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Simulation Study on Typical Maneuvering Motion of Underwater Vehicles under Ocean Currents

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Introduction

It is known that simulating the motion of underwater vehicles under ocean current interference and comparing it with the motion under no ocean current conditions shows that ocean currents have a significant impact on lateral motion. This article focuses on studying the navigation performance of underwater vehicles using significant lateral ocean currents.

Underwater Vehicle Motion Model of Cross Flow

The specific components of the ocean current in each direction in the underwater vehicle coordinate system are

$$v_{mx} = V_m \cos(\psi_m - \psi)\cos\theta_m \cos\theta + V_m \sin\theta_m \sin\theta$$

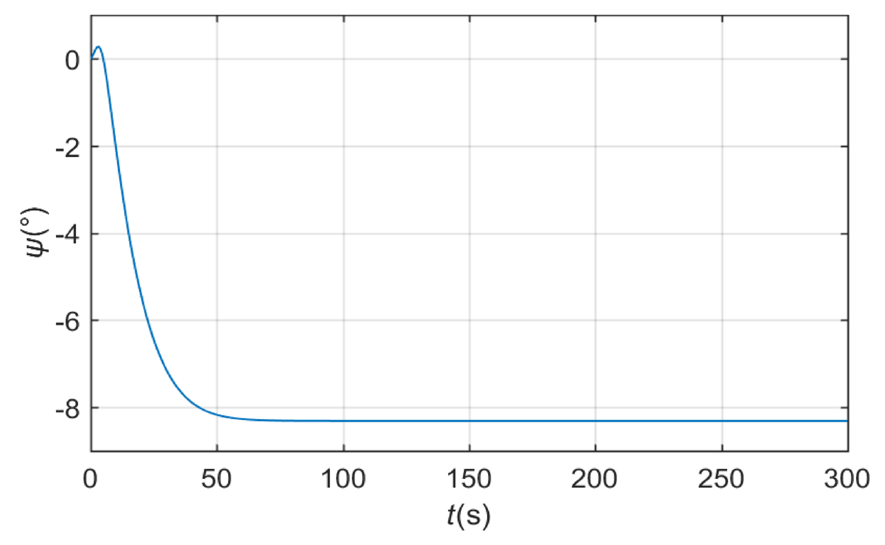
$$v_{my} = V_m \cos(\psi_m - \psi)\cos\theta_m \sin\theta \sin\phi + V_m \sin(\psi_m - \psi)\cos\theta_m \cos\phi - V_m \sin\theta_m \cos\theta \sin\phi$$

$$v_{mz} = V_m \cos(\psi_m - \psi)\cos\theta_m \sin\theta \cos\phi - V_m \sin(\psi_m - \psi)\cos\theta_m \sin\phi - V_m \sin\theta_m \cos\theta \cos\phi$$

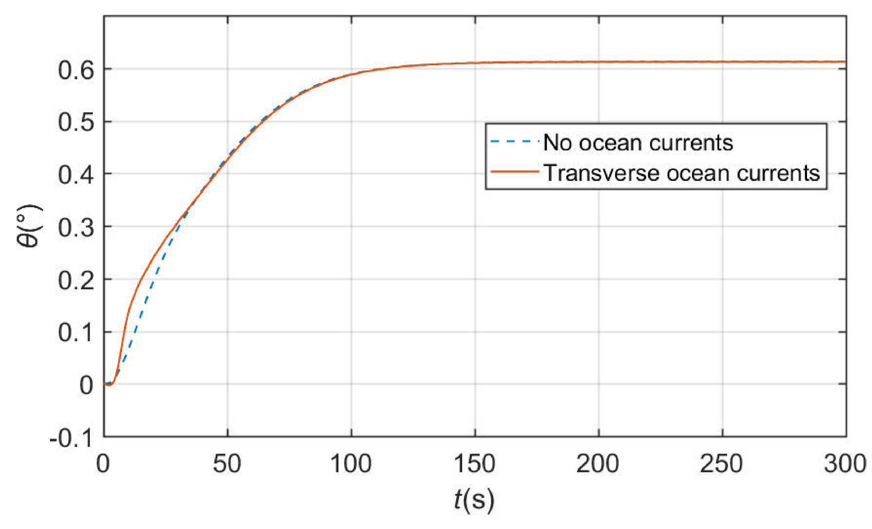
The equation for turning the bow is as follows.

$$\begin{aligned}\sum_i N_i = {} & \frac{1}{2}\rho L^5 \left[N'_{\dot r}\dot r + N'_{\dot p}\dot p + N'_{pq}pq + N'_{qr}qr \right] + \frac{1}{2}\rho L^5 \left[N'_{r|r|}r|r| + N'_{p|p|}p|p| \right] \\ & + \frac{1}{2}\rho L^4 \left[N'_{\dot v}\dot v_a + N'_{wr}w_a r + N'_{wp}w_a p + N'_{vq}v_a q + N'_{vww}v_a w_a^2 + N'_r u_a r + N'_p u_a p \right] + \\ & \frac{1}{2}\rho L^4 N'_{|v|r}\left|(v_a^2 + w_a^2)^{1/2}\right| r + \frac{1}{2}\rho L^3 \left[N'_0 u_a^2 + N'_v u_a v_a + N'_{v|v|}v_a \left|(v_a^2 + w_a^2)^{1/2}\right| + N'_{vw}v_a w_a \right] \\ & + (x_G W - x_C B)\cos\theta \sin\phi + (y_G W - y_C B)\sin\theta + \frac{1}{2}\rho L^3 u^2 N'_{\delta_r}\delta_r\end{aligned}$$

Research on the Navigation Performance of Cross Flow



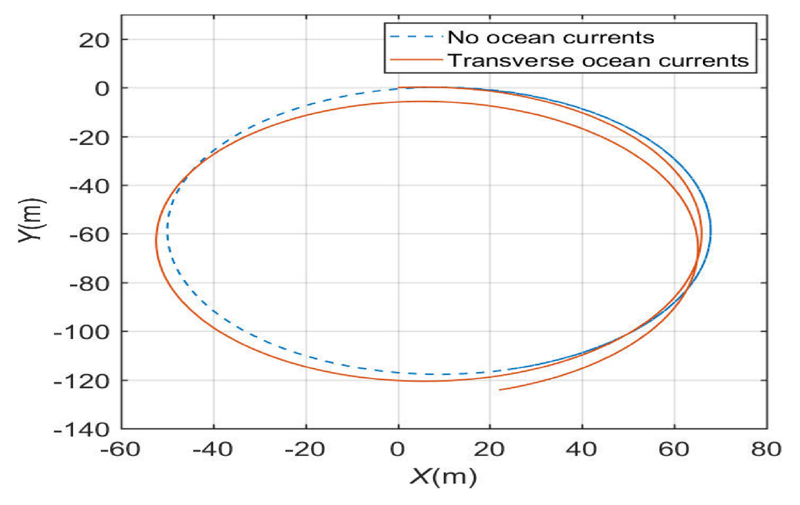
Time history curve of heading angle change during direct flight under cross flow



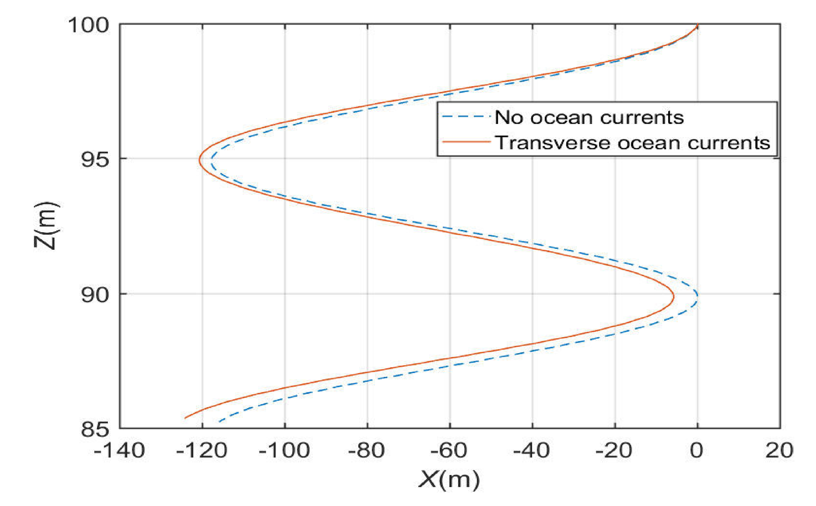
Time history curve of longitudinal angle variation in direct flight motion

The simulation results show lateral ocean currents cause lateral drift, indicating that ocean currents have a greater impact on lateral movement and a smaller impact on longitudinal position.

Simulation of Rotational Motion under Cross Flow



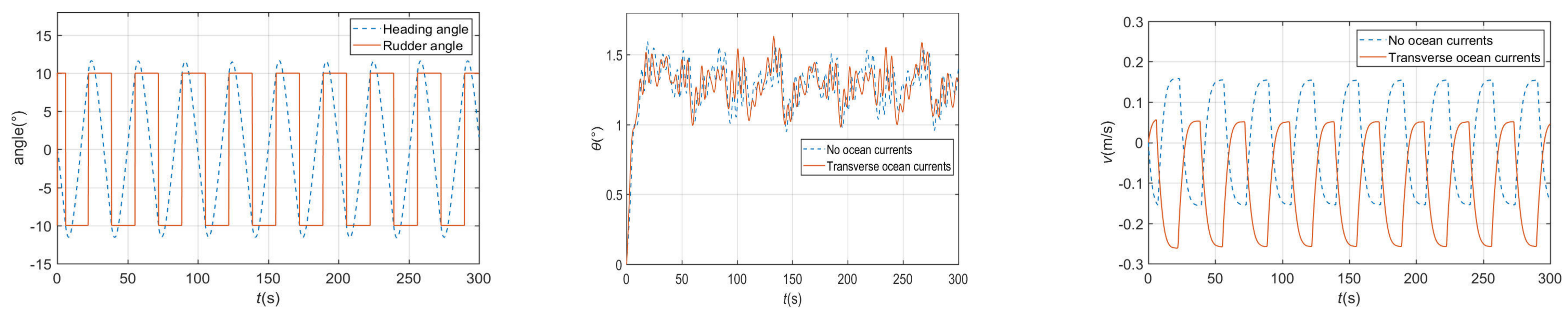
Horizontal projection of rotary motion



Vertical plane projection of rotational motion

The simulation results indicate that the asymmetric shape of the underwater vehicle causes it to move in space; The influence of ocean currents on lateral motion is greater than that on vertical motion. The presence of lateral ocean currents does not disrupt the stability of rotational motion, but cause larger lateral displacement and smaller vertical displacement.

Z-shaped motion simulation under cross flow



Time history curves of Z-shaped motion heading angle and rudder angle changes under cross flow/longitudinal inclination angle variation/speed v variation

The simulation results show that the presence of lateral ocean currents has little effect on the longitudinal inclination angle and does not disrupt the stability of Z-shaped motion, but it can cause lateral velocity and lateral displacement.

Conclusion

A simulation study was conducted on the direct, turning, and Z-shaped movements of an underwater vehicle under transverse ocean currents. The research results indicate that the motion of underwater vehicles has strong coupling and nonlinear characteristics, and the navigation is stable in the absence of ocean currents; Under the interference of lateral ocean currents, the navigation trajectory deviates, and the longitudinal speed and inclination angle have little effect, resulting in overall stable navigation; This study can provide reference for the operation and control of underwater vehicles under ocean currents.