A Study on Spinout Phenomena of Planing Craft in High Speed Turning with Radio Control Small Model

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Abstract: In this study, a free running model test system for measuring unstable phenomena of planing craft, which is an 1m radio controlled planing hull model including measurement devices and whose max speed is 12m/sec, is developed to inspect safely and easily the occurrence of instabilities instead of a real-craft test. And, by using the system, the occurrence running condition, the characteristics of motion and the mechanism of occurrence of Spinout phenomenon is investigated.

Key words: Planing craft, spinout, radio control model.

1. Introduction

Recently, high-speed planing craft, which can run at more than 100km/h, are developed owing to engine improvement and its hull weight reduction. At the high-speed running which most of a hull is exposed above the water surface, even if it runs in calm water, some peculiar unstable phenomena[1)2)] for planing craft occur. For example, Porpoising, Corkscrew, Transverse pure stability loss, Directional instability, Dutch-roll, Spinout and etc. The causes and mechanisms of some of these phenomena are not clear yet, so there are demands for development of estimation methods of their occurrence in design stage and suggestions on how to avoid their occurrence. It is important to understand the conditions of occurrence of an unstable phenomenon and the detail of motion of the phenomenon, as a first step of developing its performance estimation method. However, it is difficult to measure them by a real-craft, because it may cause capsizing, hull damage and/or crew's injury in the serious cases.

Spinout is one of the more serious consequences of high speed maneuvering, in its moderate form, Spinout is the maneuvering motion that a hull suddenly begins spinning by small disturbance in high speed turning or straight running and rapidly stops without capsizing. In the serious cases, it may cause capsizing, hull damage and/or crew's injury[3)]. In this study, in order to simulate Spinout occurring, the free running scaled model, which is a radio control planing hull 1.0m model and its maximum forward speed is 12m/sec and it includes several measurement devices, is developed. And, by using the system, the occurrence running condition, the characteristics of its motion and the scenario of occurrence of Spinout is investigated.

2. Free Running Model

2.1 Model

Fig.1 and Table 1 show the bodyplan and the principle particulars of the model. This is for an outboard engine. This type of craft is usually used in a lake or an enclosed bay, therefore its dead rise angle is small to take large vertical lift and to rise hull.

Fig.2 shows the radio control model, which is developed in this study. Its motion, track, ship speed are measured by AHRS (Attitude and Heading Reference System: Xsens MTi-G). Its Gyroscope and GPS antenna on s.s.7.43 and s.s.10 of hull. Number of motor’s rotation is measured with Hyperion Emeter II, and rudder angle is measured with a potentiometer.

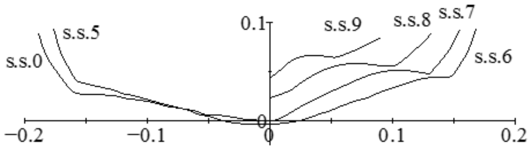

Fig. 1 – Bodyplan of the model

Table 1 Principal particulars of the model

overall length : L_{OA}[m]	1.03
breadth : B[m]	0.40
depth : D[m]	0.085
length to breadth ratio : L_{OA}/B	2.575
deadrise angle at ss5 : β_m [deg]	15
height of center of gravity : KG [m]	0.047
metacentric height : GM [m]	0.28
roll natural period : T_ϕ [sec]	0.56
pitch natural period : T_τ [sec]	0.63

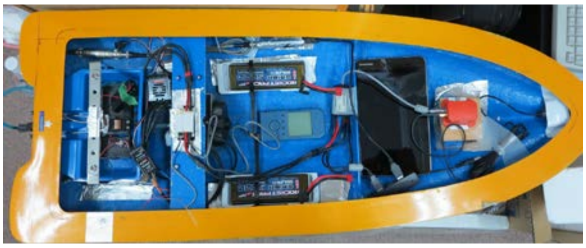

Fig. 2 – Picture of radio control model

2.2 Coordinate System

Fig.3 shows coordinate systems. They are an earth and a body fixed coordinate system. Before the model starting to run, the origins of them are the same, which is the center of gravity of the model, and the directions of x_0, y_0 and x, y axes are North and West, and direction of rotation around each axis is a right-handed screw.

3. Measurement of Spinout

3.1 Measurement Method

A free running model test with the radio control model is carried out in the pond of Osaka Prefecture University.

At first, the model is accelerated straight to reach a target speed. And rudder angle is changed to a target rudder angle with constant rudder speed. The time to reach a target rudder angle is one second for any target rudder angle. After the model starts turning motion, the control signals of forward speed and rudder angle are fixed. The measurement is continued from before starting running to after occurrence of Spinout. Table 2 shows the condition of experiment.

x_0y_0-O: earth fixed coordinate system
xy-O: body fixed coordinate system
X, Y, N: force or moment acting on craft
G: center of gravity ψ: heading angle
U, u, v: velocity r: yaw angular velocity
β: drift angle δ: rudder angle

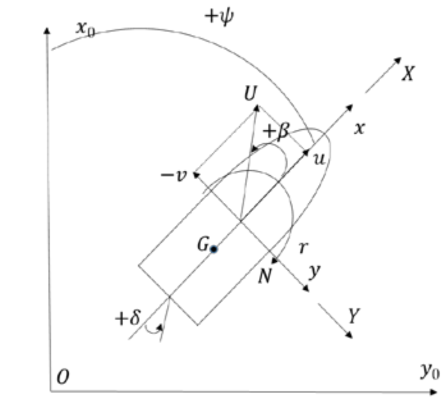

Fig. 3 – Coordinate system

Table 2 Experimental condition

displacement of the model [kgf]	6.08
initial trim angle [deg]	0
target forward speed [m/s]	7.0 ~ 11.0
maximum rudder angle δ_{max}[deg]	10.0 ~ 20.0
time for rudder turning to δ_{max} [sec]	1.0

3.2 Occurrence of Spinout

Fig.4 and 5 show typical time histories of number of propeller revolutions, rudder angles, yaw angular velocity and drift angle when Spinout occurs or does not. These data are measured for clockwise turning. When Spinout does not occur, yaw angular velocity increases just after starting steering, and it becomes a constant value after having a small peak. When Spinout occurs, yaw angular velocity rapidly increases just after starting steering, and it is continuously increase to a large peak value, and drift angle also increases and it reaches over 90 degrees.

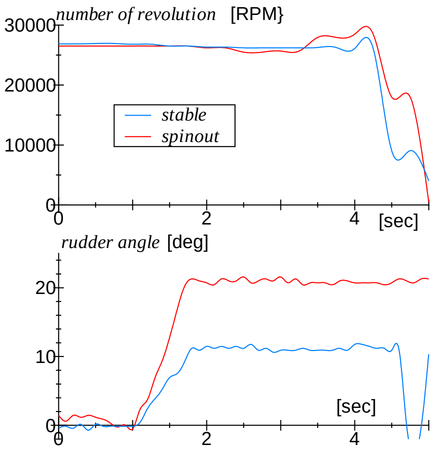

Fig. 4 – Time history of measured number of revolutions and rudder angle in the turning trial

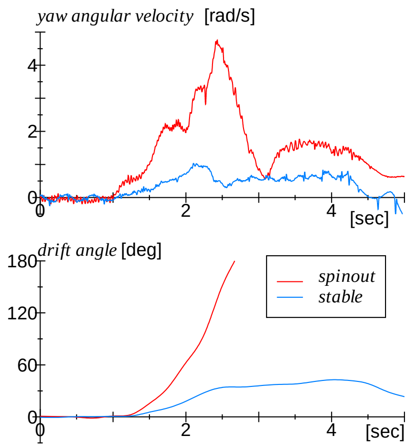

Fig. 5 – Time history of measured yaw angular velocity and drift angle in the turning trial

Fig.6 shows time histories of pitch angle, roll angle and velocity *U* in the same measurements shown in Fig.4 & 5. When Spinout occurs, after starting steering, velocity *U* decreases larger than one without occurrence of Spinout, and pitch angle rapidly decrease. The reason of this bow-down is supposed that a bow-down moment is caused by inertia force due to sudden deceleration by the change of thrust direction.

Fig.7 and 8 show a time histories of pitch angle roll angle, velocity *U*, number of propeller revolution and rudder angle when Spinout occurs without sudden deceleration. These data are measured for anti-clockwise turning. In this case, heel angle increases at first, and pitch angle rapidly decreases without sudden decrease of velocity *U*.

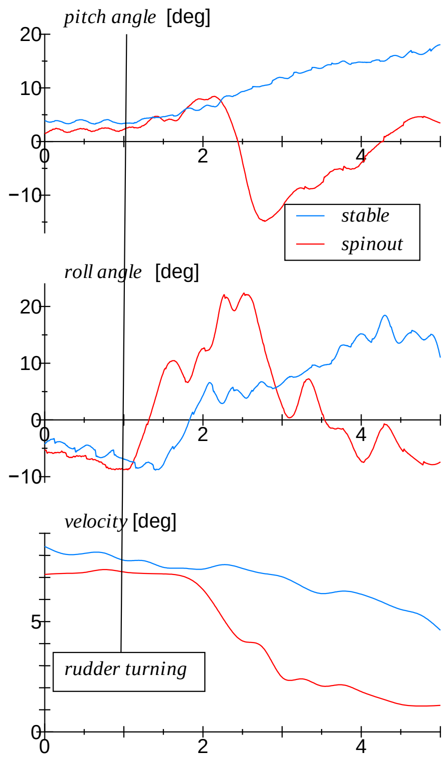

Fig.6 – Time history of measured pitch angle, roll angle, and velocity in the turning trial

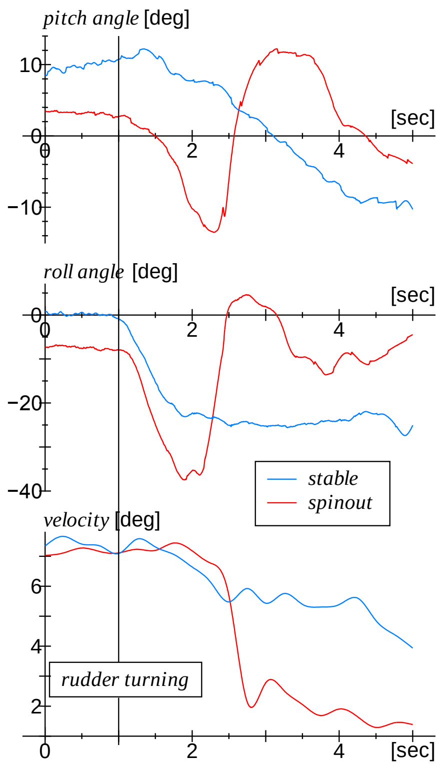

Fig.7 – Time history of measured pitch angle, roll angle and velocity at turning trial

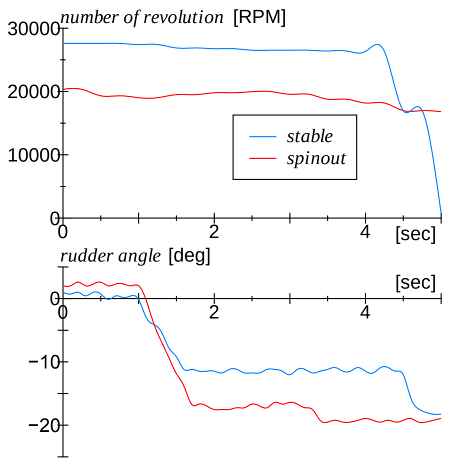

Fig.8 – Time history of measured number of revolution and rudder angle at turning trial

Fig.9 and 10 show occurrence of Spinout for all cases of measurements. From the figures, it is noted that Spinout occurs according to increase of a target rudder angle for the same forward speed. On the other hand, the occurrence speed of Spinout is different with turning direction for the same target rudder angle. The reasons of the differences is supposed that the hull is not necessarily symmetric, a moment is caused by propeller rotation of single screw etc.

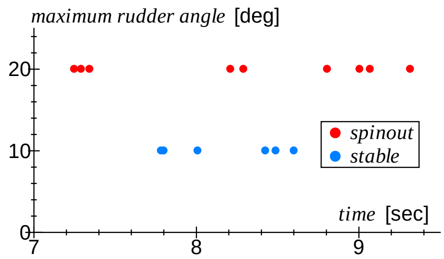

Fig.9 – Occurrence of Spinout in the right turning trial

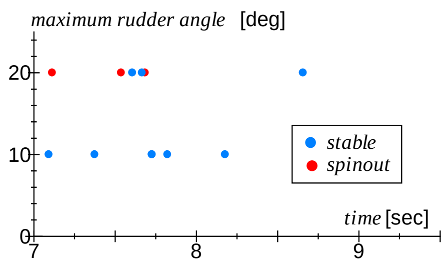

Fig.10 – Occurrence of Spinout in the left turning trial

3.3 Scenario of Spinout Occurring

From the measured data, a scenario of Spinout is discussed.

In the stable turning, the thrust cause the yaw moment which increases drift angle, and hydrodynamic forces acting on hull cause the yaw moment which decreases drift angle, usually, and these moments are balance.

When Spinout occurs, the bow-down caused by sudden deceleration or large heel angle just after starting steering moves forward the point of action of hydrodynamic forces passing the center of gravity as shown in Fig.11. Therefore, the moment caused by hydrodynamic forces acting on hull becomes the moment which increases drift angle, and it causes a rapid spin.

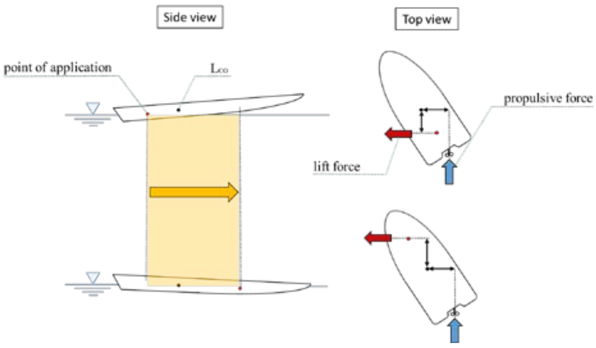

Fig.11 – Mechanism of occurrence of Spinout phenomena

4. Conclusions

In this study, a radio control free running model is developed and Spinout is measured by model test with the radio control model. Form the results, the following conclusions are obtained.

1. When Spinout occurs, the rapid deceleration or the large heel angle, which is caused by steering, cause a bow-down.
2. The rapid deceleration just after starting steering is caused by the change of thrust direction at high speed and large target rudder angle. And inertia force due to the deceleration causes bow-down.
3. For the same forward speed, larger rudder angle makes turning diameter smaller, and inside heel angle becomes larger and it is causes a bow-down.
4. The bow-down makes a wetted length longer, it moves the point of action of hydrodynamic force forward and the yaw moment, which causes drift angle, acts on a hull and Spinout occurs.

Acknowledgments

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References

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