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Phelan et al.

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(54) **RETENTION SYSTEM AND METHOD FOR A WING**

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(51) **Int. Cl.**

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F16M 9/00	(2006.01)
B64C 39/02	(2006.01)
F16B 2/10	(2006.01)
F16B 43/00	(2006.01)

(52) **U.S. Cl.**

CPC ***F16M 9/00*** (2013.01); ***B64C 39/024*** (2013.01); ***F16B 2/10*** (2013.01); ***F16B 43/003*** (2013.01); *B64C 2201/201* (2013.01)

(58) **Field of Classification Search**

CPC B64C 27/50; B64C 2201/201; B64C 2201/208; B64C 2201/206; B64C 2201/205; F16M 13/022; F16B 2/10; Y10T 24/44231

USPC 248/316.1, 316.7, 231.81, 228.7, 689

See application file for complete search history.

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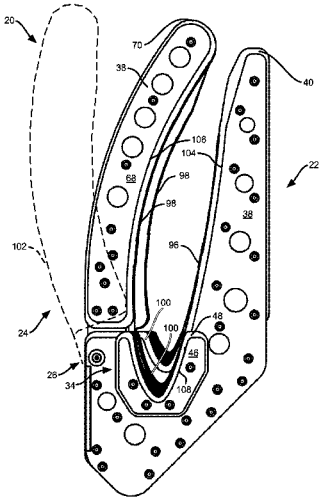
(57) **ABSTRACT**

A retention system includes a base supporting a wing spar and a post extending through the base from a first side of the base to a second side of the base. The post inserts through an aperture in the spar. A stop is selectively securable to the post over the second side of the base. A locking member engages the post on the first side of the base. The locking member is configured to selectively move the post from an unlocked position to a locked position in which the post is withdrawn toward the first side relative to the unlocked position. A biasing member encircles the post and is positioned between the stop and the second side. When the locking member is in a closed position the biasing member expands to engage the aperture and resist movement of the wing spar. A plurality of cradles may support the wing.

18 Claims, 12 Drawing Sheets



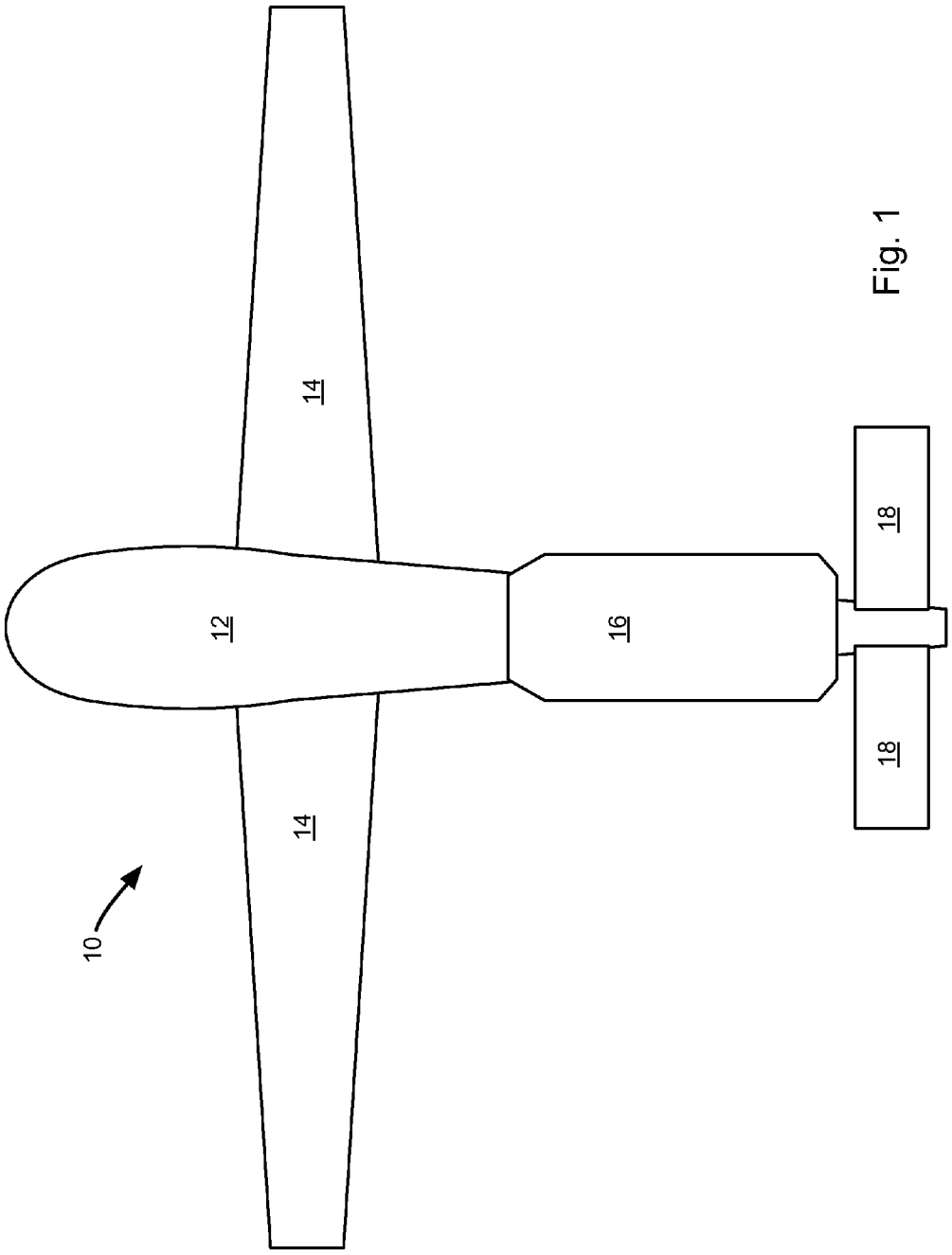


Fig. 1

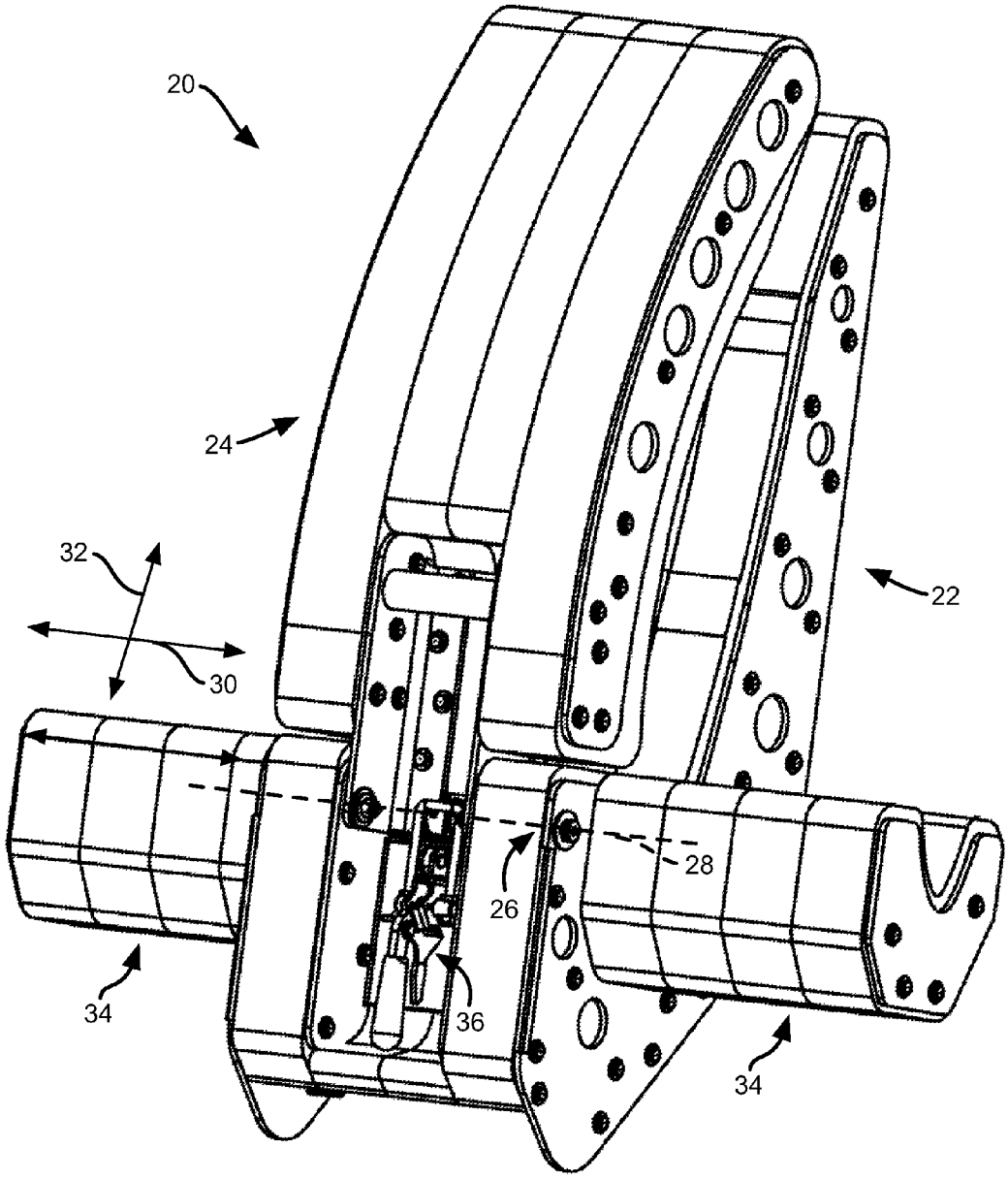


Fig. 2

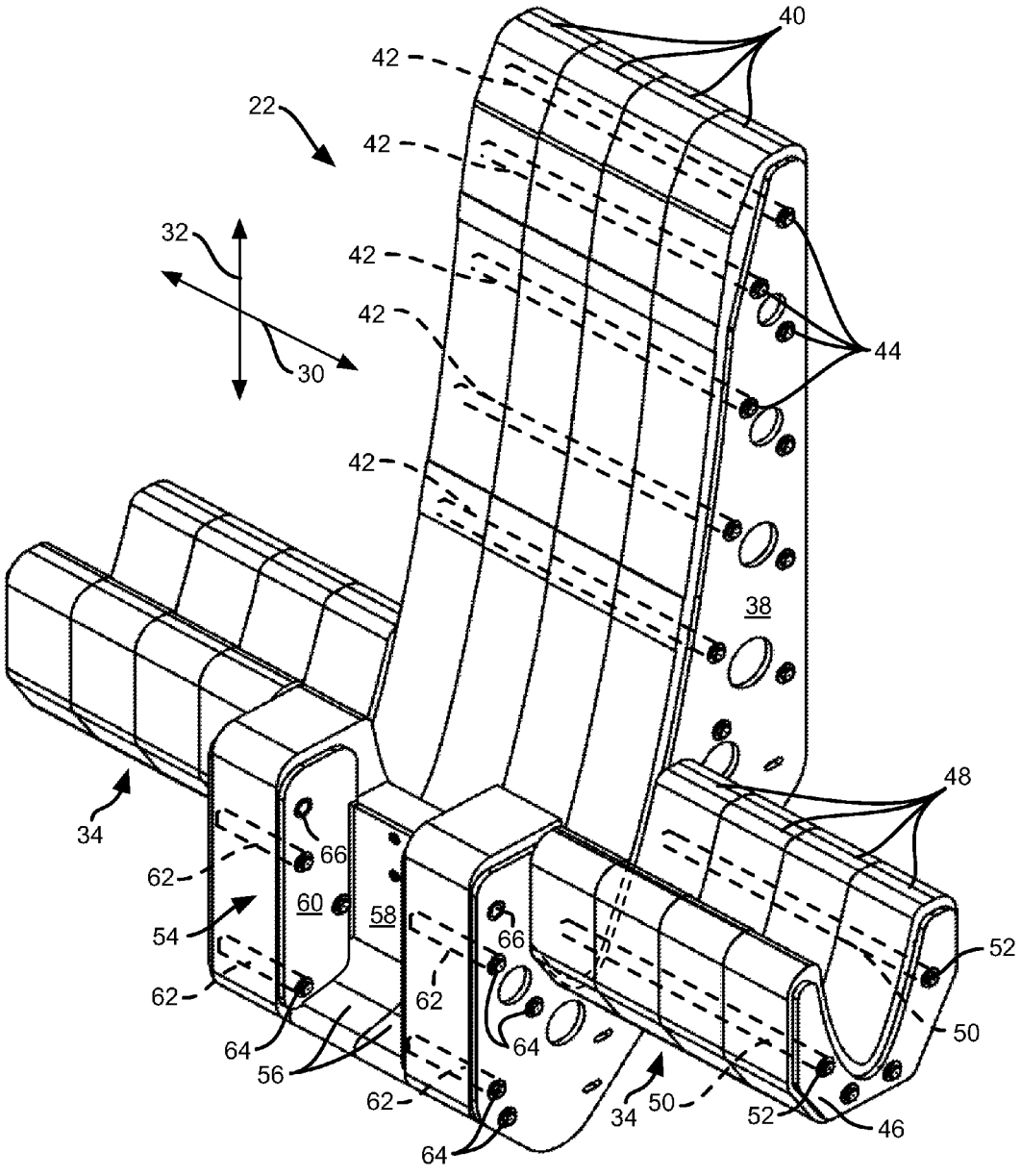

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Fig. 3

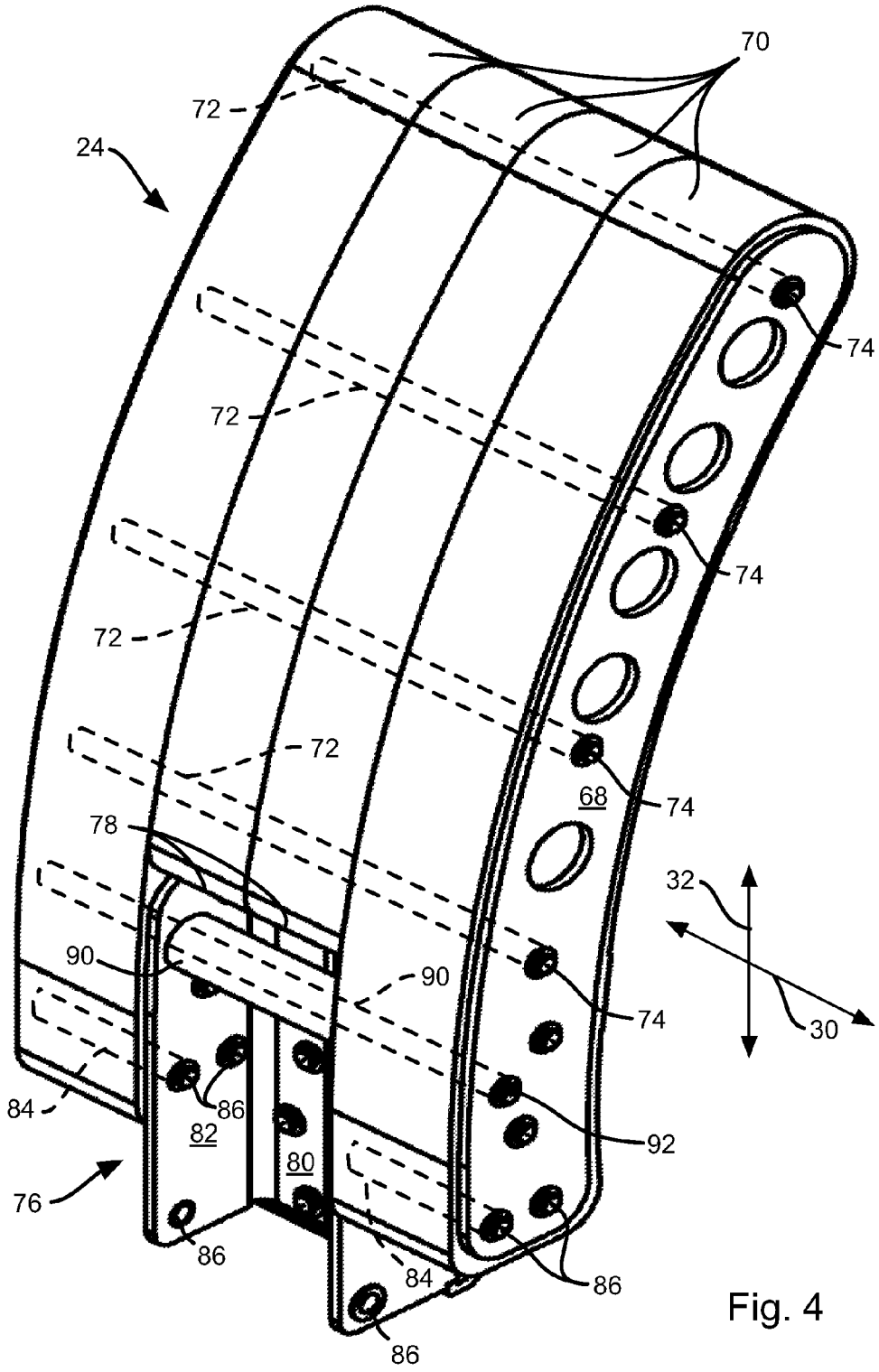
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Fig. 4

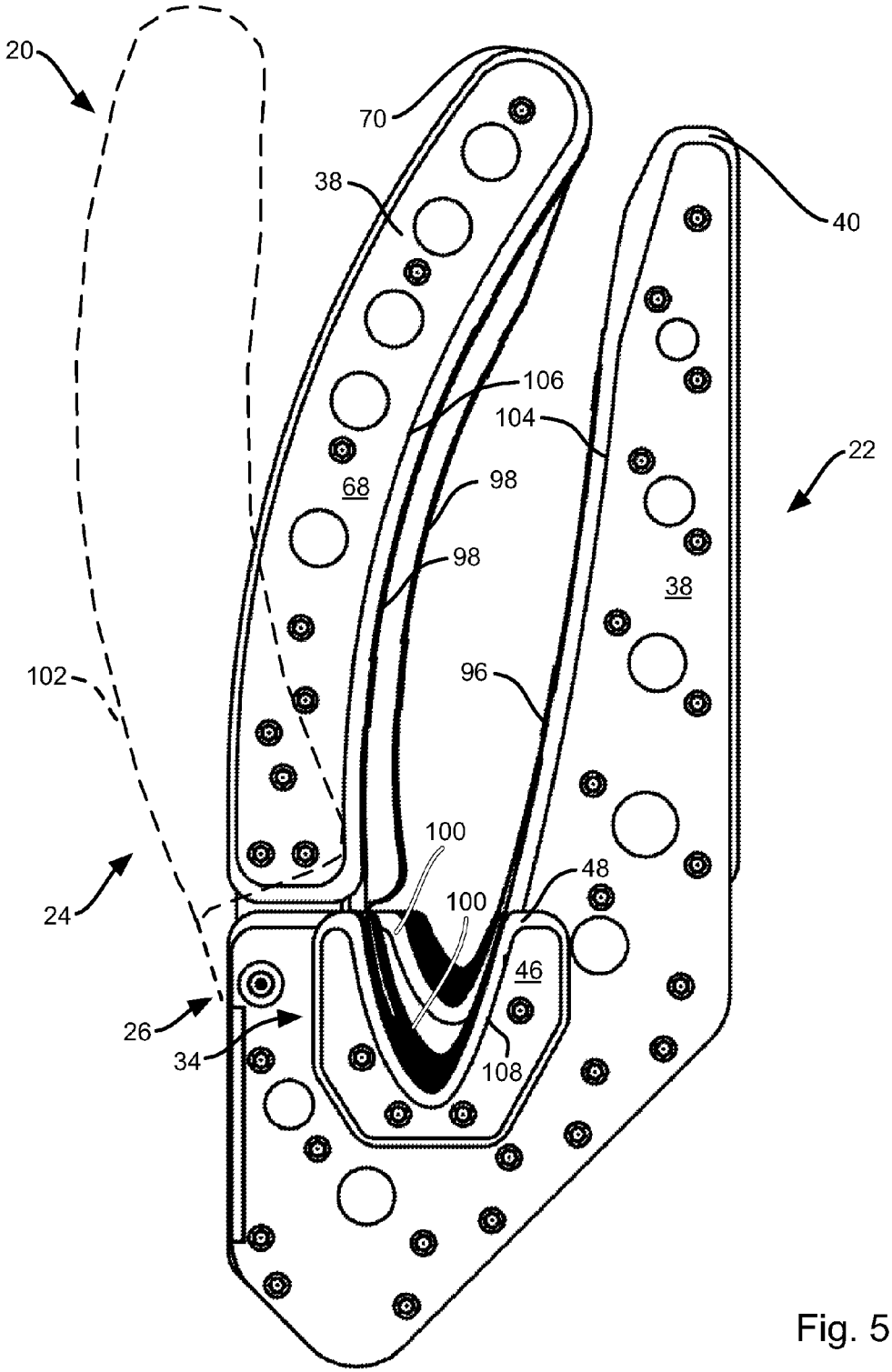

Fig. 5

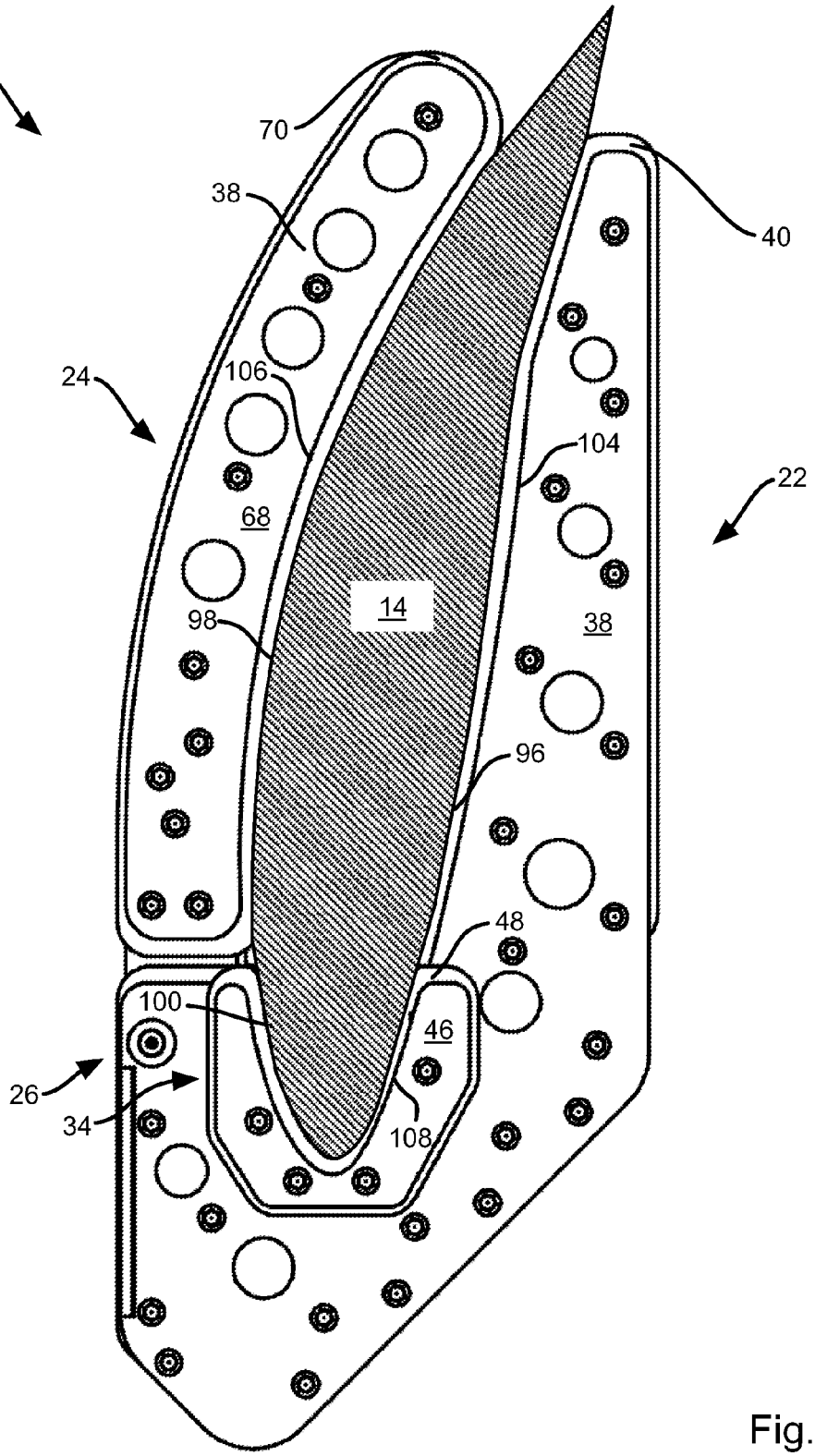

Fig. 6

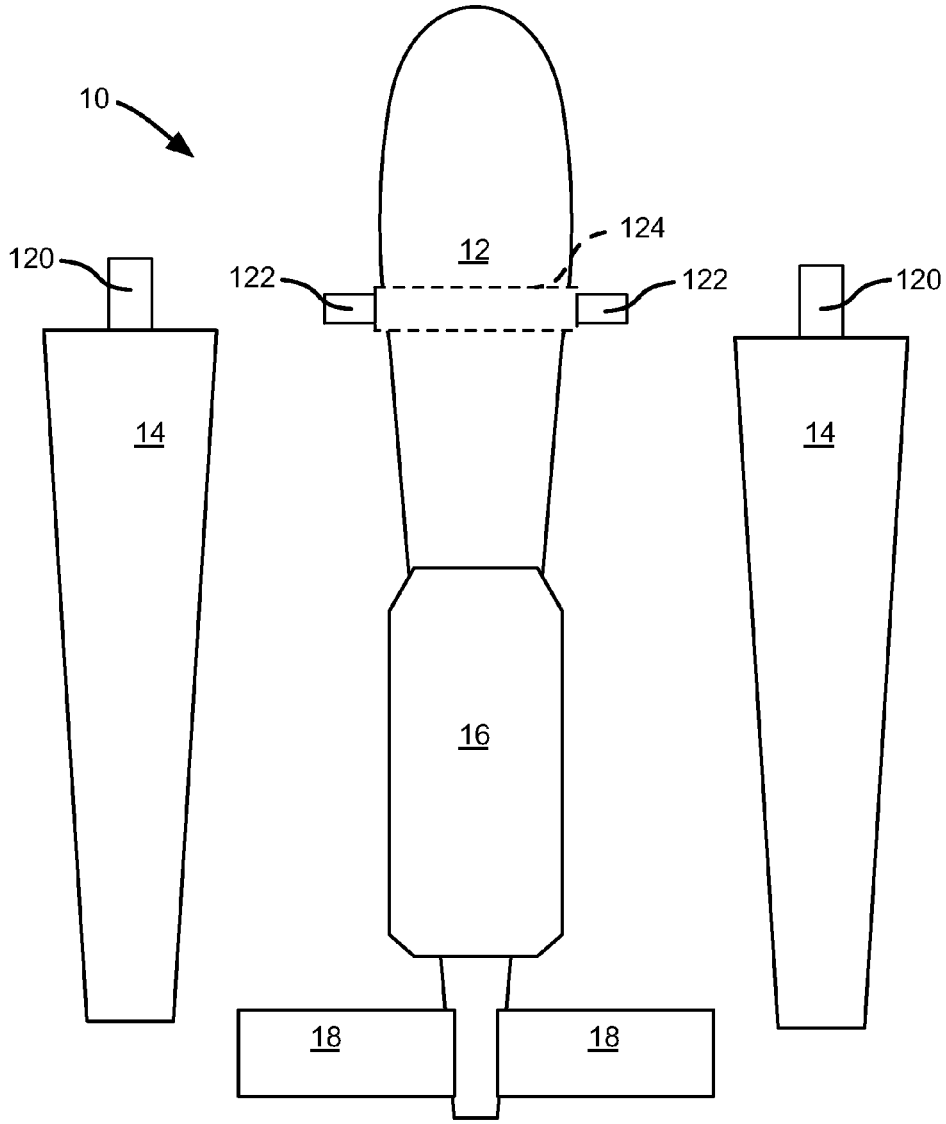

Fig. 7

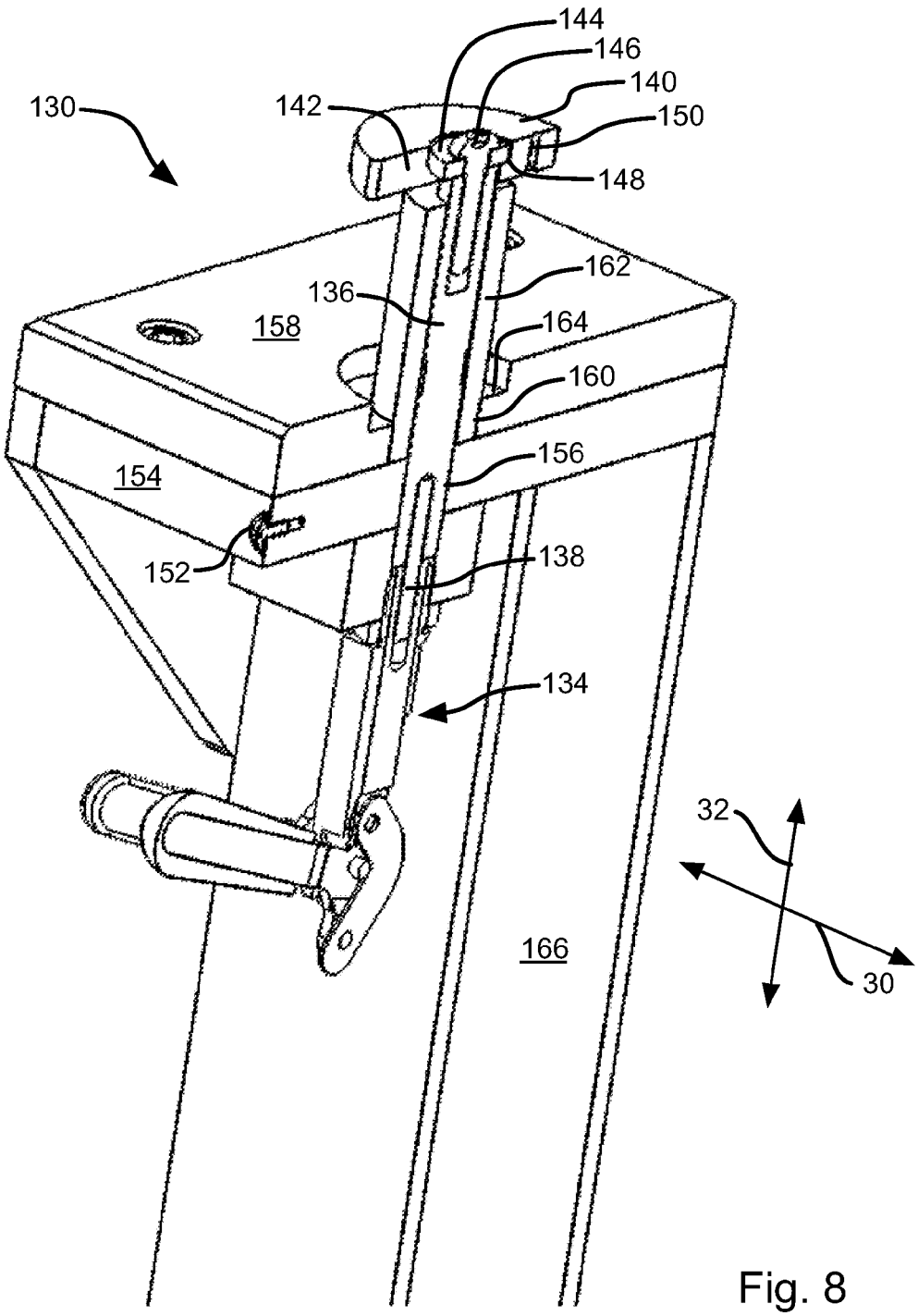
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Fig. 8

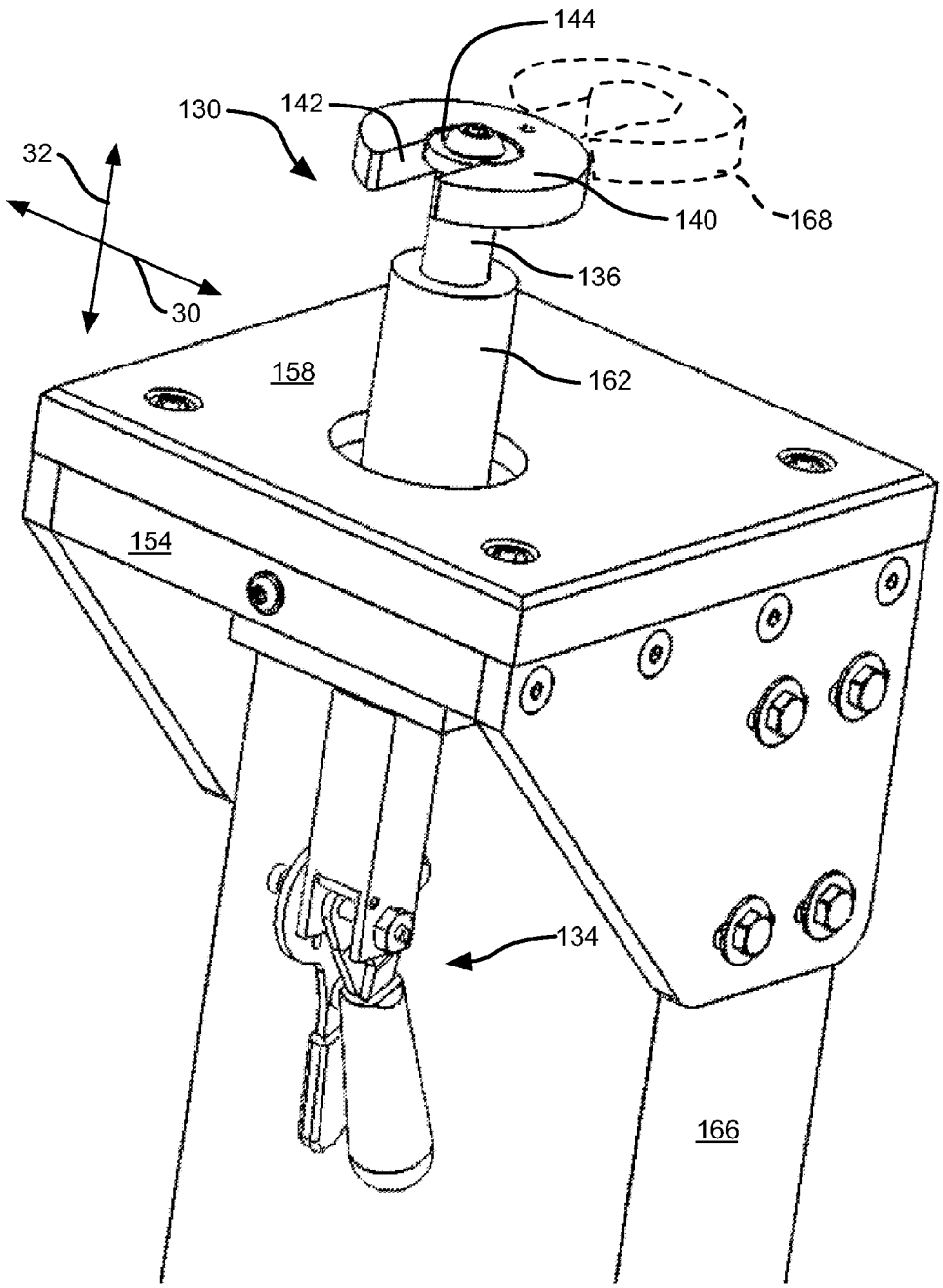

Fig. 9

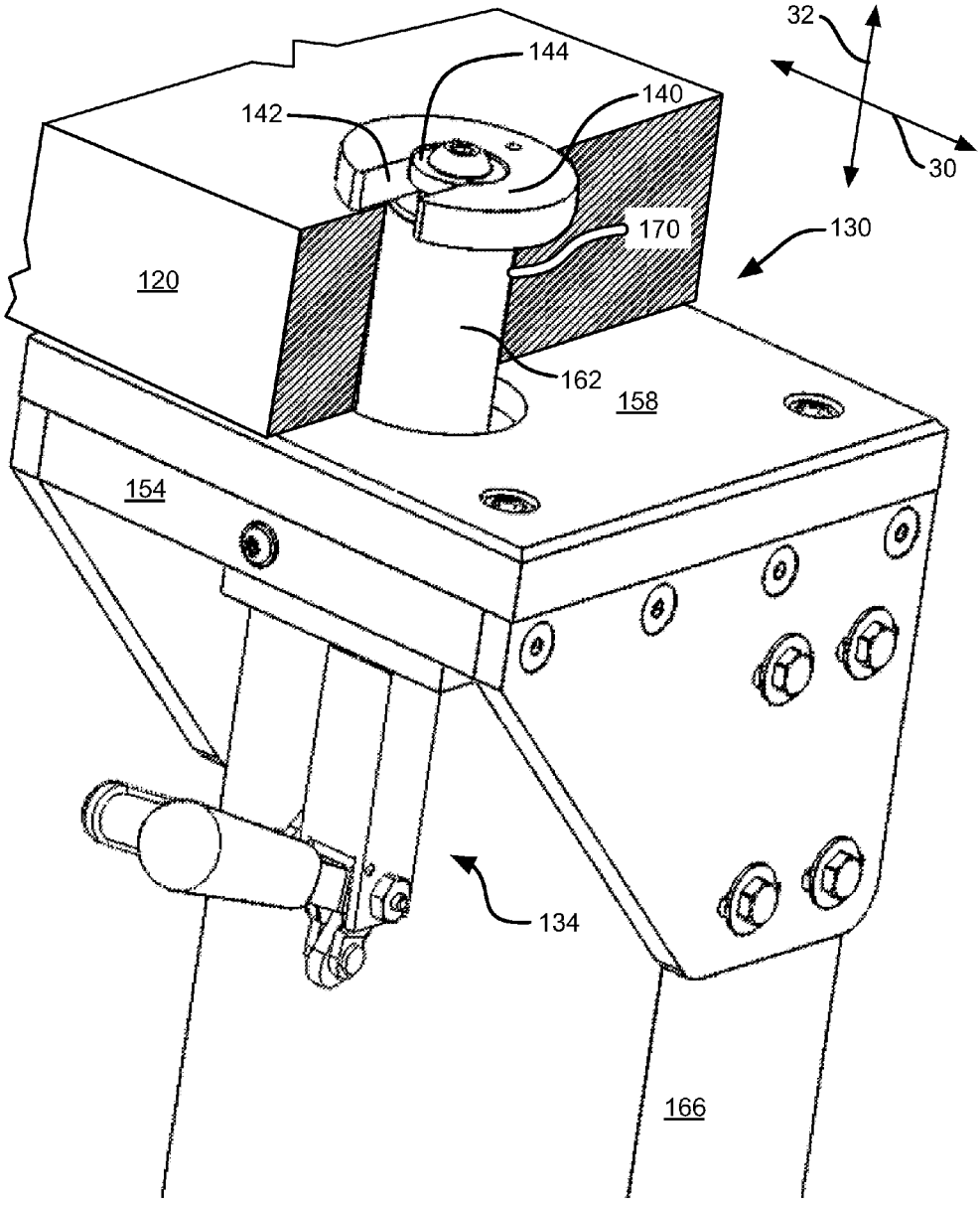

Fig. 10

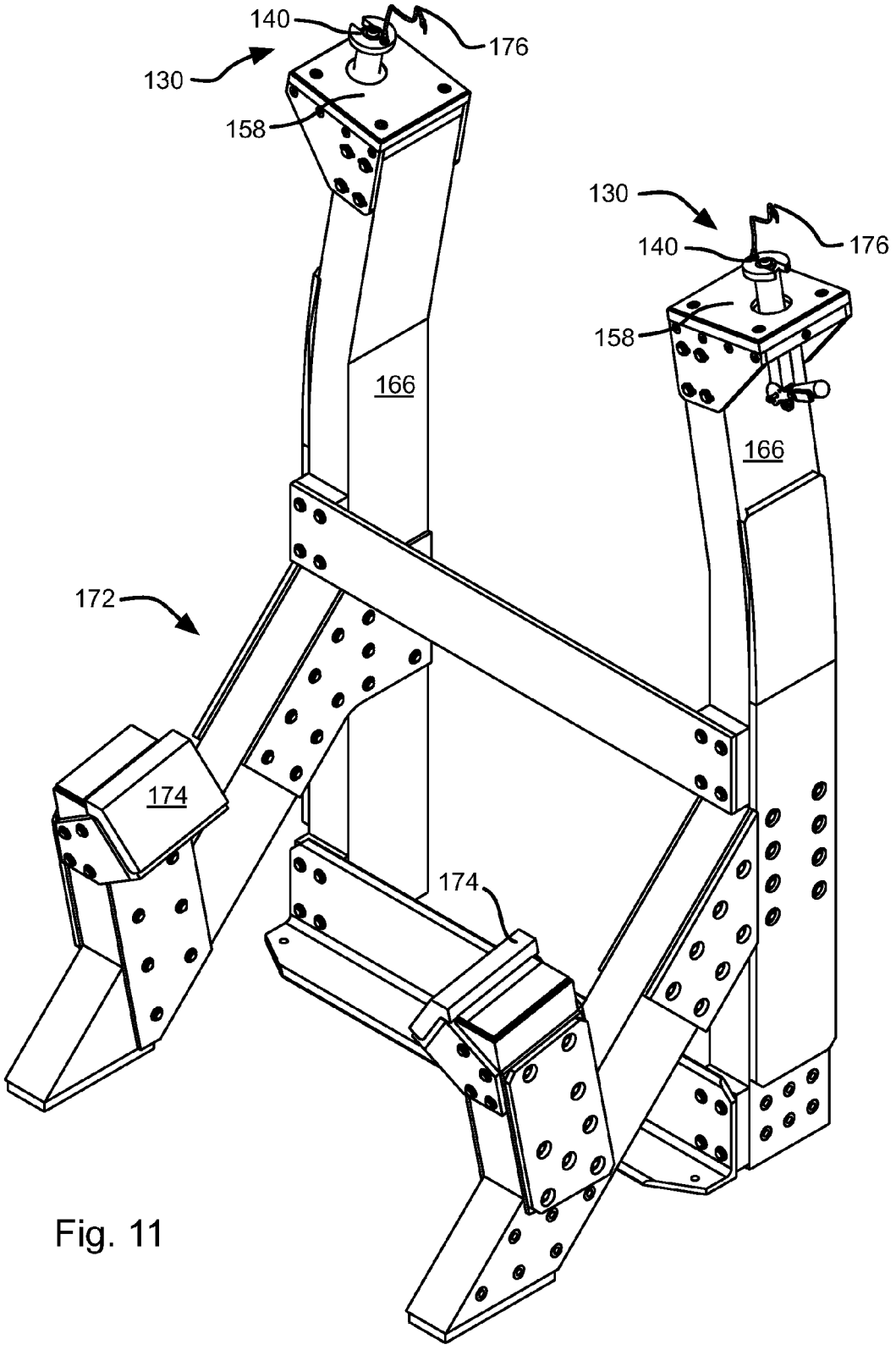

Fig. 11

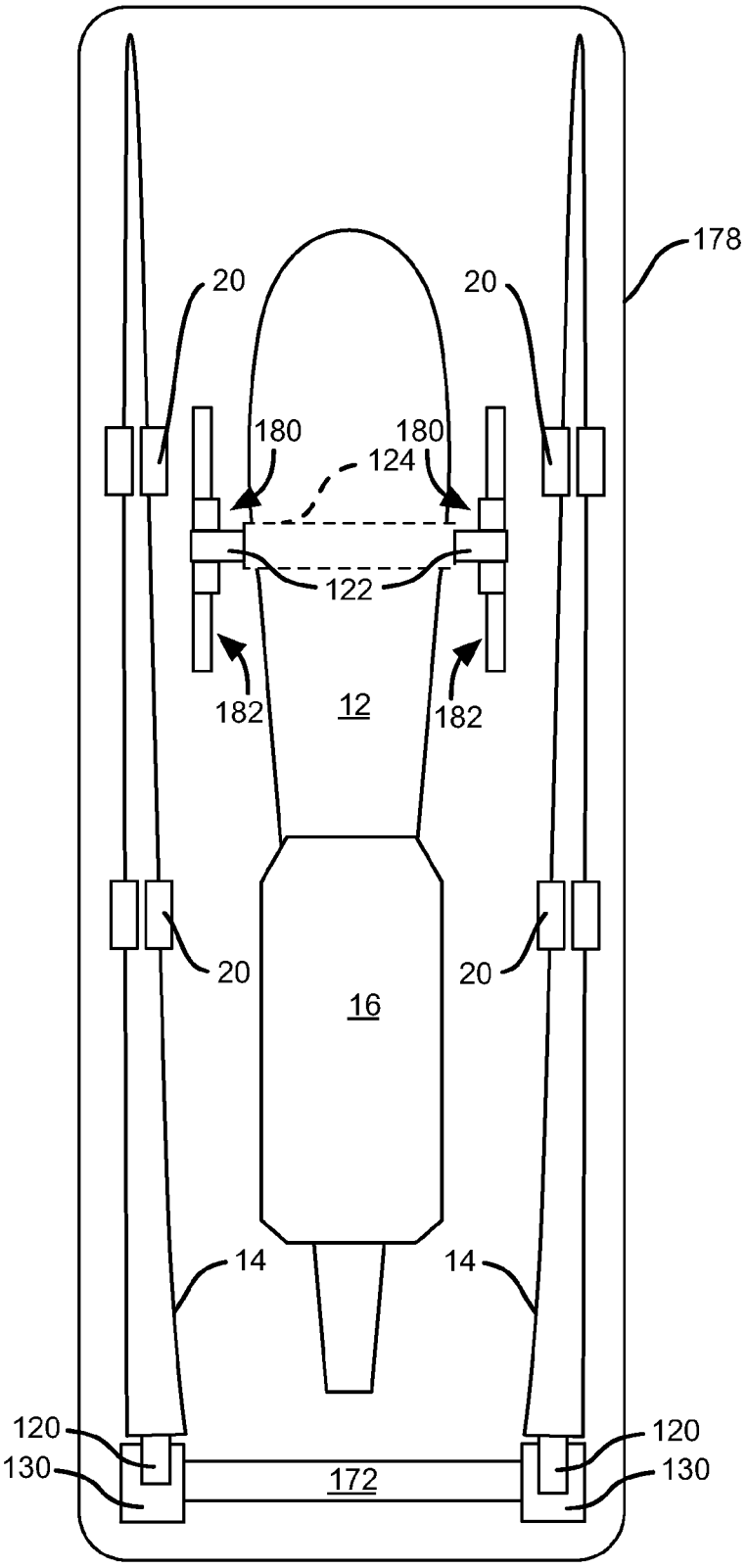
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Fig. 12

RETENTION SYSTEM AND METHOD FOR A WING

FIELD OF THE INVENTION

This application relates to systems and methods for storing and shipping an aerial vehicle, such as an unmanned aerial vehicle (UAV).

BACKGROUND OF THE INVENTION

The capabilities and use of UAVs has exploded in recent years. Some UAVs have the capacity of performing long distance surveillance as well as launching missiles. Inasmuch as a UAV has no pilot, it is often inconvenient to fly a UAV to a theatre of operation that exceeds the operational range of the drone. However, UAVs are very sophisticated machines and can also be very large.

Accordingly, it would be an advancement in the art to provide an improved means for shipping and storing a UAV.

SUMMARY OF THE INVENTION

In one aspect of the invention, one or more cradles are used to support a wing. The cradle may include first and second clamping members pivotally coupled to one another and defining a pivot axis. The first clamping member defines a first surface and the second clamping member defines a second surface. The first and second surfaces each conform to a portion of an airfoil contour of the wing and include a cushioning material. A first trough member defines a channel substantially parallel to the pivot axis and defines a third surface conforming to one of a leading edge and a trailing edge portion of the wing. In some embodiments, the trailing edge and its control surfaces are not contacted by the cradle as they are delicate. In such embodiments, the cradle contours the wing up until the control surface at which point clearance is made to avoid contact. The first trough member is positioned to engage the leading edgeportion when the wing is positioned within the first and second clamping members. A locking member engages the first and second clamping members and is configured to selectively lock the first and second clamping members having the first and second surfaces engaging the wing.

In another aspect of the invention, the first and second clamping members each include a frame and a layer of the cushioning material secured to the frame. In some embodiments, the frame includes first and second end plates and a plurality of rods secured between the first and second end plates and extending through the layer of cushioning material. The layer of cushioning material may include a plurality of cushioning members each having at least one surface that is substantially conformal to a portion of a contour of the wing at at least one longitudinal position. The layer of cushioning material may extend outwardly from the first and second end plates. The first and second end plates may define inward facing edges that are substantially conformal to the wing at the at least one longitudinal position.

Systems and methods for using the cradle are also disclosed and claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

Preferred and alternative examples of the present invention are described in detail below with reference to the following drawings:

FIG. **1** is a top plan view of an exemplar UAV such as might be used in accordance with an embodiment of the present invention;

FIG. **2** is a perspective view of a cradle for a wing in accordance with an embodiment of the present invention;

FIG. **3** is an isometric view of a rear clamping member in accordance with an embodiment of the present invention;

FIG. **4** is an isometric view of a front clamping member in accordance with an embodiment of the present invention;

FIG. **5** is a side view of a cradle in accordance with an embodiment of the present invention;

FIG. **6** is a side view of a cradle having a wing positioned therein in accordance with an embodiment of the present invention;

FIG. **7** is a top plan view of a disassembled UAV in accordance with an embodiment of the present invention;

FIG. **8** is a cross-sectional view of a spar retention system in accordance with an embodiment of the present invention;

FIG. **9** is an isometric view of a spar retention system in accordance with an embodiment of the present invention;

FIG. **10** is an isometric view of a spar retention system having a wing spar secured thereto in accordance with an embodiment of the present invention;

FIG. **11** is an isometric view of frame to which a spar retention system may be mounted in accordance with an embodiment of the present invention; and

FIG. **12** is a top plan view of a disassembled UAV secured within a container in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**, a UAV **10** may be embodied as a fixed-wing aircraft having a fuselage **12**. Wings **14** extend laterally from the fuselage **12** may define an airfoil contour. One or more propulsion sources **16** are mounted to the fuselage **12** or the wings **14**. The propulsion source **16** may be embodied as an internal combustion engine coupled to a propeller, turbo fan, or the like. The propulsion source **16** may also be embodied as a jet engine coupled to a propeller or turbo fan or used alone.

One or more tail planes **18** defining an empennage of the UAV **10** may secure to a rearward end of the fuselage **12**. The tail planes **18** may define a conventional horizontal stabilizer and vertical stabilizer with corresponding elevator and rudder control surfaces. Alternatively, tail planes **18** may include a pair of angled tail planes each with a corresponding control surface and protruding upwardly or downwardly from the fuselage **12**.

Referring to FIG. **2**, a cradle **20** may include a rear clamping member **22** and a front clamping member **24**. The front clamping member **24** may pivotally secure to the rear clamping member **22** by means of a pivot **26** defining a pivot axis **28**. In the illustrated embodiment, the pivot axis **28** is substantially parallel to a longitudinal direction **30**. The longitudinal direction **30** may be defined along a longitudinal direction of a wing clamped within the cradle **20**. A vertical direction **32** may also be defined as perpendicular to the longitudinal direction **30**. The vertical direction **32** may be substantially parallel to the chord line of a wing positioned in the cradle **20**. For purposes of this disclosure "substantially" parallel or perpendicular may be interpreted as within 10 degrees of perpendicular or parallel, preferably within 5 degrees, and preferably within 1 degree, of perpendicular or parallel. Likewise, "substantially" equal to a value may mean within +/−5% of the value, preferably within 1% of the value.

In some embodiments, troughs **34** may extend on either side of the front and rear clamping members **22**, **24**. The troughs **34** may be positioned on one or both sides of the clamping members **22**, **24** along the longitudinal direction **30**. As shown in FIG. **2**, pivot axis **28** may be located vertically adjacent the troughs **34**. Stated differently, the troughs **34** may be secured to the rear clamping member **24** near the pivot axis **28**. In some embodiments, the extent of each trough **34** in the longitudinal direction is between 0.5 and 2, preferably between 0.9 and 1, times a width of the rear clamping member **22**. In the illustrated embodiment, each trough **34** has a width substantially equal to the width of the rear clamping member **22**.

A locking member **36** engages the front and rear clamping members **22**, **24**. The locking member **36** may selectively lock the front and rear clamping member **22**, **24** relative to one another with a desired amount of locking force. For example, the locking member **36** may be any over-center latch known in the art. Inasmuch as a wing stored in the cradle **20** may be shipped by air, the over-center latch is preferably lightweight. The latching force may be defined by the latch and may be adjustable as known in the art.

Referring to FIG. **3**, in some embodiments a rear clamping member **22** may be as illustrated. The rear clamping member **22** may include cushioning members **40**. For example, one or more cushioning members **40** may be positioned between end plates **38**. In the illustrated embodiments, the cushioning members **40** are sheets of a cushioning material cut to a desired shape. The illustrated rear clamping member **22** may be symmetric about a plane perpendicular to the longitudinal axis **30**. Accordingly, for the illustrated end plate **38** a corresponding end plate **38** is located on an opposite side in a mirror configuration. The plates **38** may be fastened to one another such that the cushioning members **40** are captured between the plates. For example, each rod **42** of a plurality of rods **42** may secure to both plates **38** and further extend through the cushioning members **40** positioned between the plates **38**. The rods **42** and plates **38** may be formed of a rigid but light weight material such as aluminum, a rigid plastic, composite material, or the like. The rods **42** may therefore serve to limit compression of the cushioning member **40**. The rods **42** may have circular, rectangular, or some other cross section. In the illustrated embodiment, the rods **42** are secured to the end plates **38** by means of fasteners **44** passing through end plates **38** and engaging an end portion of a rod **42**. In some embodiments, a rod **42** may define interior or exterior threads engaging corresponding threads on the fastener **44**. In other embodiments, the fasteners **44** may be embodied as star fangled nuts and a rod **42** may define a hollow end portion for securing to a star fangled nut. In some embodiments, a backing plate is secured to both end plates **38**, such as by means of welds or other fasteners, and the cushioning members **40** are secured to the backing plate by means of adhesive or some other means.

In a like manner, a trough **34** may be defined by cushioning members **48** defining the contour of the trough **34**. The cushioning members **48** may be captured between an end plate **38** and an end plate **46**. Likewise, rods **50** may secure to the end plate **38** and the plate **46** in order to capture the cushioning members **48**. The rods **50** may pass through the cushioning members **48**. The rods **50** may secure to the end plate **46** and end plate **38** by any of the fastening means noted above, such as fasteners **52** embodied as star fangled nuts or some other fastener.

In some embodiments, a locking member **36** may mount to the rear clamping member **22** by means of a lock mount **54** secured thereto. In the illustrated embodiment, one or more of the cushioning members **40** may define a cutout portion **56** for receiving the lock mount **54**. As is apparent in FIG. **3**, the cutout portion **56** does not extend completely through the cushioning member such that the hard material forming the lock mount **54** does not contact a wing positioned in the cradle **20**. Stated differently, a portion of one or more of the cushioning members **40** remains positioned between the lock mount **54** and a wing positioned between the clamping members **22**, **24**.

The lock mount **54** may include a back plate **58** and side plates **60** extending outwardly from the back plate **58**. The side plates **60** may secure to the back plate **58** by means of screws, bolts, welds, or some other fastening means. In some embodiments, the back plate **58** and side plates **60** are formed from one monolithic member, such as a channel or rectangular tube having one wall removed. In the illustrated embodiment, the side plates **60** secure to the end plates **38** by means of rods **62** extending through one or more of the cushioning members and secured to the end plates **38** and plates **60** by means of fasteners **64**, such as star fangled nuts or some other fastening means. One or both of the end plates **38** and side plates **60** may define an aperture **66** for receiving a pivot **26**, such as one or more pivot pins **26**, extending through the apertures **66**.

Referring to FIG. **4**, in some embodiments a front clamping member **24** may be as illustrated. The front clamping member **24** may include cushioning members **70**. For example, one or more cushioning members **70** may be positioned between end plates **68**. In some embodiments, the cushioning members **40**, **48**, **70** may include a polymer, such as a foam polymer, that has a modulus of elasticity of between 0.001 and 1 GPa, and preferably between 0.01 and 0.1 GPa. This modulus of elasticity may refer to the polymer itself or the polymer after any foaming process. The illustrated front clamping member **24** is symmetric about a plane perpendicular to the longitudinal axis **30**. Accordingly, for the illustrated end plate **68** a corresponding end plate **68** is located on an opposite side in a mirror configuration. The plates **68** may be fastened to one another such that the cushioning members **70** are captured between the plates **68**. For example, each rod **72** of a plurality of rods **72** may secure to both plates **78** and further extend through the cushioning members **70** positioned between the plates **68**. The rods **72** may have circular, rectangular, or some other cross section. In the illustrated embodiment, the rods **72** are secured to the end plates **68** by means of fasteners **74** passing through end plates **68** and engaging an end portion of a rod **72**. In some embodiments, a rod **72** may define interior or exterior threads engaging corresponding threads on a fastener **74**. In other embodiments, the fasteners **74** may be embodied as star fangled nuts and the rods **72** may define a hollow end portion for securing to a star fangled nut. In some embodiments, a backing plate is secured to both end plates **68**, such as by means of welds or other fasteners, and the cushioning members **70** are secured to the backing plate by means of adhesive or some other means.

In some embodiments, a locking member **36** may mount to the front clamping member **24** by means of a lock mount **76** secured thereto. In the illustrated embodiment, one or more of the cushioning members **70** may define a cutout portion **78** for receiving the lock mount **76**. As is apparent in FIG. **3**, the cutout portion **78** does not extend completely through the cushioning member **70** such that the hard material forming the lock mount **76** does not contact a wing positioned in the cradle **20**. Stated differently, a portion of the cushioning member **70** is interposed between the lock mount **76** and a wing clamped by the front clamping member **24**.

The lock mount **76** may include a back plate **80** and side plates **82** extending outwardly from the back plate **80**. The side plates **82** may secure to the back plate **80** by means of screws, bolts, welds, or some other fastening means. In some embodiments, the back plate **80** and side plates **82** are formed from one monolithic member, such as a channel or rectangular tube having one wall removed In the illustrated embodiment, the side plates **82** secure to the end plates **68** by means of rods **84** extending through one or more of the cushioning members **70** and secured to the end plates **68** and plates **82** by means of fasteners **86**, such as star fangled nuts or some other fastening means. One or both of the end plates **68** and side plates **82** may define an aperture **86** for receiving a pivot **26**, such as one or more pivot pins **26**, extending through the apertures **86** and the apertures **66** of the rear clamping plate **22**.

In some embodiments, a bushing **90** extends between the side plates **82**. A rod **90** may pass between opposing end plates **68** and pass through the bushing **90** as well as the side plates **82**. The rod **90** may secure to the end plates **68** by means of fastener **92** in the same manner of other rods discussed hereinabove.

Referring to FIG. **5**, the front clamping member **24** pivotally secures to the rear clamping member **22** by means of the pivot **26**. In this manner, the front clamping member **24** may be pivoted away from the rear clamping member **22** in order to permit insertion of a wing, as shown by the dotted representation **102** of the front clamping member.

The cushioning members **40** of the rear clamping member **22** and the cushioning members **70** of the front clamping member **24** define conformal surfaces **96**, **100** that are shaped to conform to surfaces of a wing. Likewise, the cushioning members **48** of the trough **34** define conformal surfaces **100** conforming to one of a leading edge portion and a trailing edge portion of a wing. As noted above, in some embodiments, contact between the cradle **20** and the trailing edge of the wing **14** and any control surfaces is avoided. As known in the art, the cross-sectional shape of a wing preferably varies along the length thereof. Accordingly, the conformal surfaces **96**, **98**, **100** may conform to the surface of a wing at a particular longitudinal position. Likewise, for a given cradle **20**, the plurality of cushioning members **40** may each have a unique corresponding conformal surface **96** corresponding to a contour of the wing at a particular longitudinal position. Likewise each of the plurality of cushioning members **48** may have a unique conformal surface **100** and each of the plurality of cushioning members **70** may have a unique conformal surface **98**. In some embodiments, the conformal surfaces **96**, **98**, **100** are cut such that they are contoured in both vertical **32** and horizontal directions (e.g. in the plane of the page of FIG. **5**) and the longitudinal direction **30** in order to conform to variation in the contour of the wing in three dimensions. In other embodiments, the conformal surfaces **96**, **98**, **100** are uniform in the longitudinal direction such that the conformal surfaces **96**, **98**, **100** are contoured in only two dimensions (horizontal and vertical). For example, the arbitrary contours of the conformal surfaces **96**, **98**, **100** may be machined using a water jet cutter or other machining process that may machine precise contours in two dimensions.

In some embodiments, some or all of the conformal surfaces **96**, **98**, **100** may include a pattern of ridges or other protuberances that are positioned to be located over structural reinforcements under the skin of the wing **14** at the longitudinal location at which the conformal surfaces **96**, **98**, **100** engage the wing **14**. In this manner, pressure exerted on the wing is more concentrated on those areas that are better able to bear such pressure.

In some embodiments, the end plates **38**, **46**, **68** may define conformal edges **104**, **106**, **108** respectively that extend along the conformal surfaces **96**, **98**, **100**. The conformal edges may substantially conform to a surface that is offset from a contour of the wing contour by some constant or variable gap, such that during use, the cushioning members **40**, **48**, **70** will not compress to the point that the wing contacts the end plates **38**, **46**, **68** under expected compression forces and amounts. As noted above, the various cushioning members **40**, **46**, **70** of a cradle may not all have conformal surfaces **96**, **98**, **100** of the same shape. In such embodiments, each end plate **38** may have a conformal edge **104**, **106**, **108** that is offset from the conformal surface **96**, **98**, **100** of the cushioning members **40**, **46**, **70** adjacent thereto (e.g. the outermost cushioning members **40**, **46**, **70**.

Referring to FIG. **6**, in use a wing **14** may be placed between the front and rear clamping members **22**, **24** and the front clamping member **24** may be pivoted toward the rear clamping member **22**. As shown in FIG. **6**, the leading edge portion of the wing **14** rests in a concave portion of the rear clamping member **22** and the trough **34**. The locking member **36** (FIG. **2**) may then be engaged to apply a consistent clamping force between the clamping members **22**, **24**. As a result of the clamping force, the cushioning members **40**, **46**, **70** may compress due to engagement of the wing **14** with the conformal surfaces **96**, **98**, **100**. As noted above, the compression is preferably such that the wing **14** does not contact the end plates **38**, **46**, **68**.

Referring to FIG. **7**, to facilitate shipping and storage, the UAV **10** may be disassembled. As shown in FIG. **7** at least the wings **14** may be removed to reduce the footprint of the UAV **10**. Other parts of the UAV **10** such as the propulsion source **16** and tail planes **18** may also be removed. The wings **14** may secure to the fuselage by means of a wing spar **120**. As known in the art, a wing spar **120** provides structural rigidity to the wing **14** for transferring lift forces to the fuselage **12**. In some embodiments, wings **14** may secure by some other means or interface other than wing spars **120**, such as a plate or other structure defining a hole pattern for receiving fasteners. Following shipment or storage according to methods disclosed herein, the wings **14** may be reattached to the fuselage **12** using the wing spars **120** in order to deploy the UAV **10**.

The fuselage **12** may have indexing members **122** fastened thereto using a fastening system **124**. The fastening system **124** may be a fastening system and corresponding indexing members **122** as disclosed in U.S. application Ser. No. 13/974,350 filed Aug. 23, 2013 and entitled FUSELAGE INDEXING SYSTEM AND METHOD, which is hereby incorporated herein by reference.

Referring to FIG. **8**, as noted above, the wings **14** may be supported by means of cradles **20** as described herein. As also noted above, the cradles **20** may not provide significant resistance to longitudinal movement of the blade **20**. Accordingly, the wing spar **120** may be fastened to a storage container by means of a spar retention system **130**. The spar retention system **130** may be understood with respect to a longitudinal direction **132** that is substantially parallel to the longitudinal axis of the wing **14** used with the spar retention system **130**. A vertical direction **32** may be defined as substantially parallel to a line parallel to a line normal to a surface on which the spar retention system **130** is resting.

The spar retention system **130** may include a lock down clamp **134** and a post **136**. The lock down clamp **134** may be any lock down clamp **134** known in the art. As known in the art, a lock down clamp **134** has an open position and a closed position. The lock down clamp **134** provides a determined amount of travel between the open and closed position and

may be adjustable as to travel and clamping force in the closed position. The post **136** is coupled to the lock down clamp **134**, such as by means of a fastener **138**. The post **136** is translated upward when the clamp **134** is moved from the closed to the open position and translated downward when the clamp **134** is moved from the open to the closed position.

A stop **140** may be selectively secured to the post **136**. For example, the stop **140** may define a slot **142** sized to receive a distal portion of the post **136**. The post **136** may define a distal portion that is wider than the slot **142** to hinder removal of the stop **140**. For example, in the illustrated embodiment, a washer **144** or other structure secures to a distal end of the post **136**, such as by means of a fastener **146**, e.g. screw. In some embodiments, the stop **140** includes a seat, e.g. countersink, sized to receive the washer **144** or other widening structure. Inasmuch as the stop **140** is removable from the post, the stop **140** may include an aperture **150** or other structure for receiving a lanyard (not shown). The lanyard may be anchored to an anchor **152** secured to a base **154**.

The base **154** may support a wing spar **120** secured using the spar retention system **130**. The base **154** may define a rigid and substantially planar surface or have a contour corresponding to a contour of a wing spar **120**. For example, the base **154** may be embodied as an aluminum plate. The base **156** may be interposed between the stop **140** and the clamp **134**. The base **156** may define an aperture **156** through which the post **136** passes. In some embodiments, a cushioning member **158** secures to an upper surface of the plate **154**, e.g. opposite the clamp **134** and facing the stop **140**. The cushioning member **158** may define an aperture **160** through which the post **136** passes. The cushioning member **158** may be include a flexible polymer such as polyurethane or the like. The cushioning member **158** may have a modulus of elasticity such that the cushioning member **158** deforms in response to clamping force exerted by the clamp **134** on the stop **140**. For example, the cushioning member **158** may have a module of elasticity of between 0.001 and 1 GPa and, preferably between 0.01 and 0.1 GPa. In some embodiments, the stop **130** may also have a modulus of elasticity within either of these ranges and may include the same or different material and have the same or different modulus of elasticity as the cushioning member **158**.

A die spring **162** may encircle the post **136**. The die spring **162** may be compressed by the stop **140** when the clamp **134** is in the closed position. As a result of the compression, the die spring **162** may also expand outwardly from the post **136**. In some embodiments, the cushioning member **158** may define a seat **164**, e.g. counterbore, that has a diameter that is larger than an undeformed diameter of the die spring **162**. The seat **164** may receive a bushing or other structure secured to a wing spar **120** used in combination with the spar retention system **130**. In some embodiments, the aperture **160** defined by the cushioning member **158** is slightly smaller (e.g. between 5 and 10% smaller) than an undeformed diameter of the die spring **162** passing there through. In this manner, the cushioning member **158** may hinder movement of the die spring **162** when the post **136** is moved upward and downward.

In some embodiments, the spar retention system **130** may be mounted to a container or other storage facility directly or by means of one or more intervening members. For example, the spar retention system **130** may mount to a beam **166** that secures to a container or secures to some other member mounted to the container.

Referring to FIGS. **9** and **10**, in use the stop **140** may be removed from the post **136** as shown by the dotted representation **168**. Removing the post **136** may be accomplished by sliding the post **136** out of the slot **142**. Where the stop **140** includes a seat **148**, the stop **140** may be slid downwardly to disengage the washer **144** from the seat **148** prior to sliding the post **136** out of the slot **142**. In preparation for placement of the wing spar **120**, the clamp **134** may be placed at or near the open position such that the top of the post **136** is elevated above the base **154** and cushioning member **158** is not compressed and therefore small enough to insert through the wing spar **120**.

Referring specifically to FIG. **10**, with the stop **140** removed, a wing spar **120** may be positioned over the post **136** and die spring **162**. For example, the wing spar **120** may define an aperture **170** and in the open position of the clamp **134**, the uncompressed (or less compressed due to an open position of the clamp **134**) die spring **162** may be sized to fit through the aperture **170** as is the washer **144**. The stop **140** may be placed in the position shown having the washer **144** in the seat **148** as shown in FIG. **8** by sliding the post **136** into the slot **142**. The clamp may then be moved to the closed position as shown in FIG. **10**. In the closed position, the die spring **162** may be deformed such that it presses against the aperture **170** and if unconstrained by the aperture **170** would be larger than the aperture **170**. In some applications, the aperture **170** is tapered or has some shape other than cylindrical. The deformation of the die spring **162** may accommodate this geometry by expanding to at least partially fill part of the aperture **170** and thereby hinder movement of the wing spar **120**. The resilience of the cushioning member **158** and the stop **140** may result in deformation of these members due to the clamping force of the clamp **134** thereby reducing any scratching or denting of the wing spar **120** and providing additional grip on the wing spar **120**.

FIG. **11** illustrates an example use for the spar retention system **130**. As illustrated the beams **166** form part of a frame **172** that is mounted to a container. In some embodiments, the frame **172** may include structures for retaining or supporting other parts of the UAV **10**. For example, the frame **172** may include tail plane supports **174** that are angled or otherwise positioned to support the tail planes **18** of the UAV. The tail plane supports **174** may include cushioning surface made having some or all of the properties of other cushioning materials described herein. Also shown in FIG. **11** is a lanyard coupled to the stop **140**, such as by means of the aperture **150**. The lanyard may also be connected to some other portion of the frame **172** or spar retention system **130**, such as the anchor **152** (FIG. **8**).

Referring to FIG. **12**, the cradles **20** as disclosed herein above may be used in the storing and shipping of a UAV **10**. For example, a container **178** may store a disassembled UAV **10**. In such embodiments, a plurality of cradles **20** may secure to the container **178** either directly or indirectly by means of a fixture or frame member. The wing **14** mounts within the cradles **20** as described herein and is thereby retained against movement during shipping. In some embodiments, the cushioning members **40**, **48**, **70** may be configured relative to the end plates **38**, **46**, **68** such that the wing will not contact the plates **38**, **46**, **68** in response to deflection of the cushioning members **40**, **48**, **70** due to expected acceleration of the container **110**. The remainder of the UAV **10** may also secure within the container **178**, including the fuselage **12**.

As noted above, the fuselage **14** may have a fastening system **124** and indexing members **22** secured thereto as described U.S. application Ser. No. 13/974,350 filed Aug. 23, 2013 and entitled FUSELAGE INDEXING SYSTEM AND METHOD, which is hereby incorporated herein by reference.

The container **178** may further have receivers **180** for engaging the indexing members **122** and a corresponding

frame **182** mounting the receivers to the container **178** as described in U.S. application Ser. No. 13/974,350 filed Aug. 23, 2013 and entitled FUSELAGE INDEXING SYSTEM AND METHOD, which is hereby incorporated herein by reference.

The container **178** may be a container as described in U.S. application Ser. No. 13/974,322 filed Aug. 23, 2013 and entitled CLOSURE SYSTEM FOR CONTAINERS, which is hereby incorporated herein by reference.

The spar **120** of the wing **14** may be further restrained by means of the spar retention system **130** as described hereinabove. In this manner, movement of the wing **14** transverse to the longitudinal axis thereof may be restrained by means of the cradles **14** and movement along the longitudinal axis may be restrained by the spar retention system **130**.

While the preferred embodiment of the invention has been illustrated and described, as noted above, many changes can be made without departing from the spirit and scope of the invention. For example, although the cradle described herein is shown being used for a wing of a fixed wing aircraft, the cradle may also be used for wings of a rotary wing aircraft, windmill blades, or other long and/or delicate structures. Accordingly, the scope of the invention is not limited by the disclosure of the preferred embodiment. Instead, the invention should be determined entirely by reference to the claims that follow.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. A cradle for supporting a wing, the cradle comprising:

first and second clamping members pivotally coupled to one another and defining a pivot axis, the first clamping member defining a first surface and the second clamping member defining a second surface, the first and second surfaces each conforming to a portion of an airfoil contour of the wing and being formed of a cushioning material;

a first trough member defining a channel substantially parallel to the pivot axis and defining a third surface conforming to one of a leading edge and a trailing edge portion of the wing, the first trough member positioned to engage the one of the leading edge and trailing edge portion when the wing is positioned between the first and second clamping members; and

a locking member engaging the first and second clamping members and configured to selectively lock the first and second clamping members having the first and second surfaces engaging the wing;

wherein the first and second clamping members each comprise

a frame; and

a layer of the cushioning material secured to the frame;

wherein the frame includes first and second end plates and a plurality of rods secured between the first and second end plates and extending through the layer of cushioning material.

2. The cradle of claim **1**, wherein the layer of cushioning material includes a plurality of cushioning members each having at least one surface that is substantially conformal to a contour of the wing at at least one longitudinal position.

3. The cradle of claim **1**, wherein the layer of cushioning material extends outwardly from the first and second end plates and wherein the first and second end plates define inward facing edges that are substantially conformal to the wing at the at least one longitudinal position.

4. The cradle of claim **1**, wherein the wing is a rotary wing.

5. A cradle for supporting a wing, the cradle comprising:

first and second clamping members pivotally coupled to one another and defining a pivot axis, the first clamping member defining a first surface and the second clamping member defining a second surface, the first and second surfaces each conforming to a portion of an airfoil contour of the wing and being formed of a cushioning material;

a first trough member defining a channel substantially parallel to the pivot axis and defining a third surface conforming to one of a leading edge and a trailing edge portion of the wing, the first trough member positioned to engage the one of the leading edge and trailing edge portion when the wing is positioned between the first and second clamping members;

a locking member engaging the first and second clamping members and configured to selectively lock the first and second clamping members having the first and second surfaces engaging the wing; and

a second trough member, the first and second clamping members being positioned between the first and second trough members.

6. The cradle of claim **5**, wherein the first and second trough members each have a longitudinal width at least as great as a longitudinal width of the first and second clamping members.

7. A cradle for supporting a wing, the cradle comprising:

first and second clamping members pivotally coupled to one another and defining a pivot axis, the first clamping member defining a first surface and the second clamping member defining a second surface, the first and second surfaces each conforming to a portion of an airfoil contour of the wing and being formed of a cushioning material;

a first trough member defining a channel substantially parallel to the pivot axis and defining a third surface conforming to one of a leading edge and a trailing edge portion of the wing, the first trough member positioned to engage the one of the leading edge and trailing edge portion when the wing is positioned between the first and second clamping members; and

a locking member engaging the first and second clamping members and configured to selectively lock the first and second clamping members having the first and second surfaces engaging the wing;

wherein the second clamping members is fixedly secured to a shipping container and the first trough is fixedly secured to the second clamping member.

8. A cradle for supporting a wing, the cradle comprising:

first and second clamping members pivotally coupled to one another and defining a pivot axis, the first clamping member defining a first surface and the second clamping member defining a second surface, the first and second surfaces conforming to a portion of an airfoil contour of the wing and being formed of a cushioning material, the first and second clamping members each including:

first and second end plates;

one or more cushioning members positioned between the first and second end plates; and

one or more rods secured to the first and second end plates and extending through the one or more cushioning members; and

a locking member engaging the first and second clamping members and configured to selectively lock the first and second clamping members having the first and second surfaces engaging the wing.

9. The cradle of claim 8, wherein the one or more cushioning members each have at least one surface that is conformal to a contour of the wing at at least one longitudinal position.

10. The cradle of claim 9, wherein the at least one surface is formed by waterjet cutting.

11. The cradle of claim 9, wherein the at least one surface of the one or more cushioning members extends inwardly the first and second end plates and the first and second end plates define inward facing edges that are substantially conformal to the wing at the at least one longitudinal position.

12. The cradle of claim 8, further comprising first and second trough members positioned on either side of the first and second clamping members, the first and second trough members each defining a channel substantially parallel to the pivot axis and defining a third surface conforming to one of a leading edge portion and a trailing edge portion of the wing, the first and second trough members being positioned to engage the one of the leading edge and trailing edge when the wing is positioned between the first and second clamping members.

13. The cradle of claim 12, further comprising a third end plate secured to the first end plate and a fourth end plate secured to the second end plate, the first trough member being positioned between the first end plate and the third end plate and the second trough member being positioned between the second end plate and the fourth end plate.

14. The cradle of claim 13, wherein the one or more cushioning members are one or more first cushioning members, the first trough further comprising one or more second cushioning members positioned between the first end plate and the third end plate and the second trough further comprising one or more third cushioning members positioned between the second end plate and the fourth end plate.

15. The cradle of claim 8, wherein the first and second clamping members further include:

a locking mount positioned between the first and second end plates such that at least one of the one or more rods passes through the locking mount;

wherein the one or more cushioning members include a cutout portion sized to receive the locking mount; and

wherein the locking member is fastened to the locking mounts of the first and second clamping members.

16. A method for shipping an unmanned aerial vehicle having at least one wing, the method comprising:

providing a plurality of cradles each having first and second clamping members pivotally coupled to one another and defining a pivot axis, the first clamping member defining a first surface and the second clamping member defining a second surface, the first and second surfaces conforming to an airfoil contour of the wing and being formed of a cushioning material, a first trough member defining a channel substantially parallel to the pivot axis and defining a third surface conforming to one of a leading edge and a trailing edge portion of the wing, the first trough member positioned to engage the one of the leading edge and trailing edge portion when the wing is positioned between the first and second clamping members, and a locking member engaging the first and second clamping members and configured to selectively lock the first and second clamping members having the first and second surfaces engaging the wing;

positioning the first and second clamping members of the plurality of cradles around the wing at a plurality of positions;

locking the first and second clamping members of the plurality of cradles using the locking members thereof; and

fastening the cradles to a shipping container

wherein the first and second clamping members each comprise—

a frame; and

a layer of the cushioning material secured to the frame;

wherein the frame includes first and second end plates and a plurality of rods secured between the first and second end plates and extending through the layer of cushioning material.

17. The method of claim 16, wherein the plurality of cradles each further include a first trough member defining a channel substantially parallel to the pivot axis and defining a third surface conforming to one of a leading edge and a trailing edge portion of the wing, the first trough member positioned to engage the one of the leading edge and trailing edge portion when the wing is positioned between the first and second clamping members, the method further comprising:

positioning the at least one of the leading edge and trailing edge portion of the wing into the troughs of the plurality of cradles prior to locking the first and second clamping members of the plurality of cradles.

18. The method of claim 16, wherein the first and second clamping members each include, first and second end plates, one or more cushioning members positioned between the first and second end plates, and one or more rods secured to the first and second end plates and extending through the one or more cushioning members, the one or more cushioning members extending outwardly from the first and second end plates; and

wherein locking the first and second clamping members of the plurality of cradles using the locking members thereof comprises applying a locking force to the first and second members effective to compress the one or more cushioning members such that the first and second end plates do not contact the wing.

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