Theoretical Analysis and Model Test for Tail-Flick of Hovercraft

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ABSTRACT

Hovercraft is a kind of high-speed vehicle that glides close to the surface of the water. Due to the existence of the air cushion, tail-flick could happen to hovercraft. Tail-flick is a kind of special instability phenomenon with certain security risks, and is characterized by sudden increase in the rate of turning and the drift angle, speed decreasing, and wildly fluctuating for the angle of trim and heel, even leads to shipwreck in severe case. In this paper, a model was selected as the object of study according to some type of air cushion vehicle. The reason of tail-flick was analyzed by researching on the variation characteristic of motion parameter with the theoretical model of four-degree-of-freedom manipulative motion. The mechanism of tail-flick has been verified and further analyzed through free running model tests. The results show that tail-flick would take place at most initial sailing speed in hovercraft, which is closely related to some factors such as sailing speed, drift angle, and angular accelerated velocity. In addition, the higher angular velocity corresponds to the smaller drift angle when tail-flick is occurring. Furthermore, the tail-flick safety zone was determined by calculation analysis.

KEY WORDS: hovercraft, tail-flick, maneuvering model, free running model test.

Introduction

The hovercraft is characterized by small resistance, high speed, strong cross-barrier ability, therefore it has obvious advantages in military, rescue, breaking-ice, and mine sweeping (Gao, 2018; Yun, 1990; Wang, 2001). Due to the particularity of air cushion and flexible skirt, tail-flick phenomenon for hovercraft easily occurs, which is unstable and leads to sudden increase of angular velocity and drift angle, and decrease of speed, and oscillation of attitude angles. Thus, deep research on this phenomenon should be carried out.

The tail-flick of hovercraft is an instability phenomenon caused by interactions between water, gas and flexible skirt, closely related with the wind, wave and manipulation, which might bring a serious hazard. Given the complexity of the problem, the research by using constraint ship model experiment and theoretical method could not go far away. In addition, the experiment on real ship costs too much along with high risk, so it is necessary to adopt a self navigation model for experiment to study the tail-flick phenomenon.

A scaled self navigation model as a selected research subject was designed based on some real hovercraft in this paper. In order to ensure its motion characteristics similar to the real ship, all the geometry, propulsion, lift, manipulation were similar to the real ship. The several rotary motions were performed in the wide lake during experiment with variety of wind speed, wind direction and combination wave. Through the real-time signal acquisition system, the parameters involving with motion, environment and manipulate were acquired. In the experiment, many tail-flick phenomena were identified. According to the data obtained from the experiment, the main factors which contribute to occurrence of tail-flick were found out.

![Fig.1 A diagram of the hovercraft model.](image)

Similarity criteria

The motion of hovercraft is mainly controlled by aerodynamics, hydrodynamics and ducted propeller, which is also closely related to hover-system composed of fan, airway, and skirt (Ma, 2012). Therefore, the similarity criteria of the self propulsion model includes not only the geometry similarity, weight similarity, fluid dynamic similarity, but also hover and thrust similarity.

The forces on the hovercraft mainly consist of the wave resistance, skirt water friction force, momentum resistance, and aerodynamics. The similarity of wave resistance requires the same Froude number $F_r$ and pressure-Length ratio $P_L$ between model and real hovercraft. Momentum similarity means that both flow coefficient $Q$ and