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The Effect of Flexible Resin and Standard Resins Mixtures Variations on Dimensional Accuracy Using SLA 3D Printing

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Abstract

The present study investigates the effect of the concentration of flexible resin on the dimensional accuracy of mixtures product manufactured by 3D printing using SLA technology. Specimens were designed and according to the ASTM D412 standard. Ten variations of resin mixtures were examined. The concentrations of the flexible resins were varied from 10% to 100%. Measurements of accuracy dimension were conducted on the fabricated specimens, and the average deviation was used to estimate the dimensional accuracy. The study reveals the least deviation in dimensions in the 10% flexible resin containing mixture and the highest in the 60% flexible resin containing mixture. The results explain the fabrication tendency of flexible resins in dimensional accuracy for 3D printing.

Keywords: Dimensional accuracy, Flexible resin, SLA

1 Introduction

Rapid prototyping or also known as 3D Printing is a method of rapidly creating three-dimensional objects from digital data, which is different from conventional manufacturing. If conventional manufacturing uses the subtractive principle by cutting material, rapid prototyping works with the additive principle, adding material layer by layer [1]. A three-dimensional (3D) printing technology has both undergone a rapid development in recent years, and been widely used in various fields such as manufacturing [2], medical [3], as well as education [4]. Furthermore, since various materials are now available to meet specific needs in industries, a flexible resin is of large interest in 3D printing. Here, the flexible resin has a partial characteristic of an elastomer in which its high elongation offers the ability to be bent or stretched without being easily broken. Therefore, the flexible resin can be utilized in many applications such as prototypes, functional objects, and components that require a high elasticity. Hence, if the products of flexible resin 3D printing are used as functional objects, then the required aspect is not only the elongation but also its dimensional accuracy [5]. As a result, the dimensional accuracy is then a major challenge in the application of flexible resins since it has not widely been discussed on various reference of 3D printing.

The dimensional accuracy is important during manufacturing to assess the level of precision of an object [6]. Herein, a dimensional deviation may cause the product to be malfunction or not function optimally in high-precision manufacturing [7] especially in industries that require very high tolerances such as automotive, medical device, and aerospace [8]. In 3D printing using stereolithographic (SLA) technology, the dimensional accuracy is affected by many factors such as the printing parameters [9], curing process [10], and the properties of the material [11] The flexible resins, with their high elasticity properties, have the challenge of maintaining dimensional accuracy after the molding process. Therefore, it is important to conduct a dimensional accuracy testing on the product of flexible resin 3D printing to ensure the quality of products.

This present study experimentally investigates the effect of the concentration of a flexible resin on the dimensional accuracy of the mixture produced using SLA 3D printer. The results provide more in-depth insights into the limitations and potential uses of flexible resins in various industrial applications, as well as an overview of flexible resin 3D printing with optimal concentration of the flexible resin to achieve accurate and precise printing products.

2 Material and Methods

The methodology carried out in the present work includes the process 3D model designs using computer aided design (CAD) software, variations in the composition of resin mixtures, printing processes, and geometrical measurements of the specimens to evaluate the level of dimensional accuracy. Here, the geometry of specimen was designed following the ASTM D412 standard for tensile testing on thermoplastic elastomer materials [11]. The geometry and dimensions of the selected specimen is depicted in Fig 1. The specimen was designed using a computer software namely Solid Edge Community Edition computer-aided design. For dimensional accuracy measurement, the specimen has a total length of 115 mm (L-115), a total width of 25 mm (W-25), and a thickness of 3 mm (T-3). The position of the printed specimen at the time of resin printing is used to identify the movement of the nozzle and table during the printing process.

The resin used in this study uses resins that are already available in stores and online marketplaces to consider their availability. Standard resins use anycubic standard resins and flexible resins use Esun eResin–Flex. The physical and mechanical properties for both resins can be seen in Table 1.

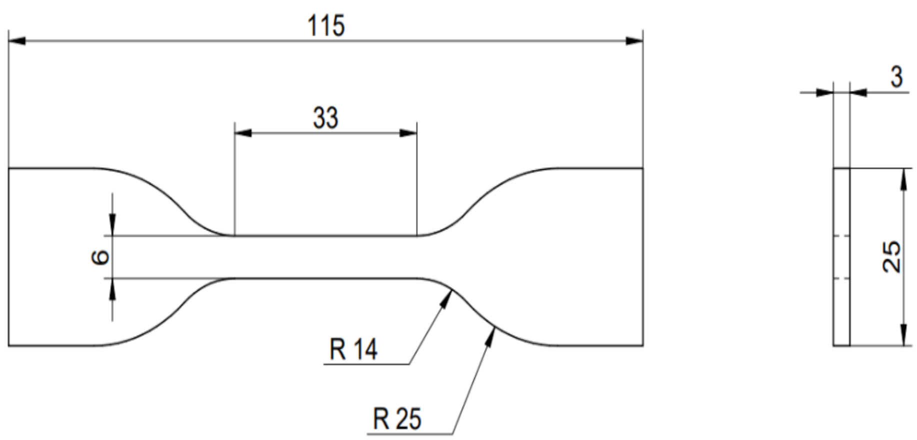

Figure 1. ASTM D412 standard specimen geometry (units in millimeters).

In this study, testing was conducted on specimens with 10 variations of a mixture of flexible resin and standard resin, which was marked with RF notation followed by a number indicating the percentage of flexible resin content in the mixture. Resin mix variations range from RF10 to RF100, with RF10 containing 10% flexible resin and RF100 being a pure flexible resin. Each variation was printed with 3 specimens, so that the total number of specimens printed was 30 pieces [12]. The concentration of the mixture of flexible resin and standard resin in each specimen can be seen in Table 2.

Tabel 1. Physical properties of standard and flexible resins used in research.

Parameter	Esun eResin-Flex	Anycubic Resin Standard
Viscosity (mPa.s)	600 – 1400	150 – 200
Density (g/cm3)	1.02 – 1.05	1.05 – 1.25
Tensile Strength (MPa)	4 – 10	36 – 45
Elongation (%)	100 – 350	8 – 12
Hardness (D)	60 – 90	82
Flexural strength (MPa)	-	50 – 65

Table 2. Concentration of a standard and flexible resin mixture on the specimen.

Specimen Notation	Standard resin (%)	Flexible resin (%)
RF10	90	10
RF20	80	20
RF30	70	30
RF40	60	40
RF50	50	50
RF60	40	60
RF70	30	70
RF80	20	80
RF90	10	90
RF100	0	100

The specimen was printed using an SLA technology machine, namely Anycubic Photon Mono X with specifications that can be seen in Table 3. Specimens were printed in a total of 3 for each variation of the mixture, so that the total number of specimens printed was 30 specimens. All specimens of flexible resin mixture variations and standard resins are printed using the same printing parameters to ensure consistency in the printing process. This is done so that the difference in dimensional accuracy produced is only influenced by variations in resin composition, not by differences in printing parameter settings. The printing parameters can be seen in Table 4.

Table 3. Specification of Anycubic Mono Photon X printer machine.

Specifications	Dimension	Unit
Machine Size	270 × 290 × 475	mm
Bed Size	192 × 120 × 245	mm
Lightsource	High quality filament (wavelength 405 nm)	
XY Resolution	0.050 (3840 × 2400)	mm
Z Resolution	0.01	mm
Layer Resolution	0.01 – 0.15	mm
Print speed	Max 60	mm/h
Material	405 (UV Resin)	nm
Technology	LCD-Based SLA	

Table 4. Specimen printing parameters.

Parameter	Value	Unit
Exposure Time	10	s
Bottom Layer Count	5	layer
Bottom Exposure Time	55	s
Lifting Distance	10	mm
Lift Speed	50	mm/min
Retract Speed	100	mm/min

The printing parameters of the specimens were set up using Chitubox software as shown in Fig. 2. The tilt position for the workpiece specimen is 450 with a dimension of length 115 with the resultant of the X axis and the Y axis, the width dimension is the resultant of the Y axis and the Z axis. The selection of printing parameters in Table 4 is a recommendation for printing parameters from the material supplier. In this study, we tried to print the recommended parameters to find out the results of the dimensional accuracy. The results of this study will be our preliminary data for further research if needed for optimization of dimensional accuracy results using flexible resins.

For the dimensional accuracy a measurement of L-115, W-25, T-3 utilized a Mitutoyo 505-730 dial caliper with a measurement range of 0-150 mm and an accuracy level of 0.02 mm. The data from each specimen are tabulated in a table showing the measurement results for each dimension as well as deviations from the initial design dimensions. The dimensional accuracy was analyzed by calculating the mean deviation. The analysis was performed to compare the variations of flexible resins to identify the trend line between the flexible resin mixture and the standard resin on the dimensional accuracy of the specimens.

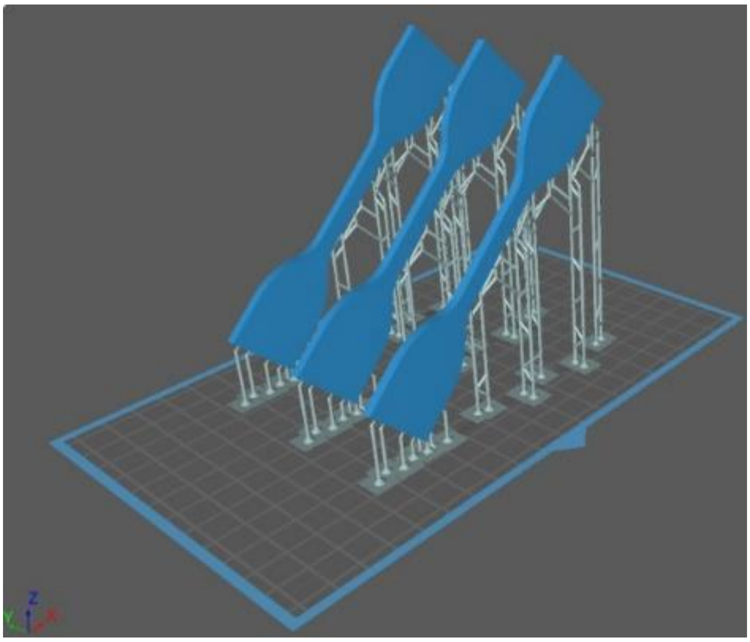

Figure 2. Position of workpiece specimens in Chitubox software.

3 Results and Discussions

The printed specimens are seen in Fig. 3. The test specimen of the print result is visible in comparison with the dimensions of the CAD design. On each dimension of the test specimen is measured at three points. From the three measurements on each of the dimensions, the average dimension was obtained and listed in Table 5.

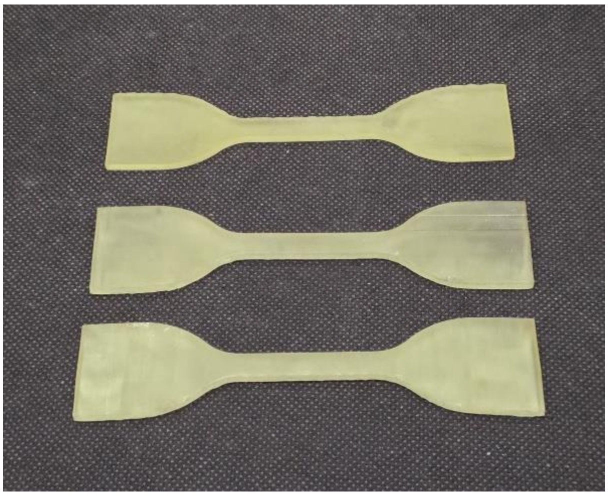

Figure 3. Test specimen prints.

Table 5. Average dimensions of the test specimen.

Specimen Notation	Dimension 3	Dimension 25	Dimension 115
RF 10	3.25	25.12	115.26
RF 20	3.44	25.30	115.70
RF 30	3.34	25.19	115.45
RF 40	3.43	25.36	115.81
RF 50	3.39	25.24	115.71
RF 60	3.38	25.39	119.26
RF 70	3.46	25.54	116.66
RF 80	3.37	25.22	116.48
RF 90	3.45	26.04	116.66
RF 100	3.63	25.23	116.79

Fig. 4 depicts the dimensional accuracy of L-115. From the results of the measured dimensions of the printed specimens, it can be seen that in each dimension deviations from the desired dimensions. The actual dimensions of the printed specimen and the tolerance amount according to the ISO with the medium can be seen in the following graph, at the Length 115 mm the medium general tolerance of ±0.3 mm is used to give the corresponding range of printed specimen dimensions. From the results of the specimen printing on the material composition, RF 10 enters the good dimensions. The largest deviation in the composition of RF 60 is 4.6 mm.

In the dimensional accuracy of W-25, there are two material compositions that are still within the tolerance of the specified dimensions there are RF 10 and RF 30 as shown in Fig. 5. The largest deviation is 1.04 mm of RF 90 composition.

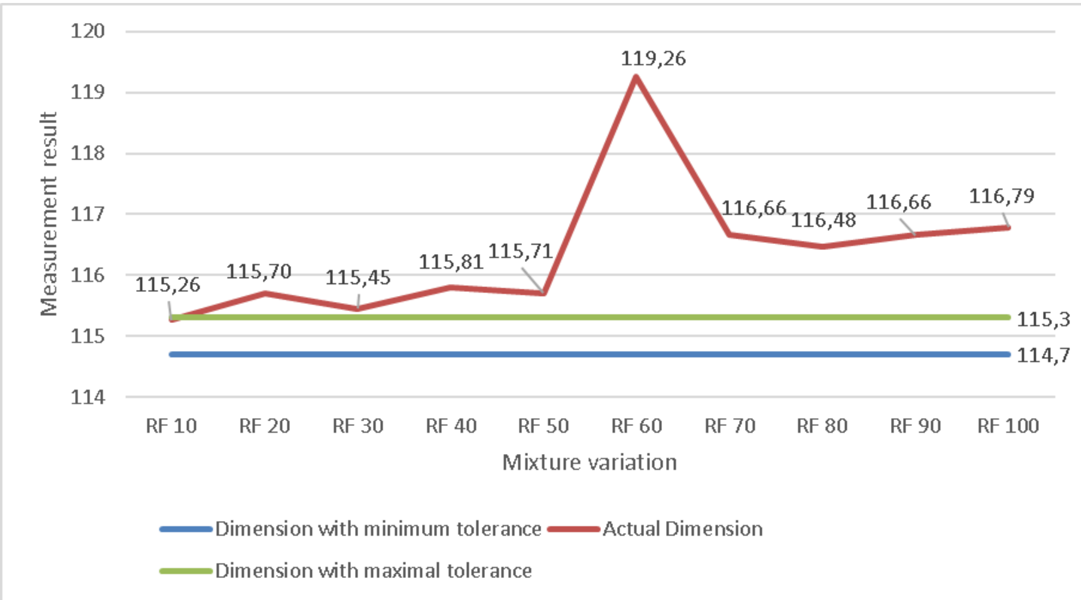

Figure 4. Dimensional accuracy test results of L-115.

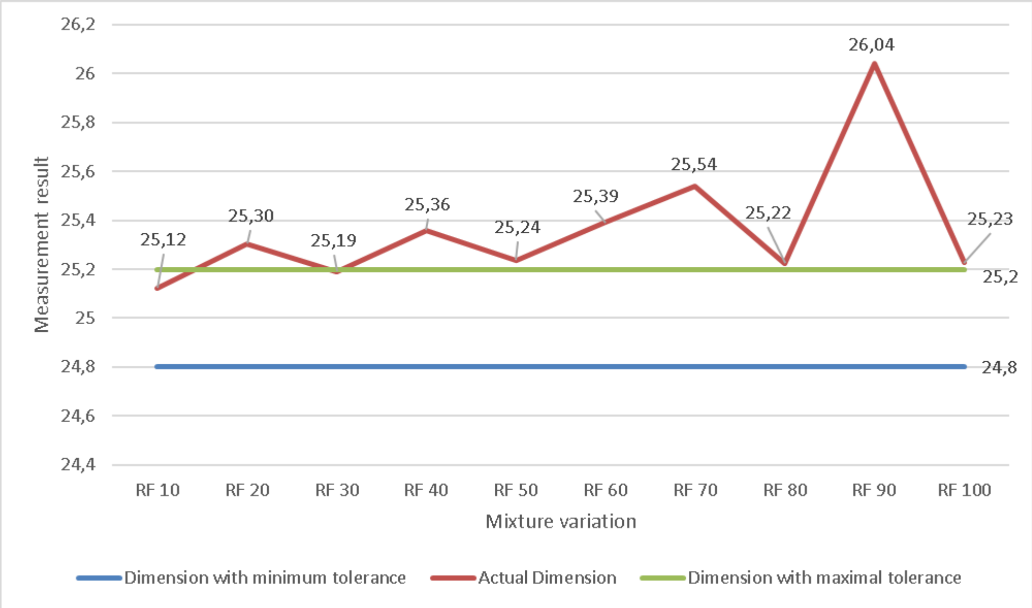

Figure 5. Dimensional accuracy test results of W-25.

Fig. 6 depicts the dimensional accuracy of L-3. From the figure it is revealed that all material compositions cannot meet the expected dimensions or fall within the predetermined tolerances. In this composition the smallest deviation is 0.24 mm and the largest deviation is 0.63 mm.

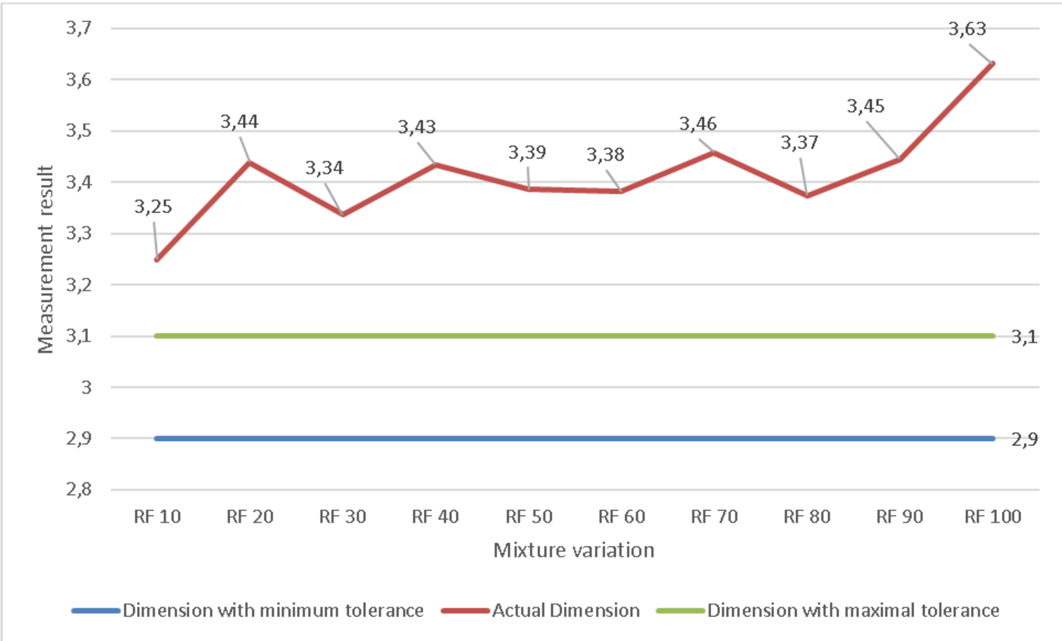

Figure 6. Dimensional accuracy test results of T-3.

Moreover, from Table 6, it can be seen the deviation of each variation of RF 10 to RF 100 for L-115, W-25, and T-3. From the rightmost column, the average deviation of the three dimensions measured is obtained. The deviation of the specimen ranges from the 0.211 mm to 1.678 mm. The smallest deviation was found in the RF 10 specimen and the largest deviation was found in RF 60. Here, RF 10 has a small deviation due to the low elasticity properties of only 10% of the flexible resin mixture, thus making the RF 10 specimen have a fairly good dimensional accuracy [13] [14].

The range of RF 10 to RF 50 has a maximum deviation value at RF 40 which is 0.535 mm. The RF 50 has an average deviation of 0.443 mm, which means that even if the mixture between flexible resin and standard resin has the same amount, it still cannot produce a deviation that is within the general tolerance.

Table 6. Average dimensions of the test specimen.

Specimen Notation	Dimension 115 (mm)	Dimension 25 (mm)	Dimension 3 (mm)	Average of Deviations (mm)
RF 10	0.262	0.123	0.249	0.211
RF 20	0.697	0.304	0.439	0.480
RF 30	0.452	0.191	0.337	0.327
RF 40	0.810	0.360	0.434	0.535
RF 50	0.706	0.237	0.386	0.443
RF 60	4.262	0.391	0.381	1.678
RF 70	1.661	0.540	0.458	0.886
RF 80	1.476	0.223	0.374	0.691
RF 90	1.661	1.041	0.446	1.049
RF 100	1.786	0.227	0.631	0.881

4 Conclusions

The process of printing product specimens has dimensional deviations. At each dimension, the smallest deviation occurs in the material composition of RF 10. As for the largest deviation in each, each test dimension differs in its material composition. The smallest deviation occurred in the composition of RF 10 of 0.211 mm, while the mean of the largest deviation in the composition of RF 60 was 1.678 mm. The machine parameters in the printing process in this study have not been the composition of the parameters. In order to have a more comprehensive picture of the influence of printing parameters on flexible resin materials, further research is needed to produce flexible resins that are more precise but do not reduce their elasticity.

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