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Storm Resistant Boat Designing Based on the Geometry and Movement of Water Strider

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Abstract

A novel conceptual model of boat is developed based on the bionic properties of water strider. This four-legged model is called storm resistance boat. Concentrated balancing forces, asymmetry of arms and smooth motion against waves and the effect of arms length on the reduction of drag and effects of wave are the major characteristics of water strider which are considered for designing this model. The results indicate the characteristic improvement of the small boat and its resistance against strong waves as well as marine ill-conditions. This boat can be considered as a high speed rescue boat in marine traffic.

Keywords: water strider, storm resistant boat, legged bionic boat design, balancing system

1 Introduction

The gravity and buoyancy forces are two major vertical loads which act on every floating object. These forces are applied in the downward and upward directions, respectively[1]. The roll stability of floating object is provided by these forces while the object tends to roll. The principles of boat designing declare that the centre of gravity always should place above the buoyancy centre to gain the metastability. When the hull of metastable boat is rolled, the gravity and buoyancy forces make a righting torque which rollbacks the boat to balancing point (Fig. 1)[2]. It should be noted that the resultant buoyancy force is the sum of the distributed forces which are applied on the entire hull. The amount and direction of these loads are directly related to the shape of hull and therefore provide some limitation in design process and form a variety of boats.

Water strider is a very light and small insect which lives on the water surface. While the macro scale bodies use distributed buoyancy forces to stay on the surface of water, in contrast, water strider uses concentrated repulsive surface tension forces instead of buoyancy ones for stability[3].

Some kinds of boats such as Small Water plane Area Twin Hull (SWATH) provide buoyancy forces in two or more separated buoyant parts. It is shown that more concentration of the buoyant forces in boat provides better maneuverability and tender motion[4]. The advantages of concentrated forces like surface tension and the reduction of drag forces are also studied by scientists in the design of biologically inspired miniature water strider robot[3].

In this paper, as some results of the first author's early work, the idea of legged boat, which is called storm resistance boat, is developed using water strider geometry and movement. This novel model uses concentrated forces as balancing system and may be controlled by electronic pumps or mechanical balancing devices

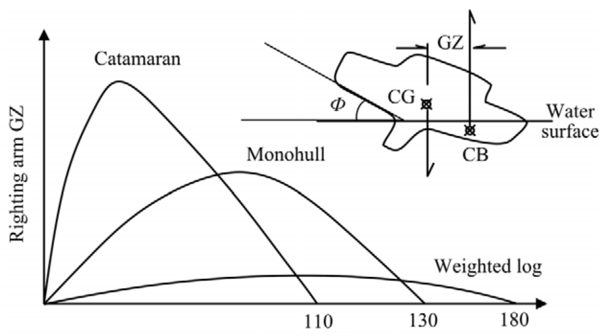

Fig. 1 Comparing the stability curves of catamaran, mono-hull and weighted log.

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and could achieve more improved properties than SWATH or other similar types of boats such as Catamaran. In addition, it employs the asymmetric and long arms to provide wave resistant movement.

2 The geometry and movement of water strider

2.1 Concentrated balancing forces

According to the boat designing methods, the shape of boats should be properly designed to produce appropriate distributed buoyancy forces which provide the roll stability. The production of these loads relating to the heeling angle is a challenge in the design of boat's hull which is called form stability[2]. In contrast, the water strider has no buoyant part and the only balancing forces are the effect repulsive surface tensions, which are concentrated in the tips of arms. The idea of concentrating the balancing forces based on water strider properties provides the variety of forms which will be independent of heel angle.

The GZ-Φ diagram of boat design process is used to describe the relation between righting torque and heel angle where the GZ is the horizontal distance between the centre of gravity and buoyancy forces and Φ is the rolling angle for the floating object (Fig. 1). When a boat tends to roll, depending on the shape of hull, the distribution of buoyancy forces is changed and causes the buoyancy centre to move to gain appropriate righting torque.

There are different types of boats with different form stability factors. As an example, a log with a small weight nailed to one side will have a very large angle of positive stability (almost 180 degrees), but it will offer very little resistance to heeling. A boat built like this, with a round bottom and very little ballast, would be dangerous, since it would roll over a wide angle and could carry little sail. Catamarans are at the other end of the scale, extremely stable at small heel angles, but only a limited angle of positive stability (Fig. 1)[5].

If the balancing forces become concentrated, the amount of righting torque will be controllable by means of vertical powered engine or mechanical mechanisms and it becomes completely independent of heel angle (Fig. 2). Controlled amount of righting torque provide a safety margin against overturning. By generating appropriate vertical forces in the tips of legs, the balancing system can prevent the amount of righting torque to meet zero, while meeting zero is possible in all kinds of stiff or tender boats in different angles (angle of positive stability).

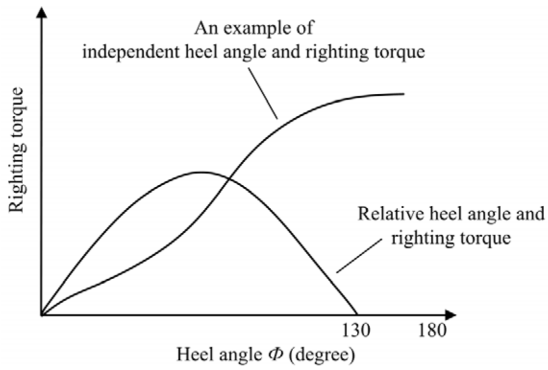

Fig. 2 The comparison of righting torque in form stability system and controlled stability forces.

2.2 Asymmetry of arms and smooth motion against waves

The asymmetry of front and back arms of water strider causes the waves not to touch the arms in the same time when the longitude axis is parallel to wave lines. For example, while a single wave coming from left side, then, A, B, B′ and A′ points are affected in order in different times (Fig. 3) and so the height of main body, which is the average of height of arms, is not affected as common boats.

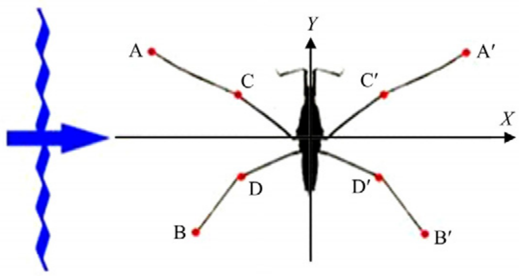

Fig. 3 Touching between a single linear wave and arms tip of water strider.

2.3 The effect of arms length and drag and waves reduction

The total resistance of a moving object on water surface has several components like wave-making resistance, skin frictional resistance, viscous pressure resistance, air resistance and appendage resistance[2]. The study of water strider shows that long and high arms protect its main body from direct contact to waves and water disturbances, as a result, the wave-making resistance, skin frictional resistance and viscous pressure resistance are completely omitted.

3 Developing the concept of legged boat

By inspiration of water strider's geometry and movement, the concept of legged boat is presented as a novel model for further design. The concentrated and controllable balancing forces, the asymmetry of arms and the heightening of the main body of boat are three major properties of this concept. Upward balancing forces in legged boat will be produced in a limited area by minimum achievable distribution. Legged boat is a four-armed floating object. The asymmetric arms carry the main body of boat above the water surface. These arms are also equipped with locomotive engines to provide the motion (Fig. 4).

When the floating object is scaled down, buoyancy force decreases. Then the surface forces, such as repulsive surface tension forces, start to dominate the distributed buoyancy force[3]. The usage of surface tension forces is not possible when the dimension of the floating object is too large. The mechanical buoyant part and the electronic powered forces are two developed concepts to produce vertical balancing forces instead of surface tension forces.

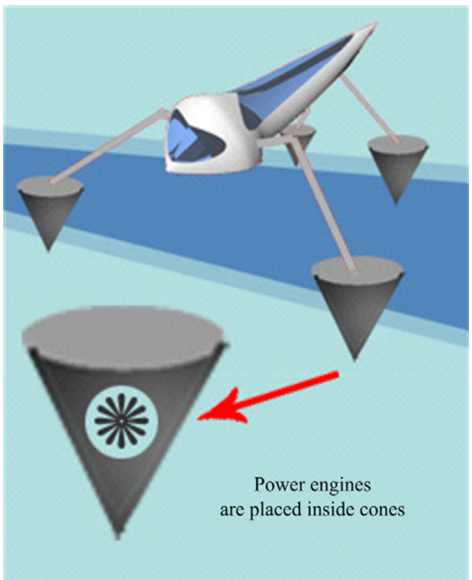

Fig. 4 Locomotive engine inside buoyant parts in mechanically controlled systems.

Four buoyant parts are attached to the tips of arms as a mechanical concept. These parts produce the appropriate upward balancing forces according to their shapes and depth of floatation. The design of shapes defines the relation between upward force and rolling angle. For instance, the righting buoyancy force will be linear if the buoyant part is cylindrical, while it is proportional to second power of depth if the buoyant part is conic (Fig. 5). Horizontal engines should be considered in the body of cones to provide the locomotion force.

As an electronic concept, four vertical engines are considered in addition to horizontals (Fig. 6). Balancing force will be produced by means of vertical engines proportional to the heel angles. Every imaginable balancing torque is accessible by defining its unique

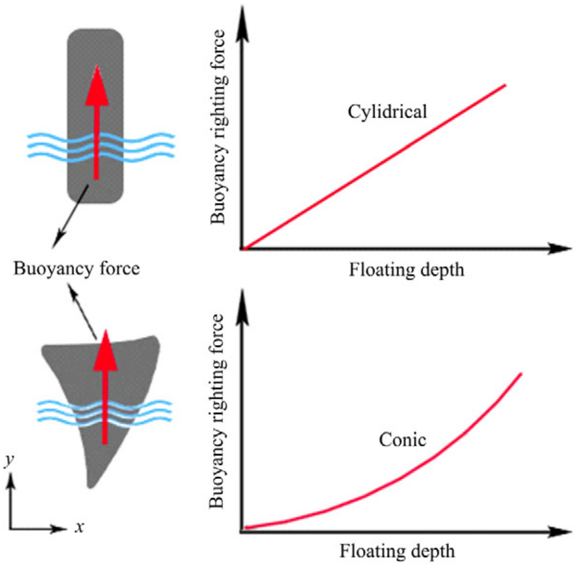

Fig. 5 Comparison between cylindrical and conic shapes.

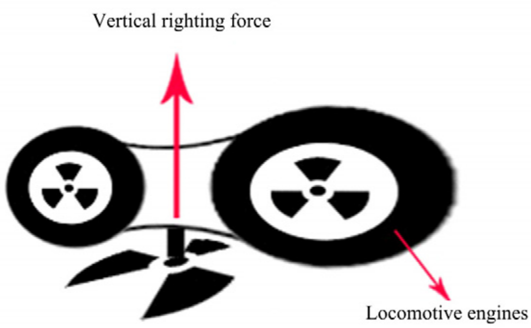

Fig. 6 Producing vertical balancing force by vertical engines and direct motion via locomotive engines.

controlling function (Fig. 2). Electronic legged boat has no need of any buoyant part and can move with minimum resisting drag force. However the combination of mechanical and electric forces is suggested to reduce the risk of electronic interruptions and reduction of engine sizes and fuel consumption.

The asymmetrical arrangement of arms is another property of the legged boat, which is inspired by water strider geometry. The legged boat can pass the linear waves easily with minimum influence as a water strider can. By equipping each arm with an electronically controlled engine, the asymmetric legged boat can also move in all direction and can always set its longitude axis parallel to the line of waves if the waves are linear. This kind of waves is usually appearing near the coasts[6].

The next property of the legged boat is the heightening of the main body of boat using long arms. When the main body of boat has no direct contact with water surface, the wave-making resistance, skin frictional resistance and viscous pressure resistance are omitted as water strider. In addition, air resistance and appendage resistance will be reduced if the new model of legged boats is aerodynamically designed.

4 Conclusion

A new idea of stable legged boat is presented based on the geometrical and movement characteristics of water strider. The first property is the roll stability which is provided by the concentrated upward forces in the tips of water strider's arms. These loads are controlled by electronic or mechanical balancing systems. The second property is the asymmetry of front and back arms, which provides wave resistant reactions when moved parallel to waves. The last one is the length of arms that keep the body above the water surface and prevent water from disturbing the main body directly. The application of the characteristics of water strider may provide a variety of style of boats and hull shapes and give boat designers the freedom in artistic concept developments. In addition, the resistance against waves and improved roll stability make the legged boat to be unique in sea ill-conditions and can be considered as a safe rescue boat.

Acknowledgement

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