PRE-NOZZLE FOR A DRIVE SYSTEM OF A WATERCRAFT TO IMPROVE THE ENERGY EFFICIENCY

The invention relates to a pre-nozzle for a drive system of a watercraft to improve the energy efficiency.

Drive systems for different types of ships to improve the drive power requirements are known from the prior art. Known from EP 2 100 808 A1 is, for example, a drive system for a ship, based on a pre-nozzle. The drive system consists of a propeller and a pre-nozzle which is mounted directly upstream of the propeller and comprises fins or hydrofoils integrated in the pre-nozzle. The pre-nozzle substantially has the shape of a flat conical cut-out, where both openings, both the water inlet and the water outlet opening, are configured as circular openings and the water inlet openings has a larger diameter than the water outlet opening. It is thereby possible to improve the propeller afflux and to reduce the losses on the propeller stream due to pre-swirl generation by means of the fins or hydrofoils integrated in the pre-nozzle.

~~It is the object~~ Embodiments of the present invention seek to provide a pre-nozzle for a drive system of a watercraft for further improvement of the drive efficiency, in particular for slow, large-volume ships.

~~This object is solved by a device having the features of claim 1.~~

According to a first aspect of the present invention, there is provided a pre-nozzle for a drive system of a watercraft, wherein the pre-nozzle comprises a water inlet opening and a water outlet opening, wherein a fin system is disposed inside the pre-nozzle, wherein the fin system is not arranged in the inlet region of the pre-nozzle, wherein no propeller is disposed inside the pre-nozzle, wherein the pre-nozzle is configured to be rotationally asymmetrical, wherein the jacket of the pre-nozzle when viewed in cross-section comprises in particular two, rectilinear sections, in particular over the entire length of the pre-nozzle.

Accordingly, the pre-nozzle for a drive system of a watercraft, in particular a ship of the type described initially, is configured in such a manner that a fin system is disposed inside the pre-nozzle. In this case, the pre-nozzle is located upstream of a propeller in the direction of travel of the ship. "In the direction of travel of the ship" is to be understood here as the forward direction of travel of a ship. No propeller is located inside the pre-nozzle as for example, in Kort nozzles. Furthermore, the pre-nozzle is located at a distance from the propeller. The fin system located inside the pre-nozzle consists of a plurality of, for

the inlet area of the pre-nozzle has no fin system and is used only to accelerate the water flow. The fin system located in the rear area of the pre-nozzle or the fin system located following the inlet area is used (additionally) to produce pre-swirl.

Furthermore, the pre-nozzle according to embodiments of the invention is configured to be rotationally asymmetrical. The axis of rotation of the pre-nozzle is thereby located along the pre-nozzle in such a manner that, when the pre-nozzle is viewed in cross-section, it lies both in vertical and horizontal alignment at the centre and preferably runs through the centre of the water outlet opening. Due to the rotationally asymmetric configuration of the pre-nozzle, the pre-nozzle is therefore not mapped onto itself during rotation by any arbitrary angle about the axis of rotation. It is thereby possible that individual surface segments, for example, a section in the area of the water outlet opening have per se rotationally asymmetric properties but the pre-nozzle as an entire unit is not a body of rotation. The rotational asymmetry further does not relate to the fin system located inside the pre-nozzle. The pre-nozzle is therefore rotationally asymmetric regardless of the arrangement of the individual fins.

The propeller which is located downstream of the pre-nozzle and at a distance therefrom, is fixed, i.e. is rotatable but not (horizontally or vertically) pivotable about the propeller axis and is rotatably mounted in a stern tube. The pre-nozzle can in this case be located with upwardly displaced axis of rotation lying above the propeller axis. The centre of gravity of the pre-nozzle therefore lies outside the propeller axis. The pre-nozzle can thereby be arranged in such a manner that its axis of rotation runs parallel to the propeller axis or runs at an angle to the propeller axis and therefore is placed obliquely in relation to the propeller axis.

The pre-nozzle is aligned centrally in the horizontal direction in relation to the propeller axis. The axis of rotation of the pre-nozzle and the propeller axis therefore lie in one vertical plane.

Nozzles are known from the prior art which are divided into two halves by an approximately vertical plane, where both halves are arranged offset with respect to one another in the longitudinal direction along the vertical plane. The pre-nozzle according to embodiments of the invention does not consist of two or more halves offset in the longitudinal direction. The water outlet opening area therefore preferably extends over only one plane and in particular not over planes which are offset with respect to one another.

The pre-nozzle is preferably configured to be closed in its circumference. For example, the pre-nozzle can be configured in one piece and closed over the entire circumference. Furthermore, the pre-nozzle can be composed of two or more parts, where the pre-nozzle is closed over the entire circumference in the assembled state. In this case, parts of the hull, for example, the stern tube can also serve to close the pre-nozzle circumferentially.

Due to the pre-nozzle according to embodiments of the invention, it is therefore possible to further improve the drive efficiency of a ship whereby the propeller afflux is improved by the configuration of the pre-nozzle and the losses in the propeller jet are reduced by the fin system disposed in the pre-nozzle due to the generation of pre-swirl. In particular, as a result of the rotationally asymmetrical configuration of the pre-nozzle, it is possible to take into account areas of the unfavourable wake and therefore further improve the propeller afflux.

In particular in the case of large, fully laden ships such as, for example, tankers, bulk carriers or tugs, the water velocity in the rear area of the ship, that is in the area of the propeller and the pre-nozzle, is different as a result of the shape of the ship or the configuration of the hull. For example, it is possible that the water velocity in the lower area of the pre-nozzle and the propeller is faster than in the upper area of the pre-nozzle or the propeller. This is particularly because the water inflow velocity in the direction of the pre-nozzle and propeller is more severely retarded or deflected by the hull in the upper region

than in the lower region. Due to the rotationally asymmetrical configuration of the pre-nozzle, it is possible to take into account the special ship's shape or the associated influencing of the water inflow velocities and therefore to accelerate the water inflow velocity in particular in the areas of unfavourable wake, for example, in the upper area of the pre-nozzle or the propeller, more strongly by the pre-nozzle than in the area of the more favourable wake, for example, in the lower area of the pre-nozzle or the propeller. The propeller inflow velocity of the water ~~is~~ can thereby be more uniformly distributed. Consequently, areas with different wake, in particular a different wake ratio in the upper and lower area of the pre-nozzle in relation to the particular flow velocity, are taken into account by the pre-nozzle according to embodiments of the invention.

A further advantage is that eddy generation can be avoided or reduced by the pre-nozzle according to embodiments of the invention. This means that the water flow deflected by the hull ~~does~~ may not appear or only appears to a small extent at outer surfaces of the nozzle body and therefore no or only a few water vortices are generated. Overall the propulsion efficiency can thus be increased. With the pre-nozzle according to embodiments of the invention and in particular as a result of the arrangement of the pre-nozzle, the flow ~~is~~ may be favourably influenced without thereby producing a high resistance or strong vortices. As a result, the propeller thrust can be increased for the same drive power by the apparatus according to embodiments of the invention or alternatively power and therefore energy can be saved at lower drive power without reducing the propeller thrust.

Compared with a circular opening of a rotationally symmetrical pre-nozzle, the water inlet opening is preferably expanded downwards and/or upwards. The directions upwards and downwards relate here to the built-in state of the pre-nozzle on a ship. Depending on the area of the unfavourable wake or depending on the hull, the water inlet opening of the pre-nozzle according to embodiments of the invention is expanded upwards or downwards. It is also possible that the water inlet opening of the pre-nozzle is expanded upwards and downwards. Due to the expansion of the water inlet opening, a larger amount of water can flow into the

water inlet opening of the pre-nozzle, whereby losses due to the water flow deflected by the hull which in part reach the outer area of the nozzle body in the case of a non-expanded water inlet opening, are reduced. The efficiency ~~is~~ may be increased due to an improved inflow.

It is furthermore preferred that at least one of the two opening areas, water inlet opening area or water outlet opening area, has a greater length in the vertical direction than in the horizontal direction. Opening areas of the pre-nozzle are to be understood in each case as the surfaces enclosed by the front-end edges of the nozzle body of the pre-nozzle. The nozzle body is typically formed by the so-called "nozzle ring". The nozzle body comprises the so-called sheathing of the pre-nozzle, where the nozzle body consists of an inner surface and an outer surface. The two surfaces are usually spaced apart from one another. The fin system is not part of the nozzle body but is connected to this at the inner surface of the nozzle body. The opening area can be formed over one or over several flat or curved planes. The length in the vertical direction is to be understood as the length of the opening area when viewed from top to bottom along its vertical central line. The greatest length in the horizontal direction is therefore to be understood similarly to the vertical direction as the width of the opening area in the area of its greatest expansion. An elliptical opening area for example has its greatest length in the horizontal direction in the area of its horizontal central line and its greatest length in the vertical direction in the area of its vertical central line. The two opening areas, the inlet opening area and the outlet opening area, can thereby be formed parallel to one another, partially parallel to one another and non-parallel to one another. The lengths in the vertical and horizontal direction in this case always run on the opening area and are therefore not necessarily direct connections of the upper front-side edge of the nozzle body with the lower edge of the nozzle body. If the opening area is formed over several planes, at least one of the two lengths has a bend and/or a curve profile.

that the profile length of the pre-nozzle in the area of the axis of rotation is greater than in the lower region of the pre-nozzle.

Consequently, the flow-through length when viewed from top to bottom is not constant within the pre-nozzle or is longer in the upper region of the pre-nozzle than in the lower region of the pre-nozzle. As a result, and in particular as a result of the narrowing of the cross-section of the pre-nozzle and the setting to the flow direction, the water velocity in the upper region of the pre-nozzle ~~is~~ may be accelerated more strongly or over a longer acceleration distance than in the lower region of the pre-nozzle. Thus, as a result of the pre-nozzle, the water velocity in the area of the unfavourable wake, in the upper inlet region of the pre-nozzle, can be accelerated more strongly than the water already inflowing at higher velocity in the lower region of the pre-nozzle. Consequently, the water outlet velocity and therefore the propeller inflow velocity ~~is~~ may be more equalised in the upper and lower region or the velocity difference is relatively small. Furthermore, the reduction in the profile length when viewed from top to bottom corresponds to an expansion of the water inlet opening area downwards since in the lower region more water which would have flowed in part from outside onto the jacket of the pre-nozzle with constant profile length of the pre-nozzle ~~is~~ may therefore ~~now~~ be captured by the opening and can flow into the pre-nozzle.

Preferably the water inlet opening area of the pre-nozzle is provided in such a manner that it has at least one angle of intersection to the cross-sectional area of the pre-nozzle or to the perpendicular to the axis of rotation of the pre-nozzle. Here angle of intersection is to be understood as that angle which is obtained by a conceptual lengthening of the water inlet opening area and the cross-sectional area of the pre-nozzle in the area of the point of intersection of the two interfaces. The angle of intersection thus corresponds to the angle between water inlet opening area and the perpendicular on the pre-nozzle axis or the axis of rotation of the pre-nozzle. Since the water inlet opening area can be formed over several planes, the water inlet opening area and cross-sectional

CLAIMS

1. Pre-nozzle ~~(10a, 10b, 10c)~~ for a drive system of a watercraft, wherein the pre-nozzle ~~(10a, 10b, 10c)~~ comprises a water inlet opening ~~(12)~~ and a water outlet opening ~~(13)~~, wherein a fin system ~~(14)~~ is disposed inside the pre-nozzle ~~(10a, 10b, 10c)~~, wherein the fin system ~~(14)~~ is not arranged in the inlet region of the pre-nozzle ~~(10a, 10b, 10c)~~, wherein no propeller is disposed inside the pre-nozzle ~~(10a, 10b, 10c)~~, ~~characterised in that~~ wherein the pre-nozzle ~~(10a, 10b, 10c)~~ is configured to be rotationally asymmetrical, wherein the jacket of the pre-nozzle ~~(10a, 10b, 10c)~~ when viewed in cross-section comprises in particular two, rectilinear sections ~~(37, 38)~~, in particular over the entire length of the pre-nozzle ~~(10a, 10b, 10c)~~.

2. The pre-nozzle according to claim 1, ~~characterised in that~~ wherein the water inlet opening ~~(12)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ is expanded in particular downwards and/or upwards to improve the water inflow.

3. The pre-nozzle according to any one of claims 1 or 2, ~~characterised in that~~ wherein the opening areas ~~(19, 20)~~ of the water inlet opening ~~(12)~~ and the water outlet opening ~~(13)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ are each enclosed by a front-end edge ~~(31, 32)~~ of a nozzle body ~~(11)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~, wherein at least one of the two enclosed opening areas ~~(19, 20)~~ has a greater length between upper profile line ~~(23)~~ and lower profile line ~~(24)~~ than in the horizontal direction.

4. The pre-nozzle according to claim 3, ~~characterised in that~~ wherein the water-inlet-side opening area ~~(19)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ is greater than the water-inlet-side opening area of a rotationally symmetrical pre-nozzle having the same central radius.

5. The pre-nozzle according to any one of the preceding claims, ~~characterised in that~~ wherein the pre-nozzle ~~(10a, 10b, 10c)~~ at least partially encloses a propeller axis ~~(41)~~ of a watercraft.

6. The pre-nozzle according to any one of the preceding claims, ~~characterised in that~~ wherein the opening areas ~~(19, 20)~~ of the water inlet opening ~~(12)~~ and the water outlet opening ~~(13)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ are each enclosed by a front-end edge ~~(31, 32)~~ of a nozzle body ~~(11)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~, wherein the two opening areas ~~(19, 20)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ are at least partially not parallel to one another.

7. The pre-nozzle according to any one of the preceding claims, ~~characterised in that~~ wherein the pre-nozzle ~~(10a, 10b, 10c)~~ has a profile length ~~(21, 22)~~, wherein the profile length is not constant and in particular in the upper region of the pre-nozzle ~~(10a, 10b, 10c)~~ and preferably in the area of the axis of rotation ~~(18)~~ greater than in the lower region of the pre-nozzle ~~(10a, 10b, 10c)~~.

8. The pre-nozzle of a ship according to claim 7, ~~characterised in that~~ wherein the profile length ~~(21, 22)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ decreases continuously within at least one region, preferably in the lower region, when viewed from top to bottom.

9. The pre-nozzle according to any one of the preceding claims, ~~characterised in that~~ wherein the opening areas ~~(19, 20)~~ of the water inlet opening ~~(12)~~ and the water outlet opening ~~(13)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ are each enclosed by a front-end edge ~~(31, 32)~~ of a nozzle body ~~(11)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~, wherein the water-inlet-side opening area ~~(19)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ has at least one angle of intersection ~~(27)~~ to the cross-sectional area ~~(34)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~.

10. The pre-nozzle of a ship according to claim 9, ~~characterised in that~~ wherein the angle of intersection ~~(27)~~ is constant and greater than 0° in at least one region.

11. The pre-nozzle according to any one of the preceding claims, ~~characterised in that~~ wherein the pre-nozzle ~~(10a, 10b, 10c)~~ has an upper profile angle ~~(28)~~ between the upper profile line ~~(23)~~ and the axis of rotation ~~(18)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ and/or that the pre-nozzle ~~(10a, 10b, 10c)~~ has a lower profile angle ~~(29)~~ between the axis of rotation ~~(18)~~ and the lower profile line ~~(24)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~, wherein the opening angle ~~(30)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ between upper and lower profile line ~~(23, 24)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ is greater than twice the upper profile angle ~~(28)~~ or greater than twice the lower profile angle ~~(29)~~.

12. The pre-nozzle according to claim 11, ~~characterised in that~~ wherein the opening angle ~~(30)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ between upper and lower profile line ~~(23, 24)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ corresponds to *the sum of twice the upper profile angle* ~~(28)~~ *and the angle of* intersection ~~(27)~~ or the sum of twice the lower profile angle ~~(29)~~ and the angle intersection ~~(27)~~.

13. The pre-nozzle according to claim 11 or 12, ~~characterised in that~~ wherein the lower profile angle ~~(29)~~ is greater than the upper profile angle ~~(28)~~.

14. The pre-nozzle according to any one of the preceding claims, ~~characterised in that~~ wherein the water-inlet-side opening area ~~(19)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ is bent or curved and in particular is formed over at least two planes, which are at an angle ~~(36)~~ to one another, wherein the angle ~~(36)~~ is greater than 90° and smaller than 180°.

15. The pre-nozzle according to any one of the preceding claims, ~~characterised in that~~ wherein the profile length ~~(21, 22)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ between upper and lower profile line ~~(23, 24)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ decreases continuously from top to bottom.

16. The pre-nozzle according to any one of claims 9 to 15, ~~characterised in that~~ wherein the value of the angle of intersection ~~(27)~~ is constant.

17. The pre-nozzle according to any one of claims 1 to 5, ~~characterised in that~~ wherein the pre-nozzle ~~(10c)~~ has a constant profile length ~~(21, 22)~~, so that the profile length ~~(21, 22)~~ is the same in the entire region of the pre-nozzle ~~(10c)~~.

18. The pre-nozzle according to any of the preceding claims, ~~characterised in that~~ wherein the rectilinear sections ~~(37, 38)~~ in a cross-sectional view interconnect a plurality of, in particular two, arcuate sections ~~(39, 40)~~.

19. The pre-nozzle according to any one of the preceding claims, ~~characterised in that~~ wherein the rectilinear sections ~~(37, 38)~~ are disposed at the side region of the pre-nozzle ~~(10)~~, in particular opposite one another.

20. The pre-nozzle according to any one of the preceding claims, ~~characterised in that~~ wherein the ratio of the greatest length of at least one opening area ~~(19, 20)~~ of the pre-nozzle ~~(10a, 10b, 10c)~~ in the vertical direction to the average profile length of the pre-nozzle ~~(10)~~ is between 1.5 : 1 and 4 : 1, preferably between 1.75 : 1 and 3 : 1, particularly preferably between 1.75 : 1 and 2.5 : 1.