IOP Conference Series: Materials Science and Engineering

PAPER • OPEN ACCESS

Identification of tensile strength properties of abaca fiber by weakest-linkage approach-statistic property of fiber diameter

To cite this article: Suardi *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **308** 012037

IOP Conf. Series: Materials Science and Engineering **308** (2018) 012037 doi:10.1088/1757-899X/308/1/012037

Identification of tensile strength properties of abaca fiber by weakest-linkage approach-statistic property of fiber diameter

Suardi*[1], H Homma[2], Abubakar[1]

[1]Graduate School Departement of Mechanical Engineering, Universitas Sumatera Utara
[2]Visiting Professor, Department of Mechanical Engineering, Universitas Sumatera Utara

*E-mail: suardi@usu.ac.id

Abstract. Fiber reinforced plastics or metals (FRPor FRM) are usually ecological materials, because their specific strength defined as the strengthperunit mass is much larger than metal, and weight ofmachines and structuresfor transport made ofFRP can be significantly reduced so that the consumption of fossil fuel scan be saved to result in tremendous reduction of CO2emissions. However, when we consider life cycle assessment (LCA) of synthetic fibers like carbon fiber and glass fiber, we can recognize much CO2 emission in production of these fibers. Therefore, more ecological reinforcement fibers must be developed. For this end, we should utilization cellulose fibers derived from plant tissue structure as an alternative fibers for synthetic fibers, which are considered as carbon neutral materials, and natural degraded material. This study selectsabaca fiber, which is a natural fiber and is abundant in Indonesia, but its usagehas not been optimized for engineering material. The purpose of this study is to identify the mechanical strength of a single abaca fiber by statistical approach. First, weakest link theory and Weibull theory are used to discuss experimental data. 90 specimens of almost identical geometry and biological aspects are tested under tension. These data are analyzed by Weibull theory or other statistical theory. Final target is to look into optimal method to reduce scatter ratio, ratio of standard deviation to mean value, of less than 0.1, which is the level of metallic materials. If we can reduce scatter ration to such level, we can design machines and structures using abaca fiber in the same way as carbon fibers or glass fibers. Summary of Diameter Measurement the all mean value is 0.1 and standardeviasi. The t-Test showed that mean value of each part is estimated as sampling from group with the same mean value, at confidence level of 99%.

1. Introduction

Fiber reinforced plastics or metals (FRP or FRM) are usually considered as ecological materials, because their specific strength defined as strength per unit mass is much larger than metallic materials, and weight of structures and machines for transportation fabricated by FRP can be significantly reduced so that consumption of fossil fuels could be saved and as a result, CO2 emission into the atmosphere could be tremendously decreased [1].

However, carbon fires, grass fibers, Kevlar fibers such as man-made fiber are not always ecological materials if we consider their life cycle CO2 emission. For instance, The Japan Carbon Fiber Manufacturer Association (JCMA), estimated amount of CO2 emission at production stage of carbon fibers, assembly stage of CFRP car, usage (driving) stage of the car, and scrapped stage of the car after 10 years usage (driving) [2]. Fiber composite technology is progressing very rapidly. Basically fiber is divided into two type, namely natural fibers (organic fibers) and manmade fibers (organic and non-organic).Natural fibers are fibers obtained from fruits, stems, and leaves, and the fibers are highly prospective commodities in the future as the commodity has advantages for a variety of industrial raw materials, and its significant contribution in saving the environment.Natural fibers have a single fiber which is the smallest unit of fiber that cannot be separated further mechanically, in general, a single bundle of macro fibrils. The macro fibril is composed of bundle of micro fibrils, which are cellulose chains, and are the main support of natural fiber materials [3].

Abaca (Musa Sapientum) is a plant that resembles a banana and originated in the Philippines which is a source of fiber spinning. In Indonesia, abaca banana also grows numerously in Kalimantan, North Sulawesi (especially on the island of Talaud in the village Essang) and Sumatra.

Abaca banana plant is a tropical plant that has advantages in terms of high fiber strength and wide usage for a raw material ofwrapping rope and cable in marine vessels, because of high resistance to salt water, a textile material, tea bag wrappers, wrapping tobacco, seat upholstery, crafts, cigarette paper and others.Natural fiber, especially, abaca fiber is produced in Sumatera as well as Kalimantan and Sulawesi in Indonesia as mentioned above, but its utilization for an engineering material is very limited. Main reason for this is wide scatter in mechanical properties of natural fibers. Integrity or reliability of structures and machines must be kept high enough to prevent users from fatal disaster by catastrophic failure.

According to the previous research[4], although the data on tensile strength of natural fiber is widely scattered, the scatter deceasesas the specific diameter variation rangedecreases. In order to use natural fibers for engineering materials, scatter of their tensile strength must be suppressed to the level of metallic materials. One way to suppress the scatter is to keep geometry, like a diameter, in a certain scatter band.

This research aims to evaluate diameter statistic properties of abaca fibers and to find a method to suppress the scatter of the tensile strength of abaca fibers.

2. Methodology

2.1. Abaca Fiber Preparation

Abaca fibers is used as a specimen obtained from the district of East Aceh, North Aceh and Aceh Jeumpa, Aceh Province. Then the fiber taken from the pseudo stem petals abaca has begun to bear fruit.

The following describes the of abaca fiber making process, starting from selecting, cutting and fiber-making positions on the stem or petals of abaca. Whereas the fiber starting from the position of the rod/bottom petals, because the rod/bottom petals are part of the oldest.

1. Then abaca fibers used in this study is the outer sheath item, namely strand 1 (one), 2 (two) and 3 (three).
2. Abaca petals cut to the same size of 120cm x 10cm,
3. Petals cut back to 3 (three) parts, namely the bottom, middle and top, each the size of 40cm.
4. Then the extraction is done using a wire comb. Extraction is done repeatedly, the extraction is done to separate the meat with fiber eyelids.
5. After extraction by using a wire comb, to get fiber is really clean, then soaking with clean water for 10 minutes.
6. Next step is cleaning back on the rest of the meat is still attached to the abaca fiber, using a blunt knife made repeated up to 15 times. This process also serves to straighten the fibers.
7. Once the fibers completely clean of its flesh, to get dry and strong fiber, then the fiber is dried (dried) using sunlight for one day (depending on weather).
8. Having obtained a dry fiber then conducted the election to be a single fiber tensile test specimens.

2.2. Specimen Geometry

Sample fibers are prepared as explained above. Then, an abaca single fiber specimen is prepared as follows. Each sample fiber is cut 80 mm long. Specimen gage length is 20 mm, and 30 mm both ends are molded into round grips as shown in figure 2. A grip is 30 mm long and made of plastic cylinder of which one end is closed. Careful attention was paid so as that the fiber is aligned in the center of the grip.

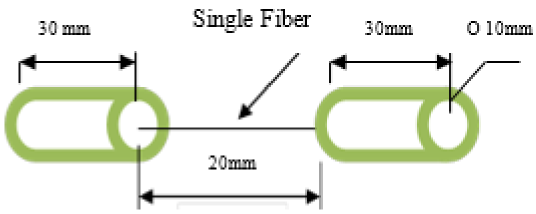

Figure 1. Specimen Geometry and Dimensions

2.3. Measurement of The Diameter
Diameter measurementis carried out using an optical digital microscope as shown in figure.3. Diameter measurement of single abaca fibers is done at three positions, near the grips, and the center of the specimen shown in figure 2. At each position, diameter is measured in two orthogonal directions as shown in figure 3. The six-measurement data for one specimen is averaged to define the specimen diameter.

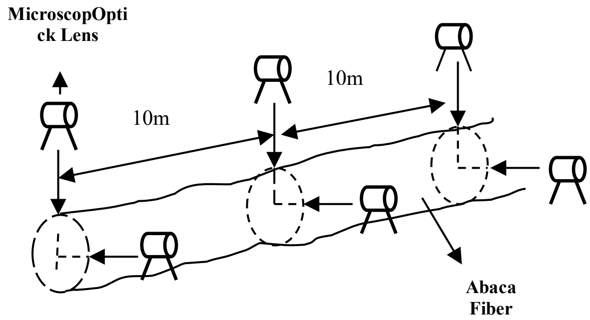

Figure 2. Schematic Diagram for Measuring The Average Diameter Of Fiber Fragment

3. Result and discussion
Diameter values measured for 30 specimens prepared from the bottom part of abaca sheathes are shown in table 1.

Table 1. Measured diameter of 30 specimens prepared from bottom part of abaca sheathes.

TP No.	Diameter	TP No.	Diameter
1	0.107	16	0.102
2	0.081	17	0.108
3	0.072	18	0.115
4	0.054	19	0.121
5	0.128	20	0.128
6	0.091	21	0.134
7	0.126	22	0.140
8	0.113	23	0.147
9	0.101	24	0.153
10	0.072	25	0.160
11	0.091	26	0.166
12	0.054	27	0.172
13	0.083	28	0.179

14	0.089	29	0.185
15	0.096	30	0.191
	Average		0.081

Using these raw data, a histogram is drawn in figure 6. According to an empirical law, 30 sample data are divided into six bands. Then, we count number of samples of which the diameter fall in each band to draw the histogram.

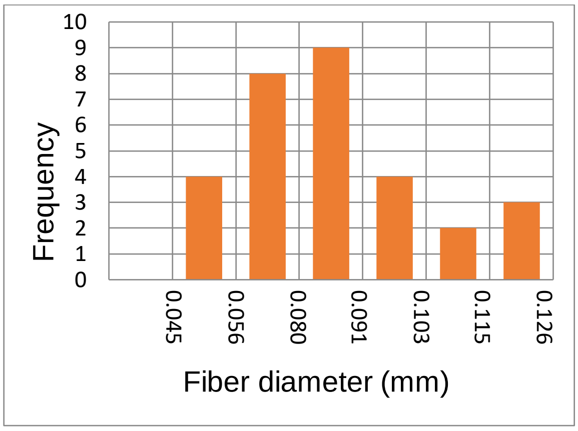

Figure 3. Histogram of fiber diameter in bottom part of abaca sheathes

From this histogram, we can calculate probability density for probability variable, fiber diameter, which is center value of each band. The probability density is plotted as function of diameter in figure 4. Similarly, probability densities for middle and top parts of abaca sheathes are plotted as a function of fiber diameter in figures 5 and 6.

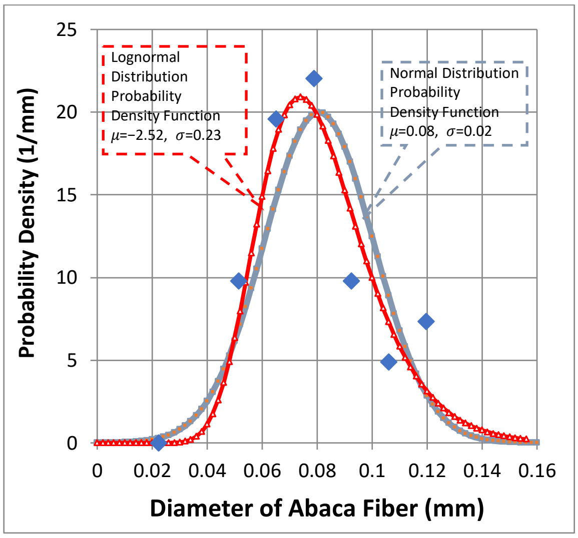

Figure 4. Probability Density for Bottom Part

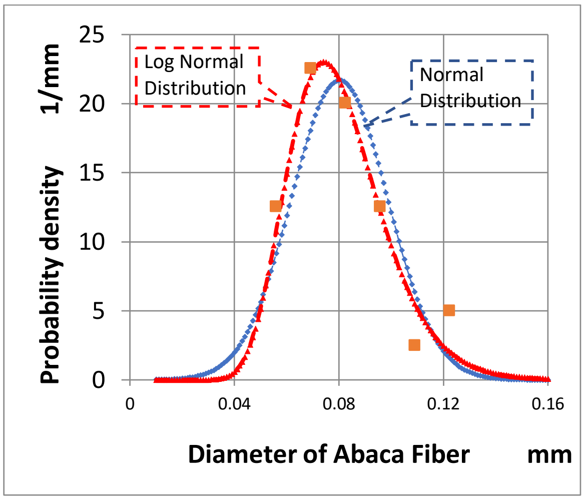

Figure 5. Probability Density for Middle part

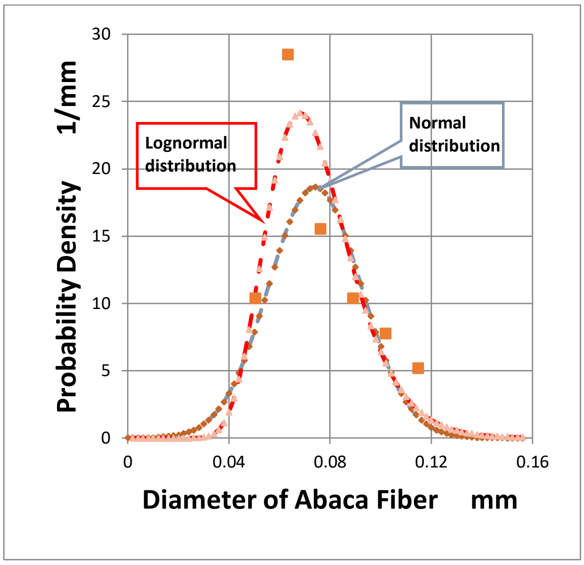

Figure 6. Probability Density for Top Part

As seen in the above figures, diameter data for all the parts fall on the normal distribution or log normal distribution line. Close examination shows that log normal distribution is more appropriate to express the scatter in the measured diameter of abaca fibers. Because measured dimensions are positive values, lognormal distribution that distribution variable must be positive is much more suitable to express the scatter rather than normal distribution of which distribution variable can be negative. E. Limpert, W. A. Stahel, and M. Abbt [4] summarize which parameters in various sience fields can be well expressed by lognormal distribution. A. S. Virk, W. Hall and J. Summer scales [5] show that cross section area of jute fiber can be well expressed by lognormal distribution. The results obtained by this research is consistent to the previous resercher's results.

As shown in figure 7 to 9, diameter distributions of all the parts can be considered to follow lognormal distribution. Because random variable ln(D), natural logarithm of fiber diameter D, follows normal distribution, we can examine whether mean values of ln(D) for three parts are the same by t-Test. In table 2, Arithmetical mean values, D_{mean}, standard deviation values, s, geometric mean values, D^*_{mean} and standard deviation, s^*, of ln(D) for three parts are summarized. Then, we assume that natural logarithmic values of diameter for all the parts of abaca sheathes can follow the normal distribution and carry out t-Test to judge whether mean diameter values of three parts are statistically the same or not.

Table 2. Summary of Diameter Measurement

Part	D_{mean}	σ	D^{*}_{mean}	σ^{*}
Bottom	0.081	0.0196	-2.547	0.240
Middle	0.080	0.0184	-2.550	0.228
Top	0.074	0.0265	-2.613	0.236

D^{*}_{mean} *: mean value of lnD*
s^{*} *: standard deviation of lnD*

The t-Test result indicates at confidence level of 99% that the mean value of natural logarithm of diameter for three parts are not same and then, we can see that mean values of diameter for each part decreases as collecting position of fiber approaches top edge of abaca sheath.
Actually, t-Test suggests that mean diameter values of the three parts are significantly different, but it should be noted that the difference in mean values for the bottom and the middle part is very small.

4. Conclusion

1. Diameter distribution in the three parts is well expressed by logarithmic normal distribution as compared with normal distribution.
2. t-Test shows that mean values in the three partsaresignificant different and a mean value of diameter decreases as collection position approaches top end of abaca sheath. However, the mean values of the bottom and the middle part is quite small.
3. Diameter distribution for all the parts is well expressed by logarithmic normal, but it is necessary to examine statistical properties of abaca fiber produced in the other area.

Further experiments are necessary to identify statistical property of abaca fiber strength and to understand statistical properties in strength through statistical properties in geometry.

References

[1] Carbonfiber, Retrieved From http://carbonfiber.gr.jp/english/tech/pdf/lca.pdf
[2] Fukumoto Y 1987 Guidelines for stability design of steel structure, edited by Y. Fukumoto, Subcommittee on stability design committee on steel structures *Japan society of civil engineers* Tokyo Japan pp 37-76
[3] Mwaikambo L Y 2009 Tensile properties of alkalized jute fibres *BioResources* **4**:2 pp566-588
[4] Limpert E, Stahel W A, Abbt M 2001 Log-normal distributions across the Sciences: Keys and Clues *BioScience* **51**:5 pp 341-352
[5] Virk A S, Hall W, Summerscales J 2012 Modulus and strength prediction for natural fibre composites *Material Science and Technology* **28**:7 pp 864-871