OPTIMIZATION OF CATAMARAN DEMIHULL FORM IN EARLY STAGES OF THE DESIGN PROCESS

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Abstrak

The amounts of research about catamaran have generated a practical formula to simplify the calculations of catamaran resistance. Ship designer will calculate the predictions of catamaran resistance rapidly. The aim of this research is focused to search the optimal demihull form where the hull form has the lowest resistance compared to other hull form models with the same displacement. To generate the different hull form, the initial hull form (parent hull) is transformed so that become some models by changing the parameter of coefficient block (Cb) in range ±10% with Lwl, T, H, volume and displacement are constant. The transformed hull form are calculated their total resistance from Froude number (Fr) 0,2 to 0,65 with spacing hull to length ratio (S/L) 0,2 to 0,4. The results of calculation show that the optimal demihull form is Model 4 where the initial hull form Cb +5%. The model has the lowest resistance compared to other models. The comparisons of resistance Model 4 with the configurations of S/L shows that the lowest resistance is S/L 0,4, so that the optimal demihull form is Model 4 with S/L 0,4.

Keywords : Optimization, Catamaran, Demihull Form

1. INTRODUCTION

At the present, the developments of catamaran are significant. Enthusiasts of catamaran are also very much in the world. This is because the catamaran has advantages compared to monohull vessel at the same displacement [1].

The amounts of research about catamarans have generated a practical formula to simplify the calculations of catamaran resistance. This makes the working time in the early stages of the design process becomes faster.

The breakdown of catamaran resistance component is the same as the monohull, just that each component is multiplied by a factor of interference between the hulls. These topics are studied by many researchers in the world related to the breakdown of interference components.

At the time reference [2] research about catamaran, the influence of interference is still much to be ignored because for practical purposes. In reference [3] research, the interference of the ship resistance components have been successfully broken and generating an empirical formula to calculate it. This will make it easier for designers to speed up the calculation of catamarans resistance prediction. Designers only need to calculate the wave resistance coefficient (Cw) of demihull catamaran.

By using reference [3] formula, it will be known total resistance of demihullalong with its interference factors. Then, to calculate the catamarans resistance is by doubling the total resistance of demihull.The aim of this research is focused to search rapidly the optimal demihull form in early stages of the design process where the hull form has the lowest resistance compared to other hull form models with the same displacement.

To generate the different demihull form, the initial demihull form (parent hull) is transformed to become some models by changing the parameter of coefficient block (Cb) using the Lackenby method. This method is moving the stations forwards and backwards without changing the section form until the required Cb are fulfilled [4]. The hull comparison by changing Cb is also described in [5] to select the bestRoll on-Roll off Truck Carrier Hull Design.

When the total resistance is low, the fuel consumption and the exhaust gases emissions produced by the ship will be lower.

2. METHODS

This study begins by determining the initial design of hull form demihull catamarans. The demihull form is then transformed by changing the parameters of Cb with parameters L, H, T and displacement is constant. The reason for not changing the length of the vessel parameters is to match the value of the Froude number (Fr) between transformed demihull forms.

The transformed demihull forms are calculated their total resistance from Froude number (Fr) 0,2 to 0,65 as presented in Table 1 with spacing hull ratio to length (S/L) 0,2 to 0,4.

Table 1. Ship Speed Range

Fr	v	
	m/s	Knot
0,20	2,83	5,44
0,25	3,49	6,80
0,30	4,23	8,16
0,35	4,89	9,52
0,40	5,64	10,88
0,45	6,30	12,24
0,50	7,04	13,60
0,55	7,70	14,96
0,60	8,44	16,32
0,65	9,10	17,68

2.1. Parent Hull

The initial demihull form (parent hull) that used in this study is The NPL Hull Form Series 4b with the principal dimensions presented in Table 2 and Figure 1.

Table 2. Principal Dimensions of Parent Hull

Particular	Demihull
Lwl	19,963 (m)
B	2,223 (m)
H	2,501 (m)
T	1,113 (m)
Cb	0,394
WSA	53,386 m^2
Volume	19,443 m^3
Displacement	19,929 Ton
L/B	9,0
B/T	2,0
$L/(Vol)^{1/3}$	7,42

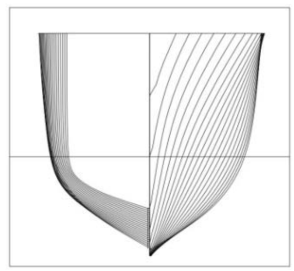

Figure 1.Parrent Hull

2.2. Hull Form Transformation

Demihull form is transformed by changing the parameter of coefficient block (Cb) in range ±10% with Lwl, T, H, volume and displacement are constant. The transformed demihulls presented in Table 3-4 and Figure 2-4.

Table 3.Demihull Form Transformations

Model	Transformation	Cb
1	Parent Hull Cb – 10%	0,353
2	Parent Hull Cb – 5%	0,373
3	Parent Hull Cb	0,394
4	Parent Hull Cb + 5%	0,413
5	Parent Hull Cb + 10%	0,428

Table 4. Transformed Demihull Forms

Parameter	Model 1	Model 2	Model 3	Model 4	Model 5
B (m)	2,479	2,347	2,223	2,119	2,043
WSA (m^2)	54,11	54,68	53,39	53,82	54,18
L/B	8,1	8,5	9,0	9,4	9,8
B/T	2,23	2,11	2,00	1,90	1,84

Table 4 shows that the result of WSA after transformations is not linear. It is not as constant as the changing of Cb. Inversely, the changing of ship breadth (B) is constant. The HigherCb the lower B.

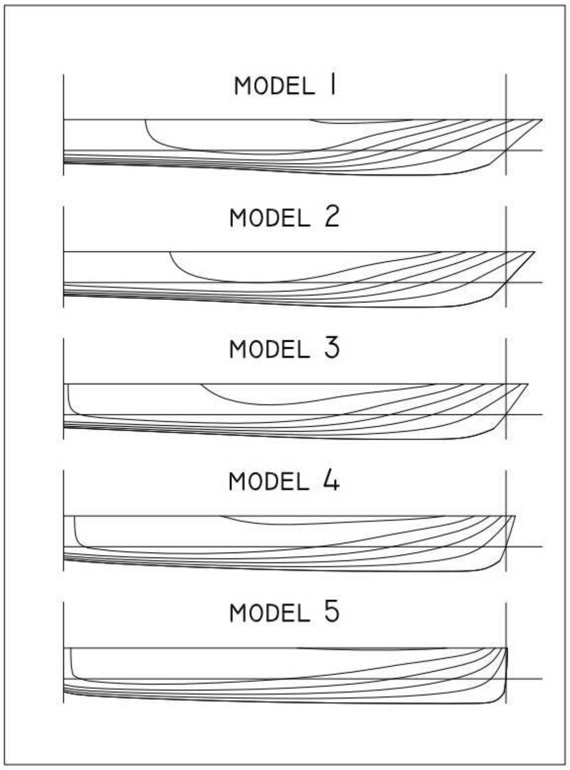

Figure 2.Transformed Demihull Forms

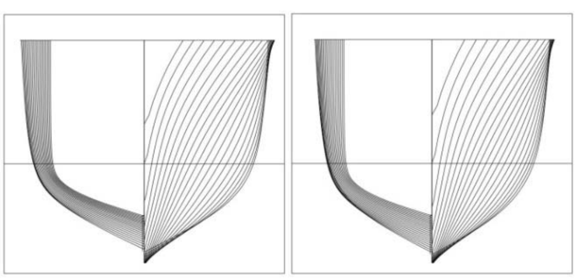

Figure 3. Model 1 and Model 2

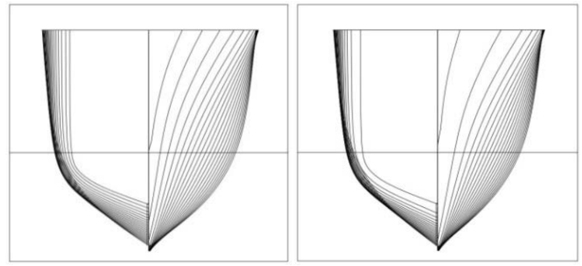

Figure 4. Model 4 and Model 5

2.3. Total Resistance Calculation

Calculation of total resistance catamarans begins by calculating the total resistance coefficient (Ct) of demihull. Because basically, the total of resistance coefficient of catamaran obtained bydoubling the total resistance of demihull along its interference. To calculate Ct demihull and its interference can use equation (1).

$$Ct = (1+\phi k)\sigma Cf + \tau Cw \qquad (1)$$

where :

Ct	=	Coefficient of total resistance
Cf	=	Coefficient of friction resistance obtained by skin friction formula ITTC'57
Cw	=	Coefficient of wave resistance. In this study Cw is calculated by Slender Body Method
ϕ	=	Pressure field change around the two hulls
σ	=	Velocity augmentation between the demihull
τ	=	Wave resistance interference factor

For practical purpose, reference [2] combine ϕ and σ into a viscous resistance interference β presented in equation (2)

$$Ct = (1+\beta k)Cf + \tau Cw \qquad (2)$$

$(1+\beta k)$ also called as Viscous Form Factor. Reference [3] modify the reference [6] formula by adding variable of S/L and also generate the empirical formulas to calculate wave interferences factor (τ) at the certain Froude Number (Fr). The empirical formula to calculate $(1+\beta k)$ presentedin equation (3) and the empirical formulas to calculate (τ) presented in equation (4-9). To calculate the total resistance demihull is using equation (10).

$$(1+\beta k) = 3{,}03(L/Vol^{1/3})^{-0{,}40} + 0{,}016(S/L)^{-0{,}65} \quad (3)$$

$$\tau = 0{,}068(S/L)^{-1{,}38} \text{ ,at Fr = 0,19} \quad (4)$$
$$\tau = 0{,}359(S/L)^{-0{,}87} \text{ ,at Fr = 0,28} \quad (5)$$
$$\tau = 0{,}574(S/L)^{-0{,}33} \text{ ,at Fr = 0,37} \quad (6)$$
$$\tau = 0{,}790(S/L)^{-0{,}14} \text{ ,at Fr = 0,47} \quad (7)$$
$$\tau = 0{,}504(S/L)^{-0{,}31} \text{ ,at Fr = 0,56} \quad (8)$$
$$\tau = 0{,}501(S/L)^{-0{,}18} \text{ ,at Fr = 0,65} \quad (9)$$

where :
Vol = Ship volume under water (m^3)
S/L = spacing hull to length ratio

$$Rt = 0{,}5*\rho*v^2*WSA*Ct \ (kN) \quad (10)$$

where :
Rt = Total resistance (kN)
ρ = Sea water density (1,025 ton/m^3)
v Ship velocity (m/s)
WSA = Wetted Surface Area (m^2)
Ct = Coefficient of total resistance

3. RESULTS AND DISCUSSION

Table 5 is viscous form factor calculated by using equation (3). Table 6 shows the result of wave resistance interference factor (τ) at the certain Froude Number (Fr) calculated by equation (4-9).

Table 5. Viscous Form Factor

S/L	1+βk
0,2	1,4047
0,3	1,3942
0,4	1,3882

Table6. Wave resistance interference factor (τ)

Fr	S/L 0,2	S/L 0,3	S/L 0,4
0,19	0,627	0,358	0,241
0,28	1,456	1,023	0,797
0,37	0,976	0,854	0,777
0,47	0,990	0,935	0,898
0,56	0,830	0,732	0,670
0,65	0,669	0,622	0,591

To obtain the wave interference factor desired, it must be interpolated from Table 6. In this study, the interpolation used is Cubic Spline Interpolation Method. The results presentedin Table 7 and Figure 5.

Table7. Cubic Spline Interpolation of τ

Fr	S/L 0,2	S/L 0,3	S/L 0,4
0,20	0,901	0,550	0,387
0,25	1,443	0,966	0,724
0,30	1,365	1,000	0,804
0,35	1,070	0,885	0,776
0,40	0,926	0,864	0,819
0,45	0,974	0,927	0,893
0,50	0,966	0,893	0,847
0,55	0,858	0,763	0,702
0,60	0,720	0,625	0,564
0,65	0,669	0,622	0,591

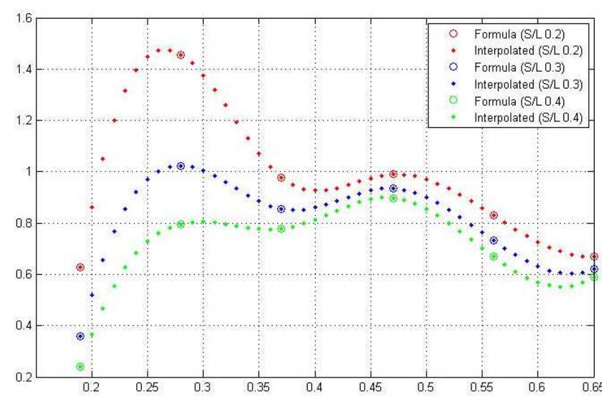

Figure 5. Cubic Spline Interpolation of τ

After all the variables are known, then calculate demihullCf and Cw to obtain demihull Ct. Calculation Cf skin friction is calculated using the formula ITTC '57 and Cw on this study calculated using Slender Body Method based on [7].

After getting demihull Ct value, then the value of the total resistance (Rt) demihull can be calculated by the equation (10). To calculate the total resistance of catamaran is 2 times the total resistance of demihull.

The results of the calculation of the total resistance catamaran S/L 0,2 is presented in Table 8 and plot graphs of ship resistance presented in Figure 6. From those 5 models that have the lowest total resistance is the model 4.

The ship resistances from Model 1 to Model 4 keep decreases for each Fr, but at Model 5 the ship resistance increases.

Table8. Total Resistance S/L 0,2 (kN)

Fr	Model 1	Model 2	Model 3	Model 4	Model 5
0,20	3,046	3,044	3,070	3,248	3,614
0,25	4,984	4,784	4,816	5,254	6,829
0,30	8,184	7,410	7,124	7,379	9,390
0,35	14,808	12,359	10,680	9,783	12,209
0,40	16,728	14,763	13,362	12,308	13,940
0,45	22,320	20,666	19,461	18,346	19,974
0,50	29,923	28,371	27,207	25,996	27,463
0,55	34,233	32,782	31,673	30,518	31,696
0,60	37,148	35,837	34,826	33,826	34,732
0,65	40,515	39,240	38,250	37,316	38,106

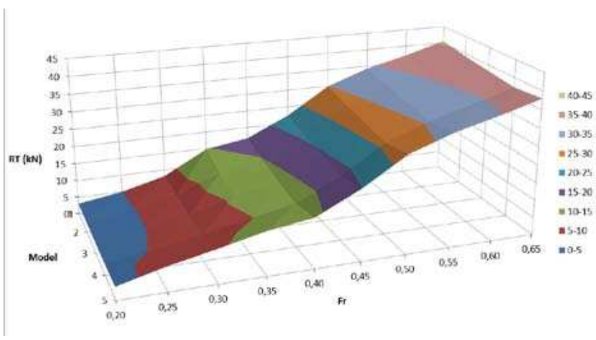

Figure 6. Catamaran Resistance S/L 0,2

The results of the calculation of the total resistance catamaran S/L 0,3 is presented in Table 9 and plot graphs of ship resistance presented in Figure 7. Over all, the ship resistance at S/L 0,3 is lower than that S/L 0,2. The ship resistance also keep decreases for each Fr from Model 1 to Model 4, but increases at Model 5. From those 5 models that has the lowest total resistance is also the model 4.

The results of the calculation of the total resistance catamaran S/L 0,4 is presented in Table 10 and plot graphs of ship resistance presented in Figure 8. All ship resistance at this S/L is the lowestcompared to other models.

The decreasing ship resistance from Model 1 to Model 4 and the increasing ship resistance from model 4 to model 5 is not significant. From those 5 models that have the lowest total resistance is also the model 4.

Table9. Total Resistance S/L 0,3 (kN)

Fr	Model 1	Model 2	Model 3	Model 4	Model 5
0,20	2,969	2,959	2,969	3,086	3,317
0,25	4,718	4,574	4,588	4,892	5,956
0,30	7,584	7,004	6,786	6,986	8,470
0,35	13,572	11,535	10,139	9,407	11,423
0,40	16,223	14,385	13,075	12,098	13,623
0,45	21,760	20,183	19,033	17,976	19,529
0,50	28,738	27,295	26,213	25,100	26,465
0,55	32,350	31,046	30,049	29,038	30,098
0,60	34,995	33,834	32,941	32,094	32,899
0,65	39,255	38,057	37,128	36,272	37,017

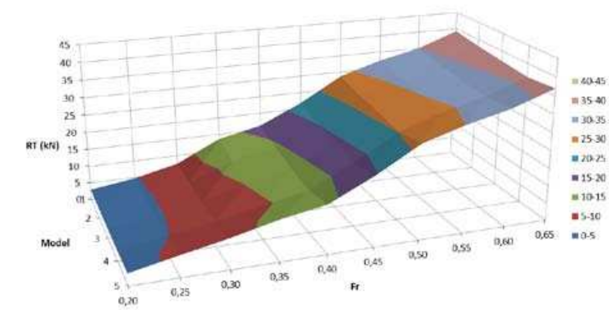

Figure 7. Catamaran Resistance S/L 0,3

Table10. Total Resistance S/L 0,4 (kN)

Fr	Model 1	Model 2	Model 3	Model 4	Model 5
0,20	2,931	2,917	2,920	3,009	3,176
0,25	4,582	4,465	4,470	4,706	5,511
0,30	7,261	6,786	6,604	6,774	7,975
0,35	12,845	11,051	9,821	9,187	10,961
0,40	15,869	14,124	12,880	11,957	13,406
0,45	21,372	19,850	18,740	17,725	19,223
0,50	27,989	26,615	25,585	24,536	25,835
0,55	31,165	29,953	29,028	28,108	29,093
0,60	33,619	32,555	31,738	30,990	31,730
0,65	38,433	37,287	36,398	35,595	36,310

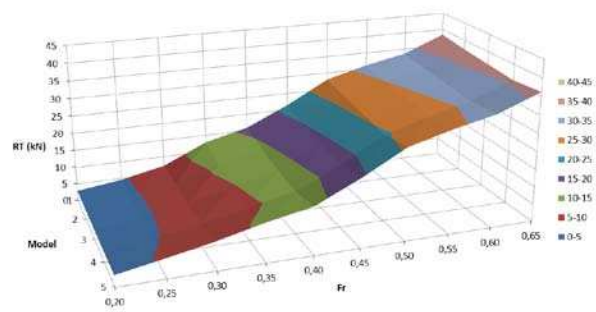

Figure 8. Catamaran Resistance S/L 0,4

The results of the calculation show that for each S/L, model 4 has the lowest resistance compared to other models. The resistance comparison of Model 4 with the configurations of S/L shows that the lowest resistance is S/L 0,4 as presented in Figure 9. From the figure it is seen that the value of the S/L 0,4 has the lowest total resistance.

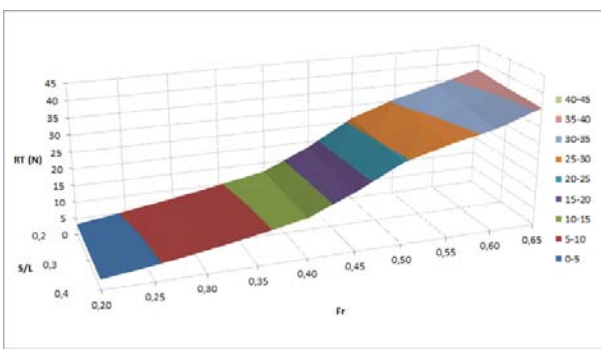

Figure 9. Catamaran Resistance Model 4

4. CONCLUSIONS

The results of calculation show that the optimal demihull form is Model 4 where the initial hull form Cb +5%. The model has the lowest resistance compared to other models. The comparisons of resistance Model 4 with the configurations of S/L shows that the lowest resistance is S/L 0,4, so that the optimal demihull form is Model 4 with S/L 0,4.

5. REFERENCES

[1] Moraes, H.B., Vasconsellos, J.M., Latrre, R.G, (2004). “Wave Resistance for High-Speed catamarans”, *Ocean Engineering,*Vol 31, pp 2253-2282

[2] Insel, M., Molland, A.F. (1991). *An investigation into the resistance components of high speed displacement catamaran*, Royal Institution of Naval Architects, Spring Meeting, paper No. 11.

[3] Jamaluddin, A., (2012), *Experimental And Numerical Investigation Into The Viscous And Wave Resistance Interferences of Catamarans* (in Indonesian), Ph.D Thesis, Faculty of Marine Technology, Institute Technology of SepuluhNopember, Indonesia.

[4] Scamardella, A., Piscopo, V. (2014). “Passenger ship seakeeping optimization by the Overall Motion Sickness Incidence”, *Ocean Engineering,* Vol 76, pp 86-97.

[5] Prabowo, A. R., Zakki, A. F. (2014). “The Investigation of Roll on-Roll off Truck Carrier Hull Design for Route TanjungPriok (Jakarta) - Tanjung Perak (Surabaya)”. *The 9th International Conference on Marine Technology*, 24-26 October, Surabaya, Indonesia.

[6] Molland, A.F., Wellicome, J.F., Couser, P.R.(1996), “Resistance Experiments on a Systematic Series of High-Speed Displacement Catamaran Forms: Variations of Length-Displacement Ratio and Breadth-Draugh Ratio”, Transaction RINA, 138A

[7] Jamaluddin, A. Utama, I.K.A.P., Hamdani, M.A., 2010. “Investigation of Interferences of Resistance Coefficient on Catamaran with Slender Body Method Computation (in Indonesian)”, *KAPAL*, Vol 7. No 2.