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Shrinkage of Biocomposite Material Specimens [HA/Bioplastic/Serisin] Printed using a 3D Printer using the Taguchi Method

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Abstract

The Fused Deposition Modeling in the rapid prototyping technique was modified using a paste-shaped material with biocomposite material. One of the correction factors for the printed test specimen results is shrinkage. The paste material used is hydroxyapatite [CA5(PO4)6(OH)2] and tapioca bioplastic. Besides these materials, sericin is added, which is produced from extracts from silkworm cocoons. The composition of the biocomposite paste used with the ratio of hydroxyapatite and bioplastic was 40:50, 50:50, 60:40, by adding 0.3% sericin to the hydroxyapatite solution. The parameters used in the printing process of the test specimens are the perimeter speed of 60 mm/s, the infill speed of 10 mm/s, and the layer height of 0.45 mm. The design in this test has dimensions of 100mm long, 25mm wide, and 3mm thick. The optimal shrinkage of the test specimens was analyzed using the Taguchi method. Specimen printing is done by using additive manufacturing method. The process is carried out using a Portabee three-dimensional printing machine that uses a FDM system modified to an Aqueous-Based Extrusion Fabrication (ABEF) system. The results obtained that the optimum composition for shrinkage of the biocomposite material was 50:50 with the addition of 0.3% sericin to the hydroxyapatite solution.

Keywords: shrinkage, biocomposite, three-dimensional printer, taguchi

1 Introduction

Many researches on biocomposite materials have been carried out. The research used examined the composition of biocomposite materials consisting of [hydroxyapatite/bioplastic/sericin]. The materials in this study were hydroxyapatite from Sigma Aldrich, tapioca starch bioplastic, and sericin extracted from caterpillar cocoons (Bombyx morii). Biomaterials can be divided into two types, namely natural and artificial biomaterials. Examples of natural biomaterials are collagen, elastin, and chitin, while artificial biomaterials are made of metals, polymers, ceramics, and composites [1]. The highest biocompatibility properties of ceramic biomaterials compared to other biomaterials. Ceramic materials in biomaterials are known as bioceramics [2].

Composite is a material formed from a non-homogeneous combination of two or more constituent materials. Due to the different characteristics of the material, it will produce a new material (composite) that has different properties from the constituent materials [3]. In the study of composite scaffold specimens using biocomposite materials with nanohydroxyapatite (nHA) and tapioca flour (bP) bioplastics. The ratio of nHA/bP biocomposite materials varied at 0, 20, 40, 60, and 80% (w/w), respectively. The tensile strength of the scaffold material was tested with the Diameter Tensile Strength (DTS) test, the highest tensile strength of the nanobiocomposite material was obtained with an nHA/bP ratio of 60% (w/w) [4]. The addition of 2.7% Camphorquinone and the use of ultraviolet light on [hydroxyapatite/bioplastic] biocomposite with a ratio of hA/bP = 47.86%/52% resulted in the fastest solidification time = 408 seconds, and resulted in a DTS test for 2576.74 KPa [5].

Zirconia content at 40% and higher can increase the porosity of the biocomposite material, then cause a decrease of 0.039 MPa in the compressive strength of the hydroxyapatite-zirconia [6].

Rapid prototyping is a method of rapidly creating three-dimensional objects from digital data. Rapid prototypes are different from conventional manufacturing processes which have the principle of making a product with a workpiece by using a cutting tool to get a three-dimensional slice of an object that fits the desired shape, instead using an additive principle that adds material to the already formed layer. Because it uses the additive principle, rapid prototyping is also known as additive manufacturing [7]. In general, the working principle of FDM is based on the deposition of melted thermoplastic filaments onto the workbench to create a layer-by-layer structure with the movement of the extrusion nozzle on the X, Y, and Z axes [8]

Basically, ABEF has a similar working principle to FDM. However, the ABEF method uses a material in the form of a semi-liquid paste for the construction of three-dimensional objects. The paste material is extruded from the container to the nozzle using the screw extrusion principle [9]. In this study, modifications were made to a three-dimensional printer-Portabee machine to modify its working principle from FDM to ABEF system. Modification of the ABEF system by using a single screw extruder.

2 Research Methodology

The ingredients in this study were hydroxyapatite (catalog no. 04328, Sigma-Aldrich) and commercial tapioca flour. Sericin is extracted from the cocoons of the silkworm (Bomix morii) by hydrothermal processing. The citric acid and glycerin materials used are technical grade materials. Biocomposite material is made by wet process or using distilled water. The hydroxyapatite suspension with a percentage of 20% (w/v) was prepared by dispersing HA powder in distilled water with a percentage of citric acid of 10% (w/w). Citric acid is used as a dispersant. The suspension material was mixed using a rotation of 1000 RPM, at a temperature of 250C for 20 hours to obtain a homogeneous suspension.

A suspension of 20% (w/v) tapioca flour was prepared by dispersing tapioca flour powder in distilled water with 3.25% (v/v) glycerin. The tapioca flour suspension was transformed into bioplastic by stirring at 600 RPM at 500C for 15 minutes. The biocomposite paste material was carried out by mixing the HA suspension with bioplastic at various mass percent ratios (w/w), as shown in Table 1. Sericin was added to each composition in a ratio of 0.3% (w/w) to the mass of the HA suspension.

Table 1. Variations in the composition of biocomposite materials

Level Factor	% mass ratio (w/w)	
	HA suspension	Bioplastic
1	40	60
2	50	50
3	60	40

The creation of a three-dimensional image of a specimen with dimensions of 100 mm x 25 mm x 3mm was created using the Solidworks software, as shown in Figure 1. A three-dimensional image file is an image saved with the 'stl' format type. . File format derived from 'stl'. converted into G-code programming language using Slic3r software. The results of the G-Code program language are entered into a three-dimensional printing machine, and the parameter settings for the material filler setting on the Portabee machine are 10 mm/s, print speed 60 mm/s, and layer height 0.45 mm. This biocomposite paste material is filled into the working material container of the Portabee three-dimensional printing machine. By using a three-dimensional Printing Portable machine that has been modified, the test specimen printouts are obtained by three-dimensional printing using the ABEF system. The process of printing specimens using a modified three-dimensional printer-machine is shown in Figure 2.

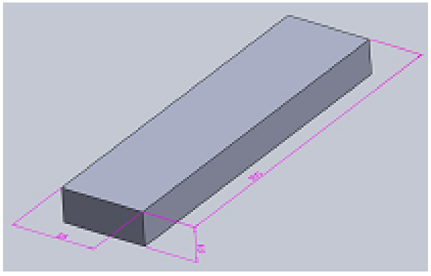

Figure 1. Test specimen design drawing

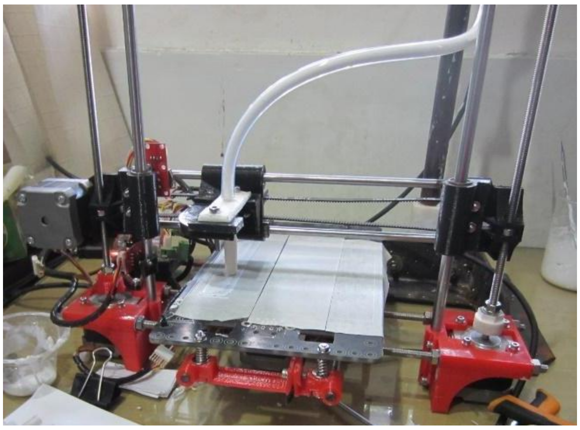

Figure 2. The process of printing test specimens using a three-dimensional printing machine

The dimensions of the test specimens were measured using a digital caliper with an accuracy of 0.01mm. After the results of measuring the dimensions of the test specimens in the form of length, width, and thickness are obtained, the measurement results are then collected. The results of the specimen measurement, the dimension value is the average of the dimension values measured at three different measuring points. Measurement of the dimensions of the specimen is illustrated in Figure 3. The shrinkage of the test specimen is carried out by calculating the final volume of the object from the results of measuring the dimensions of length, width, and thickness.

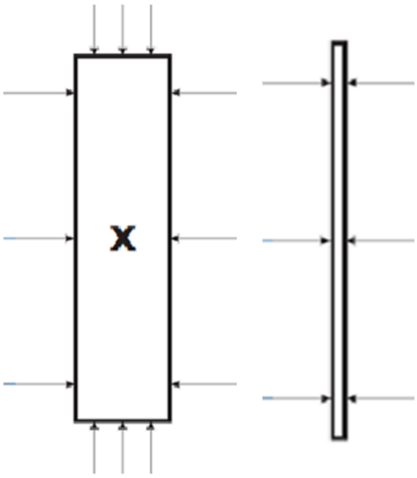

Figure 3. Test specimen measurement point

3 Results and Discussion

The results of the measurement of the dimensions of the test specimens are shown in Table 2. The results of these measurements were analyzed using the Taguchi Method with "smaller is better" characteristics.

Table 2. Measurement results of test specimens

Komposisi		DIMENSI AKHIR SPESIMEN			VOLUME
HA	BP	PANJANG	LEBAR	TEBAL	
40	40	113.09	29.34	2.58	8560.596
40	50	113.97	30.31	1.52	5250.735
40	60	115.86	34.35	2.37	9432.105
50	40	108.5	25.45	1.07	2954.618
50	50	112.75	27.09	1.14	3482.013
50	60	112.91	25.98	1.29	3784.088
60	40	120.07	25.75	1.47	4544.95
60	50	110.32	22.29	1.82	4475.44
60	60	116.24	32.74	1.29	4909.35

3.1. Mean analysis of response parameters

Calculation analysis to determine the smallest value using the mean function. This is because the characteristics of smaller is better in finding the value of the smallest discrepancy/error. In Figure 4 is shown at the smallest shrinkage at the level of 2.

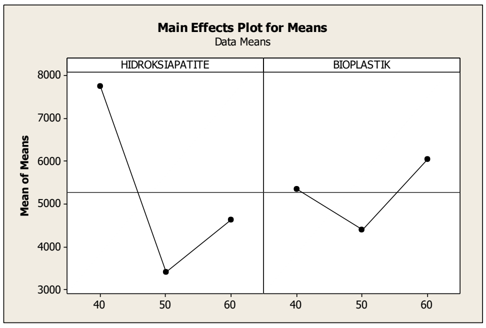

Figure 4. Graph of the analysis of the mean of the parameters affecting the response parameters

3.2. SNR analysis of response parameters

Signal to Noise Ratio (SNR) is useful for knowing the factors that influence the response. The characteristics of the SNR used are the smaller is better function. With these characteristics, the largest SNR value indicates the smallest error rate. Figure 5 shows the smallest shrinkage response at level 2.

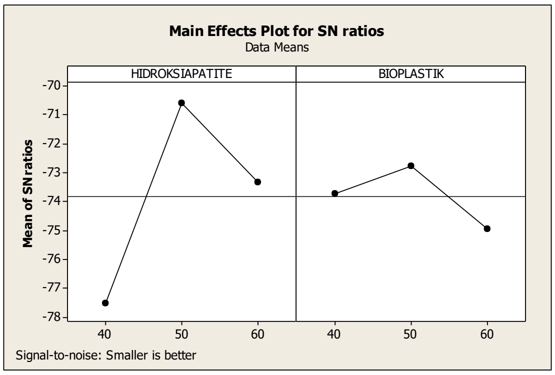

Figure 5. Graph of SNR analysis of parameters affecting response parameters

4 Conclusion

From the research process, it was found that the optimal composition of biocomposite material with the lowest shrinkage was the ratio of HA/bP 50/50 (w/w). In this study, only the composition of the biocomposite paste material for the smallest shrinkage was produced. Further research is needed on the machine process parameters during the specimen printing process.

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