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Design Stealth Fast Attack Vehicle (SFAV) 18 Meters Using Numerical Method as Coastal Patrol Vessels

Cahya Kusuma[1,2,*], Wawan Kusdiana[1] , Muhammad Syaifi[1], Wika Adhietama Sumarsono[1]

[1)] Sekolah Tinggi Teknologi Angkatan Laut, Surabaya, Indonesia
[2)] Sekolah Staf dan Komando TNI Angkatan Laut, Cipulir, Jakarta, Indonesia
*Corresponding author: kusumacahya99@gmail.com

ABSTRACT

The design of the 18 Meter Stealth Fast Attack Vehicle (SFAV) with Maxsurf software and the Savitsky method as a coastal patrol vessel is a fast ship that has stealth capabilities that can be used as a coastal patrol vessel area 12 NM to supervise fishing vessels so that fishing and marine resources do not damage the environment such as the use of tiger trawls and marine bombs. The ship model resistance and stability are analyzed using the numerical software Maxsurf Modeller Advanced V8i. Lines plan and general arrangement using AutoCAD software. Model analysis, the design of the SFAV Interceptor Vehicle uses the spiral design method, while the prediction of the resistance value uses the Savitsky preplanning and planning methods. Ship stability uses standardized values issued by IMO, which can be applied to the Maxsurf Stability Advanced V8i software. The analysis results of resistance prediction software and numerical successively 43.416 kN, 45.526 kN, with a difference of 4.6%. The stability analysis is predicted using heel angle model analysis on Maxsurf stability software in various conditions. The results meet IMO standards and capable of sea stage 4. The existence of SFAV ships will help security patrols to protect the coastal area.

Keywords: *Coastal Patrol Vessel, Numerical methods, Patrol Vessel, Planning, SFAV.*

1. INTRODUCTION

Indonesia is the largest archipelagic country in the world [1]. As the largest archipelagic country in the world, Indonesia needs fast patrol vessels for coastal areas. Fast patrol vessels are designed to be multi-role as patrol vessels and warships. As a patrol vessel, speed is the main requirement [2-5]. In this study, an 18-meter patrol vessel will be designed as an interceptor vessel. As a fast patrol vessel, the 18-meter Stealth Fast Attack Vehicle (SFAV) is designed to operate up to 12 nautical miles in coastal areas. The 18-meter SFAV fast patrol vessel is designed to be able to monitor and carry out limited patrols of fishing vessels, carry out Visit Board Search and Seizure (VBSS) activities in Maritime Interdiction Operations, prevent navigational accidents, violent crimes at sea, smuggling and other illegal activities in Maritime Domain Awareness, and mapping of disaster areas that are inaccessible to humans in Humanitarian Assistance Disaster Relief. Supervised fishing vessels so that fishing and marine resources do not damage the environment such as the use of tiger trawls and marine bombs. As a fast patrol vessel with stealth capabilities, SFAV can infiltrate special forces into the opponent's area.

This research will design a fast ship that has stealth capabilities and functions as a patrol vessel and an interceptor. This research consists of 3 stages, namely the design of the lines plan, which is then solidified and then calculated with the help of marine software in the conditions of displacement, preplanning, and planning. Then the engine requirement is calculated, and the last stage is the stability capability in load case 1 (departure), load case 2 (sailing), and load case 3 (arrival).

2. BASIC THEORY

2.1 The Construction of Stealth Radar Cross Section Reduction (RCS)

The Radar is equipment mounted on ships with electromagnetic waves emitted from the radar center towards an object and then reflected from the object to the emission source. The reflected electromagnetic waves will provide output data displayed on the radar display monitor. If the object that reflects the light is a ship, the image displayed on the radar display monitor shows that the object can be seen as a ship. Objects that have the power will reflect electromagnetic waves to the radar transmitter. An important factor in radar detection is the use of angle of reflection in construction. Like a laser beam, if the light is reflected on a mirror, if there is an oblique angle of reflection, the light will not return to the laser-emitting source itself. So that a certain angle can be used as a logical parameter for the construction of ships with stealth or stealth capabilities [6,7].

The design of the ship's construction on the water by making a certain angle will reflect the radar electromagnetic wave beam in another direction so that the electromagnetic wave beam cannot return to the transmitter source [8,9]. The reflection of electromagnetic waves that do not return to their source causes the radar receiver to be unable to read the ship's position. The angle of inclination of the construction of a ship that has a slope must be greater than 6°. The slope of the construction is intended so that the receiver of the reflected electromagnetic waves conveyed by the radar transmitter is reflected in the other direction [10]. Materials that absorb electromagnetic waves also make ships stealth [11].

2.2 Savitsky Ship Resistance Calculation Method

Small-speed vessels, when operated, will have the following ship resistance [12,13]. When the ship is stationary and moving at low speed, the fast ship resistance is the displacement hull. In this condition, the overall lift acting on the hull comes from the buoyant force. The speed of the ship increases, which has an impact on the speed coefficient, which is a function of the average width and speed of the ship and acceleration of gravity. When the ship is at the speed coefficient value reaching 0.5, there is a resultant decrease in the hydrodynamic force. Compared to pure static forces, it is associated with the position of the draft height and trim of the ship. Velocity coefficients between 0.5 and 1.5 dynamic effects result in a positive added value to the lift, although in most cases, there is no significant increase in the center of gravity or an increase in the forward of the bow. d. With a speed coefficient greater than 1.5, a fast vessel will have a dynamic lift that will result in a significant increase in the center of gravity, trim, and further elevation of the ship bow. Coefficient speed is stated by Savitsky: and increasingly heightened bow. The coefficient speed by Savitsky is shown in Formula 1 [14].

$$C_v \frac{V}{\sqrt{gb}} \tag{1}$$

Where :

C_v = Coefficient of Speed
V = Ship Speed (m / s)
g = Acceleration of Gravity (9.81 m / s^2)
b = Over Maximum Beam Chine (m)

2.3 Preplanning Hull

Daniel Savitsky's analysis have been performed on the calm waters of the data condition (smooth water) with seven series of the transom-stern hull. The analysis procedure has also been developed to predict the value of resistance vessels with transom-stern hull form in a range of preplanning conditions where the value of volumetric Froude Number is more than 2.0.

$$X = \frac{\nabla^{\frac{1}{3}}}{L_{WL}} \tag{2}$$

$$Z = \frac{\nabla}{B_{PX}^3} \tag{3}$$

$$U = \sqrt{2i_e} \tag{4}$$

$$W = \frac{A_t}{A_x} \tag{5}$$

Based on equations 2 ~ 5, the coefficient of resistance in preplanning conditions can be calculated by the equation below.

$$\begin{aligned} {R_T}/{\Delta} &= A_1 + A_2 + A_4U + A_5W + A_6XZ + \\ &A_7XU + A_8XW + A_9ZU + A_{10}ZW + A_{15}W^2 + \\ &A_{18}XW^2 + A_{19}ZX^2 + A_{24}UW^2 + A_{27}WU^2 \end{aligned} \tag{6}$$

Equation (1) is to calculate the coefficient of ship resistance with the ship's displacement weight of 100,000 lb or 45359.24 kg. For ships with different displacement weights, it is necessary to correct the calculation of the coefficient of resistance.

$$\left(\frac{Rt}{\Delta}_{corr}\right) = \left(\frac{Rt}{\Delta}_{100.000}\right) + [(C_F + C_A) - C_{F\Delta}]\frac{1}{2}\frac{S}{\nabla^{2/3}}F_{n\nabla}^2 \tag{7}$$

$$\frac{0{,}242}{\sqrt{C_{F\Delta}}} = log\ (R_n C_{F\Delta}) \tag{8}$$

$$C_F = \frac{0{,}075}{(logR_n - 2)^2} \tag{9}$$

$$S/_{\nabla^{2/3}} = \left(\frac{Lwl}{\nabla^{1/3}}\right)^2 \left[1{,}7\frac{Bx}{Lwl}x\frac{T}{Bx} + \frac{Bx}{Lwl}Cb\right] \tag{10}$$

$$F_n = \frac{V}{\sqrt{g\ x\ \sqrt[3]{\nabla}}} \tag{11}$$

2.4 Planning Hull

The total hydrodynamic resistance in surface planning consists of pressure resistance, wet surface area, and viscous resistance acting to tangential at the bottom of the ship experiencing lift [15-17]. In a fluid that has non-viscous properties, the tangential component is equal to 0, so the pressure resistance DP is as follows.

$$D_P = \Delta \tan \tau \quad (12)$$

If the formula is added to the aspect of viscous resistance (DF), then the resistance equation in the planning hull condition is as follows:

$$D_P = \Delta \tan \tau + \frac{D_f}{\cos \tau} \quad (13)$$

$$D_F = \frac{C_F \rho v^2 \lambda B x^2}{2 \cos \beta} \quad (14)$$

The ship resistance equation in the planning hull condition is as follows:

$$R_T = \Delta \tan \tau + \left(\frac{\rho V^2 \lambda B_{PX}{}^2 C_f}{2 \cos \tau \cos \beta} \right) \quad (15)$$

$$\lambda = \frac{(L_K - L_C)}{2Bx} \quad (16)$$

$$(L_k - L_C) = \frac{b \tan \beta}{\pi \tan \tau} \quad (17)$$

3. RESULT AND DISCUSSION

3.1 Construction of Stealth Radar Cross Section Reduction (RCS)

This study uses Maxsurf Modeller Advanced V8i SFAV Interceptor objects with the following data shown in Table 1 below:

Table 1. SFAV Interceptor Vehicle Specification

Specification	Value	Unit
Design speed	40	knots
Length over All	18.9	meters
Length on Waterline	17.4	meters
B (molded)	5	meters
H (molded)	2.1	meters
T(draught)	0.971	meters
Displacement	27.42	ton
Crew	6	person
Fuel oil	4500	liter
Freshwater	1500	liter
Endurance	400	NM

Lines plan SFAV 18 meters is shown in Figure 1.

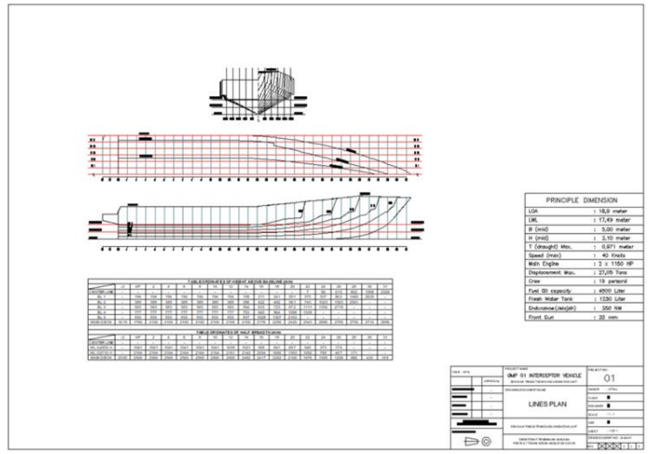

Figure 1. Lines plan SFAV 18 metres.

After drawing the lines plan is then solidified into a 3D model. 3D Model SFAV 18 meters is shown in Figure 2.

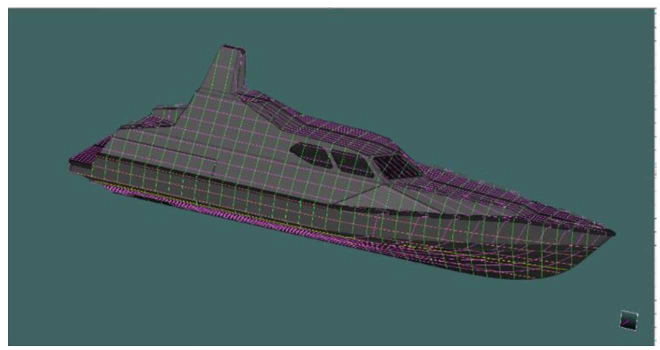

Figure 2. 3D model SFAV 18 meters

General Arrangement Model SFAV 18 meters is shown in Figure 3.

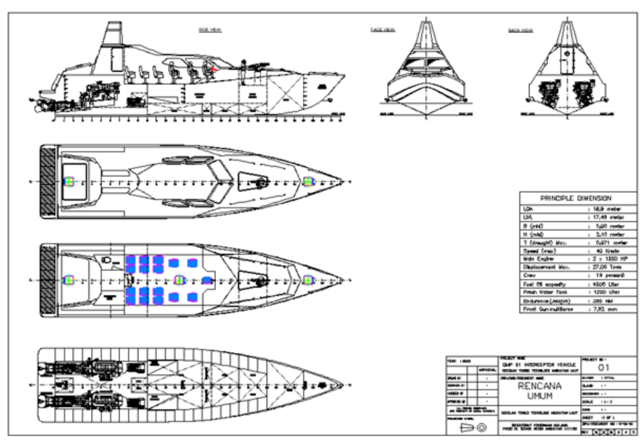

Figure 3. General Arrangement SFAV 18 meters

The results of the calculation of hydrostatic data were obtained from the Maxsurf Modeller Advanced V8i software. The following hydrostatic data obtained from the Maxsurf Modeller Advanced software is shown in Table 2.

Table 2. Hydrostatic Data based on Maxsurf Modeller Software Calculations.

Measurement	Value	Unit
Displacement	27.42	t
Volume (displaced)	26.75	M^3
Draft Amidships	0.971	m
Immersed depth	0.971	m
WL Length	17.396	m
Beam max extents on WL	4.328	m
Wetted Area	68.856	m^2
Max sect. area	2.031	m^2
Waterplane. Area	57.315	m^2
Prismatic coefficient. (Cp)	0.757	
Block coefficient. (Cb)	0.366	
Max Sect. area coefficient. (Cm)	0.483	
Waterplane. area coefficient. (Cwp)	0.761	
Precision	Highest	68 stations

Based on the data in Table 2, using the Maxsurf Resistance Advanced V8i software, the resistance values obtained at each speed and the shape of the wave appearance of the water against the hull surface are different at each speed. The following is the resistance value to the speed of the Maxsurf Resistance Advanced V8i Software analysis shown in Table 3.

Table 3. Maxsurf Resistance Software Analysis

V (knot)	V (m/s)	Fn (LWL)	Fn (Vol)	Pre Rest. (N)	Plan. Rest. (N)
20	0.788	0.788	1.900	19673.9	30017.8
21	0.827	0.827	1.995	19858.6	31299.4
22	0.867	0.867	2.090	-	32488.5
23	0.906	0.906	2.185	-	33570.6
24	0.945	0.945	2.280	-	34539.6
25	0.985	0.985	2.375	-	35398.1
26	1.024	1.024	2.470	-	36155.0
27	1.063	1.063	2.565	-	36823.8
28	1.103	1.103	2.660	-	37420.2
29	1.142	1.142	2.755	-	37960.3
30	1.182	1.182	2.851	-	38459.2
31	1.221	1.221	2.946	-	38930.8
32	1.260	1.260	3.041	-	39387.2
33	1.300	1.300	3.136	-	39838.8
34	1.339	1.339	3.231	-	40294.0
35	1.379	1.379	3.326	-	40760.1
36	1.418	1.418	3.421	-	41242.6
37	1.457	1.457	3.516	-	41746.3
38	1.497	1.497	3.611	-	42274.6
39	1.536	1.536	3.706	-	42830.5
40	1.575	1.575	3.801	-	43416.2

3.2 Preplanning Hull

Calculation of ship resistance mathematically, the determined speed variations are 19 knots, 20 knots, 21 knots, 25 knots, 30 knots, 35 knots, and 40 knots. The calculation begins with calculating the Froude number value for each speed variation using formula no. 11. Preplanning Hull in the range of values of Froude Number 1.0-2.0 [18], namely speeds of 19 knots, 20 knots, and 21 knots. After the Froude Number value is calculated for each speed variation, the resistance coefficient value can be calculated. Froude Number values at speeds of 19 knots, 20 knots, and 21 knots are not listed in the Savitsky table, so interpolation is used. The prediction results of the resistance value in the Preplanning condition are shown in Table 4 and Figure 4.

Table 4. The prediction results of the resistance value in the Preplanning condition

No	V (knot)	V (m/s)	$Fn\nabla$	Rt/Δ
1	19	9.78	1.80	0.06538
2	20	10.29	1.89	0.06690
3	21	10.80	1.99	0.08204

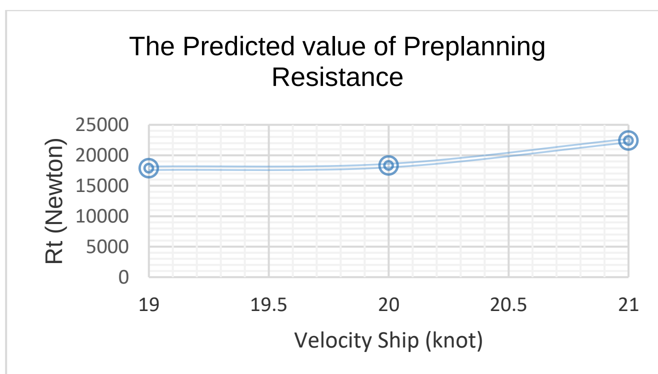

Figure 4. The prediction results of the resistance value in the Preplanning condition Planning Hull.

3.3 Planning Hull

Prediction of ship resistance in Planning conditions using Formula 15 is shown in Table 5.

Table 5. Prediction of ship resistance in Planning conditions

V (m/s)	β	τ	cos β	cos τ	tan τ	λ	Rt (N)
12.86	25.9	5.19	0.9	0.996	0.090	0.851	26042.8
15.43	25.9	5.69	0.9	0.995	0.099	0.776	28872.2
18.01	25.9	6.19	0.9	0.994	0.108	0.713	31721.3
20.58	25.9	6.69	0.9	0.993	0.117	0.659	34585.7

The results of the predicted resistance using the Maxsurf Resistance Advanced V8i software and numerical calculations at different speed variations are listed in Table 6 below.

Table 6. Prediction of Resistance Result Software Versus Numeric

Vs (knot)	Vs (m/s)	Mathematic Calculation Rt (N)	Software Rt (N)	Condition
19	9.774	17871.64	17755.1	Preplanning Hull
20	10.289	18304.35	19096.8	
21	10.803	22406.38	19673.9	
25	12.861	37722.30	35398.1	Planning Hull
30	15.433	38628.32	38459.2	
35	18.006	41550.79	40760.1	
40	20.578	45525.67	43416.2	

The maximum design speed is 40 knots. The predictive of ship resistance generated by the software is 43.42 kN while the prediction of ship resistance using the numerical calculation of the Savitsky method is 45.53 kN or 4.63% higher than using the software.

3.4 Wave Analysis

The wave view is displayed from a speed of 10 knots to a speed of 40 knots, with speeds multiples of every 10 knots using the Maxsurf resistance software:

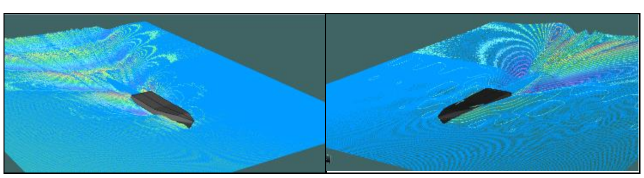

Figure 5. Wave at 10 knot (left) and 20 knots (right)

Based on the Figure 5, at a speed of 10 knots, the ship is in a displacement condition. Meanwhile, the ship with a speed of 20 knots, is in preplanning condition.

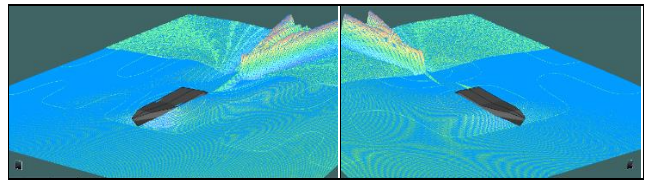

Figure 6. Wave at 30 knot (left) and 40 knots (right)

Based on Figure 6, at a speed of 30 knots and 40 knots, the ship is in a planning condition [19].

3.5 Propulsion System

The propulsion system uses two water jets [20-22]. The engine power calculation obtained 1121,671 HP with the Overall Propulsive Coefficient (OPC) value assumed to be 56% or 0.56. Overall Propulsive Coefficient (OPC) is the value of the entire efficiency of the propulsion system. So, in the selection of the main driving machine, 1200 HP is obtained.

3.6 Stability SFAV

The calculation of the ship's LWT is divided into three main parts: construction weight, machine weight, equipment, and ship outfitting weight. The construction weight calculation method is based on detailed construction planning by determining the volume and density of the material used. The weight of the equipment comes from the product guide, while the outfitting comes from the approximate value. LWT calculation is shown in Table 7.

Table 7. Light Weight Tonnage

Item	Weight (Ton)	Quantity	Total Weight (Ton)	LCG (m)	VGC (m)
Main engine	4.80	2	3.76	3.09	1.21
Waterjet	0.58	2	1.15	0.60	0.64
Main engine sparepart	0.12	1	0.12	4.51	0.55
Structural Weight	4.80	1	4.80	8.50	1.50
Generator set	0.20	2	0.39	5.10	0.85
Emergency generator	0.08	1	0.08	5.10	0.65
Electrical equipment	0.50	1	0.50	9.91	3.12
Piping Installation	0.10	1	0.10	3.09	0.55
Safety Equipment	0.09	1	0.09	7.31	2.77
Mooring equipment	0.20	1	0.20	17.20	1.31
Interiors	0.51	1	0.51	7.55	2.47
Total			11.70	3.29	0.45

DWT is the weight of the cargo consisting of weight and cargo, fuel, lubricating oil, fresh water, ballast, supplies, ammunition, crews, and man on board or the overall weight in a state of full charge and ready to sail [23]. DWT item is shown in Table 8.

Table 8. DWT item SFAV

Item	W (ton)	Qty	W (ton)	LCG (m)	TCG (m)	VCG (m)
Crew 1 + Bagage 1 (P)	0.09	1	0.09	8.97	-1.160	2.99
Crew 1 + Bagage 2 (P)	0.09	1	0.09	7.75	-1.160	2.99
Crew 1 + Bagage 3 (S)	0.09	1	0.09	8.97	1.160	2.99
Crew 1 + Bagage 4 (S)	0.09	1	0.09	7.75	1.160	2.99
Crew raw 5 + Bagage (P)	0.09	2	0.18	6.74	-1.075	2.99
Crew raw 6 + Bagage (P)	0.09	2	0.18	5.84	-1.075	2.99
Crew raw 7 + Bagage (P)	0.09	2	0.18	4.94	-1.075	2.99
Crew raw 8 + Bagage (S)	0.09	2	0.18	6.74	1.075	2.99
Crew raw 9 + Bagage (S)	0.09	2	0.18	5.84	1.075	2.99
Crew raw 10 + Bagage(S)	0.09	2	0.18	4.94	1.075	2.99
Quartermaster	0.09	1	0.09	9.98	0	2.99
Freshwater (PS)	0.894	1	0.894	11.076	0.398	0.52
Freshwater (SB)	0.894	1	0.894	11.076	-0.398	0.52
Fuel Oil Tank (P)	2.244	1	2.244	7.785	-0.534	0,53
Fuel Oil Tank (S)	2.244	1	2.244	7.785	0.534	0,53
Lubricating Oil Tank (P)	0.46	1	0.46	5.5	-0.25	1
Lubricating Oil Tank (S)	0.46	1	0.46	5.5	0.25	1
Ammunition Store	0.50	1	0.50	9.9	0	1.3
General Store	0.17	1	0.17	12.9	0	1.4
Total			9.356	83.251	2.47E-14	22.047

The capacity of the ballast tank is 4.97 tons and the sewage tank is 0.738 tons, so the design displacement is 26.76 tons or a difference in the displacement of 2.4%

Stability analysis is done by using Maxsurf stability software. The standard value of the criteria that must be met in the SFAV Interceptor model, namely the analysis model, must be able to return to its original position. The table of GZ arm length against heel angle model analysis under load case 1 (departure), load case 2 (sailing), and load case 3 (arrival) conditions is shown in Table 9.

Table 9. Load case SFAV

No.	10	20	30	40	50	60	70	80	90
1	0.27	0.522	0.730	0.875	0.922	0.888	0.794	0.652	0.468
2	0.24	0.497	0.695	0.853	0.899	0.839	0.693	0.488	0.250
3	0.21	0.444	0.646	0.794	0.839	0.795	0.686	0.517	0.306

Based on the Douglas Sea Scale, ships can be operated in waters and islands at sea stage 4 with a wave height of 1.25 m to 2.5 m. These results are obtained from the test results using the Maxsurf software at a wave height of 1.6 m and the SFAV model analysis is still in Pass status.

4. CONCLUSION

Based on numerical calculation simulation data, SFAV type fast patrol vessel with a maximum predicted speed of 40 knots has 18.9 m long (LoA), 17.4 m long (LWL), 5 m wide, 2.1 m high, and 400 NM endurance at maximum speed. The monohull hull design is processed using the Maxsurf Modeller Advance V8i software. This design has a function as a coastal patrol vessel as well as a fast vessel capable of infiltrating special forces into the opponent's area or an interceptor vessel.

The predicted value of total resistance at a speed of 40 knots using the numerical calculation of the Savitsky planning method is 45.526 kN. While the prediction of total resistance obtained from the Maxsurf software is 43.416 kN, this result has a difference of 4.64% from the calculation using the numerical method of the Savitsky method. The proposed numerical method can align with the results given by the software.

Stability analysis is carried out using Maxsurf Stability Advanced V8i software, while model analysis with load case is executed on departure, sailing, and arrival conditions. The stability prediction results were calculated using the Maxsurf software at a heel angle of 90^{o}, the length of the GZ arm at load case 1 = 0.468 m, load case 2 = 0.250 m, and load case 3 = 0.306 m. The analysis model may return to its original position when the heel angle is 90^{o}.

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