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ECONOMIC AND TECHNOGICAL CONSIDERATIONS ON THE 3D PRINTING COMPONENTS WITH SLA PRINTING PROCESS

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Abstract. The purpose scope of this paper is to analyse the economic aspects of making 3D printing components for the development of machine for experimental devices or stands used in laboratory or industrial activity. The author of this paper intends to make a clarification related to the approach of the productive economic aspects through the production of components through the additive technology of SLA type. The work is structured in 5 chapters. For the generation of the constructive elements, a laser printer will be used, where the components will be generated on the bottom-up principle. The analysis will be carried out both from a constructive and functional point of view, taking into account possibilities of component design and their realization. The next chapter is allocated to analysing how to perform the printer's command program and to check the part structure. Part of this chapter is devoted to the way and role of the elements of orientation and support of the component that is being made. The fourth chapter presents 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-economic point of view compared with other specific technologies for generating the analysed parts.
Key words: *3D printing, economic analyses, technological parameters, SLA*

1. General consideration on 3D printing resin with laser

Obtaining components or subassemblies through the additive technology of the laser beam with resin medium for generating components is a laboratory but also industrial domain specific to the make of the parts by optical polymerization. The use of the laser beam has appeared as an alternative to the light beams emitted by luminescent diodes or luminescent optical matrix screens. The power of the laser beam is optically greater than that of optical light emitted by LEDs or light screens. This will result in faster optical polymerization of the resin bonding material used in the process of generating the parts.

From a constructive point of view as can be seen in Figure 1 we have a laser beam generation structure on the plane print surface with a small thickness of 1 mm. Geometrically the design dimensions can be seen in Figure 2. The distance between the position of the focal point relative to the extremities and its center respectively shall be 2,267 mm the line width is set to 0,067 mm. This may have an influence on the thin layers subject to the polymerization process. Since the capacity to generate a layer by printing is from 0.025 mm to 0.1 mm. important is also the print speed parameter which for small thickness is 175 mm/second, while for high thickness decreases to 85 mm/second for the printer manufacturer's resin. This can determine the duration of generating a elements in terms of its generation of them. It should be shown that there is a similarity between FDM printing [1, 3] and SLA printing [2].

In both cases printing is performed linearly by generating continuous lines of material Figure 3 for FDM printing process and Figure 4 for DLP printing process. This leads us to state that if at lower speeds the elements result better for the FDM process and the SLA process is this true observation. It is reinforced by the printer manufacturer's recommendation that optimal results are achieved at speeds between 50 mm/second and 100 mm/second, with a laser power of 42 units for DLP resin and 55 units for SLA resin.

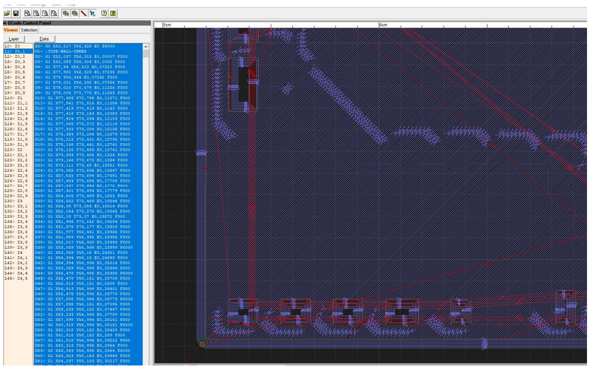


Figure 1. Constructive structure of laser system

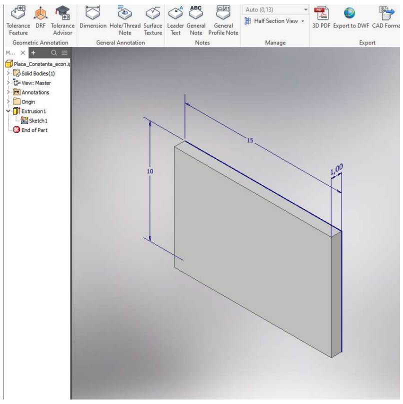


Figure 2. Geometrically the design dimensions

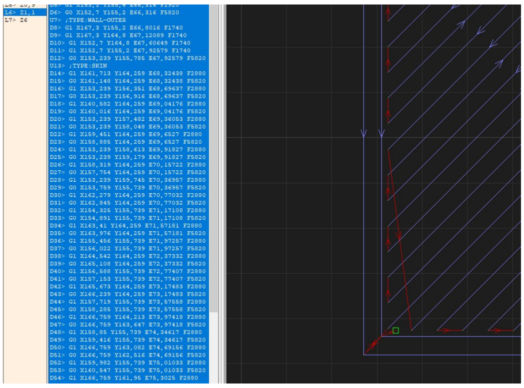


Figure 3. Generating continuous lines for FDM printing

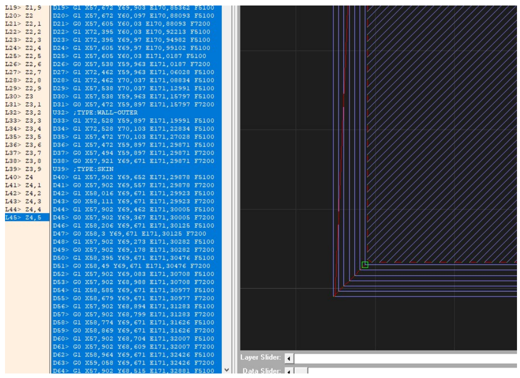


Figure 4. Generating continuous lines for SLA printing

From the point of view of the construction of components they shall be within the size of the print surface of 128 mm per 128 mm. It is important to note that the lifting position is centrally arranged on the plate for generating parts and if the position of the components is not central can create additional vibration problems when generating layers Figure 5. A second important aspect is that of generating multiple items on the print surface. It is recommended that the distribution of surface elements be made as balanced as possible on the central side and less to the side extremities Figure 6.

If we compare the time required to make the parts in the last figure through the three processes, it can be observed that for a layer thickness of 0,2 mm for FDM and 0,1 for DLP and SLA respectively we have the following results:

- For FDM at a print speed of 25 mm/sec, lower layers 5, printing time 2 minutes and 13 seconds for 5 layers, without supports at the bottom; [1]
- For DLP at a 10-second layer print time and for the lower 8 layers expose time 50 seconds, support as a medium density setting of conical type with a contact point diameter of 1,2 mm and length of 3 mm, 17 minutes print time; [4]
- For SLA to a specific default 0.1 mm layer setting with generated supports for the DLP variant as a setting, we will result in a print time of 41 minutes and 35 seconds. [2]

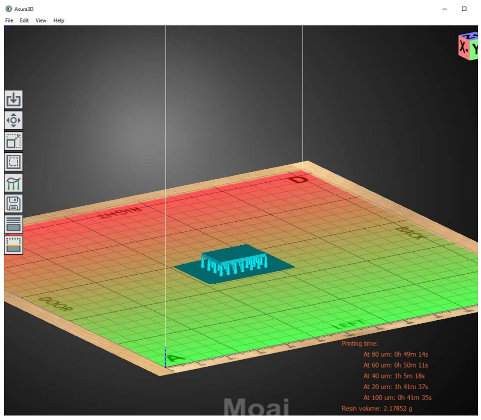


Figure 5. Central positioning for printing

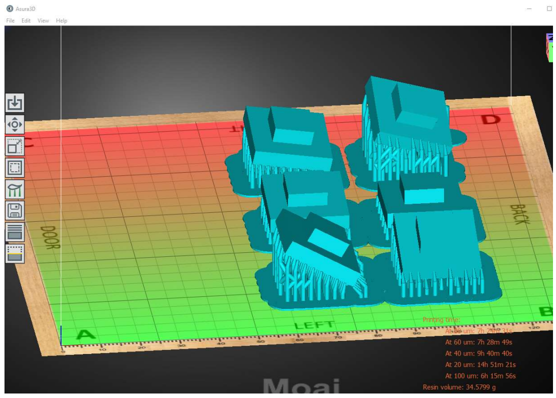


Figure 6. Distribution of elements in surface

2. Analysing how to printing the item by additive SLA technology

Since the technology of making the marks on the principle of exposure to the laser beam of a resin layer is similar to that of thermal material deposition on flat surfaces, this as a method of control of the laser beam displacement machine is done on the same type of program, namely Cura. The major difference is generated by the condition of existence when made the printing process with laser beam at the bottom of printed item the elements supporting. Due to the fact that such elements cannot be generated in the Cura program, it is necessary to carry out the supporting elements in programmed specific to the DLP process which is principled similar to that of the SLA.

Due to these aspects it can be said that the duration of the process of generating layers to achieve the printing process increases. This will result in an increase in the workmanship specific to the process of generating the machine control program. If the aspects of the mode of generation presented in the first chapter are also taken into account, it can be concluded that the laser beam processing process will be more expensive than either of the two processes on the generated of the beam displacement control program.

From the point of view of the technological parameters of generation, account should be taken of those related to the power of the laser beam which is dependent on the type of resin used. For more optically sensitive resin of the type used in the DLP process, the power must be less somewhere at half of the power of the laser source, while for resin that is specific to the laser process it must be approximately 15% higher than the previous one. An important parameter is the thickness of the resin layer, which will also determine the specific processing speed and the time during which the item will be made. These issues were presented in the first chapter.

3. Structure of the command program and ways of verifying the integrity of the item generated

From the point of view of checking the integrity of the item, the two specific aspects of the component must be taken into account:

- Check the integrity of the solid element from which is made the 3D printed item;
- Verification of the structure of the supporting elements that are necessary for the made of the intended item.

From the short presentation it can be seen that the verification steps are taken from the two processes of printing the parts, namely those of type FDM and DLP [4, 6]. These phases are made after the first step of the CAD solid generation and are made with specific programs for FDM printing. The second is carried out after generating the structure of supporting elements and has the role of controlling the integrity of the structure in order to make the printing process. The latter phase is specific to the DLP printing process. Due to these aspects it can be said that the duration of the programme for printing the item is similar to that of the DLP printing process and greater than the FDM printing process.

To better explain the part of laser beam processing, but also that of the cost of making an item are take a specific item of a laser beam processing plant shown in Figure 7. It is determine the time required to perform the verification operations that are 4 minutes for the item integrity check Figure 8 and the generation of the Figure 9 supports and respectively the integrity check of the supports generated Figure 10.

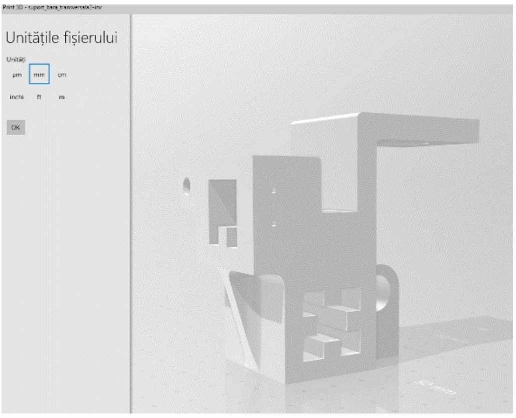


Figure 7. Item generated CAD

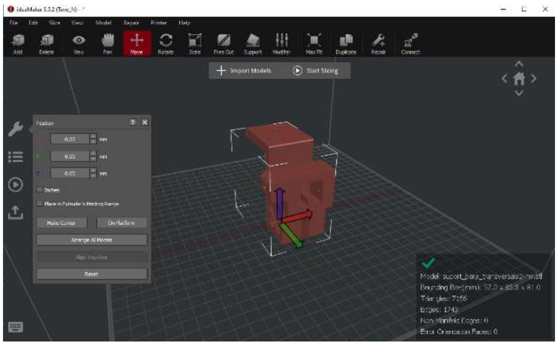


Figure 8. Item solid integrity check

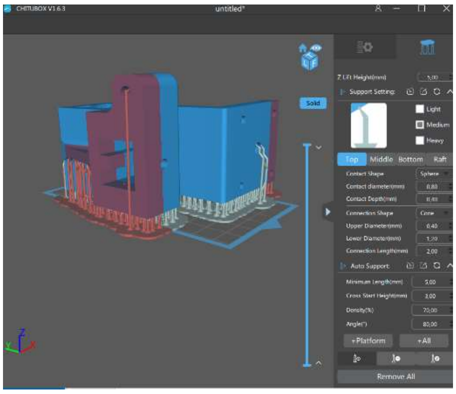


Figure 9. Generate solid supports

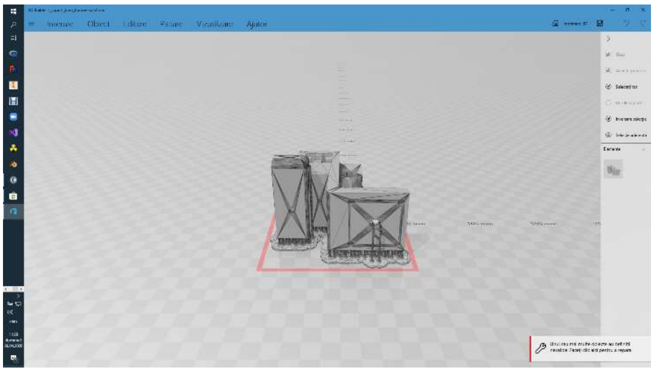


Figure 10. Check integrity with generated supports

A set of free or educational programs from the point of view of their license shall be used to carry out the operations presented. We start on the CAD side with the use of the INVENTOR program to achieve the 3D solid item. After which the generated solid will be loaded into the IDEAMAKER program to verify its integrity and perform the repair operation where necessary. After the correction is completed it will be saved as solid and imported into the CHITUBOX program for the generation of the support elements and with them added it will be exported as a solid assembly the item generated and this will be subject to edit and verification and correction process made with 3D BUILDER. The duration of the operation is dependent on the level of generation errors and the complexity of the item, starting from 5 minutes to tens of minutes respectively for complex milestones.

From the point of view of the structure of the program it is relatively similar for both types of 3D printing solution. The structure is modular with a program-specific start part and a final part with the settings specific to stopping the processing process. The part of the program itself is covered between these two parts with its specific elements. The beginning part of the program for both versions looks like Figure 11 for the FDM variant and figure 12 for SLA, respectively.

```
; *** G-code Prefix ***
;
; [mm] mode
G21
; Absolute position mode
G90
; Start heating the Bed
M140 S43
; Home the axes
G28
; Wait till the Bed is heated
M190 S43
; Heated chamber G-code is not universal
;M141 S0
;M191 S0
;
; *** Main G-code ***
;
; BEGIN_LAYER_RAFT z=0.400 z_thickness=0.400
;
; *** Selecting and Warming Extruder 1 to 195 C ***
; Select extruder, warm and wait, purge
G4 P0
M104 S195
M542
M551 P32000 S900
M543
```

Figure 11. Start module for FDM GCode program

```
;FLAVOR:Marlin
;TIME:6666
;Filament used: 0m
;Layer height: 0.1

;Generated with Cura_SteamEngine 3.5.1
M82 ;absolute extrusion mode
G28 ;Home
```

Figure 12. Start module for SLA GCode program

```
; *** Cooling Extruder 1 to 0 C and Retiring ***
; Same extruder, about to deselect, retract before cooling down
M542
M561 P6400 S900
M543
; Cool
G4 P0
M104 S0
;
; fan off
M107
; *** G-code Postfix ***
;
; All extruders are retired
; Move the head up / bed down
G91
G1 Z+10
G90
; turn off the bed & chamber (machine specific)
M140 S0
```

Figure 13. Finish module for FDM GCode program

```
;TIME_ELAPSED:203377.184588
M104 S0
M82 ;absolute extrusion mode
;End of Gcode
```

Figure 14. Finish module for SLA GCode program

In the FDM part of the program it is possible to see in addition to the specific safety command and origin positioning controls, the specific working table heating and extruder commands with a specific waiting command until the working parameters are reached. For the start part of the SLA printing program, the start part is relatively short because many of the settings are scheduled by default in the printing machine setting.

4. Economic calculation program for the generated item

Cost calculation of production of items is made taking into account the costs involved in buying printers, consumer characteristics they generate and salaries costs. To calculation are made with an EXCEL spreadsheet in which the structure of the table have more parts. First are the part of fix data Figure 15. . 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 [5]. At the bottom of the economic calculation table for FDM are two rows in which there are first the values for the consumption of material from the mass of each individually calculated item and the density of the material from which the item will be made shall be determined. The second element which are determined from economically point of view is the cost of labour which is related only to the realization of the item from the length of time during which the item will be printed. The penultimate is the cost of amortizing the value invested in the machine with which are made the printing of the item and which depends on the purchase value of the printer and the length of time in which are made the desired of depreciate value of the printer. For our case the depreciation is done in 5 years and will be determined in minutes to be able to have value in euro calculated for this type of cost. The last calculation element envisaged is the one related to the cost of the energy consumed on the print side and it depends on the power consumed for printing and the length of time the printing process is carried out.

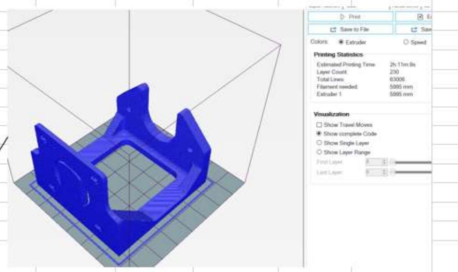
Condition for generation			
	diam	0,4	mm
	Flam	1,75	mm
	height	0,2	mm

Density gr/cmc	
ABS	1,04
PLA	1,24
PETG	1,27

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 %
1	Stepper suport X axe	PLA	Horizontal	210	33	24	5.995,00	0,0179	20
2	Stepper suport z axe	PLA	Horizontal	210	33	24	19.617,00	0,0585	20

No.	Name part	Material	Estim. time in min	Material cost in	Salary cost in Euro	Investment cost in Euro	Energy cost in Euro	Total direct cost in Euro
1	Stepper suport X axe	PLA	180	0,39	7,14	1,05	0,09	8,67
2	Stepper suport z axe	PLA	544	1,29	21,59	3,16	0,27	26,31



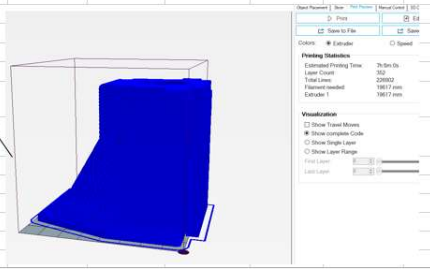


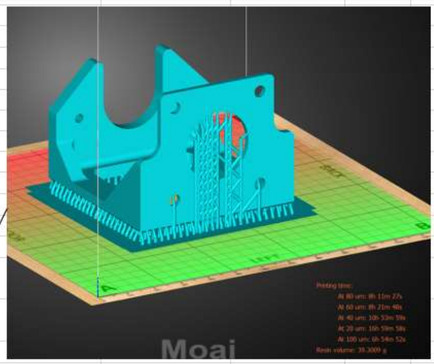
Figure 15. Cost calculation for item with FDM printing system

Condition for generation			
	DP	0,075	mm
	height	0,1	mm

Cost for generation			
	Salary	400	Euro
	Printer cost	1200	Euro
	Power printer	0,15	Wats
	Power cost	0,100	Euro/kWh
	UV tratment	30	Euro
	Resin cost	35	Euro/500 ml

No.	Name part	Part	Volume in ml	Thickness in mm	Estim. time in min	Mass in grams
1	Stepper suport X axe	1	23,50	0,05	414	39,3009
2	Stepper suport z axe	1	98,96	0,05	1062	165,493

No.	Name part	Part	Material cost in Euro	Salary cost in	Investment cost in Euro	Energy cost in Euro	Total direct cost in Euro
1	Stepper suport X axe	1	1,65	16,43	10,10	1,0E-04	28,18
2	Stepper suport z axe	1	6,93	42,14	25,92	2,7E-04	74,99



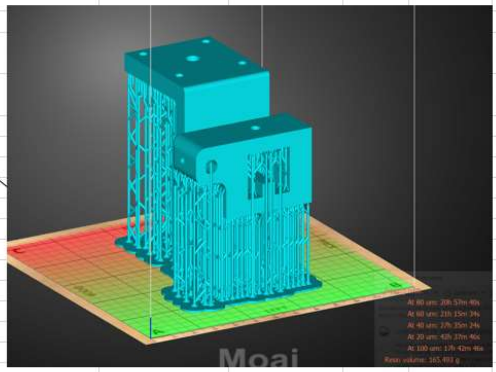


Figure 16. Cost calculation for item with DLP printing system

Cost calculation and the structure of the calculation form for 3D SLA printing is similar to the one previously presented and can be seen as an organizational mode in Figure 16.

Economic analysis may find that on the one hand due to the smaller on the thicknesses of the layers printing we have SLA durations is greater for realization of the item. At the same time the costs of completing the parts are pretty much influenced by the salary component for FDM printing type and less of the investment. For the SLA printing system the influence of the investment is half of the cost for the item printed. Cost of parts made on the version with SLA type printing system are almost triple in rapport of the price of the parts made by FDM.

5. Conclusion

This present paper allows us to analyse both the costs of printing various item by 3D SLA printing system. At the same time allow to appreciate where it is possible to 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 it is possible to determinate 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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