TRANSNAV
http://www.transnav.eu
the International Journal on Marine Navigation and Safety of Sea Transportation
Volume 16
Number 3
September 2022

DOI: 10.12716/1001.16.03.20

Mechanical Properties of Small Boat Construction from HDPE Blue Drum Scrap

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ABSTRACT: This paper discusses the mechanical properties of alternative wood substitute materials in the construction of small boats (jukung/cadik type). Jukung/cadik boat as a small fishing boat with a length overall 6,400 m, design beam 1,530 m, design draft 0.380 m, displacement 2,442 tons, wetted surface area 15.58 m2, the pressure acting on the submerged hull needed minimum material used has a strength of 0.0039 MPa or 3.92 kN/m2. The replacement material used is the HDPE blue drum scrap, which has an average thickness of 3mm, then made into two layers as laminate. The laminate process uses welding. The results of HDPE laminate material from these two layers are tested for tensile and compressive strength to meet the material strength requirements for small ship hulls. They were testing the strength of HDPE welded joints with type A1 specimens. Tension and compression of the two-layer laminate material was tested with specimens of type A2, A3, and A4. The tensile test results for A1 specimens obtained for welding tests are pretty good at 17.1 MPa, then the results of compression tests for specimen type A2, A3, and A4 on average are 23.36 MPa, which is greater than the need for the strength of the jukung/cadik hull.

1 INTRODUCTION

Indonesian fisherman small fishing boats type jukung/cadik or outrigger) are popular in Figure 1. It was built by wooden boat craftsmen, especially along the northern coast of Java. However, they are currently experiencing difficulties in wood materials, especially teak (Imron et al., 2020). In addition, the price of this wood is always increasing every year. The price for per m3 of wood with a length of 3 meters of wood the price reaches IDR 13 million (equal to 900 USD). A wooden ship with a length of less than 12 meters requires wood from 0.8 to 1.6 (m3) for the hull only with a thickness of 3 cm. Wooden boats can be used for 10 years, and after that it requires quite expensive maintenance and repairs. Wooden boat craftsmen try to make wooden boats more durable by coating them with fiberglass with a thickness of more than 5 mm, and this has led to an extraordinary increase in the price of the ship.

Fishermen really need a fishing-boat that is strong and cheap, so it is necessary to look for alternative materials to replace wood in the construction of small boats (jukung/cadik), but fishing boats must be seaworthy in accordance with special vessel regulations under 24 meters in length, to ensure the safety of fishermen while at sea. One of the materials that can be used is from HDPE blue drum scrap (fig.2). The hull of an jukung/cadik boat made of finished wood per square meter price USD 15.00/m2, and from HDPE blue drum scrap, the price per square meter of material is USD 8.57/m2.

The potential for making alternative materials in the form of natural fiber composites such as bamboo and rattan and other materials has been widely practiced, such as bamboo composites with HDPE or polyethylene (PE) and polypropylene (PP) plastics which are commonly used thermoplastics, due to price and processing temperature relatively low (Shah, 2020; Liu, et al., 2009; Yao et al., 2018). HDPE material has the morphological properties of MFR (190oC/2.16 kg) = 6.1 g/10 min, density = 0.952 g/cm3.

Indonesia produces plastic waste, especially HDPE blue drum scrap (a container for raw materials for chemical industry products or similar industries) per month, reaching 1.4 billion kg (equivalent to 5.6 million drums with a capacity of 200 liters); the total number in 2018 was 12.2 billion kg or equivalent to 48.9 million HDPE blue drum scrap (BPS 2019). High density polyethylene (HDPE) is a thermoplastic polyethylene, made from petroleum. HDPE is recyclable, and has number 2 on the symbol for recycling, is safe and has a lower risk for health and the environment (American Chemistry Council and Association of Plastic Recyclers, 2017; ISO, 2012; ASTM, 1993).

The process of utilizing HDPE blue drum scrap as a material for making jukung/cadik is very simple, namely making it a laminate material by a welding process using a thermoplastic welding machine. HDPE blue drum scrap formed into sheets with an average thickness of 3mm, then laminated from two layers, which are welded at a distance of 3cm and then pressed so that a laminated HDPE sheet is new material. Then this material is subjected to a tensile test, a flexural test, so that its mechanical properties can be known and used as a small hull construction (Badache et al., 2018).

2 VESSEL AND DESIGN CONSIDERATIONS

Jukung/cadik boat as a small fishing-boat with a length overall 6.4 m, design beam 1.53 m, design draft 0.38 m, displacement 2.442 tons (2,442 kg), wetted surface area 15.58 m2, the pressure acting on the hull submerged in water is nominally 1.5674 kN/m2 (0.0015674 MPa), with a safety factor of 2,5 times, the minimum material used has a strength of 0.0039 MPa or 3.92 kN/m2.

Small boat dimensions: 8.00 m long/length overall, 1.69 m wide and 0.50 m laden, 3.175 ton- displacement and 12.70 m2 underwater surface areas. Requires minimum hull strength of 2.50 kN/m2 or the equivalent of 0.0025 MPa, with a safety factor of 2,5 times, the minimum material used has a strength of 0.00625 MPa or 6.25 kN/m2.

Jukung is made in various sizes, the long ones are usually for transportation, and the short and wide ones are for catching fish. This small Jukung or boat was initially made from a carved piece of wood that is quite long. Manufacturing in this way wastes a lot of raw materials that are then made from thick boards/wood. Jukung, in addition to catching fish, and means of transportation in rivers and lakes, is also used as a place to sell floating in the Kalimantan river area. The Demak area has 3,872 boats, such as jukung.

The continuous use of wood for the manufacture of jukung as small boats will reduce the availability of wood in nature, disrupting the natural balance. It is the reason for the need for replacement materials that are more durable and can be recycled. One of the materials that can be utilized is HDPE blue drum scrap.

Figure 1.a. Demak Jukung Boat (BanGhoL)

Figure.1.b. Common form of jukung/cadik (https://infopublik.id/galeri/foto/detail/88083)

3 MATERIAL

The material used is from HDPE sheets which come from HDPE blue drum scrap. This HDPE has material properties: Density 940 kg/m3, Melting Point 130.8° C, crystallization temperature 111.9°C, enthalpy of fusion 178.6 kJ/kg, Thermal conductivity 0.44 W/m.°C, specific heat of solids 1.9 kJ/kg.°C, crystallinity 60% (Thakare et al., 2015). The welding wire material is High-Density Polyethylene (HDPE) Plastic Welding Rod, 4mm or 1/8 "in diameter.

Table 1. HDPE Material Properties

Density	940 kg/m3
Melting Point	130.8° C
Crystallization Temperature	111.9°C
Enthalpy of fusion	178.6 kJ/kg
Thermal conductivity	0.44 W/m.°C
Specific heat of solids	1.9 kJ/kg
crystallinity	60%

Source: Thakare et al., 2015

The HDPE welding process is required to make two sheets of HDPE plate obtained from HDPE blue drum scrap (Figure 2a). We cut the drum at the top and bottom and take the middle part in the form of a sheet, and then welding is carried out to form one material from the two thin sheets (Figure 2b).

(a)HDPE blue drum scarp (b) Joining two layers of HDPE sheet by welding

Figure 2. Joining two layers of HDPE sheet by HDPE welding

The welding strategy used is a straight-line pattern with a welding period of 3 cm, with the pattern being shown in Fig.3.

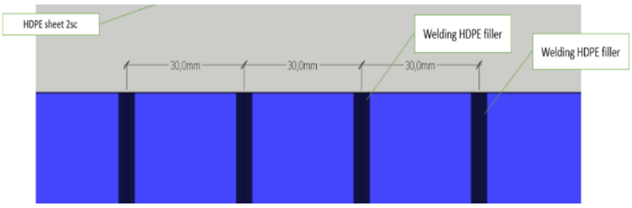

Figure 3. Welding pattern in HDPE sheet Elimination

Figure 4. Joining two layers of HDPE sheet by HDPE welding

4 EXPERIMENTS

4.1 *Preparation*

HDPE sheets are prepared from used barrels and cleaned of adhering chemicals. The sheet consists of two parts with a thickness of 3 mm. To get the material from these two layers is done by welding as shown in Figure 4, then welding is carried out according to the pattern according to Figure 5.

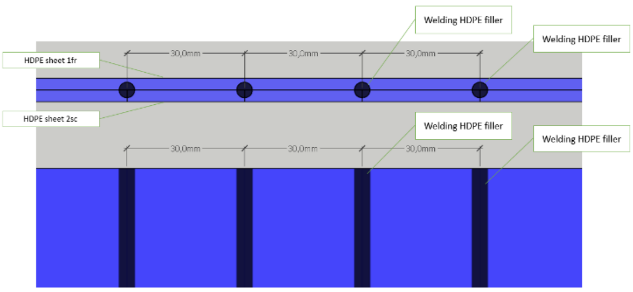

Figure 5. Welding pattern in HDPE sheet elimination

The next process is to consider the quality of the interlaminar, by showing the cross section. This process takes into account the waterproof properties of the resulting material. Figure 6 showed the result of the material from the union of two HDPE blue drum scrap sheets.

4.2 *Welding machine*

The welding process is carried out using an HDPE hot air welder with a filler of the same material. This tool can melt filler from 30oC to 680oC, power supply consumption: AC-220V 50 Hz, Heat power: 1600W, Air mass flow max 230 liters per minute.

Figure 6. Welding gun HDPE.

Figure 7. The cross-sections of material from 2 layers and watertight

This HDPE material is considered to be suitable for small ship hulls. Joints are considered by ensuring the strength of the welded joints we test. In addition, A1 is the name of sample in this study, with the amounts used being 112 pieces, A2 is the name of for samples of two layers of laminate as many as 128 pieces, A3 is for samples of two layers of laminate with cross-welding, and A4 is for samples of two layers of HDPE sheets.

4.3 *Testing machines*

The test tool used is a mechanical test device based on ASTM D638 and ISO 527-1, the magnitude of the force applied, F = EA v/(60L) ... (ISO 527-1), is directly proportional to the modulus (MPa), the cross-sectional area (mm2), and test speed (mm/min), and inversely proportional to the clamping distance (mm), and maximum capacity 10 kN

4.4 *Specimen production*

The first thing that needs to be tested is the strength of HDPE welding results to provide confidence in the strength of the connection of the material by the welding method., for that, it is necessary to weld and form a test object that is labeled with type A1, as shown in the picture.9. The dimensions of the test specimens type A1 are based on ASTM D 638, 165 mm long, and 19 mm wide (Khalaf, 2015; Bledzki et al., 2007).

The new laminated material is made from two layers of HDPE blue drum scrap sheet, as shown in Fig.8. Then these specimens are labeled type A2, A3, and A4. Type A2 welding direction is longitudinal in the tensile test, type A3 and A4 are transverse direction welding. Type A3 is tested for tension. Then type A4 is tested for pressure (bending test).

Figure 8. Laminate material

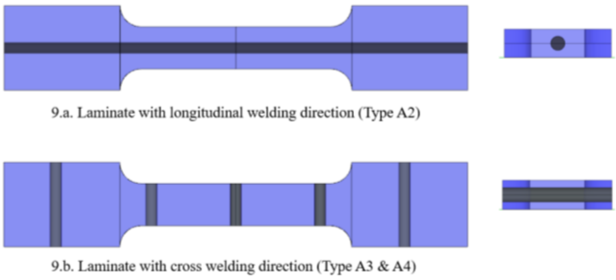

Figure 9. Laminate specimens with different welding directions.

5 RESULTS

5.1 *Specimen type A1 Test*

HDPE welding joints with a V seam pattern (single V butt joint) and an average material thickness of 3.035mm, produce an average tensile strength of 1011.94 N with a cross-sectional area of 58.79 mm2 or 17.21 MPa (Figure 7).

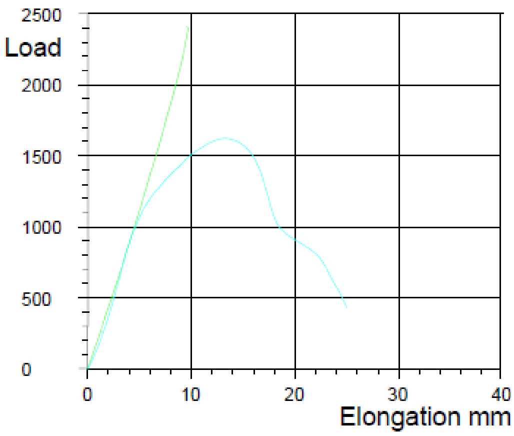

Figure 10. Results of the T-1 tension test (A1)

Tests also need to be performed to show possible failure modes and failure surfaces. The tensile test results are shown in Figure 11 and Figure 12. The results for each test are conducted, so that the standard deviation/spread in the results can be considered.

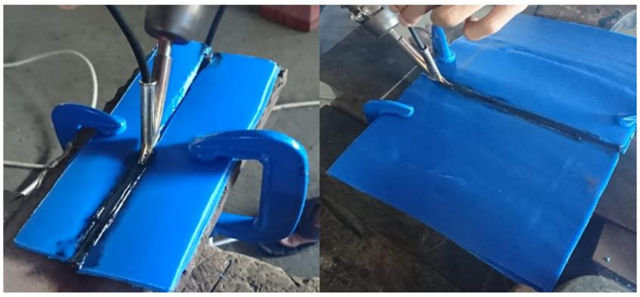

Figure 11. A1 sample making

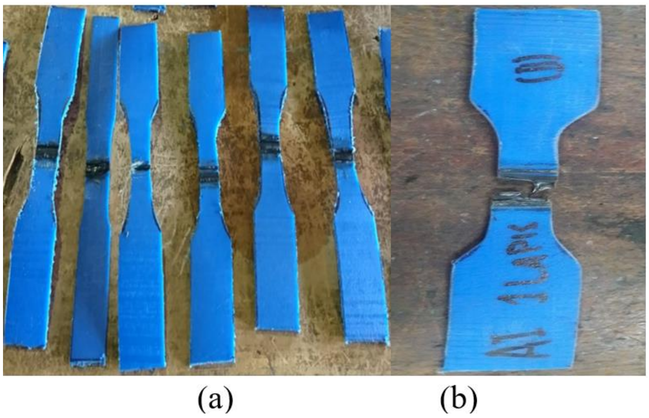

Figure 12. (a) Tensile test sample; (b) tensile test results

Moreover, Sample type A1 as many as 112 pieces is used to conduct a test for HDPE welded joints to show the frequency of the tensile test results (Figure 10). The test results show an average tensile strength of 1011,939 Newton, with a standard deviation of 0.069 and stress of 17.11 MPa, with a standard deviation of 0.062 approaching the test results without welding (the original material) for comparison is 1012.00 Newton and stress of 17.21 MPa.

5.2 *Specimen type A2 Test*

Tensile strength for two layers of laminate with longitudinal welding (A2), obtained an average thickness of 6.59 mm resulting in an average tensile strength of 2225.48 Newton, with standard deviation 0.74 with a cross-sectional area of 124.28 mm2 and average stress 17.9 MPa (Figure 13).

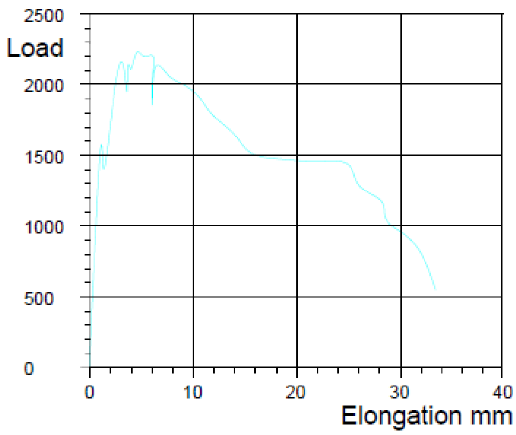

Figure 13. Results of the T-1 tension test (A2)

Figure 14. Testing process of The number of samples tested for type A2 (two layers of laminate) as many as 128 pieces.

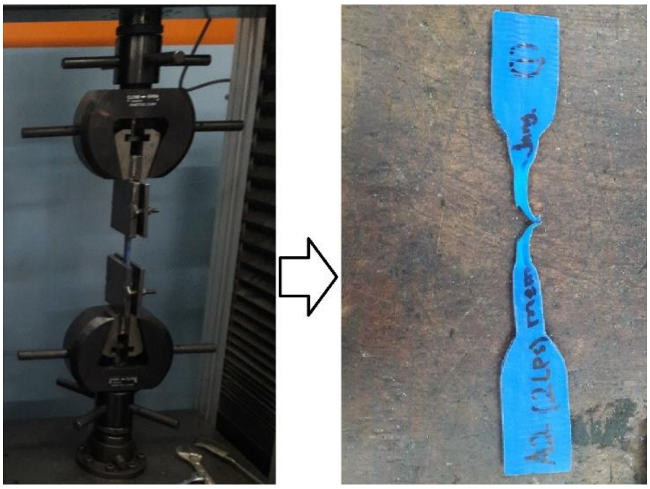

Figure 14. A2 Testing.

5.3 *Specimen type A3 Test*

Tensile strength for two layers of laminate with cross-welding (type A3) as in figure 9.a. on, obtained an average thickness of 7.42 mm resulting in an average tensile strength of 2324.26 N with a cross-sectional area of 140.31 mm2 or 16.45 MPa.

5.4 *Specimen type A4 Test*

The bending test results from two layers of HDPE sheets (type A4) have average load 104.39 Newton dan yielded an average bending stress of 23.37 MPa and the modulus of elasticity was 692.70 MPa (Figure 15; Figure 16).

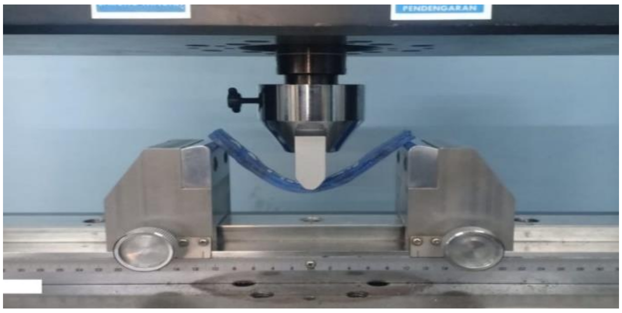

Figure 15. Bending Test

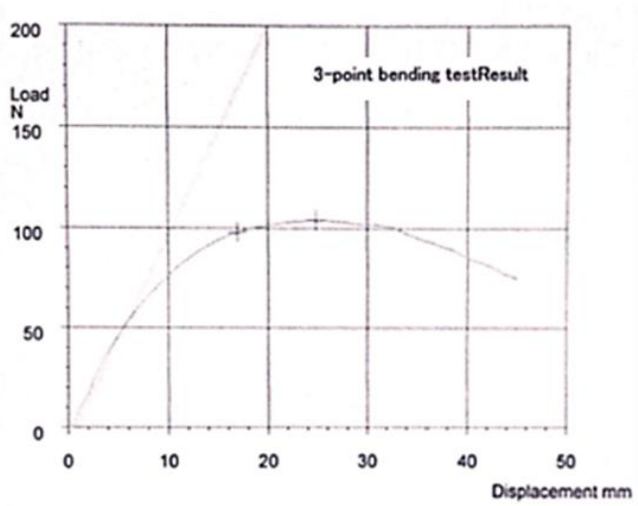

Figure 16. Bending test results (A4).

6 DISCUSSION

The difficulty in this experiment is in making the same specimen. It may be because the tools used are manual and still rely on human hand skills to make the test specimen object.

Welding strength is almost equal to the strength of the material when tested in tension, namely the average tensile strength of 1011,939 Newton. At the same time, the original material is 1012.00 Newton, and this connection strength convinces us to make a new material using the laminate method through welding treatment horizontally with a regular pattern following the pattern in Fig. 5 above.

The new material, formed from two layers of HDPE blue drum scrap with a longitudinal weld pattern, has a tensile strength of 2225.48 Newton and 2324.26 N with transverse welded polo. The average compressive strength is 104.39 Newtons, and the modulus of elasticity is 1301.40 MPa, which is far above the nominal strength required by the hull of a Jukung/small ship, which is only 0.0039 MPa.

On this occasion, this laminated material is applied to replace wood for the Jukung's hull. The next stage will be tested for the strength of the connection between the construction components, such as the hull and floor or frame and other parts. The effect of machine vibration on the strength of the construction joints will also be developed.

The application in Jukung can be seen in Fig. 17 below, which is the middle hull of the jukung with HDPE blue drum stamp laminated material.

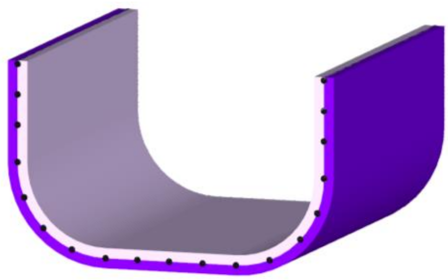

Figure 17. The middle of Junkung's hull.

7 CONCLUSIONS AND RECOMMENDATIONS

The results of the tensile and bending test for welding joints in the manufacture of HDPE sheet construction using the welding method and with lamination (sandwich), where there is an average tensile strength of 1011,939 N (Newton) or 17.21 MPa) for the welded joints. The result of the tensile test of the two-layer laminate construction obtained that the average tensile strength was 2225.48 N or equal to 17.9 MPa. The flexural test result of two-layer welded joints with an average of 23.37 MPa is much higher than the minimum requirement for small hull strength (0.0039 MPa) and the modulus of elasticity is 692.70 MPa.

The next step is how to apply it in the field of the making process of small ships using appropriate technology at a very low price by comparing it with wood materials which has expensive price. As for comparison, the hull of an outrigger/jukung/cadik boat made of finished wood per square meter price from USD 15/m2 to USD 30/m2, and from HDPE blue drum scrap, the price per square meter of material is USD 8.57/m2. So, by considering the low cost of HDPE material, it is possible to produce this material in low-tech environment. This makes it a suitable alternative to teak wood in the manufacture of outriggers at low cost, considering that most of the users are small-scale fishermen.

ACKNOWLEDGMENT

The author would like to thank the Director of the Schweißtechnische Lehr-und Versuchsanstalt Mannheim GmbH, Germany, as a form of collaboration in this research.

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