Stability Analysis of Hybrid Catamaran Fishing Vessel

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Abstract: The successful development of catamaran mode as passenger vessels has been extended to the development of catamaran fihing vessel. The study is combined with the development of hybrid power of the catamaran fihing vessel in order to minimize the use of fossil fuel and hence reduce greenhouse ga (GHG) effect. A combination power by using diesel engine, solar panels and sail is investigated. The study is focused on stability analysis with restriction to maintain its function as a fishing vessel.

Keywords : fishing vessel, hybrid power, stability, diesel engine, solar panel, sail.

1. Introduction

Development of environmentally friendly vessels has become very popular since the last 20 years. The reasons for this are attributed to the lack and high cost of oil. In the case of Indonesia, the situation has causal the fishermen into troubles with tendencies that they become bankrupt. There was a study reported that the growth of the construction of new fishing vessels in Indonesia reached about 6 % between 2001 and 2005 [1]. However, about half of those vessels have not been operated again recently the high cost of fuel oil.

Due to, there many efforts conducted by scientists, governments and IMO in order to reduce the spread of toxic gases to the atmosphere such as CO, CO_2, SO_2 and NO_2 which is caused by the use of fossil fuels by ships [2]. A new term called EEDI (energy efficiency design index) has been introducced by the IMO (international maritime organization) in 2009 in order to measure the level of efficiency of the power (SEEMP) and its effect to the green house gases (GHG) impact [3]. These findings indicate that the use of fossil fuels should be reduced into a certain level in order to maintain the environment clear and healthy.

Many efforts have been made in order to reduce the use of fuel oil. A number of power systems have been developed such the reuse of sails in combination with the use of marine diesel engine; this is later known as sail assisted engine [4]. The powering vessel without using engine and fuel oil has become more popular in connection with environmental issues, later known as green economy concept. They are: (1) the use of sail, solar powered boat and wave power mechanism individually and (2) the combination of two or three of them [30]. Although the results of those developments are still far from economic benefits, research and development of those power systems has been carried out very intensive around the world such as reported in [5, 6].

In term of the vessel itself, the use of catamaran type of vessel as medium- and high-speed passenger carriers has been popularly known and reported in many papers [7, 8 and 9]. Those successes are being considered with the possibility to apply it into the development of fishing vessels, some work on itreported in [37]. If it is successful, it can help thousands of Indonesian fishermen to survive as well

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as to reduce the effect of GHG hence cleaner and fresher.

2. LITERATURE REVIEW

2.1 The Catamaran Vessel

It has been reported in many papers that there is an increase growth on safer and more efficient ships and in particular as passenger carriers. Various types of vessel are further developed in order to satisfy those criteria. Among others, the concept of catamaran is preferred and becoming more popular [8][9][13][36]. In more details, the catamaran has unique characteristics in terms of stability, resistance, and seakeeping. Because the total width of catamaran is larger than that of equal monohull, this ship has better transverse stability [8].

2.2. Stability

Transverse Stability of vessel depends on KB, BM, KG and GM. Since Metacentre (M) is at the intersection of vertical lines through the centres of buoyancy in the initial and slightly inclined positions. GM is the most important.

As shown in Figure (A) and (B), a righting couple being formed when the vessel is heeled by the external force. The lever of the couple is known as the GZ or Righting lever. Stability or statical stability is the ability of a vessel to return to her initial position after being forcibly inclined. Moment of statical stability or righting moment is a measure of the vessel's ability to return to her initial position. It is always W*GZ tonnes-metres.

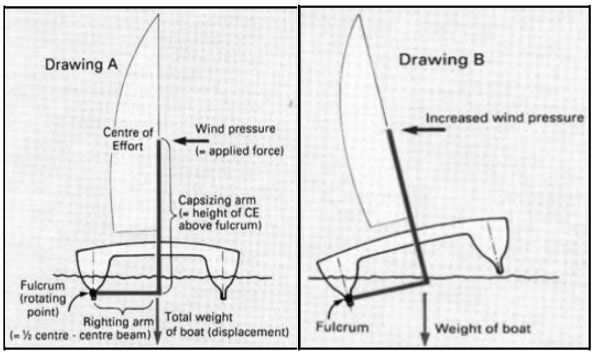

Fig.3 (A,) (B) - shows in a simple lever diagram the forces that act on a catamaran when sailing. (Source : Catamaran Stability, By James Wharram and Hanneke Boon,1991)

To balance :

W Boat x Right arm = Wind press x Capsize arm	(5)
(Righting moment) **(Capsizing moment)**	

3. METHODE

Stability analysis use Froude-Krylov Method.

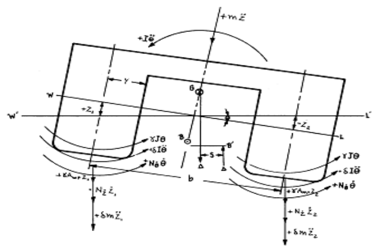

Fig.4 – Catamaran Moments and Forces

Useful formulae [34] :

KM = KB + BM (6), KM = KG + GM (7)

Substitute (6) to (7) : GM = KB + BM – KG (8)

For a ship-shaped vessel : KB ~ 0.535 x d at each WL (9)

For a ship-shaped vessel : $BM_T = C_W^2 \times B^2/12 \times d \times C_B$ (10)

For a ship-shaped vessel : $BM_L = 3 \times C_W^2 \times L^2/40 \times d \times C_B$ (11)

GZ = GM x sin θ (12)

Righting moment = W x GZ (13)

$GZ = \sin\theta(GM + (BM \times \tan^2\theta)/2$ (14)

Useful formulae [35]:

Displ (mLDC) = 2 × BWL x LWL× T c × C p × Cm × 1025 (15)

Lwt (mLCC)= 0.7 × mLDC, after Construction (16)

Lwt (mmoc) = 0.8 × m LDC, for stability (17)

BMT = 2[(BWL3 × LWL xCw2 / 12) +(LWL × BWL× Cw x (0.5BCB)2)] ×(1025 / mLDC) (18)

BML = (2×0.92xLWL3×BWL x Cw2)/12 x(1025/mLDC) (19)

4. Result and Discussion

4.1 Set up Technical Data

Particulars of Boat :

Monohull : Lwl : 13.8 m, B : 2.88 m, H : 1.3 m, T : 0.65 m, Disp.: 11.80 ton, Cb : 0.498, Cp : 0,69, Cm : 0,69, Cwp : 0,72.

Catamaran : Lwl : 13.8 m, Bdemihull : 1.318 m, Btotal : 7.118 m, H : 1.44 m, T : 0.694 m, S/L : 0.4, Disp,demihull : 5.9 ton, Disp.total : 11.80 ton, Cb : 0.432, Cp : 0,550, Cm : 0,785, Cwp : 0,72.

4.2 Result

a. S/L = 0.2

Tabel 1 Result stability calc. of Hibrid CFV S/L = 0.2

ϕ'	GM	Stab. Statis	Stab. Dinamis
		GZ	INT
0	2.030	0	0
15	1.840	0.477	0.477
30	0.776	0.388	0.865
45	-0.285	-0.201	0.663
60	-0.898	-0.777	-0.114
75	-1.347	-1.301	-1.415
90	-1.735	-1.735	-3.150

Tabel 1 shown Result stability calcculate of Hibrid CFV S/L = 0.2 use Froude-Krylov Method, and than that result convert to become Stability Curve as shown in fig. 5.

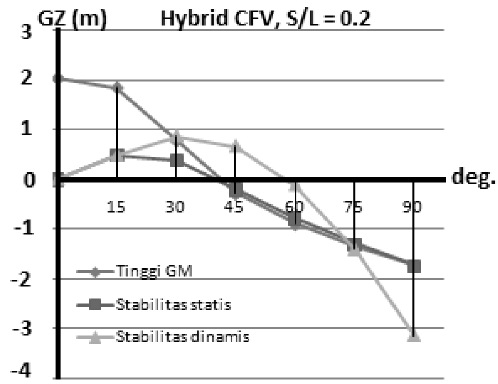

Figure.5 – Stability curve of Hybrid CFV, S/L = 0.2

Analysis :

The value of Initial Stabilty is positif, at Heel angel 0’ GM value is 2.030. Pada harga roll angle of 15 'the value of GM fell to 1,840 and the return arm (GZ) has a value of 0.477 as well as the value of the dynamic stability = 0.477. On the roll angle 15 'static stability arm value equal to the value of dynamic stabiltas arms ship. GZ value = 0 at an angle of 46.12 shaky ', the value of GM = 0 at an angle of 38.70 shaky', dynamic stability Sleeve value = 0 at an angle of 48.11 shaky '. This means that the ship is really sinking in value roll angle of 48.11 'because it is intrinsically dynamic stabiltas an energy reserve that is used to return the ship to heel original position. Value of the dynamic stability of the arm is an integral of the value of static stability. According to CB Barras, the measurement arm roll static stability at small angles (<15^0) measured at Keel boats, while for large roll angles (>15^0) measured at the center of gravity (KG) ship.

b. S/L = 0.3

Tabel 2 Result of stability calc. of Hibrid CFV S/L = 0.3

ϕ'	GM	Stab. Statis	Stab. Dinamis
		GZ	INT
0	7.861	0	0
15	3.747	0.970	0.970
30	2.032	1.016	1.986
45	0.440	0.311	2.298
60	-0.479	-0.415	1.883
75	-1.153	-1.114	0.769
90	-1.735	-1.735	-0.966

Table 2 shows the results of stability calculations were computed using a hybrid CFV Froude-Krylov method, then from these results to curves stability as described in Figure 6.

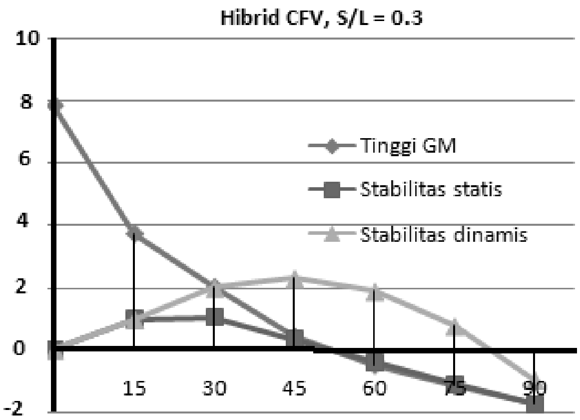

Figure 6. stability curve of Hibrid CFV SL = 0.3

analysis:
initial Stabilty of ship is positive, because the value of the angle 0^0 value of GM = 7,861. At the value of roll angle 15^0 value of GM fell to 3,747 and the return arm (GZ) has a value of 0.970 as well as the value of the dynamic stability = 0.970. On the roll angle 15 'static stability arm value equal to the value of dynamic stabiltas arms ship. GZ value = 0 at an angle of 53.57 shaky ', the value of GM = 0 at an angle of 52.28 shaky', dynamic stability Sleeve value = 0 at an angle of 83.35 shaky '. This means that the ship is really sinking in value roll angle of 83.35 'because in essence it is a dynamic stabiltas energy reserves used to back mengolengkan ship in its original position. Value of the dynamic stability of the arm is an integral of the value of static stability. According to CB Barras, the measurement arm roll static stability at small angles (<15^0) measured at Keel boats, while for large roll angles (>15^0) measured at the center of gravity (KG) ship.

c. S/L = 0.4

Tabel 3 Result of stability calc. of Hibrid CFV S/L = 0.4

ϕ'	GM	Stab. Statis	Stab. Dinamis
		GZ	INT
0	17.586	0	0
15	5.848	1.515	1.515
30	3.288	1.644	3.158
45	1.165	0.824	3.982
60	-0.061	-0.052	3.930
75	-0.959	-0.926	3.004
90	-1.735	-1.735	1.269

Table 3 shows the results of stability calculations CFV Hybrid S / L= 0.4, calculated using the Froude-Krylov method, then from these results to curves stability as described in Figure 7

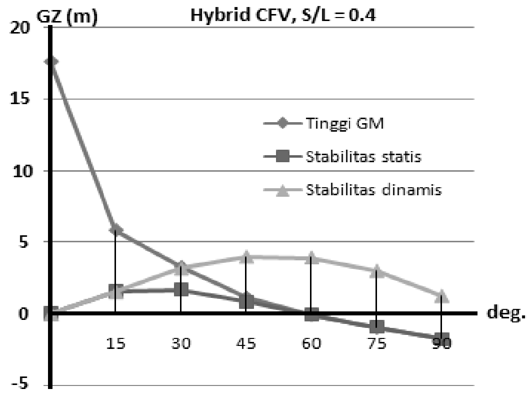

Figure 7. Stability Curve

analysis:

initial Stabilty of ship is positive, because the value of the angle 0 'value of GM = 17 586. At the value of roll angle 15 'value of GM fell to 5,848 and the return arm (GZ) has a value of 1,515 as well as the value of the dynamic stability = 1.515. On the roll angle 15 'static stability arm value equal to the value of dynamic stabiltas arms ship. GZ value = 0 at an angle of 45.89 shaky ', the value of GM = 0 at an angle of 45.74 shaky', dynamic stability Sleeve value = 1,269 m at an angle of roll 90 '. This means that the ship is really sinking in value roll angle> 90 'because it's intrinsically dynamic stabiltas an energy reserve that is used to return the ship to heel its original position. Value of the dynamic stability of the arm is an integral of the value of static stability. According to CB Barras, the measurement arm roll static stability at small angles (<15 ') measured at Keel boats, whereas for large roll angles (> 15 ') measured at the center of gravity (KG) ship.

d. Monohull – hybrid

Tabel 3 Result of stability calc. of Monohull-Hybrid

ϕ'	GM	Stab. Statis	Stab. Dinamis
		GZ	INT
0	-0.974	0.000	0.000
15	0.584	0.151	0.151
30	-0.116	-0.058	0.093
45	-0.819	-0.579	-0.486
60	-1.225	-1.061	-1.546
75	-1.522	-1.470	-3.017
90	-1.779	-1.779	-4.796

Table 4 shows the results of stability calculations Monohull-hybrid was calculated using the Froude-Krylov methods, the results described later became its stability curve as shown in figure 8.

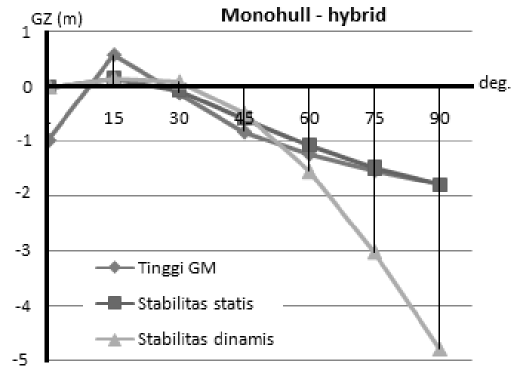

Figure 8. Stability Curve

Analisis :

initial Stabiltas of ship is negative, because the value of the angle 0 'value of GM = -0974. At the value of roll angle 15 'GM value increased to 0.584 and the return arm (GZ) has a value of 0.151 as well as the value of the dynamic stability = 0.151. On the roll angle 15 'static stability arm value equal to the value of dynamic stabiltas arms ship. GZ value = 0 at 19:16 wobble angle ', the value of GM = 0 at 16:35 wobble angle', the dynamic stability Sleeve value = 0 at an angle of 42.59 shaky '. Since the beginning of the ship had experienced unstable equilibrium, so the stability condition of the vessel from the beginning was not bad need of further analysis.

4.3 Discussion

Resume

Descript	Initial Stab	Capsize degree			Remark
		GM	S-S	S-D	
S/L=0.2	**Positif**	**46,12'**	**38.70'**	**48,11'**	**Capsize degree 48,11'**
S/L=0.3	**Positif**	**52.28'**	**53,57'**	**83.35'**	**Capsize degree 83,35'**
S/L=0.4	**Positif**	**45.74'**	**45.89'**	**> 90'**	**Capsize degree >90'**
Monohl	**Negatif**	**16.35'**	**19.16'**	**42.59'**	**Capsize degree 0'**

Note : GM=Distance of Gravity Metacentre, S-S=Static Stability, S-D=Dynamic Stability

5. Conclusions

The development of hybrid vessel gave a promising hope. Application of hybrid technology is very useful when applied to catamaran fishing vessels The Hybrid CFV S/L= 0.4 have capsizing degree more than 90' with initial stability is positive. KMt value is 17.586 m. . In more details, the catamaran has unique characteristics in terms of stability because the total width of catamaran is larger than that of equal monohull, this ship has better transverse stability.

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