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The Effect of Rectangular Parallel Key Manufacturing Process Parameters Made with Stereolithography DLP 3D Printer Technology Against Impact Strength

D Seprianto[1], R Sugiantoro[1], Sipironi[1], Yahya[1] and M Erwin[2]

[1] Mechanical Engineering Department, State Polytechnic of Sriwijaya, Indonesia
[2] State Polytechnic of Sriwijaya, Indonesia

E-mail: dickyseprianto@gmail.com

Abstract. This study aims to determine the effect of the thickness of the Layer and Exposure Time on the strength, impact toughness applied to the prototype of the reduction gear post, test specimens made using SLA DLP 3D Printer with 3D UV Resin Anycubic material and referring to ASTM D-256. In this research, creating objects using SLA DLP 3D Printer uses CAD data which is then converted into G-Code with Creation Workshop software. Factors investigated were layer thickness, exposure time with response impact strength using Charpy method of test specimens. The test result data were analyzed using ANOVA with type 2 factorial level design, 2 factorial interaction design (2FI), and replication 3 modelled by Design-Expert software. The results of the analysis revealed that the main factor that had the most influence on the impact strength of the test specimens was the layer Thickness factor with a percentage contribution of 52%, while the interaction between Layer Thickness and Exposure Time contributed 6%. Based on impact testing with a layer thickness parameter of 0.05 millimetres and an Exposure Time of 15 seconds, the optimal results are an average impact price of the Charpy method 0.005600 Joule/mm².

1. Introduction

Technological developments at this time have experienced very rapid progress, one of which is 3D printing technology or also known as additive manufacturing. 3D printing technology is the process of making solid objects from a digital file. This three-dimensional object printing process is known as additive manufacturing. This technology is applied in various fields of engineering and industry such as airplanes, bioengineering, medical devices, medical implants, and automotive products. There are many additive manufacturing systems available on the market such as stereolithography (SLA), fused deposition modeling (FDM), direct metal deposition (DMD), selective laser sintering (SLS), inkjet modeling (IJM) and stereo-lithography (SLA). [1]

The development of Digital Light Processing (DLP) 3D printer technology has made DLP a more widely used method today. Moreover, the DLP method is considered an interesting technology because it is able to print objects with a fairly fast time because the printing method is done per layer. However, the lack of standardization in the world of 3D printing and this knowledge makes research on the optimization of the process of the 3D printing machine very important.

The success of a 3-dimensional printing process is very dependent on the selection of appropriate and appropriate parameters. Determination of optimal process parameters is a very challenging job

Journal of Physics: Conference Series **1500** (2020) 012028 doi:10.1088/1742-6596/1500/1/012028

because differences in the specifications of one printing with another will certainly affect the optimal combination of parameters. Some previous studies have indeed carried out the optimization of some process parameters in the slicer software in order to get the best print results. However, each machine also has different optimum settings so that an optimal parameter in a machine may not be compatible with other machines. Of these problems, there arises the need for research to find the parameter settings in the 3D printer to produce objects with maximum quality [2].

2. Methodology

The materials and methods used in this study are as follows:

- 3D UV Resin: This resin is a liquid (resin monomer and photoinitiator) that is used to make impact testing specimens with dimensions of 50mm x 10mm x 10mm, ASTM D 256 which is assisted by a digital printer (DLP) Digital Light Processing (DLP) printing device through a projector [3].
- Stereolithography (SLA): DLP 3D Printer acts as a print specimen for impact testing by radiation from DLP projectors with a dimension of 380mm x 280mm x 1000mm.

Figure 1. 3D UV resin

Figure 2. SLA DLP 3D Printer

- Process parameters: Process parameters are one of the process variables that can affect the quality of a printed product. In this study, the focus is on Layer Thickness and Exposure Time [4]. Table 1 shows the varying layer thickness used for the study.

Table 1. Layer thickness level

Parameter	Level
Layer Thickness (Z-axis)	0,025 mm 0,05 mm

The second process parameter is the exposure time, the exposure time is the duration at which the resin is exposed under the light source for each layer. Table 2 shows the varied Exposure Time used for research.

Table 2. Exposure time level

Parameter	Level
Exposure Time	10 second 15 second

- Experimental description: Specimens are material for testing, using 3D CAD software and then converted to stereolithography (STL) format. The STL file is then continued to the slicing process by the software used by the SLA DLP 3D printer and can set process parameters such as table 1 and table 2. The geometry dimensions for specimen printing based on ASTM D 256 are conditioned for impact testing.

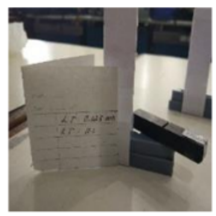
- Impact Testing and Experimental Settings: The impact test is a shock load test on something that we will examine. Impact test specimens were prepared using the above method used for testing the Charpy method [5]. The basic formula for calculating the value of the resilience value that will be used for testing this impact is:

$$\mathbf{HI} = \frac{\mathbf{Esrp}}{\mathbf{A}} \tag{1}$$

Where:
HI : *Impact* Value (*Joule*/mm^2)
Esrp : Energy absorbed (*Joule*)
A : The cross-sectional area below the notch (mm^2)

Two independent process parameter variables to be examined are shown in table 1 and table 2. Statistical analysis of the data is carried out using expert design software, analysis of variance (ANOVA) provides a study of the variations that exist in the results of experiments conducted and tests of statistical significance, *P* value, is determined according to the total error criteria by considering a 95% confidence level. The influence of a factor will be significant if the critical level value (*P*) is lower than 0.05, discarding meaningless parameters for values *P* more than 0.05 [6].

Figure 3. Impact testing machine



a) Before

b) After

Figure 4. Specimens before and after impact test

3. Results and discussion

Toughness value of the specimens was measured in a mechanical laboratory using an Impact testing machine based on ASTM D 256 standards, each specimen was tested 3 times, the same conditions and randomly. The results can be seen in table 4.

3.1 Impact Testing and Experimental Settings

The effect of layer thickness and exposure time on the value of toughness is tabulated in Table 3.
Where:
LT = layer thickness
ET = exposure time

Table 3. Toughness test result

	Width	Thickness	Notch	Energy		Broken Cross-sectional area	Impact value
Specimens	mm	mm	mm	Kg.Cm	N·m (joule)	mm²	Joule/mm²
LT: 0.025 mm ET: 10 s	10	10	2	0.9	0,08829	80	0,001104
LT: 0.025 mm ET: 10 s	10	10	2	0,8	0,07848	80	0,000981
LT: 0.025 mm ET: 10 s	10	10	2	1,1	0,10791	80	0,001349
LT: 0.025 mm ET: 15 s	10	10	2	3,3	0,32373	80	0,004047
LT: 0.025 mm ET: 15 s	10	10	2	3,5	0,34335	80	0,004292
LT: 0.025 mm ET: 15 s	10	10	2	3,2	0,31392	80	0,003924
LT: 0.05 mm ET: 10 s	10	10	2	3,5	0,34335	80	0,004292
LT: 0.05 mm ET: 10 s	10	10	2	3,7	0,36297	80	0,004537
LT: 0.05 mm ET: 10 s	10	10	2	3,6	0,35316	80	0,004415
LT: 0.05 mm ET: 15 s	10	10	2	4,5	0,44145	80	0,005518
LT: 0.05 mm ET: 15 s	10	10	2	4,8	0,47088	80	0,005886
LT: 0.05 mm ET: 15 s	10	10	2	4,4	0,43164	80	0,005396

From table 3 is the result of 12 times the impact testing using the Charpy method and it can be concluded that the value of the right toughness value is the processing thickness of the 0.05 mm layer thickness and the exposure time of 15 s .

3.2 Analysis of variance (ANOVA)

To identify the effect of Layer Thickness and Exposure Time for impact test specimens, the analysis results were analyzed using analysis of variance (ANOVA). This analysis is a calculation technique that allows estimating the contribution of each factor quantitatively to all measurements of the response results by identifying hypothesis testing about the influence of the controlled factors and their interactions. Hypothesis (H_0) was tested that there was no influence of factors on the value of the specimen's test strength. Results from ANOVA using software design experts are shown in table 5. Model F-values of 286.18 indicates this model is significant. There is only a 0.01% chance that an F-value of this magnitude can occur due to noise. A value of "Prob> F" less than 0.0500 indicates a significant model term.

Layer thickness factor:
(B) = (0,01715-0,0003005) / 0,03255 = 52%

Exposure time factor:
(C) = (0,01278-0,0003005) / 0,03255 = 38%

Interaction Factor between layer thickness and exposure time:
(AC) = (0.01278-0,0003005) / 0,03255 = 6%.

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Table 4. Summary design

Factor	*Name*	*Units*	*Type*	*Subtype*	*Min*	*Max*	*Coded*	*Values*	*Mean*	*Std. Dev.*
A	Layer Thickness	mm	Numeric	Continuous	0,025	0,05	-1,000=0,025	1,000=0,05	0,0375	0,0130558
B	Exposure Time	s	Numeric	Continuous	10	15	-1,000=10	1,000=15	12.5	2,61116

Response	*Name*	*Units*	*Obs*	*Analysis*	*Min*	*Max*	*Mean*	*Std. Dev.*	*Ratio*	*Trans*	*Model*
R1	Impact Test	Joule/mm^2	12	Factorial	0,000981	0,005886	0,00381175	0,00172028	6	None	2FI

Table 5. Constant 3D-Printing process settings

Source	*Sum Of Squares*	*df*	*Mean Square*	*F Value*	*p-value Prob>F*	
Model	3,225E-005	3	1,075E-005	286,18	<0,0001	*Significant*
A-*Layer Thickness*	1,715E-005	1	1,715E-005	456,60	<0,0001	
B-*Exposure Time*	1,278E-005	1	1,278E-005	340,26	<0,0001	
AB	2,317E-006	1	2,317E-006	61,68	<0,0001	
Pure Error	3,005E-007	8	3,757E-008			
Cor Total	3,255E-005	11				

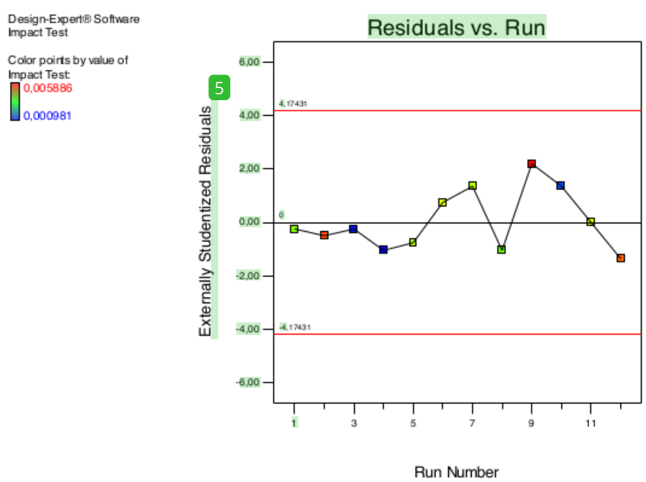

Figure 5. Independent residual graph of impact value

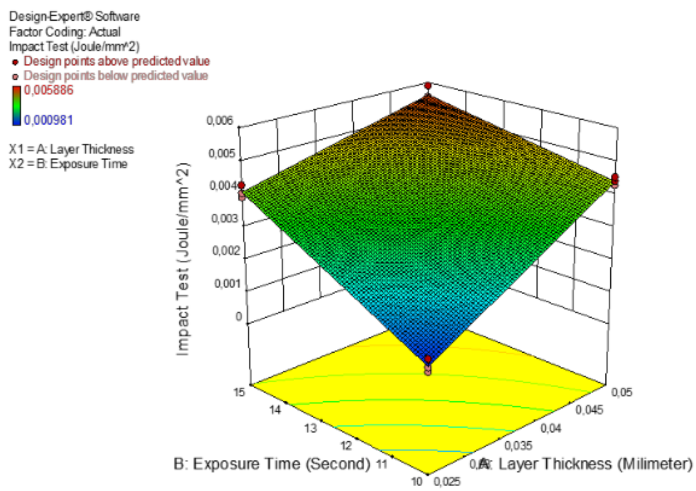

Figure 6. 3D graphics effect of factors on impact test values

4. Conclusion
Based on the results of testing and data analysis, conclusions can be drawn, as follows:
1. It is known that the optimal parameters and the influence of factors on the impact strength of the Charpy method of test specimens were made using additive manufacturing methods.
2. Based on the Impact testing Charpy method, the results of the thickness layer and exposure time parameters are 0.05 millimetres and 15 seconds
4. From the test, the layer thickness is 0.05 millimetres and Exposure Time 15 second, the optimal result is the average value of the impact value using the Charpy method is 0.005600 Joule / mm².
5. From the analysis results obtained that affect the level of strength and toughness is the layer thickness testing

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Acknowledgments

The authors acknowledge funding support from the Directorate of Research and Community Service of the Ministry of Research, Technology and Higher Education of the Republic of Indonesia through a Research grant (Institution: State Polytechnic of Sriwijaya) by contract number: 5512/PL6.2.1/LT/2019. The authors also regard thanks to all civitas academic State Polytechnic of Sriwijaya for motivation and help.

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