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HYDROFOIL SLED FOR PAYLOAD TRANSPORT

Abstract

The multiple embodiments of the present invention involve a watercraft payload carrying system for which a payload can be carried and moved in a liquid such as water. The system includes a hydrofoil that when the system is accelerated, the hydrofoil lifts the system and the payload is raised relative to the waterline. In an embodiment the watercraft payload carrying system can have multiple interconnected modules where each module has a hydrofoil and receiver for carrying a payload. In an embodiment, the watercraft payload carrying system is modularly designed where the hydrofoil and receiver are removably attached.

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Background/Summary

BACKGROUND OF THE INVENTION

[0003] Watercraft, for millennia, have been used to traverse and transport payloads across oceans, seas and rivers. The economics and mission requirements for such watercraft have played a role in their design and implementation. At times, multiple watercraft have worked together to where one watercraft transports another watercraft either by being carried within one's hull or by towing.

[0004] It may be both economically or mission requirement beneficial to tow a vehicle or payload as opposed to storing such vehicle in the hull of another. Such benefits may include elimination of loading time and having a larger selection of towing watercraft for the towed vehicle or payload. Existing towing apparatus and methods would benefit from continued improvement. One of a number of improvement goals can include enabling a larger range of towing watercraft options including watercraft with smaller towing power than had been previously contemplated.

SUMMARY

[0005] In an embodiment, the present invention relates to a watercraft payload carrying system comprising a first longitudinally extending body, a connector located on a tow side for coupling with a towing watercraft, a first receiver for coupling a payload to the longitudinally extending body and a first hydrofoil coupled to an underside of said longitudinally extending body and having a chord thickness greater on the tow side.

[0006] In another embodiment, the present invention relates to a method for transporting a watercraft towable payload comprising immersing a first module and a payload into a liquid, the first module comprising a first longitudinally extending body, a connector located on a tow side for coupling with a towing watercraft, a first receiver for coupling the payload to the longitudinally extending body, and a first hydrofoil coupled to the longitudinally extending body below the longitudinally extending body and the hydrofoil having a chord thickness greater on the tow side, coupling a towing watercraft to the first module, coupling the payload to the first module, accelerating the towing watercraft and raising a majority of the payload above a waterline of the liquid.

[0007] In another embodiment, the present invention relates to a method for assembling and disassembling a watercraft payload carrying system comprising removably coupling a first longitudinally extending body to a first hydrofoil, the first hydrofoil having a chord thickness greater on a tow side and decoupling the first longitudinally extending body from the first hydrofoil.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Throughout the several views, like elements are referenced using like references. The elements in the figures are not drawn to scale and some dimensions are exaggerated for clarity.

[0009] FIG. **1** is a perspective view of a watercraft payload carrying system according to an embodiment of the present disclosure.

[0010] FIG. **2**A is a front view of the watercraft payload carrying system in FIG. **1**, according to an embodiment of the present disclosure.

[0011] FIG. **2**B is a front view of a watercraft payload carrying system according to another embodiment of the present disclosure.

[0012] FIG. **3** is a perspective view of a watercraft payload carrying system with a payload according to an embodiment of the present disclosure.

[0013] FIG. **4**A is a perspective view of a watercraft payload carrying system with multiple modules according to an embodiment of the present disclosure.

[0014] FIG. **4**B is a top view of the watercraft payload carrying system with multiple modules in

FIG. **4**A according to an embodiment of the present disclosure.
[0015] FIG. **4**C is a front view of the watercraft payload carrying system with multiple modules in FIG. **4**A according to an embodiment of the present disclosure.
[0016] FIG. **5**A is a perspective view of another watercraft payload carrying system with multiple modules according to an embodiment of the present disclosure.
[0017] FIG. **5**B is a top view of the watercraft payload carrying system with multiple modules in FIG. **5**A according to an embodiment of the present disclosure.
[0018] FIG. **6** is a flowchart illustrating the steps for transporting a watercraft towable payload.
[0019] FIG. **7** is a flowchart illustrating the steps for assembling and disassembling a watercraft payload carrying.

DETAILED DESCRIPTION OF EMBODIMENTS

[0020] The disclosed methods and systems below may be described generally, as well as in terms of specific examples and/or specific embodiments. For instances where references are made to detailed examples and/or embodiments, it should be appreciated that any of the underlying principles described are not to be limited to a single embodiment, but may be expanded for use with any of the other methods and systems described herein as will be understood by one of ordinary skill in the art unless otherwise stated specifically. Additionally, the terminology used herein is for the purpose of description and not of limitation. Furthermore, although certain methods are described with reference to steps that are presented herein in a certain order, in many instances, these steps may be performed in any order as may be appreciated by one skilled in the art; the novel method is therefore not limited to the particular arrangement of steps disclosed herein.
[0021] It must be noted that as used herein and in the appended claims, the singular forms “a”, “an”, and “the” include plural references unless the context clearly dictates otherwise. Furthermore, the terms “a” (or “an”), “one or more” and “at least one” can be used interchangeably herein. The terms “comprising”, “including”, “having” and “constructed from” can also be used interchangeably.
[0022] Referring to FIG. **1**, a watercraft payload carrying system **100** comprising a keel **110**, a connector **120**, a receiver **130** for coupling a payload to the keel and a forward hydrofoil **140** coupled to an underside **112** of the keel is shown. The keel **110** is, in an embodiment, a longitudinally extending body that can take the form of a beam with a number of possible cross-sections including a plate, T-shaped, I-shaped, U-shaped, tubular and cylindrical. In the embodiment shown in FIG. **1**, the keel **110** has a generally T-shaped cross-section where the receiver **130** forms the upper portion of the keel. The tow side or fore side of the keel may be aerodynamically contoured to provide less drag resistance when towed. The connector **120** is located on a tow side for coupling with a towing vehicle and in an embodiment, is an eye latch. The keel **110** may also include an opening to provide a volume for a portion of a payload to lie within when attached to the system **100**.
[0023] The receiver **130**, in an embodiment, is an elongated partial tube or cylinder, having a contoured portion that is complimentary in shape to a portion of the payload. The contoured portion is oval in shape, and more particularly in an embodiment, has a circular cross-section, to complimentarily match a payload having a circular cross-section. The receiver **130** extends along length of a majority of the keel **110** having an opening generally facing away from the top of the keel **110**. The contour of the receiver is shaped to optimize a contact surface area with a payload and to reduce gaps in the supporting surface provided by the receiver. In an embodiment, the receiver **130** has an interface for coupling with a platform for carrying a payload. In this embodiment, the receiver **130** may have a flat upper surface with clamps or tie downs that form the interface, that can fasten a platform such as a cargo pallet, to the receiver.
[0024] The receiver **130** has a fastener **132** that, in an embodiment, is complimentary in shape to the payload. In this embodiment, the fastener is a clamp. In other embodiments, the fastener can be

a tie-down, a full cover or a partial cover. The fastener can be affixed to the receiver or can be separately attached to the receiver and payload when used to fasten the payload to the receiver.
[0025] In an embodiment, the receiver **130** is removably coupled or attached to the keel **110**. In this embodiment, the receiver **130** forms the top portion of the keel **110** when attached, generally forming a T-shaped cross-section with the top portion forming a complimentary section to an attached payload. When removed, the keel generally forms a plate, if when attached the receiver was attached, the cross-section was T-shaped In another embodiment, the keel generally forms an inverted T-shaped cross-section if when the receiver is attached, the cross-section was I-shaped. Multiple removable keels may comprise the watercraft payload carrying system **100** such that a receiver with a complimentary shape of can be provided for multiple differently-shaped payloads while utilizing the same keel **110** and hydrofoil **140**. In an embodiment, the hydrofoil **140** is removably coupled to the keel **110**.
[0026] The hydrofoil **140** is an aerodynamically-shaped body having a chord thickness greater in one half of the body and having an airfoil-shaped cross-section. The hydrofoil is orientated such that the chord thickness is greater on the tow side. A hydrofoil has a cross-sectional shape such that when a liquid such as water flows over the hydrofoil surface, a pressure differential is created between the upper surface and lower surface creating lift. The lift of hydrofoil cause each hydrofoil to move upward towards the waterline producing force through the structural support **210**. The amount of rise of portions of the watercraft payload system **100**, including the keel **110** and structural support **210** as well as the payload, reduces the overall drag of the watercraft payload system **100** when towed. Potential damage to the payload is reduced, particularly any sensitive component, as the payload or sensitive component is raised above the waterline, such that the drag or buffeting effects are reduced.
[0027] A second hydrofoil **146** may be coupled to the keel **110** and below the keel and aft of hydrofoil **140**. Hydrofoil **146** also provides lift to the watercraft payload carrying system **100** and may be optimally positioned in conjunction with the forward hydrofoil **140** to balance lift on the watercraft payload carrying system **100** taking into account the center of gravity. When towed, the amount of rise of the payload above the waterline of the watercraft payload carrying system **100** can be increased by having two or more hydrofoils versus a single hydrofoil. Also, optimized positioning, e.g. accounting for the center of gravity of the payload or the system with the payload attached, of multiple hydrofoils can increase the amount of rise of the payload versus sub-optimized positioning.
[0028] In an embodiment, the hydrofoil **140** may have a variable camber device such as a flap, slat, spoiler or aileron to increase or decrease the hydrofoil's lift coefficient. In an embodiment, the variable camber device is set in a generally permanent position prior to a towing. The setting of the variable camber device is done to increase or decrease the lift of the hydrofoil **140** in response to the positioning of the hydrofoil or the weight of the payload. In one example, the hydrofoil **140** may be moved to its limit in creating a lever arm extending from the center of gravity of the watercraft payload carrying system **100** with the payload attached. To further increase the lever arm force generated by the hydrofoil **140**, the variable camber device is also adjusted, deflected or deployed, to increase the lift of the hydrofoil **140**. The variable camber device may also be adjusted to reduce the risk of the watercraft payload carrying system **100** becoming airborne whereby the lift generated by hydrofoil is reduced for example by a negative or lift-reducing deflection, adjustment or deployment of the variable camber device.
[0029] In another embodiment, variable camber system is part of an active system that employs feedback on the positioning of the watercraft payload carrying system **100** to adjust the camber of the hydrofoil **140**. The feedback mechanism can comprise a tilt sensor which can sense an undesirable degree of tilt of the watercraft payload carrying system **100** such that one or more hydrofoils, e.g. as shown in FIG. **1**, have their lift coefficient adjusted by the variable camber system to produce more or less lift. In an example, the watercraft payload carrying system **100** has

a forward hydrofoil **140** and an aft hydrofoil **146**. A tilt sensor located on the watercraft payload carrying system **100** detects an undesired upward tilt of the watercraft payload carrying system **100** when being towed. The variable camber system can lower the lift coefficient of the forward hydrofoil **140** or increase the lift coefficient of the aft hydrofoil **146** or some combination of both to achieve a desired level of tilt.

[0030] In an embodiment, the variable camber system employs a height sensor as a feedback mechanism. In an embodiment, the height sensor can take the form of a optical sensing device. In another embodiment, the height sensor can take the form of an accelerometer that can measure the trajectory of the watercraft payload carrying system **100**. The variable camber system can lower or raise the lift coefficient of the forward hydrofoil **140**, the lift coefficient of the aft hydrofoil **146**, or some combination of both, to achieve a desired level of height.

[0031] Referring to FIG. **2**A, an embodiment is shown where the hydrofoil **142** is a surface piercing type. A surface piercing hydrofoil **142**, during steady state towing, will have a portion of the hydrofoil **142** lie above the waterline. In this embodiment, the hydrofoil **142** extends laterally and has three elements including a base portion, **142***a* and wing elements **142***b* and **142***c*. Wing elements **142***b* and **142***c* each extend longitudinally, and when extending laterally, are attached at an angle to the base portion **142***a* and extend upward. During steady-state towing, each of wing elements **142***b* and **142***c* will have a portion that will be above the waterline. In another embodiment, a surface piercing hydrofoil has a curved portion extending laterally and upwards towards the waterline and in yet another embodiment a surface piercing hydrofoil is a continuously curving and extends upwards when extending laterally.

[0032] A benefit of having a wing element, including wing elements **142***b* and **142***c*, or a wing portion, that extends upwards is that the wing element or wing portion provides a lift self-stabilizing feature. The lift generated by a section wing element or wing portion is greatly reduced as the section rises above the waterline because air is less dense than water. In an example, if the watercraft payload carrying system **100** were to be generating sufficient lift that its trajectory was to make it airborne, i.e. the entirety of hydrofoil **142** were to be above the waterline including base portion **142***a*, the lift would be immediately reduced and the trajectory changed. This would occur because as the hydrofoil **142** was about to rise above the waterline, the wing elements **142***b* and **142***c* would dramatically lose their lift generated as they rose above the waterline and thus the impetus for continuing to rise would change. As such, the entirety of the hydrofoil **142** would not rise above the waterline.

[0033] A structural support **210** connects the keel **110** to the hydrofoil **140**. In the embodiment of FIG. **2**A, the structural support comprises opposed slanted beams **212** and **214** that extend outward from the keel **110** to the hydrofoil **142**. Beams **212** and **214** may attach to wings **142***b* and **142***c* or in an embodiment may attach to the base portion **142***a*. A bar **218** may extend between the two slanted beams **212**, **214** to provide additional support in at least torsion, tension or compression.

[0034] FIG. **2**B, illustrates a fully submerged hydrofoil **144** design where during steady state towing, the hydrofoil **144** will be fully submerged. In this embodiment, the fully submerged hydrofoil **144** has an airfoil-shaped cross-section and extends laterally in a generally planar manner. A structural support **250** connects the keel **110** to the hydrofoil **144**. In the embodiment of FIG. **2**B, the structural support comprises a single column or beam and that extends from the keel **110** to the hydrofoil **144**. The column or beam **250** may be comprised of multiple vertical elements either adjoined, integral or non-integral. In a non-integral, non-adjoined embodiment (not shown), multiple vertical elements are coupled indirectly to the keel **110** through a beam that is connected to the keel and transmits loads from the hydrofoil **144** to the keel **110**.

[0035] FIG. **3** illustrates a watercraft payload carrying system **100** with a payload **300**. In this embodiment, the payload **300** is an underwater vehicle which can take the form of an unmanned underwater vehicle or a torpedo. The payload **300** has an oval, and more particularly circular, cross-section. The receiver **130** is complimentary in shape to the payload **300** such that the receiver **130**

has an oval shape as well. The payload **300** may include a structural fin **310** with an eyelet **312** that allows a crane to hook onto the payload **300** and lift the payload or the payload and the watercraft payload carrying system **100** together.

[0036] FIG. **4**A, FIG. **4**B and FIG. **4**C illustrate and embodiment of a watercraft payload carrying system **400** comprising a first module **408** having a first keel or first longitudinally extending body **410**, first receiver **430** and first hydrofoil **440** and a second module **458** having a second keel or second longitudinally extending body **460**, second receiver **480** and second hydrofoil **490**. A linkage **450** provides an interconnect that couples or connects the first module **408** to the second module **458**. In an embodiment, the linkage **450** comprises a beam **452** that is connected at one end to the first keel **410** and at another end to the second keel **460**. This connection may be a removable coupling. The linkage **450** may also include a second beam **454** that is connected at one end to the first keel **410** and at another end to the second keel **460** and lies aft of beam **452**.

[0037] The linkage **450**, in an embodiment, further includes structural bracing that includes at least one bar **456***a* that extends from the forward beam **452** to the aft beam **454**. Bar **456***a* resists fore and aft loads and resists relative fore aft movement between the first module **408** and the second module **458**. The bracing may further include a second bar **456***b* that also extends from the forward beam **452** to the aft beam **454** may also form part of the linkage **450**. In an embodiment, one or both of bars **456***a* and **456***b* can have an end that connects to either of keel **410** or **460**. In an embodiment, bars **456***a* and **456***b* have a common termination point and in a further embodiment, the common termination point is at or about a midpoint **470** of the forward beam **452**.

[0038] In an embodiment, one or both of bars **456***a* and **456***b* can have an end that connects to either of keel **410** or **460**. As best shown in FIG. **4**A, in an embodiment, one or both of bars **456***a* and **456***b* can have an end that connects to either of keel **410** or **460** at a junction where aft beam **454** also connects with either of keel **410** or **460** such that one or both of bars **456***a* and **456***b* are also connected to aft beam **454**.

[0039] FIG. **5**A and FIG. **5**B illustrate a watercraft payload carrying system **500** having three modules **510**, **520**, **530**. Each module has a keel, receiver and hydrofoil. Linkage **560** couples module **510** to module **520** and linkage **570** couples module **520** to module **530**. While module **520** is shown as lying between module **510** and module **530**, in an embodiment, the watercraft payload carrying system **500** is modularly designed to interchangeably allow for swappable connections and positions between each module, allowing for multiple configurations for positioning each of the modules relative to each other, when connected.

[0040] Referring to FIG. **6**, a method for transporting a watercraft towable payload is shown. The method comprises immersing a first module and a payload into a liquid **610**. In an embodiment, the first module comprises a keel or longitudinally extending body, a connector located on a tow side for coupling with a towing watercraft, a receiver for coupling the payload to the keel, and a hydrofoil coupled to the keel below the keel and the hydrofoil having a chord thickness greater on the tow side. The method further comprises coupling a towing watercraft to the module **620**, coupling the payload to the module **630**, accelerating the towing watercraft **640** and raising a majority of the payload above a waterline of the liquid **650**. In an embodiment, the liquid is water. The steps of coupling the payload to the module and coupling a towing watercraft to the module may be interchangeable in terms of whether one is performed before the other or done simultaneously.

[0041] The method for transporting a watercraft towable payload illustrated in FIG. **6** may further comprise in the step of immersing a module and a payload into a liquid, immersing a second module and coupling the module to the second module. The coupling of the module to the second module may be done before or after the step of immersing. The method may further comprise determining a center of gravity and positioning the hydrofoil or a second hydrofoil to increase the amount of rise of the payload above the waterline. The method may further comprise coupling a platform to the first module.

[0042] Referring to FIG. **7**, a method for assembling and disassembling a watercraft payload carrying system comprises removably coupling a first keel or longitudinally extending body to a first hydrofoil, the first hydrofoil having a chord thickness greater on a tow side **710** and decoupling the first longitudinally extending body from the first hydrofoil **720**. The method may further comprise removably coupling a second module to a first module, the second module comprising a second keel or longitudinally extending body, second receiver and second hydrofoil and where the first module comprises the first keel or longitudinally extending body, a first receiver and the first hydrofoil **730**. The method may further comprise removably coupling a third hydrofoil to the first keel or longitudinally extending body. The method for the step of removably coupling a second module to a first module may comprise coupling a linkage from the first keel or longitudinally extending body to the second keel or longitudinally extending body and decoupling the linkage from the first keel or longitudinally extending body and from the second keel or longitudinally extending body.
[0043] In understanding the scope of the present invention, the term “configured” as used herein to describe a component, section or part of a device includes hardware and/or software that is constructed and/or programmed to carry out the desired function. In understanding the scope of the present invention, the term “comprising” and its derivatives, as used herein, are intended to be open ended terms that specify the presence of the stated features, elements, components, groups, integers, and/or steps, but do not exclude the presence of other unstated features, elements, components, groups, integers and/or steps. The foregoing also applies to words having similar meanings such as the terms, “including”, “having” and their derivatives. Finally, terms of degree such as “substantially”, “about” and “approximately” as used herein mean a reasonable amount of deviation of the modified term such that the end result is not significantly changed.
[0044] From the above description of the Hydrofoil Sled for Payload Transport, it is manifest that various techniques may be used for implementing the concepts without departing from the scope of the claims. The described embodiments are to be considered in all respects as illustrative and not restrictive. The method/apparatus disclosed herein may be practiced in the absence of any element that is not specifically claimed and/or disclosed herein. It should also be understood that the systems and methods are not limited to the particular embodiments described herein, but is capable of many embodiments without departing from the scope of the claims.

Claims

1. A watercraft payload carrying system comprising a first longitudinally extending body; a connector located on a tow side for coupling with a towing watercraft; a first receiver for coupling a payload to the longitudinally extending body; and a first hydrofoil coupled to an underside of said longitudinally extending body and having a chord thickness greater on the tow side.
2. The watercraft payload carrying system of claim 1 where the first receiver comprises a contoured portion that is complimentary in shape to a portion of the payload.
3. The watercraft payload carrying system of claim 1 where the first receiver is removably coupled to said first longitudinally extending body.
4. The watercraft payload carrying system of claim 1 where the first longitudinally extending body, first receiver and first hydrofoil comprise a first module and further including a second module comprising a second longitudinally extending body, second receiver and second hydrofoil and where a linkage couples the first module to the second module.
5. The watercraft payload carrying system of claim 4 where the linkage is connected to the first longitudinally extending body.
6. The watercraft payload carrying system of claim 5 where the linkage is an interconnect disposed between the first longitudinally extending body and the second longitudinally extending body and is removably coupled to the first longitudinally extending body and the second longitudinally

extending body.
7. The watercraft payload carrying system of claim 4 where the linkage is connected to a structural support, where the structural support connects the first longitudinally extending body to the first hydrofoil.
8. The watercraft payload carrying system of claim 1 wherein the hydrofoil further comprises a variable camber device.
9. The watercraft payload carrying system of claim 1 further comprising a fourth hydrofoil coupled to said first longitudinally extending body and below said longitudinally extending body and aftward of said first hydrofoil.
10. The watercraft payload carrying system of claim 1 where the receiver has an interface for coupling with a platform for carrying the payload.
11. The watercraft payload carrying system of claim 4 further including a third module comprising a third longitudinally extending body, third receiver and third hydrofoil and where a linkage couples the third module to first module or the second module.
12. The watercraft payload carrying system of claim 1 where the first hydrofoil is removably coupled to the first longitudinally extending body.
13. A method for transporting a watercraft towable payload comprising: immersing a first module and a payload into a liquid, the first module comprising a first longitudinally extending body, a connector located on a tow side for coupling with a towing watercraft, a first receiver for coupling the payload to the longitudinally extending body, and a first hydrofoil coupled to said longitudinally extending body below said longitudinally extending body and the hydrofoil having a chord thickness greater on the tow side; coupling a towing watercraft to the first module; coupling the payload to the first module; accelerating said towing watercraft; and raising a majority of said payload above a waterline of said liquid.
14. The method of claim 13 where the step of immersing a first module and a payload into a liquid further comprises immersing a second module and coupling the first module to the second module.
15. The method of claim 13 further comprising determining a center of gravity and positioning the first hydrofoil or a second hydrofoil to increase the amount of rise of the payload above the waterline.
16. The method of claim 14 where the step of coupling the payload to the first module further comprises coupling a platform to the first module.
17. A method for assembling and disassembling a watercraft payload carrying system comprising: removably coupling a first longitudinally extending body to a first hydrofoil, said first hydrofoil having a chord thickness greater on a tow side and decoupling said first longitudinally extending body from said first hydrofoil.
18. The method for assembling and disassembling a watercraft payload carrying system in claim 17 further comprising removably coupling a second module to a first module, the second module comprising a second longitudinally extending body, second receiver and second hydrofoil and where the first module comprises the first longitudinally extending body, a first receiver and the first hydrofoil.
19. The method for assembling and disassembling a watercraft payload carrying system in claim 17 further comprising removably coupling a third hydrofoil to said first longitudinally extending body.
20. The method for assembling and disassembling a watercraft payload carrying system in claim 18 where the step of removably coupling a second module to a first module comprises coupling a linkage from the first longitudinally extending body to the second longitudinally extending body.