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Unmanned Mini Boat Design for the Camera Bearer of the *Vannamei* Shrimp Monitoring Device

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Abstract: The research of vanamei shrimp counting has been developed by numerous scientists, but image processing in actual pond didn't progress well. The used of image processing based on the way of capturing the image from the shrimp which located on the bottom of the pond. The way to capture the image was to put a camera under the deck of a boat. Catamaran boat model was selected to build a boat that will bring up a camera that will used to capture shrimp image. The Catamaran boat with Loa (entire length of boat body) = 670 mm, Lenght water line (Lwl) = 650 mm, B (width) = 300 mm, T (full/high) = 180 mm, Cb (block coefficient) = 0,55 and Vs (speed) = 19 knots was built to accommodate this matter. The size and specification were chosen to maintain any possibility issue that might happen when the vannamei shrimp monitoring system work.

Keywords: Vannamei Shrimp, Camera, Catamaran, Unmanned Boat

Introduction

A vannamei shrimp monitoring system that uses image processing work principles requires a boat which will bear a camera device in the process of capturing a shrimp object in a pool. Physical parameters such as boat dimensions, electrical conditions, speed, resistance, motion, load carrying ability are important aspects in the building process of unmanned mini boat. These parameters further being utilized to the design of unmanned mini boats to be created as camera carriers in a shrimp monitoring system. To get design accurately worked out, we need to calculate each physical parameter precisely (Anonimous, 2001). This boat design then will be the main part of the vanamei shrimp monitoring system.

Determination of Boat Physical Parameter

Unmanned mini boat requires several physical parameters that need to be calculated, for instance total boat resistance, boat speed (VS), Volume Displacement, Displacement, Wet Surface Area, Froude Number (Fn), Reynold Number (Rn), Coefficient of Friction Pressure (Cf), Power Efficiency (ηH), Rotative Relative Efficiency (ηrr), Propulsion Efficiency (ηp), Resistance Efficiency (ηr), Efficiency of Propulsion (ηp), Coefficient of Resistivity (Cr), Coefficient of Air Resistance (Caa), Motor Power Drive, Deliver Horse Power (DHP), Propulsive Coefficient (Pc), Power On Axle Propeller (SHP), Main Movement Power (BHP) (Couser, 2000).

For the calculation of total resistance, Guldhammer-Harvald method was used. Physical requirements that is used to calculate resistance of the boat are as follows.

Loa (length of the boat entire body)	=	670 mm
Lwl (Lenght water line)	=	650 mm
B (widht)	=	360 mm
T (high)	=	180 mm
Cb (Block Coefficient)	=	0,327
Vs (boat speed)	=	19 knot

The coefficient of boat total resistance or Ct, can be determined by summing up all existing boat resistance coefficients.

The total resistance (RT) on the boat consists of components that play role in creating a drag. In principle, there are two parts of the boat that experience the drag force - the area of the boat's sinking and the area of the boat on the surface of the water because the air also has a resistivity factor under certain conditions (Bhattacaryya, 1978). RT is used to determine the size of the Effective Horse Power (EHP) which is defined as the power

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required for a boat to move at a speed of VS and able to overcome the resistance force of the RT and more importantly to find out how much power from the main engine to the boat to be made not experience the excessive power or just cannot meet the speed because the predicted power cannot overcome the boat's resistance (Harvald, 1983).

Volume Displacement is the volume of water removed and is one of the important variables in the calculation of boat resistance. Volume of the body of the boat below the surface of the water but not including the thickness of the skin, the thickness of the keel, the thickness of the steering wheel, propeller and all the water-immersed boats (Parsons, 2003):

$$V = Lwl \times B \times T \times Cb$$

Where:
V = Volume (m^3)
B = boat width (m)
T = Height of boat (m)
Cb = Coefficient block

In this research, the value of V is, 019305 m^3.

Weight Displacement is the weight of water transferred by the volume of the dyed boat:

$$\Delta = Lwl \times B \times T \times Cb \times \rho$$

where, ρ = sea water density (1.025 ton/m^3)

In this research, D value is 19,3 kg.

The wet surface area is the surface area of the water dusted hull. Wet surfaces for normal commercial boats can be calculated using the following formula:

$$S = \rho \times Lwl(Cb \times B) + (1,2 \times T)$$

where, ρ = water density (1000 kg/m^3).

In this research, S value is 0,24765 m^2, with ratio of B/T = 1,667:

$$Fn = Vs / \sqrt{g} \times Lwl$$

Where:
Vs = Speed of boat (knot)
1 knot = 0,554 m/s
g = Gravity acceleration (9,8 m/s^2)

In this research, Fn value is 11,686:

$$Rn = (Vs \times Lwl) / v$$

Where:
v = Kinematic viscousity coefficient at 16°C = $1{,}1 \cdot 10^{-6}$ m^2/s
Vs = Speed (m/s)

In this research, Rn value is 3.300.000:

$$Cf = 0.075(\log Rn - 2)^2$$

In this research, Cf value is 0,0017.

The coefficient of the remaining boat resistance can be determined through the diagram (Guldhammer-Harvald) with the result is as follows:

$$Cr = Lwl / \nabla^{1/3}$$

Where:
∇ = Boat volume (m^3)
Fn = 11,686
Cb = 0,55

If the diagram is based on the width ratio of B/T = 2.5 then the Cr price for a boat having a width-laden ratio greater or less than that price must be corrected:

B/T = 1,67
10^3CR = 10^3CR(B/T = 2.5) +0.16 (B/T-2.5)
10^3CR = 10^3CR (B/T = 2.5) +0.16 (1,67-2.5)
Cr = 0,01328

From the Cr value we can assume that:

Cr total = ($1{,}8 \cdot 10^{-3}$) +0,01328
= 0,015

Since the data on wind in boat design is unknown, it is recommended to correct the coefficient of air resistance, where the value is:

$$Caa = 0{,}00007$$

The boat's resistance is the drag force of the fluid medium through which the boat operates at a certain speed (Harvald, 1983). The magnitude of this total inhibitory force is the sum of all components of the inhibitory force (obstacle) (Guldhammer, 1962). In simple terms the total boat resistance can be obtained by the equation, as follows:

$$CT\,Total = Cf + Cr + Caa$$

So the total resistance (RT) by entering the total CT:

$$RT = 0{,}5 \times \rho \times CT \times S \times Vs^2$$

where, s is the wet surface area of the boat (m^2). Table 1 describe the Guldhammer-Harvald equation with different Cr.

Table 1: Guldhammer-Harvald *Cr* coefficient

A	B
1. $L/\nabla^{1/3} = 2,0$	$Cr = 1,5\times10^{-3}$
2. $L/\nabla^{1/3} = 2,4$	Cr = x
3. $L/\nabla^{1/3} = 2,5$	$Cr = 1,2\times10^{-3}$

In this research, we use *RT* value of 0,0785kN. As a result of the boat's resistance, there must be a thrust of the boat used to overcome the boat drag force. Under ideal conditions, the amount of required thrust is as large as the inhibitory force on the boat. However, the condition is not very realistic, because in fact in the boat body occurs hydrodynamic phenomenon that cause degradation of the value of the thrust force (Eyres, 2001).

Calculation of Boat's Motor Power

From the figure above, it is explained that the RT is the total resistance of a boat that can inhibit the velocity (Vs) of the boat. To drive the boat with the desired speed required motor power (Lewis, 1988). While the motor power there are two types of continuous power and maximum power. Continuous power to achieve service speed and maximum power to achieve maximum speed or trial speed.

There are several terms of horse power as a known motor power in the boat that is IHP, BHP, SHP or DHP or PHP and EHP. EHP is determined from the pressure inside the cylinder or taken into account from the motor diagram. BHP is the power required to rotate the shaft and its value is less than the IHP due to the loss of power inside the cylinder. SHP is determined from torque on the shaft and EHP is the power required to drive the boat (Insel, 1992).

Effective Horse Power (EHP) is the amount of power required to overcome the drag force of the boat body (hull), so that the boat can move from one place to another with a service speed of Vs:

$$EHP = Rt \times Vs$$

Where:
1 HP = 745.699 watt
1 KW = 0,7335 HP

In this research, EHP value is 0,355 HP.

Delivery Horse Power (DHP) is the power absorbed by the boat's propellers to generate the Push Power, or in other words DHP is the power that is propagated by the propulsion motor to the propeller which is then converted into a thrust force. Power on the propeller shaft tube or DHP is calculated from the comparison between Effective Power or EHP with Propulsive Coefficients or PC:

$$DHP = EHP / PC$$

Where:
$PC = \eta p \cdot \eta rr \cdot \eta H$
$\eta H = (1\text{-}t)/(1\text{-}w)$

Wake friction (w) or current join is a comparison between the speed of the boat with the speed of water leading to the propeller. By using the formula given by Taylor then obtained:

$$w = 0.5Cb - 0.05$$

In this research, *w* value is 0,255.
The value of thrust deduction factor (*t*) can be sought from the known value of *w*:

$$t = k \times w$$

The *k* value is between 0.7-0.9 and the value of *k* = 0.8 is taken so that t is 0.18:

$$\eta H = (1-t)/(1-w) = 1,1$$

Price ηrr for boat with single screw type propeller ranges from 1.0-1.1. In the propeller planning and propeller shaft tube is taken price:

$$\eta rr = 1.05$$

The efficiency of propulation is open water efficiency which is the efficiency of the propeller at the time of open water test. The value between 40-70% and 60% were taken (Molland, 2008).

From the various explanations, the PC value is 0.693 and DHP is 0.512 HP. Shaft Horse Power (SHP) is the measured power up to the area in front of the shaft tube bearings (stern tube) of the boat propulsion system. Here the boat has engine room at the back, with loss (2-3)%, taken 2%. So that the efficiency of the bearing and the propeller tube or ηSηB is 0.98:

$$SHP = DHP / \eta s \eta b$$

In this research, SHP value is 0,522 HP.

Brake Horse Power (BHP) is the brake power (Brake Power) or power received by the boat propulsion system shaft, which is then operated continuously to drive the boat at its service speed (Vs). The magnitude of the main driving force or PB required in the planning of the propeller vanes and tubes is not detached by the efficiency of the gear and transmission system or ηG because it is planned on the connection of the power transmission system between the motor with the propeller shaft mounted wheel system tooth reduction. The gear system on this boat uses a single reduction gear or single reduction gear with 2% loss. For forward and reverse gear or Reversing Gear with 1% loss.

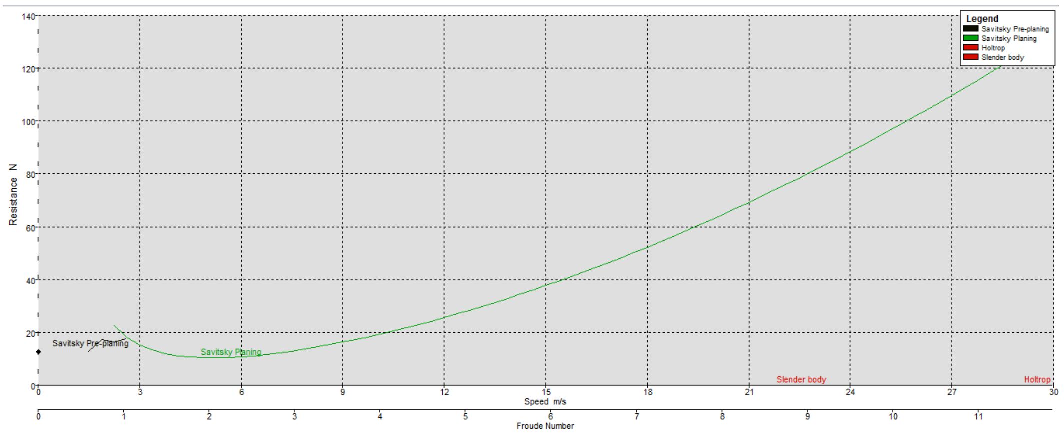

Fig. 1: Resistance Vs Speed

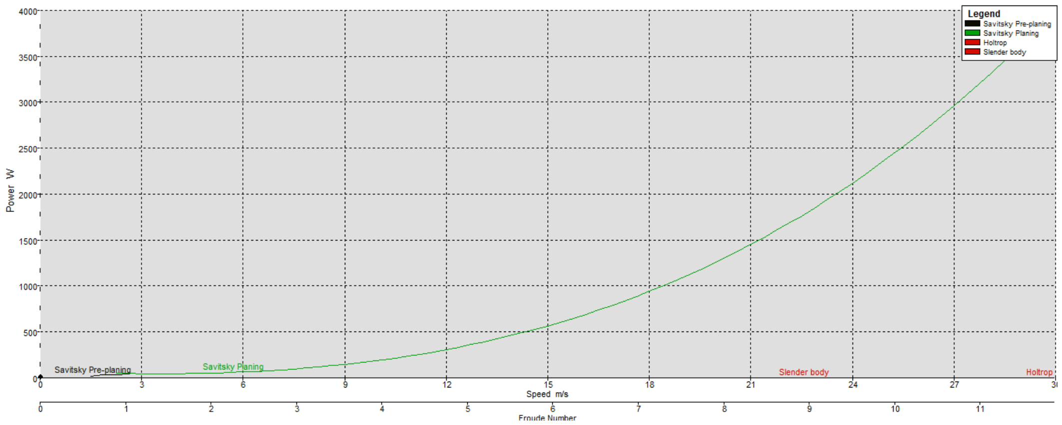

Fig. 2: Power Vs Speed

Fig. 3: Miniboat components

From the data of this system can know the efficiency of transmission gear system or ηg of each system is:

- ηg = 98% single reduction gears
- ηg = 99% reversing reduction gears

BHP (scr) is the output power of the surge motor under conditions (Continues Service Rating). Taking the value ηg = 0.98.:

$$BHPscr = SHP / \eta g$$

In this research, BHPscr value is 0,533 HP.

The magnitude of the power of this prime motor or motor is the output power on a normal voyage or SCR, where the magnitude is 80-85% of the output power at maximum or MCR. While the output power at MCR condition is:

$$BHPmcr = BHPscr / 0.85$$

In this research, *BHPmcr* value is 0,4599*HP*.

BHP (mcr) is then used as a benchmark (reference) in implementing the Engine Selection Process.

Calculation of Boat Resistance

The calculation of the resistance experienced by the boat is obtained directly from the maxsurf software. In this study, the savitsky, slender body and holtrop method is used because the type of boat that is designed is the displacement hull type where the calculation of the resistance can only be done by using the method (Siswanto, 1988). The following calculations obtained by using software maxsurf.

The following is the resulting resistance graph with the hullspeed feature on the Maxsurf Software and the Speed Power Prediction graph.

Manufacturing Process

The design of unmanned mini boats used some components such as balsa wood, brushless motor, servo motors, batteries and propeller (Santosa, 1999). Selection of these components was considered being the design and specifications that has been usually used for shrimp monitoring. Balsa wood was chosen because of its material characteristics of which the fibers orientation within the woods make it easier to be shaped and hence the body of the boat can be manufactured without taking to much time and effort (Rahman, 1998). Brushless motor (Bldc motor) which is one of motor type was selected according to the magnitude of the boat's power. This motor is used to convert electrical energy into motion energy and hence drives the propeller. Synchronous motor means that the magnetic field generated by the rotor rotates at the same frequency so that the bldc motor does not slip as it may commonly happen in the induction motors. This type of motor has a permanent magnet on the rotor and electromagnet in the stator. Bldc motors used have specifications:

Type:	D3536
Max Power:	500 W
Sfoc:	186
Machine Dimention Dimensions:	35·36 mm
Diameter of shaft:	5 mm
Battery:	7,4-14 V
RPM (max):	1250 kv
Rotation:	1250 kv·8 v 8750 rpm (max)
Engine Weight (Net Dry):	102 g

The next step, 180°C servo motor is selected as needed to turn right and left by moving the rudder. Servo motor is a device or rotary actuator (motor) designed with a closed-loop feedback control system (servo), so it can be set-up or set to determine and ensure the angular position of the motor output shaft (Stish Kumar *et al.*, 2000). Servo is a DC motor equipped with a control circuit with closed feedback system integrated in the motor. In the motor servo, the position of the axis rotation of the motor will be informed back to the control circuit inside the servo motor. The motor servo is composed of a DC motor, gearbox, Variable Resistor (VR) or potentiometer and control circuit. Potentiometer serves to determine the maximum limit of axis rotation (axis) servo motor. While the angle of the servo motor axis is set based on the width of the pulse on the servo motor control pin (Prawitasari, 2013). Power source used in this mini boat is battery powered 22000 mAh, 3S1P/3 voltage Cell/11.1V, weight 187g, dimension 106·35·24 mm with endurance 8 h usage. In this mini boat, propeller is chosen with which match to the diameter of the propeller shaft. Propeller Shaft (Propeller Shaft) is one part of power transfer system where the distance between Bldc motor and propeller is far apart. Furthermore, propeller shafts will be connected with boat propellers. Propeller is a tool for producing the most widely used thrust force of propellers rotated with a propeller shaft powered by a Bldc motor.

Furthermore mini boats are designed with Marxsurfsoftware based on previous parameters on boat calculations. Once entered maxsurf software will appear the calculation of the speed of the boat, the maximum load is transported boat and hydrostatic calculation automatically. The output of this software is also in the form of cross-sectional design which is then used as part of the boat as Fig. 4. Balsa wood is formed according to the mold to be captured into a boat body such as Fig. 5. After all parts of the boat is assembled in the market of various components that have been selected previously. The next stage in the design of mini boats is to test the work of mini boats in ponds such as Fig. 6.

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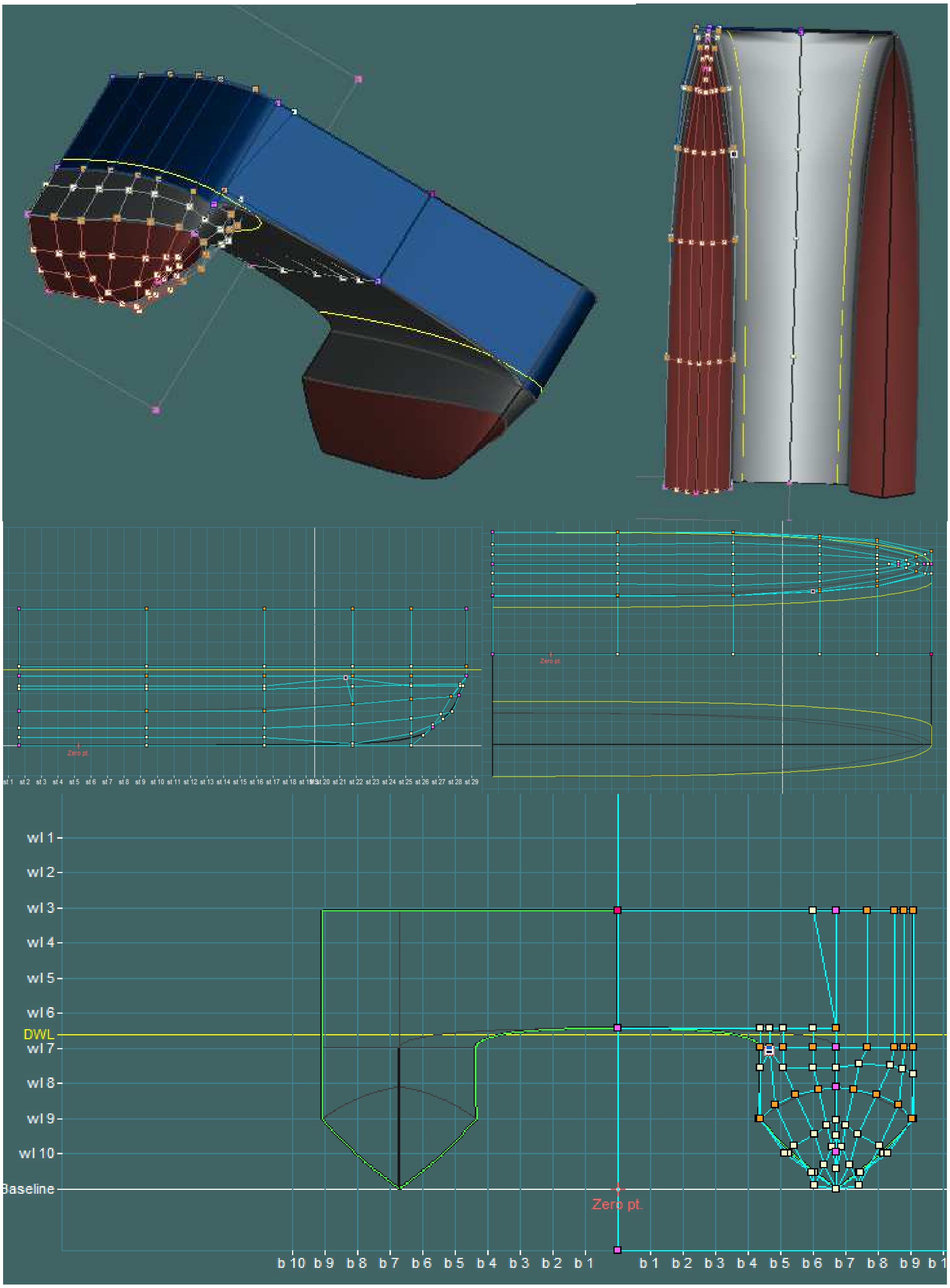

Fig. 4: Boat design

Fig. 5: Unmanned mini boat

Fig. 6: Mini boat Trial

Based on Table 2 obtained from ship stability analysis using Marxsurf software, it can be seen that the ship displacement value is 7,835 meaning that the maximum load able to lift the ship is 7,835kg with displacement volume of 7643,96 cm^3 according to its manual calculation. In Table 2 it is also found that the draft on Fp, AP and LCF is the same value of 10 cm, meaning that the design of the ship is at an ideal equilibrium point (Santoso and Sudjono, 1983). In other hydrostatic analysis parameters show the same thing, ship design is ideal condition as needed in carrying equipment of monitoring tool of shrimp in the form of camera and others.

Furthermore, in Table 3, the simulation of the stability of the ship's design on the condition of the ship is exposed to water waves that can cause the ship to overturn. It is seen that there is a change of GZ, Cp and Cb values (Watson, 1998). This change indicates that on the slope of the ship 0 to 20 degrees the ship is potentially skewed.

Table 2: Hydrostatic Analysist

Displacement kg	7.835
Volume (displaced) cm^3	7643.960
Heel deg	0.000
Draft at FP cm	10.000
Draft at AP cm	10.000
Draft at LCF cm	10.000
Trim (+ve by stern) cm	0.000
WL Length cm	65.000
Max sect. area cm^2	149.100
Sect. area amidships cm^2	117.110
Wetted Area cm^2	3025.380
Waterpl. Area cm^2	1270.420
Prismatic coeff. (Cp)	0.789
Block coeff. (Cb)	0.327
Max Sect. area coeff. (Cm)	0.675
Waterpl. areacoeff. (Cwp)	0.544
LCB from zero pt. (+vefwd) cm	18.380
LCF from zero pt. (+vefwd) cm	21.100
KB cm	6.090
KG cm	10.000
BMt cm	27.100
BML cm	52.770
GMt cm	23.190
GML cm	48.870
KMt cm	33.190
KML cm	58.870
Immersion (TPc) tonne/cm	0.001
MTctonne.m	0.000
RM at 1deg = GMt.Disp.sin(1) kg.cm	3.170
Max deck inclination deg	0.000
Trim angle (+ve by stern) deg	0.000
Density of Seawater kg/cm^3	1000.000

But above 20 degrees the value of the parameter is decreased, which means the ship will never have a slope of more than 20 degrees. This indicates that the vessel has excellent stability until it cannot be reversed if operated in a pond while loading a monitoring tool of shrimp counts.

Figures 1 and 2 illustrate the ship's performance analysis by comparing the speed with which the vessel can attain resistance and the required power. In this analysis used four methods in analyzing the Holtrop method, Slender body method, and Savitsky method both pre-planning and planning (Seif and Amini, 2004). In Figure 1 showing the relationship between resistance and velocity, it is shown that the right method is Savitsky. It appears that in the initial simulation the vessel was moving at a speed of about 2 m/s of ship resistance in the range of 20 N, the initial turbulence of the vessel made a major obstacle. However, when the speed increases to 6 m/s resistance decrease, and increases again as speed increases.

Figure 2 shows the relationship between speed and the required driving force. As in the analysis of the relationship speed and resistance, the appropriate method of analyzing is Savitsky. This is because Savitsky methods are more sensitive to small-sized ship designs, while other methods are more sensitive to large vessels (Dubrovsky *et al*., 2001). In Figure 2 it appears that the driving power requirement is proportional to the increase in speed of the speeding vessel. Figure 3 shows the ship's components corresponding to the ship's performance requirements according to the design and analysis of the stability and performance of the vessel. Figure 4 shows the design of the ship in the form of 3-dimensional design as well as seen from the top, side and front.

Table 3: Heel to Starboard Simulation

Heel to Starboard De	-50	-40	-30	-20	-10	0	10	20	30	40	50
GZ m	-0.0710	-0.0880	-0.104	-0.1160	-0.0710	0	0.0710	0.1160	0.1040	0.0880	0.0710
Area under GZ curve from zero heel m.deg	4.2106	3.4140	2.4609	1.3351	0.3601	0	0.3601	1.3351	2.4609	3.4140	4.2105
Displacement kg	3.9500	3.9500	3.9500	3.9500	3.9500	3.9500	3.9500	3.9500	3.9500	3.9500	3.9500
Draft at FP m	-0.0410	0.0070	0.0420	0.0680	0.0790	0.0820	0.0790	0.0680	0.0420	0.0070	-0.0410
Draft at AP m	-0.0720	-0.0250	0.0100	0.0390	0.0490	0.0480	0.0490	0.0390	0.0100	-0.0250	-0.0720
WL Length m	0.6500	0.6500	0.6500	0.6500	0.6500	0.6440	0.6500	0.6500	0.6500	0.6500	0.6500
Beam max extents on WL m	0.1560	0.1610	0.1680	0.3350	0.3510	0.3600	0.3510	0.3350	0.1680	0.1610	0.1560
Wetted Area m^2	0.1470	0.1460	0.1450	0.1510	0.1860	0.1970	0.1860	0.1510	0.1450	0.1460	0.1470
Waterpl. Area m^2	0.0780	0.0670	0.0600	0.0610	0.0920	0.0990	0.0920	0.0610	0.0600	0.0670	0.0780
Prismatic coeff. (Cp)	0.8340	0.8330	0.8330	0.8330	0.8080	0.8050	0.8080	0.8330	0.8330	0.8330	0.8340
Block coeff. (Cb)	0.6070	0.6040	0.6040	0.5520	0.3930	0.4710	0.3930	0.5520	0.6040	0.6040	0.6070
LCB from zero pt. (+vefwd) m	0.2840	0.2850	0.2850	0.2840	0.2840	0.2840	0.2840	0.2840	0.2850	0.2850	0.2840
LCF from zero pt. (+vefwd) m	0.2890	0.2890	0.2920	0.3040	0.2820	0.2790	0.2820	0.3040	0.2920	0.2890	0.2890
Max deck inclination deg	50.0107	40.0236	30.0435	20.0662	10.1631	2.0754	10.1632	20.0664	30.0433	40.0234	50.0107
Trim angle (+ve by stern) deg	-1.8839	-1.9658	-1.9589	-1.7696	-1.8509	-2.0754	-1.8515	-1.7720	-1.9551	-1.9571	-1.8762

Conclusion

The Catamaran boat with Loa (entire length of boat body) = 670 mm, Lenght water line (Lwl) = 650 mm, B (width) = 300 mm, T (full/high) = 180 mm, Cb (block coefficient) = 0,55 and Vs (speed) = 19 knots was built to bear camera that used for vannamei shrimp monitoring system.

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Author’s Contributions

Bambang Sampurno: Chief of research team, most contribution in research idea, partnership, team management, resources support.

Mashuri: Assistance and secretary of research team, support the needs of research activity, prepare the requirement of the research activity.

Arif Abdurrahman: Programmer of the research team.

Herry SufyanHadi: Manufacturer of the research team.

Suhariyanto: Property manager of the research.

Syamsul Hadi: Vice chief of research team, advice the progress of the research activity.

Ethics

Authors should address any ethical issues that may arise after the publication of this manuscript.

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