Impact of folding propeller spinning position for the transit performance of a hybrid-driven underwater glider

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Abstract

A hybrid underwater glider(HDUG) is developed based on a folding propeller. The blades of the propeller can fold and unfold according to the motor work or not. When it stop spinning, the blades will come to a rest position. The hydrodynamic performance will vary with the position of the blades, thus the transit efficiency of the HDUG will also vary. So there must be an optimal transit efficiency for the propeller spinning position. Thus?to investigate this problem, this paper presents a thorough approach characterizing the transit efficiency for different folding propeller spinning position of the HDUG. This paper employ first-principle analysis that concludes the effect of efficiency for spinning position of the blades. This result implies that the transit performance of the HDUG is relative to the propeller spinning angle which depends on the parameters of the designed propeller.

I. INTRODUCTION

This paper presents a thorough approach characterizing the gliding efficiency for different folding propeller spinning position of a hybrid-driven underwater glider (HDUG). A kind of HDUG with a folding propulsion mechanism has been designed in this paper as shown in Figure 1The external structure of a HDUG developed in this paper. The folding propulsion device is aft located on the hull and the two blades can be capable of timely opening or closing according to the operational mission.figure.caption.1. The HDUG features high efficiency penetrating in ocean like conventional underwater gliders and high maneuverability when the folding propulsion is in use. As a result of this kind of novel design, the HDUG has glider buoyancy-driven mode, AUV propeller-driven mode, as well as hybrid-driven mode as shown in Figure 2The HDUG has glider buoyancy-driven mode, AUV propeller-driven mode, as well as hybrid-driven mode. Where the $v_i(i = 1, 2, 3)$ is the vehicle speed in these three driven modes respectively, m_b is the net buoyancy, and n is the propeller speed.figure.caption.2. Some researchers have carried out relative work on modeling or the control method for HDUG [1–3]. For long-range survey, the HDUG should have high transit efficiency. Some works have been carried on the transit efficiency of the HDUG. We can see from Figure 3Different folding propeller spinning position.figure.caption.3 that the folding propeller spinning position is not fixed at a same position each time when the motor stop spin. So our work in this paper is to find out the impact of the folding propeller spinning position for the transit efficiency of the HDUG. This is important to the maximum survey range of the HDUG.

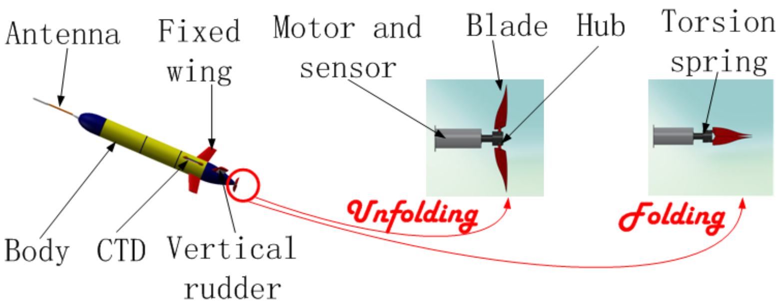

Figure 1: *The external structure of a HDUG developed in this paper. The folding propulsion device is aft located on the hull and the two blades can be capable of timely opening or closing according to the operational mission.*

II. CONTENT AND METHOD

Sections 1, 2 and 3 explain our exploration. Firstly, we use a first-principle method to obtain the transit efficiency model in glider buoyancy-driven mode with a folding propulsion mechanism based on the work of Steinberg [4]. Figure 4Variables in the dynamic motion of the HDUG.figure.caption.4 and Figure 5Illustration of

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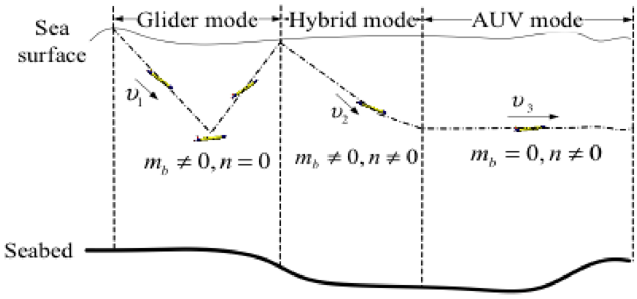

Figure 2: *The HDUG has glider buoyancy-driven mode, AUV propeller-driven mode, as well as hybrid-driven mode. Where the $v_i(i = 1, 2, 3)$ is the vehicle speed in these three driven modes respectively, m_b is the net buoyancy, and n is the propeller speed.*

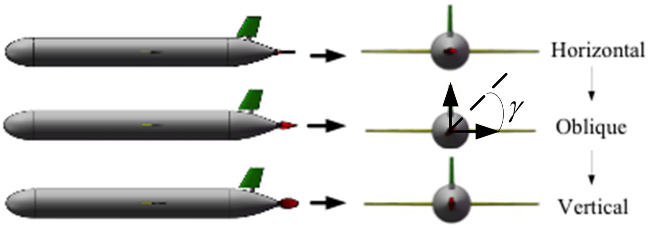

Figure 3: *Different folding propeller spinning position.*

the force acting on the hull body.figure.caption.5 shows the forces acting on the HDUG in the longitudinal plane. The transit efficiency in glider mode η_b is derived in equation (1Content and Methodequation.2.1).

$$\eta_\text{b} = \frac{\cot^2\sigma \cos\sigma (C_{Dh}\lambda_{wh}^{-2} + C_{Dfp\gamma}\lambda_{wp}^{-2})}{2(-1 + \sqrt{1 - (C_{Dh}\lambda_{wh}^{-2} + C_{Dfp\gamma}\lambda_{wp}^{-2})\cot^2\sigma}} \tag{1}$$

where σ is the gliding-path angle , $C_{Dfp\gamma}$ ($\gamma \in [0, {}^{\pi}/_{2}]$) are the propeller drag coefficients with blades in folding at different spinning angle γ when the drive motor stop spin. λ_{wh} is the wing span/hull diameter ratio, λ_{wp} is the wing span/propeller diameter ratio.

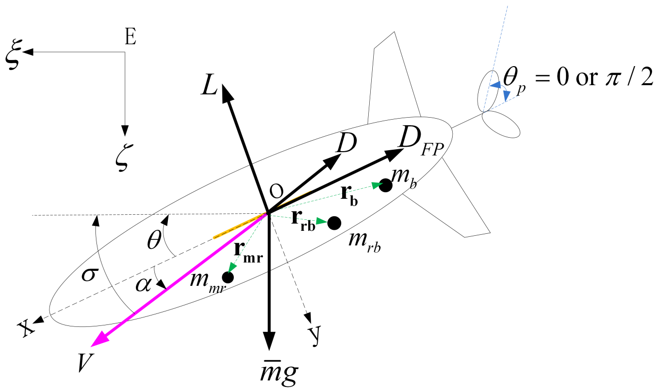

Figure 4: *Variables in the dynamic motion of the HDUG.*

From Figure 6The transit efficiency in glider buoyancy-driven mode varies with the folding propeller drag coefficients.figure.caption.6, we can see that the transit efficiency is decrease with the propeller drag coefficients increasing. So we must calculate the drag coefficients $C_{Dfp\gamma}$ to achieve the minimum value when the propeller spinning position at different spinning angle γ.

So the next task is focused on calculating the foldable propeller drag coefficients when the blades are in folding $C_{Dfp\gamma}$ ($\gamma \in [0, {}^{\pi}/_{2}]$) based on the Sea-wing glider [5] and the designed propeller (e.g., Table 1Main parameters of the propulsion mechanismtable.caption.7 is the parameters of the propeller).

Lastly, based on the previous work we study the effect of propeller spinning angle γ to glider buoyancy-driven mode transit efficiency η_b.

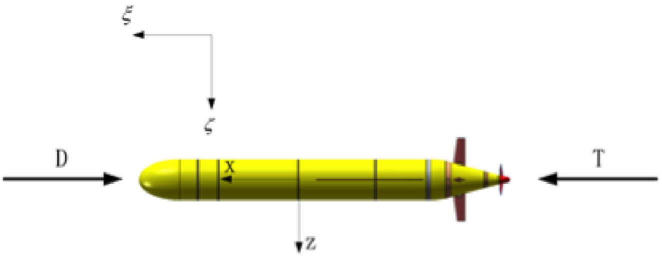

Figure 5: *Illustration of the force acting on the hull body.*

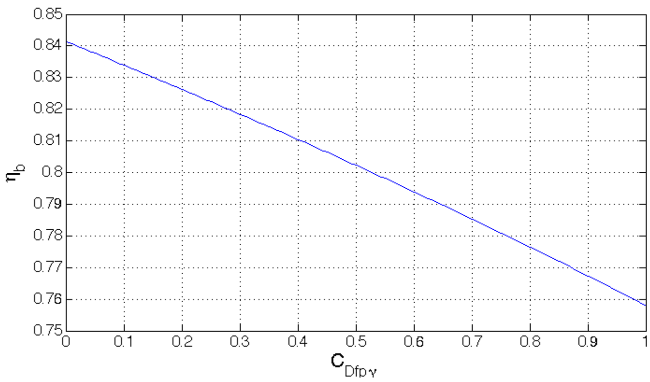

Figure 6: *The transit efficiency in glider buoyancy-driven mode varies with the folding propeller drag coefficients.*

Table 1: *Main parameters of the propulsion mechanism*

List of items	Property
Propeller diameter, D	$0.28m$
Pitch/propeller diameter ratio, P_p/D	0.786
Hub/propeller diameter ratio, d_h/D	0.14
Blade area ratio, A_D/A_O	0.275

III. Conclusion

The last section in this paper presents the preliminary main conclusions, which may be useful for the future manufacture and controller design of the folding propeller. We summarize them as the transit performance of the HDUG is relative to the propeller spinning angle which depends on the parameters of the designed propeller. The results are useful to conduct the design of the wings, hull, and propeller of the HDUG.

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