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Technical considerations on the 3d printing components with DLP 3D printing process with ecological resin

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Abstract. The purpose of this work is to analyse the technological aspects of the realization of components by 3D printing for the production of plan parts for experimental devices or stands. The author of this work envisages the realization of flat elements to which it can be determined how the organic resin material behaves when printing 3D with additive DLP technology. The work is structured in 5 chapters. In the first chapter, an analysis of how to make the plan elements by the additive DLP technology specific to the experimental programme adopted in this paper. The analysis will be carried out both constructively and functionally taking into account possibilities for designing components and making them. Chapter two is allocated to ordering technological parameters for 3D printing generation of parts defining the main technical parameters for generating them with ecological resin. The next chapter is allocated to analysing how to carry out the printer command program and check the structure of the element. In the four chapter, the dimensional measurement and control programme with dimensional and optical is presented. The last chapter is allocated to conclusions and comparisons from a technological point of view compared to other specific technologies for generating the analysed elements.
Key words: *3D printing, technologic analyses, dimensional parameters, DLP*

1. General considerations for light-beam 3D printing of resin-generated components

The study undertaken emerged as a necessity imposed by new types of resin with chemical properties that are closer both to the emission aspects compared to and in relation to the environment, but also to analyses the aspects in which the new type of resin influences the process of generating components.

The major advantage of DLP (digital light processing) printing is given by the fact that the generation of material layers related to the structure of the components is done at the same time. In terms of the structure of the generated component it is made from two distinct areas. The first is helpful for printing generation, and the second is the effective realization of the component. From the point of view of the structure of the component in the vast majority it is a closed body and have a compact structure. The support part consists of two large areas. The first is the adhesion layer usual it have eighth equal plan. The second part is pyramidal or cylindrical with a cone trunk section in the first and cylindrical or pyramidal part respectively in the second part [1, 2].

One of the problems seen in the vast majority of generation programs is that automatic generation does not always generate a uniform support structure. Therefore, it is necessary after the automatic generation part to make a correction by adding supports.

The second problem relates to the dimensions resulting from printing, which are different from the nominal value after the three directions.

The element designed for the study was generated by the two-stage prismatic type in order to be able to study the influence of the item orientation on its dimensions Figure 1 [3, 4, 6].

For generating components, a printer put in a room which is thermally protected shall be used, ensuring the conditions of temperature stability required for printing and next to it the ecological resin and the temperature and humidity measurement system are used Figure 2 [5].

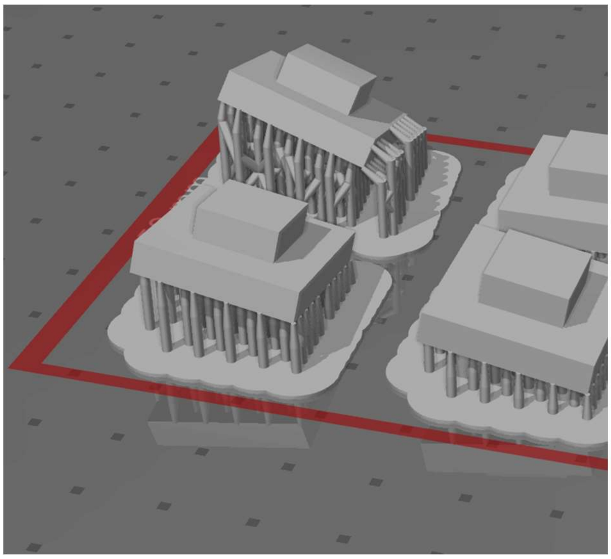

Figure 1. Item positioned with different orientation for generating layers

Figure 2. Printer, thermal chamber, apparatus measuring thermal conditions and resin used

The main advantage of using the solution is the preservation of the thermal energy generated by the 3D printer in the printing process with the reduction of its operating costs. It should be shown that the printing process is dependent on a certain temperature range to have optimal printing results 25 to 30 degrees.

A specific DLP printing program has been used to generate landmark orientation and perform the elements supporting the orientation of print marks, which allows to verify the correctness of the automatic generation of previous items CHITUBOX 64 [6].

2. Considerations on the technological parameters used to generate components

From experiments carried out with non-ecological resin it has been observed that the orientation and thickness of the layer generated can generated influence on the dimensional and geometrical sizes of parallelepiped components.

It should also be pointed out that there is a direct link between the thickness of the layer generated and the other technological parameters. So if the layer is thinner the exposure duration will be less. This duration is also dependent on the physical and chemical characteristics of the polymerization material and the basic element which is in the structure of the printing material.

An experimental program was designed from the study, where the abovementioned elements were taken into account.

The first factor which is take in consideration is the orientation of the element designed for the experiment that was oriented differently by the two axes of the element generation Figure 3. For the implementation of the measurement program the data were centralized in Table 1 form and the parts which are subject of the measurement process were numbered.

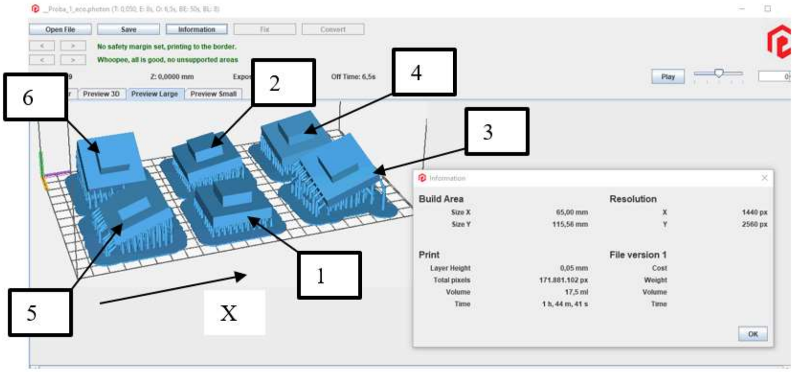

Figure 3. Item oriented at different angles for studying dimensional influence

Table 1. Item orientation relative to plan X - Y.

Item number	X Axis angle	Y Axis angle	Layer thickness in mm
1-5, 1-7, 1-3.	0	0	0.05, 0.07, 0.03
2-5, 2-7, 2-3.	15	0	0.05, 0.07, 0.03
3-5, 3-7, 3-3.	30	30	0.05, 0.07, 0.03
4-5, 4-7, 4-3.	15	15	0.05, 0.07, 0.03
5-5, 5-7, 5-3.	30	0	0.05, 0.07, 0.03
6-5, 6-7, 6-3.	40	0	0.05, 0.07, 0.03

The second parameter under consideration is that determined by the thickness of the layer that is generated when 3D printing. This thickness has been chosen in such a way that it can be symmetrical to the central value of 0.05 mm commonly used. For this value the time duration determined to be optimal from previous experiments was found to be 8 seconds. The rest of the specific elements have not been changed and have a minor influence on the dimensional changes of the element when printing 3D.

3D printed samples were organized into layer thickness groups as can be seen from Figure 4.

Figure 4. Item printed at different thickness for studying dimensional influence

3. Organizing the factors to be studied in the experiment

For the centralization of the data in the experiment, an EXCEL spread sheet was designed in which the data in Figure 5 is presented and entered for each of the samples. The figure shows the data determined for one of the three layer thicknesses generated by3D printing DLP system and this is 0.07 mm. The determination of values by vertical direction will also be made by measuring with digital calliper. The determination can be seen in Figure 6 and are organized on the three size zones that are possible to be measured without major damage to the structure of the generated supports.

Sample	Broken supports	Vertical small	Vertical high	Horizontal small	Horizontal high
Horizontal 1-7	0	10,56; 10,60; 10,59	21,03; 20,97; 21,01	10,47; 10,49; 10,49	20,92; 20,95; 20,94
X 15; Y 0 2-7	0	10,74; 10,79; 10,54	20,97; 20,96; 20,90	10,46; 10,70; 10,65	21,06; 21,08; 21,02
X 30; Y 30 3-7	1	10,47; 10,53; 10,39	20,89; 20,96; 20,85	10,43; 10,49; 10,54	20,81; 20,79; 20,90
X 15; Y 15 4-7	0	10,54; 10,57; 10,52	20,90; 20,93; 20,99	10,55; 10,54; 10,53	21,03; 20,94; 20,96
X 30; Y 0 5-7	0	10,48; 10,39; 10,41	20,88; 20,88; 20,89	10,40; 10,39; 10,38	20,87; 21,01; 20,81
X 0; Y 40 6-7	0	10,47; 10,46; 10,45	20,84; 20,85; 20,91	10,28; 10,34; 10,31	20,72; 20,84; 20,73

Figure 5. Centralized data for 0.07 mm thickness for studying dimensional comportment

From a dimensional point of view, the geometric dimensions of the items and the number of supporting elements that are broken will be measured.

Factors that cannot be determined by measurement shall be interpreted on the basis of optical assessment or structural integrity by giving notes from 1 to 6 for each of the printed layer thicknesses. Subsequently the best element within a thickness will compare with those of the other layer thicknesses best generated.

4. Dimensional or optical determination of the factors to be studied in the experiment

To determine how the size of the element are changed, it was measured in three zones in the X-Y generation plane. These areas are marginal and median, respectively for the plan direction item generated. Measurements were made for the vertical part according to the same principle as observation of dimensional changes. It should be noted that in the vertical direction the points were measured in the corner area and in the median area for each of the items, respectively, and the data are centralized in a second table to facilitate the interpretation of the information determined Figure 6.

The quality of the surfaces was optically assessed because the areas generated. It can be observed that on the areas of the edge for the items where the program has not generated supports there are trends of curving the peaks of the squares that occur in those with large sections and do not appear in those with small section.

For the assessment of the characteristics of the parts, the integrity of the item and the supporting elements generated was taken into account. The deformation in particular in the horizontal plane which was determined dimensionally it is study. The quality of the generated item it is same analyzed and this took particular account of the dimensional deviations from the nominal dimensions of the items. On the basis of these determinations, the allocation table of numeric values was made where the figure 1 was allocated for the weakest feature and the figure 6 for the best Figure 7.

Horizontal 1-7				
8,25		8,24		8,26
	4,41	4,2	3,93	
8,43	4,24		4,21	8,31
	4,21	4,27	4,24	
8,25		8,38		8,31

X 15; Y 0 2-7				
7,89		8,03		8,13
	3,85	4	4,05	
7,27	4,12			
	4,19			
8,15				

X 30; Y 30 3-7				
8,19		8,19		8,22
	3,95	3,98	4	
8,19	3,99			
	4,2			
8,15				

X 15; Y 15 4-7				
8,09		8,02		8,13
	4,12	4,06	4,08	
8,2	4,12			
	4,12			
8,08				

X 30; Y 0 5-7				
8,16				
	3,95	3,96	4,07	
8,15	3,93			
	3,95	4,06	3,88	
8,28				

X 0; Y 40 6-7				
8,16				
	3,86	4,04	3,97	
8,18	3,99			
	3,94		3,99	
8,21				

Figure 6. Centralized data for thickness of 0.07 mm in vertical direction for studying dimensional comportment

	X 0; Y 0	X 15; Y 0	X 30; Y 30	X 15; Y 15	X 30; Y 0	X 0; Y 40	
	1-7	**2-7**	**3-7**	**4-7**	**5-7**	**6-7**	
integritate	4,5	4,5	1,5	4,5	1,5	4,5	21
deformare	4,39	4,41	4,25	4,32	4,25	4,3	
	2	1	5,5	3	5,5	4	21
calitate	5	4	1	6	3	2	21
	11,5	9,5	8	13,5	10	10,5	

Figure 7. Centralized data for thickness of 0.07 mm in the direction of quality assessment, integrity

From the analysis made for the three types of dimensions, the three tables were detached from the three tables, that for the thickness of 0,07 mm the best value is obtained for the item inclined 15 degrees after both directions and at a short distance the one tilted 30 degrees after both directions.

For parts with a layer thickness of 0,03 mm, it can be seen from Figure 8 that the best results are obtained for the item generated by inclined at 15 degrees after direction X and 0 degrees. Of these two will be chosen the item at which the surface deformations are the smallest and this is the horizontal one.

In the case of the generation of 0,05 mm thickness layer item, it is found that the best results are obtained for the 15 degree inclined item after both directions.

	X 0; Y 0	X 15; Y 0	X 30; Y 30	X 15; Y 15	X 30; Y 0	X 0; Y 40	
	1-7	**2-7**	**3-7**	**4-7**	**5-7**	**6-7**	
integritate	4,5	4,5	1,5	4,5	1,5	4,5	21
deformare	4,59	4,83	4,25	4,3	4,49	4,87	
	3	2	6	5	4	1	21
calitate	5	6	3,5	2	1	3,5	21
	12,5	12,5	11	11,5	6,5	9	

Figure 8. Centralized data for thickness of 0.03 mm in the direction of quality assessment, integrity

For the three best-performing items, a parallel study will be carried out based on the measured or determined data. Figure 10 shows the flat dimensional analysis for the two square areas where the percentage deviation from the CAD dimensions used to make the solid body can be observed. From the analysis it can be observed that the smallest deviations after both directions are obtained for the mark with the thickness of the layer of 0,07 mm on the generation side.

	X 0; Y 0	X 15; Y 0	X 30; Y 30	X 15; Y 15	X 30; Y 0	X 0; Y 40	
	1-7	2-7	3-7	4-7	5-7	6-7	
integritate	4,5	4,5	1,5	4,5	1,5	4,5	21
deformare	4,47	4,32	4,5	4,31	4,38	4,47	
	2,5	5,5	1	5,5	4	2,5	21
calitate	3	1	6	2	5	4	21
	10	11	8,5	12	10,5	11	

Figure 9. Centralized data for thickness of 0.05 mm in the direction of quality assessment, integrity

	A	B	C	D	E	F	G	H	I
1									
2		0,03	mm						
3									
4		Horizontal		Broken supports		0			
5		1-7				small	high	small	high
6						10,60	21,19	6,00%	5,95%
7						10,74	21,20	7,40%	6,00%
8						10,60	21,11	6,00%	5,55%
9		small	10,84	10,77	10,71				
10		high	21,17	21,19	21,20				
11									
12		small	8,40%	7,70%	7,10%				
13		high	5,85%	5,95%	6,00%				
14									

	J	K	L	M	N	O	P	Q	R
1									
2		0,05	mm						
3									
4		X 15; Y 15		Broken supports		0			
5		4-7				small	high	small	high
6						10,58	21,12	5,80%	5,60%
7						10,75	21,10	7,50%	5,50%
8						10,67	21,22	6,70%	6,10%
9		small	10,55	10,52	10,58				
10		high	20,95	21,08	20,88				
11									
12		small	5,50%	5,20%	5,80%				
13		high	4,75%	5,40%	4,40%				
14									

	S	T	U	V	W	X	Y	Z	AA
1									
2		0,07	mm						
3									
4		X 15; Y 15		Broken supports		0			
5		4-7				small	high	small	high
6						10,54	20,90	5,40%	4,50%
7						10,57	20,93	5,70%	4,65%
8						10,52	20,99	5,20%	4,95%
9		small	10,55	10,54	10,53				
10		high	21,03	20,94	20,96				
11									
12		small	5,50%	5,40%	5,30%				
13		high	5,15%	4,70%	4,80%				
14									

Figure 10. Comparative study for dimensional changes for generated parts

0,03	mm			
Horizontal 1-7				
8,18		7,92		8,04
	4,37	4,2	4,32	
8,29	4,37			
	4,21	4,29	4,2	
8,21		8,1		7,89
2,25%		-1,00%		0,50%
	9,25%	5,00%	8,00%	
3,62%	9,25%			
	5,25%	7,25%	5,00%	
2,63%		1,25%		-1,37%

0,05	mm			
X 15; Y 15 4-7				
7,62		7,94		8,22
	3,78	4,11	4,12	
7,96	4,11		4,1	8,06
	4,02		3,97	
7,77				7,77
-4,75%		-0,75%		2,75%
	-5,50%	2,75%	3,00%	
-0,50%	2,75%		2,50%	0,75%
	0,50%		-0,75%	
-2,88%				-2,88%

0,07	mm			
X 15; Y 15 4-7				
8,09		8,02		8,13
	4,12	4,06	4,08	
8,2	4,12			
	4,12			
8,08				
1,13%		0,25%		1,62%
	3,00%	1,50%	2,00%	
2,50%	3,00%			
	3,00%			
1,00%				

Figure 11. Comparative study for vertical dimensional changes for generated parts

Comparative analysis by vertical direction can be seen in Figure 11 that we have the best results are for the item where the thickness of the layer is 0.07 mm.

From this study it can be observed that for both solutions the thickness of the layer is the best of 0.07 mm.

5. Conclusion

It is possible to see that from the study made that the print accuracy is depending on the accuracy of the way that the item is positioned and supported. It can also be seen that the dimensions for the item made by environmentally friendly resin are influenced by the same orientation and generation considerations.

By this paper was desired to see how it changes the dimensions of the part when used as the environmentally friendly resin material. It was also desired to carry out a complete study on the dimensions and quality of the generated parts.

For the case of generating parallelepiped body, recommended to change the way in which this are generated by using linear control to construct the parallelepiped area image. This, however, means changing how the program will generate the item.

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