INFLUENCE OF TECHNOLOGICAL PARAMETERS ON THE ROUGHNESS AND DIMENSION OF FLAT PARTS GENERATED BY FDM 3D PRINTING

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ABSTRACT: This paper it is focuses on the establish the principal setting parameter for the 3D printing process which have an influence on the surface characteristics of the flat parts. In the first part of the paper are analysed the principal value of the parameter which may have a relevant influence for the printing of the 3D plane surfaces for the FDM process. This method is chosen because on the one hand the costs of generating planar objects are small, but the principle of generation is relatively simple from a technological point of view. Surface analysis will be done both by optical and ruggedness measurement and dimensional measurement by digital measuring devices. The paper also refers to the methodology of generating flat surfaces and the influence of the way they are generated on the characteristics of the generated parts. It is apparent from point of view of the areas generated literature there are few references in this direction.
KEYWORDS: 3D printing; fabrication parts; roughness surface, dimension surface, FDM printing;

1. INTRODUCTION

Obtaining plan parts by depositing plasticized material in the form of lines and layers is a relatively new generation process and which, from the point of view of generation, is well known now [1, 2]. From the point of view of generating the plane parts, the process of the parts generation is similar, whatever it is the process or program of the generation takes place.

The work it is made to determine technological efficiency for the implementation of 3D printing parts and assemblies used in industry under the new conditions imposed using recyclable materials and technologies that pollute less the environment. The polluting factor must be seen both in terms of the energy resources used for the raw material and in terms of the reintroduction into the industrial circuit of the material resulting from the decomposition and re-composition of the material that has been used in the components we have name LCA (Life Care Assessment) [3], [4].

2. TYPE OF 3D CAD AND SLICER USED FOR 3D PRINTING

The generating process for a plan view is based on drawing a sketch that is then translated vertically to obtain the part volume. In (Figure 1.) it is possible to see such a part plan generated and where are put the nominal dimensional values of this part.

Generation was done with Inventor 2017. The generating phase is important, and it usually must be followed by a 3D-generated drawing verification phase and saved in a standard stl type. Checking the geometric dimensions of the items generated is very important. Typically, in the practice of the generation part the nominal cote is the value at which it is generated the part.

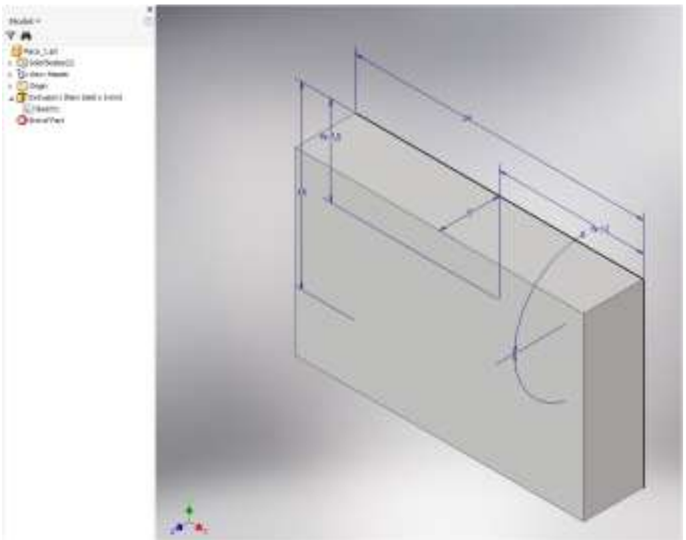
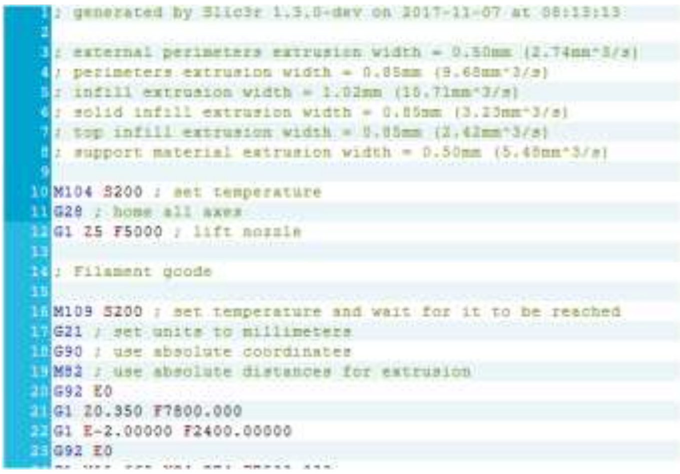


Figure 1. Part plane 3D designed [11]

The values tolerated for generating it is put in the execution documentation with his limits. It is recommended that the nominal value of the dimension, to be effectively at the nominal value at which it must be ad the amount of deviation for the contraction, so the effectively generated 3D documentation to have after the contraction the functional value. It can then verify that the ensemble can move parts relative or fixed, being able to realize the constraints imposed by the relative motion or relative positioning of the parts. It can thus be observed that it is very important to know precisely the contraction of the material after the generation directions to obtain the required conditions [6, 7].

Lastly but not the last step in 3D printing part is with an important role the control of the program code generation for the part made on the machine. In this case, it considers both the G-Code (Figure 2.) for generation and generation how it proceeds through simulation (Figure 3.).



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; generated by Slic3r 1.3.0-dev on 2017-11-07 at 08:13:13

; external perimeters extrusion width = 0.50mm (2.74mm^3/s)
; perimeters extrusion width = 0.85mm (9.68mm^3/s)
; infill extrusion width = 1.02mm (16.71mm^3/s)
; solid infill extrusion width = 0.85mm (3.23mm^3/s)
; top infill extrusion width = 0.85mm (2.42mm^3/s)
; support material extrusion width = 0.50mm (5.48mm^3/s)

M104 S200 ; set temperature
G28 ; home all axes
G1 Z5 F5000 ; lift nozzle

; Filament gcode

M109 S200 ; set temperature and wait for it to be reached
G21 ; set units to millimeters
G90 ; use absolute coordinates
M82 ; use absolute distances for extrusion
G92 E0
G1 Z0.350 F7800.000
G1 E-2.00000 F2400.00000
G92 E0
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Figure 2. G code for 3D part

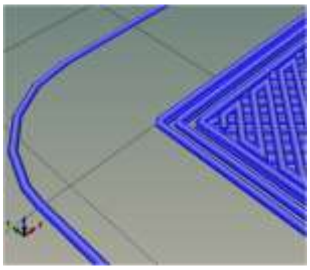

Figure 3. Simulate layers for the 3D part

Very often for achieving benchmarks will make manual corrections for the surface quality model. 3D parts in the generation process must be verified to have the roughness of functionally required for surfaces that come into contact. A higher roughness may cause greater losses through friction or rib lower than the required minimum will cause the loss of rigidity and functional errors in manual assembly processes. Usually in 3D printing layer thicknesses are chosen to value at which the surface roughness is less than the minimum required in terms of the kinematic.

For the layer generation side, two Cura 3.0.4 [8] and Slic3R 1.2.9 [9] programs have been used to ensure the generation of the parts and the comparative visualization of the generation parameters respectively. The machine control part was made using the Repetier Host 2.0.5 [10] program adapted to the printer used for generating.

Have shown that there are two types of layers, namely the top and bottom shown in the previous figure and that the central area is assigned to one or more peripheral lines for generating workpiece which can be seen in (Figure 4.).

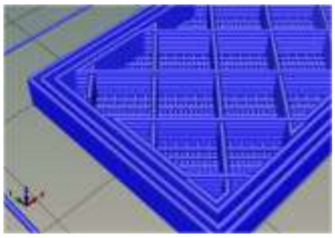

Figure 4. Intermediary layers for the 3D part

3. THEORETICAL CONSIDERATIONS AND PROCESSING METHODS OF LAYERS BY 3D PRINTING

From the point of view of obtaining the flat parts effective methods are different and the costs of the generated the parts it is different.

Considering the principles imposed for recycling it is possible to say that the process of generating 3D satisfy the conditions of the above-mentioned. So, from our point of view processes such as FFF (Fused Filament Fabrication) or FDM (Fused Deposition Modelling) are the best nor the type SLS (Selective Laser Sintering) cannot be neglected. These methods of implementation of the parts based on the operation of generating successive layers of material to the first made by melting and deposition of material in the form of wire mesh interwoven, and in the 2nd case in the form of spherical particles linked between them generated by the laser beam welded points are the base of the process.

An important aspect that should not be overlooked is the emission of particles and gases into the environment during the process of generating parts. If FFF or FDP are not generating particles or gas-dependent chemical and thermal material support or material actually deposited on layer for part generated the SLS generating both the particles in suspension in air by the fact that the material used for printing is buy type granular and with using the laser beam to produce the welding of particles it is generated gas that by the phenomenon of vaporization of the material in the melted process the particles it is released in the air and the gas as a result of the phenomenon of evaporation and melting of a controlled particle deposited.

From experimental tests, but also of the tensile strength of the parts generated, a significant role in generating layers it has the choice of parameters for made the part. Several parameters that can have direct influence are the intrinsic parameters which are set for generating the process at the start of the made the part, others are those related to the generation and not least are the parameters related to the elements of strength and processing costs.

A division of these parameters will allow us to see which of them are important in terms of economic / resistance and which are important in terms of generating layers of material by the characteristics of the surface and dimension.

Constructive parameters of equipment used to generate layer:

- The diameter of the nozzle is an important constructive parameter that can influence both print quality and cost / strength of the generated parts. How much the diameter is larger the amount of material deposited on the surface it is bigger, but also the thickness of the resulting file will increase with the decrease in the quality of the generated surfaces. For a 0.4 mm diameter of the nozzle a thickness of the inside wall of the generated layer is 0.5 mm. The generating speed was 50 mm / s. Thickness of the outer wall that is generated by two perimeter line type disposed side by side is 0.87 mm. The generating speed of the outer wall was 35 mm / s. One can observe the dependence of the nozzle diameter and the other sizes that need to be obtained. In further research, we will use nozzle with thicknesses ranging from 0.2 mm to 0.6 mm;

- layer height generated is dependent both, the volume of material deposited per unit area, but also economic considerations. A higher layer means a greater thickness with an accuracy lower surface, but lower-cost generation. Choosing this parameter is dependent on the speed of printing and from the nozzle diameter. A higher speed printing per unit length, will reduce the thickness generated and implicitly, the thickness achieved. From the nozzle diameter the value recommended is 1/4 to 2/1. Also bear in mind that the height depends on the vertical step advance system which printer was used to produce 0.1 mm. To see if there is any influence on the quality of the generated surface and the geometry of the part, three identical parts were generated with a print speed of 50 mm / s on the inside and 35 mm / s on the outside, and with infill densities of the file at 20% at a printing temperature of 220°C. The values are centralized in (Table 1). Based on these values, the mathematical regression relationship closest to the dimensional values obtained after the printout was determined.

From the analysis of the determined values, it can be observed that the greatest influence of the thicknesses of the generation layer is high on the roughness (Figure 5.) and the height of the part Z direction (Figure 6.) and respectively smaller in the horizontal directions Y longitudinal and X transversal.

The regression equation is the exponential type and grade 2;

Table 1. Roughness and dimension deviation for layer height for the plan part

Number	Height in mm	Roughness Ra in micron	X in mm	Y in mm	Z in mm	Obs.
1	0,1	3,06	20,07	49,19	5,21	
2	0,2	5,02	20,04	49,17	5,25	
3	0,3	10,5	20,09	49,45	5,37	

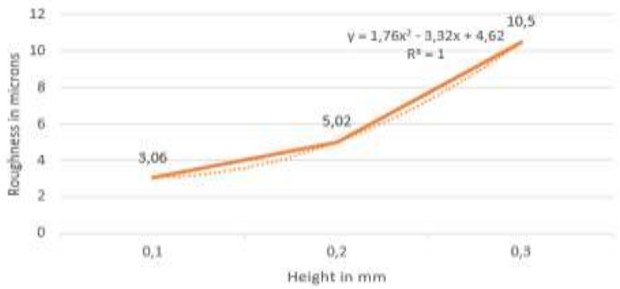

Figure 5. Roughness Ra in function of height layer

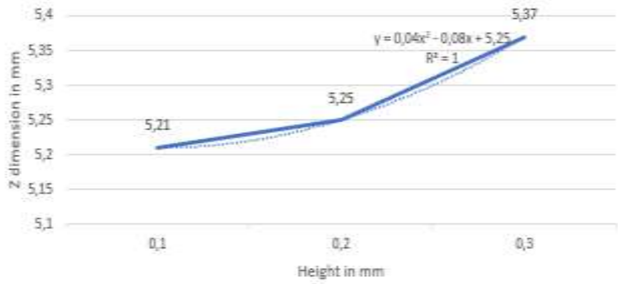

Figure 6. Z dimension part in function of height layer

- print speed it is an important parameter on the thickness, roughness, and the characteristics of the piece to be printed. A low speed ensures a better push the material in the spaces between the wires network. A higher speed ensures a more rapid thrust piece with a lower density material and unit volume lower. Recommended values are between 30 mm / s and 120 mm / s. In the made process of the piece are two distinct speeds. One that is bigger, and it is recommended for the inner part of the reference generation and one which is the outside perimeter for the exterior parts. Report of them recommended as some programs generation is 1.43 (50 mm/s inner and 35 mm/s outside for the part generated for this study);

- the temperature of printing and the temperature of the support material of the structure. This is an important parameter in the process, especially for FFF and FDM processes. This depends on the properties of the files used. For the study in (Table 2) we made the determination of the dimensional and roughness parameters for temperature values a 10°C deviation value. A higher temperature ensures a better flow, and greater internal tensions in the deposited material, and vice versa. Based on these values, the mathematical regression relationship closest to the dimensional values obtained after the printout was determined. Height it is 0,2 mm, infill 40%.

Table 2. Roughness and dimension deviation for extrusion temperature for the plan part

Number	Temperature in °C	Roughness Ra in micron	X in mm	Y in mm	Z in mm	Obs.
1	190	4,90	20,05	49,57	5,29	
2	200	5,34	20,05	49,41	5,31	
3	210	5,24	19,91	49,42	5,34	
4	220	5,02	20,04	49,17	5,37	

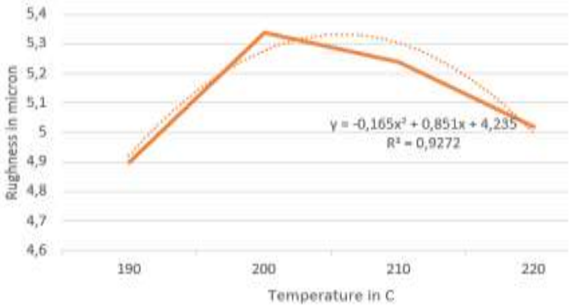

Figure 7. Roughness Ra in function of temperature extrusion

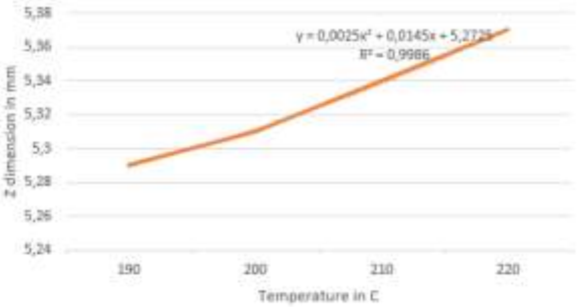

Figure 8. Z dimension part in function of temperature extrusion

From the analysis of the determined values it can be noticed that the greatest influence of the temperature on the dimensional values is represented by the high temperatures, while on the roughness the influence is of the parabolic type showing a maximum at the value of approximately 200 degrees C. The regression as the equation is of the type exponential grade 2.

- speed and distance of retirement of the head, crossing speed and printing speed are important. As much the higher it is, the less deposit of material printing and lowers default section and wire form deposited with the part implications on resistance of the part generated. At the same time, if there is no retraction, the thread will melt in continuation and deposit is made on the print surface following the fast-moving direction between the layers. It is recommended that the retraction is not large approx. 4 mm, the retraction velocity is 130 mm / s to create a thread attraction phenomenon inside the nozzle.

- line width and height deposited of the files in the first layer has an important role on adherence to material layers in the process of generating support and in the strength resistance of the part. It depends on the diameter of the nozzle and the advance of machine parameters. It is recommended for constructive reasons that the number of layers at the lower and upper surface part should be greater than 2. In future research we will make three or more layers to observe their influence on the roughness and dimensional precision. For the tests the number of layers was 2. The thickness of the line can be determined by the diameter of the extrusion nozzle which for our case is 0.4 mm by multiplying by 1.2 [5] which will result in a calculated thickness of 0.48 mm. The value is roughly equal to that measured for a layer generated with a 0.2 mm gauze and a temperature of 210 degrees C.

From the presentation mode, it is possible to conclude that that the deposit wire process is very sensitive to certain parameters. Due to this fact, should be considered in the purchase or construction of printers that allow us both in terms of construction but also functional to adjust parameters in the desired range. The first recommendation is that of a two-headed printers and systems independent of the wire feed, the second a printer with two independent feed systems with two print heads on each side.

The specific parameters which are generated the piece:

- wire material, FDM is commonly used for the standard case, the two types of materials ABS (acrylonitrile-Butadiene Styrene), which is an oil-based material and PLA (polylactic acid) which is a biopolymer which is biodegradable. There are versions of materials that are developed in the same range as the two mentioned and which may be used in specific areas. It should also be mentioned support materials, the composite materials and flexible material which are polycarbonate special type. The printer used for the study works with a 1.75 mm diameter wire. The value should be entered in the printer specifications to allow the process to be made. At the same time, you will also enter the size of the surface on which printing will be made, and the origins of the printer will be defined.

- geometric parameters of the part generated are the wall thickness, the thickness of the layer, the thickness of the support layers, the outside thickness. Need revealed that a greater thickness leads to a higher surface roughness and consequently a greater surface cylindricity and vice versa. Also, decreases mechanical strength parameters surface of the part. In practice, the thickness of the walls is recommended to be a multiple of two widths of perimeter on the two sides of the wall to ensure the arrangement of both sides of the perimeter area. It follows that the thickness of the generated perimeter line is very important to establish a wall thickness. Usually, the value considered is at least 1 mm for the wall.

- network density within the part and how to generate it. Is an important parameter because it has a direct effect on both the processing costs / strength, and the quality of surfaces and volumes that are obtained in terms of technological linear or volumetric shrinkage local, but also the geometric dimensions. A study of the influence of the density of part on the dimensional characteristics was made for a reference at which the extrusion temperature was 190 degrees C, 0,2 mm step for layer and the orientation of the wire was linear at 45 degrees inclination to the X and Y direction respectively. For the study in (Table 3) we made the determination of the dimensional and roughness parameters for infill values a 20% deviation value.

Table 3. Roughness and dimension deviation for different infill

Number	Infill in %	Roughness Ra in micron	X in mm	Y in mm	Z in mm	Obs.
1	20	5,00	19,80	49,12	5,34	
2	40	5,12	19,90	49,34	5,21	
3	60	5,76	19,85	49,09	5,39	
4	80	3,98	19,80	49,10	5,37	

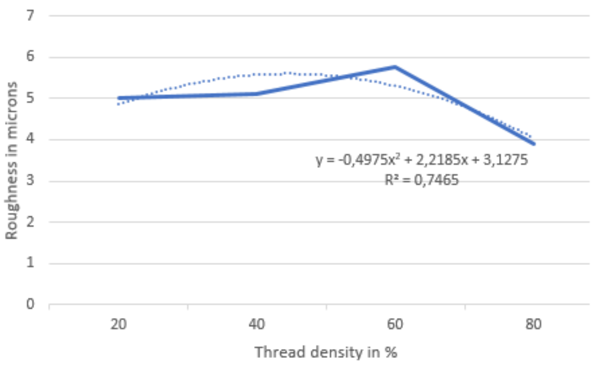

Figure 9. Roughness Ra in function of temperature extrusion

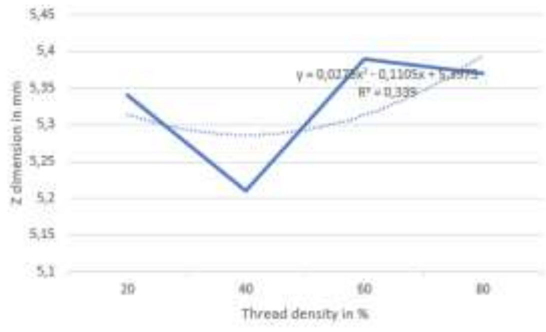

Figure 10. Z dimension part in function of temperature extrusion

From the analysis of the obtained data, it can be concluded that the density of the threads has a major inflow over the dimensional variation and lower than that related to the roughness of the surface.

- parameters for generating speed internal network and the printing have a major influence on the thickness of material deposited layer thickness and consequently generated the piece implications on the cost of processing and the piece resistance generated. In future research we will make an increase of the speed at 90 mm/s form 50 mm/s and a speed reduction to 20 mm/s to observe their influence on the roughness and dimensional precision. For the study, the speed modification will be 10 mm/s.

It has shown that ordering parameters in terms of the process may not be identical to that which is achieved through programs generation.

The specific parameters used to generate material layer:

- wire is important. The dimensions of the fry used for the plot, as well as the parameters on which it is deposited on the surface, have a major influence. At the same time, depositing parameters may influence the costs that are specific to the benchmarking process.

- type of material used for printing. Some wires are biodegradable and recyclable other only recyclable and others dissolve in various substances such as water, which is why we can consider green.

From the presented results, it is very important to know both the mechanical characteristics of the part generated, and the green. For this reason, machines, will be chosen or designed to allow deposition of organic materials with operating parameters imposed by the functional role of surfaces or parts.

4. CONCLUSION

The present study wanted to be a start of the investigation of PLA biodegradable plastic material behaviour through the FDM 3D printing process on the dimensional and surface roughness characteristics generated, to determine both the optimal parameters for the design of the parts, but also the optimal parameters for making the surfaces of the elements of a type that can be used in the industrial field, for small and medium series of production, for replacement of the parts obtained by injection of plastic as well as made of aluminium.

From the study we can see that some of the parameters have an increasing influence, while others a parabolic influence being mathematically expressed by the usual grade 2 nonlinear regression functions which provide a better R than linear regressions, exponential, polynomial etc.

5. ACKNOWLEDGEMENTS

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