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D. B. DEWEY

2,354,948

MEANS FOR CONTROLLING FEATHERING MEMBERS

Filed April 9, 1940

Fig. 1.



Fig. 2.

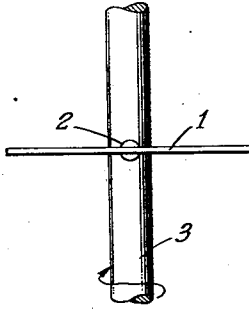


Fig. 3.

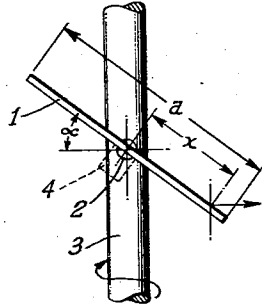


Fig. 6.

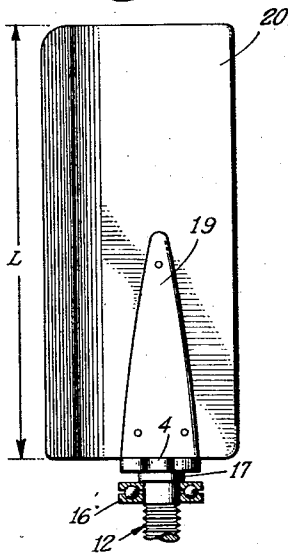


Fig. 5.

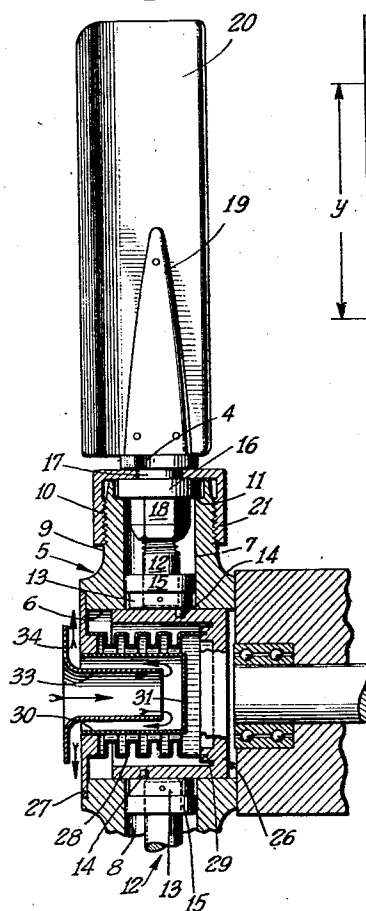


Fig. 4.

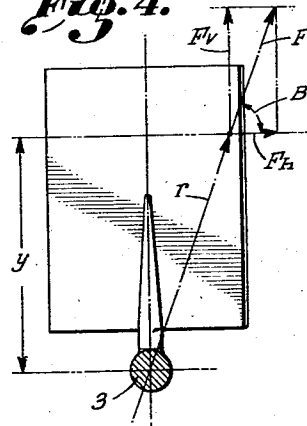
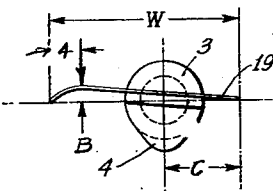


Fig. 7.



DAVID B. DEWEY
INVENTOR

BY

C. J. Wilk
ATTORNEY

UNITED STATES PATENT OFFICE

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MEANS FOR CONTROLLING FEATHERING
MEMBERS

David Brainard Dewey, Pasadena, Calif.

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4 Claims. (Cl. 170-163)

This invention pertains to improvements in methods and means of controlling the pitch of blades and other members mounted for feathering movement upon a rotatable shaft. This invention also relates to means and methods whereby the position of feathering elements or members carried by a rotatable shaft may be controlled in such manner that the positive torque tending to rotate the members about their axes is regulated, controlled and reduced to a quantity of small magnitude.

Although the present invention is primarily directed to means and methods which permit the regulatable control of pitch of any element or elements which may be rotatably mounted upon a shaft as, for example, blades mounted for rotation about axes perpendicular to the axis of rotation of a shaft, the invention in its broader aspects pertains to methods and means which are adapted for use with any and all elements and which is based upon the discovery that the positive torque which tends to rotate elements about their axes into planes perpendicular through the axis of a shaft upon which said elements are mounted may be controlled, regulated and utilized by the proper application of a mass tending to produce a negative torque.

In its most specific embodiment the present invention is directed to means and methods whereby the pitch of fans or other bladed elements rotatably mounted upon shafts may be controlled.

The motors or engines used in trucks, tractors, power shovels, passenger busses, power plants and industrial units such as derricks, etc., are ordinarily provided with a liquid cooling system comprising a radiator and a pump for regulating the cooling liquid around the motor and then through the radiator. Fans are provided, such fans being driven by the motor or engine, for passing cooling air through the radiator or around the cylinders for the purpose of reducing the temperature thereof, such means being particularly designed to prevent the motor from overheating. During winter months, such cooling system will ordinarily cool the motor to below a desired effective working range and additional devices, such as adjustable louvers, are ordinarily positioned around the radiator for the purpose of preventing cooling air from being sucked or blown through the radiator when the air temperature is so low that an inordinately low temperature exists in the cooling liquid. It is to be noted, however, that the fans are constantly driven as long as the motor is being operated.

On large trucks it has been found that a very appreciable amount of power is consumed in driving the fan. A truck engine of 100 horsepower rating may, at top engine speed, expend 20 horsepower in driving the fan.

In many cooling towers where large quantities of water are continuously cascaded over louvers for the purpose of cooling the same, large fans are employed for maintaining a circulation of air through the falling water so as to facilitate evaporation and reduce the temperature to a predetermined point.

The present invention permits the maintenance of an effective operating pitch to any and all bladed elements carried upon a shaft so that, for example, in the case of a fan adapted to pass air through the cooling system of an internal combustion motor, the pitch of the fan blades is automatically varied in accordance with the temperature of the air passing through the radiator or the temperature of the engine without the necessity of employing additional louvers, shutters, or the like. In the event the present invention is adapted to a fan blower or other device, the pitch of the blades and the volume of air circulated thereby may be automatically controlled and modified by means of temperature responsive devices which actuate and move the movable elements designed to shift or change the pitch of the blades.

Generally stated, the present invention is based upon the discovery that whenever rotatable members are mounted upon a shaft rotating at right angles to the axis of rotation of each of the members, certain forces are developed which tend to place the blade into a plane perpendicular to the axis of rotation of the shaft. When the blades are in such position, their angle of pitch is substantially nil and a tremendous amount of power needs be applied to whatever mechanism is provided for varying the angle of pitch of the blades in order to produce an adjustment in the pitch or feathered angle of the blades. In accordance with the present invention, it has been discovered that this positive torque may be neutralized or reduced to such magnitude that the pitch angle of the blades may be readily accomplished without the expenditure of large quantities of energy.

In other words, the present invention is directed to a method of facilitating the movement of members mounted upon a rotatable shaft whereby the positive torque of the members may be either completely neutralized or partially neutralized so that the residual torque (either posi-

tive or negative) is of a low magnitude and thereby susceptible to adjustment and modification by thermoresponsive devices such as a metal bellows, thermostats and the like.

An object of the present invention is to disclose and provide means and methods whereby the controlled movement of members mounted upon rotatable shafts, each of said members being rotatable on an axis perpendicular to the axis of the shaft, may be automatically and readily controlled.

A further object of the invention is to disclose and provide improved and simplified methods of construction whereby thermoresponsive devices may be caused to automatically adjust and vary the pitch or feathering angle of blades and other rotatable members mounted upon rotatable shafts.

These and other objects, uses and advantages of the present invention will become apparent to those skilled in the art from the following detailed description of certain illustrative embodiments embracing the discoveries herein referred to. In order to facilitate understanding of the invention, reference will be had to the appended drawing, in which:

Fig. 1 is a diagrammatic representation in plan of a rotatable element mounted upon a shaft.

Fig. 2 is a plan view of a rotatable element mounted upon a shaft in the position which such element would assume upon rotation of the shaft.

Fig. 3 is a plan view diagrammatic in form, showing an intermediate position of a rotatable element mounted upon a rotatable shaft.

Fig. 4 is a side elevation of the elements shown in Fig. 3.

Fig. 5 is a vertical section taken through a preferred form of mounting for feathering blades particularly adapted for use on trucks, busses and other automotive vehicles.

Fig. 6 is an enlarged front elevation of a single fan blade embodying some of the elements of the present invention.

Fig. 7 is a plan view of the blades shown in Fig. 6.

By referring to Figs. 1 and 2, it will be seen that a member 1 is rotatably mounted upon a pivot 2 carried by a shaft 3. In the event the element or member 1 is in the position shown in Fig. 1 and the shaft 3 is rotated rapidly, it will be found that the member 1 will assume the position shown in Fig. 2, namely, the member 1 will assume a position so that substantially all of the mass of the member 1 lies in a plane perpendicular to the axis of rotation of the shaft 3. This phenomenon is observed whenever the member 1 is of non-uniform cross section. By the term "non-uniform cross section," reference is made to any and all shapes which, in section parallel to the axis of rotation of the shaft 3, are not symmetrical. The term "non-uniform cross section" should exclude elements which are similar to a cylinder, sphere, hexagon or other regular polygon of homogeneous structure and in which the moments of inertia on one side of a plane passing through the rotational axis of the pin 2 are equal to the moments of inertia on the other side of the axis in various positions of such plane. In other words, masses or members 1 may be symmetrical about more than one axis but unless the moments of inertia are always balanced and equal, the member will exhibit a positive torque exemplified in Figs. 1 and 2, tend-

ing to turn the member 1 into a plane substantially perpendicular to the axis of rotation of the shaft 3. All members capable of exhibiting this positive torque are deemed to have a non-uniform cross section.

Figs. 3 and 4 are designed to diagrammatically explain the basis for the positive torque referred to. If, for example, the element 1 shown in Fig. 3 occupies a plane at an angle to the longitudinal axis of the shaft 3 and the shaft 3 is rapidly rotated, there is a component of the centrifugal force thus generated which produces a positive torque tending to rotate the blade back into the plane perpendicular to the shaft. In the event a small element of the blade 1 is considered, the centrifugal force acting upon such element may be broken up into two components F_v , F_h . The elemental torque acting on this increment of the blade is maintained by multiplying F_h by its perpendicular distance from the shaft. The total positive torque may be obtained by integrating dT over the entire area of the blade or element 1.

Stated differently, it may be said that when a member 1 is in the position indicated in Fig. 1, each particle of the member 1 is as close to the axis of the shaft 3 as it can possibly be. By reason of the rotation of shaft 3, the centrifugal forces tend to move the blade or member 1 into a position in which each element of the member 1 is as far removed from the axis of shaft 3 as possible. Obviously, the distance between some element near the edge of the member 1 and the axis of shaft 3 is least when such member 1 is in the position indicated in Fig. 1 and this distance is at its maximum when the member 1 is in the position indicated in Fig. 2. As a result of these forces generated by the revolution of shaft 3, a positive torque is developed whenever a member of non-uniform cross section is rotatably mounted upon a shaft which rapidly rotates.

By reason of the forces discussed hereinabove, it has been found impractical and extremely difficult to vary the feathering angle or pitch of any blade or other member of non-uniform cross section rotatably mounted upon a shaft. Heretofore, many complicated devices and methods have been suggested whereby the pitch angle of fan blades may be changed mechanically but all of such propositions have been found to be impractical by reason of the tremendous torque which is developed in the manner described hereinbefore. By reason of this positive torque developed in the manner stated, excessive power is required to move a blade from the position indicated in Fig. 2 to any intermediate feathering position during the rotation of the shaft 3.

The present invention is based upon the discovery that the difficulties encountered heretofore were due to the positive torque described and that such positive torque could be neutralized in whole or in part by the provision of means whereby a negative torque was generated by the rotation of shaft 3, such negative torque tending to neutralize the positive torque in whole or in part so that the residual torque, if any, was of a low order and therefore susceptible to modification by the expenditure of but small amounts of force.

In order to effectively utilize the teachings of this invention, it may be desirable to describe in greater detail the methods whereby the positive torque tending to move a feathering element of non-uniform cross section mounted upon a rotat-

ing shaft into a plane perpendicular to the axis of the shaft, is evaluated. By referring to Figs. 3 and 4, it will be noted that the forces acting upon a small element of the blade at a distance x from the axis upon which the blade is capable of feathering and at a distance y from the axis of the shaft 3 (y representing the minimum distance that this elemental portion may assume from such shaft axis), is at a distance r when the blade is at an angle α from a plane perpendicular to the axis of rotation of the shaft 3. The elemental torque dT will therefore equal $Fh (\sin \alpha)$; the horizontally directed force Fh equals $F \cos \alpha$. When converted into convenient units, the positive torque tending to move the blade into a plane perpendicular to the axis of the shaft 3 may be expressed as follows:

$$T=0.0000142W\alpha^2N^2 \sin (2\alpha)$$

where

T =torque in pound feet

W =weight of blade in pounds

α =width of blade in feet

N =revolutions per minute of shaft 3

α =the angle of displacement of the feathering element from a plane perpendicular to the shaft.

The bladed element described in Figs. 3 and 4 will tend to turn from the position shown in Figs. 3 and 4 in a counterclockwise direction (referring to Fig. 3). In accordance with the present invention, a suitable mass, generally indicated at 4 in dotted lines, may be attached to the feathering element, the magnitude of the mass and its distance from the axis of rotation of the shaft 3 being sufficient to set up a negative torque tending to rotate the blade or feathering element in a counterclockwise rotation when the shaft 3 is rotated. This mass 4, in accordance with the teachings herein described, should be sufficient to either completely or incompletely counteract the positive torque generated by the feathering element or blade itself so that the feathering element or blade will have a tendency to maintain a desired pitch angle during the rotation of the shaft 3 at any predetermined speed of the shaft and at any desired angle of pitch.

It is further to be noted that in accordance with the present invention, the aerodynamic forces acting upon the blade are overcome by the proper application of masses which produce a desired torque upon the feathering element. A feathering element in the position of Fig. 2 may be said to be in stable equilibrium during rotation but by the application of masses, such as mass 4, the blade is rendered more readily movable into intermediate positions, such as positions between those indicated in Figs. 1 and 2.

The adaptation of these teachings to a specific form of bladed element will now be described and for purposes of example only, specific reference will be had to devices adapted to control the pitch angle of blades mounted upon a rotatable hub, such fan blades being capable of maintaining proper circulation of air under various conditions of use.

More specifically, reference will be had to a fan-blade construction and control whereby such fan blades may be caused to change their pitch angle in accordance with the temperature of air, a motor, a radiator or other cooling device or liquid, lubricating oil, or the like. Most internal combustion engines, Diesel engines, etc., used as power plants in trucks, pumping units, cooling

towers, etc., are associated with a radiator through which water is circulated, the water being designed to maintain a uniform optimum operating temperature within the motor. Thermoresponsive devices may therefore be positioned within the radiator within the stream of cooling fluid passing into or out of the motor jackets, or such thermoresponsive device may react to the temperature of the air passing through the radiator. A form of device operative in accordance with the last given method is described in Fig. 5.

As there shown, a rotatable hub 5 is provided with a circular axial bore 6 and a plurality of radially extending bores 7, 8, etc., formed in bosses 9 which are externally threaded as indicated at 10. A shoulder 11 may be formed near the outer end of the bosses 9.

Rotatable studs 12 are journaled within the bores 7, 8, etc. A pin disc 13 may be pinned to the inner end of the stud 12, such pin disc having an inwardly extending eccentrically positioned pin 14. A suitable bearing 15 may be carried by the stud 12, such bearing cooperating with the bore 7. Another pressed bearing 16 may be held against a shoulder 17 of the stud 12 by means of a lock nut 18, the bearing 16 being adapted to rest against the shoulder 11. The stud 12 may be provided with an upwardly extending portion 19 to which a blade 20 is firmly attached. This entire assembly may be readily attached to or removed from the hub 5 by means of a locking cap 21 in threaded engagement with the externally threaded portion 10 of the boss 9, said cap engaging the upper portion of the thrust bearing 16. Movably positioned within the axial cylinder bore 6 is a movable member 26 having a groove or grooves formed in its outer surface, such grooves being adapted to receive the cam pins 14. The member 26 may either be reciprocable within the bore 6 or rotatable therein and the direction and pitch of the pin engaging grooves formed in the outer surface of the member 26 will vary with the motion which is imparted to the member 26.

The front of the bore 6 is provided with a cover plate 27 removably attachable to the hub 5. Said cover plate 27 carries a thermoresponsive device such as a metal bellows, which may include an outer expansible member 28 attached to a plate or end piece 29 adapted to contact the member 26. The cover plate 27 is provided with a bore 30 defined by a cup-shaped element 31 forming the interior of the metal bellows, the member 31 being rigid. The cover plate 27 may also carry means for directing air into the metal bellows or interior cup-shaped member 31 and for educting air therefrom. As shown in the drawings, this air directing means may comprise an inwardly extending tubular portion 33 and an outwardly flaring portion 34, a part at least of such outwardly flaring portion 34 being spaced from the front of the cover plate 27 so that air from a radiator or other source may enter the cup member 31 into intimate contact with such member and then be radially discharged as shown by the arrows.

It will be understood that the metal bellows is filled with a suitable liquid having desired expansion characteristics so that as the temperature of the air increases, the metal bellows will expand, causing the end plate 29 to move the member 26 and thereby increase the pitch angle of the blades 20. In the event the temperature drops, the residual positive torque developed in the blades 20 by reason of rotation of the hub

will tend to return the blades to a feathering position in a plane perpendicular to the axis of rotation of the hub.

It has also been discovered that the shape and design of blades 20 involve factors which facilitate the easy movement of the blades into and out of feathering positions. Blades particularly adapted for use in regulating the temperature of internal explosion motors of various types are preferably made in accordance with the showings in Figs. 6 and 7 wherein L represents the length of the blade, W represents the overall width, C represents the distance from the trailing edge of the blade to the axis on which the blade is feathered, A represents the distance from the entering edge to the crest of a curved entering edge portion, and B represents the displacement of such curved entering edge portion from a plane joining the entering and trailing edges. The length or L of a blade for these particular purposes should be as large as possible with respect to W. The distance C should preferably comprise from about 35% to 50% of W and best results have been obtained when C is slightly less than 50% of W as, for example, 45% of W. With the latter placement of the rotational axis, least resistance to movement of the blade out of the no pitch plane is encountered.

The distance A should always be greater than B and in actual practice A is three to eight times B. For example, given a blade measuring 5" or 6" in width, A may be 1½" and B may be about ¼".

By referring to Figs. 6 and 7 it is to be noted that a mass 4 has been placed or attached to the stud 12 at the base of the blade, this mass 4 corresponding to that diagrammatically referred to in Fig. 3 and tending to produce a negative torque sufficient to partially neutralize the positive torque generated by the blade and tending to place the blade in a plane perpendicular to the axis of the shaft upon which such blade is mounted.

The form of device shown and described in Fig. 5 hereof has been found eminently suited for use on busses, trucks and other vehicles since the device is self-contained and readily attachable. The metal bellows is a part of the fan assembly, rotates with it and when each of the blades is properly counterbalanced, accurate operation at all temperatures is assured.

I claim:

1. A feathering blade assembly comprising: a hub, radially extending bores in said hub, fan blade studs rotatably journaled in said bores, eccentrically positioned cam pins extending inwardly from said fan blade studs, an axially movable member within said hub, said member being provided with a circumferential groove adapted to slidably receive said pins, a ported cover plate for the outer end of said hub, a cylindrical closed end member carried by said plate and extending into said hub, a bellows carried by said plate and surrounding said inwardly extending member, and air induction means leading into said inwardly extending member, said air induction means including substantially radially extending air eduction channels.

2. A feathering blade assembly comprising: a hub, radially extending bores in said hub, fan blade studs rotatably journaled in said bores, eccentrically positioned cam pins extending inwardly from said fan blade studs, an axially movable member within said hub, said member be-

ing provided with a circumferential groove adapted to slidably receive said pins, a ported cover plate for the outer end of said hub, a cylindrical closed end member carried by said plate and extending into said hub, a bellows carried by said plate and surrounding said inwardly extending member, air induction means leading into said inwardly extending member, said air induction means including substantially radially extending air eduction channels, a fan blade carried by each of said studs, the rotational axis of each stud extending along said blades at from about 50% to 65% of the blade width from its leading edge, the entering portion of each blade being curved, and a mass carried by each rotatable stud and extending away from the axis of rotation of such stud, said mass being of a magnitude sufficient to produce a negative torque tending to rotate said stud and blade out of a plane perpendicular to the axis of the hub and shaft.

3. A feathering blade assembly comprising: a hub, radially extending bores in said hub, fan blade studs rotatably journaled in said bores, eccentrically positioned cam pins extending inwardly from said fan blade studs, an axially movable member within said hub, said member being provided with a circumferential groove adapted to slidably receive said pins, a ported cover plate for the outer end of said hub, a cylindrical closed end member carried by said plate and extending into said hub, a bellows carried by said plate and surrounding said inwardly extending member, air induction means leading into said inwardly extending member, said air induction means including substantially radially extending air eduction channels, and a mass carried by each rotatable stud and extending away from the axis of rotation of such stud, said mass being of a magnitude sufficient to produce a negative torque tending to rotate said stud and blade out of a plane perpendicular to the axis of the hub and shaft.

4. A feathering blade assembly comprising: a hub, radially extending bores in said hub, fan blade studs rotatably journaled in said bores, eccentrically positioned cam pins extending inwardly from said fan blade studs, an axially movable member within said hub, said member being provided with a circumferential groove adapted to slidably receive said pins, a ported cover plate for the outer end of said hub, a cylindrical closed end member carried by said plate and extending into said hub, a bellows carried by said plate and surrounding said inwardly extending member, air induction means leading into said inwardly extending member, said air induction means including substantially radially extending air eduction channels, a fan blade carried by each of said studs, the rotational axis of each stud extending along said blades at from about 50% to 65% of the blade width from its leading edge, the entering portion of each blade being curved, the front 20% to 30% of the blade being curved at the plane of the body portion of the blade, the rise of such curvature being smaller than the width of such curved portion, and a mass carried by each rotatable stud and extending away from the axis of rotation of such stud, said mass being of a magnitude sufficient to produce a negative torque tending to rotate said stud and blade out of a plane perpendicular to the axis of the hub and shaft.

DAVID BRAINARD DEWEY.