INTERNATIONAL JOURNAL OF METACENTRE
MARITIME APPLICATION, TECHNOLOGY, ENGINEERING, AND TRANSPORTATION
http://ijm-nasp.unhas.ac.id. eISSN : 2809-8307

Application of Tensile Testing on Ulin Wood And Bungur Wood as Main Materials for 20 GT Traditional Fishing Vessel Hull

Andi Mursid Nugraha Arifuddin[1]*, Alamsyah[2], Decky Burliyanto[3], Suardi[4]

[1,2,3 4]*Department of Naval Architecture, Kalimantan Institute of Technology, Balikpapan, Indonesia*

Received: 05/02/2023
Revised: 10/04/2023
Accepted: 20/05/2023
Published:28/06/20223

* Corresponding author:
andi.mursid@lecturer.itk.ac.id

Abstract

Fishing boats in North Penajam Paser are made by combining 2 types of wood in the hull. This combination of wood types is carried out to save the material procurement budget. Bungur wood is the alternative choice for shipyards for hull material combined with Ulin wood. For this reason, this paper shows the differences in the tensile strength performance of these 2 types of traditional wooden ship hull materials. The experimental method of destructive testing of the type of Tensile test was applied in this study. Where the experimental results show that the tensile strength of the crepe is 22% lower than the tensile strength of ulin wood. Meanwhile, in terms of stiffness, crepe wood is superior to ulin wood, where the difference reaches 22.22%. Bungur wood still has the potential to be used for wooden ships with an LoA (length over all) value of <15 meters or for ships that have a lower hydrostatic load than that which can be accepted by Bungur wood.

Keywords: Bungur; Destructive test; LoA; Ulin; Tensile stress

1. Introduction

Traditional wooden ships generally function as fishing vessels and cargo transport ships in Indonesia. The existence of wooden ships in this country is supported by the abundant availability of wood materials in various regions in the archipelago. Wood is still the choice for construction structures because wood is a renewable resource with low energy consumption that traps CO2 during the life of manufacture and use of the structure [1][2]. Construction using wood as the main material must also pay attention to the quality of the wood. Because in the case of construction with wooden structures, the loss of cross-section material, which often occurs due to biological factors, increases the risk of failure, thereby allowing the user to experience accidents [3]. Therefore, the character of wood must be tested because wood is an anisotropic material with anatomical complexity, which makes it difficult to generalize some of its behavior [4][5]. Currently, wood is still the choice of the traditional housing industry because the price is relatively more attractive [6].

One of the locations for wooden shipyards in Indonesia is located in Penajam Paser Utara (PPU) Regency, to be precise the Kayu Api Shipyard as shown in Figure 1. The advantages of the ships built in this area are relatively cheap prices when compared to other regions. That the availability of certain types of wood in Kalimantan is still able to meet market demand for new wooden shipbuilding. However, certain types of wood materials have begun to experience scarcity, such as the availability of ulin wood as ship hull material. Therefore, wooden ship craftsmen in the PPU area are trying to combine the use of other woods for ship hull materials such as Bungur wood.

Figure. 1 Wooden Boat Shipyard at Penajam

The location for using Bungur wood on the ship's hull is the top side (Side shell). For the lower hull (bottom) still use Ulin wood. The reason is that the bottom structure of the ship will receive a high load so that a stronger wood material is needed. Using Bungur wood in the ship's hull will have the effect of reducing the cost of ship building materials. However, an investigation is needed on the strong performance of the crepe wood material as a substitute for ulin wood on the ship's side hull. Based on that, a tensile test will be carried out on the two woods using a UTM machine.

Research related to the tensile test on wood for the needs of construction activities has been carried out by various previous researchers such as Prasetyo et al (2017) who conducted a tensile test on wood which combined meranti wood and petung bamboo to obtain a tensile strength value of 164 MPa [7]. Parlindungan et al (2017) conducted a Tensile test of a combination of petung bamboo and apus bamboo and obtained a tensile strength of 104 MPa [8]. Jose et al (2019) conducted a tensile test on aged Sylvettris and Pinaster wood and found a residual strength of 0.4 – 0.9 from its initial strength [9]. Wengang et al (2021) demonstrated a tensile test on beech wood with fig fiber variations. The results obtained show that the longitudinal fiber direction has better tensile strength than the other directions [10]. Neil et al (2012) compared the tensile strength with different specimen geometries by conducting a tensile test. The results show a non-significant difference [11].

The ship hull material generally suffers from crack-type damage which results in fracture. Cracks occur due to the tensile force acting on the hull due to the sagging and hogging conditions of the ship as the effect of water waves acting on the hull. In addition, the shelf life of wood material for ships is usually very short [12]. Thus, in this study, a simulation was shown to determine the tensile strength of these two materials by conducting a test in a laboratory called the Destructive Test type of tensile test.

2. Methods

2.1 Ship Data

The ship used as the object of research is a type of fishing boat built in the North Penajam Paser area. The ship's hull is made of 2 types of wood materials, namely ulin wood on the bottom structure and crepe wood on the side structure. The hull type used is monohull. With a propulsion system using a 30 Hp x 2 unit engine. The main dimensions of the ship are shown in Table 1.

Table 1. Principal Main Dimensions

Description		**Value**
LoA	:	21.90 m
Lwl	:	19.06 m
Lpp	:	17.76 m
B	:	4.00 m
Q	:	1.40m
H	:	2.00m
vs	:	9.00 knots
GT	:	20

2.2 Experimental Set-Up

In this study, the experimental method was used to obtain the tensile strength value of wood material for ship hulls. The type of test performed is the destructive test (DT). The tensile strength test on the wood material was carried out using a UTM (ultimate tensile machine) machine. The specifications of the UTM machine can be seen in Table 2 below:

Table 2. UTM Machine Specifications

Items	**Information**
EquipmentName	Universal Testing Machine
Certificate No	17637/CQI-Sert/09/21
capacity	100kN
Serial Number	180542
Environmental Condition	Q before = 28.50 C Q after = 28.60 C RH before = 64 % RH after = 65 %
calibration method	IK-G-01 ref. JIS B 7721 : 2009

Furthermore, the manufacture of wood specimens refers to the rules of the Indonesian National Standard (SNI) with serial number 03-3399-1994. This rule has set standard specimen sizes for wood testing as shown in Figure 2.

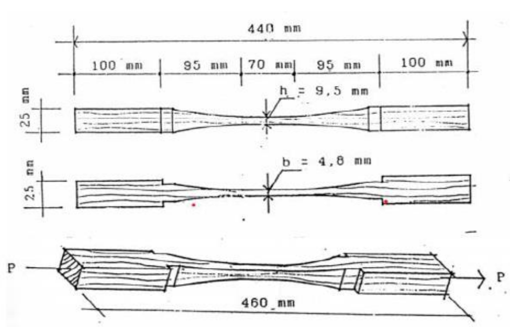

Figure 2. Specimen Dimension by SNI 03-3399-1994 [13]

The materials used as research objects, namely Bungur wood and Ulin wood originating from Penajam, East Kalimantan, were formed according to SNI standards for further tensile testing to be carried out on UTM machines. The specimens that have been prepared can be seen in Figure 3. To facilitate the identification of the test results, each wood will be given a notation code. Ulin wood is coded "U" and Bungur wood is coded "B". Based on the SNI rule, the number of test specimens for testing the tensile strength of wood materials is 5 specimens. So that 10 specimens will be tested for tensile. The results of the tensile test carried out will be processed to obtain a tensile stress value for each specimen. The equation that applies is as follows [13]:

$$ft = \frac{P}{b.h} \tag{1}$$

Where ;

ft = tensile strength (N/mm^2)
P = maximum load(N)
b = specimen cross-sectional width(mm)
h = specimen cross-sectional height(mm)

To derive Hooke's law for plane stress we consider a rectangular domain which is cut out from a disk and which is loaded only by the normal stress σx. Then the following equation applies [14],

$$\varepsilon = \frac{1}{E}\,\sigma_x \tag{2}$$

where,

ε = strain
E = elasticity (N/mm^2)
σx = Normal Stress x direction (N/mm^2)

To evaluate the load that occurs on the ship's hull against wood material, a load calculation is carried out on the ship based on the equation of the Indonesian Classification Bureau (BKI). The loads acting on the hull are divided into side loads, bottom loads, and deck loads. However, for the case in this study, the load evaluation focused on side loads and base loads. The load equation as follows [15]:

Load of Shell Side ;

$$PdSS = 2.63\ L - 2.35 \tag{3}$$

Load of Shell's bottom

$$PdBS = 3.29\ L - 1.41 \tag{4}$$

where,

$$L = \frac{LWL + LOA}{2} \tag{5}$$

L = L Scantling (m)
LWL = Length of waterline (m)
LoA = Length of overalls (m)

Based on the equation above, the value of the load acting on the hull of the fishing boat is obtained as shown in Table 3 below:

Table 3. Hull Load of Fishing Boats

No.	**Items**	**Load(kN)**
1	A load of Shell Side	51,512
2	load of Shell's bottom	65,969

3. Result and Discussion

The tensile strength test on 2 types of wood as a traditional wooden boat hull material in North Penajam Paser was carried out using the UTM tool. The type of test performed on the wood is a destructive test. The specimens tested in the study were made by following the direction of the wood grain (in the direction of the wood grain). The details of the test results for Bungur and Ulin wood are described as follows:

3.1 Bungur Wood

The crepe wood sample tested was hull material obtained from one of the traditional wooden shipyards located in Penajam Paser Utara. Bungur wood is usually used for small boats and also for large ships. In the case of large ships, it is usually used on the hull by combining it with ulin wood. In this simulation, a tensile test was carried out with 3 specimens. The test results are presented in Table 4 below:

Table 4. Performance Bungur Wood

code	Loads (N)	Moisture (%)	Elongation (mm)	Elasticity (N/mm^2)	Maximum Stress (N/mm^2)	Average Stress (N/mm^2)	Strains (%)	Average Strains (%)
B1	3467	9	0.199	5252,900	76,025	89,744	0.433	0.322
B2	4445	10.5	0.159	5722100	97,468		0.347	
B3	4365	10.2	0.099	5408,500	95,740		0.217	

Based on Table 4(Perrin et al., 2019), different strength performance values are obtained. The reason for this phenomenon is that there are different wood fiber paths for each specimen or they are not homogeneous. Control over fiber direction still looks low in this test specimen. The performance difference between B1 and B2 reaches 22%, while the difference between B2 and B3 reaches 1.805%. Another thing that can make a difference in the strong performance of the B1 specimen is the humidity of the specimen which only reaches 9%. When compared to specimens B2 and B3 it reaches ±10%. The test results show the effect of water content. The greater the water content in the wood, the better it is for the strength of the wood. For acceptable loads, Bungur wood samples are susceptible to 3000 – 4000 N. The history of loading that occurs on each specimen is shown in Figure 3.

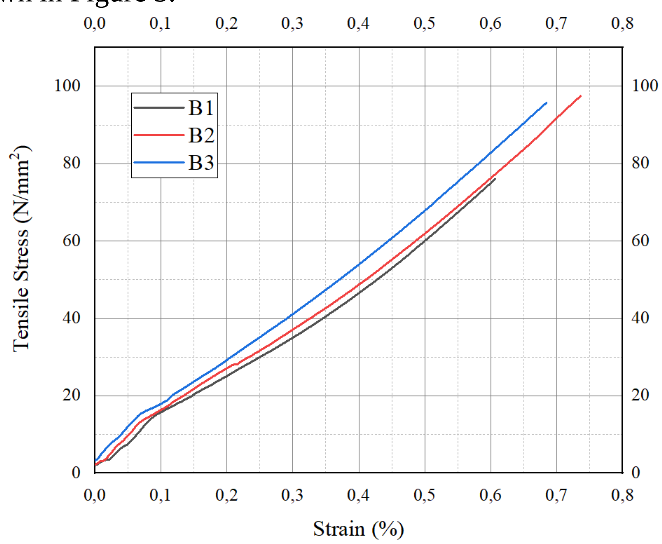

Figure 3. Relationship of Strain vs Tensile Stress in Bungur Wood

The graph in Figure 3 shows that the trend of tensile stress in each specimen is similar. However, the maximum stress in the three specimens that occur is not the same. The average stress that occurs is 89,744 N/mm2.

3.2 Ulin wood

Similar to Bungur wood, ulin wood specimens were obtained from traditional wooden shipyards which were temporarily building new ships. The number of specimens tested in this study was 3. The test results are described in Table 5 below:

Table 5. Ulin wood Performance

Code	Loads (N)	moisture (%)	Elongation (mm)	Elasticity (N/mm^2)	Maximum Stress (N/mm^2)	Average Stress (N/mm^2)	Strain (mm/mm)	Strain Average (mm/mm)
U1	9328	10.1	5,062	18589.02	204,575	171,728	0.011	0.009
U2	7742	10.3	3,369	23184.30	169,780		0.007	
U3	6421	9.2	3,507	18472.03	140,829		0.008	

The results of the tensile test on ulin wood specimens showed varied results. The load that can be accepted by the specimen is at a range of 6000 – 9000 N. The average tensile stress value obtained is 171,728 N/mm2 and the average strain value is 0.009 mm/mm. The average level of tensile stress ratio in each specimen is 20%. Similar to crepe wood, specimens that have higher moisture values show better strength values as happened in U1 and U2. The trend of the stress response that occurs in each specimen is shown in Figure 4.

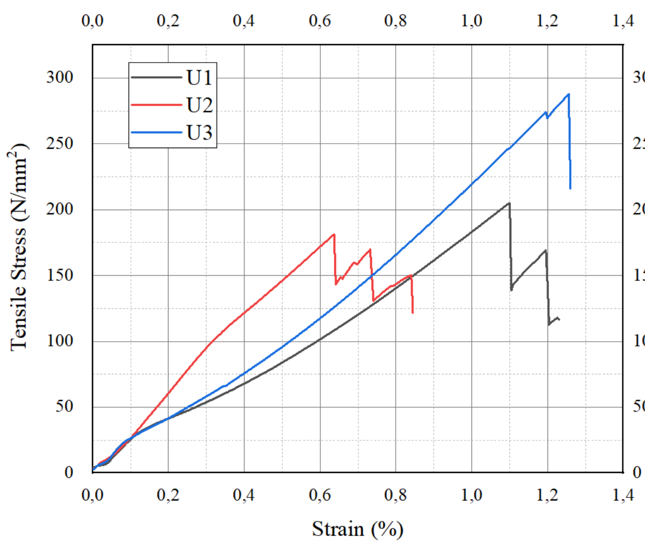

Figure 4. Relationship of Strain vs. Tensile Stress in Ulin wood

From the graph in Figure 4 it is shown that the stress values that occur in each specimen are above 100 N/mm2. However, the performance of the three specimens differs mainly at the maximum stress value. At the strain point up to 0.1 mm/mm, the elasticity values of the three specimens tend to be the same. When the strain that occurs is 0.2 mm/mm the elasticity value shows the main difference in specimen 2. The change in the direction of the wood fiber is the triggering factor for the difference in wood strength performance.

3.3 Bungur Vs Ulin Comparison

The test results show that there is a difference in the performance of the tensile strength of the two wooden ship hull materials. In the ship's hull, ulin wood is installed at the bottom of the structure because the structural load that occurs is greater than the side load. For this ship, the side load that occurs reaches 51,512 kN. Meanwhile, the bottom structure load on this ship is 65,969 kN. While crepe wood is installed on the sides of the deck. The performance comparison of the tensile strength of the wood material is shown in Figure 5 below:

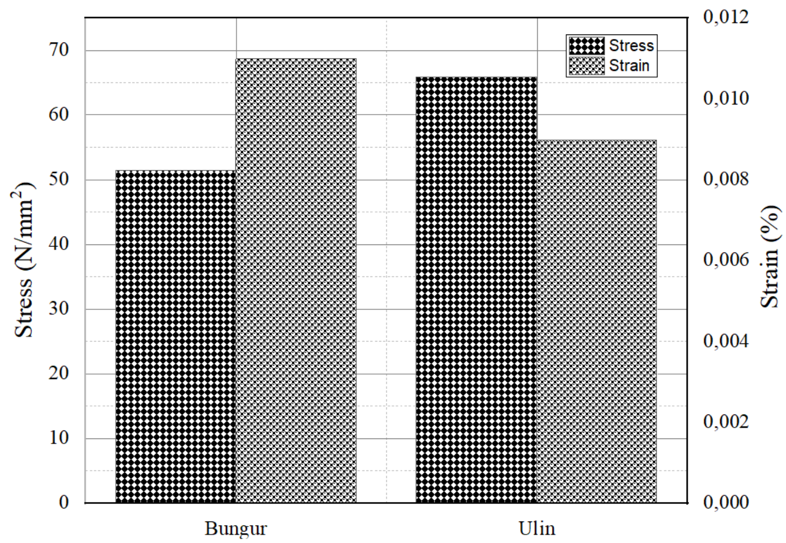

Figure 5. Comparison of Tensile Stress and Strain Performance

The graph above shows that the tensile strength of ulin wood is better than that of crepe wood. However, ulin wood looks stiffer when compared to crepe wood. The level of difference in the tensile strength of the two woods reaches 22%. Henceforth, Ulin wood is recommended to be used in ship hull parts that get a large load. Furthermore, crepe wood is used in the hull of the ship which gets a small load.

4. Conclusions

Destructive tests on wooden ship hull materials have been successfully carried out. From the experimental results, it was found that the tensile strength values of crepe wood and ulin wood were very different. The difference in the tensile strength of the two kinds of wood is up to 22%. But in terms of stiffness, crepe wood is slightly better than ulin wood where the difference reaches 22.22%. Henceforth, crepe wood is still recommended for use as a hull material on ships that have an LoA < 15 meters. However, for ships with LoA > 15, crepe wood can still be used on ship hulls that have low hydrostatic loads.

References

[1] Perrin, M., Yahyaoui, I., & Gong, X. (2019). Acoustic monitoring of timber structures: Influence of wood species under bending loading. *Construction and Building Materials, 208*, 125–134. https://doi.org/10.1016/j.conbuildmat.2019.02.175

[2] Morales Conde, M. J., Rodríguez Liñán, C., & Rubio de Hita, P. (2014). Use of ultrasound as a nondestructive evaluation technique for sustainable interventions on wooden structures. *Building and Environment, 82*, 247–257. https://doi.org/10.1016/j.buildenv.2014.07.022

[3] Perlin, L. P., Pinto, R. C. de A., & Valle, Â. do. (2019). Ultrasonic tomography in wood with anisotropy consideration. *Construction and Building Materials*, *229*. https://doi.org/10.1016/j.conbuildmat.2019.116958

[4] Fathi, H., Nasir, V., & Kazemirad, S. (2020). Prediction of the mechanical properties of wood using guided wave propagation and machine learning. *Construction and Building Materials*, *262*, 120848. https://doi.org/10.1016/j.conbuildmat.2020.120848

[5] Dackermann, U., Elsener, R., Li, J., & Crews, K. (2016). A comparative study of using static and ultrasonic material testing methods to determine the anisotropic material properties of wood. *Construction and Building Materials*, *102*, 963–976. https://doi.org/10.1016/j.conbuildmat.2015.07.195

[6] Labans, E., Zudrags, K., & Kalnins, K. (2017). Structural Performance of Wood Based Sandwich Panels in Four Point Bending. *Procedia Engineering*, *172*, 628–633. https://doi.org/10.1016/j.proeng.2017.02.073

[7] Prasetyo, Manik, P., & Arswendo, B. (2017). Jurnal Teknik Perkapalan. *Jurnal Teknik Perkapalan*, *5*(1), 291. http://ejournal-s1.undip.ac.id/index.php/naval

[8] Manik, P., Prasetyo, D. A., & Samuel, S. (2017). Analysis of Tensile Strength and Flexural Strength of Laminated Beams Combination of Petung Bamboo and Apus Bamboo for Wooden Ship Components (in Indonesia). *Kapal: Jurnal Ilmu Pengetahuan Dan Teknologi Kelautan*, *13*(3), 142–151.

[9] Machado, J. S., Pereira, F., & Quilhó, T. (2019). Assessment of old timber members: Importance of wood species identification and direct tensile test information. *Construction and Building Materials*, *207*, 651–660. https://doi.org/10.1016/j.conbuildmat.2019.02.168

[10] Hu, W., Chen, B., & Zhang, T. (2021). Experimental and numerical studies on mechanical behaviors of beech wood under compressive and tensile states. *Wood Research*, *66*(1), 27–38. https://doi.org/10.37763/WR.1336-4561/66.1.2738

[11] Kohan, N., Via, B. K., & Taylor, S. (2012). A comparison of geometry effect on tensile testing of wood strands. *Forest Products Journal*, *62*(3), 167–170. https://doi.org/10.13073/0015-7473-62.3.167

[12] Mursid, A., Arifuddin, N., Pawara, M. U., & Jamal, R. (2022). Hull Strength Investigation of Traditional Boat " Sandeq " Using Numerical Experiment. *SPECTA Journal of Technology*, *6*(2), 190–199. https://doi.org/10.35718/specta.v6i2.492

[13] Metode pengujian kuat tarik kayu di Laboratorium. (1994). Sni 03-3399. In *Badan Standardisasi Nasional*.

[14] Gross, D., Hauger, W., Schröder, J., Wall, W. A., & Bonet, J. (2018). Engineering Mechanics 2. In *Engineering Mechanics 2*. https://doi.org/10.1007/978-3-662-56272-7

[15] Biro Klasifikasi Indonesia. (2021). RULES FOR SMALL VESSEL UP TO 24 M Consolidated Edition 2021: Vol. VII.