IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Characteristics of Tensile And Impact Strength Of Fiber-owder Hybrid Composite Subjected With Uniaxial Preloading

To cite this article: T Oerbandono 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **494** 012072

IOP Conf. Series: Materials Science and Engineering **494** (2019) 012072 doi:10.1088/1757-899X/494/1/012072

Characteristics of Tensile And Impact Strength Of Fiber-Powder Hybrid Composite Subjected With Uniaxial Preloading

T Oerbandono
Mechanical Engineering Department, Brawijaya University
Jl. Mayjen Haryono 167, Malang 65145, Indonesia

Abstract. Hybrid Composite is a composite consisting of two or more materials combined at a macroscopic level. The Hybrid Composite consists of inorganic and organic materials. It is an alternative material that has special properties and can replace metals. Uniaxial preloading which was applied to reinforcement fibers before curing process to produce *compressive residual stress*. This study aimed to obtained the characteristics of the tensile and impact strength of hybrid composite subjected with uniaxial preloading on *reinforcement fiber*. The hybrid composite consists of C-Glass fiberglass woven roving, coconut shell powder and vinylester resin. The composite manufacturing method in this study was the hand lay up. The uniaxial preloadings were 0N, 50N, 100N, 150N, and 200N. Tensile test was based on ASTM D 3039 standard while impact test based on ASTM D6110-04. The experimental results shown that the application of uniaxial preloading on reinforcing fibers increased the tensile strength and impact strength of hybrid composites. The lowest tensile strength of hybrid composites 71.58N/mm^2 occurred in the uniaxial preloading 0N or without preloading. The highest tensile strength 106.05 N/mm^2 occurred in uniaxial preloading 200N. Hybrid composite specimens without uniaxial preloading had the lowest impact strength of 1.34 J/mm^2 and the highest impact strength of hybrid composites of 15.09 J/mm^2 occurred in uniaxial preloading 200N.

E-mail: toerbandono@ub.ac.id

1. Introduction

The development of materials technology has delivered a new material formed from several materials. This material is called composite. The use of composite as an alternative to metal replacement in the field of engineering is increasingly widespread. This is because the advantages possessed by composites such as lighter structures, their strength can be designed according to the loading direction, and the price is relatively cheaper. This research produces Fiber-Powder Reinforcement Composite. This is Hybride Composite which consists of reinforcing fibers in the form of inorganic materials and coconut shell powder which is an organic material.

Scherf and Wagner [7], in their research examined the effect of pre-tension applied to single fiber composites. The results showed that pre-tension fibers significantly affected the number of pieces as well as shear strength. The study explaines that the number of fiber pieces in a composite tensile test increased when the pre-tension fibers increased. Calculation of stress, shear strength, also performed by Scherf and Wagner. From the calculation it was obtained that the shear strength at the interface increased as a result of the pre-tension increase in single fiber composites.

Moallemzadeh, et.al. [1] in his research explainss the effect of tension, compression and hybrid preload on composite plates E-glass polyester which gets high speed impact at a speed range of 185 m/s to 235 m/s. Six layers, E-glass plain weave woven composite roving panels made with the hand lay up method. The results show that ballistic resistance from samples with different preload conditions decreased compared to samples that did not get preloading.

This study aims to determine the characteristics of the tensile and impact strength of Hybrid Composite which subjected with uniaxial pre-loading on reinforcing fibers. The purpose of this uniaxial preloading is to increase the tensile strength and impact strength of Composite. The materials used in this study were c-glass reinforcing fiber, coconut shell powder with 80 mesh particle size and vinylester resin as the matrix. Giving pre-loading on Hybrid Composite reinforcing fibers to produce residual compressive stress that will increase composite tensile strength. While mixing of coconut shell powder on the vinyl ester resin matrix serves as an damper and impact energy absorber.

2. Method

This research was true experimental research. Specimens for tensile and impact strength test were made using the Hand Lay Up method. This method is a simple and effective method because it can be done using a simple tool. In this method the fibers were placed on the mold, then the resin was poured and flattened using a roller so that it filled the gap evenly. The Fiber-Powder Reinforcement Hybrid Composite composition in this study consisted of fiberglass, coconut shell powder and vinyl ester resin.

2.1. Composite ingredients

The composition of Fiber-Powder Reinforcement Composite in this study consisted of fiberglass, coconut shell powder and vinyl ester resin.

Figure 1. Fiberglass woven roving

Fiberglass used in this study was woven roving type as shown in Figure 1. This type has a form of webbing which was made to overlap each other alternately so that it could distribute the load evenly in the vertical and horizontal direction. Table 1 shows the physical and mechanical properties of C-fiberglass used in the study.

Table 1. Properties of C-fiberglass

Area Weight	**600 ± 10g/m^2**
Moisture	1% Max

Loss of Ignition	0,5 ± 0,2
Type of glass	C-glass
Density g/cm^3	
Warp	3,0 ± 0,3
Weft	2,9 ± 0,3
Breaking Strength N	
Warp	3500 ± 100
Weft	3100 ±100
Oil Content	0,5-2,0%

The resin used in the study was vinyl ester ripoxy™ R-802EX produced by Showa Highpolymer Co., Ltd. Ripoxy™ combines cured properties of epoxy resin and workability of unsaturated polyester resins. Characteristics of resins are explained in table 2.

Table 2. Physical properties of cured resins [8]

Test Item	**Unit**	**Ripoxy™ R-802EX**
Liquid Property		
Viscosity	dPa – s/25°C	4~6
Density	g/cm^3	1.134
Properties of cast resin*[1]		
Tensile strength*[2]	MPa	80
Tensile modulus*[2]	GPa	3.0
Tensile elongation*[2]	%	6.0
Flexural strength*[2]	MPa	130
Flexural modulus*[2]	GPa	2.8
Compressive strength / yield point	(MPa)	120
Impact strength (Charpy)	KJ/m^3	6.9
Fatigue life*[4]	Times	500
Curing shrinkage percentage	%	7.8
FRP Properties*[5]		
Tensile strength*[6]	MPa	102
Tensile modulus*[6]	GPa	6.3
Tensile elongation*[6]	%	2.3
Flexural strength*[7]	MPa	132
Flexural modulus*[7]	GPa	6.1

Source: (Showa Denko K.K)

Coconut shell is a hard layer with a thickness between 3-5 mm. The hardness is caused by the silicate content (SiO_2) found in the shell. The percentage of coconut shell ranges from 15% -19% of the cocnut total weight. The coconut shell powder in this study had an 80-mesh particle size as shown in Figure 2.

Figure 2. Coconut shell powder

2.2 *Research Variables*

The independent variable in the research was uniaxial preloading applied to reinforcing fibers. The uniaxial preloading values used in the experiment were 0N, 50N, 100N, 150N, and 200N. The dependent variable in this study were the tensile strength and impact strength of hybrid composite. This experiment used controlled parameters. The following are the controlled parameters

- Percentage of coconut shell powder was 20% of the volume of Hybrid Composite.
- The percentage of catalyst was 2.5% of the matrix volume.
- The amount of reinforcement fiber in the longitudinal direction = 4
- Number of transverse reinforcement fiber = 62
- Curing using room temperature.

The uniaxial preloading on composite reinforcing fibers were applied in the longitudinal direction, as illustrated in figure 3.

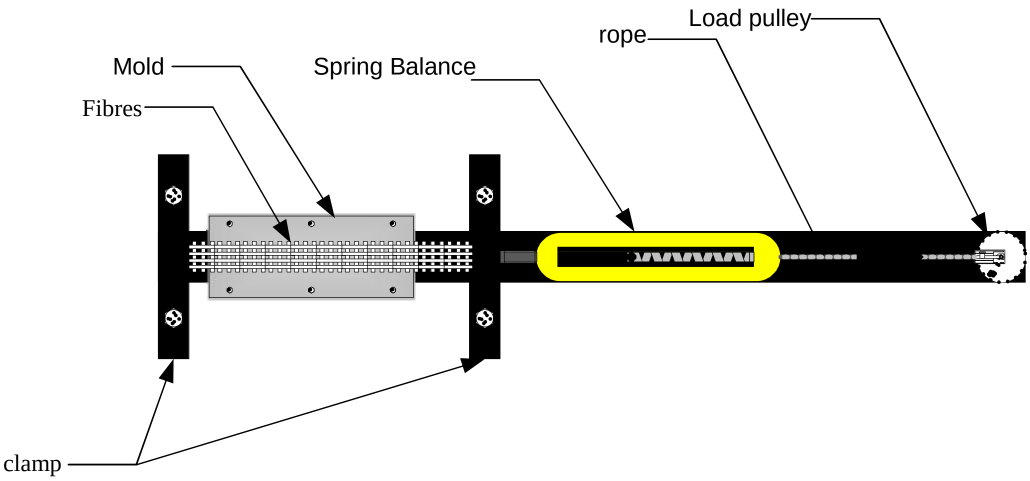

Figure 3. Uniaxial preloading on composite reinforcing fibers

The preloading direction on reinforcement fibers of hybrid composite could be illustrated in figure 4.

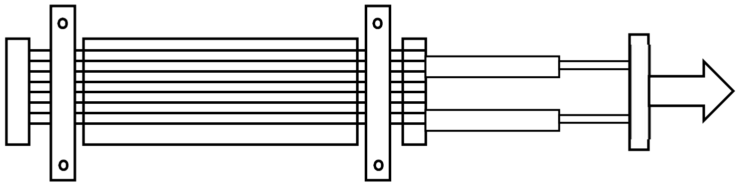

Figure 4. Direction of uniaxial preloading

Figure 4 illustrated that the reinforcing fibers were clamped at both ends and were pulled in one direction (*longitudinal direction*). The tensile force applied to C-glass reinforcing fibers was still within the elastic limit. The tensile force will be released when the composite has passed curing time. Compressive residual stress that occurs in hybrid composites can be explained in Figure 5 below.

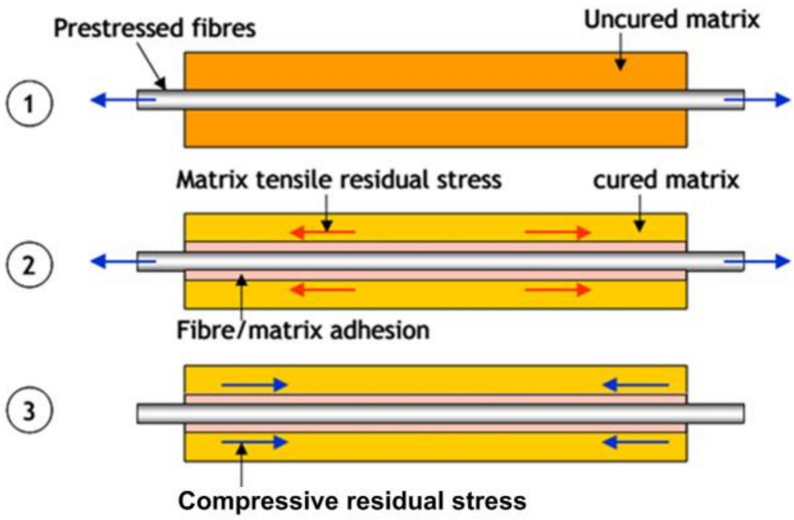

Figure 5. Illustration of compressive residual stress
1) fibers were pulled before curing.
2) the matrix was attached to the fibers and produced a tensile stress
3) forces were released from the fibers after the resin dried

Before the matrix is poured fiber, it is pulled-out with a certain force in the elastic boundary. Then the matrix is poured until it dries and sticks to the fiber. After the matrix dries the tensile force is released, the fiber will produce a reaction force that is opposite to the pull direction so that there is a compressive residual stress on the composite.

2.3. *Tests of Hybrid Composite Specimens*
Hybrid composite specimen tests consists of tensile and impact tests. Tensile test was carried out to determine the tensile strength of specimens due to uniaxial preloading applied to c-glass reinforcement fibers. Tensile tests on hybrid composites were carried out using universal testing machine.

IOP Conf. Series: Materials Science and Engineering **494** (2019) 012072 doi:10.1088/1757-899X/494/1/012072

Figure 6. Universal testing machine

Meanwhile the impact strength testing using Charpy impact testing. This test is to determine the ability of specimens to absorb impact energy as a result of adding coconut shell powder particles. Figure 7 is an example of a Charpy type impact testing machine.

Figure 7. Charpy impact testing machine

3. Results and Discussions

3.1 *Tensile Test*

Table 3 below was the tensile test results of hybrid composite specimen. The table shows the tensile strength values of specimens with various uniaxial preloading.

Table 3. Tensile test results

	Uniaxial Preloading (N)				
	F0 = 0	F1 = 50	F2 = 100	F3 = 150	F4 = 200
repetition	Tensile Strength (N/mm²)				
1	70.55	99.57	86.86	104.12	114.72
2	73.69	75.92	102.35	84.38	100.85
3	70.51	70.91	77.29	122.03	102.59
Total	214.75	246.40	266.50	310.53	318.16
mean	71.58	82.13	88.83	103.51	106.05

From table 3 known that the mean value of hybrid composite tensile strength without pre-loading was around 71.58N/mm². The average tensile strength of composites with uniaxial preloading 50N was 82.13N/mm². The uniaxial preloading 100N had average tensile strength of 88.83N/mm². The average tensile strength of uniaxial preloading 150N was 103.51N/mm^2 and the uniaxial preloading 200N was 106.05 N/mm^2.

Based on the results of the tensile test in Table 3, a graph can be drawn for illustrating the relation between uniaxial preloading and the tensile strength of hybrid composite as shown below.

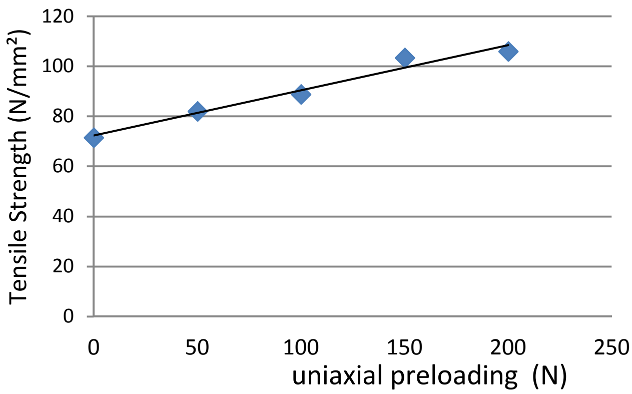

Figure 8. Relationship between uniaxial preloading and tensile strength of Hybrid Composite

From Figure 8 it is known that the application of uniaxial preloading to composite reinforcing fibers before the curing process has resulted an increase in tensile strength.

3.2 *Impact Test*

From the impact test results a table can be made which shows the impact strength of hybrid composites due to variation of uniaxial preloading applied to reinforcing fibres. Table 4 below is the results of impact tests on hybrid composites

Table 4. The results of the impact test on hybrid composites

Repetitions	Uniaxial Preloading (N)				
	F0 = 0	F1 = 50	F2 = 100	F3 = 150	F4 = 200
	Impact Strength (J/mm^2)				
1	0.46	4.55	16.28	16.28	12.71
2	2.00	11.99	3.80	16.28	16.28
3	1.57	4.55	11.99	3.80	16.28
Total	4.02	21.08	32.07	36.36	45.26
mean	1.34	7.03	10.69	12.12	15.09

From Table 4, it was known that the lowest impact strength of 1.34 (J/mm^2) occurred in hybrid composites without uniaxial preloading. The impact strength of hybrid composites increased with increasing of uniaxial preloading. The highest impact strength of 15.09 (J/mm^2) occurred in hybrid composites subjected with uniaxial preloading 200N.

Based on the data from the impact test results in table 4, a graph can be made that illustrates the correlation between the one directional pre-loading on the reinforcing fiber to the tensile strength of Hybrid Composite as shown in Figure 9 below.

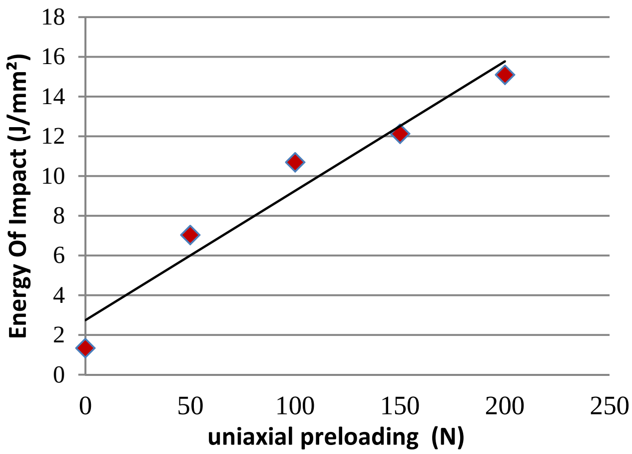

Figure 9. The relationship between uniaxial preloading and impact strength of hybrid composites

Figure 9 shows that the application of uniaxial preloading to reinforcing fibers of hybrid composite before the curing process had resulted an increase in the impact strength of composite.

4. Conclusion

From the test results it can be concluded that the application of uniaxial preloading on hybrid composite reinforcing fibers increased the tensile strength and impact strength of hybrid composites. The lowest tensile strength and impact strength of hybrid composites occurred in specimens without uniaxial preloading which were 71.58 N/mm^2 for and 1.34 J/mm^2. The highest tensile strength and impact strength obtained in specimens with uniaxial preloading 200N which were 106.05 N/mm^2 and 15.09 J/mm^2.

The increase in tensile strength of hybrid composites occured due to the presence of *compressive residual stress*. This means that a higher tensile strength was needed for breaking up hybrid composites specimen in a tensile test. The increase in impact strength of hybrid composite was caused by the addition of coconut shell powder particles. The particles had a function as impact energy absorbers during impact strength test.

References

[1] Alireza Moallemzadeh, Ali Sabet Ali, Sabet H. Abedini, *Preloaded Composite Panels under High Velocity Impact*, December 2017, International Journal of Impact Engineering 114.
[2] ASM International. (2001). *Composites.* ASM Intrnational.
[3] ASTM International. (2004). D 6110 - 04.
[4] ASTM International. (2010). Standard Test Method for Tensile Properties of Fiber Glass Composite. *ASTM D 3039.* Autar. (2006). *Mechanics of Composite Material.* New York: Taylor and Francis Inc.
[5]. *Matthews, F. L. (1999). Composite Material ; Engineering and Sience. England: Woodhead Publishing Limited.*
[6]. Mazumdar. (2002). *Composites Manufacturing.* New York: CRC Press LLC.
[7]. Scherf, J, H. D. Wagner, "*Interpretation of Fiber Fragmentation in Carbon-Epoxy Single Fiber Composites*: *Possible Fiber Re-tension Effects*", Poly. Eng. and Sci., Vol. 32, No. 1, February 1992, pp. 298-304
[8]. Showa Denko K.K. (n.d.). *Ripoxy Data Sheet.*