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STUDY ON CHARACTERISTIC ANALYSIS OF ONYX-CARBON FIBER REINFORCED MATERIAL AT PT. MATAHARI MEGAH

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ABSTRACT

Industry 4.0 focuses on automation with the help of technological and scientific developments in its application. Additive manufacturing is one of the pillars in Industry 4.0. 3D printing technology is part of additive manufacturing. One of the Indonesian companies that utilize 3D printing technology is PT Matahari Megah, the 3D-printing filament used to make a product in the company is Onyx-Carbon Fiber Reinforced. This material is used to make jaw grippers, soft jaws, threads, brackets, and jigs. However, the use of Onyx-Carbon Fiber Reinforced material is still not optimal, because there are no physical strength characteristics of the composite material. The method used in this research is to find a comparative study that starts by looking for literature studies that vary the parameters of the infill pattern and the percentage of density. In this study, the research data will be compared with the data from the literature study which will then be analyzed to find the most optimal parameters, based on the literature, the data obtained will be analyzed using the Taguchi method. From the data analysis, it is found that among the triangular, rectangular, and hexagonal infill patterns, the rectangular pattern is the most optimal. The optimal parameter configuration for the first data is by using rectangular infill pattern with 75% density percentage and for the second data by using rectangular infill pattern with 80% density percentage.

Keywords: *3D-Printing. Onyx, Carbon Fiber, Composite Material, Tensile Strength*

1. INTRODUCTION

The Industrial Revolution 4.0 focuses on automation and is aided by the development of technology and science in its application. The industrial revolution can clearly change the pattern of human life. Starting with the invention of wireless communication tools, to the invention of cyber security to protect data in the company [1].

There are 5 main pillars in the industrial revolution 4.0 including the internet of things, additive manufacturing, big data, artificial intelligence, and cloud computing. One of the technologies in additive manufacturing is 3D-printing technology. 3D-printing technology has begun to enter the industrial world because it is believed to bring progress and human welfare [2].

3D-printing technology can also be used for rapid prototyping. In the rapid prototyping process using 3D-printing technology has several advantages including making design validation faster, easier, and more efficient, because it only needs to do 3D design in the software and then can be directly printed using a 3D-printer. In addition to the rapid prototyping process, 3D-printing technology is also used for product manufacturing [3].

One of the companies in Indonesia that utilizes 3D-printing technology is PT Matahari Megah. PT Matahari Megah is a company engaged in automation, customized machines, jigs and fixtures, and general maintenance that has been established since 1987. The company utilizes 3D-printing technology to produce several products, including jaw grippers, soft jaws, threads, brackets, and jigs. One of the products being developed is the jaw gripper on the C8 robot, this gripper is made using 3D-printing technology using Onyx-Carbon Fiber Reinforced material. This gripper functions to pick up and move gears and bearings from one place to another. The problem that arises at PT Matahari Megah is the use of overwhelming materials so that it is still not optimal.

Fig 1. Jaw Gripper

Figure 1 is a jaw gripper that has been pre-molded by PT Matahari Megah using Onyx-Carbon Fiber Reinforced filament material. This gripper is still not optimal so it is also not economical, for this reason, physical strength characteristics of composite materials are needed.

Onyx-Carbon Fiber Reinforced filament is a material used by PT Matahari Megah in the 3D-printing process, because this material has stronger characteristics and can withstand deflection due to heat, but this material has a price that tends to be higher than other 3D-printing materials [4].

The innovation in this research is that if there is a material, we take the example of mc blue as raw material for making a jaw gripper, it will be more flexible, the material used will be less, the manufacturing time will be less if using Onyx-Carbon Fiber Reinforced material.

The purpose of this study is to determine the optimal parameter configuration and determine the physical strength characteristics of composite materials so that they can be used for industrial purposes.

2. RESEARCH METHOD

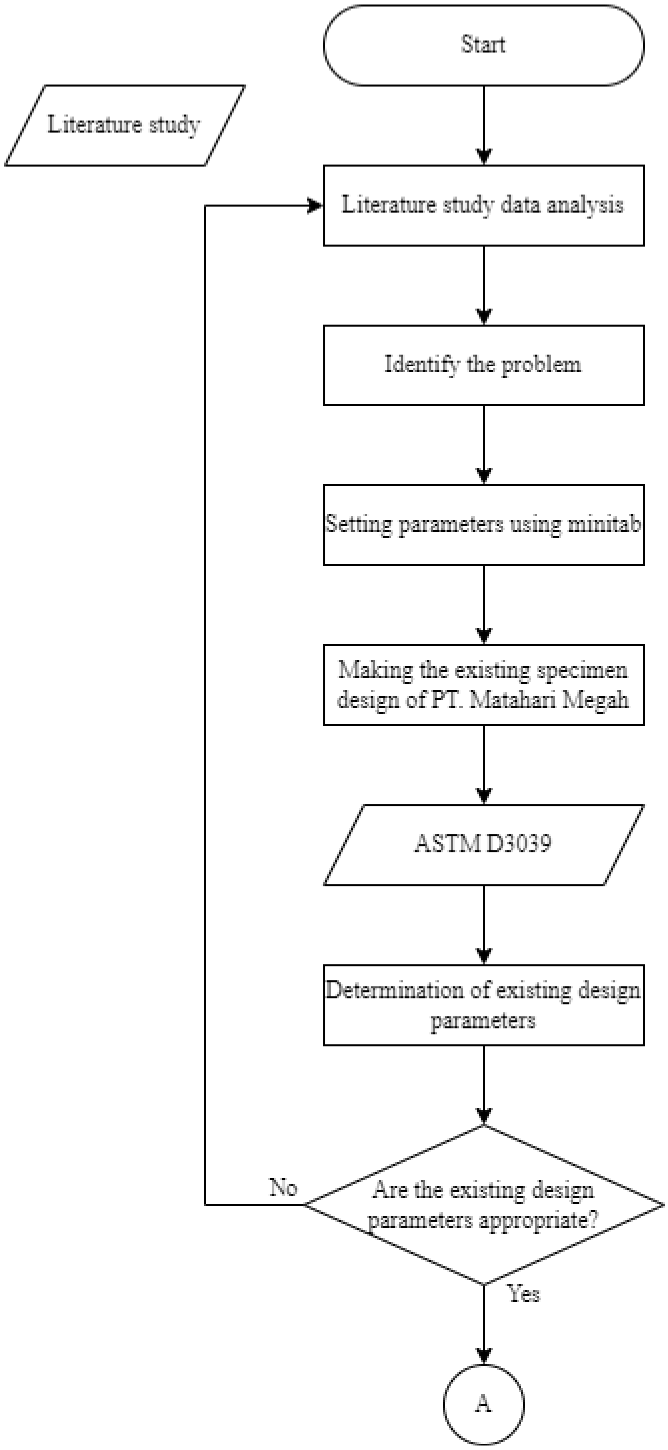

Fig 2. Reseach Flowchart

The method used for this research is the comparative study method. Starting from determining independent parameters such as the specimen used is ASTM D3039, using Onyx-Carbon Fiber Reinforced material, the nozzle temperature must be appropriate and before the 3D-Printing process, the bed has been given adhesive first. Then determine the bound parameters or dependent parameters as research material to obtain optimal parameters. After that, look for literature studies that have topics and data related to the research topic.

This research started from looking for case studies conducted from several studies that were used as preliminary studies. From the literature data obtained, it is compared with the data tested using existing parameters from PT Matahari Megah.

Comparisons are made to find out what parameters make a product more optimal and economical. This tensile testing uses ASTM D3039 specimens. Specimen geometry recommendations refer to the ASTM D3039 handbook [5].

Table 1. Geometry Recommendations of ASTM D3039 [5]

Fiber Orientation	Width, mm [in.]	Overall Length, mm [in.]	Thickness, mm [in.]
0° unidirectional	15 [0.5]	250 [10.0]	1.0 [0.040]
90° unidirectional	25 [1.0]	175 [7.0]	2.0 [0.080]
balanced and symmetric	25 [1.0]	250 [10.0]	2.5 [0.100]
random-discontinuous	25 [1.0]	250 [10.0]	2.5 [0.100]

Fiber Orientation	Tab Length, mm [in.]	Tab Thickness, mm [in.]	Tab Bevel Angle, °
0° unidirectional	56 [2.25]	1.5 [0.062]	7 or 90
90° unidirectional	25 [1.0]	1.5 [0.062]	90
balanced and symmetric	emery cloth	-	-
random-discontinuous	emery cloth	-	-

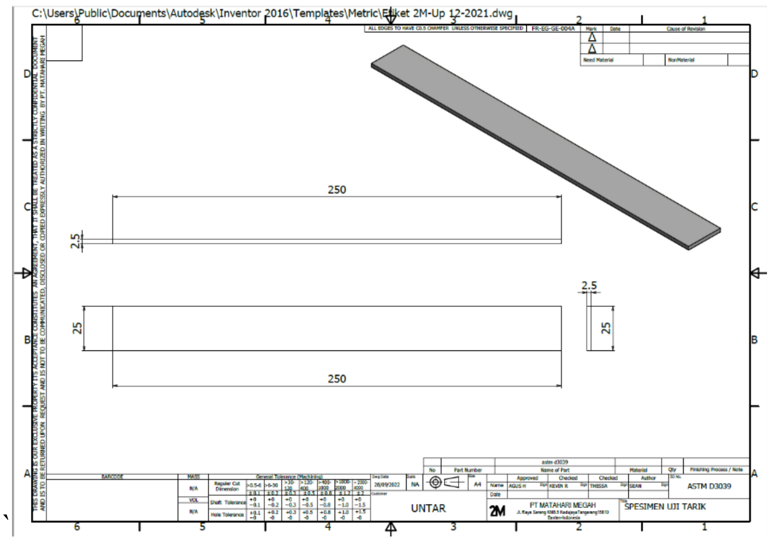

Fig 2. Dimension of ASTM D3039

3. RESULTS AND DISCUSSIONS

This analysis compares two experiments, both experiments using variations in infill pattern parameters and density percentage with each different level. The purpose of this analysis is to determine the most optimal parameter configuration.

3.1 Research and data collection procedures

The procedure for tensile testing is carried out with several steps, including

1. Ensure the test equipment and processor are in the on position.
2. Determine the gauge length on the specimen.
3. Clamp the specimen in the chuck.

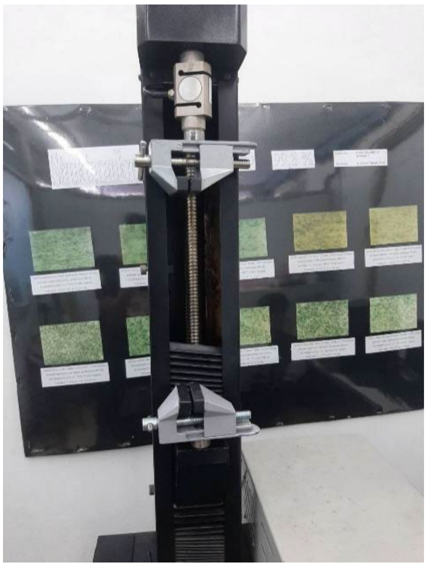

Fig 3. Chuck

4. Set the speed on the OP Panel.

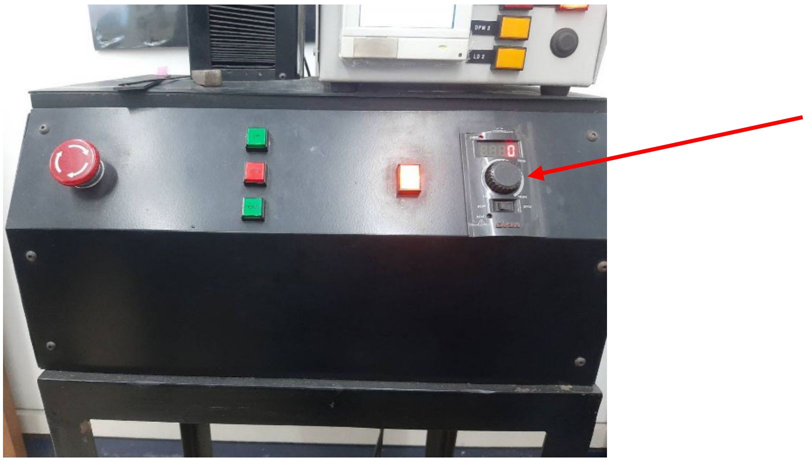

Fig 4. Set the speed

5. On the processor, press the reset button to reset the force.

Fig 5. Reset Button

6. Press start on the processor.

Fig 6. Start Button

7. Press down on the OP Panel.

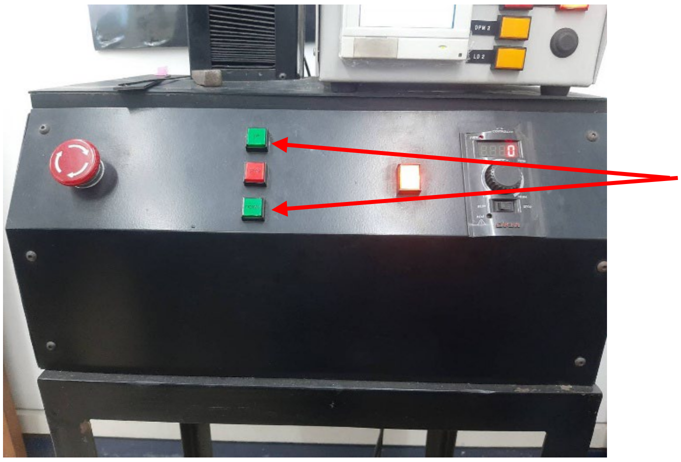

Fig 7. Up and Down Button

8. Wait for the specimen to break and record the force.
9. Press Stop button.
10. remove the specimen on the chuck.

3.2 Refinement of Parameter Determination (Data 1)

This research is taken from a journal entitled Evaluation of the Mechanical Properties of 3D Printed Carbon Fiber Composites. This experiment uses triangular, rectangular, hexagonal parameter variations, and the percentage density used is 25%, 50%, and 75% [6].

The following are the research factors and levels for this experiment

Table 2. Factors and Levels [6]

Factor	Units	Level		
		1	2	3
Infill Pattern	-	Triangular	Rectangular	Hexagonal
Percentage Density	%	25	50	75

3.3 Determine the Orthogonal Matrix Design (Data 1)

An orthogonal matrix is a square matrix whose inverse is equal to its transpose, the rows in an orthogonal matrix are unit vectors, where the dot product between two different rows is zero [7]. The selected factor is 2 while the selected level is 3. The calculation of the orthogonal matrix in this experiment is as follows [8]

Orthogonal Matrix = (Factors) x (Level – 1) .... (1)

Orthogonal Matrix = (2) x (3 – 1) = 4

So the orthogonal matrix form is $L_4\left(3^2\right)$, then by reviewing the orthogonal matrix that is in accordance with the research standards and Minitab 21 software, the orthogonal matrix $L_9\left(3^2\right)$ is selected.

Table 3. Orthogonal Matrix Design

Experiment	Factor		Tensile Strength (MPa)
	(A) Infill Pattern	(B) Percentage Density	
1	1	1	15.57
2	1	2	17.30
3	1	3	18.62
4	2	1	14.81
5	2	2	19.11
6	2	3	23.16
7	3	1	15.70
8	3	2	17.34
9	3	3	19.40

3.4 S/N Ratio Calculation (Experiment 1)

$$S/NR = -10\text{Log}\left[\frac{1}{n}\sum_{i=1}^{n}\left(\frac{1}{y_i^2}\right)\right] \quad \text{.......... (2)}$$

Description:

S/NR = Signal to Noise Ratio (Larger is Better)

n = Number of Experiment

y_i = Observation data

S/NR calculation for experiment 1

$$S/_{NR} = -10\text{Log}\left[\frac{1}{1}\left(\frac{1}{15.57^2}\right)\right] = 23.85$$

Then the results of the above calculations are sought averaged to determine the effect of levels on each research factor.

3.5 Calculation of the Effect of Level and Factor on Tensile Strength (Data 1)

Calculation of the S/N ratio value of tensile strength through a combination of levels of each factor as an example can be seen below

$$v_1 = \frac{23.85+24.76+25.40}{3} = 24.67$$

Table 4. S/N Ratio Response Tensile Strength

Level	A (Infill Pattern)	B (Infill Density)
1	24.67	23.72
2	25.44	25.06
3	24.82	26.15
Delta	0.77	2.43
Rank	2	1

From the data above, which has the highest difference is the percentage of density.

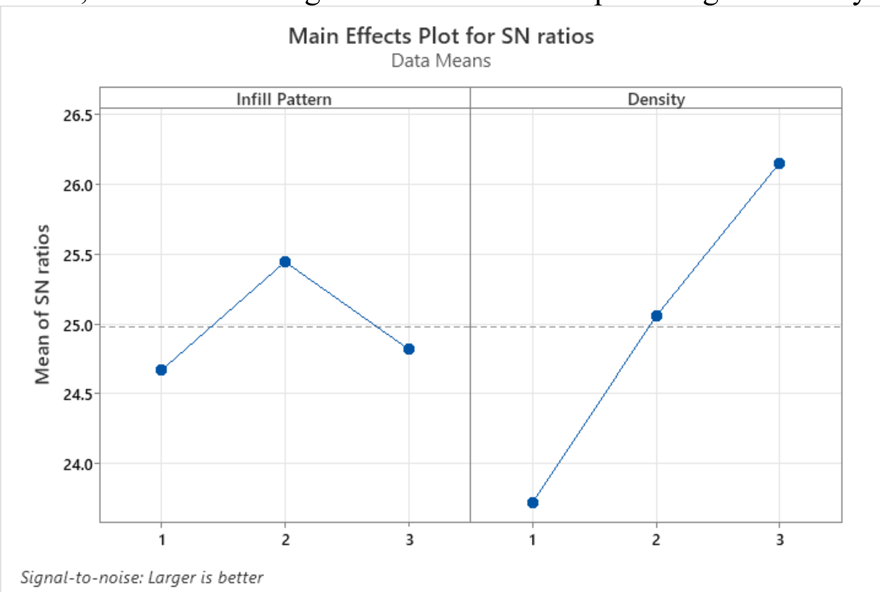

Fig 3. S/NR on Tensile Strength

Figure 3 is a graph from Table 4 showing the S/N ratio to tensile strength, which shows that infill density has a significant effect on tensile strength.

So the target value of Larger is Better is the average value of the S/N ratio of the highest level of each factor based on Table 4, namely:

Infill Pattern, A2 = Rectangular

Percentage Density, B3 = 75%

3.6 Refinement of Parameter Determination (Data 2)

This research is taken from a journal entitled Comparing mechanical properties of composites structures on Onyx base with different density and shape of fill [9]. This experiment uses triangular, rectangular, hexagonal parameter variations, and the percentage density used is 25%, 50%, and 75%.

The following are the research factors and levels for this experiment

Table 5. Factors and Levels [8]

Faktor/Parameter	*Units*	Level

		1	2	3
Infill Pattern	-	Hexagonal	Triangular	Rectangular
Infill Density	%	40	60	80

3.7 Determine the Orthogonal Matrix Design (Data 2)

The selected factor is 2 while the selected level is 3. The calculation of the orthogonal matrix in this experiment is as follows (Software, 2012)

Orthogonal Matrix = (Factors) x (Level – 1) .... (1)

Orthogonal Matrix = (2) x (3 – 1) = 4

So the orthogonal matrix form is $L_4\left(3^2\right)$, then by reviewing the orthogonal matrix that is in accordance with the research standards and Minitab 21 software, the orthogonal matrix $L_9\left(3^2\right)$ is selected.

Table 6. Orthogonal Matrix Design

Percobaan	Faktor		*Tensile Strength* (MPa)
	(A) *Infill Pattern*	(B) *Infill Density*	
1	1	1	11.94
2	1	2	11.72
3	1	3	15.17
4	2	1	11.00
5	2	2	10.94
6	2	3	12.00
7	3	1	13.56
8	3	2	15.56
9	3	3	22.72

3.8 S/N Ratio Calculation (Experiment 2)

S/NR calculation for experiment 1

$$S/NR = -10Log\left[\frac{1}{1}\left(\frac{1}{11.94^2}\right)\right]$$

S/NR = 21.54

Then the results of the above calculations are sought averaged to determine the effect of levels on each research factor.

3.9 Calculation of the Effect of Level and Factor on Tensile Strength (Data 2)

Calculation of the S/N ratio value of tensile strength through a combination of levels of each factor as an example can be seen below

$$v_1 = \frac{21.54 + 21.39 + 23.62}{3} = 22.18$$

Table 7. S/N Ratio Response Tensile Strength

Level	A (Infill Pattern)	B (Infill Density)
1	22.18	21.67
2	21.06	22.00
3	24.54	24.11
Delta	2.36	2.44
Rank	2	1

From the data above, which has the highest difference is the percentage of density.

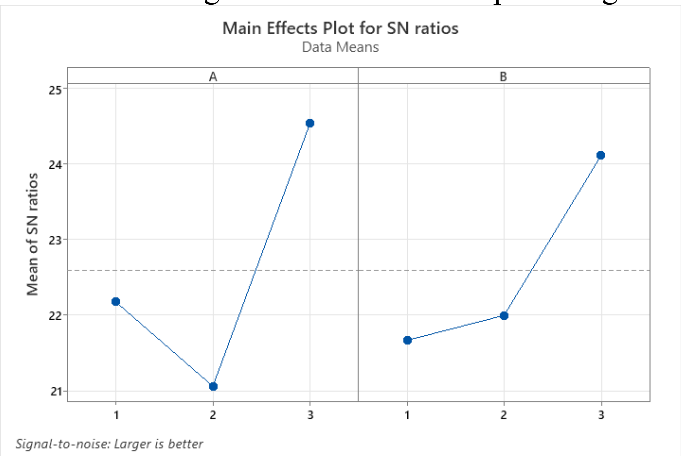

Fig 4. S/NR on Tensile Strength

Figure 4 is a graph from Table 7 showing the S/N ratio to tensile strength, which shows that infill density has a significant effect on tensile strength.

So the target value of Larger is Better is the average value of the S/N ratio of the highest level of each factor based on Table 7, namely:

Infill Pattern, A3 = Rectangular

Percentage Density, B3 = 80%

4. CONCLUSIONS AND SUGGESTIONS

Conclusion

The conclusion that can be drawn from this comparative study is that the parameter that has the most significant effect is the percentage density, because in the calculation of the signal to noise ratio of the two data, the biggest difference is the percentage density. The most optimal parameter configuration for the first experiment is to use a rectangular infill pattern with a density percentage of 75%, while for the second experiment using a rectangular infill pattern with a density percentage of 80%. This study will be a reference and reccomendation for PT Matahari Megah as well as to be a reference when conducting tensile testing using parameter variations for thesis data.

Suggestions

In the analyzed experiments, both papers did not explain in detail the research and data collection procedures, and this lack of procedures will be done in the thesis later.

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