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Design Unmanned Minesweeper Catamaran as a Tool to Make a Safer Marine Environmental Using Analytical Methods

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ABSTRACT

After the war is over, the sea mine layer must be neutralized because if the mine explodes, it will cause environmental damage and the death of marine life. Minefields with very shallow water are difficult to clear using a minehunter. Mining in shallow sediment-covered areas is still hazardous, especially if the area is bridges, shore dredging, ports, or shipping lanes. This study designed the hull of the Unmanned Mines Sweeper (UMS) Catamaran, which towing side scan sonar so that it could double function as a mine-like detection and a survey vessel for seabed environmental conditions in very shallow areas. UMS design with analysis method using Maxsurf Modeler Advanced V21.13 software. Line plan design and general settings using AutoCAD software with data obtained from models designed using Maxsurf software. Total resistance value using Maxsurf Resistance Advanced V21.13 software. UMS uses a Catamaran design with an LoA of 4.823 meters, LwL of 4.177 m, and a width of 2.24 m. The ship has a high draft of 0.498 with a displacement of 1.557 tons. The results of the resistance analysis obtained Rt of 404.94 N. The drive system uses an electric motor that can provide endurance for 6 hours.

Keywords: *Catamaran, Mine Countermeasure, Marine environmental, Numerical methods, Unmanned mines sweeper.*

1. INTRODUCTION

Naval mines are one of the weapons in modern naval warfare. Naval mines are generally used by the defense (inferior). After the war is over, naval mines that have not been neutralized are hazardous to the environment, civilians, and commercial shipping vessels [1]. Naval mines were first used in the 16th century when the first prototype mines were created to deal with pirates who interfered with shipping off the Chinese coast. Naval mines were widely used during the Russo-Japanese War in 1904-5. The negative impact of naval mines on commercial shipping has led many countries to ratify special international legal restrictions on the use of naval mines, which are currently embodied in the Hague VIII Convention on the Laying of Automatic Submarine Contact Mine. The main purpose of naval mines is to sink or damage enemy ships, but many mines are spread in shipping areas that aim to limit enemy access to sea areas with high economic and strategic value [2]. The types of marine mine fuses are magnetic, induction, pressure, infrasonic, audio frequency and contact [3].

Mine countermeasures (MCM) is a sea operation that is very risky for personnel and material losses (mine ships). To mitigate the impacts and risks of naval mines on naval operations, an evaluation of the future MCM is therefore needed to defeat the threat of naval mines [4]. Several countries have used unmanned mine sweeping, namely the RNMB Hebe (RNMB Hebe Mine countermeasures and survey, LoA 15m, Beam 6m, draught 0.8m, maximum speed 13 knot, cruising speed 10 knot, autonomous mine hunter Royal Navy), ARMCS (Royal Navy's 11 meters ARCIMS Autonomous Unmanned Surface Vessel/USV) 3, and the US Navy Common Unmanned Surface Vehicle, or CUSV.

After the war is over, layering naval mines must be neutralized. Some of the reasons mines must be neutralized are the first because if a mine explodes, it will cause casualties to anyone near the mine. The second reason is that if the mine explodes, it will damage the environment around the minefield. The damaged environment includes the seabed and all living things around the minefield. Minefields with very shallow water are challenging to clear using a minehunter, especially in minefield areas with high sedimentation rates, such as estuaries. Sea mines in shallow areas covered with sediment are still hazardous, even less if the area is bridges, shore dredging, harbors, and deepening of shipping lanes.

This study will design an unmanned mines sweeper with a catamaran model as a minesweeper auxiliary ship. This catamaran boat will tow side scan sonar as a mine detection tool. This research consists of making lines plan, solidifying it using marine software, and calculating the propulsion system. This ship will use environmentally friendly materials, electric motor propulsion, and solar panels as additional battery power.

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2. BASIC THEORY

2.1 The Marine Mine

Most countries in the world have prohibited the use of landmines because they can cause permanent disability to combatants and civilians. According to The Hague VIII and customary international humanitarian law (IHL), naval mines can be used as weapons of war. The purpose of deploying naval mines is to sink or incapacitate enemy ships. However, naval mines are spread so that the enemy does not pass through or take advantage of sea areas that have strategic value both economically and in terms of resources. Naval mines are also deliberately spread so the enemy enters the killing ground.

A naval mine is an explosive device that aims to immobilize or sink enemy ships. Naval mines are laid in the water, on the seabed, or beneath the ground [2]. The method of naval mines is contact, influence or manual [5]. Naval mines are divided into 6 types: moored mines, drifting or floating mines, bottom mines, remotely controlled mines, submarine-launched mobile mines, rising or rocket mines [6]. Some countries use unmanned surface vehicles [7,8] and remotely operated underwater vehicles [9] for mine counter measurement. The use of unmanned vessels and robots aims to reduce personnel losses during mine counter measurements.

2.2 Catamaran Boat

The catamaran is a ship with a double hull connected by a bridging structure. The shape of the hull of a catamaran is similar to a mono hull but has a slimmer waterline so that the resistance experienced is less. Besides having less resistance, the advantage of a catamaran compared to a monohull is that it has better stability. The two hulls of the catamaran are designed according to the fluid flow that passes through the tunnel. Catamaran is a ship with a double hull (Twin Hull) which is connected by a firm deck construction and stretches above it to withstand bending moments and large shear forces that act against the center line of the ship. The shape of the catamaran hull on various ships is not the same. There are many models of catamaran body shapes, but generally, there are two basic forms of catamarans: symmetrical and asymmetrical.

This study uses a catamaran-type ship so that the ship has a low draft and small friction resistance. So that in the same thrust, the speed is relatively faster with a wider deck area and smaller submerged volume and wet surface than the monohull, which produces better stability. Even though the wave frequency is rather high, the amplitude is relatively small, so the comfort level is increased. With a slight resistance, it decreases the operational costs, and the mage seems to be the guaranteed safety of the ship overturning so that the ship is more stable [10-15]. Several studies on small catamaran boats also use solar cells to add power to the boat [16,17].

2.3 Side Scan Sonar

Mine positions can be detected using sonar on minesweepers [18,19]. However, due to the large size of the sonar, the unmanned surface vehicle uses side scan sonar to detect the mine-like position. Side Scan Sonar is a detection equipment capable of displaying underwater conditions, including underwater and seabed contacts [20-23]. Side scan sonar is a kind of portable sonar that is small, so it is easy to carry by towing a small boat. Several studies have concluded that side scan sonar can be used to detect mine-like and seabed contours.

3. RESULT AND DISCUSSION

3.1 Construction of Unmanned Mines Sweeper

This study uses Maxsurf Modeler Advanced V21.13 UMS objects with the following data shown in Table 1:

Table 1. Unmanned Mines Sweeper Specification

Specification	Value	Unit
Design speed	4	knots
Length over All	4.823	metres
Length on Waterline	4.177	metres
T(draught)	0.498	metres
Boa	2.24	metres
Displacement	1.577	ton
Main Engine	2 x 4	HP

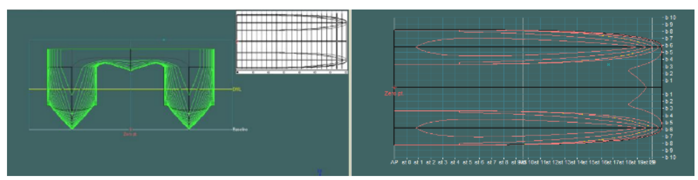

Figure 1. Design UMS using Maxsurf Modeler Advanced V21.13.

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

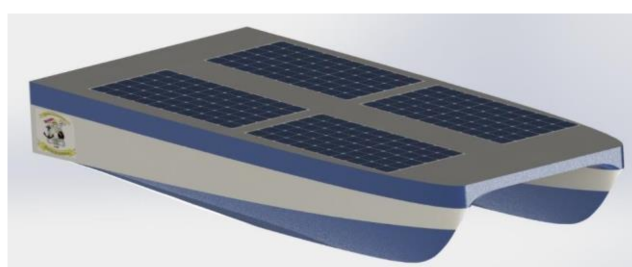

Figure 2. 3D model Unmanned mines Sweeper

General Arrangement Model Unmanned mines Sweeper is shown in Figure 3.

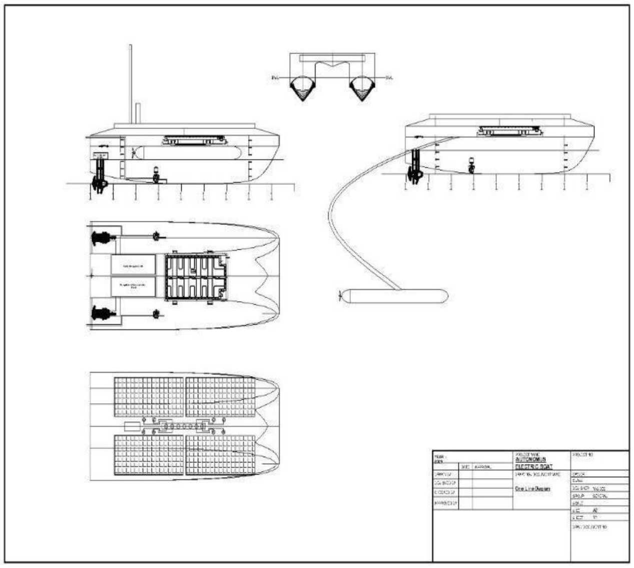

Figure 3. General Arrangement Unmanned Mines Sweeper.

The results of the calculation of hydrostatic data are obtained from the Maxsurf Modeler Advanced V21.13 software. The following hydrostatic data obtained from the Maxsurf Modeler Advanced software is shown in Table 2. Displacement calculations with hull data made from composite materials. The choice of composite is because it is light, so the draft of the ship becomes lower than other materials. The second reason is that composites are non-magnetic materials, so they do not trigger naval mines.

Table 2. Hydrostatic Data Unmanned Mines Sweeper

Measurement	Value	Unit
Displacement	1.577	t
Volume (displaced)	1.539	m3
Draft Amidships	0.3458	m
Immersed depth	0.3458	m
WL Length	4.823	m
Beam max extents on WL	02.24	m
Wetted Area	10.748	m2
Max sect. area	0.428	m2
Waterpl. Area	5.375	m2
Prismatic coeff. (Cp)	0.746	
Block coeff. (Cb)	0.48	
Max Sect. area coeff. (Cm)	0.685	
Waterpl. area coeff. (Cwp)	0.835	
Precision	Highes t	209 stations

Based on the data in Table 2, using the Maxsurf Resistance Advanced V21.13 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 resistance value to the speed of the Maxsurf Resistance Advanced V21.13 Software analysis is shown in Table 3.

Table 3. Maxsurf Resistance Software analysis

Vs	Froude No		Holtrop resist	Slender Body Resist	Slender Body Power
	LWL	Vol			
Knot			N	N	N
0.5	0.037	0.076	6.0	4.5	1.2
1.0	0.075	0.153	21.6	15.5	7.9
1.5	0.112	0.229	45.83	33.3	25.6
2.0	0.150	0.306	77.57	57.7	59.4
2.5	0.187	0.382	116.16	88.6	113.9
3.0	0.224	0.459	161.01	140.1	216.2
3.5	0.262	0.535	211.82	201.2	362.2
4.0	0.299	0.612	268.79	327.5	673.9
4.5	0.337	0.688	334.98	271.2	627.7
5.0	0.374	0.764	404.94	494.8	1272.8
5.5	0.411	0.841	481.42	560.4	1585.6
6.0	0.449	0.917	561.72	519.1	1602.2
6.5	0.486	0.994	643.90	656.7	2196.1
7.0	0.524	1.070	727.36	977.3	3519.5
7.5	0.561	1.147	814.43	1335.3	5152.2
8.0	0.598	1.223	905.16	1630.1	6708.7
8.5	0.636	1.300	989.71	1832.6	8013.8
9.0	0.673	1.376	1061.62	1957.7	9064.4
9.5	0.711	1.452	1143.07	2031.1	9926.1
10.0	0.748	1.529	1213.91	2076.8	10684.2

3.2 Wave Analysis

The wave view is displayed from a speed of 10 knots to 40 knots, with speed multiples of every 10 knots using the Maxsurf resistance software shown in Figure 5 and Figure 6.

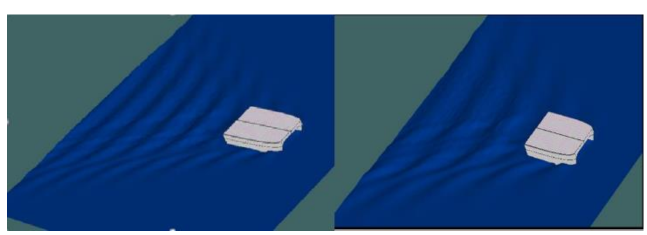

Figure 5. Wave at 2 knot (left) and 3 knots (right)

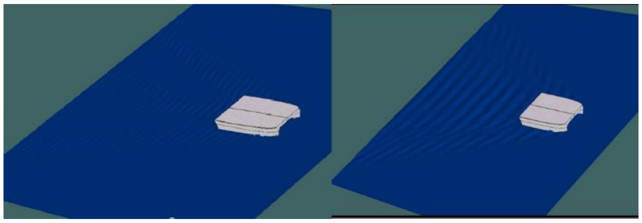

Figure 6. Wave at 4 knot (left) and 5 knots (right)

3.3 Propulsion System

The propulsion system UMS design using Electric Motor propulsion system is shown at Figure 7.

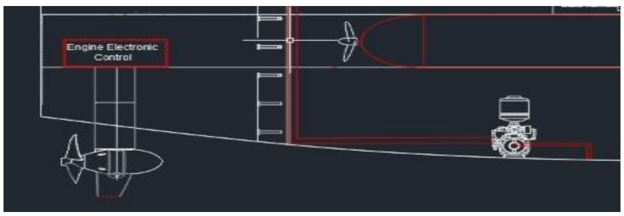

Figure 7. UMS electric motor propulsion system

UMS is designed to use an electric motor to be more environmentally friendly and low vibration. This system is also easier to control because it does not use a steering wheel. The power requirements of the UMS are shown at Table 4.

Table 4. Power requirements of the UMS

Vs	Fn		Holtrop	PE (HP)		BHP MCR	
knot	LWL	Vol	N	EHP	SHP	HP	kW
0.5	0.037	0.076	6.00	0.002	0.032	0.003	0.003
1	0.075	0.153	21.69	0.015	0.027	0.027	0.019
1.5	0.112	0.229	45.83	0.048	0.072	0.086	0.063
2	0.150	0.306	75.57	0.108	0.162	0.195	0.143
2.5	0.187	0.382	116.16	0.203	0.304	0.365	0.267
3	0.224	0.459	161.01	0.338	0.507	0.608	0.44
3.5	0.262	0.535	211.82	0.518	0.778	0.933	0.682
4	0.299	0.612	268.79	0.752	1.128	1.354	0.988
4.5	0.337	0.688	334.98	1.054	1.581	1.898	1.386
5	0.374	0.764	404.98	1.416	2.124	2.549	1.862

Based on the calculation of engine power requirements in Table 4, a power engine of 2,547 HP is needed. The specifications of the electric motor on the market are with an input power of 2,000 W. It is comparable to a 5 HP gasoline outboard motor in terms of driving power. Because the minimum required power of UMS is 4 HP, the electric motor required for each motor is 0.931 kW. The power requirement of electric motors is 1.862 kW.

3.4 Side Scan Sonar

UMS design uses side scan sonar Imagenex Model 878 Side scan Sonar. Because in addition to the light, the side scan sonar weight of 12 kg in water with required power of 15 watts is shown in Figure 8.

Figure 8**.** Side scan Sonar

3.5 Battery Management System

The battery design uses a Deep Blue Battery with a power of 40 kW to meet the criteria for the power required by the UMS, because the total power required by the UMS is at least 35 kW. The electrical power requirement is shown in Table 5.

Table 5. Electrical power requirement

No	Component	Power(W)
1	Lighting	1000
2	Navigation and radar	1000
3	Bilge pump	100
4	Propulsion system	3729
Total		5829

The electrical power requirement for 6 hours without charging is 35 kWh. UMS is supported by 4 solar panels to increase cruising endurance and is environmentally friendly. The battery uses lithium-ion cells. The battery management system (BMS) manages output, charge and discharging and provides notifications about the status of the battery pack. BMS is also powered by 4 Ea solar panels. The BMS diagram is shown in Figure 9.

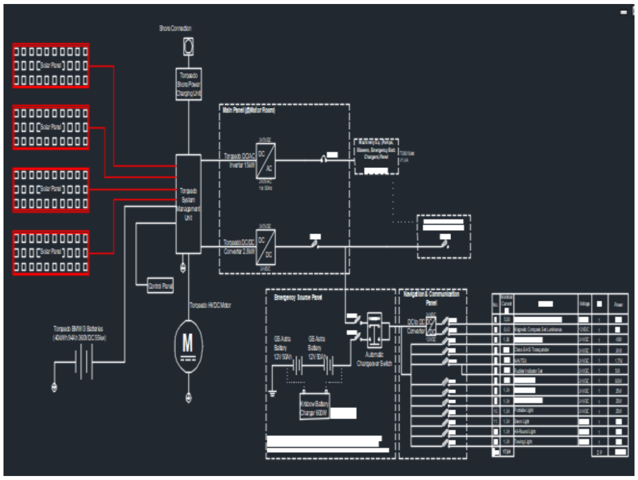

Figure 9. Battery management system UMS

3.6 Remote Control

UMS is controlled using a remote control. Modules and antennas are installed on the minesweeper ship.

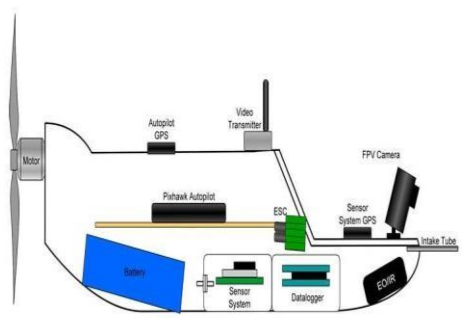

Figure 10. Autopilot working system

Where the software chosen by the author is the XCSOURCE Mini PIX4 FMU V6 32Bit PX4 Flight Controller 168Mhz software Compatible with RC Drone Car Boat RC1022. The autopilot working system is shown in Figure 10.

The remote controller chosen is the FrSky HORUS X10 because it is able to remotely control aerial models, ships, and land machines such as vehicles and robots within a specified radio frequency range. If there is trouble with the control system, the remote UMS loses power, or the range is too far, this software will automatically bring the UMS back to the mother ship. This software also functions as an autopilot controller when UMS performs mine counter measurement.

4. CONCLUSION

Based on the data and analysis of the results of this study, with predictions of ship resistance results using the Maxsurf Modeller Advance V21.13 software method. it can be concluded that the design of this UMS ship uses carbon fiber as the main material for shipbuilding with a catamaran hull design, has a design with a length of 4.8 m (LoA), a length of 4.17 m (LWL), a width of 2.24 m, a ship height of 2, 1 m, and 6 hours of endurance at maximum speed, a maximum speed of 5 knots and a ship's resistance value of 404.94 N and a propulsion system with an electric motor with a power value of 4 HP that is suitable as a propulsor on a UMS ship. Where the electric motor power is 2 KW or 5 HP. UMS towing side scan sonar during mine counter measurement.

Unmanned mines sweeper Catamaran which towing side scan sonar had double function as a mine like detection and a survey vessel for seabed environmental conditions in very shallow water.

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