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3,249,161

FEATHERING CONTROLLABLE PITCH PROPELLER

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4 Sheets-Sheet 1

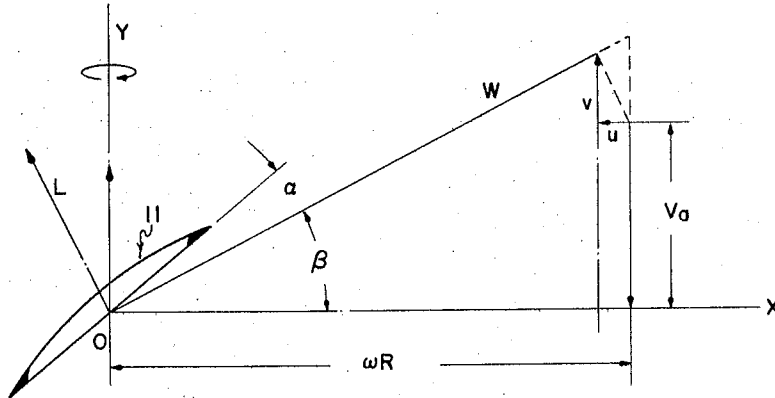


FIG. 1.

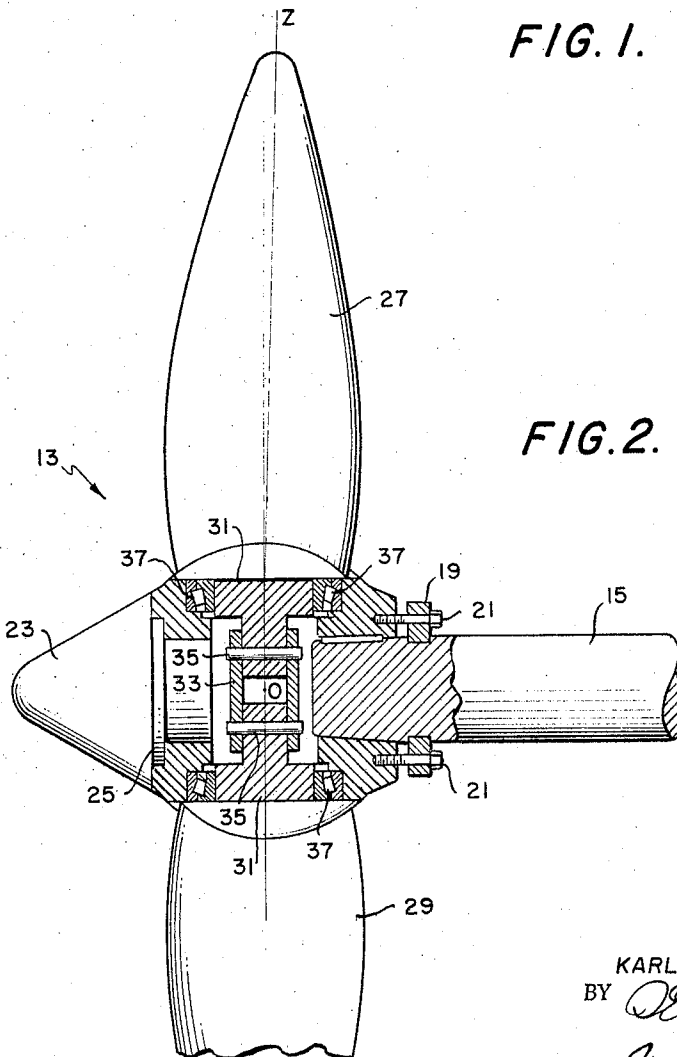


FIG. 2.

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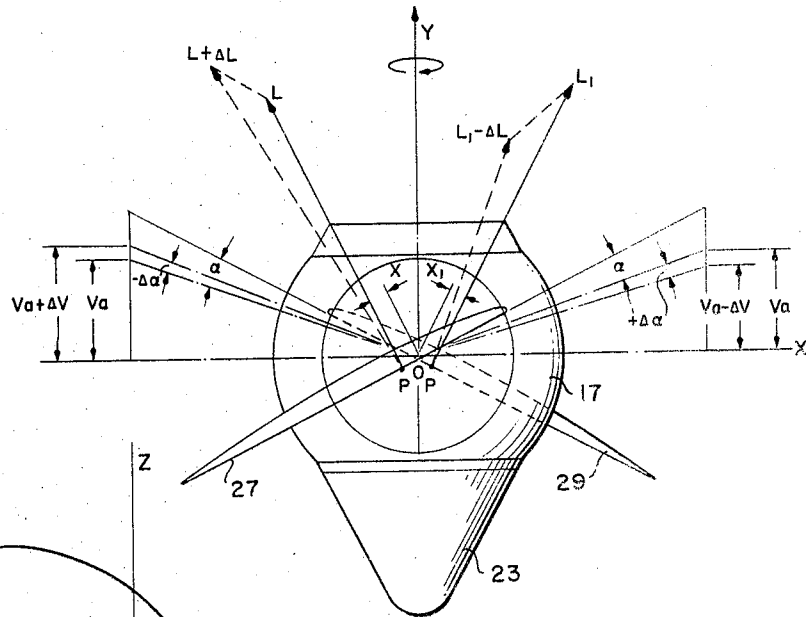


FIG. 4.

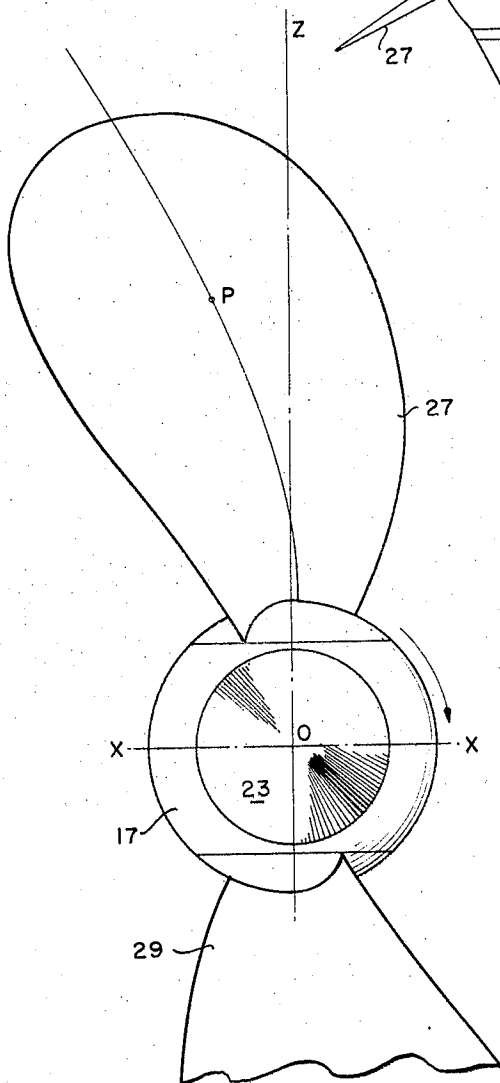


FIG. 3.

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4 Sheets-Sheet 3

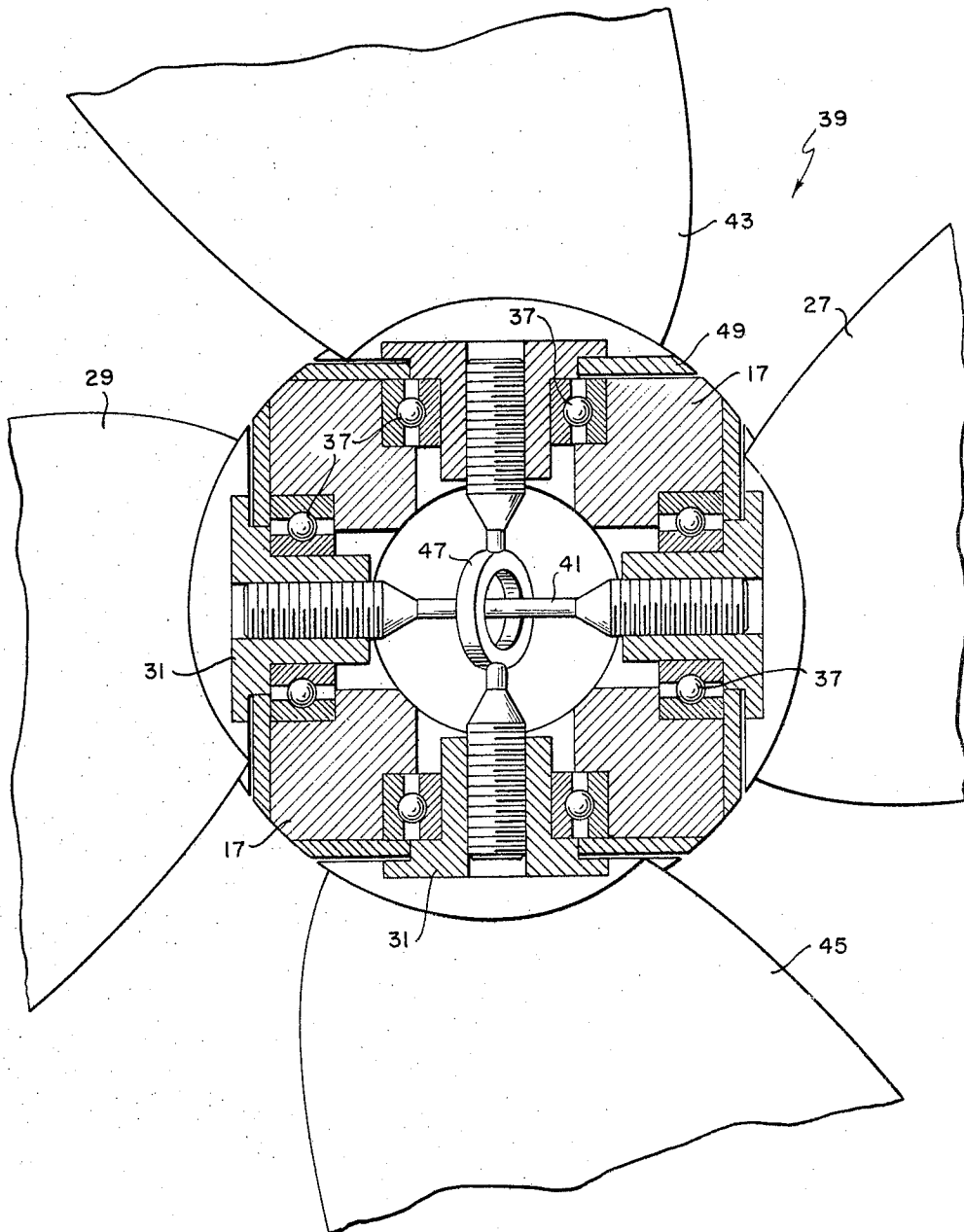


FIG. 5.

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3,249,161 FEATHERING CONTROLLABLE PITCH PROPELLER

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2 Claims. (Cl. 170-160.53)

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

The present invention relates to marine propellers and more particularly to a propeller which will reduce the fluctuations of the propeller forces and thus minimize vibrations.

The propeller located behind the hull of a ship operates in the water disturbed by the hull, or the so-called wake of the ship. The velocity distribution in this wake is not uniform, but in general varies radially and circumferentially. Radial variation is not harmful as this can be allowed for in the design of the propeller. However, circumferential variation is harmful because this variation produces pressure fluctuations causing the angle of attack of the propeller blade to vary about a mean value as the blade goes through one complete revolution. These pressure fluctuations are radiated into the surrounding water and are transmitted to the hull giving rise to the primary cause of vibration in the ship structure. Vibrations, in turn, are highly objectionable for marine vessels and must be avoided if possible.

Heretofore, attempts to reduce vibrations have resulted in arrangements of resiliently mounted propeller blades and standard controllable pitch propellers, wherein the pitch of the propellers are adjusted for varying loads and to reverse thrust without varying the direction of rotation of the shaft. The pitch adjustment, usually being effected by a bell crank arrangement in the interior of the hub activated by mechanical or hydraulic means. The prior art devices and arrangements have not proven satisfactory for the reduction of vibration due to the fluctuating wake forces.

The general purposes of this invention is to reduce the fluctuations of the propeller forces and thus minimize vibrations. To attain this, the present invention contemplates a self-adjusting feathering controllable pitch propeller arrangement whereby force fluctuations are reduced and vibrations are minimized.

An object of the present invention is the provision of a self-adjusting feathering controllable pitch propeller for minimizing ship vibrations.

Another object is to provide a rotatable blade propeller for efficient ship movement in the rearward direction.

A further object of the invention is the provision of a self-balancing propeller arrangement wherein an equilibrium of forces and moments is maintained.

Other objects and advantages of this invention will hereinafter become more fully apparent from the following description of the annexed drawings which illustrate preferred embodiments and wherein:

FIG. 1 is a representative section of a propeller blade showing the forces acting upon it;

FIG. 2 is a longitudinal sectional view along the lateral plane of a ship of a two-bladed propeller embodiment constructed according to the present invention;

FIG. 3 is a transverse view of the propeller of FIG. 2 projected on a plane transverse to the fore and aft axis of the ship;

FIG. 4 is a top view of a propeller of FIG. 3 showing the self-balancing feature of the present invention;

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FIG. 5 is a transverse sectional view of a four-bladed propeller constructed according to the present invention showing the interior hub connections;

FIG. 6 is a transverse sectional view of a further embodiment of the present invention wherein resilient means control blade adjustments; and

FIG. 7 is a view of the resilient means of FIG. 6.

FIG. 1 discloses the action of a standard screw propeller with respect to a tri-rectangular system of coordinates wherein OY is the axis about which the propeller turns and along which it advances and OZ is the axis normal to the plane of the drawings. An ogive 11 represents a blade section at radius R from the center of the hub, having a linear tangential velocity of ωR and velocity of advance of the propeller being V_a . From propeller theory it is then known that the resultant velocity W relative to the blade section is given by the expression:

$$W = \sqrt{(V_a + v)^2 + (\omega R - u)^2}$$

where,

u is the rotational slip velocity

v is the axial slip velocity.

The propeller is usually so designed that W meets the face of the blade section at an angle α , the so-called hydrodynamic angle of attack. This angle of attack causes a lift force L to be produced, the magnitude of which may be expressed by the equation:

$$L = \rho/2 A W^2 f(\alpha)$$

where,

ρ is the density of the medium

A is the area of the blade

W is the resultant velocity

f(α) is some function of α .

From this equation it is seen that when α increases, L increases and vice versa. For a given propeller, the angle of attack α varies when either the vector V_a , the vector (ωR) , or the ship velocity vectors u and v change. When the propeller is working behind a ship in the so-called wake of the ship, the wake which is not a uniform current but a highly irregular one causes the angle of attack α to vary about a mean value as the blade goes through one complete revolution. Therefore, the wake cause the angle α to vary and in turn causes the lift force L and the components of this force to fluctuate. These force fluctuations are the primary cause of vibrations in the ship structure.

The present invention minimizes force fluctuations caused by variable inflow into the propeller (variable wake) by feathering the propeller, that is, by reducing the angle of attack α when V_a , the velocity of advance of the propeller, tends to decrease (region of high wake), and increasing α when V_a tends to increase (region of low wake). Since the angle of attack is usually on the order of four to six degrees, angular adjustments ($\Delta\alpha$) required to smooth out these fluctuations need not be greater than about plus or minus 2°. To accomplish angular adjustments, each blade must of course be rotatable about the OZ axis as shown in FIG. 2. Control of the adjustments can be effected in several ways; (a) through a bell crank arrangement inside the hub actuated by mechanical or hydraulic means and programmed in suitable manner (b) through resilient means inside the hub or (c) through a special design of the blades and of the blade mounting on the hub as hereinafter described.

The essential features of a self-adjusting controllable pitch propeller are shown in FIG. 2. This figure shows a two-bladed screw propeller 13 for simplicity. Extension of the principle of this invention to a propeller with more than two blades is merely a matter of design. In

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this embodiment the multiple-bladed propeller has an even number of blades, that is two, four, six . . . blades. FIG. 2 is the longitudinal view of the propeller, that is, the propeller projected on the lateral plane of the ship. FIG. 3 is the transverse view, that is the propeller projected on a plane transverse to the fore and aft axis of the ship.

FIG. 2 shows in section the interior hub connections of the two-bladed propeller 13. The drive shaft 15 is connected to the hub 17 at one end by suitable mountings shown as a ring 19 and a plurality of bolts 21 and a hub cap or fairwater 23 is placed over a cover plate 25 at the other end. The two-bladed propeller having an upper blade 27 and a lower blade 29 is connected together in the hollow, central portion of the hub 17. Each blade is secured by any suitable means to a blade spindle 31 which extends into the center of the hub. The blade spindles are connected together by any suitable means shown as a sleeve 33 having two pins 35, one pin extending through the end portion of each spindle and through the sleeve. The sleeve thereby forms a rigidly connected two-blade propeller and the spindles ride on bearings 37 which are provided about the blade spindles, thereby enabling the rigidly connected two-bladed propeller 13 to rotate about the OZ axis. The rigidly connected two-bladed propeller construction causes the rotational motion of each pair of blades to be such that when the angle of attack α increases for the top blade by an amount $\Delta\alpha$ it decreases for the bottom blade by the same amount.

The novel arrangement of FIG. 2 is self balancing in ahead operation as is shown in connection with FIG. 4. In this figure the OZ axis is normal to the plane of the drawing, the direction of rotation of the shaft is shown and the blade area is skewed aft as shown in FIG. 3 wherein the center of pressure P of the blade 27 lies rearward of the OZ axis. When the ship velocity (V_s), the velocity of advance (V_a), and the rotation velocity (ω) are all uniform, the lift forces L and L_1 are equal. Since that the opposing blades 27 and 29 have the same shape, the moments of these forces about the OZ axis are also equal; that is

$$M = LX = M_1 = L_1 X_1$$

where

M = the moment

L = lift force

X = distance from the OZ axis to the pressure point on each blade

When there is some irregularity in the wake, the inflow angle of the upper blade is increased by the amount $\Delta\alpha$ but not for the lower blade, then the force L increases; this causes an inequality in moments, that is

$$LX > L_1 X_1$$

And the system rotates about OZ in a clockwise direction. This rotation tends to diminish α for the upper blade 27 and tends to increase it for the lower blade 29. The tendency therefore is to restore equilibrium in moments. Hence, there is a feathering action by the blades which tends to counteract the force of fluctuations reduced by wake or other flow regularities. The blades therefore exhibit an oscillatory motion in a variable wake, oscillating plus or minus two degrees about a mean value. In prior systems, the different pressures on the blades would be transmitted to the hub and the surrounding water due to the rigid connections of the hub and blade.

The system described is in stable equilibrium only for normal ahead operations. When the ship is backing, the equilibrium is unstable because the propeller is designed for forward operation. This invention provides sufficient room so that the blades can turn through 180 degrees so that, when the ship is backing and the blades have turned through the 180 degrees, operation is the same as for normal ahead operations. This reversal feature of the blades

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for backing operation is very useful because blade sections designed for best efficiency for ahead operation becomes very inefficient for backing. As a result of this decreased efficiency, the propulsive efficiency of a ship when backing is no more than $\frac{2}{3}$ of the propulsive efficiency when moving forward. Therefore, the new propeller not only tends to smooth out force fluctuations but is also capable of improving the efficiency astern by as much as 30 percent which permits reducing the size of the astern turbine without impairing maneuverability.

FIG. 5 is an embodiment of a four-bladed propeller 39 constructed according to the present invention. One pair of blades 27 and 29 are connected together by a straight connecting rod 41 attached to the respective spindles 31 and a second pair of blades 45 and 43 are connected together by a forked connecting rod 47 with the straight connecting rod inserted through the fork. Mechanical limit stops 49 are provided about the blade to allow a rotation of the blade of approximately plus or minus 5 degrees, thereby insuring adequate rotational movement of the connecting rods without interference.

A second way to smooth out wake irregularities which may be used on a propeller having any number of blades, is to control the angle of incidence of the blade by resilient means. This embodiment is shown in FIGS. 6 and 7 wherein the same reference numerals are employed as in the previous figures. The hub 17 of the multi-bladed propeller 51 has a cover plate 25a mounted on one end and a hub cap or fairwater 23a mounted over the cover plate. A plurality of holes 53, equal to the number of blades on the propeller are provided in the cover plate 25a. One part 54 of the hole in communicating relationship with the interior of the hub 17 is square in transverse cross-section and the other portion 55 of the hole in communicating relationship with the interior of the fairwater 23a is circular in cross-section with a diameter greater than the greatest dimension of the square hole and abuts the square hole at a shoulder 56. The circular hole and the shoulder form a seat for a resilient element such as a spring which rides on tension rod 59 having a middle portion 60 which is square in cross-section and is supported in sliding contact by the square hole 54. The spring 57 is adjustably biased against the seat by a tension nut 61 located at one end of the tension rod 59. The other end of the tension rod is provided with a cutaway portion which has a longitudinal flat portion 63 abutting a shoulder 64. A flat, longitudinal flexible band 65 is placed upon the flat portion of the rod and is secured thereto by a clamp and screw 67. The other end portion of the tension band is secured to the spindle 31 by any suitable means such as a clamp and screw 69 shown in the drawing. A longitudinal bar 71 having a plurality of apertures 73 at one end is secured at its other end to cover plate 25a, by a plurality of screws 75. The apertures provide a bearing surface for the lower part 77 of the spindle 31 which is received by the aperture and is supported thereby. Mechanical stops may also be provided about the blade to limit rotation of the blade.

The operation of the spring biased propeller is essentially as follows. The spring 57 is selected to bias the propeller blades to a predetermined pitch for a desired flow condition. When the propeller revolves about its axis, the pressure on the blades due to the wake causes the spring 57 to be compressed and the tension bands 65 to wrap around the spindle 31 until the compression force on the spring and restoration force of the spring is in equilibrium and the predetermined pitch of the propeller is attained. When the propeller operates in a variable wake, the varying lifting forces on the blade 27 cause the blade 27 and spindle 31 to revolve in an attempt to relieve this varying pressure. The turning of the spindle causes the tension band 65 to wrap around the spindle and to compress the spring 57 more. The spring tends to counteract the compression force by its restoration force to obtain equilibrium of forces and return to its

predetermined position, which it does when the excess pressure is removed from the blade. The returning of the spring 57 causes the tension band 65 to unwind and in turn the spindle and blade are returned to the desired operating pitch for the propeller. This spring biasing feature thus allows a propeller having any number of blades to be fabricated for operation according to the principles of the present invention.

As discussed before, another way to smooth out wake irregularities in addition to the aforescribed passive systems is to alter the angle of incidence by a programmed mechanical force. Once the wake variation is known from model tests, the angle of incidence of each blade can be controlled as the propeller rotates through 360 degrees. By proper sequencing of the actuators, which could be hydraulic rams, the operation of the system can be made automatic. The advantage of controlled adjustment of the angle of incidence over the self-balancing system is that wake variations can be anticipated and thereby, force fluctuations can be completely smoothed out. Another advantage is that as in the spring biased system, an odd number of blades as well as an even number of blades, can be used.

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

What is claimed is:

1. A feathering controllable pitch propeller for reducing ship vibrations comprising:

- a hub;
- a plurality of blade spindles spaced about said hub, each of said spindles rotatable in said hub about an axis perpendicular to the axis of rotation of the propeller;
- a plurality of propeller blades each of said blades being secured to one of said blade spindles;
- each of said blades having a blade area which is skewed aft and having a center of pressure lying aft of the blade axis of rotation;
- resilient means biasing each of said blade spindles for controlling the angle of attack of the propeller blades in response to wake force fluctuations;
- a cover plate mounted on one end of the hub having a plurality of circumferentially spaced apertures;
- a tension rod slidably mounted in each of the apertures of said cover plate;
- a spring mounted in overlying relation to one end of each of said rods;
- holding means forcing each of said springs against one side of said cover plate;
- a plurality of flexible tension bands each having one end secured to the other end of one of said rods and having its other end secured to one of said spindles;
- whereby said band winds around said spindle in response to an increase in pressure on the associated blade and unwinds under the force of said spring in response to a decrease in pressure;
- each of said apertures in said cover plate comprising two portions, with one of said portions being square in transverse cross-section, said square portion receiving a square middle portion of said tension rod thereby preventing rotational movement of said rod and twisting of said band;
- said other portion being circular in transverse cross-section and having a diameter greater than the greatest dimension of the square portion, whereby said circular portion forms a seat for said spring; and
- a longitudinal bar secured at one end to said cover plate, said bar having aperture means therein receiving

a portion of said blade spindles for providing bearing surfaces for said blade spindles.

2. A feathering controllable pitch propeller for reducing ship vibrations comprising;

- a hub;
- a plurality of blade spindles spaced about said hub, each of said spindles rotatable in said hub about an axis perpendicular to the axis of rotation of the propeller;
- a plurality of propeller blades each of said blades being secured to one of said blade spindles;
- each of said blades having a blade area which is skewed aft and having a center of pressure lying aft of the blade axis of rotation;
- a plurality of resilient means, each of said resilient means biasing one of said blade spindles for independently controlling the angle of attack of the associated propeller blade in response to wake force fluctuations without affecting the angle of attack of the other propeller blades;
- a cover plate mounted on one end of the hub and having a plurality of circumferentially spaced apertures;
- a tension rod slidably mounted in each of the apertures of said cover plate;
- said resilient means comprising a spring mounted in overlying relation to one end of each of said rods;
- holding means on said one end of each rod, said holding means forcing each of said springs against one side of said cover plate;
- a plurality of flexible tension bands each having one end secured to the other end of one of said rods and having its other end secured to one of said spindles, whereby said band winds around said spindle in response to an increase in pressure on the associated blade and unwinds under the force of said spring in response to a decrease in pressure;
- each of said apertures in said cover plate comprising two portions, a first portion receiving a portion of said tension rod and cooperating therewith for preventing rotational movement of said rod and twisting of said band;
- the second portion of each aperture being circular in transverse cross-section and having a diameter greater than the greatest dimension of said first portion, whereby said circular portion forms a seat for said spring; and
- a longitudinal bar secured at one end to said cover plate, said bar having aperture means therein receiving a portion of said blade spindles for providing bearing surfaces for said blade spindles.

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