

Development of Small Autonomous Surface Vehicle Design for Underwater Cultural Heritage

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ABSTRACT

As part of research on unmanned exploration equipment, we conducted a study related to the development of a small autonomous surface vehicle for exploring underwater heritage in areas that are difficult to access by ship. In order to develop an autonomous surface vehicle, initial conceptual design was performed by examining the constraints of the vehicle, and the hull foam was developed based on the results of the conceptual design. In addition, the developed hull foam was used to estimate the resistance and motion performance using numerical simulation methods, and the thrusters and related equipment were selected based on this.

Keywords: Autonomous surface vehicle, Hull foam, Underwater exploration

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1. INTRODUCTION

In general, underwater surveys are conducted using ships, and in areas that are difficult to access by ship small boats such as rubber boats are used to conduct underwater surveys. However, there are many cases where surveys cannot be carried out in these areas due to the possibility of problems with the operation of the boat and the safety of the surveyors. In the field of marine survey, various equipment is being developed to conduct surveys in the nearshore and shallow water area where such surveys are difficult. In particular, in recent years, unmanned exploration equipment has been developed by applying rapidly developing ICT technologies such as the 4th Industrial Revolution and 5G technology.

In the case of underwater artefacts, they are mainly excavated in shallow coastal environments rather than in deeper waters (> 110 m depth), so precision exploration at shallow water depths can increase the probability of discovering underwater artefacts. In addition, if an unmanned autonomous surface vehicle for underwater cultural property investigation is developed, it may be more efficient than the current manpower-dependent exploration method.

Therefore, as a first in developing this new technology, this research program conducted a study related to optimal hull design and development of 3m-sized unmanned surface vehicle as a fundamental study for the development of small surface autonomous vehicles that can be used in coastal areas to increase the efficiency of exploration of underwater cultural heritage.

2. HULL FOAM

Typically, a small boat has a V-shape hull to improve resistance performance, however the autonomous surface vehicle developed in this study has a maximum speed of four knots, which is similar to the Froude number of a merchant ship. In addition, as we need a flat space at the bottom of the hull to attach sensors for exploration, we developed a U-shape hull foam as Figure 1.

The conditions required for autonomous surface vehicles developed in this study can be summarised as follows.

1. Purpose: autonomous surface vehicle carries out unmanned exploration of underwater cultural heritage after being transported by a platform vessel to the exploration area.
2. Hull foam: Catamaran type for loading space
3. Size: It should be able to be loaded on a ship, and it should be able to be transported in a container.
4. Velocity: To ensure exploration quality, the maximum speed is 4 knots.
5. Operating time: Maximum 4 hours at 4 knots
6. Propulsion type: Azimuth type thruster for dynamic positioning
7. Power source: Gasoline generator (main) and battery (emergency)

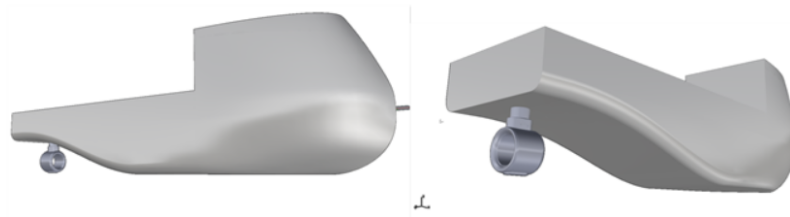


Figure 1 U-shape hull foam of autonomous surface vehicle

3. PERFORMANCE ESTIMATION

Stability calculation and motion analysis were performed to confirm the static & dynamic stability of the developed hull. Also, resistance performance was analysed to determine the specifications of the propulsion system.

3.1 Static stability

Static stability analysis was performed to confirm the stability using the software package Maxsurf stability. For static stability analysis, it is essential to estimate the weight and centre of gravity of the mounted equipment on the hull. We estimated the weight by categorising the equipment as exploration, propulsion, and navigation, resulting in an estimate of 206 kg for exploration, 110 kg for navigation, and 320 kg for propulsion. The hull weight was calculated assuming a thickness of 5 mm to give a weight (200 kg). The total weight is therefore not expected to exceed one ton. The vertical centre of gravity was assumed to be 0.5 metres above the bottom of the hull.

The result of the static analysis is shown in Table 1. The Metacentric height (GM) values are all above 1 at a draft of about 0.3 to 0.4 metres. In addition, the righting arm (GZ) as shown in Figure 2, at a draft of 0.37m, satisfies the IMO stability criteria. As a result, this autonomous surface vehicle is considered safe.

Table 1 Results of static stability

Draft (m)	0.317	0.331	0.344	0.357	0.37
Displacement (ton)	0.8	0.8463	0.8925	0.9388	0.9849
KG (m)	0.5	0.5	0.5	0.5	0.5
GM (m)	1.864	1.795	1.738	1.706	1.806

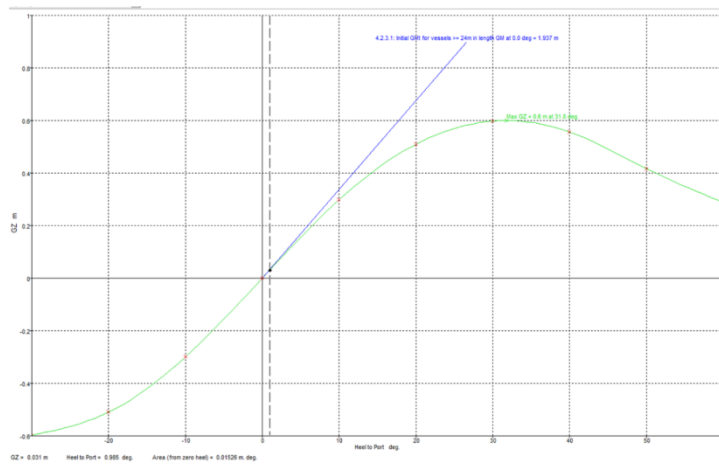


Figure 2 GZ curve at draft 0.37m

3.2 Dynamic stability

Dynamic stability analysis was performed to confirm the stability using the software package Maxsurf motion. The motion analysis was performed in strips for ship speeds (2, 4 knots), and irregular wave conditions were considered using ITTC spectrum and the wave height and period of Sea-State 2.

The results of the analysis are shown as Figures 3 and 4. As the speed increases, the heave is increasing in a head sea (180 degree) and decreasing in the following sea (0 degree). Overall, however, the motion is small, less than 10 cm. In the case of roll, the largest value of 1.4 deg. is found in the beam sea (90 degree), which is estimated to be stable, and the same as heave, the roll tends to decrease in the quartering sea (45 degree) as the speed increases. In the case of pitch, the motion tends to increase as the speed increases, and the largest motion is found in the following sea (0 degree) as 1.33deg. However, the difference between stern and stem draft is about 7cm, which is considered to be stable considering the hull length.

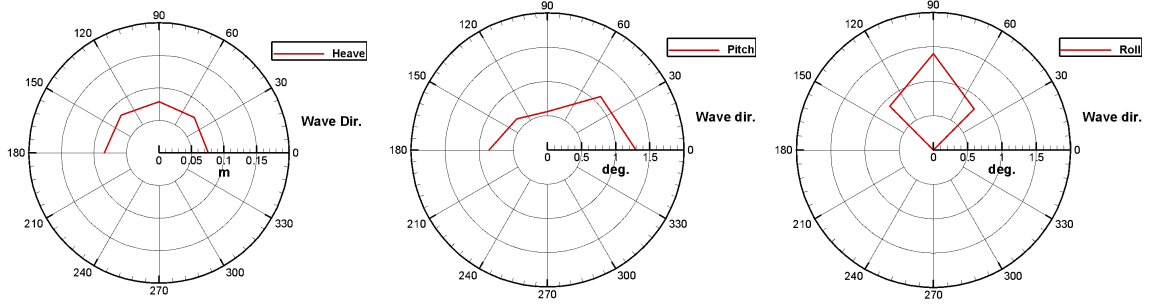


Figure 3 Results motion analysis at 2 knots

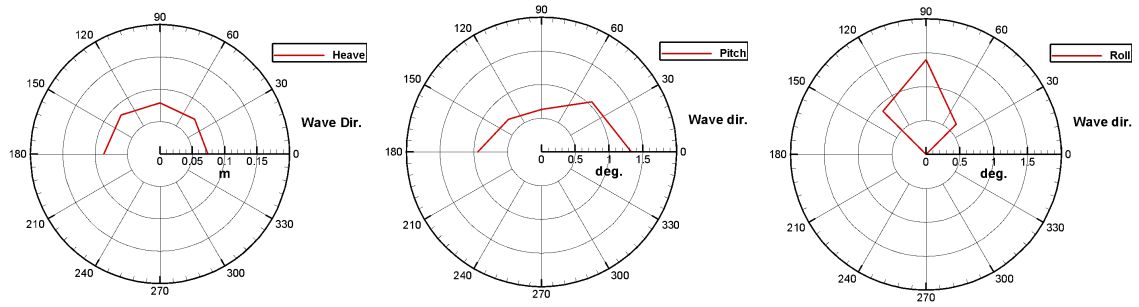


Figure 4 Results motion analysis at 4 knots

3.3 Resistance performance

Resistance performance was performed to determine the specifications of propulsion system. In this study, the commercial software Star-CCM+ was used. The governing equations were the continuity equation and momentum equation for three-dimensional unsteady incompressible viscous flow. For detailed analysis conditions, refer to Seok and Park (2020a). The numerical simulation was performed under two conditions of draft at 360 mm and at 370 mm. For a draft of 370 mm, we also performed additional analysis under ship speed conditions of 2-5 knots to determine the resistance performance.

The results of the analysis are shown in Table 2 and Figure 5. When the speed is 4 knots, it can be seen that the resistance acting on the ship increases as the draft increases by 10 mm, and the increase is approximately 4 percent. When the draft is 370 mm, the resistance acting on the ship increases according to the ship speed, and the resistance is estimated to be 530N at the target speed of 4 knots. Therefore, assuming that the efficiency of the propulsion system is 50%, 1060 N is required for the ship to reach a target speed.

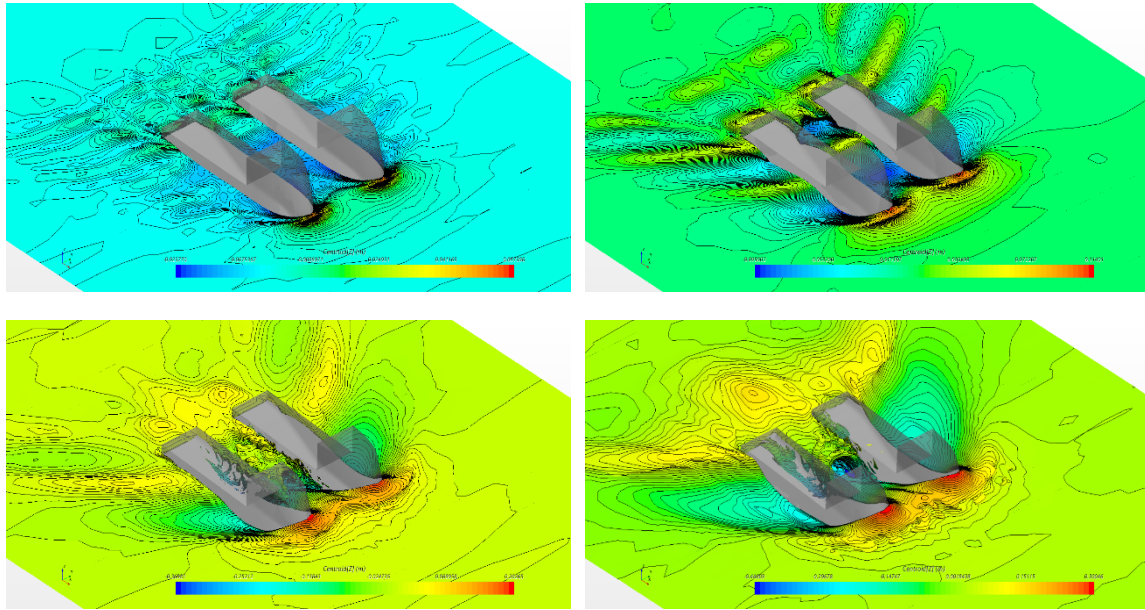


Figure 5 Results of resistance performance from 2 knots to 5 knots

Table 2 Results of resistance simulation

Type	draft (mm)	Speed (knots)	Resistance (N)
Autonomous surface vehicle	360	4	510
	370	2	32
		3	116
		4	530
		5	1,230

4. RESULTS

In this paper, research on the development of initial hull foam and performance estimation for the developed autonomous surface vehicle was conducted. For the development of the hull foam, the requirements of the autonomous surface vehicle were reviewed, and U-shape hull foam was finally developed. In addition, stability analysis and resistance performance estimation were performed on the developed hull foam using commercial software such as Maxsurf stability, Maxsurf motion, and Star ccm+. For static analysis, the weight and centre of gravity of each part were estimated, and static and dynamic analysis were performed using it. As a result, it was confirmed that the developed hull was safe. Additionally, the resistance performance estimates indicated that the autonomous surface vehicle would require approximately 1000 N of propulsion to achieve its target speed of 4 knots. Based on the results of this study, a propulsion system will be selected and the autonomous surface vehicle will be built, and its performance will be confirmed by sea trial after construction.

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