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The Effect of Parameter Process 3D Printer Technology Digital Light Processing to Geometric of Shaft

A Zamheri^{1,2} D Seprianto³ Carlos RS² Indri A³ TC Persada¹

¹ Mechanical Engineering Department, State Polytechnic of Sostren, Indonesia
² Electrical Engineering Department, State Polytechnic of Sostren, Indonesia
³ Informatics Management Department, State Polytechnic of Sostren, Indonesia
Corresponding author: Email: dzamheri@gmail.com

ABSTRACT
The development of Industrial technology 4.0 was characterized by cyber-physical systems. This era make it easier for humans to connect with other humans, with industrial machines, and with the environment around them. With the industrial revolution 4.0 can be significantly increase the productivity. At this time, the single part products are often needed, where the product is used only a little and without needed for mass production or be known a custom design. The products that are custom design can be made by a 3D Printer (3DP) machine. 3D Printing is one of the newest technologies in the printing world, where the 3D printing technology is an easy to print and easy to develop the solid product with 3DP technology. In this study, the printing objects of 3DP using CAD data and then converted into G-Code using Creation Workshop software version 1.0.0.73. This study aims to determine the effect of layer thickness and exposure time to geometric of shaft made by 3D Printer with technology Digital Light Processing (DLP). The specimens used is 100 x 100 mm with material Liquid Photopolymer Resin. The data from the test results analyzed using ANOVA with a 5-level design type and 2 factorial interactions (2FI) with 5 replications modeled by the Design-Expert® 10 trial version software. The results of the 3-point method analysis show that the main factor of most influences on the cylindricity of the test specimens is the layer thickness factor, and the optimum combination of parameters in this study is layer thickness 0.175 mm and exposure time 15 seconds.

Keywords: 3DP-DLP, ANOVA, Layer Thickness, Exposure Time, Cylindricity

1. INTRODUCTION

The technological developments enter the Industrial 4.0 era is marked by cyber-physical systems. This era makes it easier for humans to connect with other humans, with industrial machines, and with the environment around them. Of course, the industrial revolution 4.0 can significantly increase the productivity. At this time, single part products are often needed where only one or more products are used without need the mass production or known custom design [1]. Custom design products can be made using a 3D Printer (3DP) machine. 3D Printing technology has process for making solid objects using a 3D printer with a commands files program. The process of printing 3D objects is known as additive manufacturing [2]. This technology is applied at various engineering and industrial fields such as airplanes, biotechnology, medical devices, medical implants and automotive products. There are various additive manufacturing technologies available in the market such as Fused Deposition Modeling (FDM), Direct Metal Deposition (DMD), Selective Laser Sintering (SLS), Inkjet Modeling (IM), Digital Light Processing (DLP), and Stereolithography (SLA) [3].

First time SLA (Stereolithographic Apparatus) machine was produced by 3D Systems in 1982. The process for construction the photopolymer on the machine uses a UV (Ultraviolet) laser. The Ultraviolet light sheet out following the pattern who made in 3DP software. The raw material for making 3D objects using SLA technology has called a photopolymer liquid resin which is made from a mixture the chemical elements. In the printing process, there are several parameters such as Layer Thickness, Exposure Time, Overhang Angle,

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¹ Mechanical Engineering Department, State Polytechnic of Sriwijaya, Indonesia

² Electrical Engineering Department, State Polytechnic of Sriwijaya, Indonesia

³ Informatics Management Department, State Polytechnic of Sriwijaya, Indonesia

*Corresponding author. Email: dickyseprianto@gmail.com

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The development of Industrial technology 4.0 was characterized by cyber-physical systems. This era make it easier for humans to connect with other humans, with industrial machines, and with the environment around them. With the industrial revolution 4.0 can be significantly increase the productivity. At this time, the single part products are often needed, where the product is used only a little and without needed for mass production or be known a custom design. The products that are custom design can be made by a 3D Printer (3DP) machine. 3D Printing is one of the newest technologies in the printing world, where the 3D printing technology is an easy print and easy to develop the solid product with 3DP technology. In this study, the printing objects of 3DP using CAD data and then converted into G-Code using Creation Workshop software version 1.0.0.75. This study aims to determine the effect of layer thickness and exposure time to geometric of shaft made by 3D Printer with technology Digital Light processing (DLP). The specimens tested is Ø20 x 100 mm with material Liquid Photopolymer Resin. The data from the test results analyzed using ANOVA with a 3-level design type and 2 factorial interactions (2FI) with 3 replications modeled by the Design-Expert® 10 trial version software. The results of the 5-point method analysis show that the main factor of most influences on the cylindricity of the test specimens is the layer thickness factors, and the optimum combination of parameters in this study is layer thickness 0.075 mm and exposure time 15 seconds.

Keywords: 3DP-DLP, ANOVA, Layer Thickness, Exposure Time, Cylindricity

1. INTRODUCTION

The technological developments enter the Industrial 4.0 that is marked by cyber-physical systems. This era makes it easier for humans to connect with other humans, with industrial machines, and with the environment around them. Of course, the industrial revolution 4.0 can significantly increase the productivity. At this time, single part products are often needed where only one or more products are used without need the mass production or known custom design [1]. Custom design products can be made using a 3D Printer (3DP) machine. 3D Printing technology has process for making solid objects using a 3D printer with a commands files program. The process of printing 3D objects is known as additive manufacturing [2]. This technology is applied in various engineering and industrial fields such as airplanes, bioengineering,

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Hatch Spacing, the Fill spacing, Hatch Overcure, Border Overcure, and the Fill Cure Depth. The Parameters are the crucial part for greatly effects of accuracy and strength level of each layer, therefore selection and setting of these parameters is very important [4]. In the world of machining, the functional characteristics of a machine component will be obtained after the component was assembled with its partner components, to get good functional characteristics the good geometric are needed [5], so the correct alignment and roundness can reduce vibrations and more efficient to use and extend the lifetime product.

2. LITERATURE REVIEW

Computer Aided Design (CAD) is a software used to draw a solid model or surface model that begins with a point, line, or symbols who have a specific meaning. The results of CAD has a shape 2D or 3D drawings, besides that the design model usually has properties such as mass, volume, surface area, center of gravity and etc. so that is why CAD can be integrated with CAE (Computer Aided Engineering) and CAM (Computer Aided Manufacturing) software. The several of CAD software usually used is Alias, CATIA, Autodesk® Inventor®, Pro / ENGINEER®, Parasolid®, SolidWorks™ and Power Shape and UGS NX [6].

Rapid Prototyping is a technique to form and assemble the product with quickly who using an integration method between CAD (Computer Aided Design) and the machines with rapid prototyping systems such as 3D Printer and CNC [7] And according to [8] explains that rapid prototyping is the process to forming objects from 3D data layer per layers, that opposed to the manufacturing process on revolving machines, mostly reducing unnecessary parts. Rapid Prototyping technology is a valuable technology for manufacturing. With this technology, it can realize 5 "any": any material, any part, any quantity, any location and any industrial field [9].

Scientific publications conducted by [10] have a big impact in rapid prototyping technology, almost all technologies used in 3D Printing machines today use one of several methods from previous studies and combine with new technology, where the process of printing objects solid with a 3D printer using a command with form the program files or known additive Manufacturing (AM). There are a variety of AM technologies available on the market such as Fused Deposition Modeling (FDM), Direct Metal Deposition (DMD), Selective Laser Sintering (SLS), Inkjet Modeling (IJM), Digital Light Processing (DLP), and Stereolithography (SLA), DLP is an additive Manufacturing process used to produce layered parts to solid model through the photopolymerization [11]. Based on printing using UV light, DLP has the

advantage of reducing production time and increasing the accuracy of production results [12].

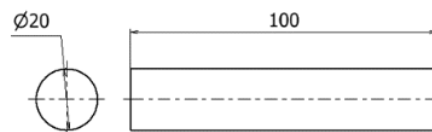
The shaft is an important component of a rotating machine, Shaft is used to transmit power and motion [13]. Shaft with the incorrect geometric can produce the problems such as excessive vibration, noise, and increased temperature [14], moreover can make the damage to shaft itself or other components.

Design experiments are used to study the performance of process or system that is usually visualized like a combination of machines, methods, people and other resources. Because of it that need to use a statistical approach who applied to the experimental process. The experimental design aims to obtain and collect more information or data as necessary and useful to conducting research on the issues to be discussed. Research also be carried out an efficiently to considering the time, cost, energy and materials that must be used [6].

3. METHODOLOGY

The method used in this research covering literature, design and experimental studies on the cylindricity deviations value of the print results Object 3DP SLA-DLP. This research was conducted at the CNC Laboratory in Department of Mechanical Engineering, State Polytechnic of Sriwijaya. In this study, the test specimens were made using 3DP SLA-DLP where the material used is photopolymer (resin). Test specimens are made according to ISO 1101 / ISO 12180-1 with sized Ø20x100 mm. This study aims to determine the effect of parameter process 3d Printer technology digital light processing to geometric of Shaft. The step for making specimen among is.

- Designing 3D models using Autodesk® Inventor® CAD software..
- Export 3D model to Creation Workshop (CW) software
- Setting the 3DP process parameters using CW and Slice 3D models with 3DP SLA-DLP to finish



Information :
 Ø = 20 mm L = 100 mm

Figure 1 Dimension of cylindricity specimens

Table 1. Fixed factor for making testing specimens

No	Parameter	Value	Unit
1	Off Time	1	s
2	Bottom Exposure	60	S
3	Bottom Layers	8	
4	Z Lift Distance	6	mm
5	Z Lift Speed	3	mm/s
6	Z Retract Speed	3	mm/s

Table 2. Controlled factor for making testing specimens

Parameter	
Layer Thickness	Exposure Time
0.025 mm	10
0.05 mm	12,5
0.075 mm	15

Analysis of the data from the cylindricity measurement in this study uses analysis of variance (Two-Way ANOVA) with the experimental 2-level factorial design method and investigated the effect of relationship of 2 factors on the cylindricity measurement (2 factorial interactions), in analyzing the data used Design Expert software version 10 (trial license). The data obtained from the results of the cylindricity measurement were analyzed by analysis of variance. ANOVA basically aims to test the hypothesis (H0) that the mean of two or more populations is the same. The concept of analysis variance has based on the concept of the F distribution and can be applied to the analysis of the relationship between the various observed variables. In statistical calculations, analysis of variance has strongly influenced by the assumptions used such as a normal distribution, identical (variance homogeneity), independent (freedom from error) and model linearity. This assumption can be seen by making a graph based on the residuals of the difference between the actual test results and the predicted data.

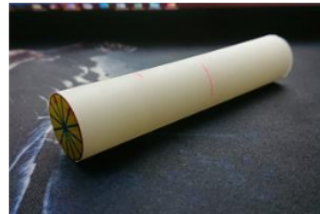
Two-Way ANOVA (analysis of variance) in this study is used to determine the existences of differences effect in several independent variables (factors) and the dependent variable (response) and each variable has three levels [15]. To determine the effect of variables on response, it is necessary to calculate the sum of squares in ANOVA [6]. In this study, there are several equipment and materials used, namely:

1. 3D Printer Digital Light Processing Technology
2. Laptop
3. Dial Indicator Knuth
4. Autodesk® Inventor® 2019, Education Version
5. Creation Workshop (CW)
6. Design Expert 10 Trial Version
7. V-Block

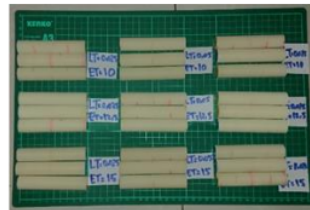
8. Calipers
9. Liquid Photopolymer Resin

4. RESULTS AND DISCUSSION

After completing the measurement of the cylindricity testing specimens, data from the measurement results has obtained and then be analyzed to determine the factors that effect on the cylindricity, then the percentage contribution of each factor to the response can be found. In accordance with the basic principles of experimental design, it is applied completely randomly (randomization), namely a design where the treatment is applied completely randomly to the experimental units [19]. The measurement of specimens is carried out in accordance with the measurement design matrix in 3rd Table, with 3 replications and resulting 27 test specimens in 2nd Figure.



a) Testing specimen



b) 27 Testing specimen



c) Cylindricity Measurement

Figure 2 Cylindricity Measurement for specimen.

Table 3. Controlled factor for making testing specimens

Std	Run	Factor 1 A: Layer Thickness (mm)	Factor 2 B: Exposure Time (s)	Response Cylindricity (mm)
25	1	0,025	15	0,082
24	2	0,075	12,5	0,047
15	3	0,075	12,5	0,045
8	4	0,05	15	0,043
5	5	0,05	12,5	0,038
9	6	0,075	15	0,025
18	7	0,075	15	0,02
12	8	0,075	10	0,035
4	9	0,025	12,5	0,039
17	10	0,05	15	0,037
3	11	0,075	10	0,036
11	12	0,05	10	0,05
10	13	0,025	10	0,055
1	14	0,025	10	0,054
6	15	0,075	12,5	0,043
2	16	0,05	10	0,052
22	17	0,025	12,5	0,04
20	18	0,05	10	0,048
14	19	0,05	12,5	0,042
27	20	0,075	15	0,015
7	21	0,025	15	0,085
21	22	0,075	10	0,034
23	23	0,05	12,5	0,04
26	24	0,05	15	0,04
19	25	0,025	10	0,056
13	26	0,025	12,5	0,041
16	27	0,025	15	0,088

From 3rd Table, random test graph data is obtained, as in 3rd Figure as follows:

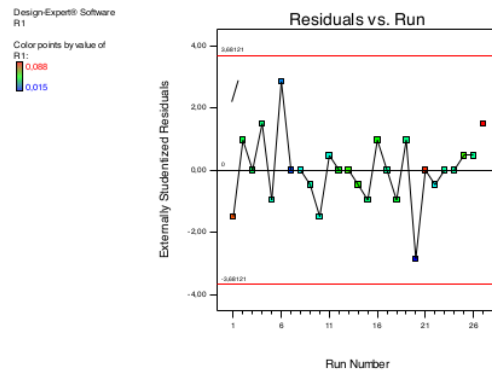


Figure 3 Residual vs Run

From the measurement data in Table 3 and Table 4, the influence of these factors can be analyzed using the analysis of variance (ANOVA) method which assisted by Design-Expert® Trial Version software on the Cylindricity Measurements of testing specimens made using 3D Printer Digital Light Processing technology. The ANOVA results are shown in Table 5.

Based on the results of ANOVA ($F_{count} > F_{table}$), then the hypothesis (H_0) is rejected, so it can be concluded that the layer thickness, exposure time and their interaction with a confidence level of 95% ($\alpha = 0.05$) have an effect on the cylindricity of the testing specimens. Table 5th show that the layer thickness factor provides the largest percentage contribution to the cylindricity of the testing specimen, namely 41%, this value is obtained from the difference between the squares of the exposure time factor and the average squared error divided by the total squares. The percentage value of the contribution of each factors that affects to cylindricity, namely:

layer thickness factor:
$$= \frac{((3,267E-003) - (1,160E-004))}{(7,683E-003)} = 41\%$$

exposure time factor
$$= \frac{((2,167E-004) - 1,160E-004)}{(7,683E-003)} = 1\%$$

layer thickness and exposure time factor interaction
$$= \frac{((4,083E-003) - (1,160E-004))}{(7,683E-003)} = 52\%$$

Table 4. Mean, standard deviation, and the ratio of cylindricity specimens

	Name	Units	Min.	Max.	Mean	Std. dev	Obs	Analysis	Ratio
Factor	Layer Thickness	mm	0.025	0.075	0.025	0.02041241			
	Exposure Time	s	10	15	12.5	2.04124145			
Response	Cylindricity	mm	0.015	0.088	0.0456	0.01718974	27	Factorial	5.86667

Table 5. The results of ANOVA from the cylindricity measurement specimens

ANOVA for selected factorial model							
Analysis of variance table [Partial sum of squares - Type III]							
Source	Sum of Squares	Df	Mean Square	F ₀	F _{Tabel}	Percentage contribution value	
Model	7,567E-003	8	9,458E-004	146,77	<0,0001	97%	Significant
A-Layer Thickness	3,267E-003	2	1,633E-003	253,45	<0,0001	41%	
B-Exposure Time	2,167E-004	2	1,083E-004	16,81	<0,0001	1%	
AB	4,083E-003	4	1,021E-003	158,41	<0,0001	52%	
Pure Error	1,160E-004	18	6,444E-006				
Cor Total	7,683E-003	26					

The maximum and minimum values obtained from the response based on the actual experimental results can be seen in Figure 4th.

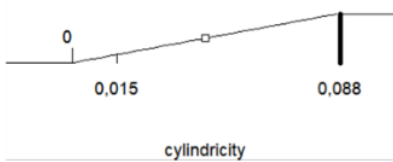


Figure 4 Data Maksimum and Minimum from the response

To get the optimum value of the response with factors layer thickness and exposure time based on the 2-level factorial ANOVA experimental design made with assisted of design expert software can be seen in Table 6.

Table 6. The Optimum results from response

Layer Thickness	Exposure Time	cylindricity	Desirability	
0,075	15	0,02	0,932	Selected
0,075	10	0,035	0,726	
0,075	12,5	0,045	0,589	

5. CONCLUSION

The results of the discussion and analysis in this study can be concluded that:

- a) The results analysis Known that the factors of affect to the cylindricity of shaft is layer thickness: 41%, exposure time: 1%, interaction of layer thickness and exposure time: 52%
- b) From the analysis of the cylindricity measurements of shaft, the most optimal combination of parameters is layer thickness: 0.075 mm, exposure time: 15 s with a value 0.02 mm on the cylindricity deviation.

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