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1 Identification of tensile strength properties of abaca fiber by weakest-linkage approach-statistic property of fiber diameter Suardi*1, H Homma2, Abubakar1

1Graduate School Departement of Mechanical Engineering, Universitas Sumatera Utara

2Visiting Professor, Department of Mechanical Engineering, Universitas Sumatera Utara

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

Fiber reinforced plastics or metals (FRP or FRM) are usually ecological materials, because their specific strength defined as the strength per unit mass is much larger than metal, and weight of machines and structures for transport made of FRP can be significantly reduced so that the consumption of fossil fuel can be saved to result in tremendous reduction of CO₂ emissions.

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 utilize 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 selects abaca fiber, which is a natural fiber and is abundant in Indonesia, but its usage has 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 ratio 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 standard deviation is 0.01. 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 fibers, glass 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 2 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 of wrapping 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 decreases as the specific diameter variation range decreases. 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 3 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 measurement is 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 10m m 10m m MicroscopOpti ck Lens Abaca Fiber Fragment 4 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 0 1 2 3 4 5 6 7 8 9 10 1 2 3 4 5 6 7 Frequency Fiber diameter (mm) 0.5 10 15 20 25 0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 Probability Density (1/mm) Diameter of Abaca Fiber (mm) Lognormal Distribution Probability Density Function ?? =-52, ?? =0.23 Normal Distribution Probability Density Function ?? =0.08, ?? =0.02 0.126 0.115 0.103 0.091 0.080 0.056 0.045 5 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 science 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 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 0 5 10 15 20 25 0 0.04 0.08 0.12 0.16 Probability density 1/mm Diameter of Abaca Fiber mm Normal Distribution Log Normal Distribution 0 5 10 15 20 25 30 0 0.04 0.08 0.12 0.16 Probability Density 1/mm Diameter of Abaca Fiber mm Lognormal distribution Normal distribution 6 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 ?? ???? ?? ?? ???? * ?? * 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 $\ln D$ s^* : standard deviation of $\ln D$ 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 parts are significant 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.

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