The Analysis of Tensile Strength of High-Density Polyethylene for Shipbuilding

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Abstract: Since years ago, ships have been made using various types of materials. The materials that be used, such as wood, steel, aluminium, and others. However, some of materials still have disadvantages, such as easily weathered, unrecyclable, and expensive. There is still a need for alternative materials that are cheap and environmentally friendly. HDPE can be used as an alternative because it has the above characteristics. It is necessary to analyse its mechanical properties first before applicated because of related to the strength of the material. One of its mechanical properties is tensile strength. Therefore, this study was conducted to analyse the mechanical properties of HDPE by testing. This research was conducted to determine the mechanical properties of tensile testing for the three brands of HDPE which were applied as the basic material for shipbuilding by referring to the Turk Loydu acceptability standard. The HDPE material was processed into test specimens and tested for tensile strength. Based on the tests that have been carried out, the highest mechanical properties of HDPE material were obtained, ultimate tensile strength and yield strengths of 32.7 and 26.89 MPa (Local HDPE), respectively. Fracture tensile strength and maximum strain of 29.60 MPa and 46.92% (HDPE ROCHLING), respectively. While the strain at yielding point was 2.39% (HDPE AGRU). Based on the acceptance standards of Turk Lyodu, HDPE ROCHLING could be used as a basic material for shipbuilding in terms of the acceptability of mechanical properties after tensile testing.

1 INTRODUCTION

Along with the development of technology, various types of materials have been used as basic materials for shipbuilding. The materials that have been used are wood, steel, aluminium, and fiberglass. Some of the above materials still have weaknesses, such as wood that is easily weathered, steel and aluminium which are expensive, or fiberglass which unrecyclable. Meanwhile, currently the use of materials that are durable, environmentally friendly, and has an economical price is a new concern for ship owners. Thus, from these problems, other alternative materials are still needed that can be applied as basic materials for shipbuilding.

HDPE (high density polyethylene) can be an alternative base material for shipbuilding. Currently, more than 70% of the plastics produced or used by the community are Polyethylene (PE), Polypropylene (PP), Polystyrene (PS), and Polyvinyl Chloride (PVC) so that many or even most of the current studies and research must relate to these four the type of polymer (Praputri et al, 2016). HDPE has characteristics which is durable against aging and corrosion, and recyclable (Siswandi, 2016). Before applied as a ship structural material, it was necessary to know in advance about the physical and mechanical properties of HDPE. Mechanical properties describe the characteristics of the material when it is subjected to loading.

Knowing the mechanical properties of HDPE were certainly related to the strength of the material. The strength of a material is needed to determine the level of resistance of the material to deformation that occurs due to loading. As for one of the mechanical properties that need to be known, namely tensile strength (tensile strength). Tensile strength can be generated through a series of tensile tests (tensile

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strength tests). Therefore, to determine the tensile strength of HDPE and determine whether the material can be applied as a basic material for shipbuilding, the authors made a solution through tensile strength testing.

2 EXPERIMENTS

The material was used in this research was HDPE sheet with three different brands (HDPE AGRU, Local, ROCHLING). The manufacture of test specimens was carried out by directly attaching a specimen mall whose dimensions have been designed based on the ASTM D-638 part type I standard. The dimensions of the test specimens that have been regulated in ASTM D-638 are listed in Table 1.

Table 1: The dimension of tensile test specimen according the ASTM D-638.

Dimension	*7 or under* (*Thickness,* mm)		*Tolerances*
	I	II	
W	13	6	0.5
L	57	57	0.5
WO	19	19	6.4
LO	165	153	*no max*
G	50	50	0.25
D	115	135	5
R	76	76	1

(Source: ASTM D-638, 2004)

The shape of the test specimen has also been adjusted to the ASTM D-638 standard as can be seen in Figure 1.

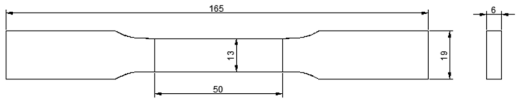

Figure 1: The specimen of tensile strength according ASTM D-638.

After the test specimens were made, tensile strength testing was carried out using a universal testing machine (UTM) with the SHIMADZU UH-600kNI brand with a testing speed of 50 mm/min. As for after the test, the results will be processed to reveal the mechanical properties after the tensile strength test, such as maximum tensile strength and yield strength.

3 RESULTS

The research conducted by Jamal in 2017 showed that fishing boats/pompong boats made of HDPE can 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). Fitria also conducted a 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 time the research is focused on knowing the mechanical properties of HDPE material before it is applied and calculated as ship construction.

Based on the characterization carried out with the tensile testing machine, the mechanical properties data after the tensile test were obtained in the form of tensile strength, strain, and modulus of elasticity as shown in the following table.

Table 2: Tensile strength of HDPE materials.

No.	Merk	Ultimate Tensile Strength (MPa)
1	AGRU HDPE	25.43
2	Local HDPE	32.75
3	*ROCHLING* HDPE	25.37

According to The Table 1 above, it shown that the results of the tensile strength test produce maximum tensile strength values for the three HDPE brands. The maximum tensile strength value is owned by Local HDPE, which is 32.75 MPa. Meanwhile, HDPE AGRU has the smallest maximum tensile strength, which is 25.37 MPa. The size of the tensile strength of a material is influenced by factors, such as the type of material, crystallinity, type of resin and additives used.

Table 3: Yield strength of HDPE materials.

No.	Merk	Yield Strength (MPa)
1	AGRU HDPE	14.06
2	Local HDPE	26.89
3	*ROCHLING* HDPE	20.54

Based on Table 2 above, it shows that the results of the tensile strength test produce yield strength values for the three HDPE brands. The value of the largest yield tensile strength is owned by Local HDPE, which is 26.89 MPa. Meanwhile, HDPE AGRU has the smallest maximum tensile strength, which is 14.06 MPa. There are previous studies that analyze the tensile strength of HDPE materials. Research conducted by Eva in 2016 on the effect of fillers on the mechanical properties of nano composites showed that the tensile strength of HDPE material was 22.59 MPa (Ginting, 2016). This concludes that the tensile strength values of the three HDPEs studied are above the tensile strength values of other HDPE studies.

After knowing the value of the mechanical properties of HDPE material that has been raised from the tensile strength test, it will then be referred to one of the accepted standards for mechanical properties of HDPE material for shipbuilding basic materials, namely Turk Lyodu for Polyethylene Crafts. The criteria and minimum acceptance set by Turk Lyodu on the mechanical properties of HDPE material can be seen in Table 3.

Table 4: Standar Keberterimaan HDPE dalam *Türk Loydu Tentative Rules for Polyethylene Crafts.*

No	*Property*	*Properties of* HDPE	*Unit*
1	*Tensile ultimate stress*	Min. 24	MPa
2	*Tensile yield stress*	Min. 17	MPa
3	*Tensile break stress*	Min. 14	MPa
4	*Elongation at yield*	1 to 27	%
5	*Elongation at break*	10 to 1500	%

Based on Table 8 above, it shows that the results of the acceptance of the mechanical properties of HDPE material after tensile testing resulted in the conclusion that only ROCHLING brand HDPE met the Turk Lyodu acceptability standard for mechanical properties after tensile strength testing. Meanwhile, Local HDPE does not meet the acceptability standard only for the value of the maximum strain. AGRU's HDPE does not meet the acceptable standards for maximum tensile and yield strength values. So from this, only HDPE ROCHLING material can be implemented as a basic material for shipbuilding based on mechanical properties after tensile strength testing.

4 CONCLUSIONS

Based on the tensile strength tests that have been carried out, each of the highest mechanical properties of HDPE material is obtained, namely the maximum tensile strength of 32.7 MPa (Local HDPE); yield tensile strength of 26.89 MPa (Local HDPE); fracture tensile strength of 29.60 MPa (HDPE ROCHLING); strain at yielding point of 2.39% (HDPE AGRU); maximum strain of 46.92% (HDPE ROCHLING).

Based on the acceptance standard of HDPE material mechanical properties regulated by Turk Lyodu, HDPE ROCHLING material can be used as a basic material for shipbuilding based on the acceptability of mechanical properties after tensile strength testing.

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