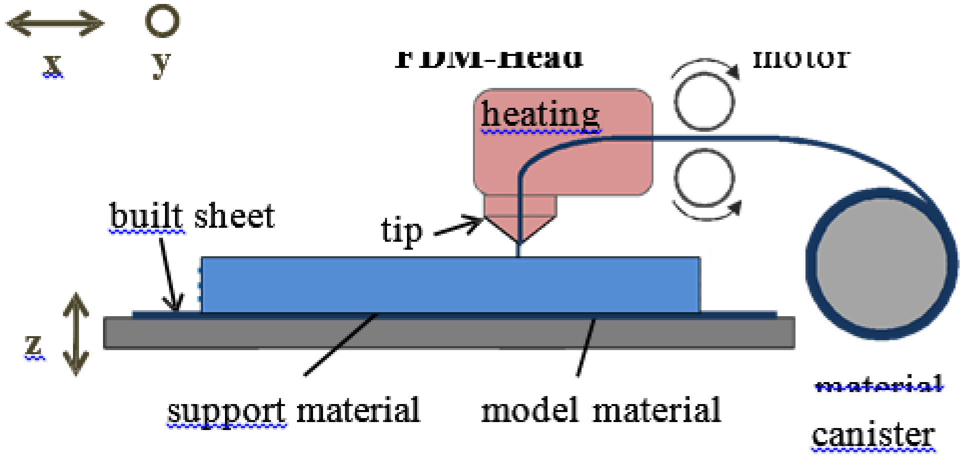


Figure1. FDM-Process.

The FDM head processes in the coordinate directions x and y and is very accurate. By lowering the platen in the z-direction, manufacturing layer by layer is possible. If necessary, an additional support material is used to provide a build substrate if the component part shows an overhang, offset or cavity. This additional material prevents the component part from collapsing during the building process. The support material itself can easily be removed after the building process by breaking it off or dissolving it in a warm water bath.

Process Parameters

The FDM technique has particular toolpaths to fill one part layer. The most used toolpath is the raster fill. First the perimeter of the layer is formed by the contour toolpaths, and then the interior is filled with a back and forth pattern and an angle of 45° to the x-axis. Alternating layers are filled with a raster direction at 90° to one another, like shown in Figure 2.

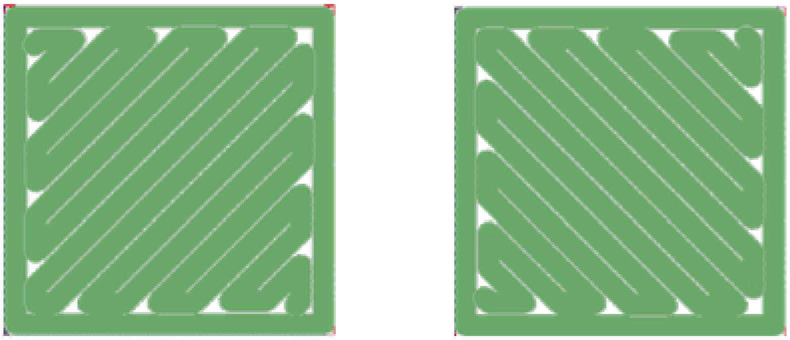


Figure 2. Raster Fill with Raster Direction at 90° to one another.

Other strategies to fill one layer are to generate all contours or only contours to a specified depth. Furthermore, many parameters can be changed to generate a part.

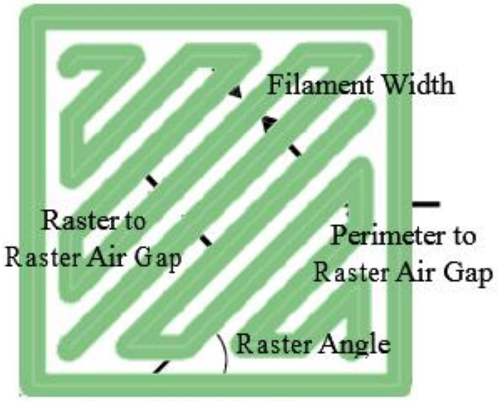


Figure 3. Parameter of Toolpath.

Some of these parameters are the width of the filament and the angle between the x-axis and the raster fill. Other changeable parameters are the air gap between the raster in the fill pattern as well as the air gap between the raster fill and the contour, etc. In some publicized papers [3,4,5,6] was shown, that a change of one parameter would impact the mechanical properties of a part.

Material

Polyetherimide (PEI) with the trade name Ultem*9085 is an amorphous and transparent polymer [7]. This material is desirable due to its mechanical properties, relatively low density compared to traditional materials, and flame, smoke, and toxicity properties [8] that allow its use in aircraft cabins. The material PEI is used on FDM machines for the manufacturing of end products.

Mechanical Properties

The mechanical behavior of a part is the reaction of a material to a mechanical stress. The applied force causes deformation of a component depending on the direction of the applied force and the mechanical properties and size of the component geometry. In this paper the tensile properties of specimens manufactured with different toolpath parameters are presented. There was no post- processing of test specimens. Tests were performed according to the American standard ASTM D638, at an ambient temperature of 23°C and a relative humidity of 50%. The velocity was 5 mm/min and the specimens were loaded until they broke. A load cell with 5kN was used for this test.

The specimens were built up with the geometry as per ASTM D638 specifications in the directions X, Y and Z (on its edge, flat and up) with a contour and an inner part raster fill. The generation of the toolpath was made with the preset parameters of the native software with a raster fill and an angle of 45° to the x-axis. The build directions of the specimens are presented in the following illustration.

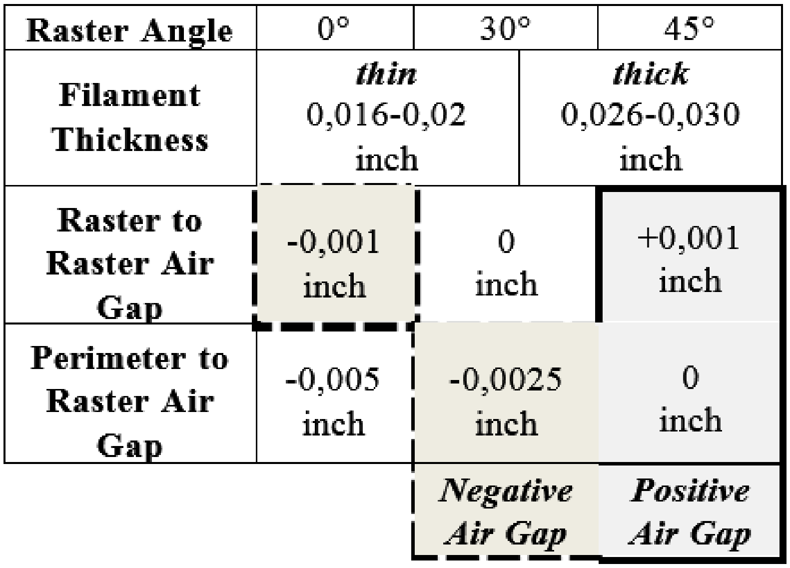
First tensile tests show different strength and strain characteristics for each build direction. The results were published in [9]. Test specimens built in X-direction obtain the best strengths and elongations before the specimen break. Specimen build up in Y-direction accomplish lower strength values and specimen build in Z-direction has the lowest tensile strength. The tensile loadings for samples built in Z direction affect the welded layers crosswise, thus the weld between separate layers is not strong enough to resist the tensile loading. For samples built in X- and Y-directions the tensile loadings affect the structure in the layer direction. Furthermore, the sample parts show different break behaviors due to their different inner part structure. Hence, the tensile properties depend on the given structure and as a result of the build direction. This result reflects not only the material characteristics in general, but also reflects the material characteristics as a function of the inner building properties and toolpath generation.

Results from Parameter Variation

To analyze the influence of the toolpath parameters for the material Ultem*9085 a parameter variation test was accomplished. The three build directions in X, Y and Z were considered.

Varied parameters were the raster angle between the x-axis and the raster fill the thickness of the filament with a thin and a thick value. Furthermore the air gap between the raster in the fill pattern and the air gap between the raster fill and the contour were changed. The values used are shown in the following Table 1.

Table 1. Parameters for the Variation Tests.



Raster Angle	0°	30°	45°
Filament Thickness	***thin*** 0,016-0,02 inch	***thick*** 0,026-0,030 inch	
Raster to Raster Air Gap	-0,001 inch	0 inch	+0,001 inch
Perimeter to Raster Air Gap	-0,005 inch	-0,0025 inch	0 inch
		Negative Air Gap	***Positive Air Gap***

Specimen built up with the raster to raster (R/R) air gap at -0,001 inch and the perimeter to raster (P/R) to air gap at -0,005 inch show an overfilling by using a certain parameter set. Thus this parameter combination will not be considered in this paper. The results from three parameter sets for each raster angle were analysed in detail; a negative air gap with P/R= -0,0025inch and R/R= -0,001inch, a positive air gap with P/R= 0,000inch and R/R= +0,001inch and a standard parameter set of 0,00inch for the P/R and R/R (normal).

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