APPARATUS AND METHOD FOR REDUCING FLUID DRAG ON A SUBMERGED SURFACE

VORRICHTUNG UND VERFAHREN ZUR VERRINGERUNG VON FLUIDWIDERSTAND AUF EINE UNTERGETAUCHTE FLÄCHE

APPAREIL ET PROCÉDE DE REDUCTION DE LA TRAINEE D'UN FLUIDE SUR UNE SURFACE IMMERGEE

Designated Contracting States:
AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HU IE IS IT LI LT LU LV MC NL PL PT RO SE SI SK TR

Date of publication of application:
29.10.2008 Bulletin 2008/44

Proprietor: North Shore Partners
Lake Oswego,
Oregon 97034 (US)

Inventors:
• STUBBLEFIELD, Donald, P.
Lake Oswego, Oregon 97034 (US)

Representative: Patentanwaltskanzlei Matschnig & Forsthuber OG
Siebenstergasse 54
1071 Wien (AT)

References cited:
US-B2- 6 789 491

Note: Within nine months of the publication of the mention of the grant of the European patent in the European Patent Bulletin, any person may give notice to the European Patent Office of opposition to that patent, in accordance with the Implementing Regulations. Notice of opposition shall not be deemed to have been filed until the opposition fee has been paid. (Art. 99(1) European Patent Convention).
Description

BACKGROUND OF THE INVENTION

[0001] The invention relates to devices and methods for reducing surface friction drag on the hull of a vessel traveling through water.

[0002] Surface friction drag or "skin friction" drag is a significant component of the total power required to propel a surface vessel through water. Reducing surface friction drag enables vessels to travel at higher speeds and/or more efficiently. Accordingly, reducing surface friction drag has been the subject of a great deal of research in the field of vessel hull design for both surface and submerged vessels.

[0003] The magnitude of surface friction drag on a particular vessel hull depends, in part, upon the viscosity of the liquid through which the hull is traveling (usually fresh or salt water), the density of the liquid and the surface tension between the liquid and the submerged surface of the hull.

[0004] As shown schematically in Fig. 2, the effects of surface friction drag are focused in a "boundary layer" 22, a layer of liquid in which momentum is transferred from the surface 16 of the hull 14 to the liquid 12. Momentum transfer is the greatest in the portion of the liquid that is closest to the surface 16 of the hull 14 and decreases to the edge 26 of the boundary layer 22. Momentum transfer in the boundary layer 22 results in a reduction in the velocity of the water 12 relative to the surface 16 of the hull 14, as well as turbulence. A velocity gradient 24 shows the decrease in relative velocity of the water 12 from the edge of the boundary layer 26 to the surface 16 of the hull 14. Relative velocity is represented by the length of each arrow.

[0005] One means of reducing surface friction drag is the introduction of gas into the boundary layer 22, which reduces the fluid density and viscosity in the boundary layer 22. The relatively low density and viscosity of the gas results in less momentum transfer, and therefore, less surface friction drag. This technique is sometimes referred to in the art as "air lubrication".

[0006] Air lubrication has been successfully implemented in hovercraft, in which the vessel sits atop a large cushion of air. Air cushions are not practical for use with vessels having a significant draft, however, because water pressure increases with depth, which causes the air cushion to quickly rise to the surface of the water. Enormous amounts of power are required to push an air cushion down into a few inches of water (several centimeters). This problem has been addressed, in part, by using small bubbles of air (i.e., micro-bubbles) instead of a larger air cushion. Small bubbles rise much more slowly in water than a large air cushion.

[0007] Full-scale use of micro-bubbles has been proven very difficult. The inventions of the prior art have faced three major technical challenges in successful use of micro-bubbles to reduce surface friction: (1) injecting micro-bubbles at a sufficient volumetric rate to fill a significant portion of the boundary layer, (2) keeping the micro-bubbles from migrating out of the boundary layer, and (3) adjusting the volumetric flow rate of micro-bubbles as the velocity of the vessel changes.

[0008] Most prior art air lubrication systems use either a pump or pressurized air to supply the volume of micro-bubbles. This approach is deficient in several respects. Firstly, power must be expended to pump or pressurize the air. In all cases, the power expended to pump or pressurize the air completely offsets the power savings from reduced surface friction drag. Secondly, it is very difficult to inject pumped or pressurized air into the boundary layer. A typical boundary layer is only a few millimeters thick near the bow of the vessel, which is where the air is injected in most prior art systems. Given that the micro-bubbles themselves are at least one millimeter in diameter and are typically injected at an angle to the direction of flow F of the boundary layer, it is very difficult to prevent the micro-bubbles from passing through the boundary layer and into the free-flow water area. Thirdly, the prior art does not provide for an injection flow rate for micro-bubbles that varies in proportion to the vessel's speed. This results in the micro-bubble injection rate being ideal at only one speed. At all other speeds, the injection rate is higher or lower than the ideal rate.

[0009] Other prior art air lubrication systems, such as the system described in U.S. Patent No. 6,125,781, purport to aerate water flow into the boundary layer of a vessel hull using a tube that has one or more ports on the submerged surface of the vessel hull and is open to the air at the opposite end. In such prior art systems, it is hypothesized that air will be "sucked" through the port(s) and into the boundary layer. This hypothesis is based on flawed assumptions. It has been determined that these types of systems only work on vessels with very shallow drafts, traveling at high speeds. For example, air would not begin to be sucked into the boundary layer along the hull of a vessel having a draft of 3.973 inches (10.09 cm) until the vessel reached a speed 90.6 miles per hour (40.5 m/s). This is not a feasible speed for most surface vessels.

[0010] Document US 2001/0022152 A1 discusses a frictional resistance reducing vessel, where a negative pressure region is formed in the water accompanying operation of a hull and bubbles are guided to this negative pressure region.

[0011] Another prior art system for reducing surface drag is referred to in the art as a ventilated step chine, which is used primarily in high-performance watercraft. An example of a ventilated step chine design is described in U.S. Patent No. 5,452,676. Although ventilated step chines appear to provide some performance and efficiency improvements, the ventilated step chines of the prior art do not entrain significant amounts of air into the boundary layer. This is due, in part, to the fact that the ventilated step chines of the prior art do not produce turbulent mixing of air and water in the vicinity of the step.
Conventional ventilated step chines merely reduce the effective surface area of the hull, so that the frictional effects of water act on a smaller area. The reduction is only a small percentage of the total surface area of the hull; therefore, ventilated step chines provide little, if any, surface friction reduction.

Accordingly, there is a need for an efficient air lubrication system that is capable of entraining air bubbles into the boundary layer of a wide variety of vessels, including those having a substantial draft and a system that functions at much more reasonable speeds.

SUMMARY OF THE INVENTION

The invention comprises an apparatus that entrains a secondary fluid into a primary fluid flow while the primary fluid flows in a boundary layer that is adjacent to a surface of an object moving through the primary fluid. The apparatus comprises a flow diverting member that diverts a first portion of the primary fluid away from the surface of the object, which results in a reduced pressure region located between the first portion of the primary fluid and the surface of the object. The apparatus also includes an opening that enables the secondary fluid to flow into the reduced pressure region, an inlet through which a second portion of the primary fluid flows and an array of nozzles located downstream from the inlet. The secondary fluid is accelerated as it passes through the nozzles. The nozzles are oriented to direct the second portion of the primary fluid through the reduced pressure region so that at least a portion of the secondary fluid is entrained into a portion of the primary fluid.

In another respect, the invention comprises a method for reducing frictional drag on a hull of an object designed to be propelled through a primary fluid, where the hull includes a surface that is at least partially submerged in the primary fluid. The method comprises first diverting a first portion of the primary fluid away from the surface of the object, which results in a reduced pressure region located between the first portion of the primary fluid and the surface of the object. An opening is provided that enables a secondary fluid to flow into the reduced pressure region, the secondary fluid having a lower density than the primary fluid. At least a portion of the secondary fluid is entrained into a portion of the primary fluid by directing a second portion of the primary fluid through the reduced pressure region.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 shows a vessel moving in a body of water in a direction of propulsion D;
Fig. 2 shows the detail area 2-2 from Fig. 1;
Fig. 3 shows a view from the underside of a first embodiment of an entrainment device;
Fig. 4 shows a sectional view taken along line 4-4 of Fig. 3;
Fig. 5 shows a second embodiment of the entrainment device, shown from the underside and rear;
Fig. 6 shows a bottom view thereof;
Fig. 7 shows a sectional view thereof taken along line 7-7 of Fig. 6;
Fig. 8 shows a watercraft that incorporates a third embodiment of the entrainment device, shown from the underside and rear; and
Fig. 9 shows a sectional view thereof taken along line 9-9 of Fig. 8.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

The principles and operation of the entrainment device according to the present invention are better understood with reference to the drawings and the accompanying description. In order to aid in understanding of the invention, reference numerals that are referred to in the specification with respect to one or more figures may appear in additional figures without a specific reference to such additional figures in the specification. Terms used herein and in the claims to describe the relative position of elements of the invention, such as "above" and "below," are intended to refer to the invention in the orientation shown in Figs. 4, 7 and 9.

Referring to Figs. 3 and 4, reference numeral 30 refers generally to an entrainment device 30 of the present invention. The entrainment device 30 can either be formed as part of the hull 14 of the vessel 10 or retrofitted to an existing hull. The entrainment device 30 comprises an inlet 34, a flow diverting member 36, a plurality of nozzles 37 and a base 38. As used in the specification and claims, the term "nozzle" is intended to mean a device that directs flow of a fluid and not intended to be limited to nozzles that change the velocity of the fluid.

Because this embodiment of the entrainment device 30 will be submerged and is part of a vessel 10 which will be moving in open waterways, the entrainment device 30 should be designed to resist corrosion and be sufficiently durable to withstand moderate impacts from small objects. Accordingly, the entrainment device 30 is preferably made from metal having anti-corrosive properties or rigid plastic.

The entrainment device 30 is designed to be located along the hull 14 of the vessel 10, preferably close to the bow 18 of the vessel 10, as shown in Fig. 1. As will be explained herein, surface friction reduction benefits are realized downstream from the entrainment device 30. Therefore, placing the entrainment device 30 close to the bow of the vessel 10 maximizes the beneficial effects of the entrainment device 30.

Fig. 4 shows the entrainment device 30 attached to the hull 14 and protruding downwardly from the lower surface 16 of the hull 14 into the boundary layer 22. As shown in Fig. 4, water is flowing in the direction...
F. Water flowing toward the entrainment device 30 in the boundary layer 22 is represented in a simplified fashion in Fig. 4 as two portions of the boundary layer flow: an inlet flow stream 50 and a diverted flow stream 52.

As water approaches the inlet 34, the inlet flow portion 50 is drawn into the inlet 34 through an opening 35 and is directed through the nozzle 37. The shape of the inlet 34 may vary depending upon the draft and normal operating speed of the vessel 10, but is preferably shaped to minimize drag. It has been found that low drag inlet shapes in accordance with guidelines set forth by the National Advisory Committee on Aeronautics (NACA) are suitable.

The diverted flow stream 52 is directed downwardly by the flow diverter 36 and separated from the inlet flow stream 50. Separation of streams 50 and 52 occurs between points F1 and F2. Maximum flow separation occurs at point F2, where the diverted flow stream 52 passes over a trailing edge 40 of the flow diverter 36. The velocity of the diverted flow stream 52 is also increased as it flows over the diverter 36.

In order for flow separation to occur, the trailing edge 40 of the flow diverter 36 must extend into the water further than the portion of the surface 16 of the hull 14 that is immediately downstream from the trailing edge 40 of the flow diverter 36. This portion of the surface 16 of the hull 14 is referred to herein and in the claims as the downstream leading edge 41 of the hull 14.

In this embodiment of the invention, the flow diverter 36, including the trailing edge 40, protrudes downwardly from the hull 14. Alternatively, the downstream leading edge 41 of the hull 14 could be recessed relative to the trailing edge 40 of the flow diverter 36. This alternative configuration is shown in Figs. 8 & 9, which are discussed herein.

The flow separation and increased velocity of flow results in a reduced pressure region located between the trailing edge 40 and the vessel hull 14 at point F2. A vent 27 is provided that is open to the air at its upper end (not shown). The vent 27 includes an opening 28 located downstream from the nozzle 37. The reduced pressure region provided by the diversion of the diverted flow 52 allows a pocket of air 42 to be drawn down into the reduced pressure region. As used herein the term "region" and "reduced pressure region" should be understood to mean a three-dimensional region, i.e., a volume.

Between points F2 and F3, there is an area in which the pocket of air 42 abuts the surface 43 of the diverted flow stream 52. This area will be referred to herein and in the claims as a "free surface" 45.

The nozzle 37 preferably increases the velocity of the inlet flow stream 50 to an exit velocity V4 and directs the inlet flow stream 50 toward the free surface 45. This causes the inlet flow stream 50 to act as a plunging jet, which entrains air bubbles 56 from the pocket 42 into the diverted flow stream 52. Preferably, the nozzles 37 are positioned just below the surface 16 of the hull 14 so that the inlet flow stream 50 is parallel to the flow F of the boundary layer 22 as it exits the nozzles 37.

As shown in Fig. 3, three nozzles 37 are provided in this embodiment. A greater or lesser number of nozzles 37 could be provided in different applications. The amount of convergence of each nozzle 37 (i.e., the ratio of the diameter of the nozzle throat to the diameter of the inlet) is chosen so that the inlet flow stream 50 has a sufficient exit velocity V4 to entrain the air. Unnecessary high convergence should be avoided because backpressure at the nozzle is directly proportional to the amount of convergence of each nozzle.

In order for entrainment of air to occur, the velocity V4 (including direction and magnitude) of the inlet flow stream 50 must differ from the velocity V5 of the diverted flow stream 52 along the free surface 45 in the area of impingement. In this embodiment, the velocity V5 of the diverted flow stream 52 is directed at about a 45-degree angle relative to the velocity V4 of the inlet flow stream 50 at point F3.

Downstream from the entrainment device 30, the inlet flow stream 50 and the diverted flow stream 52 rejoin. Entrainment of air into the inlet flow stream 50 reduces the viscosity and density of the boundary layer flow 22. As discussed above, the reduced viscosity and density in the boundary layer results in a corresponding reduction in skin friction drag. For example, it has been estimated that a 50% air/water mixture will reduce skin friction on the hull of a submerged vessel by about 50%.

The basic function of the entrainment device 30 is to create a reduced pressure region into which air is drawn and to entrain air into the boundary layer flow 22 through turbulent mixing downstream form the entrainment device 30. In this embodiment, such turbulent mixing is created by directing a second flow stream through the air at an increased velocity. The location, size, and arrangement of the entrainment device 30 will, of course, depend upon the size and configuration of the vessel 10 and the hull 14. In most applications, it will be desirable to have an array of entrainment devices 30 arranged in a row across the hull 14 at a location near the bow 18. Such an array of entrainment devices 30 is preferably transverse to the direction D of propulsion of the vessel 10. The number of entrainment devices 30 will depend upon the width of the hull 14. In some applications it may be desirable to include multiple rows of entrainment devices 30, particularly in vessels having extremely long hulls.

Different configurations could be used for the entrainment device 30, such as the alternate embodiment shown in Figs. 5-7. In Figs. 5-7, features that correspond to features shown in the first embodiment of the entrainment device 30 are designated by reference numerals that are increased by a factor of 100. For example, the second embodiment of the entrainment device is designated by reference numeral 130. The velocity reference points (V1 through V4) and flow reference points (F1 through F4) in Fig. 4 correspond to V1B through V4B and...
F_{1B} through F_{4B}, respectively, in Fig. 7. The entrainment device 130 is similar to the first embodiment of the entrainment device 30, in that it includes an inlet 134, a diverting member 136, and a plurality of nozzles 137. The primary differences between the second embodiment of the entrainment device 130 and the first embodiment 30 are in the shallower slope of the diverting member 136 and the shape of the inlet 134. These differences are best seen in Fig. 7.

Yet another embodiment of the invention is shown in Figs. 8-9, in which features that correspond to features shown in the first embodiment of the entrainment device 30 are designated by reference numerals that are increased by a factor of 200. For example, the second embodiment of the entrainment device is designated by reference numeral 230. The velocity reference points (V_1 through V_4) and flow reference points (F_1 through F_4) in Fig. 4 correspond to V_{1C} through V_{4C} and F_{1C} through F_{4C}, respectively, in Fig. 7.

The entrainment device 230 shown in Figs. 8-9 functions in essentially the same way as the two other embodiments described herein, but is adapted for use in high-speed power boats. The entrainment device 230 includes a vent 226 which comprises a channel that preferably extends transversely across the hull 214 of the vessel 10. The vent 226 extends to a point above the water line 270, so that air can flow into and out of the vent 226.

In this embodiment, the trailing edge 240 of the flow diverter 236 coincides with the front edge of the vent 226 and the downstream leading edge 241 of the hull 214 coincides with the rear edge of the vent 226. The flow diverter 236 does not protrude downwardly from the surface 216 of the hull 214. Instead, the downstream leading edge 241 of the hull 214 is recessed relative to the trailing edge 240 of the flow diverter 236, i.e., it is positioned slightly higher in the water than the trailing edge 240 of the flow diverter 236.

As in the other embodiments of the present invention, this embodiment includes an inlet 234 that directs the inlet flow stream 250 through a nozzle 237. The inclusion of the inlet 234 and nozzle 237 results in impingement mixing, and therefore, much more air entrainment than a conventional ventilated step chine. The entrainment device of the present invention could also be used in applications other than surface vessels. For example, the entrainment device could be used to reduce friction in pipe flow by placing entrainment devices on the inner surface of the pipe.

It is recognized by those skilled in the art, that changes may be made to the above-described embodiments of the invention without departing from the scope of the appended claims.

Claims

1. An apparatus (30) that entrains a secondary fluid into a primary fluid flow while the primary fluid flows along a surface (16) of an object (14), the apparatus (30) comprising:

   an inlet (34) through which a first portion (50) of the primary fluid flows, the first portion (50) of the primary fluid entering through a first opening (35) and exiting the inlet (34) through at least one nozzle (37);

   a flow diverting member (36) located downstream from the first opening (35) of the inlet (34), a second portion (52) of the primary fluid flowing over the flow diverting member (36); and

   a second opening (28) that enables the secondary fluid to flow into a first region (42) defined by a volume of reduced pressure, the second opening (28) being located at or downstream from the flow diverting member (36) and between the surface (16) of the object (14) and the second portion (52) of the primary fluid;

   characterized in that the at least one nozzle (37) directs the first portion (50) of the primary fluid through a free surface (45) located where the second portion (52) of the primary fluid abuts the first region (42), so that at least a portion of the secondary fluid is entrained into a portion of the primary fluid; wherein the flow diverting member (36) includes a trailing edge (40) spaced apart from a lowermost portion of the at least one nozzle (37).

2. The apparatus of claim 1, further characterized in that the surface (16) of the object (14) includes a downstream leading edge (41) located downstream from the trailing edge (40) of the flow diverting member (36), and the trailing edge (40) is positioned below the downstream leading edge (41).

3. The apparatus of claim 2, further characterized in that the at least one nozzle (37) is located below the downstream leading edge (41) and above the trailing edge (40).

4. The apparatus of any of claims 1, 2, or 3, further characterized in that the flow diverting member (36) protrudes downwardly from the surface (16) of the object (14).

5. The apparatus of any of claims 1 to 4, further characterized in that the first portion (50) of the primary fluid exits the at least one nozzle (37) along a path that is parallel to the surface (16) of the object (14).

6. The apparatus of any of claims 1 to 5, further characterized in that the second opening (28) is located downstream from the at least one nozzle (37).

7. The apparatus of any of claims 1 to 6, further char-
The method of claim 13, further characterized in that at least a portion of the inlet (34) is recessed into the surface (16) of the object (14).

8. The apparatus of any of claims 1 to 7, further characterized in that the at least one nozzle (37) has an exit end, and the opening (28) is located downstream from the exit end of the at least one nozzle (37).

9. The apparatus of any of claims 1 to 8, further characterized in that the at least one nozzle (37) is a converging nozzle.

10. The apparatus of any of claim 1 to 9, further characterized in that the flow diverting member (36) has a leading edge, and the leading edge of the flow diverting member (36) is located no lower than the lowermost portion of the at least one nozzle (37).

11. The apparatus of any of claim 1 to 10, further characterized in that the apparatus (30) is attached to the surface (16) of the object (14).

12. A vessel (10) characterized by an apparatus (30) according to any one of claims 1 to 11.

13. A method for reducing frictional drag on a hull (14) of an object designed to be propelled through a primary fluid, the hull (14) having a surface (16) that is at least partially submerged in the primary fluid, the method comprising:

- separating a first portion (50) of the primary fluid from a second portion (52) of the primary fluid by passing the second portion (52) of the primary fluid over a trailing edge (40) of a flow diverting member (36), which results in a reduced pressure region (42) located between the second portion (52) of the primary fluid and the surface (16) of the object;
- providing an opening (28) that enables a secondary fluid to flow into the reduced pressure region (42), the secondary fluid having a lower density than the primary fluid; and characterized by

entraining at least a portion of the secondary fluid into a portion of the primary fluid by directing the first portion (50) of the primary fluid through a nozzle (37) and impinging the second portion (52) of the primary fluid with the first portion (50) of the primary fluid, wherein the trailing edge (40) of the flow diverting member (36) is spaced apart from a lowermost portion of the nozzle (37).

14. The method of claim 13, further characterized by entraining at least a portion of the secondary fluid into a portion of the primary fluid by impinging the second portion (52) of the primary fluid with the first portion (50) of the primary fluid comprises directing the first portion (50) of the primary fluid through the reduced pressure region (42).

15. The method of claim 13 or 14, further characterized by entraining at least a portion of the secondary fluid into a portion of the primary fluid by impinging the second portion (52) of the primary fluid with the first portion (50) of the primary fluid comprises passing the first portion (50) of the primary fluid through the nozzle (37) which increases the velocity of the first portion (50) of the primary fluid.

**Patentansprüche**

1. Vorrichtung (30), welche ein sekundäres Fluid in einen Strömung eines primären Fluids während eines Vorbeiströmens des primären Fluids an einer Oberfläche (16) eines Objekts (14) mitnimmt aufweisend:

- einen Einlass (34), durch den ein erster Anteil (50) des primären Fluids fließt, wobei der erste Anteil (50) des primären Fluids durch eine erste Öffnung (35) eingeführt und den Einlass (34) durch zumindest eine Düse (37) verlässt,
- ein Strömungsablenkteil (36), das stromabwärts zur ersten Öffnung (35) des Einlasses (34) angeordnet ist, wobei ein zweiter Anteil (52) des primären Fluids über das Strömungsablenkteil (36) fließt, und
- eine zweite Öffnung (28), die dem sekundären Fluid ein Einstromen in einen durch ein Volumen verringerten Drucks definierten ersten Bereich (42) ermöglicht, wobei die zweite Öffnung (28) am oder stromabwärts zum Strömungsablenkteil (36) und zwischen der Oberfläche (16) des Objekts (14) und dem zweiten Anteil (52) des primären Fluids angeordnet ist;

dadurch gekennzeichnet, dass die zumindest eine Düse (37) den ersten Anteil (50) des primären Fluids durch eine dort, wo der zweite Anteil (52) des primären Fluids mit dem ersten Bereich (42) zusammenkommt, befindliche freie Fläche (45) führt, sodass zumindest ein Teil des sekundären Fluids in einen Teil des primären Fluids mitgerissen wird, wobei das Strömungsablenkteil (36) eine von einem am niedrigsten gelegenen Teil der zumindest einen Düse (37) bestandende Hinterkante (40) aufweist.

2. Vorrichtung nach Anspruch 1, dadurch weiter gekennzeichnet, dass die Oberfläche (16) des Objekts (14) eine stromabwärts der Hinterkante (40) des Strömungsablenkteils (36) angeordnete hintere Anströmkante (41) aufweist und die Hinterkante (40) unterhalb der hinteren Anströmkante (41) liegt.
3. Vorrichtung nach Anspruch 2, dadurch weiter gekennzeichnet, dass die zumindest eine Düse (37) unterhalb der hinteren Anströmkante (41) und oberhalb der Hinterkante (40) angeordnet ist.

4. Vorrichtung nach einem der Ansprüche 1, 2 oder 3, dadurch weiter gekennzeichnet, dass das Strömungsablenkteil (36) nach unten von der Oberfläche (16) des Objekts (14) hervorsteht.

5. Vorrichtung nach einem der Ansprüche 1 bis 4, dadurch weiter gekennzeichnet, dass der erste Anteil (50) des primären Fluids die zumindest eine Düse (37) entlang eines Weges verlässt, der parallel zur Oberfläche (16) des Objekts (14) verläuft.

6. Vorrichtung nach einem der Ansprüche 1 bis 5, dadurch weiter gekennzeichnet, dass die zweite Öffnung (28) stromabwärts der zumindest einen Düse (37) angeordnet ist.

7. Vorrichtung nach einem der Ansprüche 1 bis 6, dadurch weiter gekennzeichnet, dass zumindest ein Teilbereich des Einlasses (34) in die Oberfläche (16) des Objekts (14) vertieft ist.

8. Vorrichtung nach einem der Ansprüche 1 bis 7, dadurch weiter gekennzeichnet, dass die zumindest eine Düse (37) ein Austrittsende aufweist und die Öffnung (28) stromabwärts des Austrittsendes der zumindest einen Düse (37) angeordnet ist.

9. Vorrichtung nach einem der Ansprüche 1 bis 8, dadurch weiter gekennzeichnet, dass die zumindest eine Düse (37) eine konvergente Düse ist.

10. Vorrichtung nach einem der Ansprüche 1 bis 9, dadurch weiter gekennzeichnet, dass der Strömungsablenkteil (36) eine Anströmkante aufweist und die Anströmkante (41) des Strömungsablenkteil (36) nicht niedriger als der am niedrigsten gelegene Teil der zumindest einen Düse (37) liegt.

11. Vorrichtung nach einem der Ansprüche 1 bis 10, dadurch weiter gekennzeichnet, dass die Vorrichtung (30) an der Oberfläche (16) des Objekts (14) angebracht ist.

12. Wasserfahrzeug (10) gekennzeichnet durch eine Vorrichtung (30) nach einem der Ansprüche 1 bis 11.

13. Verfahren zur Verringerung des Reibungswiderstands an einer Hülle (14) eines Objekts, das zur Fortbewegung durch ein primäres Fluid ausgelegt ist, wobei die Hülle (14) eine Oberfläche (16) hat, die zumindest zum Teil in das primäre Fluid eingetaucht ist, wobei das Verfahren beinhaltet:

- Trennen eines ersten Anteils (50) des primären Fluids von einem zweiten Anteil (52) des primären Fluids dadurch, dass der zweite Anteil (52) des primären Fluids über eine Hinterkante (40) eines Strömungsablenkteils (36) geleitet wird, wodurch sich ein zwischen dem zweiten Anteil (52) des primären Fluids und der Oberfläche (16) des Objekts (14) liegender Bereich (42) verringerten Drucks ergibt;
- Bereitsstellen einer Öffnung (28), die einem sekundären Fluid ein Einströmen in den Bereich (42) verringerten Drucks ermöglicht, wobei das sekundäre Fluid eine geringere Dichte hat als das primäre Fluid; und
- gekennzeichnet ist durch Mitreißen zumindest eines Teils des sekundären Fluids in einen Teil des primären Fluids durch Führen des ersten Anteils (50) des primären Fluids durch eine Düse (37) und Auftreff en des zweiten Anteils (52) des primären Fluids auf den ersten Anteil (50) des primären Fluids, wobei die Hinterkante (40) des Strömungsablenkteils (36) von einem am niedrigsten gelegenen Teil der Düse (37) beabstandet ist.

14. Verfahren nach Anspruch 13, dadurch weiter gekennzeichnet, dass das Mitreißen zumindest eines Teils des sekundären Fluids in einen Teil des primären Fluids durchführen des ersten Anteils (50) des primären Fluids durch eine Düse (37) und Auftreffen des zweiten Anteils (52) des primären Fluids auf den ersten Anteil (50) des primären Fluids, wobei die Hinterkante (40) des Strömungsablenkteils (36) von einem am niedrigsten gelegenen Teil der Düse (37) beabstandet ist.

15. Verfahren nach Anspruch 13 oder 14, dadurch weiter gekennzeichnet, dass das Mitreißen zumindest eines Teils des sekundären Fluids in einen Teil des primären Fluids durchführen des zweiten Anteils (52) des primären Fluids auf den ersten Anteil (50) des primären Fluids das Führen des ersten Anteils (50) des primären Fluids durch den Bereich verringerten Drucks (42) beinhaltet.

Revendications

1. Appareil (30) qui entraîne un fluide secondaire dans un écoulement de fluide primaire pendant que le fluide primaire s'écoule le long d’une surface (16) d’un objet (14), l’appareil (30) comprenant :

- une admission (34) à travers laquelle une première partie (50) du fluide primaire s’écoule, la première partie (50) du fluide primaire entrant par une première ouverture (35) et sortant de l’admission (34) par au moins une buse (37) ;
- un organe de déviation d’écoulement (36) situé
en aval de la première ouverture (35) de l'admission (34), une seconde partie (52) du fluide primaire s'écoulant sur l'organe de déviation d'écoulement (36) ; et une seconde ouverture (28) qui permet au fluide secondaire de s'écouler dans une première région (42) définie par un volume de pression réduite, la seconde ouverture (28) étant située au niveau ou en aval de l'organe de déviation d'écoulement (36) et entre la surface (16) de l'objet (14) et la seconde partie (52) du fluide primaire ; caractérisé en ce que la au moins une buse (37) dirige la première partie (50) du fluide primaire à travers une surface libre (45) située là où la seconde partie (52) du fluide primaire est adjacente à la première région (42), de sorte qu'au moins une partie du fluide secondaire est entraînée dans une partie du fluide primaire ; dans lequel l'organe de déviation d'écoulement (36) comprend un bord de fuite (40) espacé d'une partie la plus basse de ladite au moins une buse (37).

2. Appareil selon la revendication 1, caractérisé en outre en ce que la surface (16) de l'objet (14) comprend un bord d'attaque aval (41) situé en aval du bord de fuite (40) de l'organe de déviation d'écoulement (36), et le bord de fuite (40) est positionné en dessous du bord d'attaque en aval (41).

3. Appareil selon la revendication 2, caractérisé en outre en ce que ladite au moins une buse (37) est située en dessous du bord d'attaque en aval (41) et au-dessus du bord de fuite (40).

4. Appareil selon l'une quelconque des revendications 1, 2 ou 3, caractérisé en outre en ce que l'organe de déviation d'écoulement (36) fait saillie vers le bas à partir de la surface (16) de l'objet (14).

5. Appareil selon l'une quelconque des revendications 1 à 4, caractérisé en outre en ce que la première partie (50) du fluide primaire sort de ladite au moins une buse (37) le long d’un trajet qui est parallèle à la surface (16) de l’objet (14).

6. Appareil selon l’une quelconque des revendications 1 à 5, caractérisé en outre en ce que la seconde ouverture (28) est située en aval de ladite au moins une buse (37).

7. Appareil selon l’une quelconque des revendications 1 à 6, caractérisé en outre en ce qu’au moins une partie de l’admission (34) est en retrait dans la surface (16) de l’objet (14).

8. Appareil selon l’une quelconque des revendications 1 à 7, caractérisé en outre en ce que ladite au moins une buse (37) a une extrémité de sortie, et l’ouverture (28) est située en aval de l’extrémité de sortie de ladite au moins une buse (37).

9. Appareil selon l’une quelconque des revendications 1 à 8, caractérisé en outre en ce que ladite au moins une buse (37) est une buse convergente.

10. Appareil selon l’une quelconque des revendications 1 à 9, caractérisé en outre en ce que l’organe de déviation d’écoulement (36) a un bord d’attaque, et le bord d’attaque de l’organe de déviation d’écoulement (36) n’est pas situé plus bas que la partie la plus basse de ladite au moins une buse (37).

11. Appareil selon l’une quelconque des revendications 1 à 10, caractérisé en outre en ce que l’appareil (30) est fixé à la surface (16) de l’objet (14).

12. Vaisseau (10) caractérisé par un appareil (30) selon l’une quelconque des revendications 1 à 11.

13. Procédé de réduction de la traînée de frottement sur une coque (14) d’un objet conçu pour être propulsé à travers un fluide primaire, la coque (14) ayant une surface (16) qui est au moins partiellement submergée dans le fluide primaire, le procédé comprenant :

la séparation d’une première partie (50) du fluide primaire d’une seconde partie (52) du fluide primaire en faisant passer la seconde partie (52) du fluide primaire sur un bord de fuite (40) d’un organe de déviation d’écoulement (36), ce qui crée une région de pression réduite (42) située entre la seconde partie (52) du fluide primaire et la surface (16) de l’objet ; la fourniture d’une ouverture (28) qui permet à un fluide secondaire de s’écouler dans la région de pression réduite (42), le fluide secondaire ayant une masse volumique inférieure au fluide primaire ; et caractérisé par l’entraînement d’au moins une partie du fluide secondaire dans une partie du fluide primaire en dirigeant la première partie (50) du fluide primaire à travers une buse (37) et en faisant se rencontrer la seconde partie (52) du fluide primaire et la première partie (50) du fluide primaire, dans lequel le bord de fuite (40) de l’organe de déviation d’écoulement (36) est espacé d’une partie la plus basse de la buse (37).

14. Procédé selon la revendication 13, caractérisé en outre par l’entraînement d’au moins une partie du fluide secondaire dans une partie du fluide primaire en faisant se rencontrer la seconde partie (52) du fluide primaire et la première partie (50) du fluide
15. Procédé selon la revendication 13 ou 14, caractérisé en outre par l’entraînement d’au moins une partie du fluide secondaire dans une partie du fluide primaire en faisant se rencontrer la seconde partie (52) du fluide primaire et la première partie (50) du fluide primaire comprenant le passage de la première partie (50) du fluide primaire à travers la buse (37), ce qui augmente la vitesse de la première partie (50) du fluide primaire.
Fig. 6
REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader’s convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 6125781 A [0009]