Flexural Analysis of High-Density Polyethylene as a Shipbuilding Materials

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Abstract: Ships are transportation at sea for the community which made from materials, such as wood, steel, and others. Along with the development of technology, the use of durable and recyclable materials has become a new concern so that other alternative materials are still needed as the basic materials for shipbuilding. HDPE can be used as an alternative material due to its characteristics of durability and recyclable. It was necessary to know in advance the mechanical properties of HDPE due to its strength. One of its mechanical properties is the flexural strength. Therefore, research was conducted on the analysis of the mechanical properties of HDPE through flexural strength testing. This research was conducted to determine the flexural strength and flexural modulus of the three brands of HDPE to be applied as a basic material for shipbuilding by referring to the Turk Loydu acceptability standard. The HDPE material is processed into test specimens and flexural strength testing was carried out. The analysis data obtained in the form of flexural strength and flexural modulus of HDPE AGRU of 24.44 and 372.35 MPa, local HDPE of 58.16 and 648.54 MPa, and HDPE ROCHLING of 61 and 650.15 MPa. Based on the analysis, it can be concluded that HDPE ROCHLING had the greatest strength and flexural modulus. Meanwhile, HDPE that could be used as the basic material for shipbuilding based on flexural strength, namely local HDPE and ROCHLING HDPE.

1 INTRODUCTION

Ships are a common transportation which used by the community for inter-island goods distribution activities and fishing at sea. The materials that are usually used in shipbuilding, such as wood, steel, aluminium, fiberglass. Nowadays, 90% of fishing boats in Indonesia were made from wood (Huwae and Santoso, 2016). Along with the development of technology, the use of materials that are durable, environmentally friendly, and recyclable has become a new concern for society. The ships production might be used for a long period of time. Therefore, other alternative materials are still needed that could be applied as basic materials for shipbuilding.

HDPE (high density polyethylene) could be an alternative base material for shipbuilding due to its characteristics, the durability against aging and corrosion, and recyclable (Siswandi, 2016). Used-HDPE's ships would not become waste because it recyclable into other derivative products. Therefore, shipbuilding which made from HDPE has begun to be widely implemented.

Of course, before being applied as a structural material for ships, it is necessary to know in advance about the characteristics of HDPE. One of the characteristics that need to be known is the resistance of the material to deformation due to loading or the influence of perpendicular forces. Regarding the level of material resistance due to loading, it is closely related to the flexural strength of a material. The flexural strength of HDPE material can be revealed through a destructive test, namely a bending test.

The flexural strength testing of a material is the best way to determine the strength and ductility of a material. In this test, the upper cross section of the test specimen will experience compressive stress due to loading and the back will experience tensile stress (Siswanto, 2021). Therefore, to determine the flexural strength of HDPE and determine whether the material

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can be applied as a basic material for shipbuilding, the authors make a solution by testing the flexural strength to reveal the mechanical properties of HDPE material.

2 EXPERIMENTS

The material which used in this research was HDPE sheets with three different brands (HDPE AGRU, Local, ROCHLING). The manufacture of test specimens is carried out through stages, making moulds, attaching the mould to the material, forming and cutting, re-checking dimensions, cleaning, and coding the test specimens. The mould was attached to the material whose dimensions have been designed according to the ASTM D-790 standard. The dimensions of the test specimens that have been regulated in ASTM D-790 for material thickness over 3.2 mm are 127 mm x 12.7 mm x 3.2 mm (ASTM, 2003). The shape of the test specimen has also been adjusted to the ASTM D-790 standard can be seen in Figure 1 below:

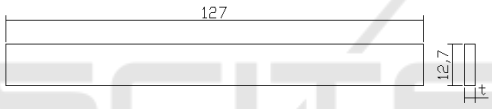

Figure 1: Testing specimen according of ASTM D-790.

After the test specimen was made, the flexural strength testing was carried out using a universal testing machine (UTM) with the SHIMADZU UH-600kNI brand with a testing speed of 2.7 mm/min. The processing of the test results was carried out after the testing process was completed to bring up the value of the mechanical properties after the flexural strength test, flexural strength, and flexural modulus.

3 RESULTS

The fishing boats or pompong boats made of HDPE could be used as a substitute for wood-based materials, this research was carried out only on the design side of fishing boats, without calculating the size of the construction (Jamal, 2017). Similar study in 2021 on tourist boats made of HDPE, where in determining the construction size of HDPE ships using the rules from DNVGL-ST-0342 (Fitria, 2021). Based on these two studies, this research was focused on knowing the mechanical properties of HDPE material before it was applied and calculated as ship construction.

Based on the characterization carried out with the flexural testing machine, the mechanical properties data after the flexural test were obtained in the form of flexural strength, flexural strain and flexural modulus as shown in Table 1.

Table 1: Flexural strength of HDPE materials.

No.	Merk	Flexural Strength (MPa)
1	AGRU HDPE	24.44
2	Local HDPE	58.62
3	*ROCHLING* HDPE	61.00

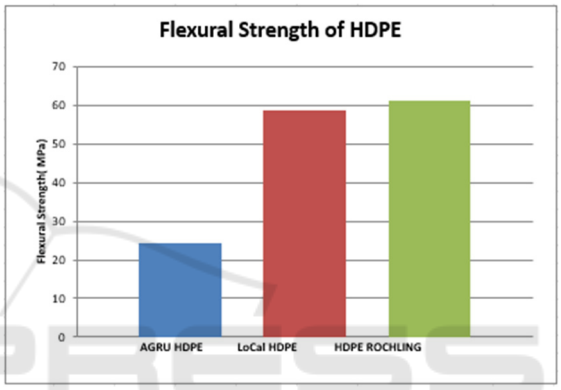

Figure 2: Flexural strength of HDPE.

Based on Table 1, shown that the test results produced the flexural strength values of the three HDPE brands. HDPE ROCHLING had the largest flexural strength value, which was 61.00 MPa. Meanwhile, HDPE AGRU had the smallest flexural strength, which was 24.44 MPa. There were previous studies that discuss the flexural strength of HDPE materials. Looking at the research conducted by Fetrissa in 2017 on the effect of the addition of LLDPE on the mechanical properties of HDPE, the flexural strength value of HDPE was 17.69 MPa. Based on this, the bending strength values of the three HDPE brands studied were above the flexural strength values of other HDPE studies. After knowing the value of flexural strength, it would be referred to one of the accepted standards for mechanical properties of HDPE material for shipbuilding, namely Turk Lyodu for Polyethylene Crafts. The criteria and minimum acceptance set by Turk Lyodu on the mechanical properties of HDPE material could be seen in Table 2.

Table 2: Acceptance standard of HDPE in *Türk Loydu Tentative Rules for Polyethylene Crafts.*

No.	*Property*	*Properties of* HDPE	*Unit*
1	*Flexural Strength*	Min. 40	MPa

(Source: *Turk Lyodu,* 2014)

The results of the acceptance of the mechanical properties of HDPE material after the flexural test resulted in the conclusion that the Local HDPE and HDPE ROCHLING met the standard values of the Turk Lyodu acceptability for the mechanical properties after the flexural strength test, it was flexural strength. Meanwhile, Local HDPE did not meet the acceptability standard due to the flexural strength value was below the acceptability standard.

In addition, the mechanical properties after bending testing in the form of flexural modulus can be seen as shown in Table 3.

Table 3: Flexural modulus of HDPE.

No.	Merk	Flexural Modulus (MPa)
1	AGRU HDPE	372.38
2	Local HDPE	648.54
3	*ROCHLING* HDPE	650.15

The results of the flexural strength test resulted in the flexural modulus of the three HDPE brands. HDPE ROCHLING has the largest flexural strength value, which is 650.15 MPa. Meanwhile, HDPE AGRU has the smallest flexural strength, which is 372.38 MPa. The research conducted by Ahmed in 2019 on the comparison of the physical and mechanical properties of HDPE and PP materials resulted in a bending modulus of HDPE material of 450 MPa (Awad, 2019). The results above were not accepted according to the standard which was minimum of flexural modulus of HDPE was less than 750 MPa.

The results of the acceptance of the mechanical properties of HDPE material after the bending test, it is concluded that there was no HDPE brand that meets the Turk Lyodu acceptability standard value for the mechanical properties after the flexural strength test, the flexural modulus. The three brands of HDPE cannot be implemented as a basic material for shipbuilding based on the mechanical properties of the flexural modulus

4 CONCLUSIONS

Based on the flexural strength testing that has been carried out, each of the highest mechanical properties of HDPE material was obtained, it was the flexural strength of 61 MPa and the flexural modulus of 650, 15 MPa (HDPE ROCHLING). Based on the accepted standard of mechanical properties of HDPE material regulated by Turk Lyodu, HDPE ROCHLING and Local HDPE materials can be used as basic materials for shipbuilding based on the acceptability of mechanical properties of flexural strength.

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