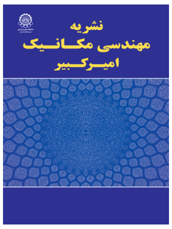

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Experimental and Numerical Investigation of Fatigue Behavior of Polylactic acid Components Made by Additive Manufacturing Method

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ABSTRACT: Additive manufacturing includes emerging methods that with reduced production time and ability to produce parts with complex geometry, are now widely used in variety of industries. Fused deposition modeling process is one of the most popular methods of additive manufacturing and so far, a lot of research has been done to model and improve the mechanical behavior of the parts produced by this method. The purpose of this research is to conduct an experimental study to model and investigate the effect of fused deposition modelling process variable on fatigue behavior of poly-lactic acid components, along with the development of numerical tools to predict this behavior. This paper uses the Taguchi algorithm to design experiments for experimental study. By performing fatigue testing on the sample and analyzing the result, the optimal value of the desired variable, as well as their effects are determined that the variable of fill density, nozzle temperature and layer thickness have the highest impact on fatigue life, respectively. The finite element simulation is performed by assuming assumption and its results are evaluated with the values of the optimized sample fatigue test. The result of experimental modeling and finite element simulation show that the models presented predict the poly-lactic acid components parts fraction with R-Sq 96.3% and 98.7% fatigue behavior, respectively.

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1- Introduction

Fused deposition modeling is the major technique in Additive Manufacturing (AM) that talk about the process where sequential layers of material are deposited in a computer-controlled location to create a three-dimensional body. The main limitation of this technique is the low mechanical properties of parts fabricated by FDM. Many studies have been done to investigate the effects of process parameters on the mechanical properties of final part [1].

In the present work, experimental investigations have been carried out to evaluate the effects of process parameters on the fatigue behavior of fabricated parts. By performing fatigue testing on the sample and analyzing the result, the optimal value of the desired variable, as well as their effects are determined that the variable of fill density, nozzle temperature and layer thickness have the highest impact on fatigue life, respectively. The finite element simulation is performed by assuming assumption and its results are evaluated with the values of the optimized sample fatigue test.

2- Methodology

In this work, the experimental tests have been designed to study the effects of four process variables including fill density, nozzle temperature, layer thickness and bed temperature on the fatigue life. By performing fatigue testing on the sample and analyzing the result, the optimal value of the desired variable is determined. The finite element simulation is performed by assuming assumption and its results are evaluated with the values of the optimized sample fatigue test.

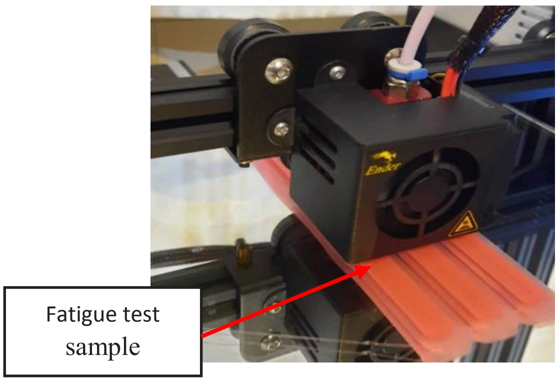

Fig. 1. Fatigue test sample manufacturing

Taguchi algorithm has been applied to design of experiments. Fig. 1 shows the manufacturing of parts. PLA filament made by Yousu Plastic Technology Co. has been used. The test samples according to ASTM D7774-12 have been fabricated. The dimensional modeling has been shown in Fig. 2.

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3- Results and Discussion

The Table 1 shows experimental results of the fatigue life times.

Signal-to-Noise Ratio (SNR or S/N) to compares the level of a desired signal to the level of background noise has been used [2]. It is shown in Fig. 3. As seen in this figure, the S/N ratio raised with nozzle temperature elevation. Fig. 4 shows the stress-fatigue life curve for parts made by PLA.

4- Finite Element Modeling

Finite element modeling has been done in ANSYS 18.2. In this technique Stress – Life method [2] has been used. Fig. 5 shows the boundary condition and external force exerted on the body.

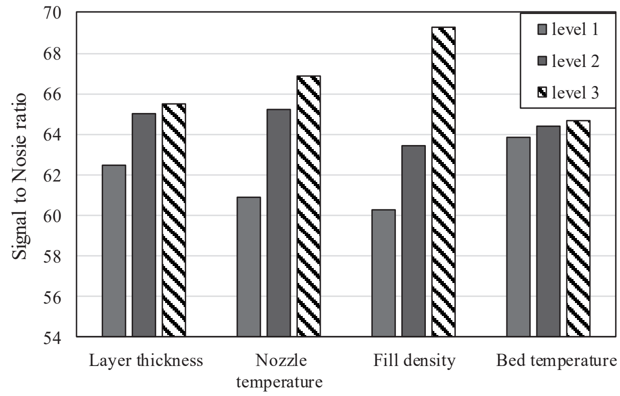

Fig. 3. Signal to noise ratio

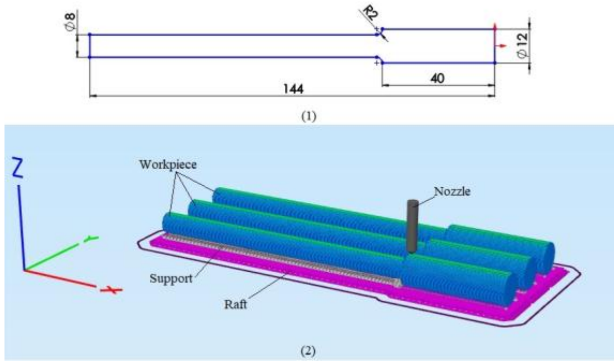

Fig. 2. Sample dimensional modeling

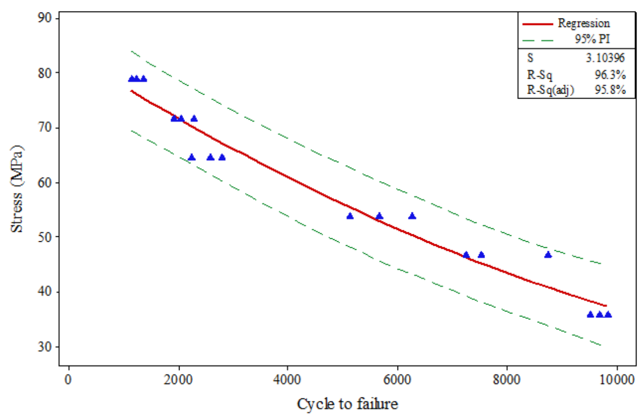

Fig. 4. Stress-fatigue life curve for PLA parts

Table 1. Fatigue life time test results

Cycle	Number	Cycle	Number	Cycle	Number
725.389	19	834.197	10	816.062	1
507.772	20	1632.12	11	888.601	2
1650.26	21	3082.09	12	1323.83	3
1341.97	22	1051.81	13	997.409	4
1967.68	23	2049.22	14	1378.24	5
3790.16	24	3753.89	15	2012.95	6
1777.2	25	1015.54	16	1069.95	7
4261.666	26	1613.99	17	1233.16	8
6256.48	27	3282.83	18	3663.21	9

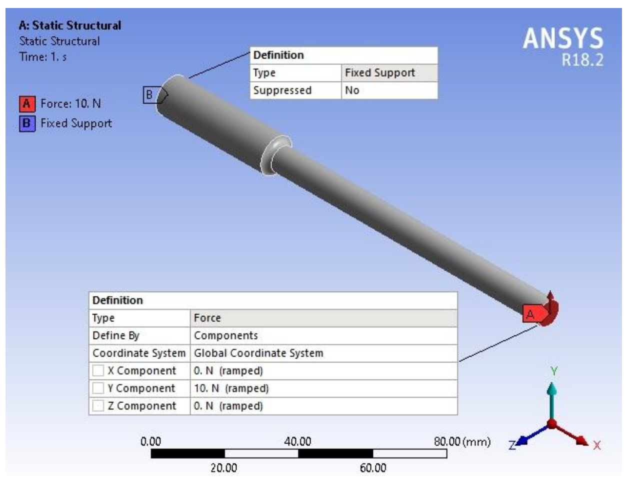

Fig. 5. FEM Model & Boundary conditions

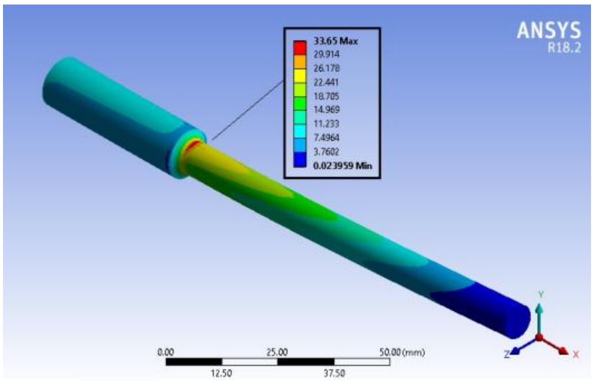

Fig. 6. Stress results, 10 N force

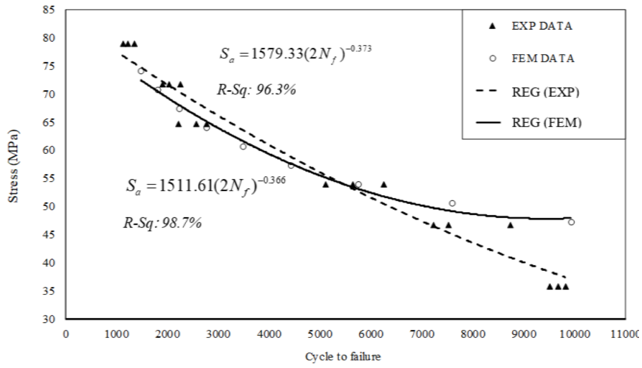

Fig. 8. Experimental and FEM results

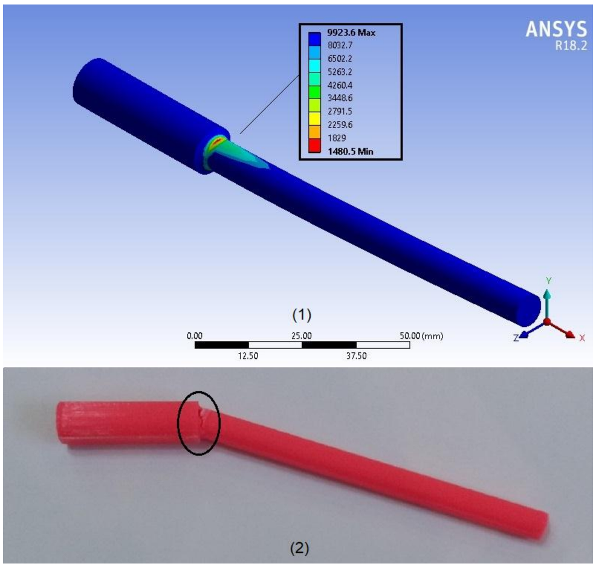

Fig. 7. (1) Stress results from 22 N force (2) Fracture location on experimental sample

Fig. 6 shows the stress distribution results on the sample with 10N force. This sample has 9923.6 cycle lifetime.

Fig. 7 shows the location of fatigue fracture on the experimental test and could be compared with the results of FEM modeling. Fig. 8 shows the experimental and finite element modeling results which display a good correlation between the results.

5- Conclusions

In this work, experimental and numerical study has been done on the fatigue behavior of parts made by PLA using FDM technique. The optimum values of four process parameters including fill density, nozzle temperature, layer thickness and bed temperature have been achieved.

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