

## **Ship**

The invention concerns a ship in accordance with the preamble of claim 1. Such a ship is known from the publication Keuning, J.A.; Toxopeus, S.; Pinkster, J.; The effect of bow-  
5 shape on the seakeeping performance of a fast monohull; Proceedings of FAST 2001 conference, September 2001; page 197-206; ISBN 0 903055 70 8, publisher The Royal Institute of Naval Architects. In this publication the ship according to the invention is described as the AXE BOW design. The customary  
10 design of the vertical bow of the AXE BOW design which is specific for high speeds is with a sharp bow, which means the sides more or less intersect to a sharp nose that cuts in the water. The disadvantage of this customary design is that with small yaw angles this leads to vortex shedding near the bow  
15 and this has a disadvantageous effect on the course stability of the ship.

In order to overcome this disadvantage the ship is in accordance with claim 1. By giving the bow of this ship designed for high speeds a considerable radius the flow along  
20 the bow is more stable which improves the course stability at small yaw angles.

In accordance with an embodiment of the invention the ship is according to claim 2. In this way excessive stagnation point resistance and spray generation are avoided.

25 In accordance with an embodiment of the invention the ship is according to claim 3. In this way it is easy to obtain minimal flare in the bow sections so that the displaced volume in waves increases only more or less linearly with the draught and so leads to better ship behavior in waves.

30 In accordance with an embodiment of the invention the ship is according to claim 4. In this way, the fins give the ship improved course stability independent of any control sys-

tem. The location of the fins forward of the propulsion means and the rudder(s) prevents aeration of the fins in situations whereby due to at the rear of the ship incoming waves the rudders lose their grip as a result of this aeration, thereby  
5 improving course stability under adverse conditions.

In accordance with an embodiment of the invention the ship is according to claim 5. By having the fins in a slight angle they are preloaded and are immediately active at small yaw angles, which improves their positive effect.

10 In accordance with an embodiment of the invention the ship is according to claim 6. In this way the ship can be brought in a speed dependent trim position independent of the load or mass distribution in the ship, thereby reducing drag and improving propulsion efficiency.

15 In accordance with an embodiment of the invention the ship is according to claim 7. By using the flow direction out of the nozzles both for steering and creating the adjustable upward or downward force a compact design is possible.

In accordance with an embodiment of the invention the  
20 ship is in accordance to claim 8. The combination of the stationary fins with the horizontal fin for generating the upward or downward force makes a compact design possible whereby due to the depth of the horizontal fin the aeration of the horizontal fin is prevented.

25 The invention will be explained in more detail below with reference to several exemplary embodiments by means of a drawing, in which:

Figure 1 shows a perspective view of a ship according a first embodiment of the invention, whereby the propulsion means in-  
30 cludes propellers,

Figure 2 shows a body plan of the design of the ship according to the invention, whereby figure 2a shows the various cross

sections, figure 2b shows the side view and figure 2c shows the bottom view,

Figure 3 shows schematically the aft of the ship in accordance with figure 1 in back view and in side view,

5 Figure 4 shows schematically the aft of the ship in accordance with a further embodiment of the invention in back view and in side view,

Figure 5 shows schematically the bottom view of the aft of the ship of the previous embodiments and specifically the toe angle of the vertical fins, and  
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Figure 6 shows a perspective view of an aft ship according to an further embodiment of the invention, whereby the propulsion means include waterjets.

Figure 1 shows a ship 1 which is designed in accordance  
15 with the body plan according to figure 2. The ship 1 is designed for high speeds and has a single long and slender hull with sides 19, whereby the length of the hull is at least five times the beam and for longer ships as much as seven to eight times the beam. In shorter ships the beam is relatively larger  
20 as the hull must include the propulsion means and a wider beam ensures that there remains sufficient stability. The ship 1 has one or more propellers 8 and one or more rudders 9. For manoeuvring there is a bow thruster 4 near a bow 3. The layout on deck is as usual for instance with a wheel house 2.

25 As can be seen in figure 2 the hull of the ship 1 has a special design, in more detail the design is such that a reduction of the Froude Kriloff forces in particular in the foreship is achieved by minimizing the change in momentaneous submerged volume of the hull whilst it makes larger relative  
30 motions relative to the water level due to waves or the ships motions. This results in a design applying vertical sides 19 as much as feasible. A further measure in the design is to reduce the change in waterline beam of the sections in par-

ticular in the foreship whilst it makes the foresaid larger relative motions. This implies there is a minimal flare in the bow sections and a bow 3 has a more or less vertical line or extends less than 5 degrees forward or backward. By doing so the change of the added mass of the sections is minimized and with that also the changes in the hydrodynamic lift in the foreship are minimized. By increasing the freeboard and bringing the deck line 15 higher towards the bow 3 in the foreship sufficient reserve buoyancy is guaranteed.

The amount of increased shear in the foreship, shown in figure 2 as deck line 15, is dependent on ship size, speed and wave climate involved. A downwards sloping centre line 5 towards the foreship prevents the sections there to leave and re-enter the water whilst the ship is performing larger relative motions. The centre line 5 is at it lowest near the bow 3 near point 16 which indicates the maximum draught relative to a waterline 17. The amount of negative slope in the bottom 21 is dependent on ship size, speed and wave climate involved. The deadrise angle of the sections from bow to stern is carefully determined in order to minimize exciting forces and yet maintain sufficient hydrodynamic lift with minimal resistance.

Summarized the shape of the hull is such that the hull is long and slender, there is no flare in the bow sections and the sides 19 at the bow sections are almost vertical. Near the bow 3 the sides 19 make an angle  $\alpha$  seen in a horizontal plane which is smaller than 40 degrees. There is an increased sheer forward and down sloping centreline forward and the entry of the waterlines 20 are rounded. In order to reduce the wetted surface the bow 3 is rounded with a radius R of at least 0,1m. Depending on the beam of the ship the radius can be at least 1% of the beam. A further advantage of this radius R is that vortex shedding along the sides 19 of the ship is avoided in this way. This vortex shedding might occur in this design at small yaw angles when the

bow is too sharp as is usual with fast ships. The vortex shedding must be avoided as it might lead to course instability. In order to prevent that the rounded bow 3 generates too much stagnation point resistance and/or generates too much spray the radius R is less than 4 % of the beam.

When applying this new hull shape further additional measures must be taken for maintaining adequate yaw or course keeping stability and to prevent undesirable control problems in particular in following or stern quartering waves. The hull itself generates destabilizing yaw and sway forces and moments which may lead to these instabilities. By the introduction of fixed vertical stabilizing fins or skegs 6 at the aft end of the hull these instabilities are prevented. The fins 6 preferably have airfoil type section shapes and have reasonable aspect ratios to generate adequate lift to counteract the destabilizing effects in yaw and sway of the hull. They are designed to optimize the yaw stability in particular at the cost of minimal increase in resistance. The fins 6 are located away from the center line 5 and preferably near the sides 19 so that they are away from the disturbed area in the water which is the result of the maximum draught 16 of the bow 3 which is much deeper in the water than an aft ship 10. Preferably they are located in front of the rudders 9 and the propulsion means, so that they maintain grip on the flowing water even when the rudders 9 are aerated due to incoming waves from the stern quarter of the ship.

The restoring moment of the hull in pitch is relatively small when compared to similar craft. To a lesser extent this is also true for the restoring force in heave. The heave motion but in particular the pitch motion may be very effectively reduced by the application of one or more activated horizontal fins 7 at the aft ship 10. These fins 7 generate positive or negative lift and can be adjusted manually, if

used only for trim control, or be controlled by (on board) sensors and control algorithms. In the embodiment of figure 1 there are two horizontal fins 7 which may work together and so bring forces on the aft ship 10 that counteract the heave and/or pitch of the ship 1 and can bring it in its optimal trim. In another embodiment the two horizontal fins 7 may be controlled in such a way that they create counter acting upward and downward forces and so create a torque in longitudinal direction on the ship 1 that counteracts rolling so that under proper control the stability can be improved.

The submerged horizontal fins 7, wetted on both sides, rely for the lift generation on both the high pressure and the suction side common for foils and they are preferably placed sufficiently deep below the water level to prevent ventilation or suction side cavitations along the fins 7. Specifically they can be used for active control of the trim angle in calm water dependent on the speed of the ship 1 in order to yield optimum attitude of the ship, for active control of the pitch and heave motion by auto pilot and control algorithm and also by applying differential steering for port and starboard horizontal fins the rolling motion can be controlled.

Figure 3a shows the ship 1 of figure 1 in back view with the vertical fins 6 whereby on each side of the center line 5 two fins 6 are located and whereby between these two fins 6 one horizontal fin 7 is mounted. Figure 3b shows the same in side view. For reasons of clarity the propellers 8 and the rudders 9 are not shown. As can be seen in figure 1 the propellers 8 and rudders 9 are located aft of the fins 6 and 7. It will be clear that for the propulsion of the ship 1 various designs are possible, such as three propellers 8 as shown in figure 1, two propellers, two propellers with one waterjet, one propeller with two waterjets and also two or more waterjets as shown in figure 6 (discussed hereafter).

Figures 4a and 4b show similar views of a further embodiment of the vertical fins 6 and the horizontal fins 7. In this embodiment the horizontal fin 7 extends from both sides of the vertical fin 6. The vertical fin 6 is located slightly away from side 19 so that the horizontal fin 7 does not extend outside the beam of the ship 1. The two horizontal fins 7 extending to both sides of the vertical fin 6 have a common axis and are connected to a single drive so that they move together. In the embodiment shown in figure 4 the horizontal fins 7 at starboard generate in a forward moving ship 1 an upwards directed force and the horizontal fins 7 at port generate a downwards directed force. These two forces form an anti-clockwise directed torque on the ship 1, which torque can be used to counteract forces that are for instance a consequence of waves.

The front edge of the vertical fins 6 is shown as more or less vertical as in this way the water flow around the blade is most effective for creating a stabilizing force. It will be clear that the same conditions will apply if the vertical fins 6 are for instance vertical to the plane of the underside of the ship 1, as long as the front edge of the fin is more or less perpendicular to the water flow relative to the fin 6. The front edge of the vertical fins 6 can also be slightly swept back so that material folded around the front edge is guided towards the fin's end and comes free of the fin. In the shown embodiments the vertical fins 6 are combined with horizontal fins 7. It will be clear that for proper functioning of the vertical blades 6 this is no requirement. Figure 5 shows that the vertical fins 6 make a slight angle  $\beta$  with the center line 5 so that when the ship 1 moves in a straight line forward there are stable flow conditions around the fin 6 in the length of the fin 6 seen in flow direction and a correcting force is immediately available if waves push

against the aft ship 10 and change the flow direction towards the fin 6 and flow conditions around the fin 6. The value of angle  $\beta$  depends on the local flow conditions and so on the shape of the underside of the ship 1. In practice the value of angle  $\beta$  may be between 1 and 3 degrees or approximate 1,5 degrees.

In the shown embodiments the blades of the horizontal fins 7 have a horizontal rotation axis, so ensuring similar aeration conditions along the length of the fin 7. Depending on the specific conditions this is not always essential. For instance in order to reduce flow resistance under normal conditions it might be advantageous to have the horizontal fin 7 seen perpendicular to the length parallel to the underside of the ship 1. In situations where there is no need to counteract the rolling of the ship 1 it is sufficient to have a horizontal fin 7 with a single drive, which can be over the full width of the ship 1 and which is only used for ensuring the proper trim of the ship 1. For stability this horizontal fin 7 can be supported in the center.

Figure 6 shows the aft ship 10 of a further embodiment for which the hull is designed in similar way as in figure 1. The propulsion of the ship 1 in this embodiment is with waterjets. For course stability there are vertical fins 12, these vertical fins are more or less the same as the earlier discussed vertical fins 6 without the there added horizontal fins 7. In the underside of the ship there are water inlets 11 for intake of water that flows towards the waterjets and the water flows out of the nozzles 14 in the direction of a centre line 13. For steering the centre lines 13 can be moved in a known way in a horizontal plane. For generating upward and downwards forces on the aft ship 10 the centre lines 13 can be moved in a similar way in a vertical plane around a horizontal axis. The control of the direction of the centre lines 13 is ar-

ranged in a similar way as the control of the horizontal fins 7 and is preferably connected to an auto pilot for active control having a control algorithm and applicable sensors for determining positions and movements of the ship.

## Claims

1. Ship designed for use at high speed and heavy seas having a single long and slender hull with a narrow beam and a more or less vertical bow (3), whereby the front half of the  
5 hull has more or less vertical sides (19), minimal flare in the bow sections and towards the bow (3) an increase in draught at its center line (5) combined with a more or less similar increase of freeboard and whereby the aft end (10) of the hull has a flat or slightly V-shaped bottom with one  
10 or more propellers (8) and/or waterjets (14) as propulsion means characterized in that the bow (3) has a fillet radius (R) of at least 1 % of the beam.
2. Ship according to claim 1 whereby the fillet radius (R) is less than 4 % of the beam.
- 15 3. Ship according to claim 1 or 2 whereby the sides (19) near the bow (3) form a sharp angle ( $\alpha$ ) of less than 40 degrees.
4. Ship according to claim 1, 2 or 3 whereby at the aft end (10) of the hull in front of the rudder and the propulsion means near each side (19) at least one more or less verti-  
20 cal stationary fin (6;12) is mounted.
5. Ship according to claim 4 whereby the stationary fins (6;12) make towards the bow an angle ( $\beta$ ) of 1 - 3 degrees with the center line (5).
6. Ship according to one of the previous claims whereby the  
25 hull has at the aft end (10) of the hull adjustable force generating means (7;14) for generating an upward and/or downward force.
7. Ship according to claim 6 whereby the adjustable force gen-  
30 erating means are formed by the nozzles (14) of the water-jets.

8. Ship according to claim 6 whereby at the aft end (10) of the hull in front of the rudder and the propulsion means near each side (19) at least one more or less vertical stationary fin (6;12) is mounted and the adjustable force generating means include at least one more or less horizontal fin (7) attached to the stationary fins near their maximum depth perpendicular to the ships center line and which horizontal fin(s) is/are rotatable around the longitudinal axis of the horizontal fin(s).