

# Design and Performance Analysis of a New Environmental Energy Powered Marine Vehicle

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**Abstract.** The efficient and reliable marine vehicle is an important tool to develop marine resources, and the lack of reliable power supply methods is one of the important issues that restrict the development of marine vehicle. This paper designs a new type of marine vehicle that can use environmental energy to absorb wave energy and convert it into electricity. The generated electric energy is temporarily stored in a battery or directly supplied to its own equipment. This article describes the main structure of the new marine vehicle and focuses on the energy module of the vehicle. And the energy module has been analysed and optimized. In this paper, the influence of the blade angle on the performance characteristics of the energy module is numerically analysed, and its variation law which lays a foundation for further structural optimization is obtained.

## 1. Introduction

The ocean occupies more than 70% of the surface area of the earth and contains a large amount of natural resources, such as biological resources, mineral resources, and marine energy [1, 2]. Therefore, all countries have actively engaged in the application of civil and even military applications related to the oceans. In the process of developing marine resources, having a highly efficient and reliable marine vehicle can make a country or organization have a dominant position [3]. Marine vehicles are known for their underwater concealed voyage operations and strong underwater attack ability. They are often used in detection, tracking, and other underwater operations. Its navigation environment mainly includes geographical environment and hydrological environment. As we all know, reliability and endurance are the basis for the execution of marine vehicle [4]. In the ocean, there are many factors that affect the reliability and endurance of marine vehicles. Among them, the power supply capacity and power supplementation capability are the key factors. If these factors are not taken into account, the marine vehicles will not be able to complete the scheduled tasks, and the marine vehicles will lose power or even be lost, causing heavy losses. The complex marine environment elements not only bring opportunities for the navigational operations of marine vehicles, but also bring high performance requirements.

This paper designs a new type of marine vehicle that can utilize environmental energy, namely wave energy and convert it into electricity. The generated electric energy is temporarily stored in a battery or

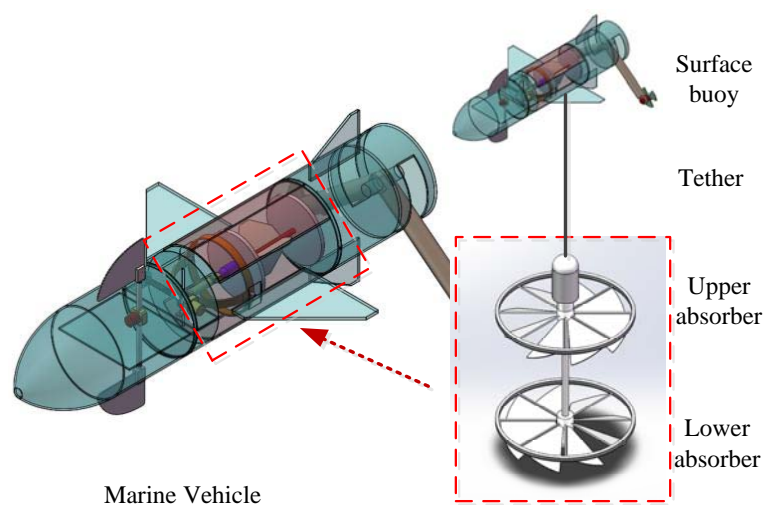


directly supplied to its own equipment. Wave energy, as a widely distributed energy source in the ocean, has the characteristics of high energy density [5-7]. This article describes the main structure of the new marine vehicle and focuses on the performance characteristics of the energy module. And the energy module has been analyzed and optimized.

The rest of this article is organized as follows: Chapter 2 mainly introduces the new marine vehicle and its environmental energy module; Chapter 3 mainly describes the working principle of the environmental energy module of the marine vehicle; Chapter 4 analyzes the effect of blade angle on device power; Chapter 5 draws the conclusion. It summarizes and summarizes the full text.

## 2. Marine Aircraft's overall structure and energy module

This type of new marine vehicle that can utilize the environmental energy is shown in Figure 1. The left figure shows the overall structure and the right figure shows the energy module.



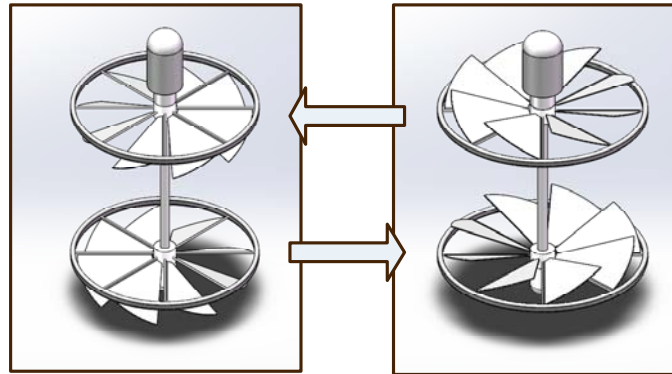
**Figure 1.** Schematic diagram of the marine vehicle energy module.

The basic structure of this marine vehicle is basically similar to that of current marine vehicle, and its innovation lies in its energy module. The energy module includes a battery and a wave energy absorber, which can provide a continuous source of energy for the marine vehicle by absorbing the wave energy of the surrounding environment. This new design can greatly improve the cruising ability and operating capability of the marine vehicle.

The energy module of this new marine vehicle can set different maximum blade rake angles in advance according to different sea conditions to optimize the performance characteristics of the equipment; the design of the double-layer counter-rotating adaptively absorber converts wave energy directly into rotational mechanical energy required for motor power generation. This design greatly simplifies the energy transfer progress and provides a new idea for improving the aircraft's life.

## 3. working principle

The new WEC consists of two parts, a floating surface buoy and an underwater absorber, which are connected by a tether. The underwater absorber mainly includes small-scale generator with built-in speed-increasers, upper and lower wave energy absorbers. The floating buoy of the water responds to the undulating motion of the waves to reciprocate up and down, converting the wave energy into the mechanical energy required for the generator of the underwater absorber. The underwater absorber converts mechanical energy in the form of linear reciprocating motion into mechanical energy in the form of rotational motion and eventually converts it into electrical energy through generator. Its working principle is as follows, shown in figure 2.



**Figure 2.** Schematic diagram of working principle.

When the surface buoy rises, the underwater absorber is dragged by the buoy. The upper surface of the blade of the absorber is impacted by seawater and adaptively oscillated downward (as shown in Figure 2). The seawater continues to impact the inclined blades and generates thrust to drive the blades forward. As the blades are arranged in a circumferential array, the absorber rotates in rotation. Due to the opposite arrangement of the vanes of the double-layer absorber, the direction of rotation is reversed.

When the surface buoy sinks, the underwater absorber sinks under gravity. The lower surface of the vane of the absorber is impacted by seawater and adaptively oscillated upward (as shown in Figure. 2). The seawater continues to impact the inclined blades and generates thrust to drive the blades forward. The absorber maintains the previous direction of rotation, that is, the direction of rotation does not change.

#### 4. Effect of blade angle on the power of the device

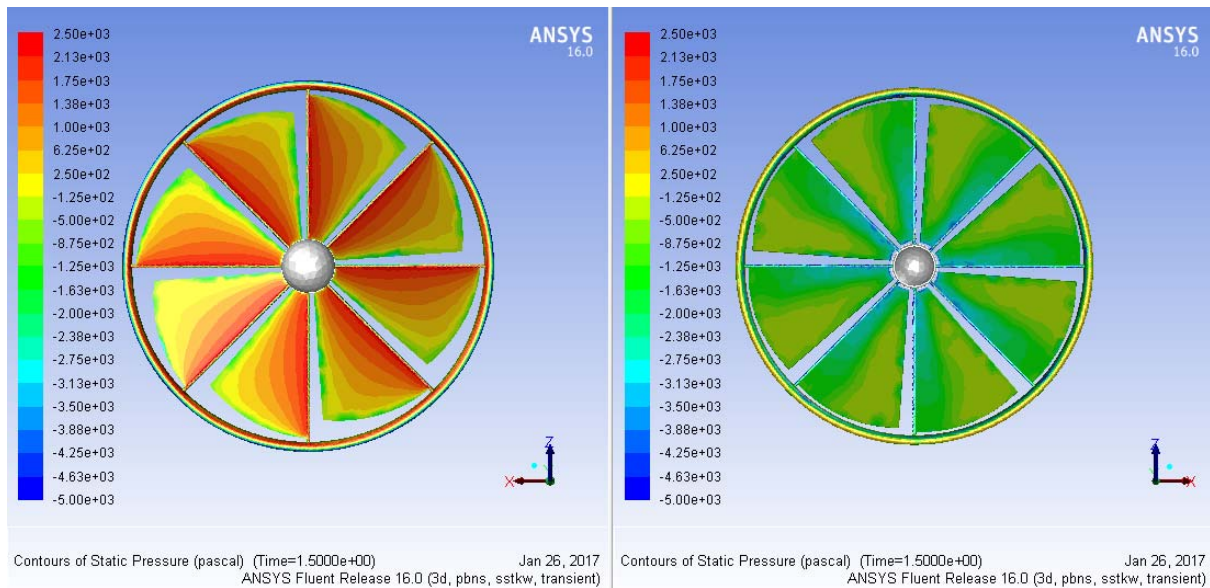
In order to accurately analyze and predict the performance characteristics of underwater absorber, this chapter selected ANSYS FLUENT 16.0 as an analysis tool, which is an efficient and accurate commercial CFD software. The software obtains parameter distribution and equipment performance characteristics of the flow field by solving Navier-Stokes equations which are discretized by finite volume method in spatial direction.

The blade acts as a key component in the absorber, and its angle directly affects the performance characteristics of the absorber. In order to facilitate the analysis and investigation of the performance characteristics of the underwater absorber, we only took the upper absorber as the research object. The key numerical configuration is shown in Table 1.

**Table 1.** The main configuration of numerical analysis.

Content	numerical configuration
Inlet condition	Velocity inlet
Inlet velocity	2.0m/s
Outlet condition	Pressure outlet
Turbulence model	k-omega SST
Simulation method	Sliding mesh
Rational speed	60 r/min

Through the above CFD analysis, we can obtain the pressure clouds of the blade as shown in Figure 3.



**Figure 3.** Pressure distribution on the blade surface of upper absorber.

The above figure shows the pressure cloud of the upper absorber blade with a blade angle of  $30^\circ$ . The absorber blades are impacted by the seawater, and a pressure difference is generated between the pressure side and the suction side. The thrust of the differential pressure on the blades eventually forms the torque of the absorber. As can be seen from the figure, the high pressure area of the blade is mainly concentrated on the leading edge of the blade. The pressure on the pressure side of the blade is mainly positive, and the pressure on the suction side is mainly negative. The pressure difference across the blade surface gradually decreases along the chord length and approaches zero at the trailing edge. Therefore, the output torque of the absorber is mainly provided by the pressure difference at the leading edge of the blade. Therefore, it can be concluded that increasing the relative velocity can increase the pressure difference on both sides of the leading edge of the blade and expand the area of the high pressure differential zone, which in turn allows the absorber to generate a larger rotational torque. Through the CFD analysis of the upper absorber, we can also obtain its main performance data, as shown in Table 2.

**Table 2.** The performance characteristics of the upper absorber.

Angle	Torque (Nm)	Power (W)	Efficiency (%)
10	6.17	38.75	6.99
20	12.15	76.32	13.77
30	14.12	88.69	16.01
40	14.02	88.09	15.90
50	11.49	72.19	13.03

As can be seen from the above Table 2, the performance characteristics of the upper absorbers with different blade angles are not uniform at a relative velocity of 2 m/s. By analyzing its torque, power and efficiency values, the relationship between its performance characteristics and blade angle can be obtained. From Table 2, it can be seen that the values of the three parameters increase first and then decrease as the blade angle increases. Among them, the highest value was obtained around  $30^\circ$ . Therefore, different blade angles must be selected according to the conditions of the environment in which the marine vehicle is located in order to maximize its performance characteristics.

## 5. Conclusion

This paper proposes a new type of marine vehicle. Its innovation lies in its ability to use the surrounding environmental energy. The energy module of the marine vehicle effectively integrates a wave energy absorber. The effective absorption and utilization of the surrounding ocean energy by the wave energy absorber greatly improves the cruising ability of the marine vehicle and prolongs the working time of the aircraft. In this paper, the influence of the blade angle on the performance characteristics of the energy module is analyzed numerically, and its variation law is obtained, which lays a foundation for further optimization.

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