United States Patent [19]
Chilman

[11] **3,792,937**
[45] **Feb. 19, 1974**

[54] **BLADED ROTORS**

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[73] Assignee: **Dowty Rotol Limited,** Gloucester, England

[22] Filed: **Oct. 12, 1971**

[21] Appl. No.: **187,981**

[52] **U.S. Cl.** **416/157**
[51] **Int. Cl.** **B64c 11/38**
[58] **Field of Search**. 416/157, 157 A, 61, 167, 165, 416/166, 164, 137, 208, 206, 162, 154, 156

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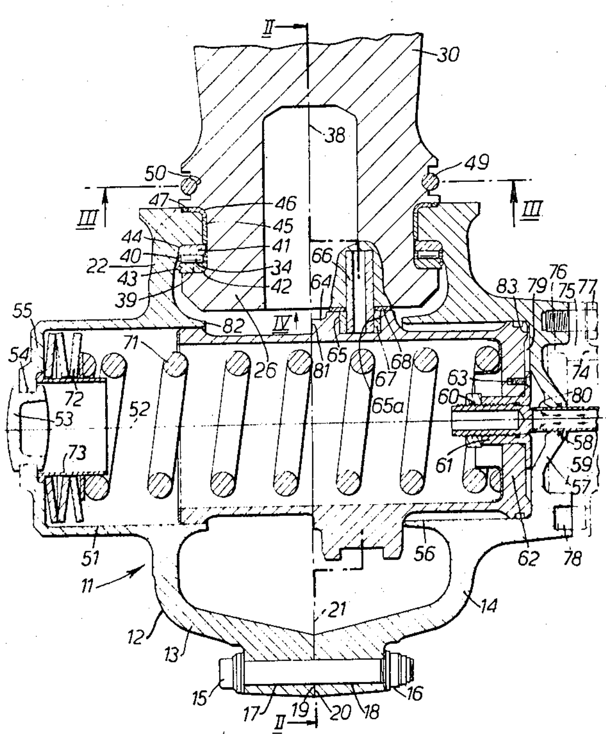
Primary Examiner—Everette A. Powell, Jr.
Attorney, Agent, or Firm—Young and Thompson

[57] **ABSTRACT**

A bladed rotor includes a hub defined by two casing parts having portions which, when the parts are held together by securing means, form sockets in which the blades of the rotor are mounted. A guide is provided in one of said parts and another guide is provided in the other of said parts. The guides are separated by space defining means and support a control member movable with respect thereto. Means provided in said space connect said control member to the blades and movement of that member adjusts the blades.

10 Claims, 4 Drawing Figures



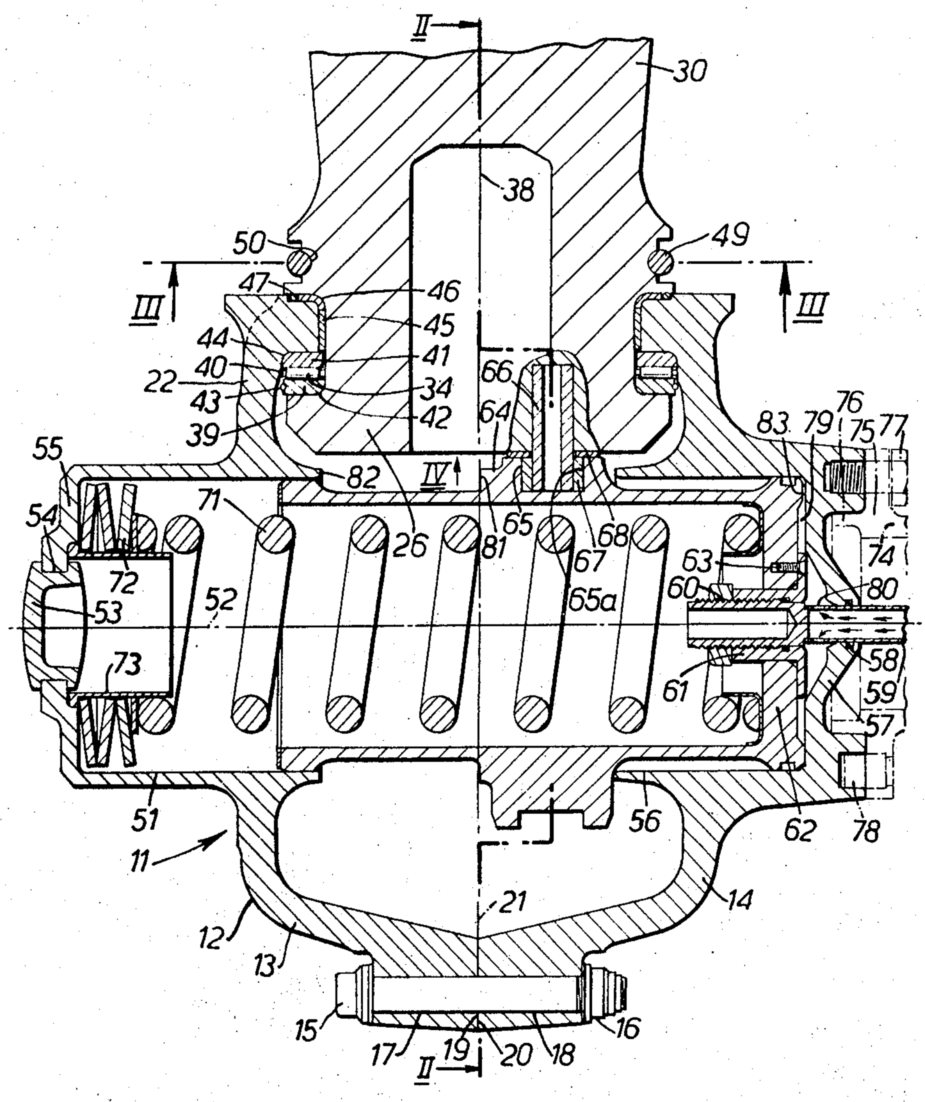

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FIG. 1.

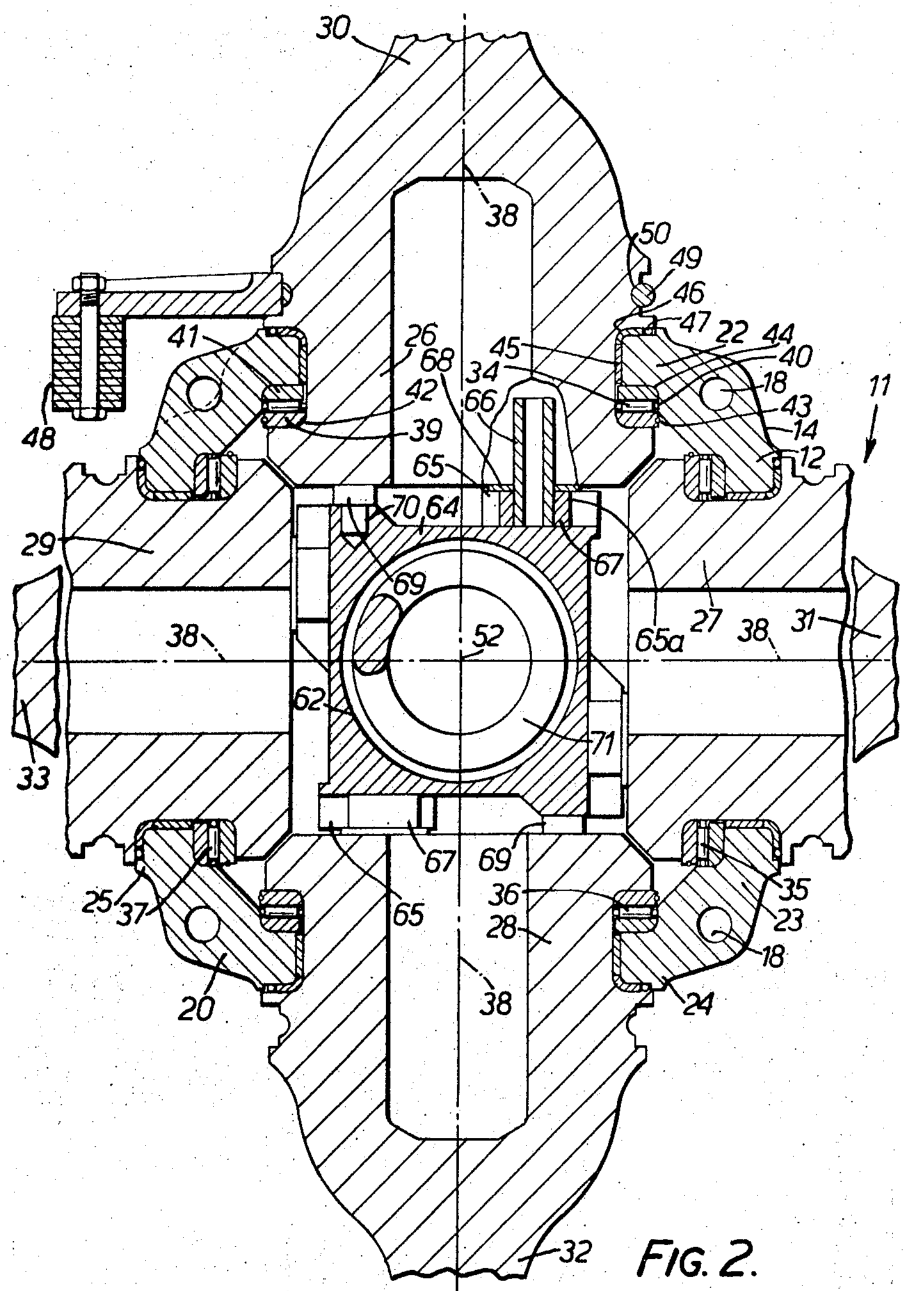
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FIG. 2.

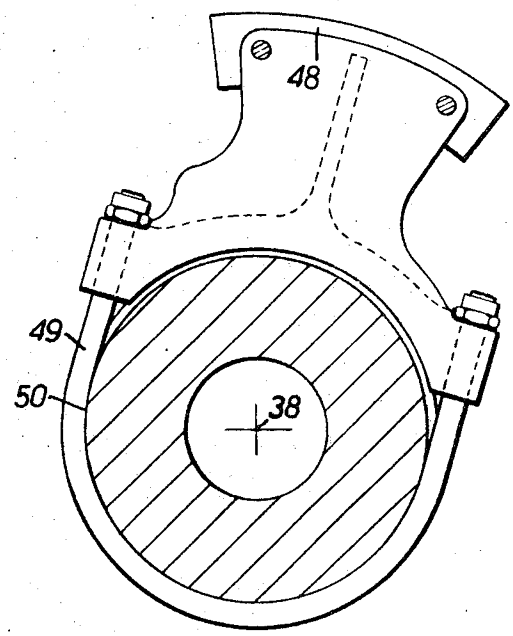

FIG. 3.

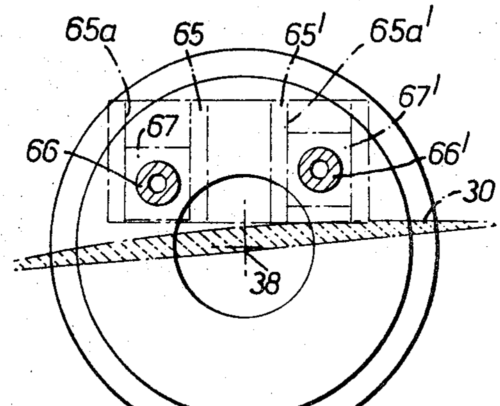

FIG. 4.

BLADED ROTORS

This invention relates to bladed rotors.

According to this invention a bladed rotor includes a hub defined by two casing parts having portions which, when the parts are held together by securing means, form sockets in which the blades of the rotor are mounted, a guide in one of said parts and a guide in the other of said parts, said guides being separated by a space and supporting a control member movable with respect thereto, and means in said space connecting said control member to the blades whereby movement of that member adjusts the blades.

The securing means may include bolts provided in the vicinity of the sockets.

Each blade may be mounted in an anti-friction bearing provided in its socket, each said bearing being split in a diametral plane thereof.

The bladed rotor may be a propeller suitable for an aerial vehicle, and the blades thereof may be of variable-pitch. Alternatively the blades may be of variable-twist or variable camber.

The guides may comprise bores and said control member comprise a piston which together form a pitch-change motor.

The pitch-change motor may be of single-acting hydraulic type. The motor may be operable under the control of a speed-sensitive centrifugal governor and/or under the control of a manually-operable hydraulic valve having a follow-up mechanism associated therewith.

Movement of said piston under hydraulic pressure may be in a direction appropriate to pitch-fining of the blades, such movement being against the effort of first spring means.

The range of movement of the piston may be sufficient to afford movement of the blades beyond fine pitch, through zero pitch into the reverse pitch range for effecting braking of the associated vehicle.

In this case further spring means may be provided, engageable by said piston and compressed thereby as the piston moves through that part of its range corresponding to reverse pitch of the blades.

The first said spring means may be a mechanical coil spring and said further spring means may comprise a Belleville washer stack, both said coil spring and said stack being arranged with their axes coincident with the rotational axis of the rotor.

Blades of the rotor may carry fly-weights so disposed with respect to each blade longitudinal axis as to assist said first spring means in biassing the blades in the pitch-coarsening direction.

The piston may have surfaces spaced apart from the adjacent end faces of the roots of at least certain of the blades with portions upstanding from those surfaces which have such sliding relationship with said faces and which are so disposed in relation to the respective blade longitudinal axis, as substantially to prevent angular displacement of said piston about the rotational axis of the rotor with respect to said hub, the area of the face associated with each upstanding portion which is in engagement with the respective blade root end face being small in relation to the area of that root end face.

One embodiment of the invention will now be particularly described by way of example with reference to the accompanying drawings of which,

FIG. 1 is a cross-section of a propeller hub and of a part of a blade mounted in the hub,

FIG. 2 is a cross-section taken along line II—II,

FIG. 3 is a sectional view taken long the line III—III on FIG. 1, and,

FIG. 4 is a partial view in the direction of the arrow IV on FIG. 1.

Referring to the drawings, a bladed rotor in the form of an aircraft propeller **11** includes a hub **12** comprising two aluminum alloy casing parts **13** and **14** held together by securing means which take the form of four bolts **15** and four nuts **16**, the bolts passing through holes **17** and **18** provided in the parts **13** and **14**.

The engaging faces **19** and **20** of the parts **13** and **14** lie in a plane **21**. The parts **13** and **14** together define four sockets **22, 23, 24** and **25** which receive the root portions **26, 27, 28** and **29** of aluminium alloy propeller blades **30, 31, 32** and **33** which are each mounted in respective roller bearings **34, 35, 36** and **37** for pitch variation about the respective longitudinal pitch-change axis **38**.

The inner race **39**, the roller cage **40** and the outer race **41** of each of these bearings are split in a diametral plane thereof. Each inner race **39** is held in a suitably-shaped seating **42** in its respective blade root portion by a wire ring **43**, while each outer race **41** is located in a suitably-shaped recess **44** formed in the respective hub socket.

Each blade has nylon bearing inserts **45** and **46** and a sealing ring **47** in the position shown. These components are also split in a diametral plane.

Each blade also carries a fly-weight assembly **48** so positioned thereon as in operation to produce moments about the blade longitudinal axis which oppose the inherent centrifugal twisting moments in the blades, and which bias the blades in the pitch-coarsening direction. Each fly-weight assembly is held fast to its blade by a U-bolt **49**, the U-bolt and part of the fly-weight assembly engaging a peripheral recess **50** in the blade.

As shown in FIG. **1**, the part **13** is formed with a guide in the form of a bore **51** whose axis is coincident with the rotational axis **52** of the rotor. The bore **51** is closed at its forward end portion by a hard rubber plug **53** which engages an aperture **54** formed in the end wall **55**.

Similarly, the part **14** is provided with a guide in the form of a bore **56**, of the same diameter as the bore **51**, which is axially-spaced from the bore **51** and whose axis is also coincident with the axis **52**. The rearward end portion of the bore **56** is closed by a wall **57** which has an aperture **58** through which an oil supply tube **59** passes coaxially with the axis **52**. The forward end portion of the tube **59** is screw-threadedly connected at **60** to a flanged member **61** which in turn is held fast with respect to a pitch-change motor piston **62**, which is of aluminium alloy, by means of set screws as at **63**. The piston **62** is hollow and is supported for axial sliding movement in the axially-spaced bores **51** and **56**, thus to form a control member for the blades.

Although generally of cylindrical shape, the piston **62** is provided with a central portion of generally square cross-sectional shape as at **64** which includes four upstanding portions **65** each of which is associated with a respective crank pin **66** projecting from each blade root portion **26, 27, 28** and **29**. Each crank pin **66** projects into a bore provided in a respective slide block **67** which is itself slidingly mounted in a channel of the respective upstanding portion **65**, a washer **68** being provided between the end face of the respective blade root portion and the portion **64**.

As shown in FIG. **2**, two slide buttons **69** forming further upstanding portions are located in short bores **70** provided in the central portion **64**, being positioned between the end faces of the two blade root portions **26** and **28** and the central portion **64** to prevent tilting of the piston about its longitudinal axis during its axial movement.

First spring means in the form of a mechanical coil spring **71** is provided between the right-hand portion in FIG. **1** of the piston **62** and a Belleville washer stack **72** which forms an abutment for the coil spring. The Belleville washer stack **72** is housed at the forward end portion of the bore **51** and seats upon a tubular insert **73**. The coil spring **71** is also located on the insert **73** so that both the coil spring and the Belleville washer stack are co-axially arranged with respect to the rotational axis **52**.

The propeller is intended for fitment upon an engine output shaft shown in dotted lines at **74** with a mounting flange **75** and spigot portion **76**. The rearward portion of the part **14** is so shaped as to fit upon the spigot **76**, and eight set bolts, one of which is shown at **77**, which pass through the flange **75** retain the propeller upon the shaft **74**, two locating dowels, one of which is shown at **78**, also being provided.

In FIG. **1** of the drawings the piston **62** is shown in its extreme rearward position corresponding to maximum coarse pitch of the blades **30, 31, 32** and **33**. The chamber **79** to the rear of the piston **62** is chargeable with liquid under pressure supplied through the tube **59** and passing into the chamber through ports **80** in the tube.

The central portion **64** of the piston **62** is provided with a stop face **81** at the position shown in FIG. **1** which comes into engagement with the face **82** of the casing part **13** at the maximum reverse pitch condition, while the face **83** at the rearward end portion of the piston comes into engagement with the wall **57** at the fully-feathered condition.

The construction of the hub hereinbefore described is of relatively simple and inexpensive construction because the pitch-change motor simply comprises the portions of the casing parts **13** and **14** having the two bores **51** and **56** and the piston **62** supported by these bores. The axial spacing between the bores gives a relatively large access opening for connection of the piston to the roots of the propeller blades for pitch-change.

In order to assemble the components of the propeller, the casing part **14** is positioned with its face **20** horizontal and the appropriate outer half-races **41** of the split roller bearing **34, 35, 36** and **37** are fitted into their recesses **44** complete with the half-sets of rollers in their half-cages **40**. The appropriate halves of the inserts **45** and **46** and of the sealing rings **47** are also fitted.

The four blades **30, 31, 32** and **33** each fitted with its two-part inner race **39** held thereon by the wire ring **43** are placed in position complete with their crank-pins **66** and washers **68**. Such placing is substantially simultaneous with the fitting of the piston **62** complete with its slide blocks **67** and slide buttons **69**, the crank-pins being entered into the slide blocks.

The other outer half-races **41**, complete with their half-sets of rollers in the respective half-cages **40** are now placed in position on the blade root portions. The other halves of the inserts **45** and **46** and of the sealing rings **47** are also fitted.

A special tool (not shown) is applied to the part **13** for compression of the coil spring **71** and the Belleville washer stack **72**. This tool is applied with the plug member **53** removed.

The part **13** complete with the tool in its operative position is fitted to the assembly of components and secured by the bolts **15** and the nuts **16**. The tool is then adjusted to allow the coil spring **71** and Belleville washer stack **72** to expand to their full free length, whereupon the tool is released and removed from the assembly and the plug member **53** is fitted to the aperture **54**.

The fly-weight assemblies **48** are then fitted to the blades.

Suitable balance weights (not shown) are bolted in convenient manner to the hub as necessary for balance of the structure. The tube **59** is fitted to the flanged member **61** just prior to mounting the propeller on the engine shaft **74**.

In operation of the propeller, liquid under pressure admitted under the control of a control valve assembly (not shown, but carried by the engine structure) into the chamber **79** causes compression of the coil spring **71** and movement of the piston **62** and thus of the blades **30, 31, 32** and **33** in the pitch-fining direction, to the left in FIG. **1**, the blocks **67** which are of nylon, sliding in their respective upstanding portions **65**, and the washers **68**, which are basically of polytetrafluoroethylene material, and the buttons **69**, which are also basically of polytetrafluoroethylene material, affording low friction between the linearly moving piston **62** and flat end faces of the blade root portions **26, 27, 28** and **29** as the blades rotate about their pitch-change axes **38**.

Such movement is also against the effort of the fly-weights **48** which assists the coil spring **71** is biassing the blades in the pitch-coarsening direction.

As the blades reach the pitch piston required by the setting of the control valve assembly, the tube **59** applies a follow up signal to the control valve assembly to arrest the supply of pressure liquid through the tube and to hold the piston **62** hydraulically against the effort of the spring **71** so that the blades are held in the selected position.

In practice, the blades are positioned at approximately 0° for engine starting, at approximately 18° for take-off of the aircraft, at approximately 35° for flight cruise, and at approximately 15° for approach idling.

To move the blades into reverse pitch for aircraft braking upon touch-down, they are caused to pass through the 0° position by suitable adjustment of the control valve assembly, the piston **62** then compressing the coil spring **71** until the −5° blade angle position is reached, whereupon the piston **62** commences to compress the Belleville washer stack **72** as well as further to compress the coil spring **71**.

AS the blades reach their −15° position, which in this embodiment is the maximum reverse (negative) pitch angle, the face **81** engages the face **82**. FIG. **4** indicates the range of pitch-change movement, showing the extreme crank-pin positions at **66** and **66'**.

The Belleville washer stack **72** is of higher rate than the coil spring **71** and serves to overcome the aerodynamic twisting moments, (otherwise effective upon the blades to move them in the pitch-fining direction), thus to move the blades back into the positive pitch range when the hydraulic pressure in the chamber **79** is sufficiently relieved by appropriate selection of the control valve assembly.

Subsequent movement of the blades in the pitch-coarsening direction in the positive range is under the effort of the coil spring **71** and also the fly-weights **48** which oppose the centrifugal twisting moments inherent in the blades, the rate of pitch-change then being dependent upon the out-flow of liquid from the chamber **79** as is permitted by the control valve assembly.

As the blades approach the feathered (85° position) the rotational speed of the propeller naturally falls and the fly-weights **48** in themselves would be inadequate to move the blades to their fully feathered condition. The coil spring **71** is of sufficient rate as to ensure completion of the feathering movement.

During such pitch-change movement, tilting of the piston **62** about the rotational axis **52** is substantially prevented in one direction (the clockwise direction when viewed in FIG. **2**) by each of the two buttons **69** which are in sliding engagement with the respective blade root end face and is substantially prevented in the other direction (the anti-clockwise direction when viewed in FIG. **2**) by the upstanding portions **65** and the associated washers **68**, the latter also engaging the respective blade root end face. Since the area of the face of each button **69** and of the face of each washer **68** in engagement with the respective blade root end face is small in relation to the area of the root end face, since the material of each button and each washer is basically polytetrafluoroethylene, and since the slide blocks **67** are of nylon, low friction is afforded between the linearly moving piston **62** and the flat root end faces of the blades as the blades are driven about their longitudinal axes for pitch-change. Thus the arrangement provides a low-friction pitch-change connection between the pitch-change motor and the blades.

The piston is thus constructed in a manner which avoids the use of splines or rods in its mounting in the hub and in its connection to the blades.

It will be seen that by the simplified construction the forgings from which the hub parts **13** and **14** are produced can be of the same basic shape, the differences between the forward portion of the hub structure and the rearward portion of the hub structure being obtained by machining. However, lhe fact that only one basic forging shape is required contributes to the inexpensiveness of this propeller construction.

The invention is not limited to the provision of four blades on the hub as any other desired number of blades, with a piston of suitable cross-sectional shape in the zone of the blade root end portions, may be provided.

Further the invention is not limited to aircraft propellers as with advantage it may well be applied to any other bladed rotor, for example propellers for air-cushion vehicles, for boats, ships and the like, or alternatively, fans for vehicles or fixed installations, or the bladed rotors of ram-air turbines.

Although in the embodiment described with reference to the drawings the blades each have fly-weights attached thereto, in other embodiments no such fly-weights may be provided, or alternatively in yet other embodiments further fly-weights may be provided. Again, on a four-bladed propeller, only two fly-weights may be provided on opposite blades.

Further, although in the embodiments described with reference to the drawings the blades of a bladed rotor are variable in pitch, in other embodiments they may instead be variable in twist, or variable in camber. Also, the rotor may instead be of non-reversible pitch type.

Again, although in the embodiment above described with reference to the drawings the piston moves rearwardly of the propeller for pitch-coarsening, in alternative embodiments in the piston instead moves forwardly of the propeller for pitch-coarsening.

Further, in alternative embodiments of the invention, instead of the pitch-change motor of the bladed rotor being controlled by a manually-operable control valve assembly, it may be controlled by a speed-sensitive centrifugal governor, or by a manually-operable control valve assembly and a speed-sensitive cntrifugal governor.

The invention is not limited to the type of pitch-change motor described with reference to the drawings, as in other embodiments it may be of double-acting hydraulic type, or again in other embodiments the motor may not be of hydraulic type but instead may be of pneumatic type.

Again, instead of the control member taking the form of a piston movable in bores, in other embodiments the control member may be a device other than a piston mounted in guides other than bores and displaceable with respect to the guides by mechanical, electrical or other suitable means.

I claim:

1. A bladed rotor including a hub casing defined by two casing parts, each having a first portion including radially-outwardly-directed projections, the two portions being of substantially identical form so that when said parts are held together in assembled relation by securing means said projections form radially-outwardly-directed sockets of circular cross-section in which the blades of the rotor are mounted with freedom for pitch-change adjustment about their longitudinal axes, the plane in which the said two parts are in engagement being disposed diametrically of all the sockets, each of said casing parts also having a single cylindrical portion projecting from its said first portion, the two cylindrical portions being of substantially identical form and extending from the first portions away from each other with their axes coincident with the axis of rotation of the rotor, space-defining means which separate the two cylindrical portions, the one axially from the other, one end closure wall provided at the end of one of said cylindrical portions remote from said plane, another end closure wall positioned at that end of the other of said cylindrical portions remote from said plane, a piston comprising a hollow rod, which is disposed with one end portion thereof in slidable engagement with respect to the inner wall of said one cylindrical portion, and a piston head formed by an end wall which closes the other end portion of the hollow rod and which is disposed in slidable engagement with respect to the inner wall of said other cylindrical portion, and means provided in said space which connect the piston to the blades, said other cylindrical portion and its end closure wall forming a chamber for said piston into which fluid is suppliable under pressure for effecting axial sliding movement of the piston with respect to the cylindrical portion and thus adjustment of the blades about their longitudinal axes.

2. A bladed rotor including a hub casing defined by two casing parts, each having a first portion including radially-outwardly-directed projections, the two portions being of substantially identical form so that when said parts are held together in assembled relation by securing means said projections form radially-outwardly-direction sockets of circular cross-section in which the blades of the rotor are mounted with freedom for pitch-change adjustment about their longitudinal axes, the plane in which the said two parts are in engagement being disposed diametrically of all the sockets, each of said parts also having a single cylindrical portion projecting from its said first portion, the two cylindrical portions being of substantially identical form and extending from the first portions away from each other with their axes coincident with the axis of rotation of the rotor, space-defining means which separate the two cylindrical portions, the one axially from the other, one end closure wall provided at that end of one of said cylindrical portions remote from said plane, another end closure wall positioned at that end of the other of said cylindrical portions remote from said plane, a piston comprising a hollow rod, whic is disposed with one end portion thereof in slidable engagement with respect to the inner wall of said one cylindrical portion, and a piston head formed by an end wall which closes the other end portion of the hollow rod and which is disposed in slidable engagement with respect to the inner wall of said other cylindrical portion, mechanical spring means, whose axis is coincident with said axis of rotation, which means at one end engages said one end closure wall and which so projects into said hollow rod as at its other end to engage said end wall forming said piston head, and means provided in said space which connect the piston to the blades, said other cylindrical portion and its end closure wall forming a chamber for said piston into which fluid is suppliable under pressure for effecting axial sliding movement of the piston against said spring means and thus adjustment of the blades about their longitudinal axes.

3. A bladed rotor including a hub casing defined by two casing parts, each having a first portion including radially-outwardly-directed projections, the two portions being of substantially identical form so that when said parts are held together in assembled relation by securing means said projections form radially-outwardly-directed sockets of circular cross-section in which the blades of the rotor are mounted with freedom for pitch-change adjustment about their longitudinal axes, the plane in which the said two parts are in engagement being disposed diametrically of all the sockets, each of said casing parts also having a single cylindrical portion projecting from its said first portion, the two cylindrical portions being of substantially identical form and extending from the first portions away from each other with their axes coincident with the axis of rotation of the rotor, space-defining means which separate the two cylindrical portions, the one axially from the other, one end closure wall provided at that end of one of said cylindrical portions remote from said plane, another end closure wall positioned at that end of the other of said cylindrical portions remote from said plane, a piston comprising a hollow rod, which is disposed with one end portion thereof in slidable engagement with respect to the inner wall of said one cylindrical portion, and a piston head formed by an end wall which closes the other end portion of the hollow rod and which is disposed in slidable engagement with respect to the inner wall of said other cylindrical portion, means provided in said space which connect the piston to the blades, and said piston and said cylindrical portions being dimensioned to afford a range of sliding movement of the piston corresponding to a range of movement of the blades which includes positive and negative pitch, a first mechanical spring means and a second mechanical spring means the axes of which are coincident with said axis of rotation, said first spring means at one end engaging said end wall forming said piston head and at the other end engaging said second spring means, and said second spring means at its end remote from the first spring means engaging said one end closure wall, and said other cylindrical portion and its end closure wall forming a chamber for said piston into which fluid is suppliable under pressure for effecting axial movement of the piston against said spring means and thus adjustment of the blades.

4. A bladed rotor including a hub defined by two casing parts having portions which, when the parts are held together in assembled relation by securing means, form radially-outwardly-directed sockets of circular cross-section which house anti-friction bearing means by way of which the blades of the rotor are mounted with freedome for pitch-change adjustment about their longitudinal axes, the plane in which said two parts are in engagement being disposed diametrically of all the sockets, and said two parts each having a respective bore portion provided with an end closure wall remote from said plane, the axis of one bore portion being coincident with that of the other bore portion, space-defining means which separate said bore portions axially one with respect to the other, a hollow piston wholly enclosed within said two assembled casing parts with one end portion thereof slidably supported in said one bore portion and the other end portion thereof slidably supported in said other bore portion, said piston closed at said other end portion and there forming with said other bore portion an expansible pitch-change motor chmber which is connectible with fluid under pressure, means provided in said space which connect the piston to the blades whereby sliding movement of the piston with respect to the bore portions under the pressure of fluid in said chamber effects adjustment of said blades, a mechanical coil spring so extending within said hollow piston as at one end to engage the closed end portion thereof, and a Belleville washer stack which at one end is engaged by the other end of said coil spring and which, at its other end, engages the end closure wall of said one bore portion, said stack being engageable by said piston and compressible thereby as the piston moves through part of its range of movement, and both said coil spring and said stack being arranged with their axes coincident with the rotational axis of the rotor.

5. A bladed rotor including a hub defined by two casing parts having portions which, when the parts are held together in assembled relation by securing means, form radially-outwardly-directed sockets of circular cross-section which house anti-friction bearing means by way of which the blades of the rotor are mounted with freedom for pitch-change adjustment about their longitudinal axes, the plane in which said two parts are in engagement being disposed diametrically of all the sockets, and said two parts each having a respective bore portion, the axis of one bore portion being co-

incident with that of the other bore portion, space-defining means which separate said bore portions axially one with respect to the other, a hollow piston wholly enclosed within said two assembled casing parts with one end portion thereof slidably supported in said one bore portion and the other end portion thereof slidably supported in said other bore portion, said piston being closed at said other end portion and there forming with said other bore portion an expansible pitch-change motor chamber which is connectible with fluid under pressure, and the piston having surfaces spaced apart from the adjacent end faces of the roots of at least certain of the blades with portions upstanding from those surfaces which have such sliding relationship with said faces and which are so disposed in relation to the respective blade longitudinal axis, as substantially to prevent angular displacement of said piston about the rotational axis of the rotor with respect to said hub, the area of the face associated with each upstanding portion which is in engagement with the respective blade root end face being small in relation to the area of that root end face, spring means disposed between said piston and an abutment of said one bore portion, and means provided in said space which connect the piston to the blades whereby sliding movement of the piston with respect to the bore portions under the pressure of fluid in said chamber and against the effort of said spring means effects adjustment of said blades.

6. A bladed rotor as claimed in claim **3,** wherein said first spring means comprises a coil spring and the second spring means comprises a stack of spring washers, the external diameter of said stack being substantially greater than that of said coil spring.

7. A bladed rotor as claimed in claim **4,** wherein a ported tube is connected to said piston and provides means by way of which fluid under pressure is introduced into said chamber for effecting movement of the piston against the effort of said coil spring and stack in the direction corresponding to adjustment of the blades in the pitch fining direction.

8. A bladed rotor as claimed in claim **4,** wherein said casing parts include stop means with which the piston is co-operable and which afford the piston an extent of movement corresponding to movement of the blades in the positive pitch range and the negative pitch range, movement from the positive pitch range to the negative pitch range, and vice versa, being through zero pitch, and said stack being engaged by said piston only when the blades are in the negative pitch range.

9. A rotor as claimed in claim **1,** wherein said securing means include bolts provided in the vicinity of the sockets.

10. A rotor as claimed in claim **2,** wherein each blade is mounted in an anti-friction bearing provided in its socket, each said bearing being split in a diametral plane thereof.

* * * * *

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,792,937 Dated February 19, 1974

Inventor(s) John Alfred Chilman

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

On the cover sheet insert:

-- [30] Foreign Application Priority Data

Great Britain 52557 Nov. 4, 1970 --.

Signed and Sealed this

thirtieth **Day of** *March 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

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