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Fremdragne publikationer:
DE-C1- 4 223 570
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GB-A- 2 177 365
JP-A- S5 726 086
JP-A- 58 000 492
JP-A- 58 016 981
Description

The invention relates to a device for reducing the drive power requirement of a single-propeller or multi-propeller ship, in particular for broad-built and non-broad-built, not very fast ships.

DE 42 23 570 C1 discloses a flow guide surface for variable pitch propellers. In the case of this flow guide surface, it is provided that the flow is influenced by an upstream ring nozzle as a diffuser. For this purpose, a deceleration of the incident flow is carried out in the near region and an acceleration of the incident flow is carried out in the externally lying region. The diffuser diameter is less than 65% of the propeller diameter. Such a nozzle is embodied as a deceleration nozzle or as a diffuser with a ring nozzle vaulted to the outside. This diffuser decelerates the flow in its region, which can lead to an improvement in the propulsion efficiency only as a result of very thick hubs, as in the case of variable pitch propellers. Such a nozzle is therefore not embodied as an acceleration nozzle with a vaulting of the ring nozzle to the inside. The nozzle presented in this publication therefore does not accelerate the flow in its region and is not suitable for all types of propeller, in particular is not suitable for fixed propellers. An active principle of a fore-nozzle, which comprises increasing the propeller flow speed in regions of very high co-flow, is not described in DE 42 23 570 C1.

JP 07 267109 A discloses a propeller arrangement with a ring-shaped nozzle and fins arranged in a star shape. The propeller diameter corresponds approximately to the ring diameter of the nozzle.

JP 58 000492 A shows a further propeller arrangement by means of which an improvement in efficiency and a reduction in drive power requirement should be possible. This arrangement also comprises fins as well as a structure consisting of six
elements arranged in a honeycomb-like manner.

JP 57026086 shows a ship with a fore-nozzle which is arranged in front of the propeller and is inclined forwards, a number of fins being provided which are installed at one end side on the fore-nozzle.

The object of the present invention is to create a device which serves to reduce the drive power requirement of a ship. An improvement in efficiency and an adjustment of the fins or hydrofoils to the incident flow should furthermore be achieved. The propeller incident flow should furthermore be improved.

This object is achieved by a device with the features of Claim 1.

According to this, the device according to the invention is formed in such a manner that the device installed on the hull at a short distance in front of the propeller consists of a fore-nozzle with fins or hydrofoils placed inside the fore-nozzle, the fore-nozzle, at the top thereof, can be tilted forwards relative to a horizontal transverse axis that extends through the centre of the fore-nozzle, preferably by up to 8°.

With a device formed in such a manner, it is possible to reduce the drive power requirement of a ship. The possible gain increases with an increasing degree of thrust load of the propeller. The device is particularly suitable for slow, broad-built ships, such as tankers, bulkers and tugboats and also for not very fast ships of all types. The device itself is installed fixedly on the hull in front of the propeller of the ship and comprises both functional elements fore-nozzle and fins or hydrofoils.

The active principle of the fore-nozzle lies in increasing the propeller incident flow speed in regions of very high co-flow
and reducing the propeller incident flow speed in regions of low co-flow, the nozzle itself generating thrust, and that of the fins or hydrofoils arranged within the fore-nozzle in the generation of a pre-swirl, wherein both functional elements are directed at different sources of loss, namely the fore-nozzle at a reduction in the effective thrust load and the fins or hydrofoils at a reduction in the swirl losses in the propeller slipstream. The efficiency of the propulsion system is increased by both effects.

Due to the fact that the device is installed as close as possible in front of the propeller, a maximum effect is achieved, and indeed also in different cases of loading.

It should also be noted that the device according to the invention is not only suitable for broad-built ships; it can be used in all not very fast ships, for example, $V \leq 25$ kn, with the same effect. Use for very large container ships is also possible.

The fins or hydrofoils furthermore connect the hull to the fore-nozzle.

The fins or hydrofoils are placed asymmetrically within the fore-nozzle and radially with respect to the propeller axis.

Further advantageous configurations are the subject matter of the subordinate claims.

In order to achieve a maximum effect, the trailing edge of the device or fore-nozzle is affixed no further than 0.3 times the propeller diameter upstream of the propeller plane. The fore-nozzle, at the top, is preferably tilted forwards by approximately 4°.

According to a further configuration, the fore-nozzle is laterally rotated about a vertical axis which preferably extends through the centre of the fore-nozzle such that the
fore-nozzle is tilted forwards on the upwards-striking side of the propeller.

The invention furthermore provides that the fore-nozzle is laterally rotated by up to $3^\circ$, preferably by $1^\circ$, about a vertical axis which preferably extends through the centre of the fore-nozzle, such that the fore-nozzle is rotated forwards on the upwards-striking side of the propeller, wherein the rotation can also be $0^\circ$, but not in the other direction.

The invention further provides that the thickness of the profile of the fore-nozzle is less than 12 % of its length. The thickness of the profile of the fore-nozzle can advantageously be 7.5 % or 9 % of its length.

A further configuration provides that the fins or hydrofoils in radial direction comprise a variable angle of attack, wherein the fins or hydrofoils are twisted such that said fins or hydrofoils on the inside of the ship are oriented upwards, and the angle of attack decreases outwards towards the fore-nozzle.

The fore-nozzle is thus rotationally symmetrically placed about an axis being offset preferably above the propeller axis, wherein the inner diameter of the fore-nozzle is at most 90 % of the propeller diameter.

The fins or hydrofoils are preferably placed at the rear end of the fore-nozzle, wherein the vaulted side of the hydrofoil-shaped and lentiform cross-sectional profile of the fin or of the hydrofoil is oriented upwards on the upwards-striking side of the propeller, and is directed downwards on the downwards-striking side of the propeller. The arrangement of four fins or hydrofoils in the inner space of the fore-nozzle is preferred, but does not represent a restriction particularly since a small or larger number of fins or hydrofoils can also be provided.
Exemplary embodiments of a ship with a propeller, which rotates at the top to starboard, of the device according to the invention are represented in the drawing and in which drawing:

5

Fig. 1 shows, in a side view from starboard, the device according to the invention consisting of a fore-nozzle with fins or hydrofoils arranged in its inner space,

10 Fig. 2 shows the device in a view from behind, fins or hydrofoils not being represented in an adjusted manner,

Fig. 3 shows an enlarged cross-section through the profile of a fin or a hydrofoil:

15 Fig. 4 shows a side view of the rear contour,

Fig. 5 shows a body plan of the rear ship,

20 Fig. 6 shows the fore-nozzle with fins or hydrofoils arranged in its inner space according to Fig. 1 with positional arrangements of the fins,

Fig. 7 shows a side view of the device with a fore-nozzle tilted forwards by 4° at the top,

25 Fig. 8 shows a graphic view of the fore-nozzle with fins directed and twisted upwards on the inside of the ship,

30 Fig. 9 shows a diagram of power savings in the case of use of the device according to the invention,

Fig. 10 shows a diagram of power requirement with and without the device according to the invention and

35 Fig. 11 shows a diagram of power savings in the case of use of the device according to the invention in different types of ship.
According to Fig. 1, device 10 according to the invention consists of a fore-nozzle 20 with a cylindrical shape or a differently configured form or cross-sectional form which is attached fixedly to the hull being provided directly in front of the propeller, not represented in the drawing, of a hull 100. Fins or hydrofoils 30 are placed in inner space 20a of fore-nozzle 20. Fore-nozzle 20 is placed rotationally symmetrical to axis 21, which is displaced upwards, on the hull.

In the case of the exemplary embodiment represented in Fig. 2, four fins or hydrofoils 30a, 30b, 30c, 30d are placed in a star-shape with different fin or hydrofoil lengths in inner space 20a of fore-nozzle 20. These four fins or hydrofoils are placed asymmetrically within the fore-nozzle and radially in relation to propeller axis PA. Fins or hydrofoils 30a, 30b, 30c, 30d connect fore-nozzle 20 to hull 100 and are placed at the rear end of fore-nozzle 20 facing the propeller, vaulted side 32 of hydrofoil-shaped or lentiform cross-sectional profile 31 of fins or hydrofoils 30, 30a, 30b, 30c, 30d being oriented upwards on the port side of the ship or upwards on the upwards-striking side of the propellers and downwards on the starboard side of the ship or the downwards-striking side of the propeller. Fins or hydrofoils 30a, 30b, 30c, 30d are furthermore oriented forwards and upwards on the port side and forwards and downwards on the starboard side (Figs. 2 and 3). The direction of rotation of the propeller is carried out in arrow direction X (Fig. 1). Fins or hydrofoils 30 or 30a, 30b, 30c, 30d arranged in inner space 20a of fore-nozzle 20 are adjustable in their angular positions and lockable in the set angular positions.

According to one exemplary embodiment with a propeller which rotates upwards to starboard, fins or hydrofoils 30; 30a, 30b, 30c, 30d assume the following preferred radial angular positions and initial angular positions:
<table>
<thead>
<tr>
<th>Port (BB)</th>
<th>Lower fin (30a)</th>
<th>Fin angle</th>
<th>Angle of attack</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port (BB)</td>
<td>Middle fin (30b)</td>
<td>292.5°</td>
<td>12°</td>
</tr>
<tr>
<td>Port (BB)</td>
<td>Upper fin (30c)</td>
<td>337.5°</td>
<td>8°</td>
</tr>
<tr>
<td>Starboard (SB)</td>
<td>Fin (30d)</td>
<td>90.0°</td>
<td>10°</td>
</tr>
</tbody>
</table>

and indeed in the case of a fin angle definition: seen from the rear: 12 O’clock = 0°, increasing in a clockwise direction, it being possible for the fin angles and angles of attack to deviate from the indicated values.

According to the embodiment represented in Figs. 1, 3 and 6, the fins or hydrofoils have a lentiform cross-sectional profile 31 with a vaulted side wall 32 and with a base surface 33 running in a straight line. The arrangement and the position, for example, of both fins 30 in relation to propeller axis PA is such that the upper fin is running with its base surface 33 approximately parallel to propeller axis PA, whereas the upper fin assumes a position in which its base surface 33 is running at an angle a of at least 5°, preferably of 10° in relation to propeller axis PA. Other angular positions of the fins are possible. Fins 30a, 30b, 30c, 30d preferably have in general the positions shown in Fig. 2.

Fore-nozzle 20 according to Figs. 1 and 6 is formed by a mould 25 with a cross-sectional profile 26 with a wall portion 26a lying on the outside and running obliquely at an angle to propeller axis PA and with an internal wall portion 26b running in a straight line and parallel to propeller axis PA, which wall portion 26b has in the region facing away from the propeller an arc-shaped wall portion 26c which forms a transition into outside wall portion 26a. Externally lying wall portion 26a can also be formed to be arc-shaped. The propeller side is indicated by PS in Fig. 6.

As Fig. 7 shows, device 10 is installed on hull 100 at a short distance in front of propeller 101. Device 10 should be placed
as close as possible in front of propeller 101. Fore-nozzle 20 is placed, at the top thereof, so as to be tilted forwards relative to a horizontal transverse axis that preferably extends through the centre of the fore-nozzle, preferably by up to 8°. In Fig. 7, fore-nozzle 20 is tilted forwards by 4° at the top. The trailing edge of fore-nozzle 20 is affixed no further than 0.3 times the propeller diameter upstream of the propeller plane.

Fore-nozzle 20 can furthermore be rotated laterally, i.e. by up to 3°, about a vertical axis that preferably extends through the centre of the fore-nozzle so that the fore-nozzle is rotated forwards on the upwards-striking side of propeller 101. Rotations of up to 1° appear to be optimal here. 0° can also be appropriate, but not in the other direction.

The thickness of the profile of fore-nozzle 20 is less than 12 % of its length. The thickness of the profile of fore-nozzle 20 is preferably 7.5 % or 9 % of its length.

Fins or hydrofoils 30, 30a, 30b, 30c, 30d can have a variable angle of attack in the radial direction, the fins or hydrofoils being twisted so that the fins or hydrofoils are oriented upwards on the inside on the ship and the angle of attack reduces to the outside towards fore-nozzle 20 (Fig. 8).

The thickness configuration of the profile of fore-nozzle 20 and the configuration that fins or hydrofoils 30, 30a, 30b, 30c, 30d have a variable angle of attack in the radial direction are essential for highly broad-built ships; they can also be used in fast ships.

As a result of the configuration according to the invention of device 10, significant power savings are obtained, as is apparent from the diagram of Fig. 9, that the power savings are achieved by the use of device 10 for three ships, of which in the case of two ships with different draughts (X = design speed).
The diagram according to Fig. 10 shows the power requirement in the case of a bulk carrier with 118,000 DWT with and without device 10.

Particularly high gains can be attributed e.g. in the case of ships with 12,000 DWT to a thick hub in the case of a variable pitch propeller, the losses of which are reduced by device 10.

The degree of thrust load is particularly high in the case of very large, slow ships. The diagram of Fig. 11 shows the potential power savings by device 10 as a function of the $C_T$ value. An assignment to types of ship is provided in the lower part of Fig. 11.

The device according to the invention is characterized by the features indicated in the description and the claims and by the configurations represented in Figs. 1 to 11 of the drawings.

With device 10 there has been developed a novel apparatus, which improves propulsion, for broad-built slow ships, as a result of which fuel is saved or ships can travel faster. The device comprises two combined elements installed fixedly on the ship: a nozzle directly in front of the propeller and a fin system integrated therein. The nozzle improves the propeller incident flow in the region of an inexpedient downstream flow and generates thrust itself; the fin system reduces the losses in the propeller wash and in the propeller hub swirl as a result of pre-swirl generation, as a result of which the propeller thrust is increased with the same driving power. The effects complement one another.

The power savings which can be achieved by the device are substantially dependent on the propeller loading, this extending from 3 % in the case of small multi-purpose ships up to 9 % in the case of large tankers and bulkers. The power savings are almost independent of the draught of the ship and
of the speed. The device is suitable for new constructions and for retrofitting.
List of reference numbers

<table>
<thead>
<tr>
<th>Reference</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Device</td>
</tr>
<tr>
<td>20</td>
<td>Fore-nozzle</td>
</tr>
<tr>
<td>5 20a</td>
<td>Inner space</td>
</tr>
<tr>
<td>21</td>
<td>Axis of the fore-nozzle</td>
</tr>
<tr>
<td>25</td>
<td>Mould</td>
</tr>
<tr>
<td>26</td>
<td>Cross-sectional profile</td>
</tr>
<tr>
<td>26a</td>
<td>Wall portion</td>
</tr>
<tr>
<td>10 26b</td>
<td>Wall portion</td>
</tr>
<tr>
<td>26c</td>
<td>Wall portion</td>
</tr>
<tr>
<td>30</td>
<td>Fin/Hydrofoil</td>
</tr>
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<td>Fin/Hydrofoil</td>
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<tr>
<td>30c</td>
<td>Fin/Hydrofoil</td>
</tr>
<tr>
<td>30d</td>
<td>Fin/Hydrofoil</td>
</tr>
<tr>
<td>31</td>
<td>Cross-sectional profile</td>
</tr>
<tr>
<td>32</td>
<td>Vaulted side wall</td>
</tr>
<tr>
<td>20 33</td>
<td>Base surface</td>
</tr>
<tr>
<td>100</td>
<td>Hull</td>
</tr>
<tr>
<td>101</td>
<td>Propeller</td>
</tr>
<tr>
<td>25 25</td>
<td>Port</td>
</tr>
<tr>
<td>SB</td>
<td>Starboard</td>
</tr>
<tr>
<td>PA</td>
<td>Propeller axis</td>
</tr>
<tr>
<td>PS</td>
<td>Propeller side</td>
</tr>
<tr>
<td>X</td>
<td>Direction of rotation of the propeller</td>
</tr>
<tr>
<td>30 α</td>
<td>Angle</td>
</tr>
</tbody>
</table>
Patentkrav

1. En- eller flerskruet skib omfattende en på en propellerakse (PA) anbragt propeller (101) og en anordning (10) til reduktion af skibets motorkraftbehov, idet anordningen (10), der med lille afstand er anbragt på skibsskroget (100) foran propellenen (101), består af en fordyse (20) med finner eller vinger (30; 30a, 30b, 30c, 30d), der er placeret inde i fordySEN, at fordySEN foroven er vippet fremad omkring en omkring en horisontal, tværliggende akse, som løber gennem fordySENS midtpunkt, kendetegnet ved, at finnerne eller vingerne (30; 30a, 30b, 30c, 30d) forbinder skibsskroget med fordysen (20), og at finnerne eller vingerne (30; 30a, 30b, 30c, 30d) er placeret asymmetrisk inde i det indre (20a) af fordysen (20) og radialt i forhold til propelleraksen (PA).

2. Skib ifølge krav 1, kendetegnet ved, at anordningen eller fordysen (20) med sin bagkant er fast anbragt ikke længere væk end 0,3 gange propellerdiameteren foran propellerneuaret.

3. Skib ifølge et af kravene 1 eller 2, kendetegnet ved, at fordysen (20) foroven er vippet ca. 4° fremad.

4. Skib ifølge et af kravene 1 til 3, kendetegnet ved, at fordysen (20) er drejet til siden omkring en lodret akse, således at fordysen (20) på den opadslæende side af propelleren (101) er skubbet fremad.

5. Skib ifølge krav 4, kendetegnet ved, at fordysen (20) kan drejes op til 3° til siden omkring en lodret akse, som fortrinsvis forløber gennem fordysens
midterpunkt, således at fordysen (20) på den opadslående side af propelleren (101) er drejet fremad.

6. Skib ifølge et af de forgående krav 1 til 5, kendetegnet ved, at tykkelsen på fordysens (20) profil er mindre end 12 % af dens længde.

7. Skib ifølge krav 6, kendetegnet ved, at tykkelsen på fordysens profil er 7,5 % eller 9 % af dens længde.

8. Skib ifølge et af de foregående krav 1 til 7, kendetegnet ved, at finnerne eller vingerne (30; 30a, 30b, 30c, 30d) i radial retning har en variabel indstilling svinkel, idet finnerne eller vingerne er drejet (tvistet) således, at finnerne eller vingerne indvendigt på skibet er rettet opad, og indstilling svinklen aftager udad i forhold til fordysen (20).

9. Skib ifølge et af de foregående krav 1 til 8, kendetegnet ved, at fordysen (20) med en indvendig diameter, der er mindre end 90 % af propellerens diameter, er placeret rotationssymmetrisk med opad skubbet, oven over propelleraksen (PA) liggende akse (21).

10. Skib ifølge et af de foregående krav 1 til 9, kendetegnet ved, at finnerne eller vingerne er placeret på den bageste ende af fordysen (20), idet den hvælvede side (32) på det linseformede tværsnitsprofil (31) på finnen eller vingen (30; 30a, 30b, 30c, 30d) på den opadslående side af propelleren er rettet opad og på den nedadslående side af propelleren peger nedad.

11. Skib ifølge et af de foregående krav 1 til 10, kendetegnet ved,
at finnerne eller vingerne (30; 30a, 30b, 30c, 30d) indtager følgende foretrukne radiale vinkelstillinger og udgangsvinkelstillinger:

<table>
<thead>
<tr>
<th>Finnevinkel</th>
<th>Indstillingsvinkel</th>
</tr>
</thead>
<tbody>
<tr>
<td>backbord (BB) nederste finne (30a)</td>
<td>247,5°</td>
</tr>
<tr>
<td>backbord (BB) midterste finne (30b)</td>
<td>292,5°</td>
</tr>
<tr>
<td>backbord (BB) øverste finne (30c)</td>
<td>337,5°</td>
</tr>
<tr>
<td>styrbord (SB) finne (30d)</td>
<td>90,0°</td>
</tr>
</tbody>
</table>

10 12. Skib ifølge et af de foregående krav 1 til 11, kendtegnet ved, de i det indvendige rum (20a) på fordysen (20) placerede finner eller vinger (30) kan ændres eller indstilles i sine vinkelindstillinger.
Power savings for 3 ships, of which 2 with different draughts

Speed in knots

Fig. 9
Power requirement with and without invention

![Graph showing power dependency versus speed in knots with and without invention.]

Fig. 10
Power savings by invention

Saving as a function of the CTh value

Fig. 11