A rotor blade folding system includes a damper assembly which is selectively lockable. The damper assembly is locked to position each blade yoke in a predetermined lead/lag position to minimize strain upon elastomeric bearings between the blade yoke and the rotor hub and contained in the damper. The rotor blade is then folded relative to the blade yoke to a predetermined blade fold angle.
DAMPER POSITIONER FOR A ROTOR BLADE FOLDING SYSTEM

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a blade fold system for a helicopter, and more particularly to a rotor blade positioning system which positions each rotor blade prior to blade folding while minimizing applied strain to elastomeric bearings within the rotor head.

[0002] While the flight capabilities of helicopters makes them effective vehicles for a wide variety of missions, operation of helicopters in certain circumstances may be limited by the overall structural envelopes thereof. The large radial dimensions of helicopter rotor assemblies results in helicopters having relatively large structural envelopes, which may limit their utility in some circumstances.

[0003] Helicopters, particularly military helicopters utilized for maritime flight operations, may be required to conduct operations from ships for extended periods of time. Shipboard space is generally at a premium, and the large structural envelopes of helicopters means that stowage during periods of non-use requires a relatively significant allocation of such limited space. Furthermore, strategic and tactical considerations in the military utilization of helicopters has led to a requirement for helicopters having main rotor assemblies that may be readily reconfigured for rapid deployment, routine transport, and/or stowage through reduction in structural envelopes.

[0004] Several options are available to reduce the structural envelopes of helicopters to facilitate rapid deployment, routine transport, stowage, and/or to reduce the vulnerability thereof to environmental conditions. One option is to design the main rotor assemblies thereof so that the main rotor blades may be folded about the main rotor hub assembly. Main rotor blade folding operations are typically implemented automatically.

[0005] One helicopter with an automatic blade folding system is the CH-53E. The CH-53E is currently the world’s largest shipboard compatible helicopter. A significant consideration in the design of the CH-53E is shipboard compatibility. The CH-53E in a stored configuration effectively defines the maximum structural envelope which will fit on the elevators and in the hangar deck of United States Marine Corps Amphibious Assault Ships.

[0006] Prior to folding blades on any helicopter, the blades must be located and locked in a pre-set blade fold position such that a blade hinge axis is oriented to allow folding of each blade to its proper folded position. On aircraft such as CH-53E, blade positioning is accomplished using a series of hydraulic actuators and stops. The current CH-53E rotor head utilizes a hydraulic actuated piston incorporated into the damper as a pitch lock. Accumulator pressure drives the damper to hold the blade in the pre-set blade fold position in which the yoke is driven to full lag or lead position. The swashplate is then located in a pre-set position such that each blade is at the correct pitch angle for the blade pitch locks to engage. Since pitch motion occurs between the sleeve and the spindle, a hydraulic actuated pin on the sleeve engages a lug on the spindle to lock the spindle and sleeve together to prevent pitch motion. These components function independently as the current CH-53E rotor head employs separate conventional bearings for pitch, flap, and lead/lag blade motions.

[0007] Elastomeric rotor heads with elastomeric bearings provide numerous advantages over conventional rotor head assemblies which utilize separate bearings for pitch, flap, and lead/lag blade motions. Elastomeric rotor heads provide such significant advantages, that current aircraft such as the CH-53E may be modernized to include an elastomeric rotor head.

[0008] Current blade folding systems are not transferable to an elastomeric rotor head as the elastomeric bearings and visco-elastic damper are essentially springs which are always biased toward a predetermined position. Deflection away from the predetermined position strains the elastomeric bearings and visco-elastic damper. Significant deflection over prolonged time periods, such as during a blade fold position, may eventually damage the elastomeric rotor head system.

[0009] Accordingly, it is desirable to provide a blade folding system for an elastomeric rotor head system which positions each rotor blade prior to blade folding while minimizing applied strain to elastomeric bearings within the rotor head.

SUMMARY OF THE INVENTION

[0010] The rotor blade folding system according to the present invention generally includes an electric motor mounted to a damper housing of the damper assembly to drive a damper gear train and selectively lock a damper rod relative the damper housing in a blade fold position to minimize strain on an elastomeric bearing.

[0011] In operation, a blade fold controller operates the electric motor to rotate a sleeve about the damper axis such that an outer circumferential jack screw drives a plunger along the damper axis toward the damper rod. Concurrently therewith, an inner circumferential jack screw of the sleeve drives a puller along the damper axis until a puller bushing contacts a damper rod puller stop. The plunger and the puller trap the damper rod in a predetermined blade fold position. The damper assembly is locked at a predetermined length such that the elastomeric bearing is isolated when the rotor blade is folded. Once each yoke is locked by the damper assembly in the blade fold position, the blade fold controller drives the rotary actuator to rotate each rotor blade to a predetermined blade fold angle.

[0012] To unfold the blades, the blade fold controller reverses the rotary actuator to return the rotor blade to a flight position and reverses the electric motor to release the damper rod such that the yoke and damper assembly returns to a flight configuration.

[0013] The present invention therefore provides a blade folding system for an elastomeric rotor head system which positions each rotor blade prior to blade folding while minimizing applied stress to elastomeric bearings within the rotor head.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The various features and advantages of this invention will become apparent to those skilled in the art from the following detailed description of the currently preferred embodiment. The drawings that accompany the detailed description can be briefly described as follows:
FIG. 1 is a general perspective view of an exemplary rotary wing aircraft embodiment for use with the present invention with a main rotor assembly in a flight position;

FIG. 2 is a top plan view of a main rotor assembly illustrating a single blade and blade fold system;

FIG. 3 is a general perspective view of an exemplary rotary wing aircraft embodiment for use with the present invention with a main rotor assembly in a folded position;

FIG. 4A is a sectional view of a damper assembly in flight condition;

FIG. 4B is an expanded sectional view of a damper assembly in flight condition;

FIG. 4C is a sectional view of a damper assembly in a blade fold condition;

FIG. 5 is a top plan view of a main rotor assembly illustrating the rotor blades in a folded position;

FIG. 6 is an expanded top view of a main rotor assembly illustrating the rotor blades in a folded position.

FIG. 7 is an expanded side perspective view of a main rotor assembly illustrating the rotor blades folded relative a blade yoke.

The preferred embodiment describes the details of the damper assembly.

FIG. 1 schematically illustrates a rotary-wing aircraft 10 having a main rotor assembly 12. The aircraft 10 includes an airframe 14 having an extending tail 16 which mounts an anti-torque rotor 18. The main rotor assembly 12 is driven through a transmission (illustrated schematically at 20) by one or more engines 22. This description includes the particular structural features of the main rotor assembly 12 of a Sikorsky CH-53 helicopter configuration as illustrated in the enclosed embodiment for discussion purposes. The present invention may be embodied for use with rotor assemblies of other helicopters, turbo-prop, tilt-rotor aircraft and other elasticmeric bearing based rotor assemblies.

Referring to FIG. 2, the rotor assembly 12 includes seven rotor blade assemblies 24 (one shown) each mounted to a rotor hub 26 which rotates about an axis of rotation R. Each rotor blade assembly 24 includes a rotor blade 28, a hinge assembly 30, a rotary actuator 32, a sleeve 34, a yoke 36 an elastomeric bearing 38, a damper assembly 40 and a blade pitch lock assembly 42.

The yoke 36 is mounted to the rotor hub 26 through the elastomeric bearing 38 such that the blade assembly 24 may be moved in flapping, pitch and lead/lag motions as generally understood. The damper assembly 40 reacts with the yoke 36 to dampen lead/lag motions and vibration of the blade assembly 24.

A rotor blade folding system 44 generally includes the blade pitch lock assembly 42, the rotary actuator 32, a retractable blade retaining pin 33, the damper assembly 40 and a blade fold controller 47 (illustrated schematically) to selectively position each rotor blade assembly 24 in a particular folded position to minimize the aircraft structural envelope (FIG. 3).

Referring to FIG. 4A, an example damper assembly 40 includes a damper rod 46 that is movable relative to a damper housing 50 by two axial elastomeric bearings 48. The damper housing 50 includes a fluid which damps movement of the damper rod 46 along a damper axis D to react against lead/lag motions of the blade assembly 24 and to dampen vibration. The lead/lag and vibration damping operation of the damper assembly 40 is generally understood.

A rod mount 52 extends from near an end of the damper rod 46 and a housing mount 54 extends from the damper housing 50. The mount 52 and 54, which are ball mounts, other links or a combination of them, mount the damper assembly 40 between the rotor hub 26 and the yoke 36 of each blade assembly 24 (FIG. 2).

Referring to FIG. 4B, an actuator such as an electric motor 56 is mounted to the damper housing 50 to drive a damper gear train 57 to selectively lock the damper rod 46 relative to the damper housing 50 in a predetermined blade fold position to minimize strain on the elastomeric bearings 38 and 48. With the damper rod 46 locked, the damper assembly 40 locks the yoke 36 in a corresponding position relative to the rotor hub 26 (FIGS. 2, 5). The blade fold position in one example is a mid-position of the damper assembly 40, however, other locked positions will be useful to suit the needs of a particular embodiment.

The electric motor 56 includes an output shaft 58 which drives an output gear 60. The output gear 60 is in meshing engagement with a sleeve 62 at gear teeth 64. The sleeve 62 is rotationally mounted upon a sleeve bearing 66 which is mounted about an inner damper housing 68 such that the sleeve 62 rotates about the damper axis D in response to operation of the electric motor 46.

The sleeve 62 includes an outer circumferential jackscrew 70 and an inner circumferential jackscrew 72. The outer circumferential jackscrew 70 and the inner circumferential jackscrew 72 are preferably oppositely directed screw threads. That is, the outer circumferential jackscrew 70 is right hand and the inner circumferential jackscrew 72 is left hand or vice-versa. It should be understood that other threaded members or gears other than a jackscrew or in combination therewith may also be used with the present invention.

The outer circumferential jackscrew 70 engages a plunger screw thread 74 which is located within the inner diameter of a plunger 76. The plunger 76 includes an anti-rotation feature 78 which includes a radial pin 80 which extends into a housing slot 82 such that the plunger 76 slides along the axis D but does not rotate.

The inner circumferential jackscrew 72 engages a puller screw thread 84 located along a length of a puller 86. The puller 86 includes an anti-rotation feature 88 such that the puller 86 slides along the axis D but does not rotate. In one example, the puller 86 is splined at 90 and the inner damper housing 68 is splined at 92.

The puller 86 slides within a tubular hollow cavity 93 formed within the damper rod 46. Preferably, a puller bushing 94 moves with the puller 86 and is slideable within the damper rod 46 to selectively contact a damper rod puller stop 96 (in the position illustrated in FIG. 4C).
A blade fold controller 47 (illustrated schematically) operates the electric motor 56 to drive the output gear 60 which is in meshing engagement with the sleeve 62. The sleeve 62 rotates about the damper axis D such that the outer circumferential jack screw 70 cooperates with the plunger screw thread 64 to drive the plunger 76 along axis D toward the damper rod 46. Eventually, the plunger 76 moves into the position shown in FIG. 4C. Concurrently therewith, the inner circumferential jack screw 72 of the sleeve 62 cooperates with the plunger screw thread 64 to drive the plunger 86 along the damper axis D in an opposite direction until the puller bushing 94 contacts the damper rod puller stop 96 as shown in FIG. 4C. In this position, the plunger 76 and the puller 86 trap the damper rod 46 in the blade fold position. That is, the damper assembly 40 is locked at a predetermined length such that the yoke 36 cannot pivot relative to the hub 26. This locked condition isolates the elastomeric bearing 38 from strain when the rotor blade is folded (FIGS. 3, 5).

Once the plunger 76 and the puller 86 trap the damper rod 46 and the damper assembly 40 is locked, each rotor blade assembly 24 may be positioned in pitch by articulating the swashplate prior to engaging the blade pitch lock assembly 42 (FIG. 2). That is, the blade pitch lock assembly 42 locks the yoke 36 once the yoke 36 has previously been articulated by the swashplate. When the swashplate is positioned properly, all the blades 28 are at a predetermined pitch angle for each blade pitch lock assembly 42 to engage. Separately, the blade pivot axis B (FIGS. 3 and 6) for each blade 28 is typically at a different angle, pitch-wise, from a fixed point on the yoke 36, such that each blade 28 will fold to its own predetermined blade fold position (FIG. 7). That is, the angle between the blade fold pivot axis B and the yoke 36 center plane is different for each blade assembly 24. This is typically accomplished by creating different sleeves and hinges for each blade assembly 28 such that the more forward blades will fold generally under the rearward blades (FIG. 3). Referring to FIG. 5, once the damper assembly 40 is locked and the blade pitch lock assembly 42 engaged, the blade control 47 stops the electric motor 56 through communication with a sensor such as a limit switch or the like. The blade pitch lock assembly 42 (FIG. 2) is then engaged such that each yoke 36 is positioned for folding of each rotor blade 28. Once each yoke 36 is positioned for blade 28 fold, the controller 47 drives the rotary actuator 32 to rotate each rotor blade 28 to a predetermined blade fold angle about the blade fold pivot axis B (FIGS. 3 and 6).

Referring to FIG. 6, the rotary actuator 32 rotates each rotor blade 28 to a predetermined blade fold angle α, α, about a blade fold pivot axis B - B, (also illustrated in FIG. 7). Notably, minimal strain is placed on the elastomeric bearing 38 as the damper assembly 40 locks each yoke 36 relative to the rotor hub 26.

To unfold the blades, the blade fold controller 47 reverses the rotary actuator 32 to unfold the rotor blades 28 (α to zero) then retracts the plunger 76 and the puller 86 to release the damper rod 46 such that damper assembly 40 (FIG. 4A) and the yoke 36 return to a flight configuration.

It should be understood that relative positional terms such as “forward,” “all,” “upper,” “lower,” “above,” “below,” and the like are with reference to the normal operational attitude of the vehicle and should not be considered otherwise limiting.

Although particular step sequences are shown, described, and claimed, it should be understood that steps may be performed in any order, separated or combined unless otherwise indicated and will still benefit from the present invention.

The foregoing description is exemplary rather than defined by the limitations within. Many modifications and variations of the present invention are possible in light of the above teachings. The preferred embodiments of this invention have been disclosed, however, one of ordinary skill in the art would recognize that certain modifications would come within the scope of this invention. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described. For that reason the following claims should be studied to determine the true scope and content of this invention.

What is claimed is:

1. A damper assembly including a damper rod for rotor blade assembly comprising:
   - an actuator;
   - a plunger driven by said actuator to limit movement of a damper rod from a first direction; and
   - a puller driven by said actuator to limit movement of said damper rod from a second direction such that the damper rod is selectively axially locked in a blade fold position along a damper axis.

2. The damper assembly as recited in claim 1, further comprising a sleeve drivable about the damper axis by said actuator, said sleeve defines an outer circumferential jack screw and an inner circumferential jarscrew.

3. The damper assembly as recited in claim 2, wherein said outer circumferential jarscrew drives said plunger.

4. The damper assembly as recited in claim 3, further comprising an anti-rotation feature extending from said plunger.

5. The damper assembly as recited in claim 2, wherein said inner circumferential jarscrew drives said puller.

6. The damper assembly as recited in claim 5, further comprising an anti-rotation feature extending from said puller.

7. The damper assembly as recited in claim 6, wherein said puller slides at least partially within a hollow cavity formed within the damper rod.

8. The damper assembly as recited in claim 7, wherein said puller includes a puller bushing slidably within said hollow cavity to selectively contact a damper rod puller stop.

9. A rotor blade assembly comprising:
   - a rotor hub;
   - a yoke mounted to said rotor hub with an elastomeric bearing;
   - a damper assembly mounted to said rotor hub and said yoke, said damper assembly including a damper housing and a damper rod slidable along a damper axis relative to said damper housing;
   - an electric motor;
   - a gear train in meshing engagement with said electric motor;
a plunger driven by said gear train to limit movement of said damper rod from a first direction; and

a puller driven by said gear train to limit movement of said damper rod from a second direction such that said damper rod is selectively axially locked in a blade fold position along a damper axis.

10. The rotor blade assembly as recited in claim 9, further comprising a sleeve drivable about the damper axis by said gear train, said sleeve defines an outer circumferential jackscrew and an inner circumferential jackscrew, said outer circumferential jackscrew drives said plunger, and said inner circumferential jackscrew drives said puller.

11. The rotor blade assembly as recited in claim 9, wherein said puller slides at least partially within a hollow cavity formed within the damper rod.

12. The rotor blade assembly as recited in claim 11, wherein said puller includes a puller bushing slidable within said damper cavity to selectively contact a damper rod puller stop.

13. A method of folding a rotor blade comprising the steps of:

(1) sliding a plunger along a damper axis and limit movement of a damper rod of a damper assembly from a first direction;

(2) sliding a puller along the damper axis to limit movement of the damper rod from a second direction such that said damper rod is selectively axially locked between the plunger and the puller in a blade fold position along the damper axis; and

(3) folding a rotor blade to a predetermined blade fold angle about a blade fold pivot axis.

14. A method as recited in claim 13, wherein said step (1) further comprises rotating a sleeve with the electric motor and sliding the plunger with said sleeve.

15. A method as recited in claim 14, wherein said step (2) further comprises rotating a sleeve with the electric motor and sliding the puller with said sleeve.

16. A method as recited in claim 13, including performing said step (1) and said step (2) simultaneously.

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