Sept. 29, 1964 J. D. BROOKS 3,150,625

HYDRODYNAMIC APPARATUS

Filed May 1, 1962

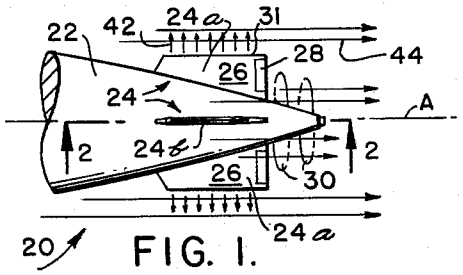


FIG. 1.

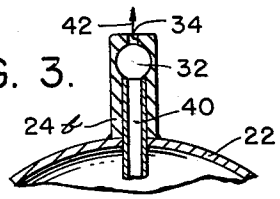


FIG. 3.

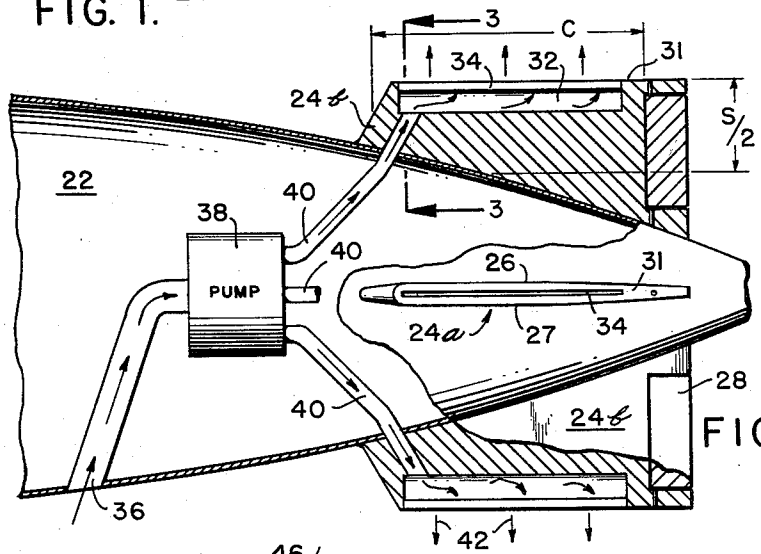


FIG. 2.

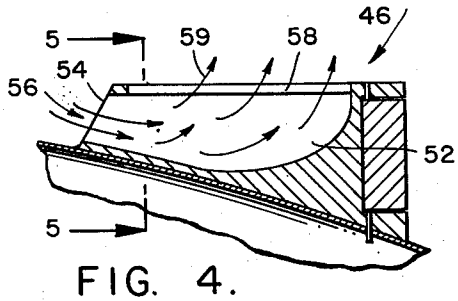


FIG. 4.

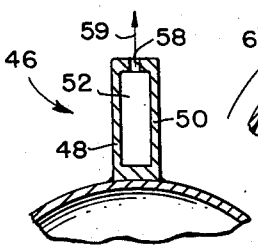


FIG. 5.

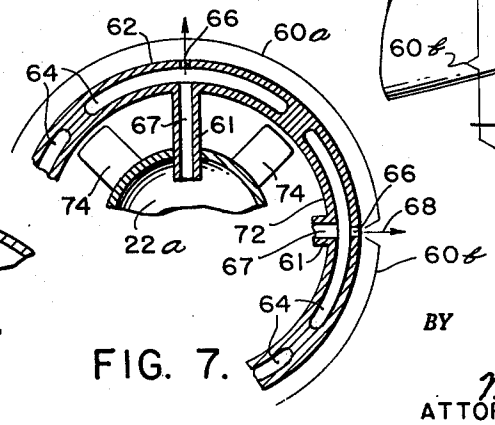


FIG. 7.

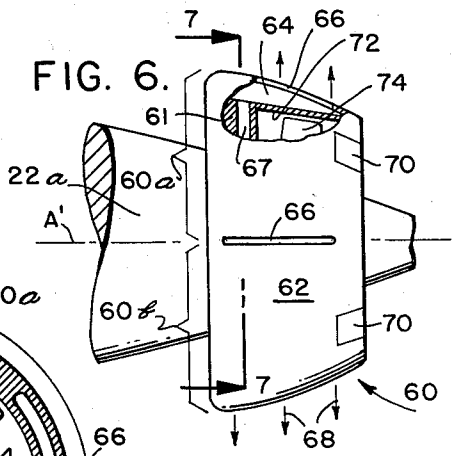


FIG. 6.

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United States Patent Office 3,150,625 Patented Sept. 29, 1964

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HYDRODYNAMIC APPARATUS

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Filed May 1, 1962, Ser. No. 191,650
7 Claims. (Cl. 114—20)
(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to hydrofoil apparatus for stabilizing the movement of an object through a water medium, and more particularly to improvements in their stabilizing surfaces.

For purposes of this specification, a "hydrofoil" is defined as an element having a surface, flat or curved, designed to obtain reaction from the "water medium" through which it moves.

The need for stabilizing the movement of an underwater object increases with the increase of weight density of the object. In the art of underwater weapons, such as torpedoes, or missiles that are launched from underwater stations, there is a trend toward increased weight densities, and therefore a corresponding need for more effective stabilization. Normally, additional margins of stability may be simply obtained by increasing the surface area of a stabilizing hydrofoil. However, in many instances the expanse of the fins, shrouds or other stabilizing hydrofoil structures are limited by the diameter of launching tubes or other military requirements. In these instances the art has been confronted with the problem of increasing the stabilization effectiveness, while maintaining the expanse of the hydrofoil structure within the space limits.

Accordingly, an object of the invention is to provide novel and improved hydrofoil apparatus for stabilizing the movement of objects through a water medium.

Another object is to provide methods and means for improving the performance of a stabilizing hydrofoil, particularly where the space available for the hydrofoil structure is limited.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing wherein:

FIG. 1 is a top plan of the tail end of a torpedo provided with stabilizing fins forming the subject of the invention;

FIG. 2 is an enlarged view of FIG. 1, partly in section taken on line 2—2 of FIG. 1;

FIG. 3 is a fragmentary section taken along line 3—3 of FIG. 2, with the fin thickness shown to an exaggerated scale;

FIG. 4 is a longitudinal section of a modified fin structure;

FIG. 5 is a section taken along line 5—5 of FIG. 4, with the transverse width of the fin shown in an exaggerated scale;

FIG. 6 is a side elevation of the tail portion of a torpedo employing another form of the invention; and

FIG. 7 is a fragmentary section taken along line 7—7 of FIG. 6, with the radial width of the shroud ring shown in an exaggerated scale.

According to conventional theory, a stabilizing hydrofoil has a surface having at least two distinct cooperating zones. When the body being stabilized is diverted from stable movement, the forces of the water stream acting upon these distinct zones become unbalanced and the resulting force differential acts in a direction tending to restore stability. Briefly, the invention contemplates the injection of a liquid stream into the ambient water medium surrounding a stabilizing hydrofoil to form a liquid "seal" separating the distinct zones acted upon by the unbalanced forces. It has been found that such injection very noticeably improves the effectiveness of the stabilizing hydrofoil. A presently believed explanation of this phenomenon is that the unbalance forces are due to differences in the dynamic pressure of the water stream adjacent the respective distinct zones of the hydrofoil surface, and that the injected stream forms a pressure seal between these zones which is effective to cause larger pressure differentials to exist between the zones. Whatever the reason for the phenomenon, it has been definitely established that this ejection results in material improvement in the stability of a body moving through water.

Referring now to the drawing and in particular to FIG. 1, the invention is shown in application to a self-propelled torpedo 20, having a body which forms a rearwardly tapered tail cone 22. Affixed to tailcone 22 are four longitudinally extending fixed stabilizing fins 24 in equiangularly spaced relationship about the longitudinal axis A of torpedo 20. Two of the fins 24*a*, 24*a* form a diametrically opposed pair aligned along a normally horizontal plane, and the other two 24*b*, 24*b* form another such pair aligned along a normally vertical plane. Each fin 24 is in effect a hydrofoil surface with opposed surfaces symmetrically formed about its plane of alignment. For example, the fins 24*a* have an upper surface 26 and a lower surface 27, FIG. 2. Disposed behind each stabilizing fin 24, and forming a relatively smooth continuation thereof, is a conventional steering rudder 28. Each rudder is pivotally mounted about a radial axis generally coinciding with the front edge of the rudder, and steering of the torpedo is effected by controlling the deflection of the rudders about their associated axes, in a conventional manner. One or more propellers 30 are disposed at the rear end of torpedo 20 to propel same.

Formed in each fin 24, in a position adjacent its outer or fin tip 31 edge, is a longitudinally extending cylindrical chamber 32, best shown in FIGS. 2 and 3. Each chamber 32 communicates with ambient water by a narrow radially extending slit-like discharge orifice or opening 34. Sea water is taken in through an intake 36, and pumped by means of a suitable pump 38 through delivery lines 40 to chamber 32. The pressure of pump 38 causes water to be discharged or ejected from each chamber 32 into the ambient water through an opening 34 associated with the chamber. The water being discharged through openings 34 form four continuous sheet-like streams or jets 42 aligned along the horizontal or vertical planes of alignment of the respective fins. Each jet 42 flows in a radially outward direction, which is substantially perpendicular to the stream lines 44 of the water medium surrounding the torpedo. It will be apparent that discharge openings 34 form a limited or restricted outlet for chambers 32 and are therefore in effect nozzles for the ejection of jets 42. Pump intake 36 is preferably adapted to take water from the boundary layer immediately adjacent the torpedo body, where the dynamic pressure is relatively low, to reduce the momentum losses of the pumping system. As will be apparent from inspection of FIG. 2, the "half-span" $S/2$ which is the medium distance between the inner and outer boundary of each fin, is short relative to the "Chord" C, which is the medium distance between the leading and trailing edge of each fin. Fins having such relative proportions are commonly called "low aspect ratio" fins.

The operation of fins 24 and the water ejection arrangement will now be explained according to the present understanding of the invention. Let it be assumed that

initially the torpedo 20 is moving with a zero angle of attack relative to the stream lines 44, FIG. 1, of the water medium. In this condition the flow stream exerts equal forces on surfaces 26 and 27 of the pair of fins 24 that are aligned along the horizontal plane, and therefore such forces are balanced and the effective vertical force on the horizontally aligned pair of fins is zero. Suppose then that some disturbance causes the torpedo to pitch in a clockwise direction in the vertical plane. As the result of this pitching movement the horizontally aligned fins 24*a* develop a positive angle of attack relative to stream lines 44. For this condition of a positive angle of attack the dynamic pressure of the water stream adjacent upper surface 26 of the fins decreases, relatively, and the dynamic pressure of the stream adjacent lower surface 27 increases. The sheet-like jets 42 issuing from the lateral edges of the horizontal fins 24*a* effectively form a pressure seal between the zones adjacent surfaces 26 and 27 at each fin tip 31, and thereby augmenting the differential pressure across the fins. This pressure differential, created by the angle of attack and augmented by jets 42, exerts an upwardly directed stabilizing force on fins 24*a*. Since the fins are near the tail of the torpedo such upward force tends to overcome the clockwise pitching movement of the torpedo and restore it to stable movement. In a similar manner, diversions from a normal zero angle of attack in a horizontal plane are resisted and corrected by the vertically aligned stabilizing fins 24*b* and the jets associated therewith. The degree of effectiveness of jets 42 in improving the torpedo stability has been found to increase with the ratio of the momentum of the jets 42 relative to that of the flow stream which the jets displace. Proportioning of this ratio may be accomplished by suitable choice of total orifice area of openings 34 and delivery pressure furnished by pump 38. Although jets 42 will produce reactive forces, these forces are effectively balanced since the jets are equiangularly spaced about the torpedo axis A.

FIGS. 4 and 5 show a modified form of stabilizing fin 46, which operates to eject a laterally directed stream of water by ram pressure instead of an internal pumping system. Fin 46 is of a hollow construction having relatively thin walls 48 and 50. The space between walls 48 and 50 form a water conduit chamber 52 which opens to the leading edge 54 of the fin forming a ram intake opening 56. An elongated narrow slit-like discharge opening 58, similar to opening 34 of FIG. 1, is formed in the outer lateral edge of the fin. Chamber 52 is contoured to guide the water from intake opening 56 to discharge opening 58 and to change the direction of water flow to cause it to flow in a generally radially outward direction. As fin 46 moves, water is scooped into conduit chamber 52 by intake opening 56 and is thence discharged through opening 58, under the difference between the ram pressure at the leading edge and the much lower dynamic pressure at the outer lateral edge. In a similar manner to jets 42 of FIG. 1, the water being discharged through opening 58 forms a continuous sheet-like jet 59 aligned along the plane of alignment of fin 46 and flowing in an approximately radially outwardly direction.

Referring now to FIGS. 7 and 8, a torpedo tailcone 22*a* is provided with a concentrically disposed annular element commonly called a "shroud ring" 60. Shroud ring 60 is mounted upon the tailcone 22*a* by means of four equiangularly spaced struts 61. The outer surface 62 of shroud ring 60 provides a stabilizing hydrofoil surface, as will be discussed more fully in connection with the description of operation to follow. Shroud ring 60 is formed from a uniform streamlined section which, in a central longitudinal plane, has a substantially greater length than radial thickness. Thus shroud ring 60 is a continuous hydrofoil section surrounding the torpedo tailcone 22*a*. Formed in shroud ring 60 are four equiangularly spaced chambers 64. Communicating each chamber 64 and ambient water is a radially extending slit or elongated discharge opening 66, each slit or discharge opening being aligned in either a horizontal or vertical plane through the torpedo axis A'. Suitable means is provided to supply water under pressure to chambers 64, such as an internal pumping system similar to that of FIG. 1, having pump delivery lines 67 extending through the mounting struts 61. Alternatively, ram pressure may be employed by opening chamber 64 to the leading edge of shroud ring 60 to form ram intake openings similar to intake opening 56 of FIGS. 4 and 5. The pressurized water supplied to chambers 64 is discharged from the chamber into the water medium, and forms four continuous sheet-like radially outwardly flowing jes 68 aligned along the horizontal or vertical plane of alignment of the respective opening 66 through which each jet flows. To complete the description of the parts associated with shroud ring 60, four conventional equiangularly spaced rectangular steering tabs 70, are disposed in rectangular openings formed in the trailing edge of the shroud ring. Each tab 70 is pivotally mounted about an axis generally coinciding with the front edge of the tab, and steering of the torpedo is effected by controlling the deflection of each tab in conjunction with the other tabs, in a conventional manner. In torpedoes of the pump-jet propulsion type, the inner surface 72 of shroud ring 60 may serve as ducting within which one or more pump jet blades 74 may rotate. The pump jet blades 74 are not an essential feature of the invention, their inclusion merely indicating that the presence of the invention does not exclude shrouds that further serve as pump jet ducts.

The operation of shroud ring 60 will be explained by illustration of the effect of a position angle of attack in the vertical plane, and for purposes of such explanation it will be convenient to consider shroud ring 60 as consisting of an upper half-ring 60*a* and a lower half-ring 60*b*. The positive angle of attack will cause the pressure of the flow stream to decrease in the zone adjacent the outer surface of upper half-ring 60*a* and increase in the zone adjacent the outer surface 62 of lower half-ring 60*b*. The pressure differential between such zones produces an upward directed stabilizing force acting on the tail of the torpedo, which stabilizing force tends to restore the torpedo to its zero angle of attack condition. It will be apparent, therefore, that outer surface 62 of the complete shroud ring 60 forms a continuous stabilizing hydrofoil surface, of which diametrically opposed portions cooperate to produce unbalanced forces which resist diversions from stable movement. The operation of shroud ring 60, thus far described is, per se, old and conventional. In accordance with the present invention the jets 68 that lie in the horizontal plane form a liquid seal which separates the zones adjacent the outer surfaces of upper and lower half-rings 60*a* and 60*b*, respectively, and thereby augment the effectiveness of shroud ring surface 62, alone, in stabilizing the torpedo. Similarly, the jets 68 that lie in the vertical plane operate to augment the stabilizing effect of the shroud ring for deviations from a zero angle of attack in the horizontal plane.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. In combination with a vehicle adapted for travel through a water medium, and having a stabilizing hydrofoil with first and second cooperating surfaces adapted to be acted upon by unbalanced forces of the water medium to produce a stabilizing force when said hydrofoil is diverted to an angle of attack, said vehicle including means for delivering at least two continuous sheet-like

streams of liquid into ambient water adjacent the hydrofoil and in directions generally perpendicular to vehicle movement, said directions being such that the streams form a liquid seal between said first and second surfaces and such that the reactive forces produced by the streams in directions perpendicular to movement are balanced, to thereby increase the stabilizing effect of the hydrofoil.

2. A device in accordance with claim 1 wherein said stabilizing hydrofoil comprises a plurality of longitudinally extending and angularly spaced fins affixed to said vehicle, said means for delivering a stream cooperating with each fin to form a sheet-like stream of liquid flowing in a radially outward direction from each fin and aligned along the plane of the fin.

3. A device in accordance with claim 1 wherein said stabilizing hydrofoil comprises a continuous shroud ring surrounding and formed about the central axis of the vehicle, said means for delivering a stream cooperating with said shroud ring to form a plurality of angularly spaced sheet-like streams of liquid flowing in a radially outward direction from said shroud ring.

4. A device in accordance with claim 1 wherein said means for delivering the liquid includes a pump.

5. A device in accordance with claim 1 wherein said means for delivering the liquid includes a ram intake, said ram intake being formed in the leading edge of said stabilizing hydrofoil.

6. Apparatus for stabilizing an underwater vehicle in movement along its longitudinal axis comprising, in combination; a set of four stabilizing fins equiangularly spaced about said axis, each of said fins having opposed surfaces which are symmetrically formed relative to a plane through said longitudinal axis and having an outer edge portion, said set of fins adapted to generate a stabilizing force upon deviation of the vehicle from movement along said direction, each of said fins having an elongated liquid discharge opening formed in its outer edge portion, and means for delivering a continuous stream of liquid through each discharge opening into the ambient water medium, said streams of liquid each forming a sheet-like jet of liquid aligned along the plane of the associated fin, to thereby increase the stabilizing effect of the fins.

7. Apparatus for stabilizing an underwater vehicle in movement along its longitudinal axis, comprising, in combination; an annular shroud ring having an outer surface, said outer surface having diametrically opposed portions adapted to generate a stabilizing force upon deviation of the vehicle from movement along said direction, said shroud ring having a set of four equiangularly spaced elongated longitudinally extended liquid discharge openings formed in the outer surface thereof, said set of four openings comprising two pairs of diametrically opposed openings, and means for delivering a continuous stream of liquid through each opening of said set of openings into the surrounding water medium, the streams delivered through diametrically opposed openings forming radially outwardly directed sheet-like jets of liquid lying in a single plane through said longitudinal axis to thereby increase the stabilizing effect of the annular shroud ring.

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