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WATER ENTRY SYSTEM

STATEMENT OF GOVERNMENT INTEREST

[0001] 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 therefore.

CROSS REFERENCE TO OTHER PATENT APPLICATIONS

[0002] Not applicable.

BACKGROUND OF THE INVENTION

(1) Field of the Invention

[0003] The present invention relates to water entry of unmanned underwater vehicles and more specifically to suppression of cavity formation upon entry of such vehicles into the water.

(2) Description of the Prior Art

[0004] Underwater vehicles, such as torpedoes, are generally designed for speed, reliability and stealthy operation. Such vehicles are often introduced into the water by means of a high-speed air launch platform or via an in-air rocket launch system from a surface ship.

[0005] As is known in the art, upon impact with water of an object traveling at high-speed, a cavity is quickly established about the object behind its front most portion. The cavity causes only the front most portion of the object to be in contact with the liquid. As a result, the body only experiences pressure drag during the cavity formation and added mass phases, i.e., when the body accelerates the fluid elements from rest. There is virtually no skin friction drag on the body. Since the cavity greatly reduces drag, the body can travel a considerable distance in the fluid before it slows to the point where the cavity closes on the underwater body.

[0006] The drag associated with an object is a function of how large, how heavy and how blunt the object entering the water is. An unmanned underwater vehicle (UUV), such as a torpedo or other torpedo-shaped object, will travel a considerable distance as it enters the water due to the formation of the cavity. This results in the need for high-speed water entries of such vehicles to be conducted in sufficiently deep water or at lower speeds. These restrictions reduce the allowable operational window for an air-dropped UUV.

[0007] What are needed are systems to increase the drag of an underwater vehicle without compromising vehicle stealth. In addition, there is a need to reduce the speed of the vehicle after entering the water to improve operation in shallow water environments. Further, the systems need to be integrated into current UUV hull configurations. Still further, there is a need that the systems not interfere with normal vehicle operations.

SUMMARY OF THE INVENTION

[0008] It is therefore a general purpose and primary object of the present invention to provide systems for increasing the drag of an underwater vehicle so as to slow its speed through the water.

[0009] The drag is increased by disrupting the cavity that forms during high-speed transit of the vehicle through the water. A series of inlet ports are positioned in regions of the vehicle where pressure stagnation occurs during transit. Flow passages connect these inlets to outlet ports at regions of lower pressure. Pressure differences between respective inlet and outlet ports cause flow jets of air or water in the respective passages. The jets produce a high flow rate normal to the original cavity boundary.

[0010] The jets serve to increase drag in at least two manners. In one case, the flow jet normal to the cavity interface broadens the cavity to increase drag and slow the vehicle. In a second case, the jets cause waves on the cavity interface to break down the stable cavity. As a result, the vehicle surface is wetted, skin friction drag is produced and the vehicle slows.

[0011] In one embodiment, a cavity reducing system for an aquatic vehicle increases drag on an underwater vehicle. The system includes one or more inlet ports positioned at a stagnation region of the vehicle. One or more outlet ports are positioned at a cavity formation region of the vehicle. The system further includes passageways connecting the inlet ports to the outlet ports. A pressure difference between one of the inlet ports and one of the outlet ports causes a flow of water through the connecting passageway. The outlet port directs the flow away from the vehicle to disrupt cavity formation about the vehicle and increase vehicle drag.

[0012] In another embodiment, one or more of the outlet ports are positioned at a propulsor region of the vehicle. In a further embodiment, closable covers are provided for the outlet ports. Closable covers can also be provided for the inlet ports. One or more sensors trigger operation of the covers depending on the speed of the vehicle. The sensors can be positioned within a forward portion of the vehicle adjacent the passageways.

[0013] In a further embodiment, a forward portion of a high-speed underwater vehicle comprises one or more inlet ports at a stagnation region of the forward portion; one or more outlet ports at a cavity formation region of the forward portion; and corresponding passageways through the forward portion to fluidly connect respective inlet ports and outlet ports. A flow from one inlet port through the passageway is directed by the outlet port to disrupt formation of a cavity about the forward portion.

[0014] In another embodiment, closable covers are provided for the outlet ports and one or more sensors within the forward portion initiate activation of the closable covers depending on a speed of the vehicle. The forward portion of the high-speed underwater vehicle can comprise instrumentation for controlling operation of the vehicle.

[0015] In another embodiment, an aquatic vehicle includes a stagnation region of the vehicle surface having an inlet port formed therein and a cavity formation region of the vehicle surface having an outlet port formed therein. The aquatic vehicle also includes a confined passageway through the, which fluidly connects the inlet port and the outlet port. The passageway is capable of confining a flow from the inlet port through the passageway to the outlet port. The flow is directed by the outlet port to disrupt formation of a cavity in the cavity formation region.

[0016] In a further embodiment, the vehicle includes a controller positioned within the vehicle and a closable cover for the outlet port. The controller selectively opens and closes the closable cover depending on a speed of the vehicle. In another embodiment, the vehicle further includes a propulsor region having a rear outlet port positioned therein. The vehicle can further include a controller positioned within said vehicle and a closable cover for the rear outlet port, which the controller selectively opens and closes depending on a speed of the vehicle. In addition, the propulsor region of the vehicle can include a rear inlet port positioned therein.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] A more complete understanding of the invention and many of the attendant advantages thereto will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein like references numerals and symbols designate identical or corresponding parts throughout the several views and wherein:

[0018] **FIG. 1** illustrates a prior art vehicle traveling through a fluid medium and having formed a cavity;

[0019] **FIG. 2** is a plot of the pressure field about the vehicle of **FIG. 1**; and

[0020] **FIG. 3** illustrates a vehicle having flow passages and traveling through a fluid medium.

DETAILED DESCRIPTION OF THE INVENTION

[0021] Referring now to **FIG. 1**, there is shown a side view of a prior art vehicle **10** upon entry into fluid medium **2**. Vehicle **10** has a pressure field associated with its motion in medium **2** in the direction of arrow **4**. At a point ***s*** along vehicle **10**, cavity **12** forms. Line **I** of **FIG. 1** illustrates the interface between cavity **12** and medium **2**. As is known in the art, the location where cavity **12** forms will depend on the geometry of vehicle **10**.

[0022] Referring also to **FIG. 2**, there is shown a plot **100** of the pressure field along the contour of vehicle **10**. Starting from an arbitrary point forward of vehicle **10** and proceeding in a direction indicated by arrow **X**, **FIG. 2** indicates that the pressure increases and reaches a maximum (P_{max}) at a stagnation region **14** along forward portion **10a** of vehicle **10**. Stagnation region **14** is the region on the vehicle substantially perpendicular to major hydrodynamic flow where pressure is at a relative maximum and velocity is at a relative minimum. Continuing along vehicle **10** to point **s**, plot **100** indicates that the pressure drops at the formation of cavity **12**. As shown in plot **100**, the pressure within cavity **12** is low compared with that at stagnation region **14**. This pressure difference may be used to passively drive a flow.

[0023] As is known to those of skill in the art, the geometry of vehicle **10** may result in a thin vapor layer being formed at forward portion of vehicle **10** (not shown in **FIG. 1**). However, the pressure in the vapor layer would also be at the stagnation pressure such that the shape of plot **100** would remain generally the same and the pressure difference also may be used to passively drive a flow, in this case, of vapor. For clarity, but not limitation, the following discussion is directed to the case where no vapor layer is formed.

[0024] Referring now to **FIG. 3**, there is shown a side view of vehicle **110** upon entry within fluid medium **102**. A series of inlet ports **116** are positioned in forward portion **110a** of vehicle **110**, corresponding to stagnation region **14** of **FIG. 1**. Flow passages **118**, shown in phantom in **FIG. 3**, connect inlet ports **116** to outlet ports **120**. Generally, the exterior geometry of vehicle **110** corresponds with that of vehicle **10** of **FIG. 1** with the exception of inlet ports **116** and outlet ports **120**. Outlet ports **120** are positioned along vehicle **110** at locations within cavity region **12** along vehicle **10** of **FIG. 1**.

[0025] The pressure difference between inlet ports **116** and outlet ports **120** causes flow jets to form in passages **118**. Passages **118** and outlet ports **120** are configured such that the major component of flow is directed normal to a potential cavity boundary that would otherwise form along vehicle **110**.

[0026] The normal flow (indicated by arrows **122**) can increase drag on vehicle **110** in two manners to varying degrees depending on the chosen geometry of vehicle **110**, inlet ports **116**, passages **118** and outlet ports **120**. As the sizes of the inlet ports **116**, passages **118**, or outlet ports **120** are increased, the normal flow will increase. Increased normal flow broadens the free stream flow streamlines such that a larger pressure drag is produced.

[0027] In addition, the normal flow induces wave formation on the boundary of an incipient cavity so as to hinder the formation of a stable cavity. The incipient cavity quickly breaks down and surface **110b** of vehicle **110** is wetted, increasing skin friction drag. Both the increased pressure drag and increased skin friction drag slow vehicle **110** more quickly than would otherwise be the case without the effects of the normal flow.

[0028] As shown in **FIG. 3**, rear inlets **124** can be positioned in the region of propulsor **126** to similarly drive flow to rear outlets **128** through rear passages **130**. Being positioned on the body away from the transition region, rear outlets **128** act to increase friction drag.

[0029] Flow passages **118** are confined such that instrumentation **132** can be positioned within forward portion **110a** of vehicle **110** to control operation of vehicle **110**. Additionally, sensors **134** can be located in forward portion **110** to determine when vehicle **110** has slowed sufficiently below the speed where cavity formation is a concern. Sensors **134** can be any type of fluid velocity sensor capable of detecting fluid speed in the region about vehicle **110**. Outlet covers **136** and inlet covers **138** joined to actuators can be provided for sealing outlet ports **120** and inlet ports **116** when not in use. Rear outlets **128** and rear inlets **124** can also be provided with outlet covers **136** and inlet covers **138**. Readings from sensors **134** can cause one or more controllers **140** to activate outlet covers **136** to seal outlet ports **120** and rear outlets **128** to minimize drag on vehicle **110**. For clarity but not limitation, controllers **140** are shown adjacent rear inlets **124**.

[0030] Though of minor drag consideration since normal flow is minimal, sensors **134** similarly can activate inlet covers **138** for inlet ports **116** and rear inlets **124**. For clarity of illustration in **FIG. 3**, only one of the outlet covers **136** and one of the inlet covers **138** are designated at forward portion **110a** and near propulsor **126**.

[0031] What have thus been described are systems for increasing the drag of an underwater vehicle by disrupting the cavity that forms during high-speed transit of the vehicle through the water. Inlet ports are positioned in regions of the vehicle where pressure stagnation occurs during transit. Flow passages connect these inlets to outlet ports at regions of lower pressure. The pressure differences cause jets to flow in the respective passages.

[0032] The jets are directed normal to the cavity boundary. The jets can broaden the cavity to increase drag and slow the vehicle. Additionally, or in combination, the jets can cause waves on the cavity interface to break down the stable cavity, which results in the vehicle surface being wetted, producing skin friction drag and slowing the vehicle.

[0033] In addition to inlet ports being located at a forward end of the vehicle, inlet ports may also be located near the vehicle propulsor unit. Corresponding outlet ports can be similarly positioned near the rear of the vehicle, with jets generally normal to the vehicle surface to increase friction drag and also slow the vehicle.

[0034] Sensors and other instrumentation for controlling the vehicle can be positioned at a forward end of the vehicle and can ascertain the speed of the vehicle. Once the vehicle has slowed to operational speed, the sensors can activate covers that can close the ports. The covers can decrease the noise radiated by the vehicle and hence increase the stealth of the vehicle.

[0035] By disrupting the cavity and slowing the vehicle, the systems described herein allow water entry of high-speed underwater vehicles in shallow depths, such as when torpedoes are air dropped into shallow water. The systems operate without the need for a pump, thus eliminating a cause of radiated noise.

[0036] Obviously many modifications and variations of the present invention may become apparent in light of the above teachings. For example, the flow through the passages can be controlled by the sensors selectively activating the port covers. In this manner, the rate of slowing can be controlled.

[0037] It will be understood that many additional changes in details, materials, steps, and arrangements of parts which have been described herein and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims.

Attorney Docket No. 96673

WATER ENTRY SYSTEM

ABSTRACT OF THE DISCLOSURE

A water entry system increases the drag of an underwater vehicle by disrupting the cavity that forms during high-speed transit of the vehicle through the water. A series of inlet ports are positioned in regions of the vehicle where pressure stagnation occurs during transit. Flow passages connect these inlets to outlet ports at regions of lower pressure. Pressure differences cause jets to flow in the respective passages. The jets produce a high flow rate normal to the original cavity boundary. The jets serve to increase drag in at least two manners. In one case, a flow jet normal to the cavity interface broadens the cavity to increase drag and slow the vehicle. In a second case, a jet can cause waves on the cavity interface to break down the stable cavity. As a result, the vehicle surface is wetted, producing skin friction drag and slowing vehicle.

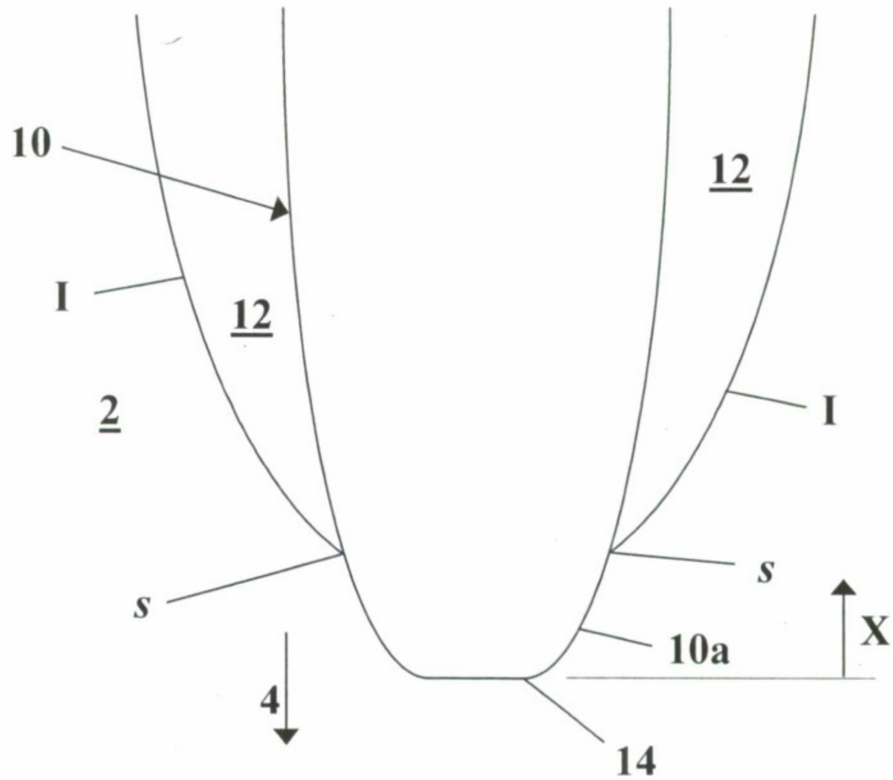

FIG. 1
(PRIOR ART)

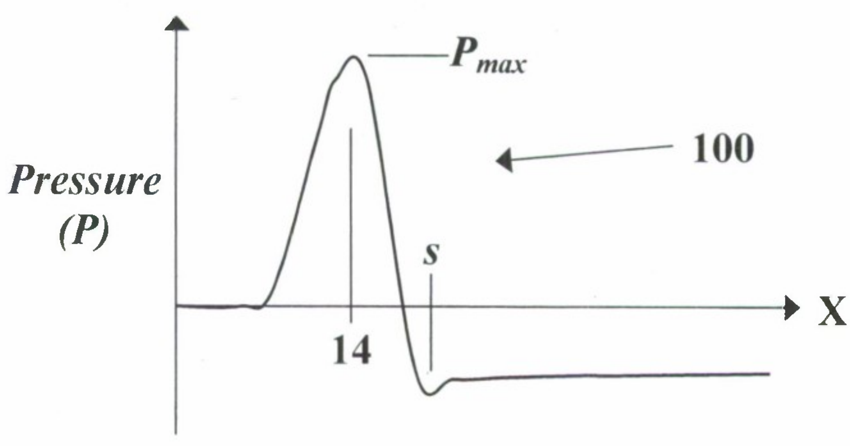

FIG. 2

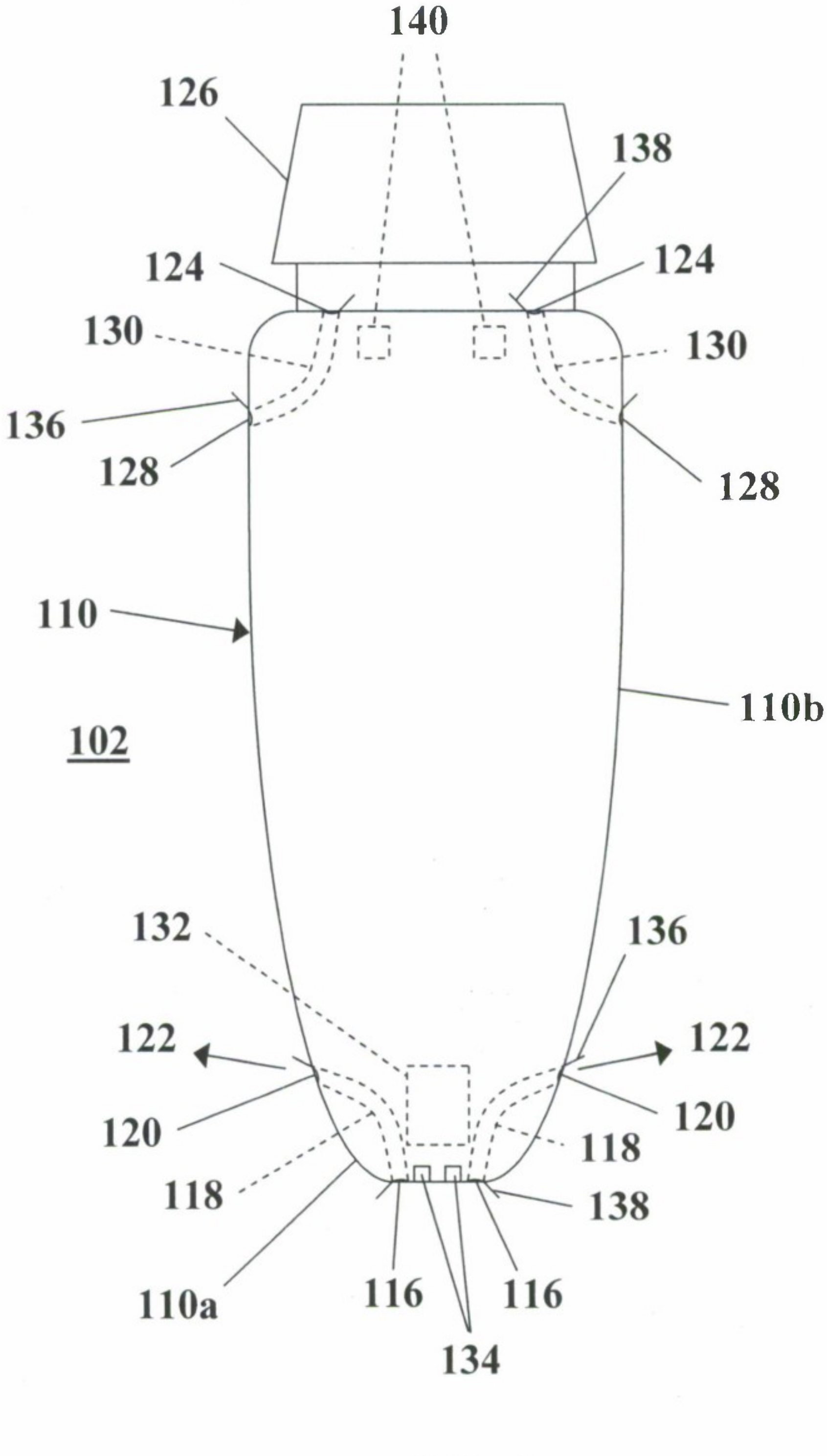
140
126
138
124
124
130
130
136
128
128
110
110b
102
132
136
122
122
120
120
118
118
138
110a
116
116
134

FIG. 3