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EXPLORING DIMENSIONAL PRECISION OF PARAMETRICALLY DESIGNED COMPONENTS USING Z-ULTRAT MATERIAL

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Abstract. In this work, we investigated the dimensional accuracy of parametrized parts in the Catia V5 software. We adopted an experimental plan, applying the Taguchi methodology to evaluate the influence of process variables on dimensional accuracy. Process parameters such as layer thickness, infill percentage, and wall thickness were varied within the experiments, and the obtained results provided essential information regarding the influence of these parameters on the precision of parts obtained through additive manufacturing technology.

Keywords: Flatness deviation, FDM 3D printing, Parametrizing

INTRODUCTION

In the automotive industry, but not limited to it, the dimensional precision of component parts is a critical feature in the production process, with a significant impact on the quality and performance of the final products. 3D printing has emerged as a revolutionary paradigm in component manufacturing, opening new horizons for innovation and efficiency. In this context, dimensional accuracy stands out as a critical factor, and the utilization of Catia V5 software and the concept of parametrization adds a significant dimension to the design and production process [1], [2], [3].

Parametrization in Catia V5 is a technological approach involving the definition and utilization of parameters to control the geometric features and dimensions of a component. Essentially, parametrization allows for the definition of variables, such as length, width, or height, in a flexible manner, providing the capability to easily adjust these values based on project requirements.

The primary purpose of parametrization in Catia V5 is to provide increased flexibility in the design process. By establishing parameters, designers can quickly and precisely adjust component dimensions, facilitating their adaptation to changing project or production requirements. This approach offers more detailed control over the shape and dimensions of components, optimizing project efficiency and accuracy.

In the context of 3D printing, parametrization in Catia V5 brings significant benefits. By adjusting parameters, dimensional accuracy of parts intended for 3D printing can be optimized, ensuring they precisely meet the desired specifications [4], [5]. Moreover, parametrization facilitates the integration of rapid adaptability into part design, allowing them to successfully fit various applications and contexts [6], [7], [8].

In the development and design process, selecting the appropriate material for functional prototypes is a critical decision that significantly influences the outcomes of the final product. From this standpoint, Z-ULTRAT stands out as a popular and strategic choice for functional prototypes. There are several compelling reasons that support the preference for Z-ULTRAT over other plastic materials.

Firstly, Z-ULTRAT offers superior durability and resilience, ensuring that prototypes can withstand rigorous testing and functional evaluation. Additionally, Z-ULTRAT boasts excellent 3D printing properties, facilitating smooth and precise printing processes. Moreover, Z-ULTRAT is a cost-effective option due to its competitive pricing and widespread availability, making it economically viable for projects requiring the development of functional prototypes. Furthermore, Z-ULTRAT provides a diverse range of colors and finishing options, allowing for enhanced customization and aesthetic appeal in prototype development.

MATERIAL, SAMPLES AND MEASURING EQUIPMENT

Z-ULTRAT is a notable thermoplastic material, particularly chosen for additive manufacturing applications. Known for its high impact resistance, Z-ULTRAT enables the production of parts with remarkable durability and a uniform surface texture. This material stands out for its ability to create parts with mechanical and technological properties comparable to those obtained through traditional processes, such as injection process.

For this study we used ZORTRAX M200 Plus 3D printer to create samples with a slim shape (Figure 1). Various design parameters were varied to create the samples: constructive (wall thickness) and technological (layer thickness and infill density) (Table 1).

Nine structures with different values of printing parameters were produced, whose nominal dimensions L, H, and W are identical.

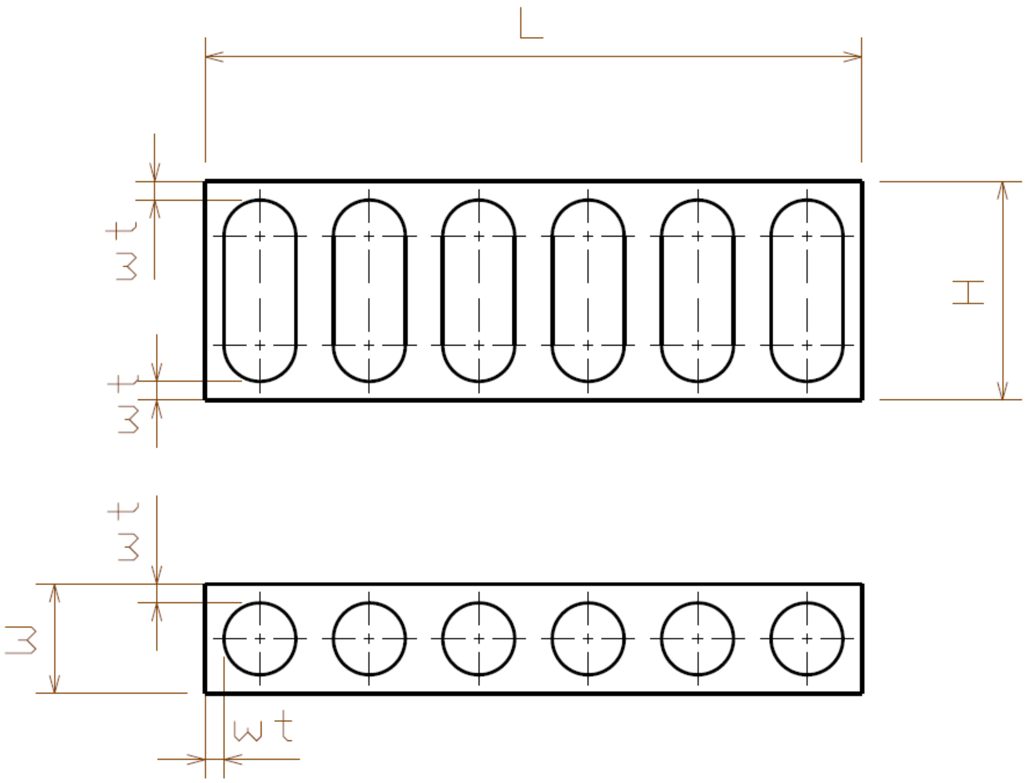

Figure 1. Geometry of the specimen

Minitab 19 software was utilized to generate a Taguchi plan of experiments. Specifically, a 3x3 Taguchi plan was selected for this experiment, comprising three factors and three levels.

Table 1. The values of the input parameters

	Wall thickness	Layer thickness	Infill density
S1	1,5	0,19	50
S2	2,5	0,29	10
S3	2,5	0,19	90
S4	2,0	0,14	90
S5	2,0	0,29	50
S6	2,5	0,14	50
S7	1,5	0,14	10
S8	1,5	0,29	90
S9	2,0	0,19	10

PARAMETRIZING

Catia V5 R19 software was used to realize the 3D model of the specimens, figure 2. Parametrizing a part in CATIA V5 involves initially defining the fundamental geometry, followed by implementing parameters to control dimensions and respective attributes. This stage involves assigning variable dimensions and mathematical relationships, thus facilitating subsequent adjustments to the model. Through the use of parameter tables and formulations in CATIA V5, quick adjustment of dimensions is enabled, ensuring maximum flexibility in the design process. This parametric approach optimizes the workflow, reducing the time required for modifications and providing increased adaptability based on specific project requirements. Ultimately, parametrizing in CATIA V5 significantly contributes to the efficiency of the design process and enhances the quality of the final products.

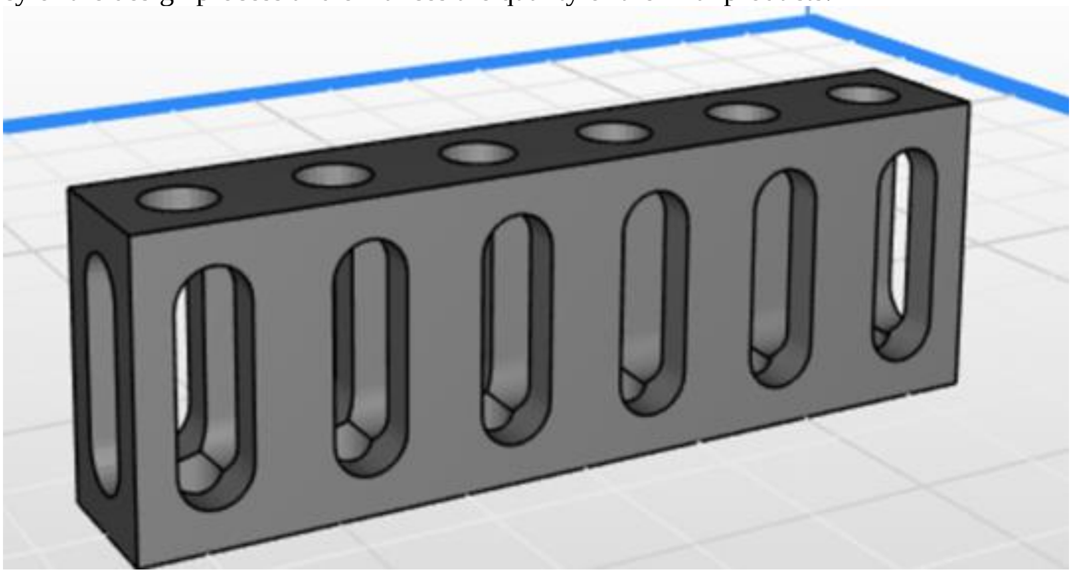

Figure 2. The specimen imported in Z-Suite software

To define the parameters of the analyzed part, we will access the Knowledgeware/Knowledgeware Advisor workshop from the Start toolbar in the Catia software. The three parameters of the part will be entered: wall thickness, number of bores, and length of the part, as shown in figure 3.

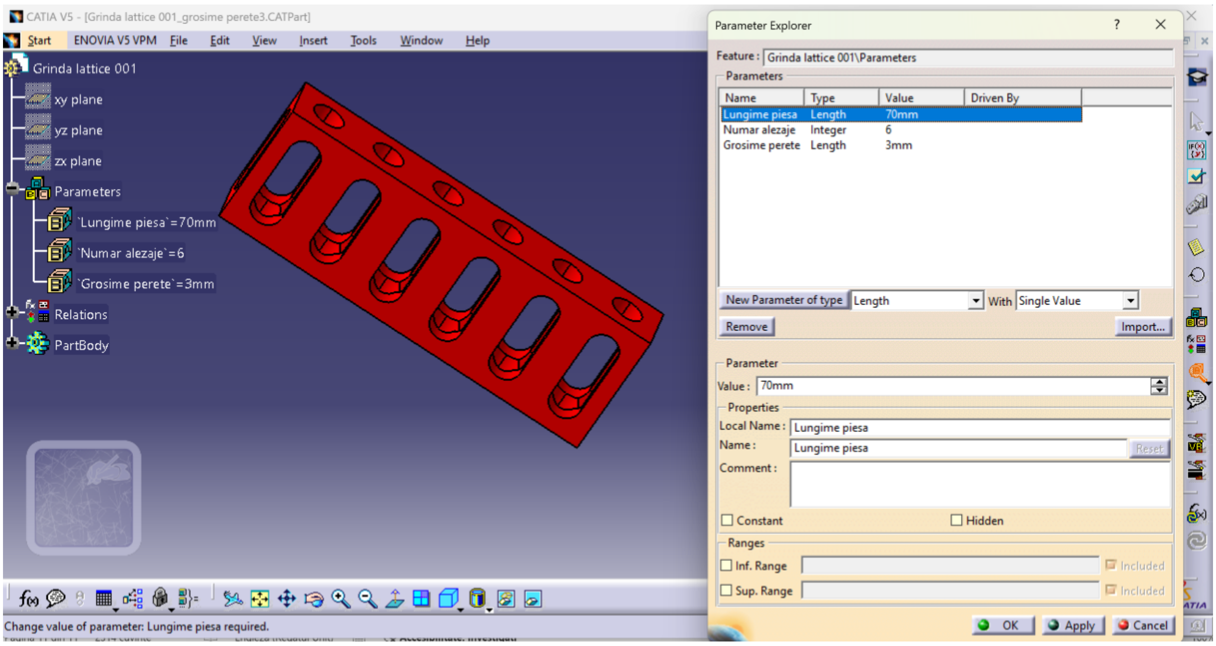

Figure 3. The specimen imported in Knowledgeware Advisor

Continuing, we will develop scientific formulas based on the previously defined parameters, so that the entire part is parametrized. For instance, the width of the part will be correlated through a mathematical formula with the length parameter, ensuring that any modification to the length of the part automatically generates a corresponding change in width.

Another example of parameterization usage involves generating the number of bores using the formula presented in the figure 4.

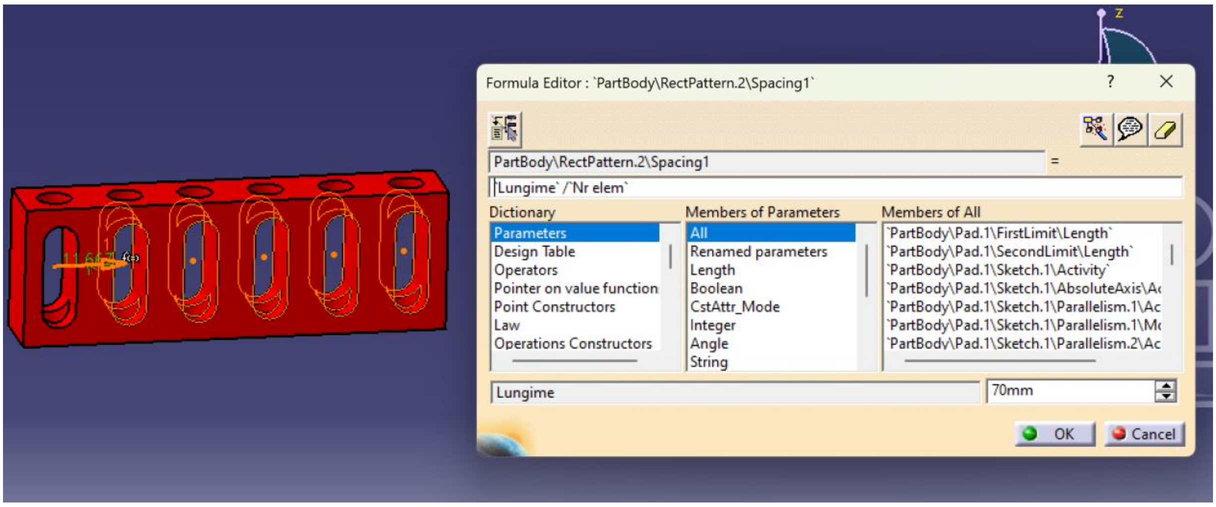

Figure 4. Knowledgeware Advisor – formula editor

In order to realize a dimensional and shape qualitative analysis of the specimens produced following the variation of the constructive and technological parameters presented earlier, fourteen points were measured on each sample, as illustrated in Figure 5, observing both the deviation from the nominal dimension L, as well as the degree of deformation of the upper plane of the part.

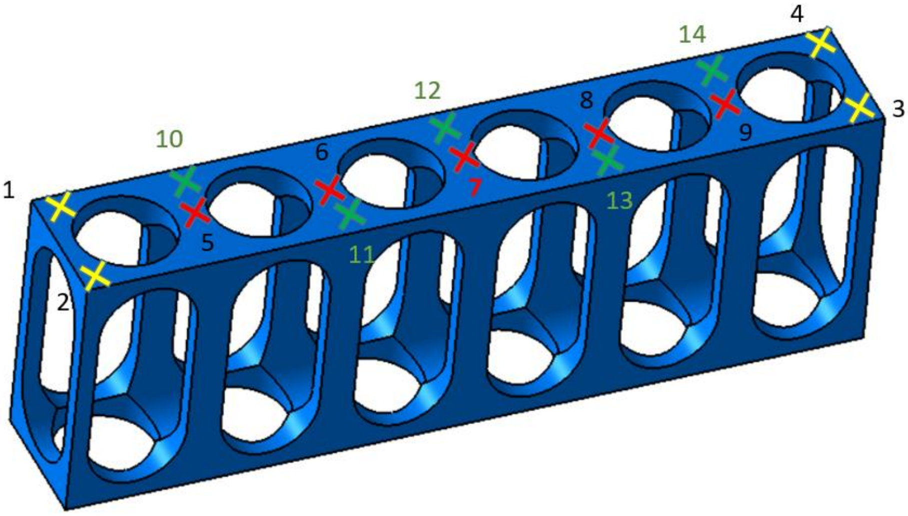

Figure 5. The measuring schemes

We employed a dial comparator stand with an accuracy of 0.01 mm to measure the dimensions on the samples.

a

b

Figure 6. The measuring stands (a - measuring in a point different of P7; b –measuring in point P7)

For each sample, point P7 was designated as the reference, with the dial comparator value set at 0.00mm. Subsequently, all other points were measured relative to point P7, as detailed in Table 2.

Table 2. The measured values in each point

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14
S1	-0,03	-0,04	-0,02	0,01	-0,01	0,01	0,00	0,01	-0,02	0,02	0,03	0,01	0,01	0,03
S2	0,02	-0,02	-0,03	0,01	0,01	-0,01	0,00	0,00	0,00	0,01	-0,03	-0,02	0,00	-0,02
S3	-0,02	-0,05	-0,02	-0,01	0,00	0,00	0,00	0,03	0,00	0,04	-0,03	0,02	0,01	0,00
S4	-0,01	-0,03	-0,03	-0,02	0,00	0,00	0,00	0,00	-0,01	0,00	-0,01	0,00	-0,01	-0,01
S5	0,05	0,04	0,02	0,03	0,04	0,01	0,00	0,00	0,01	0,00	0,00	0,00	0,01	0,00
S6	-0,03	-0,03	-0,04	-0,05	0,00	0,00	0,00	0,02	0,00	-0,01	-0,01	0,00	0,01	0,00
S7	-0,03	-0,04	-0,07	-0,08	-0,03	0,00	0,00	-0,04	-0,04	-0,02	-0,01	-0,01	-0,04	-0,03
S8	-0,03	-0,05	-0,03	-0,04	-0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	-0,02	-0,01
S9	-0,04	-0,05	-0,05	-0,05	0,00	0,00	0,00	-0,01	-0,01	-0,01	0,00	-0,02	-0,02	-0,02

For each sample, the flatness deviation was calculated with the formula (1) and the results is showed in table 3:

$$Flatness_{deviation} = \frac{\max(h) - \min(h)}{L} \qquad (1)$$

Where:
max(h)- the maximum height measured from the reference plane;
min(h)- the minimum height measured from the reference plane;
L- the total length of the sample.

Table 3. The values for the flatness deviation

	Max	Min	L [mm]	Flatness deviation [mm]
S1	0,030	-0,040	70	0,0010
S2	0,020	-0,030	70	0,0007
S3	0,040	-0,050	70	0,0013
S4	0,004	-0,030	70	0,0038
S5	0,050	0,000	70	0,0007
S6	0,020	-0,050	70	0,0010
S7	0,000	-0,080	70	0,0011
S8	0,000	-0,050	70	0,0007
S9	0,000	-0,050	70	0,0007

FINDINGS

The experimental design utilized to establish a correlation between the "flatness deviation" and the design parameters is presented in Table4.

Table 4. The values for parameters of the experimental plan

	Wall thickness	Layer thickness	Infill density	Flatness deviation
S1	1,5	0,19	50	0,0010
S2	2,5	0,29	10	0,0007
S3	2,5	0,19	90	0,0013
S4	2,0	0,14	90	0,0038
S5	2,0	0,29	50	0,0007
S6	2,5	0,14	50	0,0010
S7	1,5	0,14	10	0,0011
S8	1,5	0,29	90	0,0007
S9	2,0	0,19	10	0,0007

With the Minitab software, a regression analysis was realized: Flatness deviation versus Wall thickness, Layer thickness and Infill density of the specimen, figure 7.

Regression Equation

Flatness deviation = 0,02402 - 0,00833 Wall thickness - 0,0158 Layer thickness - 0,000001 Infill density

Coefficients

Term	Coef	SE Coef	T-Value	P-Value	VIF
Constant	0,02402	0,00506	4,75	0,005	
Wall thickness	-0,00833	0,00200	-4,16	0,009	1,00
Layer thickness	-0,0158	0,0131	-1,21	0,282	1,00
Infill density	-0,000001	0,000025	-0,05	0,962	1,00

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0,0024522	78,97%	66,36%	30,46%

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Regression	3	0,000113	0,000038	6,26	0,038
Wall thickness	1	0,000104	0,000104	17,32	0,009
Layer thickness	1	0,000009	0,000009	1,45	0,282
Infill density	1	0,000000	0,000000	0,00	0,962
Error	5	0,000030	0,000006		
Total	8	0,000143			

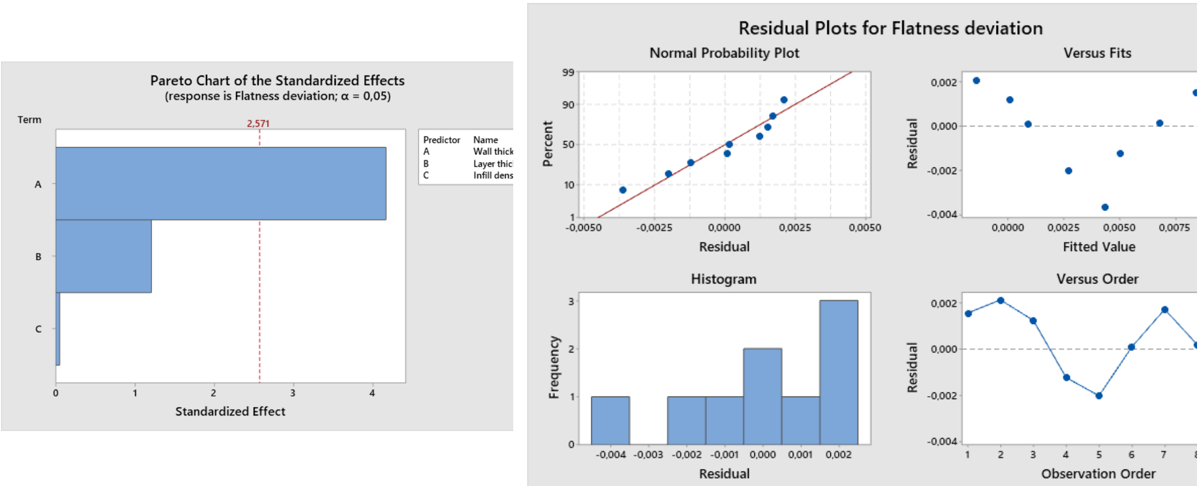

Figure 7. Regression rapport made by Minitab software.

Examining Figure 7, we can discern from the Pareto chart that the parameter of "Wall thickness" exerts a notable impact on the flatness deviation. Moreover, the histogram illustrates a distribution closely resembling a normal distribution.

CONCLUSIONS

Using Minitab software, a regression equation was derived to correlate flatness deviation with printing parameters such as wall thickness, layer thickness, and infill density. The findings presented in this study offer valuable scientific insights into enhancing the quality of Additive Manufacturing parts.

The deviation in flatness of the top surface of parts produced through Additive Manufacturing is significantly influenced by the wall thickness, with a lesser impact from the layer thickness and infill density of the specimen.

Future actions aim to conduct a series of tests on multiple samples to achieve a more comprehensive understanding of dimensional variations. This approach will enable designers to glean crucial insights into the effects of both technological and design parameters on the dimensional accuracy of Additive Manufacturing parts.

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