SHIP LIGHTWEIGHT ESTIMATION AT CONCEPT DESIGN STAGE: CASE OF INDONESIA SINGLE ENDED RO-RO FERRIES

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ABSTRACT

In recent years there have been many crossing vessels, especially those designed and built domestically. At the concept design stage, designers generally use the parent ship design method to determine the main dimension by taking one example of a reference ship with specifications close to the owner's requirements. However, this will be an obstacle if the existing ship specifications are unavailable, so designers must be able to perform initial calculations, especially predictions of the Lightweight (LWT). This paper introduces empirical formulas that utilize regression analysis to estimate LWT of Indonesia Single Ended Ro-Ro ferries. The formula of LWT based on Gross Tonnage (GT) requirements are presented.

Keyword: Lightweight, Single Ended Ro-Ro Ferries, Gross Tonnage

Introduction

Indonesia's economic condition continues to grow. Geographical conditions consist of many islands, and the need for means of transportation both for passengers and goods between islands is vital to support Indonesia's economic growth. In the past, there were still many ferry boats purchased from abroad, whether buying new or used vessels. The reason for this is that the process of buying used ships is faster and cheaper than building new ships domestically [1].

At present, numerous ferries are domestically designed and constructed for inter-island crossings. To create a suitable ship design, various factors such as main dimensions, speed, payload, GT, CB, DWT, and LWT must be taken into consideration. In order to gather such data, comparative data from existing and previously built vessels with similar specifications is required. By utilizing this data, regression analysis can be performed to achieve good results.

The aim of this research is to develop an empirical formula for estimating the lightweight (LWT) of ferries based on existing ship data. The formula will be linked to the gross tonnage (GT) of the ship to allow for the calculation of LWT based on GT data provided by the shipowner. The development of such a formula is necessary since there is no existing empirical formula for determining the LWT of ferries during the concept design stage, especially in Indonesian shipyards. Even if two ships have the same size, their LWT may differ due to several factors, such as the availability of building materials, including the size and profiles of the plates used. Moreover, technological advancements in shipbuilding, such as automated tools, may also affect the resulting LWT.

Ferry

Ferry is a ship usually identical for transporting passengers and goods. A passenger ship is used for passenger transportation with more than 12 passengers, excluding crew [2]. Ferry ships can be Ro-Ro ships to increase efficiency or serve more comprehensive needs.

Roll-on/roll-off (Ro-Ro) ships are designed to transport vehicles, such as motorcycles, cars, and trucks. It is called roll-on/roll-off because these vehicles must be driven to enter and exit the ship, in contrast to lift-on/lift-off (Lo-Lo), which uses a crane for loading and unloading.

This ship is equipped with a ramp door to facilitate the entry and exit of vehicles at the wharf, usually located at the stern and bow. The advantage of the

Ro-Ro ship is that the cargo enters the ship along with land transportation, so the cargo does not need to be stacked in the stacking yard first.

Ship Design Method

The design process is a process that is carried out repeatedly to produce a design that is in accordance with what is desired. In the design process for the construction of new ships, there are several design stages, namely, concept design, preliminary design, contract design, and design details [3].

Light Weight Tonnage (LWT)

Light Weight Tonnage (LWT) consists of the weight of the ship's hull, tools and equipment, and engine system. The steel's weight on the ship includes the ship's shell plates, profiles, supports, and brackets on the ship, as well as additional loads for safety reasons. The weight of the engine system on the ship consists of the main engine, propulsion unit, shafting, propeller, and additional loads for safety reasons. The weight and equipment on the ship must be listed first. So, it can be concluded that LWT is the weight of an empty ship without cargo or consumables [4,5].

Gross Tonnage (GT)

Gross tonnage (GT) or gross tonnage of the ship is the calculation of the volume of all spaces located below the ship's main deck plus the volume of enclosed spaces located above the main deck, be it the superstructure or the deckhouse. It is the total of all closed rooms on the ship, then multiplied by the K_1 coefficient. On ferries included in the GT are passenger space, navigation room, vehicle space if closed as a whole, side rooms that are closed and found on the vehicle deck, and all spaces below the main deck.

Methodology

Data Collection

This data collection was carried out by searching data at several shipyards and the Ship Classification Bureau. The data needed are the ship's GT calculation data, general arrangement, and stability booklet, which contains the ship's LWT data.

Data Analysis

The data obtained is analyzed according to the requirements. The analysis carried out includes recalculation of GT based on general arrangement drawing. The GT value can be calculated using the following equation (1) [6]:

$$GT = K_1 V \quad (1)$$

where:

V : Total volume of all enclosed space on the ship (m3)

K_1: 0,2 + 0,02log10 V

Then, analysis of the relationship between GT and LWT is calculated by using the regression method. The term regression was originally meant to estimate the value of one variable against another variable. Regression analysis is a technique for building straight-line equations and using those equations to make predictions. The mathematical model in explaining the relationship between variables in the regression analysis uses the regression equation, which is a mathematical equation that defines the relationship between two variables [7].

With the regression method discovery, the application of this method can also be used in the maritime world, especially in the ship-building process, both to determine the main dimensions of the ship and to determine LWT.

Application of the New Formula and Comparison with the Existing Formula

The accuracy of the new formula obtained by analyzing the regression method is tested by trying to make examples of owner requirements. The LWT value of new formula will be compared with the LWT value generated by existing formula [8].

$$LWT = Ws + Wm + Wo + Wmargin \quad (2)$$

where

LWT : lightweight

Ws : the structural weight

Wm : propulsion machinery weight

Wo : outfit and hull engineering weight

Wmargin : Lightship design (or Acquisition) weight margin that is included as protection against the underprediction of the required displacement.

$$Ws = K*E^{1.36}(1+0.5(CB'-0,7))$$

$$CB' = CB + (1 - CB)[(0.8D - T)/3T]$$

$$E=L*(B+T)+0,85*L*(D-T)+0,85\sum_i^n Li\ hi + 0,75\sum_i^n Li\ hi$$

where

K : structural weight coefficient

CB : Block Coefficient

D : Depth

T : draught

L : Length

B : Breadth

h : profile area of the deckhouse

Wm = Wme + Wrem

Wme = $\sum_{i}^{n} 12\ (MCRi/Nei)^{0.84}$

Wrem = Cm $(MCR)^{0.70}$

Where:

MCR : Maximum Continuous Rating

i : the index on multiple engines

Cm : 0.83 for passenger vessels and ferries

Wo = C_O LB

Where:

Co : function of ship type and length

Result and Discussion

Relationship between GT and LWT

Based on data collected of LWT and recalculation of GT based on general arrangement drawing by using equation (1), the relationship between GT and LWT is shown in Figure 1.

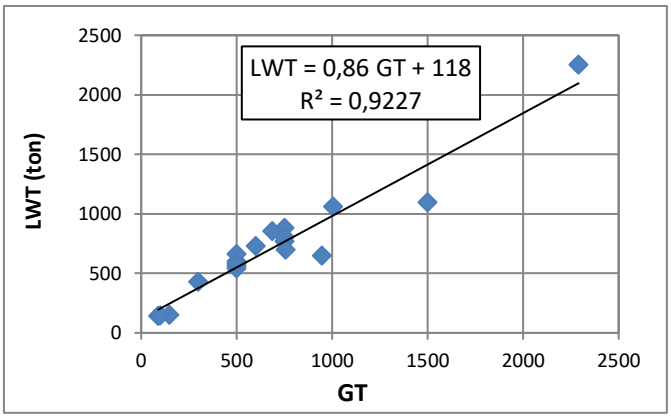

Figure 1. GT and LWT Relationship

Based on linear regression in Figure 1, the relationship between GT and LWT is shown in equation (3).

LWT = 0,86 GT + 118 (ton) (3)

LWT Estimation By New Formula

LWT of three different GT requirements i.e. 500 GT, 750 GT, and 1000 GT is calculated by using equation (3). The results of LWT estimation of those three ships are shown in Table 1.

Table 1. LWT estimation by using new formula

No	GT	LWT (ton)
1	500	548
2	750	763
3	1000	978

LWT Estimation by Existing Formula

LWT of three different GT requirements i.e., 500 GT, 750 GT, and 1000 GT is calculated by using equation (2). The results of LWT estimation of those three ships are shown in Table 2.

Table 2. LWT estimation by using existing formula

No	GT	LWT (ton)
1	500	531
2	750	868
3	1000	1159

Comparison of the New and the Existing Formula Results

The comparison of LWT between the results produce by new and existing formula is shown in Table 3.

Table 3. LWT comparison results

GT	LWT (ton)			Diff. to real (%)	
	New formula	Existing Formula	Real	New formula	Existing Formula
500	548	531	564	-2,8%	-5,9%
750	763	868	772	-1,2%	12,4%
1000	978	1159	1064	-8,1%	8,9%

Based on Table 3, generally shown that for all ship tonnage, the LWT results of new formula is lower differentiation compared to real data than existing formula. For tonnage of 500 GT, LWT from new formula is 548 ton while existing formula is 531 ton which has difference to real data is -2.8% and -5.9% respectively. For tonnage of 750 GT, LWT from new formula is 763 ton while existing formula is 868 ton which has difference to real data is -1.2% and 12.4% respectively. Finally, for tonnage of 1000 GT, LWT from new formula is 978 ton while existing formula is 1159 ton which has difference to real data is -8.1% and 8.9% respectively.

Conclusion

This study has produced an empirical new formula for lightweight (LWT) estimation of single ended ro-ro ferry for Indonesia case by the function of Gross Tonnage (GT). The obtained formula is LWT (ton) = 0.86GT + 118. Compared to the existing formula, new formula gives better results which is lower difference to real data for all tonnage cases.

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