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

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ABSTRACT: Establish the principal setting parameter for the 3D printing process of flat and round parts made from ABS it is and important parts of 3D printing process. In the first part of the paper it is made a study of the principal value of the parameter which may have a relevant influence for the ABS 3D printing for flat and round surfaces made from ABS for the FDM process. In this part it is made a study of the difference from PLA material used in 3D printing to ABS material used. For the study we use simple form to reduce the costs of generating, and have in this working the possibility to study the important aspect of the technological view point. Surface analysis will be done both by optical and dimensional measurement by digital measuring devices. The paper also refers to the methodology of generating flat and round surfaces and the influence of the way they are generated on the characteristics of the generated parts.
KEYWORDS: 3D printing; fabrication parts; roughness surface, dimension surface, ABS FDM printing;

1. INTRODUCTION

Obtaining plan or round parts by depositing plasticized material made with ABS (Acrylonitrile Butadiene Styrene) 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 and round parts, the process of generation is similar, whatever it is the process or program of the generation takes place.

The work it is orientated to determine technological efficiency for the implementation of ABS material for 3D printing parts by FDM (Fused Deposition Modelling) used in industry, under the new conditions imposed, using recyclable materials and technologies that pollute less the environment or in the working space. 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. ABS MATERIAL USED FOR 3D PRINTING

So, as you can see from (5, 6) ABS is a material with superior strength properties in relation with PLA (Polylactic Acid) material. From point of strength it is 80% from ABS injection moulded material. The tensile strength for ABS it is 37 – 110 MPa in relation to 50 MPa for PLA. Important in some application it is the glass transition temperature which is 110 °C for ABS and 60 °C for PLA. PLA it is a biodegradable material in some condition, while ABS is not biodegradable material, but it is an recyclable material. An important aspect in terms of technology is the possibility of finishing the surface by processes of surface finish by chemical (acetone) materials. Both materials can be processed by the printing process, with some restrictions on PLA.

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

The generating process for a plan and round parts is based on drawing a sketch that is then translated vertically to obtain the part volume. The flat part it is presented in [7]. For cylindrical parts were generally two types. One cylindrical full and one cylindrical tubular type. In (Figure 1.) it is presented the round part generated and where are put the nominal dimensional values of this part.

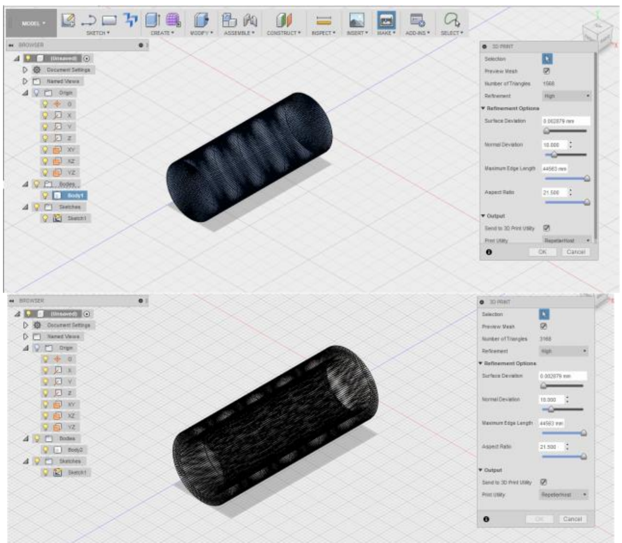

Figure 1. Part round cylindrical and tubular3D designed [12]

Generation was done with Fusion 360. The generating phase is important, and it usually must be followed by a 3D-generated design verification phase and saved in a standard stl file 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. In 3D printing the nominal value it is establish by the method of the correction for material that have different value of the contraction in the three directions. As it is known in 3D printing the thermal proprieties is important for the dimension generated.

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 cylindrical parts and generation how it proceeds through simulation (Figure 3.).

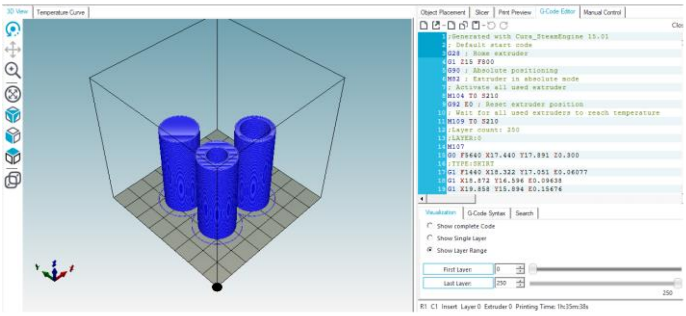

Figure 2. G code for cylindrical 3D part

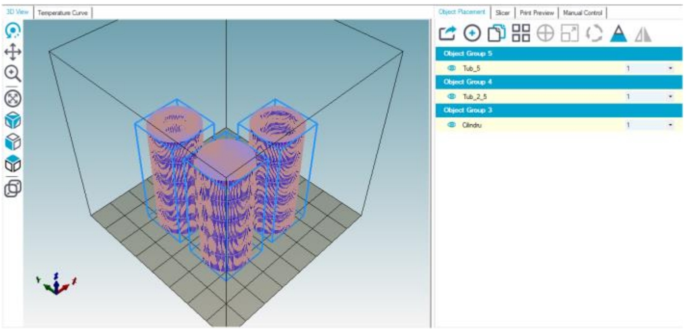

Figure 3. Simulate layers for the cylindrical 3D part

The generation of the simple rectangular parts are made by lines in plan, for generate cylindrical parts is more complex and involves significant technological aspects. The first aspect that can be seen from (Figure 3.) is that the cylindrical element is generated from successive lines and not from circles in code generation programs. For example, we will take the case of a cylinder generated by positioning it horizontally and vertically. The same is the case with the orientation of the prism, but for this important case is only the economic aspect of the generation and not the technological aspect.

For the layer generation side are used two programs one it is Cura 3.0.4 [9] and second it is Slic3R 1.2.9 [10]. The machine control part was made using the Repetier Host 2.0.5 [11] program adapted to the printer used for generating.

From the Fusion 360 generating side, it is possible to observe that the recommended generation option is of the circular with superimposed layer. It should also be noted that for the horizontal arrangement of the tube or cylinder, supportive elements must be used to obtain the circular shape. Thus, the generation time increases significantly. For example, we'll take the case of a horizontal cylinder. For the vertical generation solution, the duration is 37 minutes and 30 seconds with 250 layers. For the horizontal solution the duration is 39 minutes and 25 seconds with 498 layers.

Table 1. Time for 3D printing cylindrical elements

Number	Type	Infill %	Quality mm	Time
1	Tub 5 mm	20	0,2	44 min 31 sec
2	Tub 2,5 mm	20	0,2	40 min 23 sec
3	Cylinder	20	0,2	37 min 30 sec
4	Tub 5 mm	80	0,2	1 h 13 min 18 sec
5	Tub 2,5 mm	80	0,2	52 min 2 sec
6	Cylinder	80	0,2	1 h 5 min 9 sec

Table 2. Length for 3D printing cylindrical elements

Number	Type	Infill %	Quality mm	Length in mm
1	Tub 5 mm	20	0,2	2332
2	Tub 2,5 mm	20	0,2	2030
3	Cylinder	20	0,2	2238
4	Tub 5 mm	80	0,2	4358
5	Tub 2,5 mm	80	0,2	2781
6	Cylinder	80	0,2	5524

Adhesion type no, quality 0,2 mm, support type no, speed print 55 mm/s. perimeter speed 37 mm/s, infill speed 55 mm/s

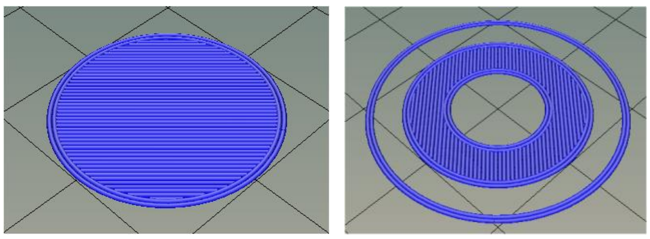

Figure 4. Top/bottom layers for cylindrical 3D printed part [11]

Have shown that there are two types of layers, namely the top and bottom shown in (Figure 4.) and that the internal area is assigned to one or more peripheral lines for generating workpiece which can be seen in (Figure 5.).

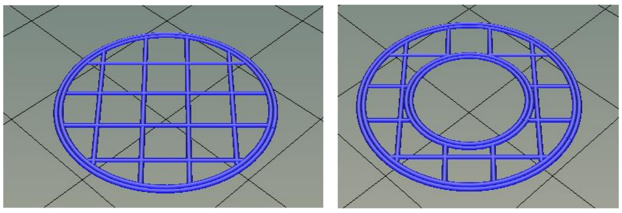

Figure 5. Intermediary layers for cylindrical 3D printed part [11]

If the tilting or horizontal positioning is required from a functional point of view, either stiffening ribs or cylindrical or linear support should be provided. In (Figure 6.), there is presented the generated solution for a cylindrical element disposed horizontally with 2360 mm filament used.

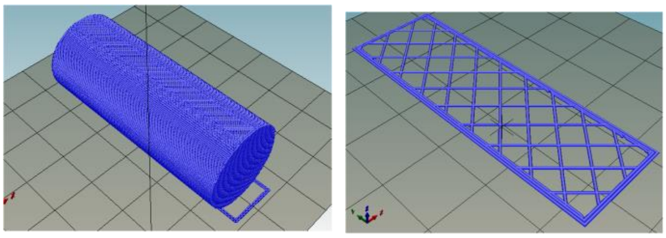

Figure 6. Intermediary layers for cylindrical 3D printed part [11]

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

From the point of view of obtaining the flat and cylindrical parts made from ABS effective methods are different and the costs of the generated the parts are 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 technological, economical / resistance and which are important in terms of generating layers of material by the characteristics of the parts.

Constructive parameters of equipment used to generate layer:

- 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. The forces required for printing are dependent on the ratio of the cross section of the thread diameter to the diameter of the nozzle. A good rapport it is 4,375 (1,75 mm to 0,4 mm). The diameter of the nozzle has an influence on the thickness of the side wall, upper and lower struts through the thickness of the generated layer.

- 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. To see if there is any influence on the dimension of the generated parts, three identical parts were generated with a print speed of 45 mm / s on the inside and 31 mm / s on the outside, and with infill densities of the file at 20% at a printing temperature of 240°C and 80 °C for bead temperature. The values are centralized in (Table 3) and are for 5 mm Z dimension. Based on these values, the mathematical regression relationship closest to the dimensional values obtained after the printout was determined.

Table 3. Dimension deviation for layer height for the plan part

Number	Height in mm	X in mm	Y in mm	Z in mm	Obs.
1	0,1	20,07	49,99	4,73	
2	0,2	20,26	50,02	4,74	
3	0,3	20,37	50,08	4,77	

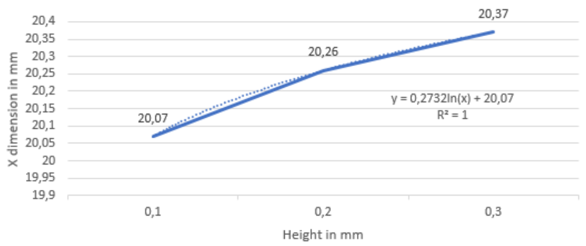

Figure 7. X dimension in function of height layer

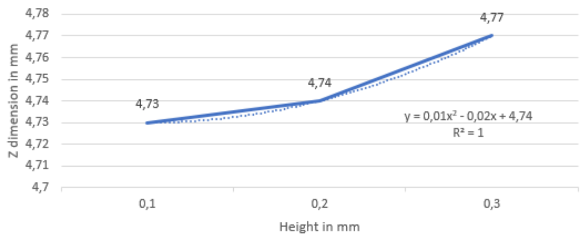

Figure 8. Z dimension part in function of height layer

The regression equation for X dimension it is logarithmic and for Z dimension it is exponential type grade 2;

- the temperature of printing is important for ABS. For this study in (Table 4) we made the determination of the dimensional 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 X and Z dimensional values was determined. Height it is 0,2 mm, infill 20% and 80 °C for heated bead. 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 dimension influence is of the parabolic type showing a maximum at the value of approximately 245 degrees C for X dimension and 250 degrees C for Z dimension. The regression as the equation is of the type exponential grade 2.

Table 4. Dimension deviation for extrusion temperature ABS

Number	Temperature in °C	X in mm	Y in mm	Z in mm	Obs.
1	240	20,26	50,02	4,74	
2	245	20,30	50,18	4,85	
3	250	20,31	50,00	4,70	

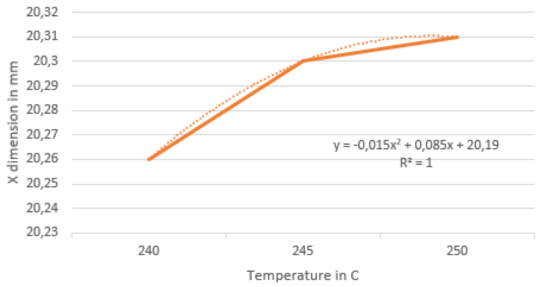

Figure 9. X dimension in function of temperature extrusion

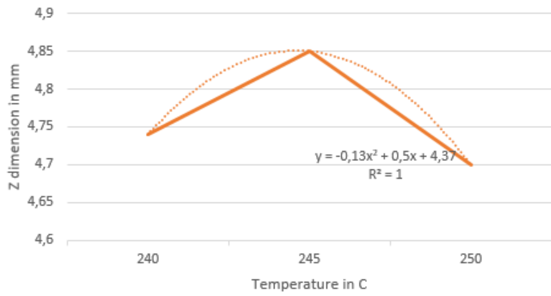

Figure 10. Z dimension part in function of temperature extrusion

- the temperature of the support material of the structure are important for ABS. For this study in (Table 5) we made the determination of the dimensional 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 X and Z dimensional values was determined. Printing temperature is 250 °C, height it is 0,2 mm, infill 20%.

From the analysis of the 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 dimension influence is of the parabolic type showing a maximum at the value of approximately 80 degrees C for X dimension and 90 degrees C for Z dimension. The regression as the equation is of the type exponential grade 2.

Table 5. Dimension deviation for bead temperature ABS

Number	Temperature in °C	X in mm	Y in mm	Z in mm	Obs.
1	80	20,31	50,00	4,70	
2	90	19,95	49,88	5,06	
3	100	20,08	50,14	4,85	

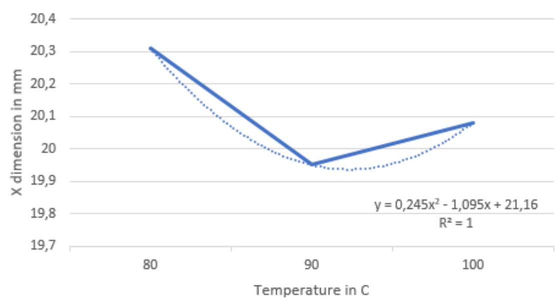

Figure 11. X dimension in function of bead temperature

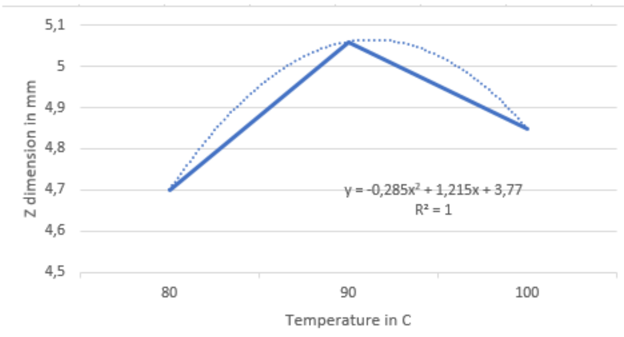

Figure 12. Z dimension part in function of bead temperature

- 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 100 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 3 for ABS. 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 [6] which will result in a calculated thickness of 0.48 mm.

The specific parameters which are generated the piece:

- wire material for FDM process it is commonly used for the standard case, the ABS (acrylonitrile-Butadiene Styrene) which is an oil-based material There are versions of materials that are developed in the same range as the two mentioned and which may be used in specific areas. The printer used for the study works with a 1.75 mm diameter wire and it is an Tevo Tarantula standard type. 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 200 mm x 200 mm x 200 mm, and the origins of the printer will be defined.

- geometric parameters of the part generated are the thickness of the pars, 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 specific dimension of the material. In practice, the thickness of the walls is recommended to be a multiple of three widths of perimeter for ABS. 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.

A study of the influence of the geometric parameter for plan part made from ABS was made for a reference at which the extrusion temperature was 250 degrees C, 0,2 mm step for layer and the orientation of the wire was linear at 45 degrees inclination. For the study in (Table 6) it is e made the determination of the dimensional and roughness parameters for infill values a 20% deviation value. From the analysis of the 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 dimension influence is of the parabolic type showing a maximum at the value of approximately 5 mm for X dimension and 7,5 mm for Z dimension. The regression as the equation is of the type exponential grade 2.

Table 6. Dimension deviation for thickness parts

Number	Thickness in mm	X in mm	Y in mm	Z in mm	Obs.
1	2,5	19,97	49,99	2,69	
2	5	20,31	50,00	4,70	
3	7,5	19,89	49,93	7,49	

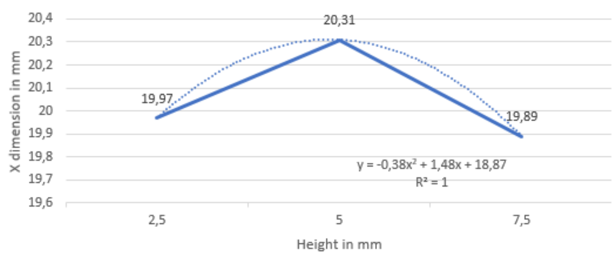

Figure 13. X dimension in function of thickness parts

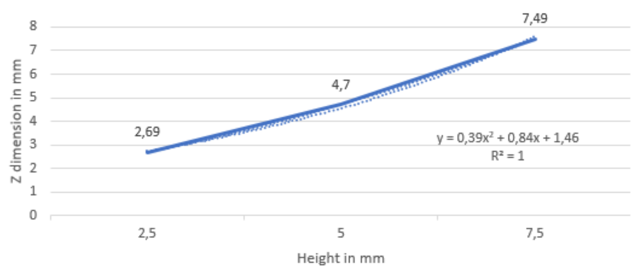

Figure 14. Z dimension in function of thickness parts

- 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.

• 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.

The specific parameters used to generate material layer:

• wire is important. The dimensions of the thread used for the plot (usually 1.75 mm and 3 mm threads are used), as well as the parameters on which it is deposited on the surface (the print speed of the component parts), have a major influence. At the same time, depositing parameters may influence the costs that are specific to the benchmarking process.

• the flow of material that is deposited in the unit of time. A less than 100% flow causes the threads to no longer stick to each other, and a larger one produces a lateral push on the previously attached thread. If you want a higher density material between the wires can increase output by 10% over the normal value.

5. CONCLUSION

The present study wanted to be a start of the investigation of ABS plastic material labor through the FDM 3D printing process on the dimensional characteristics generated, to determine both the optimal parameters for the design of the parts, but also the optimal parameters for making the dimension 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.

6. ACKNOWLEDGEMENTS

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