The influence of aerodynamic on stability performance of amphibian on rough water

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Abstract. In allusion to the aerodynamic lift difference between tank test model and full scale plane, a simulation method of lift to tank test model is put forward, and conduct model test on rough water at the model status with boundary layer control technology (BLC) and without BLC, and then we study the influence of aerodynamic lift on trim and heaving characteristic of the test model systematically, the results turn out to be that: the influence of aerodynamic on trim is affected by test velocity, at relatively low speed, this difference can be ignored, but at higher speed, the maximum trim value difference lies the range of 2%~7%, and the wave length corresponding to the maximum value decreases. The influence of aerodynamic on heaving is affected by wave length, at relative shorter wave length, the heaving value decreases a little between the model with BLC and without BLC, this difference lies about 10%, but this difference increases to 15%~40% at higher wave length.

1. Introduction
The rough water performance of amphibian includes water resistance, pitching, heaving and water load, these items are influenced by the aerodynamic and hydrodynamic of the plane. In order to enhance rough water performance, researchers had done much work on design, test and analysis concerning the hull parameters, and they recommend the hull should have a high value of length-beam ratio[1-8]. Studies show that, amphibian has the rough water performance of sea condition of level 3 and level 4 partly through hydrodynamic configuration optimization design, but can not achieve the goal of rough water performance on level 5 sea condition, so much work concerning aerodynamic optimization design must be done.

With the research progress of AG600 amphibian, researchers have done much work concerning analysis, model test, trial flight, and master the design method of seaworthiness to wave height 2m. In order to enhance the amphibious seaworthiness from 2m to 3m, domestic scholars conduct the research of boundary layer control technology (BLC), which can significantly increase the aerodynamic lift[9,10], they had conducted the wind tunnel model test and studies show that the maximum aerodynamic lift coefficient can increase from 3 without BLC to 6 with BLC, in order to verify the seaworthiness of plane with BLC, tank model test is also conducted, and analyze the influence of BLC on water resistance, pitching, heaving and loads, this paper presents the tank model test and analysis results.

2. Tank model test with BLC
Boundary layer control technology terms that high pressure gas is blowed-out from the gap located on trailing edge of the wing flap, which can increase the kinetic energy of the airflow among the boundary layer, and delay the airflow separation, so the plane can get better aerodynamic performance
and high lift coefficient when the flap is located at a large angle. When conducting the tank model test, the lift coefficient of the model must be the same as of the full scale plane which is ascertained by wind tunnel test. Since the tank model test is based on the similarity of Frude Number, the Frude Number of the model and the full scale plane is the same, but the Reynolds Number of the model is smaller 2 orders of magnitude to the full scale plane. Figure NO.1 shows the aerodynamic lift coefficient difference between the model and the full scale plane, it turns out that aerodynamic lift coefficient is much more lower than the plane, so the difference value of lift must be compensated on the tank test model. This can make sure that the aerodynamic and hydrodynamic of the model and the plane are nearly the same.

![Figure 1. The difference of lift coefficient between the model and the plane](image)

In order to compensate the aerodynamic lift, we invent a compensation mechanism whose principle is shown as Figure NO.2, it contains mental frame, movable pulley block, crown block, rackslide, moveable kickstand, screwlead and rope. The rope convolves the movable pulley block and crown block well-aligned, and the connect with the towing staff which is hinged at center of gravity of the model, the crown block and moveable pulley block are connected with the mental and moveable kickstand respectively, there are a few springs between the upper and lower moveable kickstand, and the moveable kickstand could slide smoothly on the rackslide. By adjusting the distance between the upper and lower moveable kickstand through the screwlead, we could tighten the rope, and a needed force is exerted on the model throw the rope. The model could heav regularly when sliding on the wave during test, the rope is tightened up all the time and its strain maintain nearly the same.

Test model is the scaled model of an amphibian with no power, there are a lot of blowhole at the wing flap, which is used to blow-out high pressure gas. By adjusting the pressure and velocity of the gas we could change the lift coefficient of the model, combine with the lift compensation mechanism, we could increase the maximum lift coefficient of the model as same as the full scale plane, which is 6.2 when the model is of BLC and 3.08 without BLC.

Tank test method is shown as Figure NO.2, the car slide along the rail and drive the model with the test velocity, and the model has only three degrees of freedom, that is moving along course, trimming and heaving. The towing staff pass through the linear bear and hinged with the model at the center of gravity, so the towing staff can heave with the model. The navigation pole pass through the anti yaw and could prevent the model from yaw. The inertial measurement unit is located at the inner model, the line displacement transducer and force balance are located at the upper and lower of towing staff, which are used to measure the trim angle, heaving and water resistance of the model.
Figure 2. Tank model test

Technical status of the tank model test is shown as Table NO.1, switch to the full scale plane, the wave height is 1.6m, and wave length lies within 1.2 to 4.2 times the length of the hull, and the test velocity is 28%, 41%, 58%, and 68% of takeoff velocity ($V_{TO}$).

| Wave height (mm) | Wave length (m) | Test velocity (m/s) |
|-----------------|----------------|---------------------|
|                 |                | With BLC            |
| 122             | 4.7, 7.1, 9.4, 11.8, 14.1, 16.5 | 4.3, 6.5, 8.7, 10.8 |
|                 |                | No BLC              |
|                 | 3.0, 4.3, 6.5, 7.1               |

3. The influence of aerodynamic on pitching

The trim comparison at different wave length, test velocity of the model with BLC and without BLC are shown as Figure 3 to Figure 6, it turns out that: at the test speed of 28%$V_{TO}$, the trim value and curve types are nearly the same; at the test speed of 41%$V_{TO}$, the trim curve type remains the same but the maximum value difference increases; at the test speed of 58%$V_{TO}$, the maximum value of trim and curve types are nearly the same, but wave length corresponding to the maximum value decreases; at
the test speed of 68%\(V_{TO}\), the maximum value remains the same but the curve type difference increase a lot compared to that at velocity of 58%\(V_{TO}\), and the trim value difference at the same wave length increased a lot compared to that at the velocity of 28%\(V_{TO}\) and 41%\(V_{TO}\).

In conclusion, the aerodynamic influence on the maximum trim value is not obvious when the model is of BLC and without BLC, the difference of maximum value lies the range of 2%～7%, this can be interpreted as that: the model with BLC has much larger lift coefficient and this decreases the contact area between the hull and water, but distribution of the force exerted on the hull by wave water alters a little, that means the torque stressed on hull does not change apparently, so the trim value and its curve type alters a little.

4. The influence of aerodynamic on heaving

The heaving comparison at different wave length, test velocity of the model with BLC and without BLC are shown as Figure NO.7 to NO.10. The heaving curve type remains the same at all test velocity when the model is of BLC and no BLC, but the heaving value of the model with BLC is apparently lower than that of the model without BLC, and this difference is affected by wave length, the maximum decrease ratio of heaving when the model is of BLC remains 10% compared with that with without BLC at the wave length 60m. With the wave length goes up, this decrease ratio becomes much larger, mostly remains more than 15%, and maximum ratio can goes up to 40%.
The heaving between the model is of BLC and without BLC remains nearly the same at short wave length, is could be explained that, the water with short wave length support the hull with much more effect, the aerodynamic lift take less effect on heaving than hydrodynamic. With the wave length goes up, the support of the water with long wave length decreases, and the aerodynamic lift takes more effect, so the heaving of model with BLC is much more lower.

5. Conclusions
Through tank model test on rough water at the model status with BLC and without BLC, we study the influence of aerodynamic lift on trim and heaving characteristic of the test model systematically, and get the following conclusion:

(1) The influence of aerodynamic on trim is affected by test velocity. At all of the test velocity, the maximum trim value at model status with BLC remains nearly the same compared with that of the model without BLC, this value difference lies the range of 2%~7%, and curve type remains the same shape at relatively low speed (28%V_{TO}, 41% V_{TO}), and changes a lot at higher speed (58% V_{TO}, 68% V_{TO}), this difference shows that the wave length corresponding to the maximum value of the model with BLC decreases.

(2) The influence of aerodynamic on heaving is affected by wave length. At relative shorter wave length, the heaving value decreases a little between the model with BLC and without BLC, this difference lies about 10%, but this difference increases to 15%~40% at higher wave length.
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