INFLUENCE OF TECHNOLOGICAL PARAMETERS ON THE STRUCTURE AND DEFORMATION OF FLAT OR ROUND PARTS GENERATED BY DLP 3D PRINTING

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ABSTRACT: The paper is focuses to establish the principal setting parameter for the 3D printing DLP (Digital Light Processing) process, which have an influence on the surface characteristics of the flat or round parts. In the first part of the paper are analyzed the principal value parameter which may have a relevant influence for the printing of the 3D plane surfaces for the DLP process. This method was chosen because a relative reduce costs of generating planar surface for objects occurs, but also for the generation mode is relatively simple from a technological point of view. The printer and the program used for generation is presented, which both constructively and functionally will be analyzed, both as functionality and as component design possibilities. Next chapter allocated to the ordering of technological parameters of 3D generation by printing the parts with define the main technological generation parameters of the parts with statistically ordering data. This step is important to ensure the assembly conditions of the components, and also to the fact that the materials used to make the parts produce different behavior after the three directions in terms of contractions and the dimensions variation. In the last chapter are presented some of the domain specific elements generated by 3D printing with DLP are used. Surface analysis will be done both by optical and dimensional measurement of surface. The dimensional measurement of the part made with digital measuring devices and optical method. The paper also refers to the generating methodology of flat or round surfaces and the influence 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.
KEY WORDS: 3D printing, surface dimension, DLP printing, fabrication parts, statistical data

1. CONSIDERATIONS ON THE DLP 3D PRINTING PROCESS

To be able to realize the study it is necessary the first conception of a model to study the DLP 3D printing process. To observe how it modifies the surface and dimensional characteristics have generated a probe that is the square (Figure 1). Generation was made with Fusion 360 Educational version [1]. The volume of the probe is 4.044,524 mm^3 and the area is 2.346,35 mm^2.

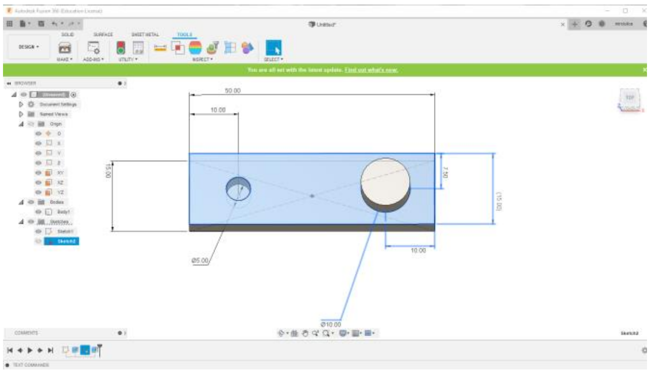

Figure 1. CAD generated probe

It has a flat surface and lower respectively. We also generated two specific items. One a cylinder with 10 mm diameter and other a hole with 5 mm diameter.

For the generation of the probe it is necessary to save the 3D CAD model generated in a solid form with a specific resolution. In (Figure 2) the generation with high resolution is presented. The difference with the others cases is dependent on the resolution that it can be generated in particular areas.

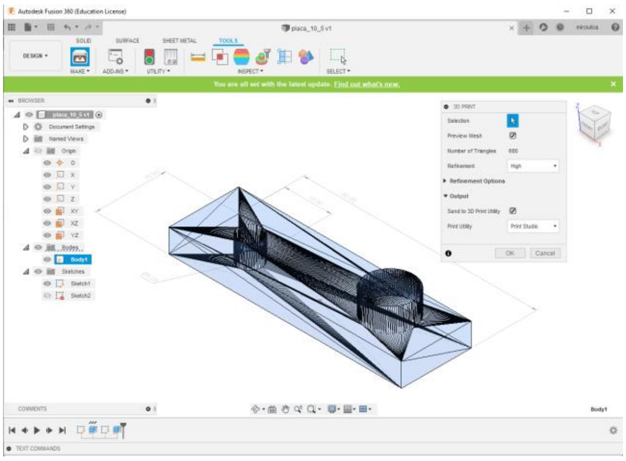

Figure 2. Figure 4. Probe high resolution generation

There is such a major difference that will highlight the realization of the concluding part of the paper in order to identify the optimal generation. In (Table 1) is presented the specific data generation process of the hole and the cylinder.

Table 1. Data for the hole and cylinder of generation part

Refinement	Number Triangles	Circular points		Arc length circle	
		Cylinder	Hole	Cylinder	Hole
High	680	57	40	0,55	0,39
Medium	392	55	38	0,57	0,41
Low	256	49	24	0,64	0,65

By the analysis of the data, it is possible to see that as the diameter increases the number of point's increases for generating results. The point's difference between the parts in the greater precision towards the middle is less than the low precision area. The arc length circle is determined by dividing the perimeter length circle by the number of points. It is possible to see that the arc length decreases as the resolution increase.

The precision of 3D printed generation DLP is 47 microns for Anycubic Photon 3D printer [2]. It is possibility to see that the number of points will be smaller for a linear arc as the resolution increases.

2. PRINTER AND PROGRAM USED TO THE DLP 3D PRINTING PROCESS

2.1 Printer and resin type

For the probe 3D printing there are used a 3D printer type Anycubic Photon [2] (Figure 3).

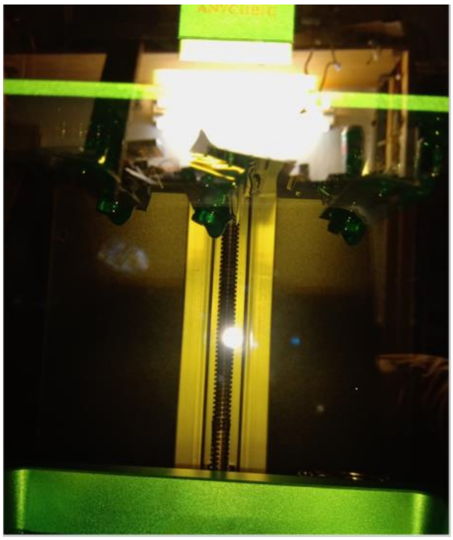

Figure 3. Anycubic Photon 3D printer for generated probe

The important characteristics of the print probe in this printer case, are:

- Print size 115x65x155 millimeter,
- Layer height 25 to 100 microns,
- Display LCD,
- XY DPI 47 microns,
- Y axis resolution 1,25 microns,
- Printing speed suggested 10 to 20 millimeter/hour.

2.2 Resin using for printing

To print the probes is used a specific resin for this type of printer. Its color was transparent green [3]. The characteristics of this resin are:

- Solidify wavelength is 405 nanometers,
- Hardness type D is 79,
- Tensile strength is 23,4 MPa (36 to 52 MPa),
- Elongation is 14,2% (11 to 20%),
- Bottom exposure time 20 to 60 second,
- Normal exposure time 5 to 15 second,
- Solid density 1,05 to 1,25 gram/cm^2,
- Viscosity at 25° is 150 to 200 MPa*s.

2.3 Structure probe of printing and the printing program

It is possible to see that the generation is done vertically from bottom to top. For generation it is necessary a surface adhesion to flat rectangular plate of the printer. They are also required support elements of the probe that will need to secure a tractive force large enough to ensure mechanical strength during generation (Figure 4). It is possible to see that certain programs are proposing CAM (Computer Aided Manufacturing) which have a version of optimum orientation of the probe and an automatically mode of the support arrangement. In the case referred are used for generate CAM solution Print Studio from Autodesk [4] and an Ember 3D printer [5] for generation setting.

The importance of the support elements is double from other points of view in relation to the previous one.

The first related to deformation at the contact surface of supports with the probe. In terms of constructive elements for support of the probe, it is possible to generate it after several types of geometric sections.

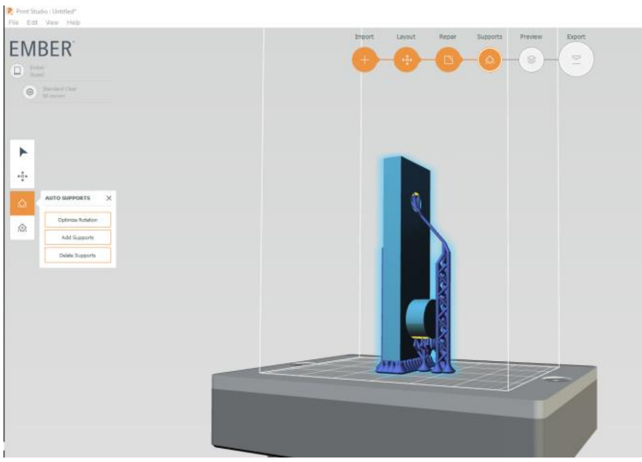

Figure 4. Position and supports for generated probe for Ember printer with Photo Studio program

Support's commonly used is the cylindrical type (Figure 5). It is possible to see from the two picture that in terms of geometric structure it is composed by three parts. The first one consist of a lower plan or cylindrical is usual used as the base. The second one is intermediate by the cylindrical type with smaller size of the base. The last one is the most important because it is in contact with the probe surface, which may be conical or pyramid. An important aspect to note is that using the program provided by the printer in automatic generation is a problem in lateral part of the probe. On the (Figure 5.) on the left part, the support elements are only partially supported by the generated surface. Due to this fact, it is preferred to generate elements manually in which case it can be disposed with vertical orientation on the surface or on the side oriented as shown in the (Figure 5) on the right.

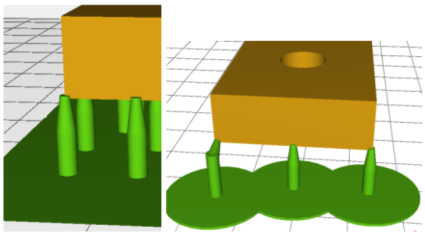

Figure 5. Geometrical structure of constructive elements for generated probe

The second one is determined by its position in order to prevent loss of contact between free zones at the continue generation of the probe. In (Figure 6) the probe is generated which is positioned for generated the slicer screen. The generation values are:

- Volume of resin 14,6 ml,
- Time of printing 1 hour and 29 minutes,
- Layer height 0,05 mm,
- Number of layers for generation 349,
- 8 layers at bottom with 50 seconds for bottom,
- 8 seconds for normal layer expose time.

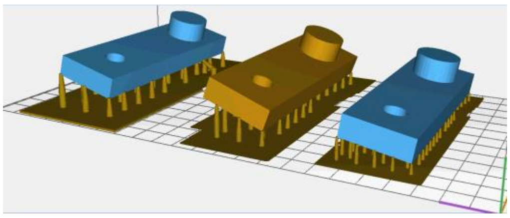

Figure 6. Probe left high resolution 15°, middle medium resolution 20°, right low resolution 20°

It should be note that the modification of the supports type has an effect both on the thickness of the adhesion layer, but also on the arrangement and the section of the supports.

3. CONSIDERATION ON ORDERING THE TECHNOLOGICAL PARAMETER FOR 3D GENERATION BY PRITNING FLAT OR ROUND PARTS

The process of the probe is dependent from technological parameter, which can generate an effect on the printing process.

Firs is the probe orientation, second is the supports type and then is the type of the element of assign the extension or contraction of the part dimension.

For FDM (fuse deposit processing) the similar study was made in [7, 8].

The printing technological value is determinate by the resin solidification and is not so different for the position or orientation of the probe.

3.1 Orientation probe for printing

The influence is determinate by the probe orientation related to the vertical direction of generation. In (Figure 7) the specific elements of the sample to which the supporting elements that was removed, is presented also with the samples made by the arrangement of a specific rectangular element with orientation in the four specific positions.

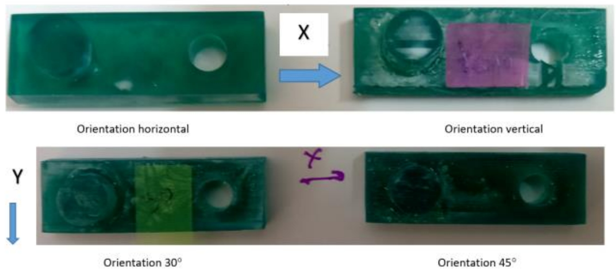

Figure 7. Probe type 1 without supports

In (Figure 8) it can be seen the samples after generating with supports.

Figure 8. Probe type 1 with supports

The positioning of measuring the sample weight it can be observed on the vertical position. The X and Y direction of dimensional measurement are presented in both figures. Table 2 presents the value of mass probe with support and after removed the support elements relative to the total weight of the probe.

Table 2. Data for mass for generation part

Orientation	Mass in grams		
	Printed	Probe	Supports
Horizontal	7,1	5,2	1,9
Vertical	6,1	5,0	1,1
10° orientation T2	6,5	5,5	1,0
20° orientation T2	8,3	5,5	2,8
30° orientation T2	7,6	5,5	2,1
30° orientation T1	6,7	4,8	1,9
45° orientation T1	7,6	4,9	2,7

It is possible to see that the differences between the vertically or the oriented samples are not significant. The horizontal sample thanks in particular to the fact that the surface is not perfectly flat. The concentration caused by the generation 3D printed of reinforced resin unevenly T1 have 45x15x5 mm and T2 have 50x15x5 mm.

In (Figure 9) it is plotted variation of mass support elements relative to the total weight of the item. For plot and regression equation the EXCEL 2013 Educational version was used [6].

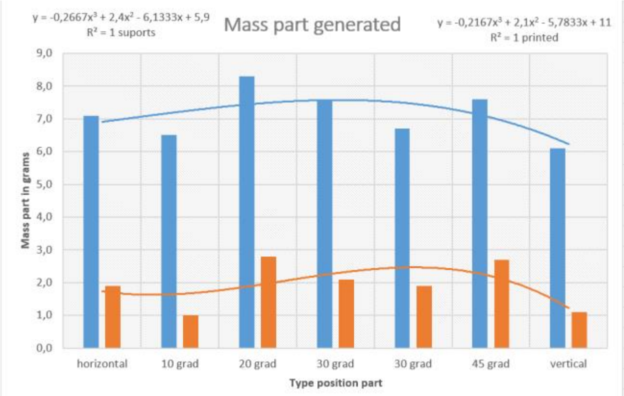

Figure 9. Graphical variation of the printed part mass

From the graphical representation of the mass evolution, it can be seen the similarity between the two regression equations. One can say that the positioning of the sample has an influence on the extra material consumption. We will be able to determine based on its cost for a particular marker orientation achieved.

3.2 Support's for probe for printing

It is possible to see this aspect in (Figure 9) but also in (Table 2). Ona 30 degrees-oriented probe with medium and hard support it is a difference of 0.7 grams on the 3D print support side. It is also apparent that for an environmental support an increase of a supporting material related to the versions that support easy or hard 10 degrees 30 degrees.

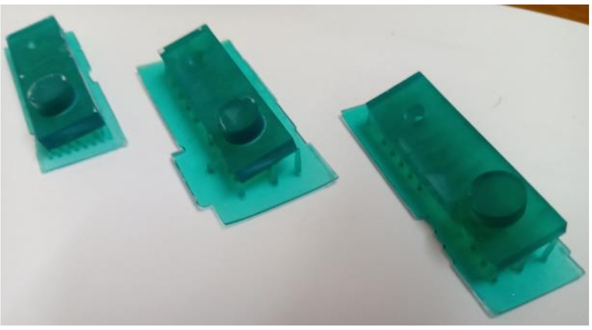

Figure 10. Probe type 2 with supports

Minimum value of supports is 1,0 grams for 10 degree and maximum value is 2,8 grams for 20 degree. Median and average value are 1,9 grams for horizontal and 30-degree position.

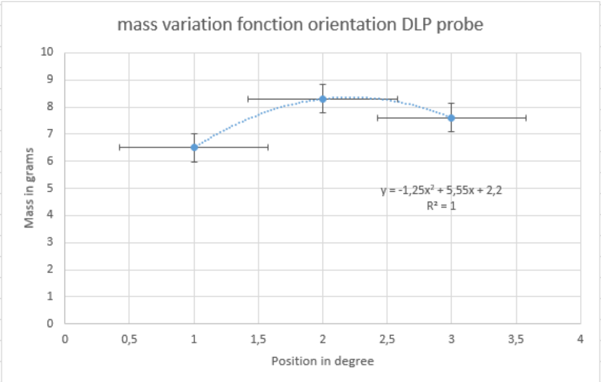

Figure 11. Graphic variation of mass with orientation probe T2

It is possible to see from the graphical representation (Figure 11) that the mass has an increase on the middle of the printed part with supports. The regression equation R=1 has a good value and the equation is polynomial two degree.

3.3 Geometry precision generation circular part

If the generation of the cylindrical parts is possible to see that for the print DLP generation of a circle the resolution of version, generating with low-resolution is in relation with the printing process. In (Figure 12) it is possible to see the circle line generated on the top of the cylinder periphery.

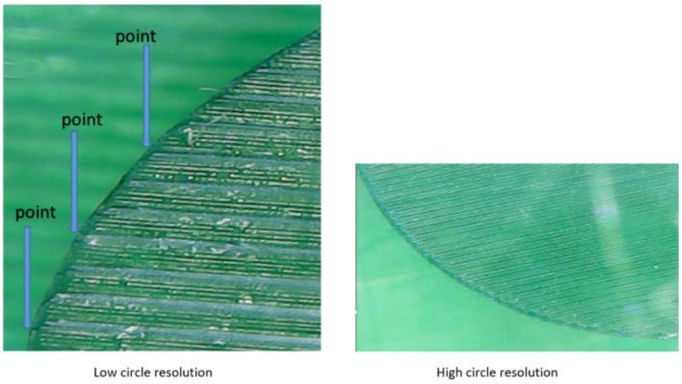

Figure 12. Probe high resolution generation

In the high-resolution case the generated point is nearly right position for the low-resolution of the left position. In this situation the point distance is relatively large.

From the (Figure 12.) it can be seen that the geometry of the completed cylindrical part is accorded with the assumptions envisaged on the part of the solid model performing.

3.4 Dimensional precision generation circular part

If the generation of the cylindrical parts is possible to see that for the print DLP, generation of a cylinder the dimension printed is dependent of the printed probe orientation (Table 3).

From (Figure 13) it is possible to observe that the maximum deviation difference of the cylindrical form results by the vertical generation position of the cylindrical body.

Table 3. Data for cylinder generated part

Position	Design	Length			
		X	Y	Dev X	Dev Y
horizontal	10	10,74	10,73	0,74	0,73
10 deg	10	10,60	10,54	0,60	0,54
20 deg	10	10,57	10,49	0,57	0,49
30 deg	10	10,62	10,48	0,62	0,48
30 deg	10	10,73	10,62	0,73	0,62
45 deg	10	10,85	10,56	0,85	0,56
vertical	10	10,95	10,28	0,95	0,28

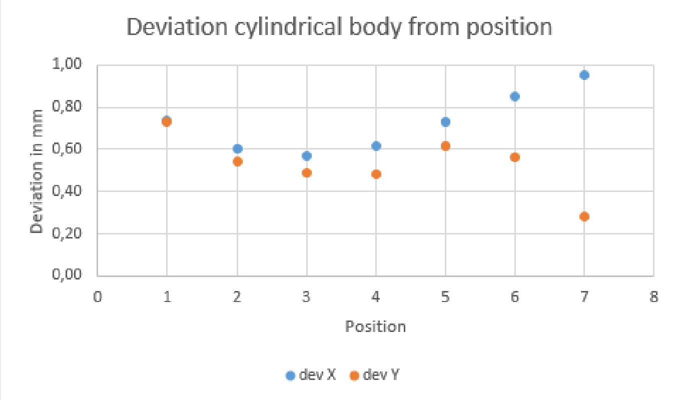

Figure 13. Graphic deviation for cylindrical body

If the generation of the orifice parts can be seen by the DLP print, the dimension printed of a generation hole is dependent on the printed probe orientation (Table 4).

Table 4. Data for hole generated part

Position	Design	Length			
		X	Y	Dev X	Dev Y
horizontal	7,5	6,99	7,03	-0,51	-0,47
10 deg	5	4,93	4,87	-0,07	-0,13
20 deg	5	4,96	5,02	-0,04	0,02
30 deg	5	4,94	4,91	-0,06	-0,09
30 deg	7,5	7,05	6,84	-0,45	-0,66
45 deg	7,5	7,05	6,66	-0,45	-0,84
vertical	7,5	7,15	6,12	-0,35	-1,38

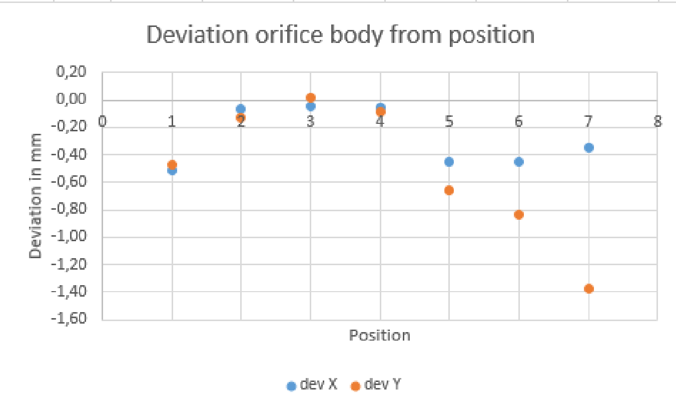

Figure 14. Graphic deviation for cylindrical body

By the (Figure 14) it can be seen that the maximum deviation difference of the orifice form results in the vertical generation position of orifice body.

In the cylindrical part case, it is a positive deviation by the printed dimension in opposition with the geometric dimension. For orifice part, it is a negative deviation. Both are due to the reflection phenomena or refraction during the generation of the resin occurring with the luminous beam.

3.5 Dimensional precision generation flat part

To the flat parts generation, it can be mentioned that the print DLP generation of a length (Table 5.) has the maximum deviation in the horizontal position and minimum for 30 degrees.

Table 5. Data for length for generation part

		Length		
Position	Type	Design	Printed	Deviation
horizontal	1	45	47,58	2,58
10 deg	2	50	52,55	2,55
20 deg	2	50	52,50	2,50
30 deg	2	50	52,48	2,48
30 deg	1	45	47,38	2,38
45 deg	1	45	47,46	2,46
vertical	1	45	47,57	2,57

In (Figure 15) it is plotted the variation of length dimension of the probe. From the graphical representation of the length evolution, it can be seen the dimension variation of different probe position and the regression equations of mass probe generation.

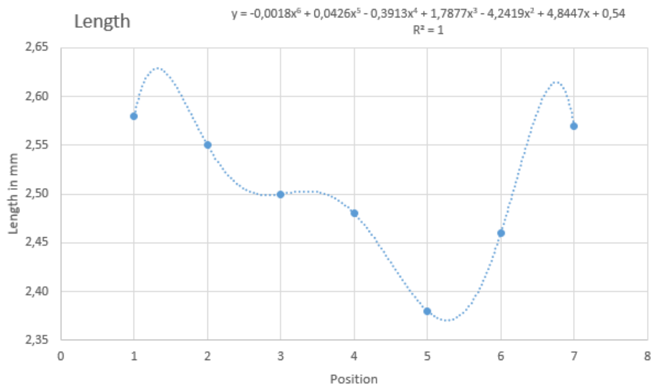

Figure 15. Graphic variation of length printed part

From the graphical representation of the mass evolution, it can be seen the similarity between the two regression equations. One can say about a result that the sample positioning has an influence on the extra consumption of material. One can be able it, to determine based on its cost for a particular marker orientation achieved.

In (Table 6) it is possible to see the deviation value for the three linear generated part for a body planar probe.

If a comparison between the three linear dimensions of the geometric probe printed were made, it is possible to observe (Figure 14.) that for the length, the deviation is the same on all position. About the width, the deviation is big on horizontal position and smaller on vertical one.

Table 6. Data for linear three part for generation part

Position	Length	Width	Height
horizontal	2,58	1,10	0,31
10 deg	2,55	0,84	0,33
20 deg	2,50	0,83	0,34
30 deg T1	2,48	0,80	0,30
30 deg T2	2,38	0,70	0,19
45 deg	2,46	0,60	0,50
vertical	2,57	0,23	0,50

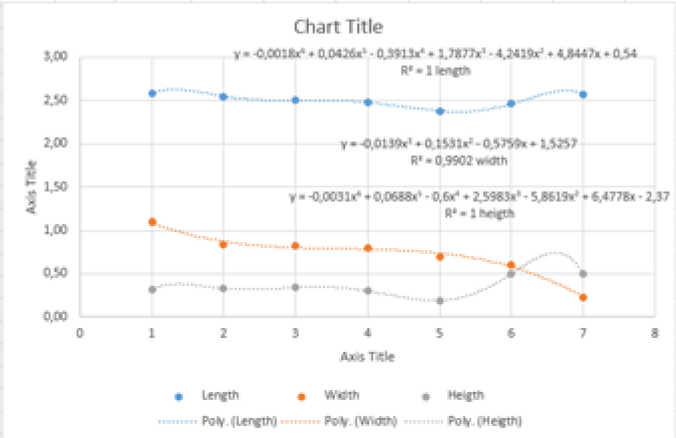

Figure 16. Graphic of linear elements of a probe

For height, the deviation is not very different for all position.

4. CONSIDERATION OF DOMAIN TO USED 3D PRINTED FLAT OR ROUND PART MADE

With DLP 3D printing, parts whose size is near to the XY size of the print table. That is for small inclination angles for the 3D printed probe for XY size table.

It follows by those analyzed that the milestones of any rectangular or circular form for 3D printing. For these will take in consideration to achieve the dimensional probe negative corrections for exterior surfaces and positive for the interior surfaces [9, 10].

5. CONCLUSION

By this study, one can see that the print accuracy is much higher than the precision of digital solid output. This it either is possible to say that or change by increasing the optical pixel diameter, or by changing how images are generate for printing process.

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

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