

A propulsion arrangement in a ship

#### TECHNICAL FIELD

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The invention relates to a propulsion arrangement in a ship according to the preamble of claim 1.

10 The arrangement is intended to be used in ships provided with at least one propulsion unit situated at the stern of the ship. The ship can either have only one propulsion unit situated at the stern of the ship or two parallel propulsion units situated at the stern of the ship on opposite sides of the center line of the hull of the ship. Propulsion units are used especially in large ships e.g. cruisers, tankers transporting oil or liquefied natural gas, vehicle carriers, container ships and  
15 ferries.

#### BACKGROUND ART

20 WO publication 98/54052 discloses a ship with twin propellers and twin Schilling rudders i.e. a respective rudder for each propeller. Each rudder is pivotably mounted by a respective shaft, has a bulbous nose portion, a waisted mid-portion and a flared tail. The flared tail flares outwardly substantially only on the inner side of each rudder i.e. the side which faces the other rudder pair. Each rudder has an upper plate and a lower plate with the plates much more extensive on the inner  
25 side than on the outer side, the plates being aligned with streamlines from the respective propeller and the lower plate having a downwardly angled portion on the inner side. The rudders seem to form some kind of a toe-out angle in relation to the centerline of the hull.

30 US patent 7,033,234 discloses a method for steering a planning V-bottomed boat with double individually steerable drive units with underwater housings, which

extend down from the bottom of the boat. When running at planning speed straight ahead, the underwater housings are set with a so called toe-in angle, i.e. inclined towards each other with opposite angles of equal magnitude relative to the boat center line. When turning the boat, the inner drive unit is set with a  
5 greater steering angle than the outer drive unit.

JP patent publication 2006007937 discloses an arrangement in a ship with two pods with contra-rotating propellers situated at the stern of the ship. The first pod is in a first embodiment mounted stationary into the skeg so that the shaft line is  
10 inclined upwards. The second pod is fastened by means of a horizontal axis to a steering table, which steering table rotates around a vertical axis and which steering table can be lowered and raised by means of hydraulic cylinders. The shaft line of the second pod is aligned with the shaft line of the first pod. The rear end of the first pod is in a second embodiment fastened with a horizontal axis to  
15 the skeg and the front end of the first pod is fastened to a vertical cylinder. The inclination of the first pod can thus be adjusted with the cylinder. Both pods are in a third embodiment fastened to opposite ends of a common frame, which frame is supported from the middle part a horizontal axis to a steering table, which steering table rotates around a vertical axis and which steering table can be lowered and  
20 raised by means of hydraulic cylinders. There is no separate rudder in this arrangement and the steering of the ship is done by rotating either only the second pod situated after the first pod in the driving direction of the ship around a vertical axis or by rotating both pods around a vertical axis.

## 25 SUMMARY OF THE INVENTION

The object of the invention is to improve prior art propulsion arrangements in ships.

30 The propulsion arrangement according to the invention is characterized by the features in the characterizing portion of claim 1.

The propulsion arrangement comprises at least one propulsion unit situated at the stern of the ship. The ship comprises a hull having a horizontal water line. The at least one propulsion unit comprises a hollow support structure attached to the hull,  
5 a chamber attached to the support structure, an electric motor within the chamber, a propeller at the front end of the chamber, said propeller being connected by means of a shaft to the electric motor, and a pivotably supported rudder at the rear end of the chamber.

10 The at least one propulsion unit is according to the invention mounted so that the shaft line forms a vertical tilt angle in the range of 1 to 8 degrees in relation to the water line so that the front end of the chamber is lower than the rear end of the chamber in relation to the water line.

15 The vertical tilt angle of the at least one propulsion unit improves the water inflow angle to the propeller, which improves the efficiency of the propeller.

The vertical tilt angle of the at least one propulsion unit also reduces noise and vibrations in the hull of the ship, which are due to cavitation as the improved  
20 inflow angle to the propeller reduces cavitation.

The vertical tilt angle of the at least one propulsion unit also reduces shaft line vibrations and forces. This is due to the fact that there are less asymmetric forces acting on the propeller when the water inflow angle to the propeller is improved.  
25 Reduced loads and vibrations will increase the lifetime of the bearings of the shaft as well as other components affected by these vibrations and forces.

The invention can advantageously be used in a ship having two propulsion units situated side by side at opposite sides of the center line of the ship at the stern of  
30 the ship. Each propulsion unit is advantageously mounted in a toe-out position forming a horizontal tilt angle in the range of 0.5 to 6 degrees in relation to the

center line of the hull. The front end of the chamber is thus inclined away from the center line of the hull of the ship and the rear end of the chamber is inclined towards the center line of the hull of the ship.

- 5 This toe-out arrangement of the propulsion units will further improve the efficiency of the propellers and reduce noise and vibrations in the hull of the ship.

The invention can be used in large ships provided with at least one propulsion unit at the stern of the ship, e.g. cruisers, tankers transporting oil or liquefied natural  
10 gas, vehicle carriers, container ships and ferries. The power of the propulsion unit in such large ships is in the order of at least 1 MW.

#### BRIEF DESCRIPTION OF THE DRAWINGS

- 15 Some specific embodiments of the invention are described in the following in detail with reference to the accompanying figures, in which:

Figure 1 shows a prior art propulsion arrangement.

- 20 Figure 2 shows one embodiment of a propulsion arrangement according to the invention.

Figure 3 shows another embodiment of a propulsion arrangement according to the invention.

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Figure 4 shows a top view of a further embodiment of a propulsion arrangement according to the invention.

## DETAILED DESCRIPTION OF SOME SPECIFIC EMBODIMENTS

Figure 1 shows a prior art propulsion arrangement. The arrangement comprises a propulsion unit 10 situated at the stern of the ship. The propulsion unit 10 comprises a support structure 11, a chamber 12, an electric motor 13, a shaft 14, a propeller 15 and a rudder 16. The chamber 12 is connected with the hollow support structure 11 to the hull 100 of the ship. The shaft 14 has a first end which is connected to the electric motor 13 and a second end protruding from the front end of the chamber 12 and being connected to the propeller 15. The propeller 15 is thus situated at the front end of the chamber 12. The electric motor 13 can be an induction motor or a synchronous motor. The propulsion unit 10 is fixed to the hull 100 of the vessel with the support structure 12. This means that the propeller 15 will remain in a fixed position in relation the hull 100 of the vessel all the time. A rudder 16 is situated at the back end of the chamber 12. The rudder 16 is pivotably connected to the hull 100 and the chamber 12 by means of an axis 17. The rudder 16 is formed so that it forms a smooth continuation of the support structure 11 and the chamber 12. The lower part of the rudder 16 extends at a distance below the chamber 12. A steering gear, which is not shown in the figure, rotates the rudder 16 based on the commands from the navigation bridge. The figure also shows the driving direction S of the ship.

The shaft 14 forms a shaft line SL of the propulsion unit 10. The shaft line SL and the water line WL are parallel, which means that the angle  $\alpha$  between them is 0 degrees. The angle between the axis 17 of the rudder 16 and the shaft line SL i.e. the angle  $\gamma$  is 90 degrees. The angle between the axis 17 of the rudder 16 and the water line WL i.e. the angle  $\delta$  is also 90 degrees.

Figure 1 also shows the flow lines F of the water flowing to the propulsion unit 10. It can be seen from the figure that the flow lines F do not enter the propeller 15 of the propulsion unit 10 at an optimum angle. This weakens the hydrodynamic efficiency of the propeller 15.

Figure 2 shows one embodiment of a propulsion arrangement according to the invention. The propulsion unit 10 corresponds as such to the propulsion unit shown in Fig. 1. The difference compared to the arrangement shown in Fig. 1 is that the shaft line SL of the propulsion unit 10 forms a vertical tilt angle  $\alpha$  in relation to the water line WL. This means that the front end of the chamber 12 is lower than the back end of the chamber 12 in relation to the water line WL. The angle of the water flow F entering the propeller 15 will be improved when the propulsion unit 10 is vertically tilted. This means that the hydrodynamic efficiency of the propeller 15 will be improved. The angle between the axis 17 of the rudder 16 and the water line WL i.e. the angle  $\delta$  is still 90 degrees as in figure 1. The angle between the axis 17 of the rudder 16 and the shaft line SL i.e. the angle  $\gamma$  is, however, less than 90 degrees in this embodiment due to the vertical tilting of the propulsion unit 10. The figure also shows the driving direction S of the ship.

Figure 3 shows another embodiment of a propulsion arrangement according to the invention. This arrangement corresponds as such to that of Fig. 2 i.e. the propulsion unit 10 is tilted at an angle  $\alpha$  in relation to the water line WL. The difference is in the arrangement of the rudder 16. The angle between the axis 17 of the rudder 16 and the shaft line SL i.e. the angle  $\gamma$  is 90 degrees in this embodiment, which corresponds to the situation in Fig. 1. This means that the axis 17 of the rudder 16 has been tilted in relation to the water line WL, i.e. the angle  $\delta$  is more than 90 degrees. The arrangement where the rudder 16 axis 17 forms a right angle with the shaft line SL is advantageous in respect of the flow generated by the propeller 15. The figure also shows the driving direction S of the ship.

Figure 4 shows a top view of a further embodiment of a propulsion arrangement according to the invention. There are two propulsion units 10, 20 situated side by side at each side of the center line CL of the hull 100 at the stern of the ship. Each propulsion unit 10, 20 comprises a chamber 12, 22 connected with a support

structure to the hull 100 of the ship, a propeller 15, 25 situated at the front end of the chamber 12, 22 being driven by an electric motor 13, 23 positioned in the chamber 12, 22. A rudder 16, 26 is further situated at the rear end of the chamber 12, 22. Each propulsion unit 10, 20 can either correspond to the propulsion unit  
5 shown in Fig. 2 or Fig. 3. This means that each propulsion unit 10, 20 is vertically tilted in relation to the water line WL with the angle  $\alpha$  as shown in Fig. 2 and Fig. 3. The arrangement of the rudder 16, 26 can be either that shown in Fig. 2 or that shown in Fig. 3. The figure also shows the driving direction S of the ship.

10 The shaft lines SL of the propulsion units 10, 20 are in this embodiment arranged in a toe-out position in relation to the center line CL of the hull 100 of the ship. The shaft lines SL form a horizontal tilt angle  $\beta$  with the center line CL of the hull 100 of the ship so that the shaft lines SL will cross each other at a point on the center line CL of the hull of the ship, said crossing point being situated after the  
15 ship. The front end of the chambers 12, 22 is inclined outwards (toe-out position) in relation to the center line CL of the hull 100 of the ship and the back end of the chambers 12, 22 is inclined inwards in relation to the center line CL of the hull 100 of the ship. The toe-out angle  $\beta$  is in the range of 0.5 to 6 degrees. The figure also shows a cargo tank 200 for liquefied natural gas (LNG) on the ship.

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This toe-out arrangement of the propulsion units 10, 20 will further improve the water inflow angle to the propellers 15, 25. This toe-out arrangement will improve efficiency and reduce vibrations in the hull and in the shaft.

25 The efficiency of the embodiment shown in fig. 2 is probably the same as that of the embodiment shown in fig. 3. The steerability of the ship might be a little bit better with the embodiment shown in fig. 2 compared to the embodiment shown in fig. 3. The embodiment shown in fig. 3 might on the other hand be better in view of processibility and product architecture as the tilt angle  $\alpha$  is regulated with  
30 the installation angle of the product, but there is no need to modify the product itself in each project. The product could on the other hand have a predetermined

vertical tilt angle  $\alpha$  of e.g. 4 degrees according to the arrangement shown in fig. 2 and the rest e.g. 2 degrees in a situation where the total vertical tilt angle  $\alpha$  should be 6 degrees would then be achieved according to the arrangement shown in fig. 3.

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The vertical tilt angle  $\alpha$  and the horizontal tilt angle  $\beta$  i.e. the toe-out angle have to be determined separately for each ship or series of ships. The optimization of the vertical tilt angle  $\alpha$  and the horizontal tilt angle  $\beta$  is done based on model test for each ship or series of ships. The optimization is done separately for the vertical tilt  
10 angle  $\alpha$  and the horizontal tilt angle  $\beta$ . The goal in the optimization is to minimize the fuel consumption i.e. to increase the efficiency. The best efficiency is normally achieved when the water inflow to the propeller is straight.

At least one generator (not shown in the figures) is provided within the hull 100 of  
15 the ship providing electric power to the electric motors 13, 23 in the propulsion units 10, 20 through an electric network (not shown in the figures).

The separate rudder 26 is in the figures pivotably supported at the hull 100 and at the chamber 22 of the propulsion unit 20. The rudder 26 can be pivotably  
20 supported at the hull 100 and/or at the propulsion unit 20. The rudder 26 can thus be pivotably supported only at the hollow support structure 21, or at the hull 100 and the hollow support structure 21, or at the hull 100 and the chamber 22, or at the chamber 21 and the hollow support structure 21.

25 The examples of the embodiments of the present invention presented above are not intended to limit the scope of the invention only to these embodiments. Several modifications can be made to the invention within the scope of the claims.

## CLAIMS

1. A propulsion arrangement in a ship, wherein the ship comprising a hull (100) having a horizontal water line (WL) and a center line (CL), and wherein said propulsion arrangement comprising:
- 5     - at least one stationary propulsion unit (10, 20) situated at the stern of the hull (100),
- said at least one propulsion unit (10, 20) comprising:
- 10       - a hollow support structure (11) being attached to the hull (100),
- a chamber (12) having a front end and a rear end, said chamber (12) being attached to the support structure (11),
- an electric motor (13) within the chamber (12),
- a shaft (14) having a first end and a second end, said first end of the shaft (14) being connected to the electric motor (13) and said second end of the shaft (14)
- 15       protruding from the front end of the chamber (12) and being connected to a propeller (15), the centre axis of said shaft (14) forming a shaft line (SL), and
- a pivotably supported rudder (16) at the rear end of the chamber (12),
- characterized** in that:
- 20       - the at least one propulsion unit (10, 20) is mounted so that the shaft line (SL) forms a vertical tilt angle ( $\alpha$ ) in the range of 1 to 8 degrees in relation to the water line (WL) so that the front end of the chamber (22) is lower than the rear end of the chamber (22) in relation to the water line (WL).
2. A propulsion arrangement according to claim 1, **characterized** in that the
- 25     propulsion arrangement comprises two stationary propulsion units (10, 20) situated side by side on opposite sides of the center line (CL) of the hull (100) of the ship at the stern of the ship, each propulsion unit (10, 20) being mounted so that:
- 30       - the shaft line (SL) forms a vertical tilt angle ( $\alpha$ ) in the range of 1 to 8 degrees in relation to the water line (WL) so that the front end of the chamber (22) is lower than the rear end of the chamber (22) in relation to the water line (WL), and

- the shaft line (SL) forms a horizontal tilt angle ( $\beta$ ) in the range of 0.5 to 6 degrees in relation to the center line (CL) of the hull (100) of the ship so that the front end of the chamber (22) is inclined away from the center line (CL) and the rear end of the chamber (22) is inclined towards the center line (CL).

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3. A propulsion arrangement according to claim 1 or 2, **characterized** in that the ship is a cruiser, a tanker transporting oil or liquefied natural gas, a vehicle carrier, a container ship or a ferry.

10 4. A propulsion arrangement according to any of claims 1-3, **characterized** in that the power of the at least one propulsion unit (10, 20) is at least 1MW.