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ECONOMIC AND TECHNOGICAL CONSIDERATIONS ON THE 3D PRINTING COMPONENTS IN UNIVERSITY LABORATORIES MADE FROM STUDENTS

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Abstract. The scope of this research is to analyse the economic aspects of the 3D printing parts for making parts and functional sub-assemblies for different machinery. The author intends in this work to make a clarification on the economic approaches of processing FDM (Fused Deposition Modelling) and DLP (Digital Light Processing) materials which can be used for generating mechanically required items. The paper it is structured in 5 chapters. In the first chapter, there is an ordering of the materials based on the literature, but also from its own experience in generating parts by 3D printing. Synthesis is made both in terms of physical and mechanical properties, but also from the point of view of economic as well. It should be shown that the comparison will also be made from the point of view of 3D printing generation since two different printing processes are used both as the principle of generation and the way of obtaining the 3D parts. For generating, two printers will be used, which both constructively and functionally will be analysed, both as functionality and as component design possibilities. The second chapter affected to the ordering of technological parameters of 3D generation by printing the parts with defining the main technical parameters of generation of the parts. This step is important both to ensure the assembly conditions of the components, but also to the fact that the materials used to make the parts produce different comportment after the three directions in terms of contractions and the variation of the dimensions. The third chapter analyses the main ways of generating the parts with the presentation of some of the domain-specific elements generated by 3D printing with FDM and DLP. In the fourth chapter is presented the economic calculation program made with practical applications related to the parts generated in the previous chapter. The last chapter is allocated to the conclusions and comparisons from the technological-economical point of view compared to other specific technologies for generating the analysed parts.
Key words: *3D printing, economic analyses, technological parameters, FDM, DLP*

1. Introduction

Generation of 3D components in the field of electromechanical industry is currently in full expansion, with major trends of change in the way in which the phases are addressed for generating these parts. In the past of time the labor of parts was based upon the mechanical removal processing of materials, by metal erosion, milling, drilling or lathe, or with concentrated energy with electrical erosion, laser, beam, but also on the melting or plastic deformation at a cold or hot temperature.

The present trend is to replace energy-consuming technologies, with others in which energy consumption is greatly reduced. Should also be highlighted that the use of materials that can be reused by regeneration as a prerequisite for the reduction of manufacturing costs, but also reusing the materials from which they are made. Considering the mentioned aspects, it can be affirmed that, for parts or sub-assemblies can be used in different conditions with reduced or lover solicitation of the component. It is possible to make this part by 3D printing both by FDM [1] or DLP.

In terms of the generation of 3D printing, should be borne in mind that, the techniques are recommended to be used in the field of student, especially by the aspects of the reused parts by recycling the materials of the components after the research or labor processes.

The costs to make the component for the specific elements of the process are grouped in five categories:

- the cost of the material used in printing and materials used to realize the part process and printing process;
- the cost of time of the printing generated part and printing the parts,
- the cost of post-processing printed part;
- the cost of the printer with which it generated the part;
- the cost of energy used for generation and the maintenance of environmental conditions during the printing process;

One of the divisions which can be made in terms of their functional role of the part generated is:

- materials which have a role of the positioning and fixing;
- materials which have a translation or rotation operations movement at low speeds and which function can be considered as static movements;
- materials in which the translation and/or rotation surface loads are executed at high speeds;

In the literature, but also in the works of the author's previous-generation process FDM [4] was analyzed from several points of view and for many types of materials used for the components of achievement.

In relation to the procedure for processing by thermoplastic which means deposition of layers derived from sequence of lines on each layer after a specific rule. The major difference of the DPL is because the deposit of material is made by converting from liquid in solid form in the presence of a focused beam of light on the surface of the liquid layer.

In both processes generate must be consider that the cycle of implementation of such components is one identical until the printing phase. The first phase is the generation part that usually is done with specialized programs Fusion 360, Inventor or CATIA. As an example we take two of the component of a laser installation that have been designed by students at license paper [2] generated in CATIA and save as .step files [6]. Figure 1 is the stepper structure left part of the laser 2,5 Wats installation for cutting or engraving materials. In Figure 2 is the fix component for laser structure.

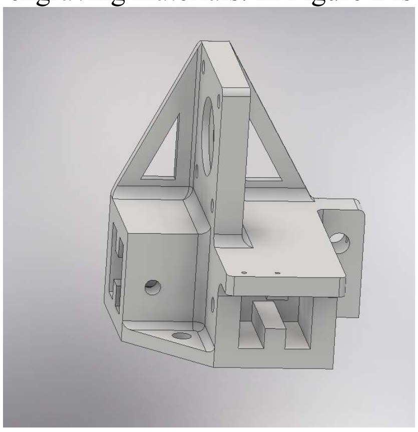

Figure 1. Stepper structure for laser

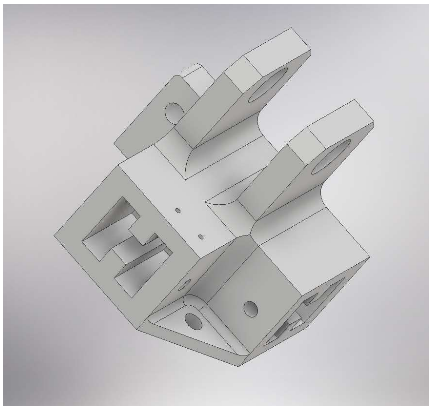

Figure 2. Component of the fix laser structure

After the previous stage shall pass to the phase of checking the integrity of the structure and realization of positioning in view of generating processing program structure for 3D printing. To verify the integrity of the program and the subsequent generation but processing for printing we use FDM ideaMaker [5] software which is free. The next phase is the positioning to minimize the cost of printing and generating program for realization of printing on an FDM for both pieces Figure 3 for stepper and Figure 4 for fix component.

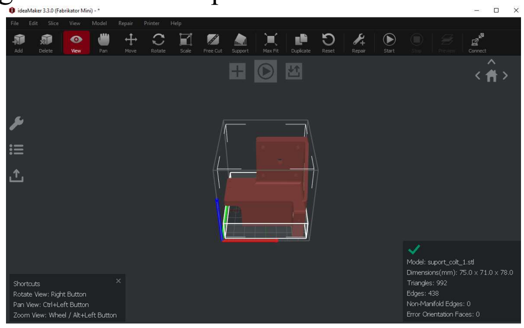

Figure 3. Stepper part verify

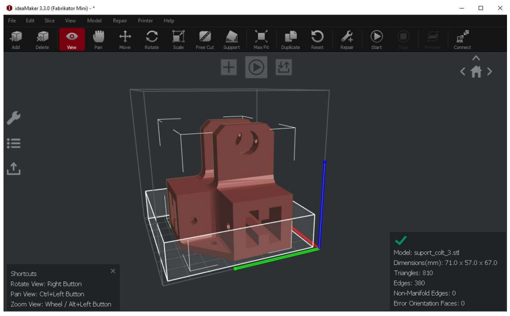

Figure 4. Fix part verify

In this phase the students are able to optimization of the position to achieve as soon as possible but also as correct printing. It is very important the role of the functional component should be ensured.

In the process of generating printed FDM parts should be envisaged the existence of bases supporting structure that is generated. They are presented for the case of linear type in Figure 5 and Figure 6.

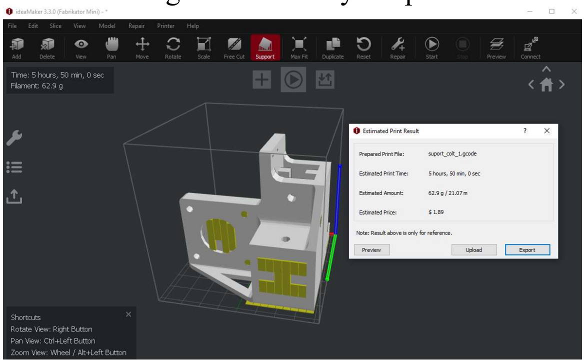

Figure 5. Stepper part verify

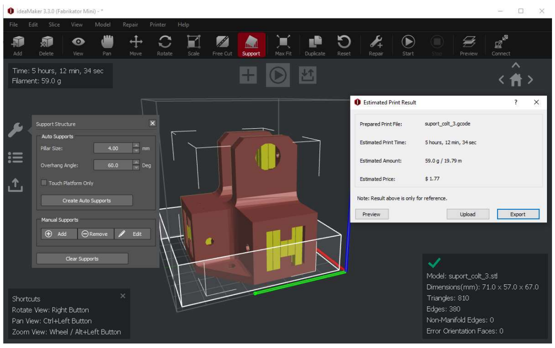

Figure 6. Fix part verify

After checking the layers will export the generated file and will load into the printer's memory for its generation.

Generation process of parts on a DLP is in part identical to the FDM. The difference is in the positioning of the Green printing location and realization that supports generation and layers Figure 7. To generate layers we use a dedicated printer generation program ANYCUBIC Photon Slicer V1.3.6.

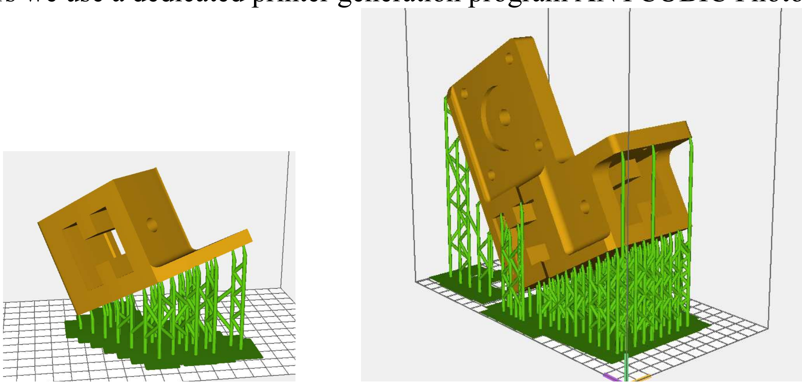

Figure 7. Stepper part generated for 3D printing resin

A major problem on the side of design is the adaptation of the constructive conditions that must be satisfied by the part designed at the printing conditions. Because of the limited dimensions of the printing surface, will have some pieces to be made up of two or more parts. This is apparent in the case of the item above which you can on an FDM achieve one-piece body, while for the realization by the DLP is that it needs to be cut Figure 7. The part was cut after a set of line oriented in horizontal and vertical line inclined at 45 degrees. The combination of the components and their position it is important to be satisfy.

The major difference can be observed in terms of the generation of 3D-printed components is that position of the part in the printed surface it is different. If the positioning is performed horizontally for FDM to the surface to have good adhesion when printing, with DLP resin part subject to generation process shall be positioned at a distance of a few mm from the surface will be printing and will be provided with a storm whose minimum distance between them is 5 .. 8 mm to make the process of printing.

Due to this major differences to functional generate layer printing in order to make the layer for the case to be made of successive movements FDM linear in the XY plane, as can be seen in Figure 8 while the DLP method keeps the bright beam open a precise period of time Figure 9.

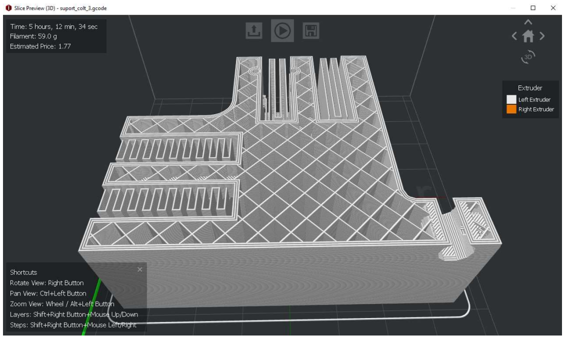

Figure 8. FDM linear generation layer

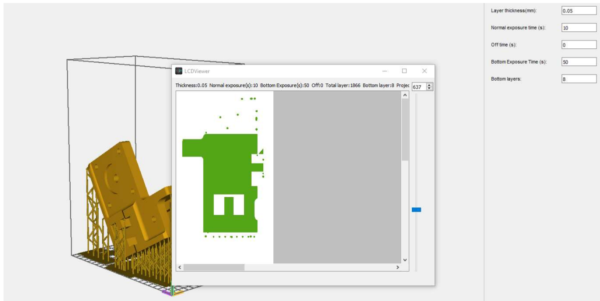

Figure 9. DLP generation layer

Students have the opportunity to become acquainted with the process of generating, but also with the generated process of parts through the two 3D printing processes. At the same time can test both technology to generate parts [3], but also to make comparison with others technique of their generation.

From the point of view of the mechanical properties of components generated one can state that the mechanical resistance is good and the behavior of materials at requests is good.

2. Technological parameters of 3D generation by printing the parts

The process of deposition of layers for achieving part printed in FDM technology is a complex one [4], being analyzed from the standpoint of the dimensional characteristics as well as characteristics of the surface.

Grouping of specific parameters of the process is achieved by:

- characteristics of making of the layer, where the height of the layer is 0,2 mm usual, and first layer is 0,3 mm, speed for printing is 50 mm/sec, inner shell speed is 40 mm/sec, other shell speed is 25 mm/sec, first layer speed is 30 mm/sec, for a good printing of first layer Figure 10, number of shells usual 3,
- characteristics of the extruder is the extrusion width 0,4 mm usual, retraction speed 20 mm/sec for reduce the vibration, temperature for extrusion 210° and 20° for bed,
- characteristics of the inner structure of the part named infill Figure 11, usual 20 ... 40 % for density, the parts generated have 30 % density, type of pattern used is grid at 45° to 135° for all type of generated layer, number of bottom solid layer usual 3 to 5, and top layer, usual 3 to 7, bottom and top speed 50 mm/sec,
- characteristics for support usual lines for a good printed structure, infill ratio 30% and 60° for this structure, usual 5 to 10 is good from point of deformation of the superior printed part,
- platform addition used is skirt only for this material and parts generated,

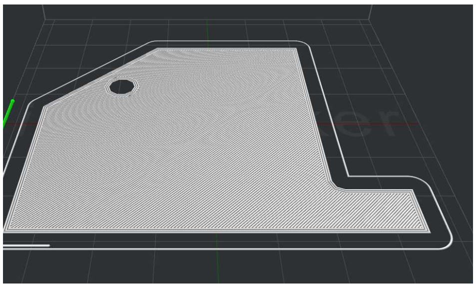

Figure 10. First layer

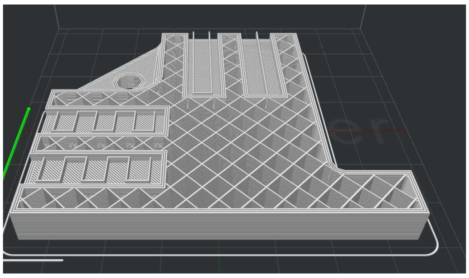

Figure 11. Layer nr.37 structure

It can see both the complexity of elements can be adjusted and is likely to influence the process of implementation of the layers. The program structure is one specific numeric type being orders GCode Figure 12.

From the point of view of the process of program generation for DLP 3D printing on principle can be seen that the number of parameters that can be adjusted is much lower, due in particular to the fact that it generates full marker without goals or items perimeter. Of adjustable parameters, including:

- characteristics of making of the layer, where the height of the layer is 0,05 to 0,07 mm usual 0,05 mm, normal expose time 8 to 10 sec, bottom expose time 50 to 80 sec, and number of bottom layer 5 to 10 usual 8, Figure 13 layer 354 generated,

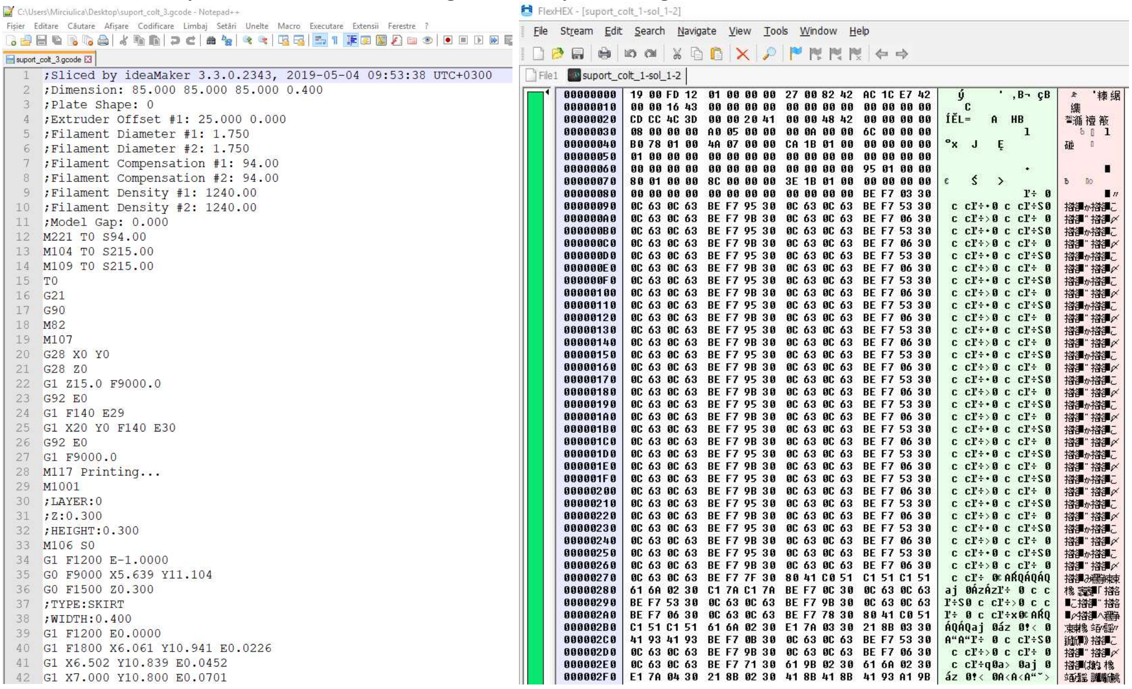

Figure 12. GCode program generated for 3D FDM printing part left and 3D DLP printing part right

From the analysis carried out it may find that although the number of parameters of the command variant is lower for DLP than FDM, the intervention programming to correct program generation structure is much more difficult than the DLP in FDM.

3. Parts generated by FDM or DLP printing technique

Analysed tracks were generated and installed on the stand to verify how the functionality of their interconnection Figure 14. At the up side is the part for stepper motor, with this engine mounted and guiding one of the side bars, and extruded aluminum mounting fitted to the end. The down side is observed the second piece with elements mounted on it.

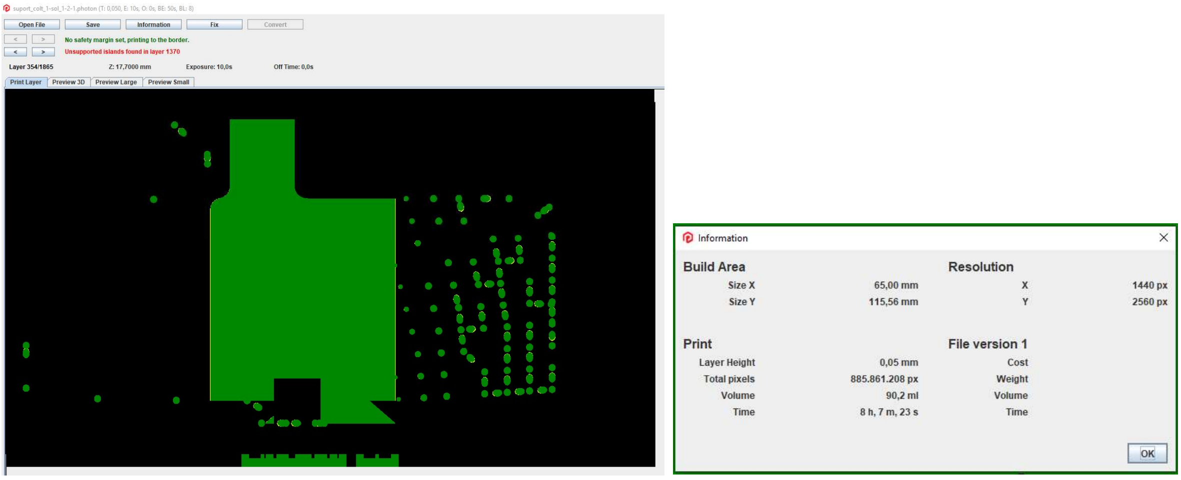

Figure 13. Layer generated for 3D DLP printing part and print information

It can be seen from the right up the structure carried out in terms of infill structure, while at the right down side it can see the quality of the surface structure generated by 3D FDM-type print. It was the preferred printing FDM for reasons relating to the costs of manufacture and not for reasons of mechanical strength.

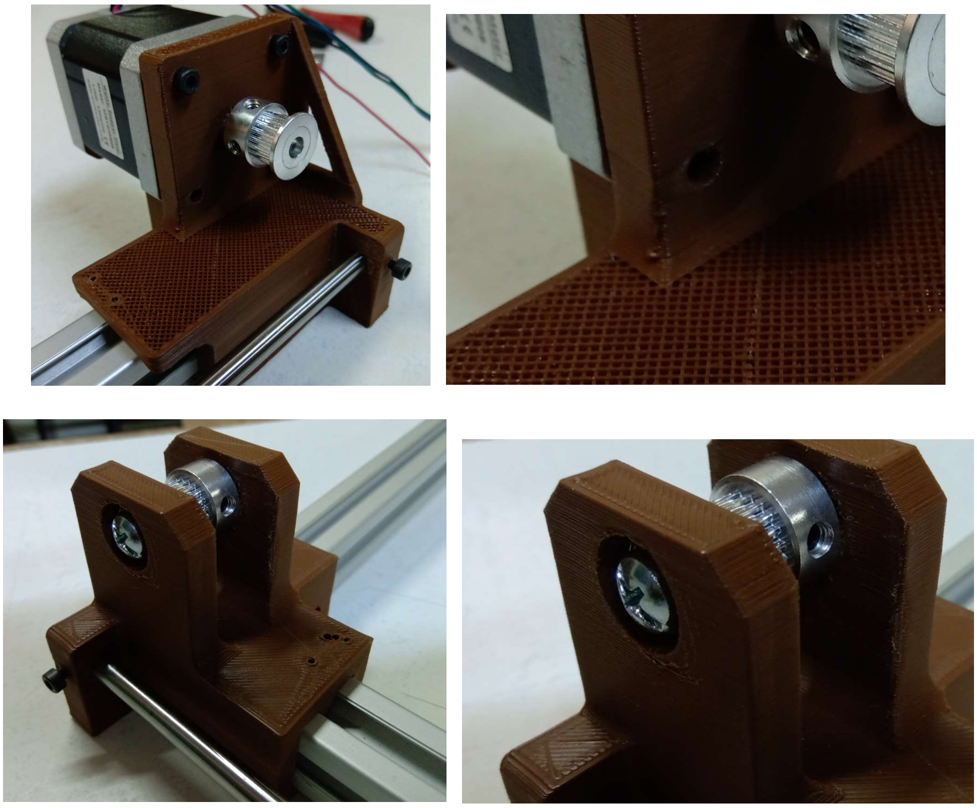

Figure 14. Parts generated and structure of this part generated up for stepper motor, down for fix part

4. Economical calculation program for FDM or DLP printing parts

Cost calculation of production of parts analysed is done taking into account the costs involved in buying printers, consumer characteristics they generate and any salaries costs. To streamline the process was devised a tabular type layout EXCEL allowing both values previously mentioned, but also to be able to make a comparison between the two methods of processing 3D-printed.

The calculations have been based on specific elements of the acquisition was that printers made through direct purchasing, materials that were purchased through direct acquisition. At the top of the table on the calculation formulas are presented, and the lower the resulting values for FDM Figure 15.

Cost for generation	Salary	400	Euro
	Printer cost	293	Euro
	Power printer	300	Wats
	Power cost	=ROUND(0,454/4,7;2)	Euro/kWh
	Filament cost	19,15	Euro

Lenght in mm	Weight in kg	Infill in %	Estim. time in min	Material cost in Euro	Salary cost in Euro	Investment cost in Euro	Energy cost in Euro
21070	0,0629	20	350	=+ROUND(J10*22;2)	=+ROUND(L10*$M$2/168/60;2)	=+ROUND(L10*$M$3/168/60/5;2)	=+ROUND($M$5*$M$4/1000/60*L10;2)
19790	0,059	20	312	=+ROUND(J11*22;2)	=+ROUND(L11*$M$2/168/60;2)	=+ROUND(L11*$M$3/168/60/5;2)	=+ROUND($M$5*$M$4/1000/60*L11;2)

Condition for generation	diam	0,4	mm
	height	0,2	mm

Cost for generation	Salary	400	Euro
	Printer cost	293	Euro
	Power printer	300	Wats
	Power cost	0,1	Euro/kWh
	Filament cost	19,15	Euro

No.	Name part	Material	Pozition	Temperature in C	Speed in mm/s infill	Speed in mm/s perimeter	Lenght in mm	Weight in kg	Infill in %	Estim. time in min	Material cost in Euro	Salary cost in Euro	Investment cost in Euro	Energy cost in Euro	Total direct cost in Euro
1	Stepper part	PLA	Horizontal	210	50	30	21070	0,0629	20	350	1,38	13,89	2,03	0,18	17,48
2	Fix part	PLA	Horizontal	210	50	30	19790	0,059	20	312	1,30	12,38	1,81	0,16	15,65

Figure 15. Parts calculated for FDM 3D printing process

The calculations have been based on specific elements of the acquisition was that printers made through direct purchasing, materials that were purchased through direct acquisition. At the top of the table on the calculation formulas are presented, and the lower the resulting values for DLP Figure 16.

n	diam	0,4	mm
	height	0,2	mm

Cost for generation

Part	Volume in ml	Thickness in mm	Estim. time in min	Material cost in Euro	Salary cost in Euro	Investment cost in Euro	Energy cost in Euro
1	88,6	0,05	=8*60+38	=+ROUND(E11*$M$7/500;2)	=+ROUND(G11*$M$2/168/60;2)	=+ROUND(G11*($M$3+$M$6)/168/60/5;2)	=+ROUND($M$5*$M$4/1000/60*G11;2)
2	19,1	0,05	=4*60+23	=+ROUND(E12*$M$7/500;2)	=+ROUND(G12*$M$2/168/60;2)	=+ROUND(G12*($M$3+$M$6)/168/60/5;2)	=+ROUND($M$5*$M$4/1000/60*G12;2)
1	99,4	0,05	=7*60+55	=+ROUND(E13*$M$7/500;2)	=+ROUND(G13*$M$2/168/60;2)	=+ROUND(G13*($M$3+$M$6)/168/60/5;2)	=+ROUND($M$5*$M$4/1000/60*G13;2)

Condition for generation	diam	0,4	mm
	height	0,2	mm

Cost for generation	Salary	400	Euro
	Printer cost	500	Euro
	Power printer	60	Wats
	Power cost	0,1	Euro/kWh
	UV tratment	30	Euro
	Resin cost	30	Euro/500 ml

No.	Name part	Part	Volume in ml	Thickness in mm	Estim. time in min	Material cost in Euro	Salary cost in Euro	Investment cost in Euro	Energy cost in Euro	Total direct cost in Euro
1	Stepper part	1	88,6	0,05	518	5,32	20,56	5,45	0,05	31,38
		2	19,1	0,05	263	1,15	10,44	2,77	0,03	14,39
2	Fix part	1	99,4	0,05	475	5,96	18,85	5	0,05	29,86

Figure 16. Parts calculated for DLP 3D printing process

Economic analysis may find that on the one hand due to the smaller on the thicknesses of the layers printing we have DLP durations greater realization of parts. At the same time the costs of completing the parts are pretty much influenced by the salary component and less of the investment. Cost of parts made on the version with DLP are almost double the parts made by FDM.

5. Conclusion for 3D printed parts by FDM or DLP printing technique

This study allows us to analyse both the costs of achieving various milestones by 3D printing. At the same time allow students to appreciate where you have used a particular type of process, and where another process, and to determine the level of the costs involved in the process of 3D printing.

Last but not least you can highlight the technological strategy of making parts and the complexity of their generation process from the design stage to the actual realization through the two processes listed.

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