TiMER

Trends in Mechanical Engineering Research

THE EFFECT OF VOLUME FRACTION AND FIBER LENGTH ON THE TENSILE AND IMPACT STRENGTH OF SILK FIBER REINFORCED COMPOSITES

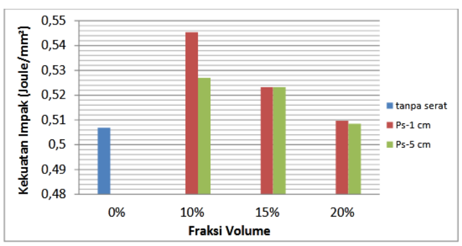
Sinarep Sinarep[a], Ardani Muhamad[b], Salman Salman[b], Iman Saefuloh[b], Zainuri Ahmad[a]*

[a] Department of Mechanical Engineering, Faculty of Engineering, Universitas Mataram, Mataram, NTB, Indonesia

[b] Department of Mechanical Engineering, Faculty of Engineering, Universitas Sultan Ageng Tirtayasa, Serang, Banten, Indonesia

*Corresponding author: a.zainuri@unram.ac.id

Graphical abstract



Article history
Received
26 June 2023
Received in revised form
28June 2023
Accepted
29 June 2023
Published
30 June 2023

Abstract

Material engineering technology every year always makes new breakthroughs in creating high-quality materials and have an adequate contribution. Natural fiber reinforced composite material is one of the materials currently used as fillers in composite products. Composite with natural income also has a variety of advantages offered, namely low prices and abundant availability. This study discusses the fraction of fiber volume and fiber length on the tensile strength and impact of fiber reinforced silk fibers (Samia chynthia rucini). In this study the volume fractions of fiber used were 10%, 15% and 20% with a fiber length of 10 mm and 50 mm using an epoxy resin matrix. From the composite tensile test results prove the increase in tensile strength obtained increases the volume of silk fiber in the composite. 20% with a fiber length of 10 mm is 6.859 MPa, while the lowest tensile strength value in composites with a fiber volume fraction of 0% is 1.653 MPa. The impact test shows the strength of 10% fiber volume fraction composite with 10 mm fiber length that is 0.54535 J/mm^2, while the lowest impact strength value is 0% fiber volume fraction composite that is 0.50686 J/mm^2.

Keywords: Composite, Silk Fiber, Epoxy Resin, Tensile Strengt, Impact Strength.

Abstrak

Teknologi material setiap tahunnya selalu membuat terobosan baru dalam menciptakan material berkualitas tinggi. Material komposit bertulang serat alam merupakan salah satu material yang digunakan sebagai bahan pengisi pada produk komposit. Komposit dengan natural income juga memiliki berbagai keunggulan yang ditawarkan yaitu harga yang murah dan ketersediaan yang melimpah. Penelitian ini membahas fraksi volume serat dan panjang serat terhadap kekuatan tarik dan impak serat sutera yang diperkuat serat (Samia chynthia rucini). Pada penelitian ini fraksi volume serat yang digunakan 10%, 15% dan 20% dengan panjang serat 10 mm dan 50 mm menggunakan matrik resin epoksi. Hasil uji tarik membuktikan peningkatan pada kompositd fraksi volume 20% dengan panjang serat 10 mm adalah 6,859 MPa, sedangkan nilai kekuatan tarik terendah pada komposit fraksi volume serat 0% adalah 1,653 MPa. Uji impak menunjukkan kekuatan komposit fraksi volume serat 10% dengan panjang serat 10 mm yaitu 0,54535 J/mm^2, sedangkan nilai kekuatan impak terendah pada komposit fraksi volume serat 0% yaitu 0,50686 J/mm^2.

Kata kunci: komposit, serat sutra, resin epoxy, kuat tarik, kuat *impact*

1.0 INTRODUCTION

Many studies have been carried out towards the development of composites, especially composites

Fibers can be classified based on their origin, namely natural fibers and artificial fibers. Natural fibers consist of animal protein fibers and plant fibers. One of the natural fibers derived from animal protein is silk fiber. Silk fiber contains fibroin which makes the mechanical strength of the fiber high. It has good flexibility and bicompatibility, and has little water absorption ability. Silk fiber is a natural protein fiber that comes from silkworms. There are several types of silkworms such as the mubei silkworm (bombyx moriL) which are mostly cultivated throughout the world because they are able to produce silk fibers that are soft and smooth and have relatively good mechanical strength. (Sumantri, 2017).

Silk fiber when spun by silkworms comes out of two adjacent holes, raw: fibroin (fiber) 76%, sericin (adhesive) 22%, wax 1.5%, mineral salts 0.5% (Ichwan, 2013). The other types of silkworms are the silkworm Attacus atlas, Cricula trifenestrata heef, Samia Cynthia rucini. These three types of silkworms are types of wild silkworms that usually live in forests and consume different foods, such as mahogany tree leaves, jatropha tree leaves and cassava leaves. Research on natural fiber reinforcing composites was carried out in line with the progress of exploitation of the use of natural materials in everyday life. To obtain high mechanical properties, natural fibers have been given a variety of treatments that can improve their mechanical properties (Widiartha, I.G dkk, 2012).

The development of silk fiber in Indonesia will provide opportunities for the community to cultivate more widely in order to support the people's economy. Silk fiber is a necessity for industries that need silk fiber, such as the textile industry for the purposes of designing clothes. Apart from the main benefits of silk fiber, the use of silk fiber as a reinforcement material for composite structures is still very minimal. Moreover, the type of silk fiber produced by different types of silkworms, such as silkworms that eat cassava leaves (Samia cynthia rucini).

The purpose of this study was to determine how much influence the volume fraction of silk fiber (samia chynthia rucini) 10%, 15% and 20% with a fiber length of 10 mm and 50 mm with an epoxy matrix had on the tensile strength and impact strength of the composite.

2.0 METHODOLOGY

Silk fiber (samia chynthia rucini) was extracted from silkworm cocoons with 80˚C water for 40-60 minutes to remove sericin, wax and mineral salts contained in the silk fiber, then dried in the sun with the aim of reducing the water content contained in silk fibres. Next, the sliver process is carried out to make yarn with a carded model and cut silk fibers with a size of 10 mm and 50 mm.

Figure 1. Silk fiber

Epoxy resin is used as a binder (matrix) in the process of making silk fiber composites (samia chynthia rucini) with a ratio of epoxy to hardener of 2:1

2.1. Making molds and specimens

Making tensile test specimen molds using silicone rubber sheets with a thickness of 6 mm. The standard dimensions of the tensile test specimens use the ASTM D3039M-00 standard. For impact test specimens using multiplex and insulation with a thickness of 12.90 mm. The standard dimensions of the impact test specimens use the ASTM D256-04 standard. The fiber used in the manufacture of composites is silk fiber (samia chynthia rucini) with random fiber orientation. The composite manufacturing process is as follows:

1. Tools and materials are prepared in advance according to the fiber length of 10 mm and 50 mm, with a volume fraction of silk fiber of 10%, 15% and 20%.
2. The matrix used is epoxy resin and hardener with a ratio of 2:1
3. Prepare a tensile test specimen mold according to ASTM D3039M-00 standard and an impact test specimen mold according to ASTM D256-04 standard.
4. Silk fiber is weighed according to the calculation of the mass fraction of the fiber volume of 10%, 15% and 20%.
5. Pouring the epoxy resin matrix into the specimen mold.
6. Closing the mold using a sheet of glass
7. Coating the cover of the mold with a sheet of wood so that the glass does not break when pressed using a clamp.
8. Put pressure on the mold by using a clamp so that the specimens produced are in accordance with the standards used. 9. Waiting for the composite to harden for 8-10 hours so that it is completely dry.
10. Removing the finished specimens on the mold using the help of a cutter.

2.2. Testing of specimens

a. Tensile strength test

The tensile strength test is one of the mechanical stress-strain tests that aims to determine the strength of the material against tensile forces or to obtain the modulus of elasticity of the silk fiber composites used in this study. The dimensional standard used for tensile test specimens is the ASTM D3039M-00 standard.

The composite tensile test steps are as follows:

1. The first step is to measure the dimensions of thetensile test specimen first including length (l), width (b) and thickness (d).
2. Then the tensile test specimen is installed right on the two clamps and it is confirmed that the load reading shows zero.
3. Next, the operator inputs the specimen data.
4. The pulling speed is 10 mm/minute
5. Specimen testing process.
6. Take a picture of the fracture of the tensile test specimen.

b. Impact strength test

Impact test is a test using fast loading or shock loading which is carried out on the impact test object. The impact test aims to measure the resistance of the composite composition to shock loads. The shape and dimensions of the test specimens in the impact test in this study refer to ASTM D256-04

The procedures for impact testing are as follows:

1. The first step is to measure the dimensions of the specimen first including length (l), width (b), thickness (d).
2. Then measure the depth of the notch on the specimen.
3. Then install the test object on the pedestal and pay attention to the position of the notch.
4. Calibrate the impact tester.
5. Then lift the pendulum and release the lever.
6. Then record the value of the energy absorbed to break the test object and observe the fracture that occurs

3.0 RESULTS AND DISCUSSION

3.1. Tensile strength

Tensile test was carried out to determine how much influence the volume fraction of silk fiber (samia chynthia rucni) 10%, 15% and 20% had with a fiber length of 10 mm and 50 mm with an epoxy matrix. Tensile strength testing was carried out at the Physics Laboratory, Faculty of Mathematics and Natural Sciences, University of Mataram.

The following is a graph of the average values of stress and strain of the composite on the volume fraction of silk fiber 10%, 15% and 20% with fiber lengths of 10 mm and 50 mm.

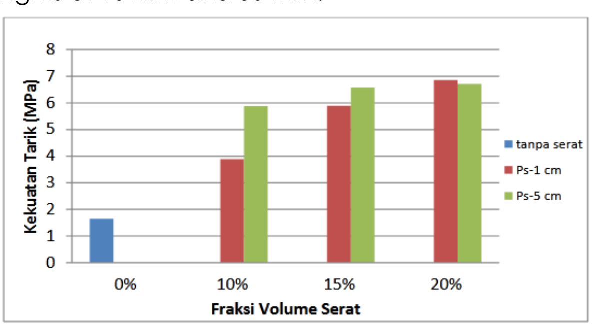


Figure 2. The relationship between tensile strength and fiber volume fraction and fiber length

In Figure 2 the highest tensile strength value of the silk fiber composite (samia chynthia rucini) is found in the 20% fiber volume fraction with a fiber length of 10 mm, namely 6.859 MPa. Followed by a 20% fiber volume fraction with a fiber length of 50 mm, which is 6.706 MPa. Then in the fiber volume fraction of 15% with a fiber length of 50 mm, a tensile strength value of 6.578 MPa was obtained.

Then followed by a 15% fiber volume fraction with a fiber length of 10 mm with a tensile strength value of 5.888 MPa, a 10% fiber volume fraction with a fiber length of 50 mm with a tensile strength value of 5.878 MPa and a 10% fiber volume fraction with a fiber length of 10 mm is obtained tensile strength value of 3.884 MPa. Whereas the lowest tensile strength value is found in composites with 100% epoxy composition (without fiber), namely 1.653 MPa.

The tensile strength of each test specimen increases with increasing composition of the fiber volume fraction in the matrix starting from specimens with a composition of 0% fiber and 100% epoxy with the lowest tensile strength value of 1.653 Mpa, while the highest tensile strength is obtained in specimens with a composition of 20% fiber and 80% epoxy which is 6.859. With these data, the increase in fiber volume fraction in silk fiber composites (samia chynthia rucini) results in an increase in the tensile strength value. And based on the data there was an increase in tensile strength from 0% fiber to 20% fiber, namely 24.09%.

Whereas the effect of fiber lengths of 10 mm and 50 mm applied to the composites shows that the test specimens with a composition of fiber volume fraction of 10% and 15% show that fiber lengths of 50 mm have a high tensile strength value than specimens with a length of 10 mm. However, in specimens with a fiber volume fraction composition of 20%, it is inversely proportional to specimens of 10% and 15%. Where the fiber length of 10 mm has a higher tensile strength value than the fiber length of 50 mm. Based on the tensile test data reference, the factor that affects the tensile strength value of the 20% fiber volume fraction specimen with a fiber length of 10 mm is higher than the 20% fiber volume fraction specimen with 50 mm fiber length is the dimension factor of the test specimen which is not homogeneous.

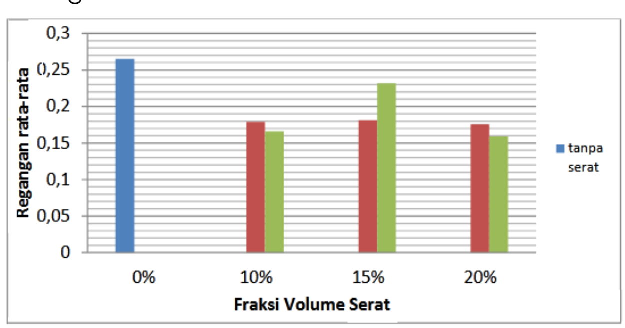


Figure 3. Relationship of strain with volume fraction and fiber length.

In Figure 3 the highest average strain value is found in specimens with a composition of 0% fiber and 100%

epoxy, namely 0.265, then specimens with a fiber volume fraction of 15% with a fiber length of 50 mm with a strain value of 0.232. Then specimens with a fiber volume fraction of 15% with a fiber length of 10 mm have an average strain value of 0.181 and specimens with a fiber volume fraction of 10% with a fiber length of 10 mm have an average strain value of 0.179. Whereas the 20% fiber volume fraction specimen with 10 mm fiber length had an average strain value of 0.176, the 10% fiber volume fraction specimen with 50 mm fiber length obtained an average strain value of 0.161 and the 20% fiber volume fraction specimen with fiber length 50 mm has an average strain value of 0.157.

The relationship between the average strain value and the volume fraction of silk fiber reinforced composites (samia chynthia rucini) shows that specimens with a composition of 0% fiber and 100% have higher average strain values compared to specimens with a fiber volume fraction of 10%, 15 % and 20%. As for the effect of fiber lengths of 10 mm and 50 mm applied to the composite, it was shown that the test specimens with a composition of 10% and 20% fiber volume fraction with a fiber length of 10 mm had an average strain value higher than that of a fiber length of 50 mm. Whereas for specimens with a fiber volume fraction of 15%, it was inversely proportional, where the average strain value of 50 mm fiber length was higher than the average strain value of the composite with 10 mm fiber length.

The following is a graph of the average value of the composite modulus of elasticity at volume fractions of 10%, 15% and 20% silk fiber with fiber lengths of 10 mm and 50 mm.

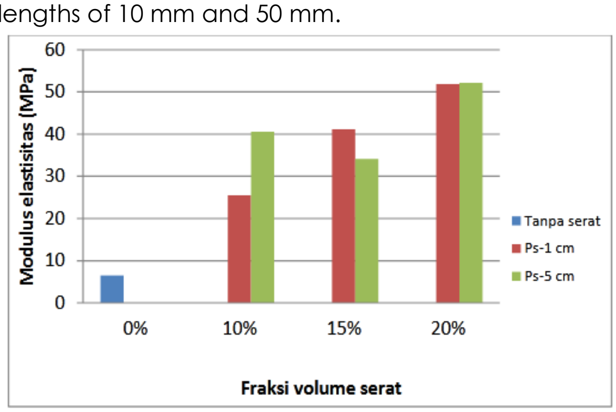


Figure 4. The relationship between the modulus of elasticity and the volume fraction and fiber length

From the research results also obtained the average value of the modulus of elasticity of each specimen at the fiber volume fraction of 10%, 15% and 20% with a fiber length of 10 mm and 50 mm. As seen in Figure 4, the highest average value of the elastic modulus is found in the composite with a fiber volume fraction of 20% with a fiber length of 50 mm, namely 52.148 MPa, followed by specimens with a fiber volume fraction of 20% with a fiber length of 10 mm with an average value -The average modulus of elasticity is 51.850 MPa. then specimens with a fiber volume fraction of 15% with a fiber length of 10 mm have an average modulus of elasticity of 41.1422 MPa, specimens with a fiber volume fraction of 10% with a fiber length of 50 mm have an average modulus of elasticity of 40.5464 MPa , specimens with a fiber volume fraction of 15% with a fiber length of 50 mm have an average elastic modulus value of 34.1313 MPa, next for specimens with a fiber volume fraction of 10% with a fiber length of 10 mm have an average elastic modulus value of 25, 5277 MPa. while the lowest average modulus value was found in specimens with a fiber volume fraction of 0% fiber, namely 6.5162 MPa.

For the effect of fiber lengths of 10 mm and 50 mm applied to the specimens, it shows that specimens with a fiber volume fraction of 10% and 20% with a fiber length of 50 mm have an average elastic modulus value higher than that of a fiber length of 10 mm. Whereas in specimens with a fiber volume fraction of 15% it was inversely proportional to the specimens with a fiber volume fraction of 10% and 20% where the average value of the elastic modulus with a fiber length of 10 mm was higher than that of a fiber length of 50 mm.

3.2. Impact Strength

An impact test was carried out to determine how much influence the volume fraction of silk fiber (samia chynthia rucni) 10%, 15% and 20% had with a fiber length of 10 mm and 50 mm with an epoxy matrix. The impact strength test was carried out at the Metallurgical Laboratory, Faculty of Engineering, University of Mataram.

The following is a graph of the average impact strength of composites at volume fractions of 10%, 15% and 20% silk fiber with fiber lengths of 10 mm and 50 mm.

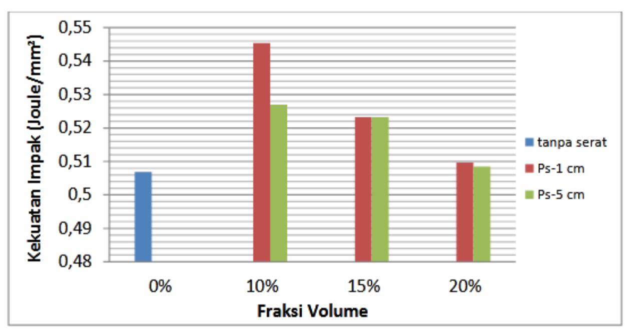


Figure 5. Relationship between impact strength and fiber length and volume fraction

A graph of the average impact strength value of each fiber volume fraction with a length of 10 mm and 50 mm is obtained. As seen in Figure 5, the highest impact strength value of silk fiber composites is found in the volume fraction of 10% fiber with a fiber length of 1 cm, which is 0.54535 J/mm^2, followed by the volume fraction of 10% fiber with a fiber length of 50 mm, which is 0.52701 J/mm^2, then at a fiber volume fraction of 15% with a fiber length of 50 mm, an impact strength value of 0.52391 J/mm^2 is obtained. Then followed by a 15% fiber volume fraction with a fiber length of 10 mm with an impact strength value of 0.52322 J/mm^2, a 20% fiber volume fraction with a fiber length of 10 mm with an impact strength value of 0.50965 J/mm^2 and a fiber volume fraction 20% with a fiber length of 50 mm obtained an impact strength value of 0.50854 J/mm^2. Meanwhile, the lowest impact strength value was found in composites with 100% epoxy composition (without fiber), namely 0.50686 J/mm^2.

It can be seen that the relationship between the average value of impact strength and fiber volume fraction of silk fiber reinforced composite (samia chynthia rucini) shows that a volume fraction of 10% has the highest impact strength value, followed by a composite with a fiber volume fraction of 15% and a fiber volume fraction of 20 %. While composites with 100% epoxy composition (without fiber) have the lowest impact strength value. With these data it shows that there was an increase in impact strength from 0% composite to 10% fiber composite with a percentage increase in impact strength of 92.94%.

As for the effect of fiber lengths of 10 mm and 50 mm applied to the composite, it shows that the test specimens with a composition of 10% and 20% fiber volume fraction with a fiber length of 10 mm have a high impact strength value compared to a fiber length of 50 mm. Whereas in specimens with a fiber volume fraction composition of 15%, it was inversely proportional to the fiber volume fraction specimens of 10% and 20%.

4.0 CONCLUSION

From the results of research and discussion of testing of silk fiber reinforced composites (samia chynthia rucini) the following conclusions can be drawn:

1. The highest tensile strength is found in the composite with a volume fraction composition of 20% silk fiber with a fiber length of 10 mm, namely 6.859 MPa. While the lowest tensile strength value is found in composites with 100% epoxy composition (without fiber), namely 1.653 MPa. while the effect of fiber length applied to the composite shows that the composite with a fiber volume fraction composition of 10% and 15% has a high tensile strength in specimens with a fiber length of 50 mm compared to specimens with a fiber length of 10 mm. On the other hand, the tensile strength of composites with a composition of 20% fiber volume fraction is inversely proportional to the tensile strength of 10% and 15% fiber volume fraction composites. Where the fiber length of 10 mm has a higher tensile strength value than the fiber length of 50 mm. Thus the higher the percentage of volume fraction of silk fiber (samia cynthia rucini) given, the higher the tensile strength value obtained.
2. The highest impact strength was found in the composite with a volume fraction composition of 10% silk fiber with a fiber length of 10 mm, namely 0.54535 J/mm^2. Meanwhile, the lowest impact strength value was found in composites with 100% epoxy (without fiber) composition, namely 0.50686 J/mm^2. With regard to the effect of fiber length applied to the composite, it shows that the composite with a fiber volume fraction composition of 10% and 20% has a higher impact strength in specimens with a fiber length of 10 mm than in specimens with a fiber length of 50 mm. Whereas the composite with a volume fraction composition of 15% silk fiber was inversely proportional to the composite fiber volume fraction of 10% and 20%. Where the highest impact strength is found in specimens with a fiber length of 50 mm compared to a fiber length of 10 mm.

Acknowledgement

The author would like to thank those who have helped carry out this research, especially the Department of Mechanical Engineering and Laboratory of the University of Mataram

References

[1] Aguswandi, Badri., M, Yohanes.,, *Analisis Sifat Mekanik Komposit Serat Sabut Kelapa Sebagai Alternatif Pengganti Kayu Untuk Pembuatan Kapal Tradisional*. Jom FTEKNIK, Volume 3 No. 2 Oktober 2016.

[2] ASTM, D, 3039M-00, 2001, Standard Test Method for Tensile Properties for Polimer Matrix Composite Materials, American Society for Testing and Materials, Philadelphia.

[3] ASTM. D 256-04, Standar Test Methods For Determining The Izod Pendulum Impact Resistance Of Plastics.

[4] Ichwan, M., Gunawan, S., Noerati, S. 2015. Bahan Ajar Pendidikan & Latihan Profesi Guru (PLPG) teknologi tekstil. Sekolah Tinggi Teknologi Tekstil. Bandung.

[5] Kurniawan, F.B.K. 2018 *Komposit Serat Bambu Dengan Variasi Orientasi Susunan Serat Sebagai Material Alternatif Peredam Suara*. Jurusan Teknik Mesin. Fakultas Sains Dan Teknologi. Universitas Sanata Dharma Yogyakarta.

[6] Moeliono.M.,Siregar.Y., 2012 *Rekayasa Bahan Baku Sutera Dan Limbah Kokon Untuk Rompi Tahan Peluru.* Jurnal Riset Industri Vol.VI No. 1

[7] Munandar, Imam. 2013. *Kekuatan tarik serat ijuk* (Arega Pinnata Merr). Jurusan Teknik Mesin Fakultas Teknik Universitas Lampung : Bandar Lampung.

[8] Suartama, I.P.G., Nugraha, I.N.P., Dantes,K.R., 2016. "*Pengaruh Fraksi Volume Serat Terhadap Sifat Mekanis Komposit Matriks Polimer Polyester Diperkuat Serat Pelepah Gebang*". Jurnal Jurusan Pendidikan Teknik Mesin. 5, (2), 5-11.

[9] Sumantri, T.D.A. 2017. Pengaruh Penambahan Serat Kepompong Ulat Sutera (Bombyxmori L.) Terhadap Kekuatan Fleksural Resin Komposit Flowable. Jurnal Skripsi. Program Studi Pendidikan Dokter Gigi. Fakultas Kedokteran Gigi. Universitas Muhammadiyah Surakarta.

[10] Wahyu.A., Sumarji., Djumhariyanto.D. 2014. *Pengaruh Variasi Panjang Serat Dan Variasi Fraksi Volume Terhadap Kekuatan Mekanik Material Komposit Polyester Dengan Penguat Serat Daun Nanas*. Jurusan Teknik Mesin. Fakultas Teknik Universitas Jember.

[11] Widiartha, I.G., Sari, H.N., Sujita., 2012. Study Kekuatan Bending Dan Struktur Mikro Komposit Polyethylene Yang Diperkuat Oleh Hybrid Serat Sisal Dan Karung Goni. Jurnal Dinamika Teknik Mesin. 2, (2), 92-98