Stability Of Redesigned Hull Line Of Manado Prototype Purse Seine Vessel

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Abstract : This study was aimed at knowing the effect of redesigned hull line of small purse-seiner on the vessel stability. Data inputs and simulation employed Maxsurf modeller Advanced and Maxsurf Stability Enterprice applications. Results showed different stability value of the vessel with new hull line from the prototype one that also met the standard stability of International Maritime Organization (IMO). Moreover, increase in vessel stability value occurred in the redesigned hull line of PKU-4 compared with that of the prototype vessel, PKU-1, and the redesigned vessel hull line of PKU-2 and PKU-3. This finding confirms that the hull line of Manado prototype purse seiner could be improved in order to have better stability.

Keyword: static stability, dynamic stability, vessel, purse seine.

1. INTRODUCTION

Vessel stability is the ability of the ship to back to its initial position after experiencing inclination due to the pressures from outside or in the vessel or after experiencing temporal moments [1], About 50-60% of accidents through capsizing of the vessel result from flooding and stability loss [2], [3]. The vessel length-width ratio is often used as ship stability indicator in which less width will reduce the stability, and higher width will give better stability [4]. Nevertheless, the principle dimension and the ratio of vessel length (L), width (W), and depth (D) will not directly give the description of the vessel shape, determine and reflect the performance of crucial aspects, such as stability, resistance, loading capacity, manuver, and others [5]. Indonesian fishermen's vessels below 25 M long is, in general, still built traditionally [6], belonging to the group of Galician ships [3]. For this, the traditional fishermen have long utilized wooden boats and until now they still this type of wooden boat due to inexpensive building costs compared with the steel-materialized boat [7], [8]. Purse seine vessel is one of the fisheries vessels with typical shape variations depending upon where the vessel is built. Although this vessel possesses different shapes in different localities, all these are designed to support the vessel activities since the vessel stability is absolutely needed in purse seine fishing operations. A study on the stability level of several wooden purse seine vessels in North Sulawesi, by comparing the purse seine vessels from Manado, Bitung, and Molibagu [9], found that the purse seine vessel from Manado has better stability than that from Bitung and Molibagu. A simulation of the vessel main dimension ratio is also made to know and evaluate the change in fisheries vessel design and stability [10]. Therefore, this study aims to redesign the hull line of Manado purse seine vessel through simulation of major vessel dimension ratio in order to know the effect of the new hull line on the vessel stability.

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Vessel stability is divided into static and dynamic stability [11]. The former is indicated with the righting arm value (GZ) and the latter is expressed in area below the static stability curve. Vessel stability is one of the major requirements to guarantee the vessel security and the working comfort on the ship [12]. The crucial points in vessel stability are centre of gravity (G), centre of bouyancy (B), and metacentre (M) [2], [13]:

(a). Center of Gravity is known as G point of a ship, a gathering point of all forces pressing down the ship. The position of G point on the empty ship is determined by the stability experiment. The position is dependent upon weight division on the ship. As long as no weight is shifted, the G point will not change even though the vessel is swerved or nodding.

(b). Center of Buoyancy is known as B point of the ship, a gathering point of the resultant forces pressesing upright upward the vessel part immersed in water. The capture point of B is not a fixed point, but it will be moved by changes of the ship load.

(c). Metacenter is known as M point of the ship, it is a false point of the boundary at which point G should not pass to maintain the vessel at a positive stability (stable). Metacentric point can change its position and depends on the magnitude of the angle. All vessel types of either single or multiple hull have good stability as far as the metacenter point is above the vessel gravity point [14].

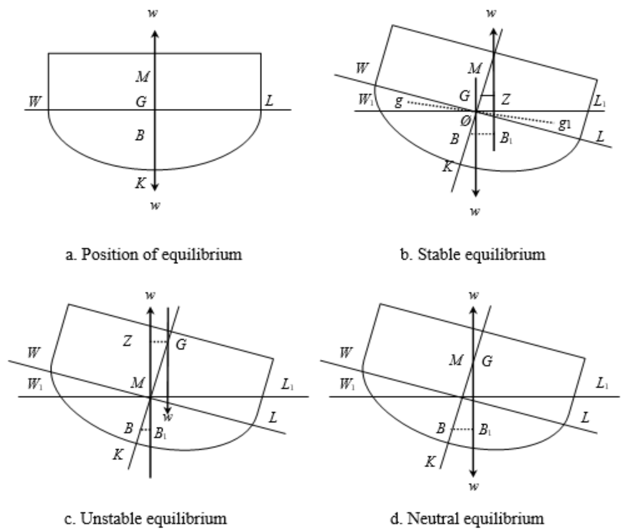

***Figure 1**. Vessel equilibrium (Smith, 1975). B - centre of buoyancy, G - centre of gravity, M - Metacentre, GZ - Righting arm, K - Keel, WL - Water line, w – Force, Ø - Rolling angle.*

Nomura and Yamazaki (1977) claimed [15] that main requirement to have the ship balance on the seawater is the center of buoyancy (B) should be in the straight line as the center of gravity (G), and the center of gravity (G) itself should be under the metacenter (M). Rawson and Trupper [16] added that the vessel balance position will be obtained if all forces and moments on the ship equal to zero. Based on the relative position of M point to the center of gravity (G), There are 3 categories of vessel condition [17], [18]: if M position is above G, the ship will in stable condition; the M position is the same as G, the ship will be in neutral; and if M position is below G, the ship will be in unstable condition (Table 1). The objective of the study is to find better stability of fishing vessel through hull line redesign of the standard wooden fishing vessels in North Sulawesi.

2. METHOD

2.1. Data source

This study utilized a virtual simulation through Advabced Maxsurf software application. Data used the present hull-line of the prototype purse seiners from 3 different localities, Manado, Bitung and Molibagu. These vessel prototypes represent the purseiner types from the northern, eastern, and southern parts of North Sulawesi. The stability testing has shown that the prototype of Manado fishing vessel has better stability than those from Bitung and Molibagu [9]. The redesign of Manado prototype vessel in the form of hull line was done by taking the ratio of principle dimension in width (B) and depth (D), and then proportionally changing the structure of hull line design in 3 dimensions. Changes in length (L), width (B), and depth (D) ratio were done based on the standard ratio of main dimension of small puse seine vessel given [1] as follows: L/B = 3.10 – 4.30, B/D = 2.10 – 5.00, and L/D = 9.50 -11.00. From the median of the principle dimension scale, 3 new hull line forms were obtained and coded as Perikanan Kelautan Unsrat (PKU): PKU-1 (prototype Manado), PKU-2. PKU-3, and PKU-4. (Figure 2, 3, 4, 5).

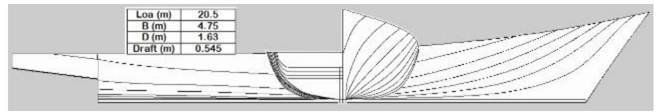

***Figure 2**. Hull line of PKU-1*

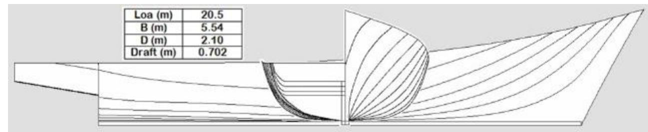

***Figure 3.** Hull line of PKU-2*

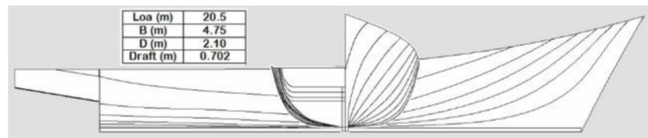

***Figure 4.** Hull line of PKU-3*

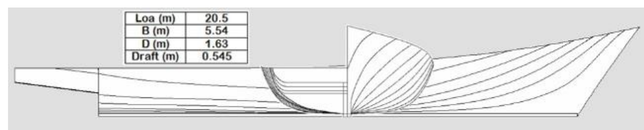

***Figure 5**. Hull line of PKU-4*

The principle dimension of these 4 object vessels is presented in Table 1.

Table 1.
Principle dimension of the vessel at mean loading condition.

Vessel	Principle Dimension			
	Length (m)	Breadth (m)	Depth (m)	draft (m)
PKU-1	20.5	4.75	1.63	0.545
PKU-2	20.5	5.54	2.10	0.702
PKU-3	20.5	4.75	2.10	0.702
PKU-4	20.5	5.54	1.63	0.545

The new hull-line design data of the Manado prototype vessel were exported in IGS format using version 3.43-Free-Ship Plus Application. The IGS-formatted hull line data of the vessel were then converted into mds format using V8i (20.00.02.31) Maxsurf modeler advanced application, and presented in the form of tables and figures.

2.2. Data analysis

Data analysis was carried out by imputing the hull line data and other supporting data in relation with vessel stability, then applying Maxsurf Stability Enterprice V8i (20.00.02.31) software application and presented in the form tables and figures. The static vessel stability was presented in GZ curve following Attwood and Pangelly (1967) [19]:

$$GZ = \sin \Theta \, (GM + \tfrac{1}{2} BM \tan^2 \Theta) \quad (1)$$

$$BM = I / V \quad (2)$$

where BM = distance of floating point up to M (m),
V = volume displacement (m3),
I = Moment inertia (m4),
GM = Gravity metacenter (m),
Θ = Sudut oleng (°).

The area below the static stability curve is considered as vessel dynamic stability value following Simpson I formula [15]:

a. Area 0^0-10^0
   h = 0.08725 rad., Y_0 = m , Y_1 = m , Y_2 = m
   Area = $^h/_3$ ($1Y_0 + 4Y_1 + 1Y_2$) = m.rad. (3)
b. Area 10^0-30^0
   h = 0.1745 rad., Y_0 = m , Y_1 = m , Y_2 = m
   Area = $^h/_3$($1Y_0+4Y_1+1Y_2$) = m.rad. (4)
   Area 0^0-30^0 = (a) m.rad.+(b) m.rad = m.rad.(A)
c. Area 0^0 - 40^0
   h =0.1745 rad.,Y_0 = m ,Y_1 = m ,Y_2 = m ,Y_3 = m, Y_4 = m
   Area =$^h/_3$($1Y_0+4Y_1+2Y_2+4Y_3+1Y_4$)= m.rad.(B)(5)
d. Area 30^0 - 40^0
   h = 0.08725 rad. ,Y_0 = m ,Y_1 = m ,Y_2 = m
   Area = $^h/_3$($1Y_0+4Y_1+1Y_2$)= m.rad.(C) (6)
   Note: (5^0) = 0.08725; h (10^0) = 0.1745

The ship stability criteria followed the International Maritime Organization (IMO) standard of Code A.749(18) Ch3 [20].

3. RESULTS AND DISCUSSION

Static stability analysis covering the slope angle and the length of righting arm (GZ) of the compared vessels at the average load condition is shown in Table 2 and Figure 6.

Table 2.
Vessel tilt angle and length of righting arm (GZ) at the average load condition.

Vessel tilt angle (degree)	Length of vessel righting arm, GZ (m)			
	PKU-1	PKU-2	PKU-3	PKU-4
-30	-0.447	-0.489	-0.214	-0.754
-20	-0.376	-0.398	-0.178	-0.627
-10	-0.223	-0.228	-0.101	-0.381
0	0	0	0	0
10	0.223	0.228	0.101	0.381
20	0.376	0.398	0.178	0.627
30	0.447	0.489	0.214	0.754
40	0.473	0.551	0.242	0.758
50	0.377	0.505	0.251	0.595
60	0.188	0.332	0.149	0.351
70	-0.039	0.1	-0.021	0.071
80	-0.281	-0.158	-0.218	-0.226
90	-0.523	-0.425	-0.425	-0.523
100	-0.753	-0.685	-0.627	-0.807
110	-0.961	-0.925	-0.813	-1.066
120	-1.135	-1.134	-0.972	-1.289
130	-1.267	-1.297	-1.092	-1.464
140	-1.343	-1.4	-1.162	-1.576
150	-1.349	-1.427	-1.169	-1,608
160	-1.256	-1.34	-1.077	-1.525
170	-0.95	-1.005	-0.772	-1.201
180	0	0	0	0

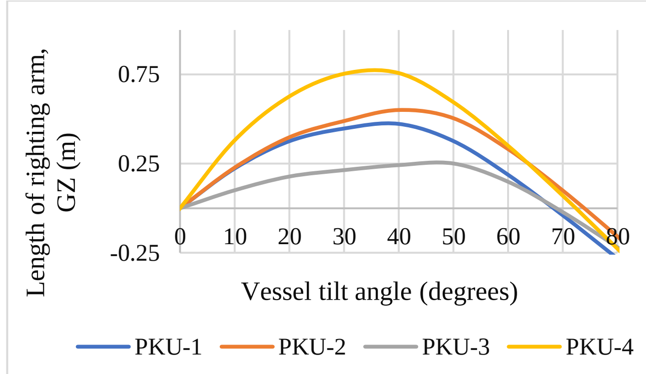

Figure 6. *Ship static stability curve at mean load condition.*

Table 3.
GZ values of 4 purse seine vessels at the average load condition and International Maritime Organization (IMO) standard value of Code A.749(18) Ch3

GZ curve value	IMO Standard (Minimum value)	Object vessel			
		PKU-1	PKU-2	PKU-3	PKU-4
A(0-30^0)	0.055$_{m\text{-}rad.}$	0.146	0.154	0.069	0.247
B(0-40^0)	0.090$_{m\text{-}rad.}$	0.228	0.246	0.108	0.381
C(30-40^0)	0.030$_{m\text{-}rad.}$	0.081	0.092	0.039	0.134
D(Sudut GZ_{max})	30$_{deg}$	38.2	41.8	46.4	35.5
E(GZ_{min})	0.20$_m$	0.475	0.553	0.257	0.776
F(GM)	0.35$_m$	1.366	1.377	0.609	2.355

Table 2 shows that the four object vessels have positive GM (M position above G) meaning that the vessels are in stable condition [17]. In this condition, the righting moment could be achieved, a moment where its righting arm moves opposite to the slope of the vessel so that when the vessel experiences inclination it could return upright. GZ is a righting arm as righting moment component after multiplied by the vessel displacement (Δ). The evaluation on vessel stability is conducted through evaluation on the vessel static and dynamic stability. The former is indicated by the righting arm GZ value, whereas the letter is indicated with the area below the static stability curve. Although all these object vessels have the stability value that meets the IMO standard (Table 3), PKU-4 has much better stability value than the other 3 vessels for all item criteria (A-F). It could result from the addition of the width size and still has relative KG value similar to the prototype vessel (PKU-1). PKU-2 gets addition of width size and depth size and PKU-3 has only addition of the depth. If compared with the same type of the traditional fishing vessel, KMN Purbasari [21], PKU-4 has longer righting arm GZ, 0.776 M, while KMN Purbasari has 0.716 M, indicating that PKU-4 has better stability than that of KMN Purbasari. Length and width ratio of the vessel is often used as the vessel stability indicator, in which small width size will reduce the stability [3]. [4], [22]. Such a condition will influence the inertia moment value of the water line (I), BM value, and righting arm (GZ) value. In addition, metacenter position (M point) is determined by the inertia moment of the water line and the vessel's hull line submersion [23].

4. CONCLUSION

All prototype purse seine vessels and the redesigned hull line have met the standard stability of International Maritime Organization. Nevertheless, this study found that the redesigned hull line of PKU-4 had higher stability than the prototype vessel PKU-1 and the redesigned hull line of PKU-2 and PKU-3. Therefore, there is potential to increase the purse seiner's stability in Manado in order to have better fishing vessels.

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