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(54) **ROTOR SYSTEM FOR HELICOPTERS**

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2001.

(51) **Int. Cl.⁷** **B64C 1/14**

(52) **U.S. Cl.** **244/17.11; 244/17.19;**
446/37

(58) **Field of Search** 244/17.19, 60,
244/17.11; 416/169 R, 32; 446/37; 403/362,
361, 300, 308, 281, 278

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Primary Examiner—Peter M. Poon

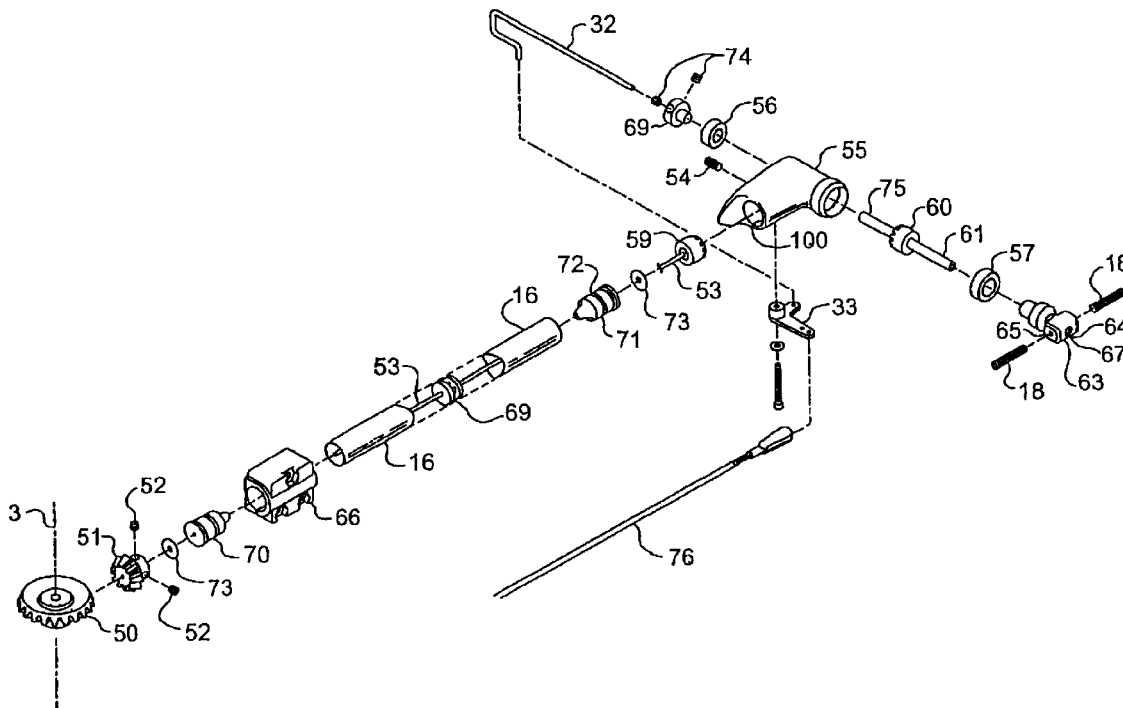
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(57) **ABSTRACT**

A tail rotor system for a helicopter includes a gear box housing retainer (66) coupled to the tail boom (16) of the helicopter. The tail rotor system also includes a power-limiting device (50) configured to disconnect the tail rotor from a power plant for driving the tail rotor about a rotor axis of rotation.

12 Claims, 19 Drawing Sheets



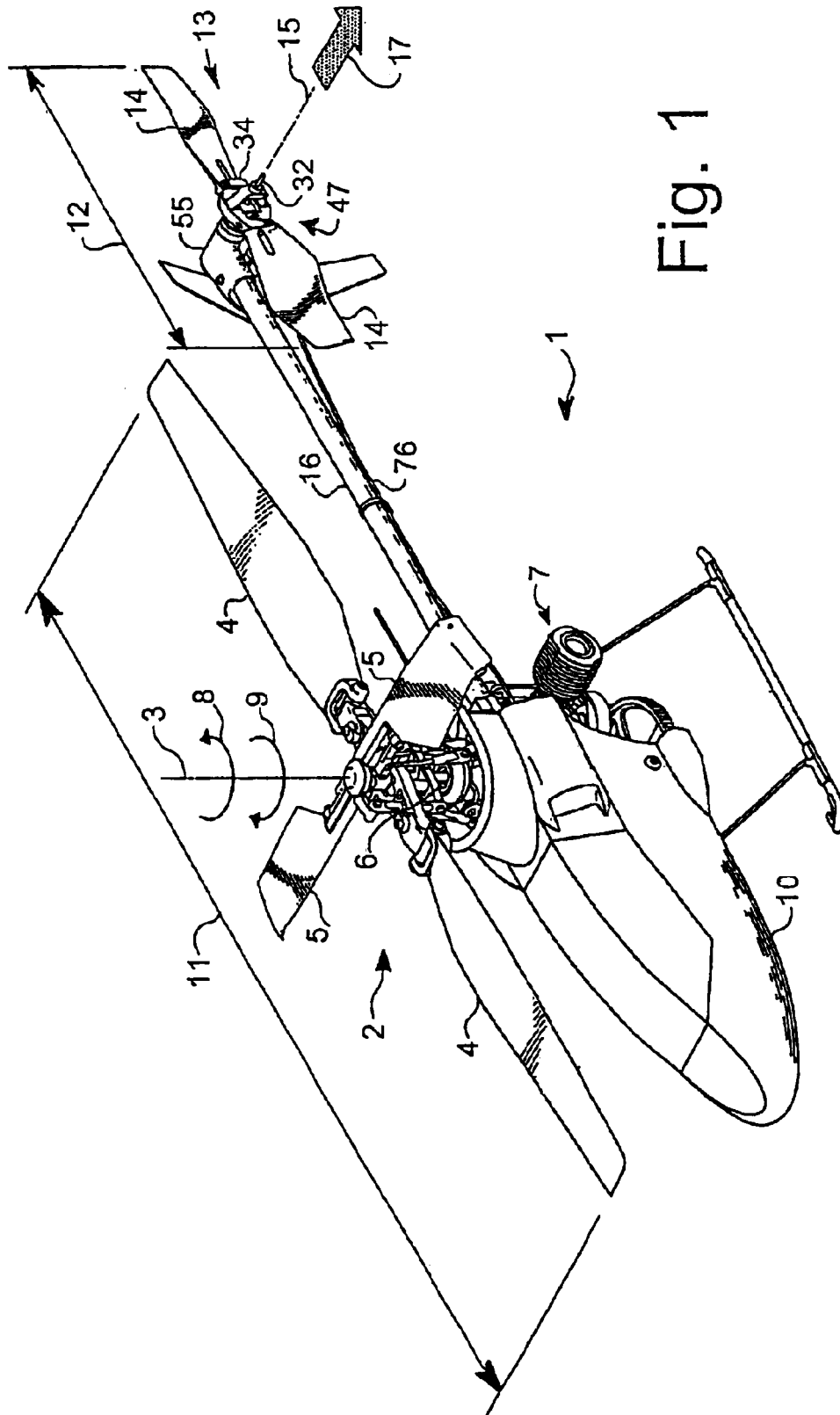


Fig. 1

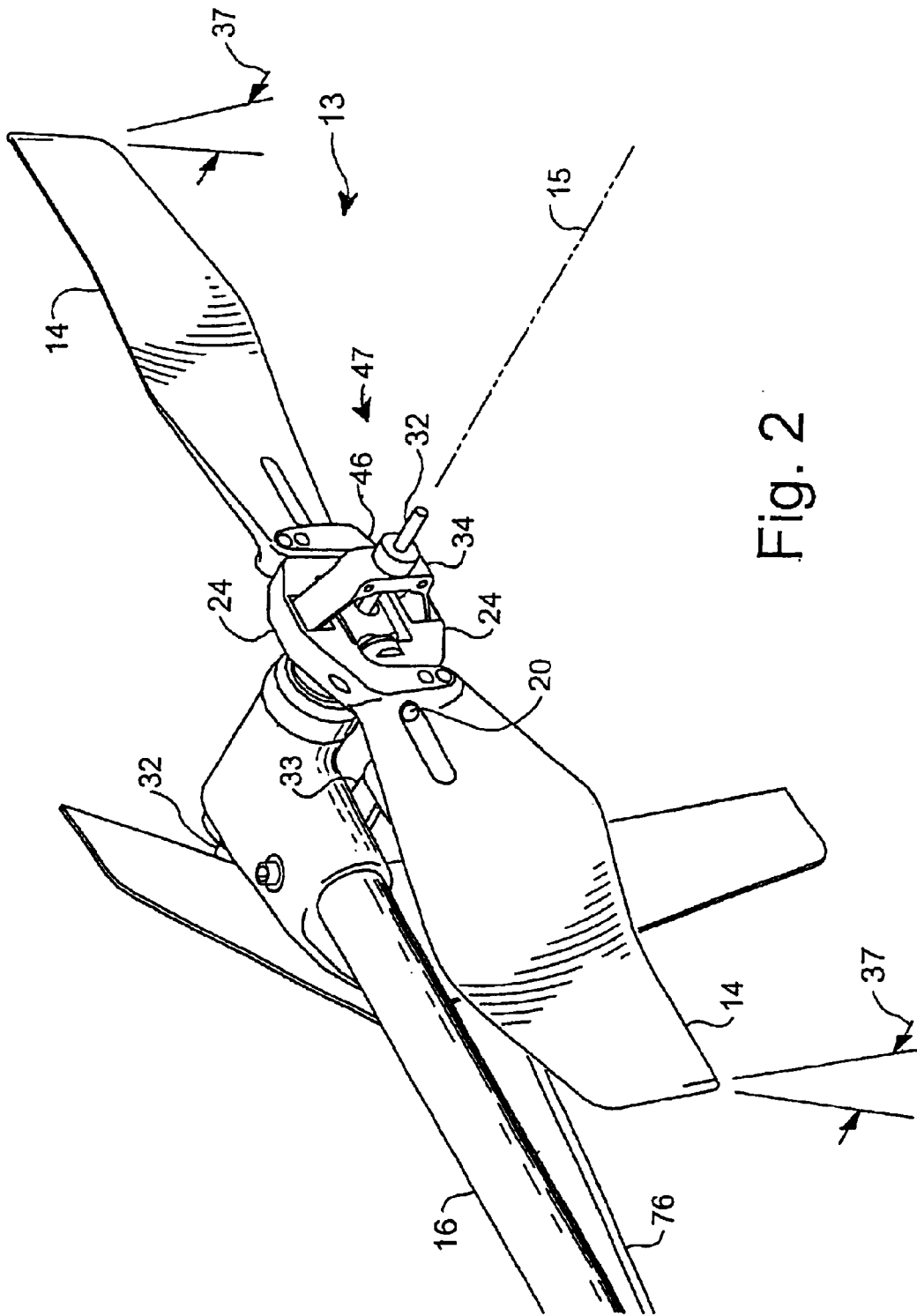


Fig. 2

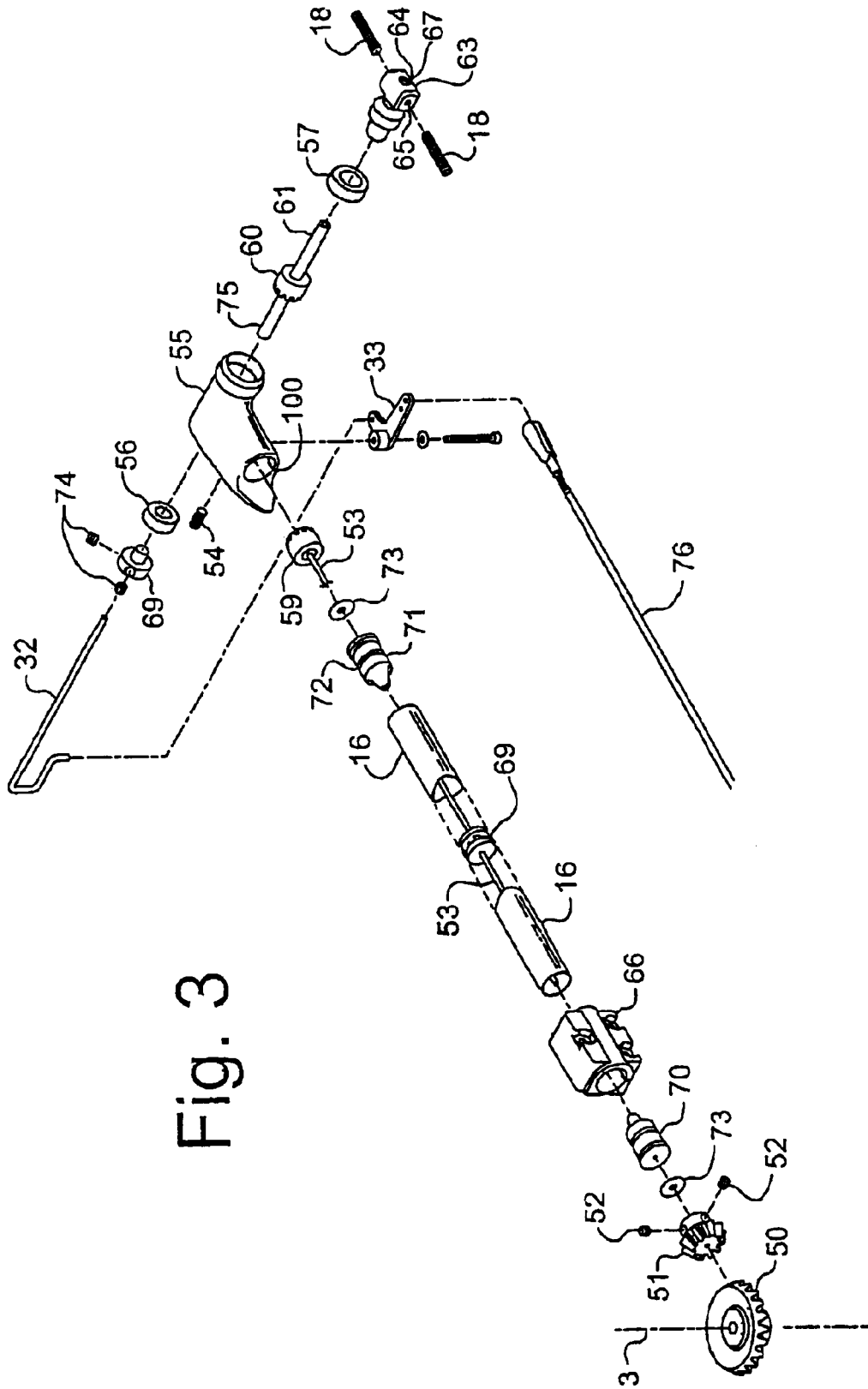


Fig. 3

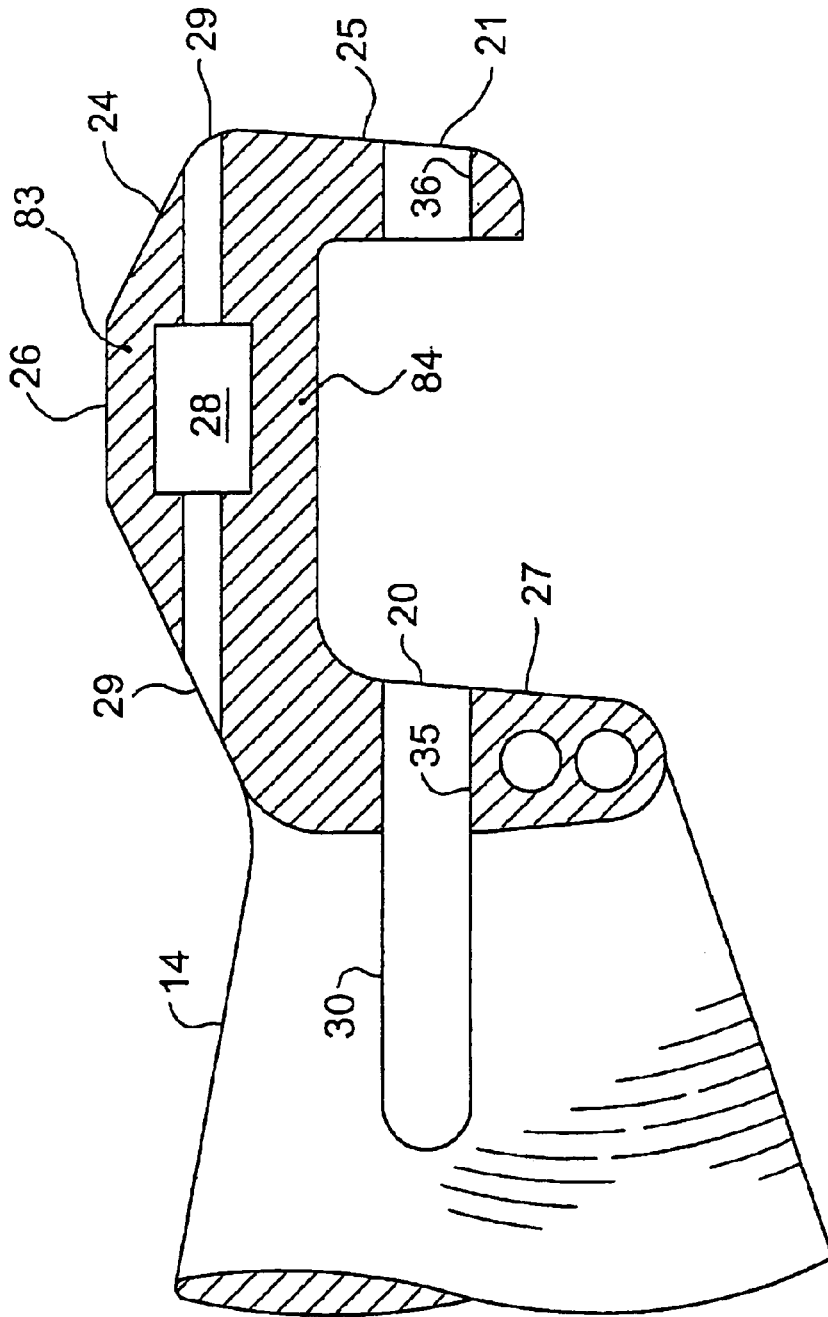


Fig. 4

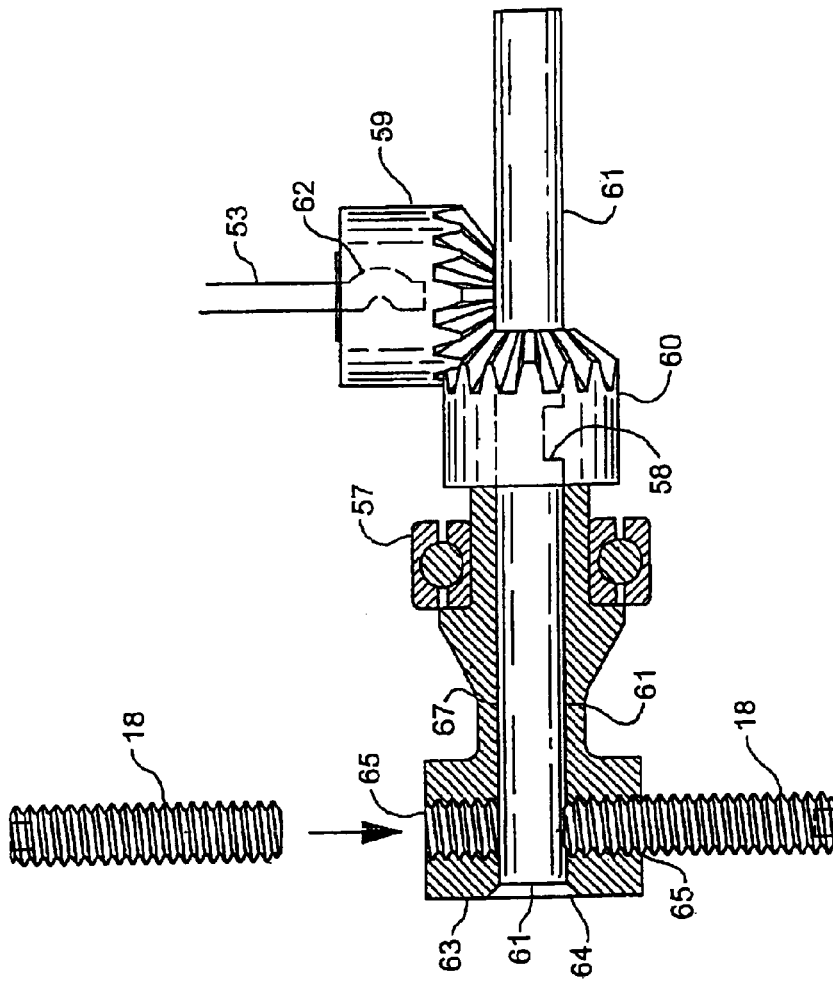


Fig. 6

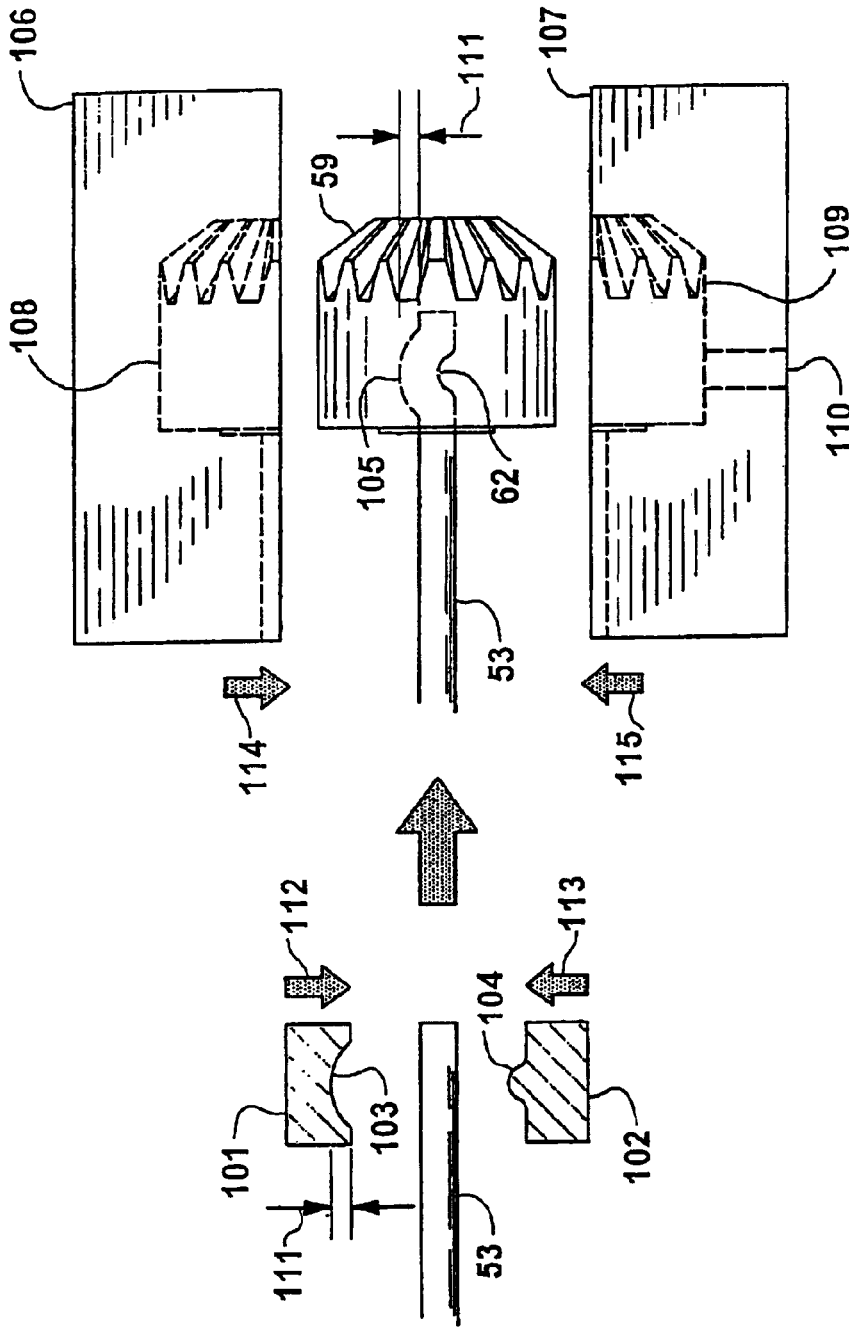


Fig. 6A

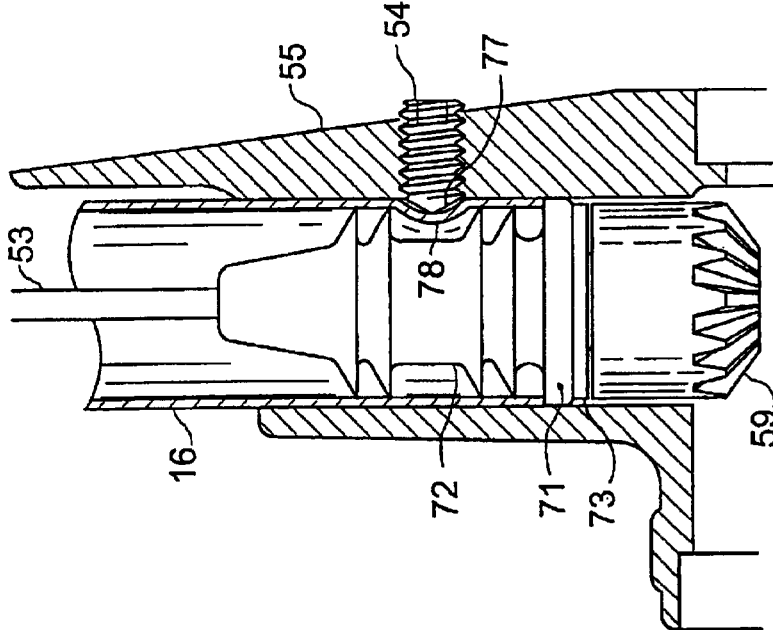


Fig. 8

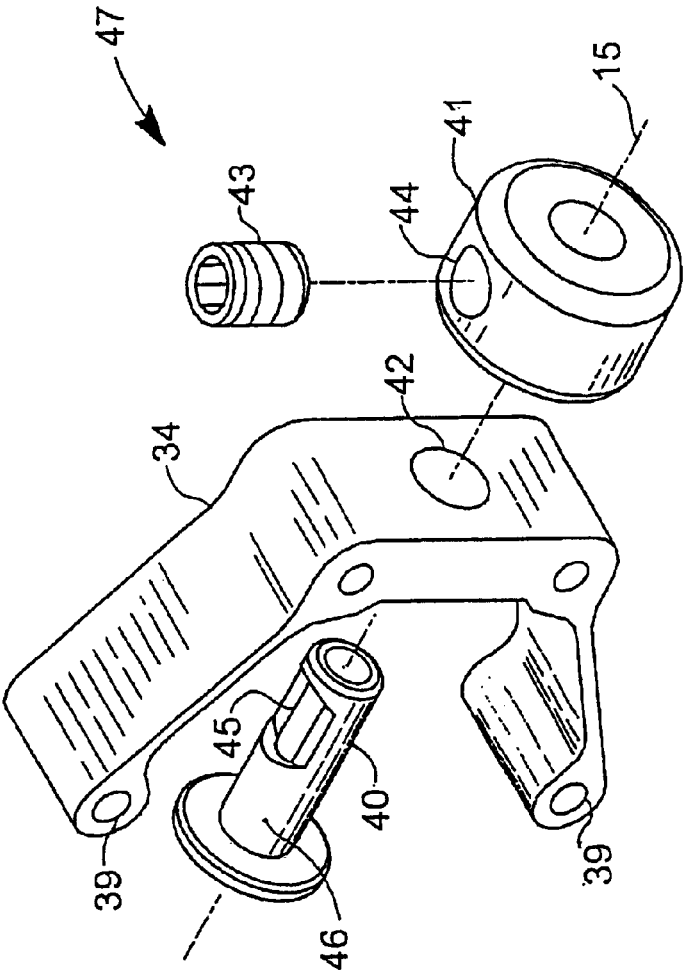


Fig. 9

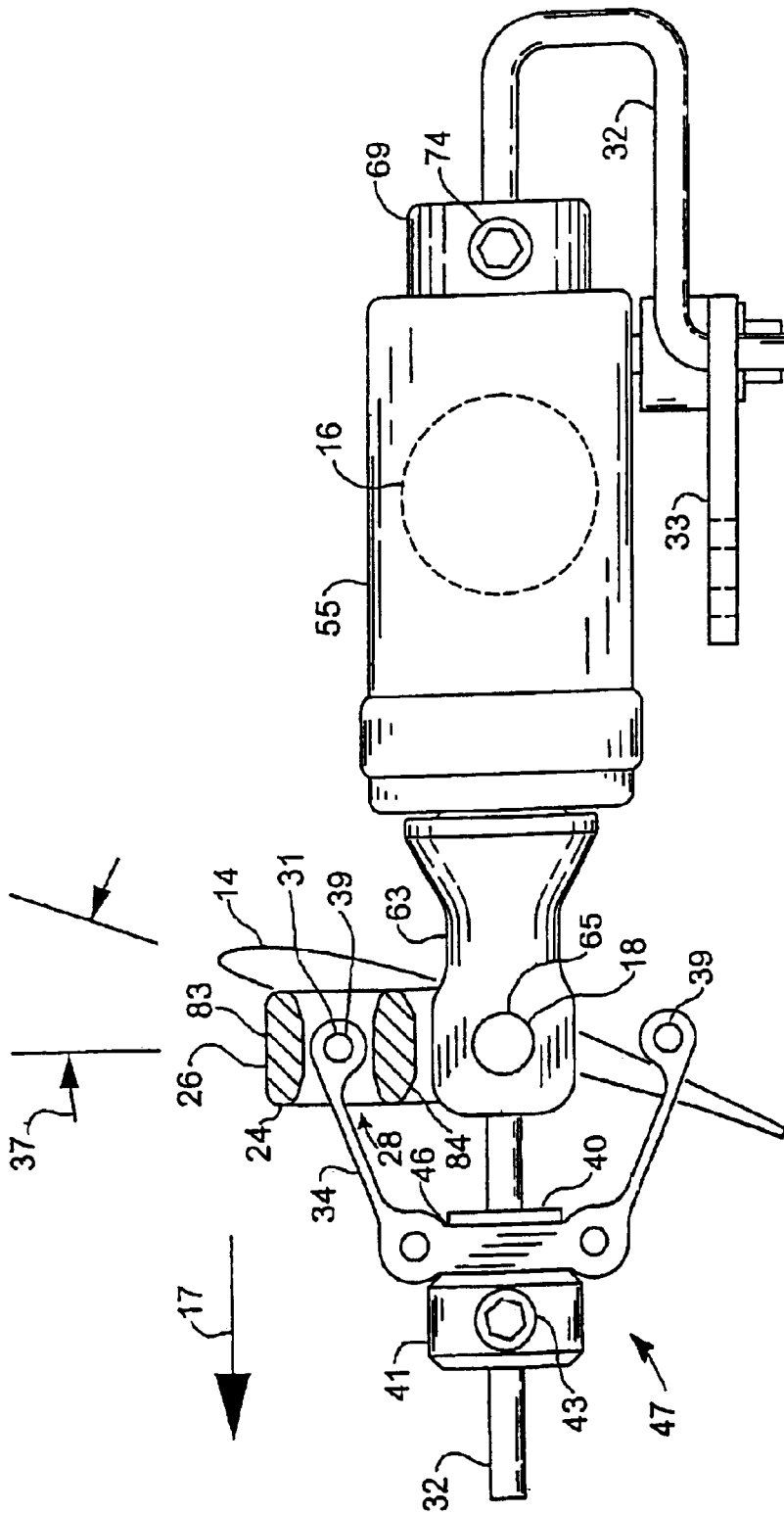


Fig. 10

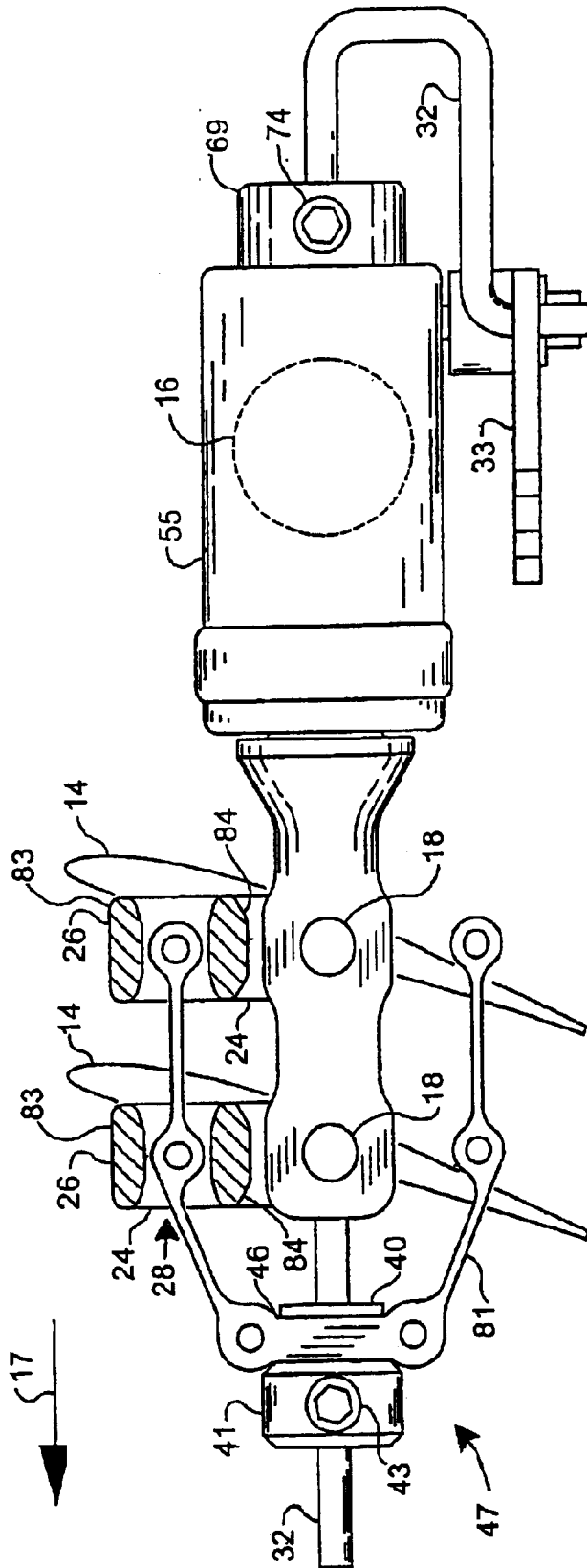


Fig. 11

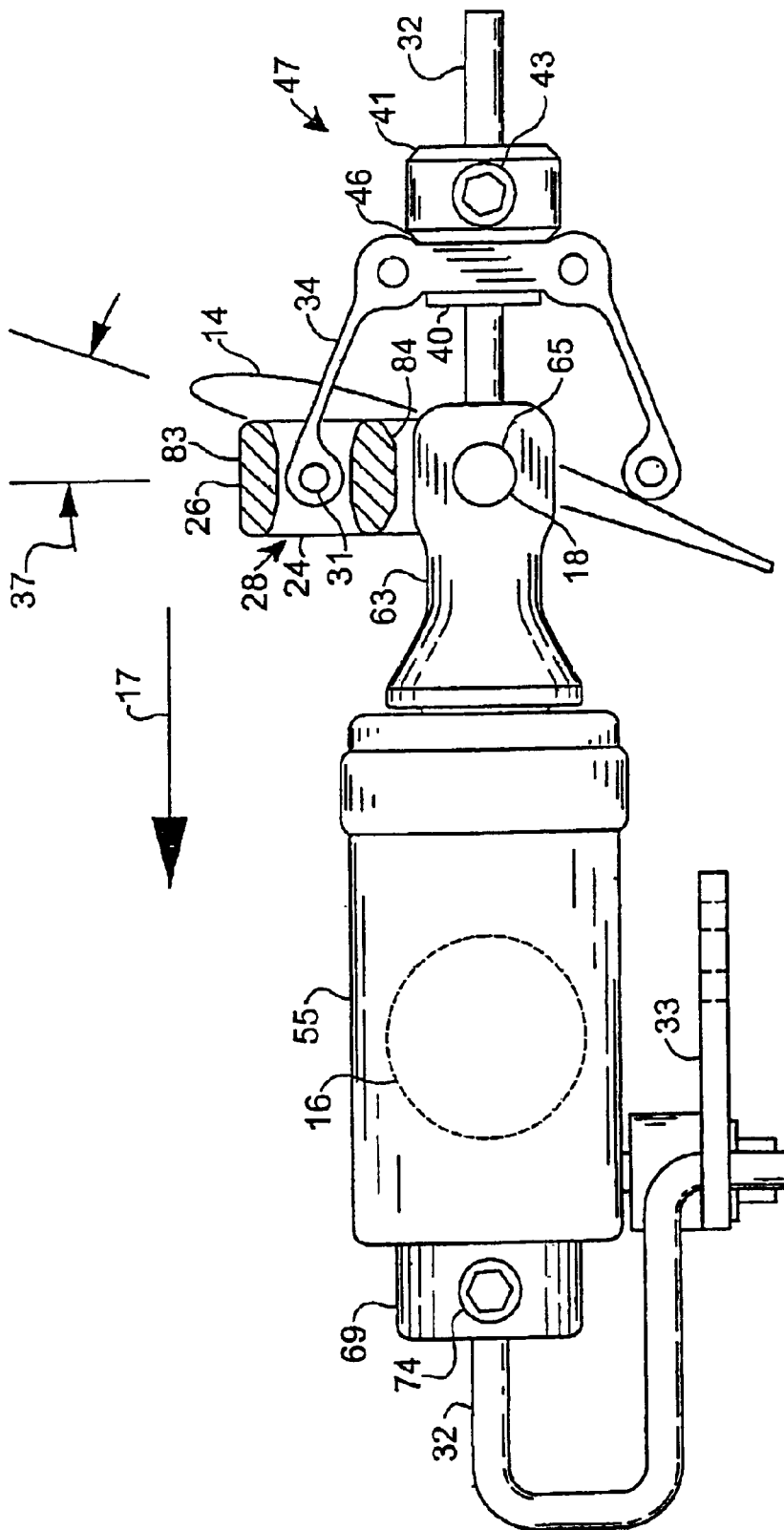


Fig. 12

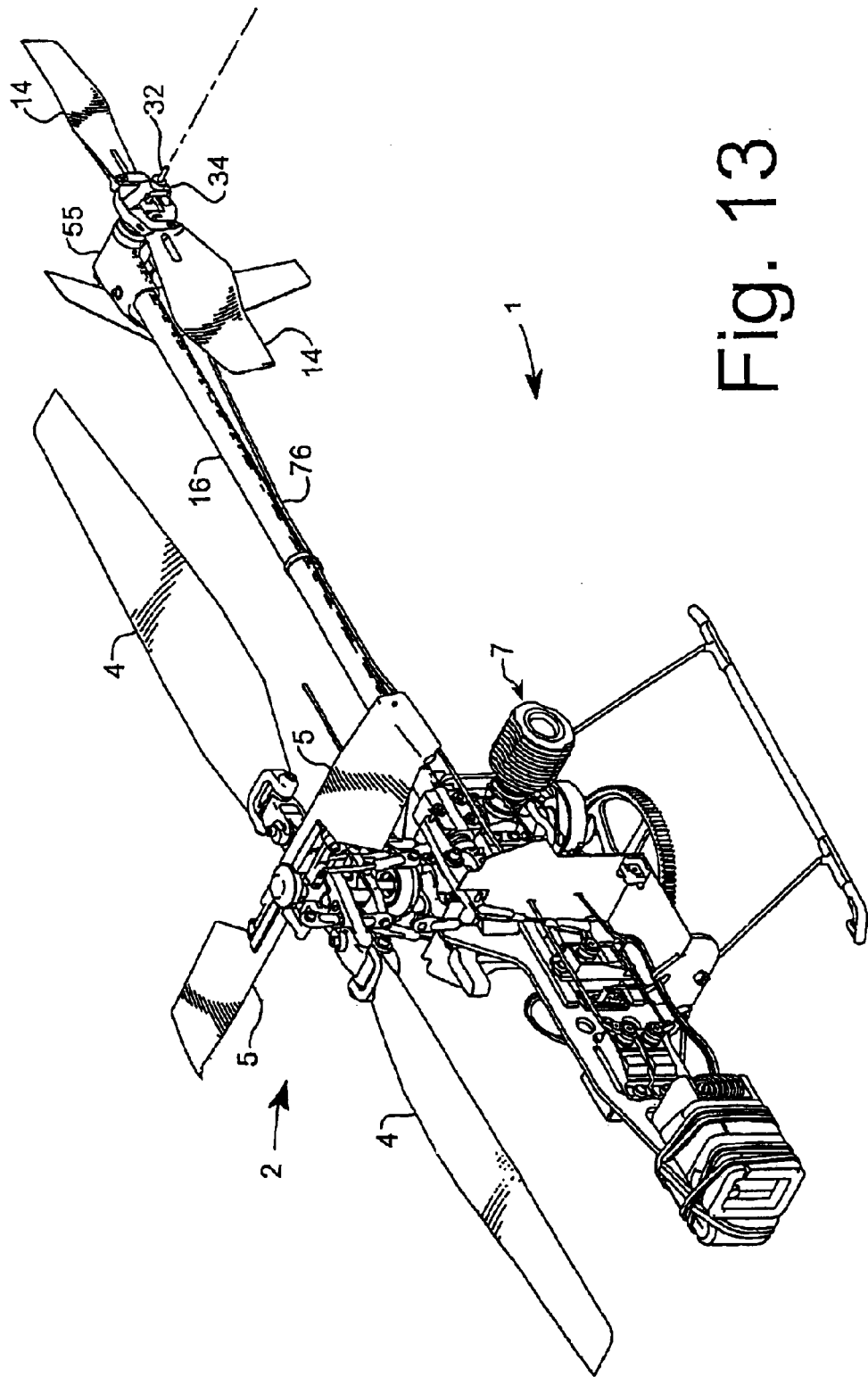
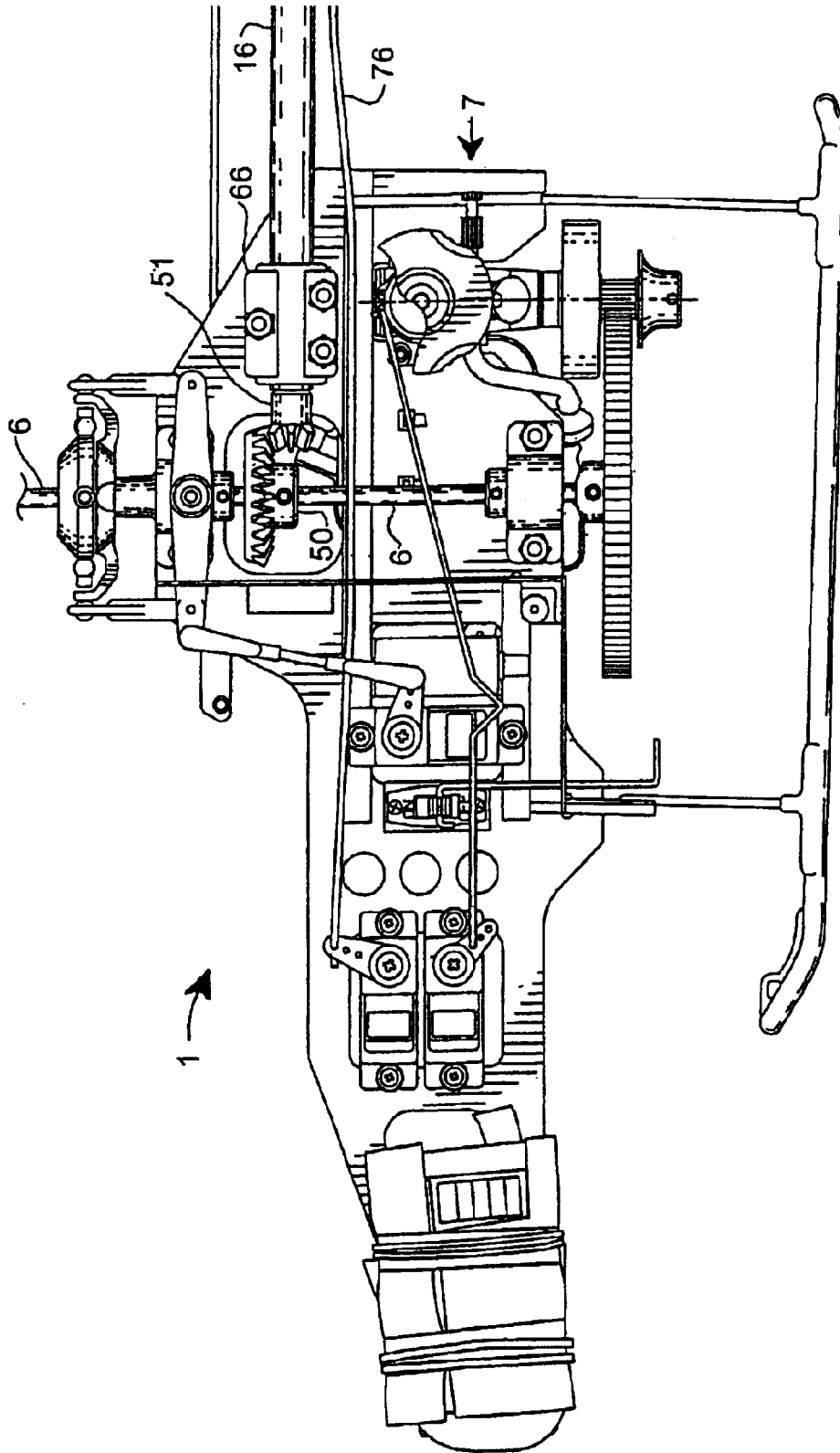


Fig. 13

Fig. 14



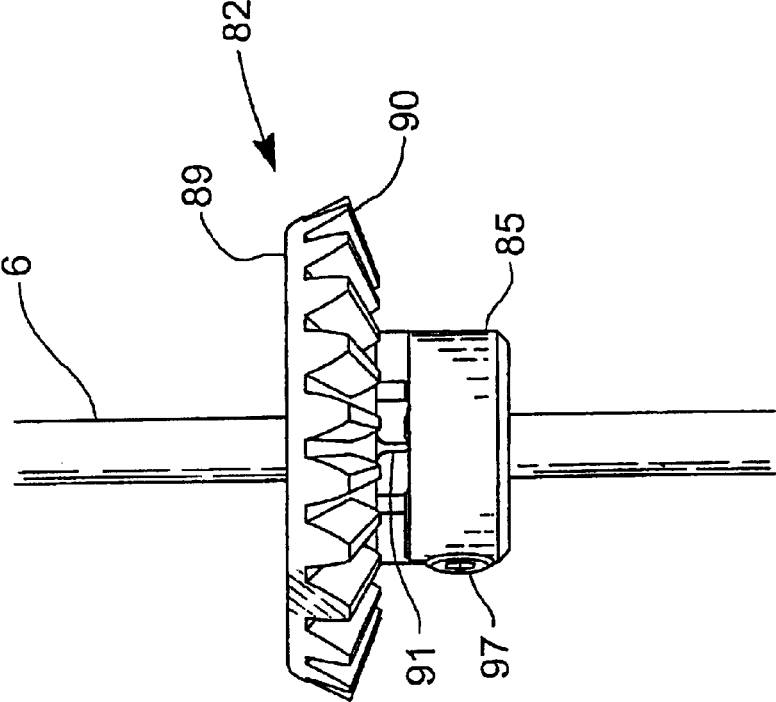


Fig. 15

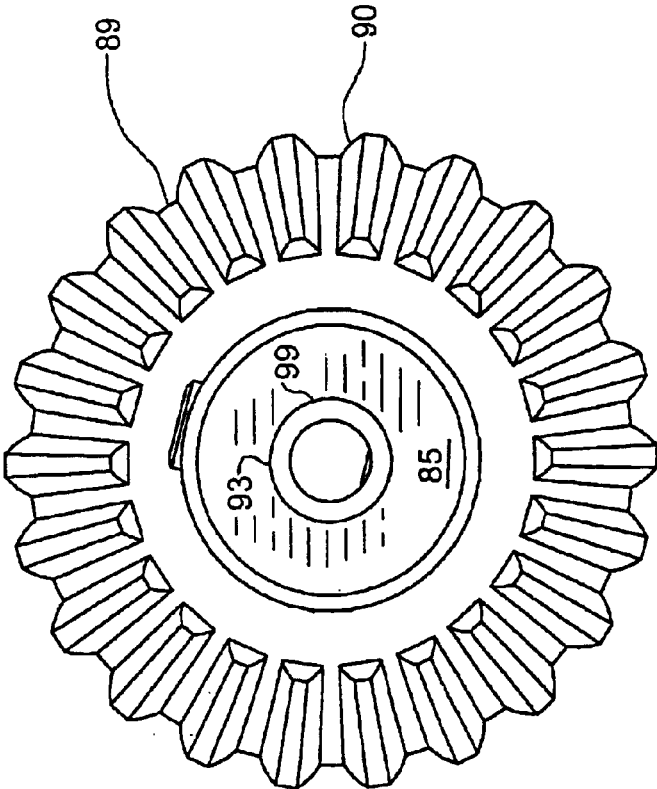


Fig. 16

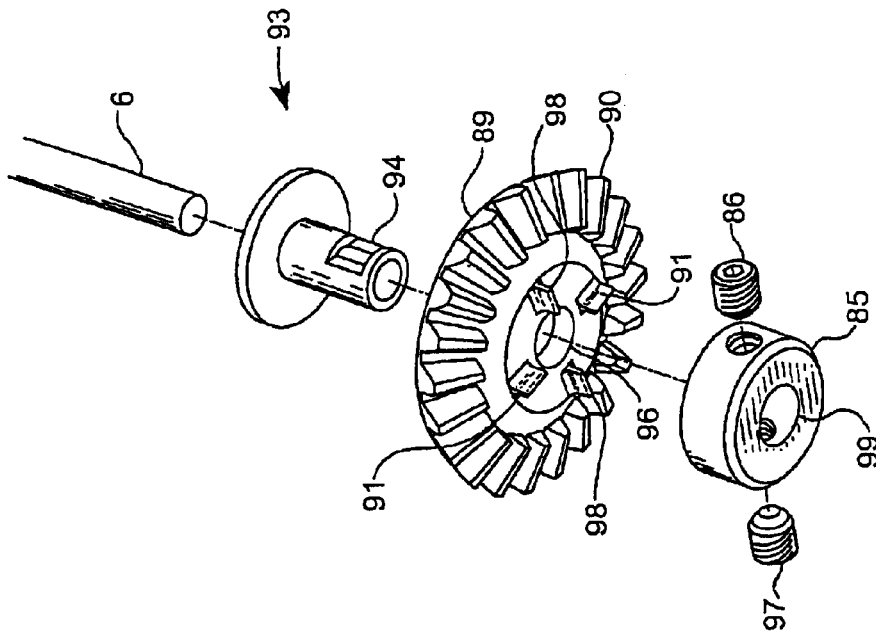


Fig. 17

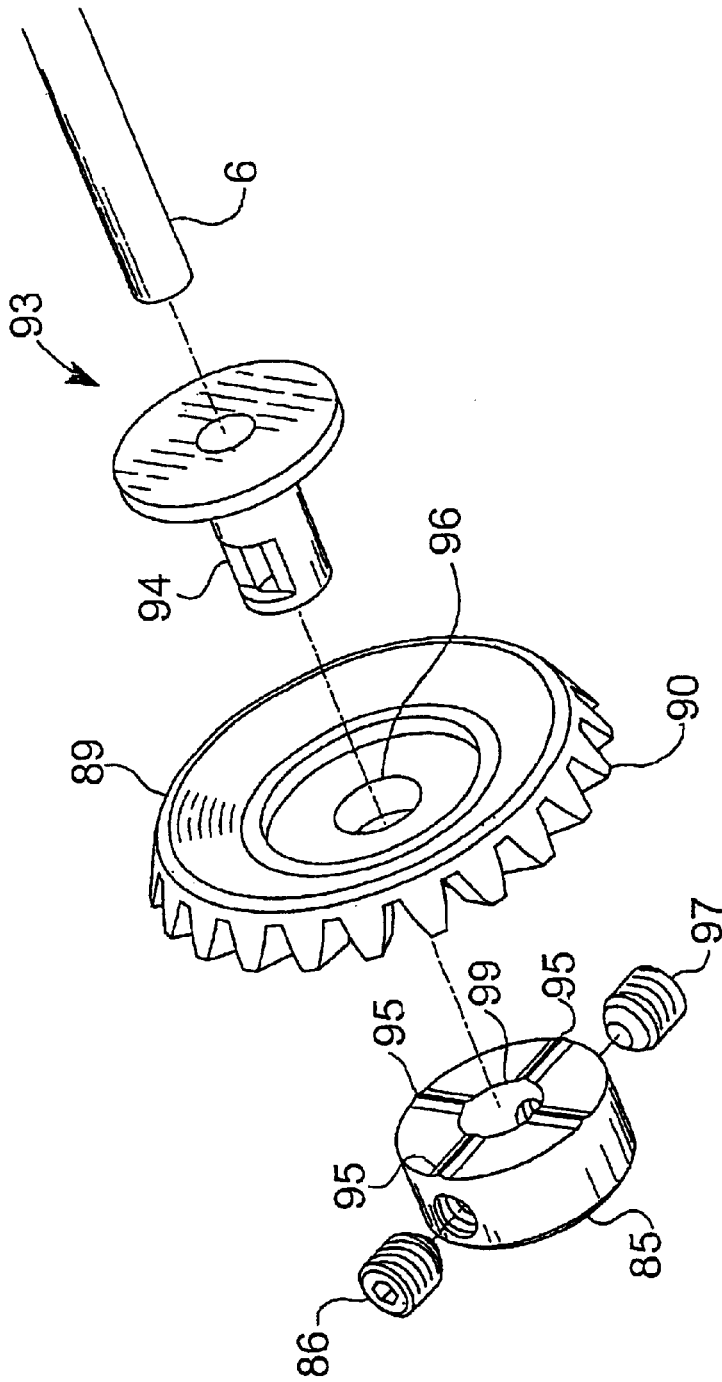


Fig. 18

ROTOR SYSTEM FOR HELICOPTERS

This application claims the benefit of Provisional Application No. 60/317,003, filed Sep. 4, 2001.

BACKGROUND AND SUMMARY

The present disclosure relates to rotor systems for helicopters and similar aircraft, and in particular to tail rotors.

Helicopters are flying machines which can fly in any direction or hove over a point on the ground without moving. Helicopters usually have a single main rotor mounted on top of a body or fuselage of the helicopter to generate a lift force to hold the helicopter in the air, and a tail rotor or other yaw control system to maintain directional control of the helicopter. Several different yaw control systems have been developed (such as blown tail booms and shrouded fans), but traditional tail rotor systems with exposed tail rotor blades are still the most popular.

With all of their rotating rotor blades, gears, and mechanical linkages helicopters are typically more complicated and expensive than other types of aircraft such as fixed-wing airplanes. Helicopters are also generally more difficult to fly than airplanes, and model helicopters are particularly difficult to control. As a result, pilot of model helicopters frequently crash and damage their models. Model helicopters can be very expensive to repair, so relatively few modelers have the patience, skill, and budget to master them. Components that reduce the complexity and cost of helicopters make helicopters more available to the general public, easier to maintain and repair, and generally more competitive with other types of aircraft.

Tail rotor systems on helicopters are extremely important because the control the direction of flight. Tail rotors are also more likely to be damaged than other parts of a helicopter because they are often operated near obstruction such as trees or the ground, and are lightly constructed to prevent a tail-heavy condition of the helicopter which would adversely affect the helicopter in flight. Impact of the tail rotor blades on an obstruction can cause the helicopter to loose control and crash. Tail rotor failure and tail blade strikes, on obstructions are one of the most common types of helicopter accidents which lead to personal injures of the pilot and bystanders and loss of the helicopter. What is needed is a tail rotor system that is simple, inexpensive and less susceptible to damage.

According to the present disclosure, a helicopter tail rotor system comprises a tail boom, a gear box associated with the tail boom, and tail rotor blades mounted for rotation relative to the gear box. The tail rotor system further comprises a retainer configured to move in a retainer aperture provided in the gear box to engage and deform the tail boom to retain the gear box in a mounted position on the tail boom. Thus, a method is disclosed herein for moving a retainer relative to a gear box to deform the tail boom to secure the gear box in a fixed position on the tail boom.

In illustrative embodiments, the gear box includes a gear box housing formed to include the retainer aperture and a rotatable bevel gear mounted for rotation in the gear box housing and coupled to rotate with a rotatable drive shaft extending through the tail boom. The tail rotor blades are adapted to rotate in response to rotation of the drive shaft and the bevel gear coupled to the drive shaft. The retainer is used to retain the gear box housing in a fixed position on the tail boom without hindering rotation of the drive shaft in the tail boom or the bevel gear in the gear box housing.

Additional features of the disclosure will become apparent to one skilled in the art upon consideration of the

following description of the various embodiments which illustrate the best mode for carrying out the disclosure as presently perceived.

BRIEF DESCRIPTION OF THE DRAWINGS

The following detailed description refers particularly to the accompanying figures which are drawn to scale in which:

FIG. 1 is a perspective view of a representative helicopter including an improved tail rotor system in accordance with the present disclosure;

FIG. 2 is an isometric perspective view of a tail rotor assembly of the helicopter illustrated in FIG. 1 showing exterior details of the tail rotor assembly;

FIG. 3 is an exploded isometric perspective view of the tail boom and tail rotor gear box assembly of the helicopter illustrated in FIG. 1 showing tail rotor drive components situated within the tail boom and tail rotor gear box;

FIG. 4 is a partial view of a tail rotor blade illustrated in FIG. 2 showing the blade grip attachment area cut away to show interior detail;

FIG. 5 is a partial view of the tail rotor blade assembly illustrated in FIG. 2 showing the blade grip attachment area cut away to show interior detail;

FIG. 6 is a top elevation view of the tail rotor hub assembly illustrated in FIG. 2, with the tail rotor hub and shaft bearing cut away to show interior detail, and with most tail rotor and tail boom components removed for clarity;

FIG. 6a is a simplified side elevation view of a mechanical pressing operation and an injection molding operation illustrating a method for manufacturing a tail rotor drive gear according to the current disclosure;

FIG. 7 is a top elevation view of the tail rotor gear box illustrated in FIG. 2 cut away to show interior detail before insertion of a tail boom holding screw, with most tail rotor components removed for clarity;

FIG. 8 is a top plan view of the tail rotor gear box illustrated in FIG. 2 cut away to show interior detail after insertion of a tail boom holding screw, with all tail rotor components removed for clarity;

FIG. 9 is an exploded isometric perspective view of the tail rotor spider assembly illustrated in FIG. 2 with all other parts of the tail rotor removed for clarity;

FIG. 10 is a rear end elevation view of the tail rotor assembly of the helicopter shown in FIG. 1 with one tail rotor blade grip shown in cross section at the spider attachment area, and with all parts of the helicopter forward of the gear box and the rear half of the tail rotor assembly removed for clarity;

FIG. 11 is a rear end elevation view of the tail rotor assembly of a second embodiment of the current disclosure having a double tail rotor blade assembly with two tail rotor blades shown in cross section at their respective spider attachment areas, and with all parts of the helicopter forward of the gear box and the rear half of the tail rotor assembly removed for clarity;

FIG. 12 is a rear end elevation view of a third embodiment of the current disclosure having a tail rotor blade in a "puller" configuration with one tail rotor blade shown in cross section at the spider attachment area, and with all parts of the helicopter forward of the gear box and the rear half of the tail rotor assembly removed for clarity;

FIG. 13 is an isometric perspective view of the helicopter shown in FIG. 1 with the body cover (canopy) removed to show interior detail;

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FIG. 14 is a side elevation view of the helicopter shown in FIG. 1 with the body cover (canopy) removed to show interior detail including, for instance, radio-control system components and tail rotor drive train components;

FIG. 15 is a side elevation view of a tail rotor slip-clutch in accordance with the present disclosure extracted from the tail rotor power transmission system of the helicopter shown in FIG. 1;

FIG. 16 is a top plan view of the slip-clutch shown in FIG. 15;

FIG. 17 is a first exploded isometric view of the slip-clutch shown in FIGS. 15 and 16 showing individual mechanical components thereof and particularly the underside of upper clutch plate according to the current disclosure; and

FIG. 18 is a first exploded isometric view of the slip-clutch shown in FIGS. 15 and 16 showing individual mechanical components thereof and particularly the upper side of a clutch hub according to the current disclosure.

DETAILED DESCRIPTION

Referring to FIG. 1, a helicopter 1 is designed to include a large main rotor 2 which rotates about a main rotor axis of rotation 3 to lift helicopter 1 into the air. Helicopter 1 also includes a smaller tail rotor 13 which rotates about a tail rotor axis of rotation 15 to counteract the torque produced by main rotor 2 and steer helicopter 1. Tail rotor 13 is mounted at the end of a tail boom 16.

Both main rotor 2 and tail rotor 13 of helicopter 1 are driven by a power plant 7 such as engine or an electric motor (not shown) usually located within the fuselage (body) of helicopter 1 near main rotor shaft 6 (mostly hidden) although tail rotor 13 could also be operated by, for instance, a separate motor or engine (not shown) mounted at the end of tail boom 16. A streamlined fuselage shell 10 covers the front of helicopter 1, but does not extend back to tail rotor 13. In alternative embodiments, the fuselage shell may extend back to tail rotor 13 and enclose the tail boom 16. FIG. 1 is drawn to scale. Main rotor span 11 is 24" (twenty-four inches) and tail rotor span 12 is 8" (eight inches) in the case of a flying model helicopter.

Although helicopter 1, shown in FIG. 1, is a model helicopter, man-carrying helicopters (not shown) also have main rotors and tail rotors, and that other types of rotary wing aircraft (such as tilt-rotor aircraft) use thrust-producing appendages. Such full-sized helicopters can operate in a similar fashion and benefit in similar ways from the current disclosure.

Illustratively, main rotor 2 of helicopter 1 includes two main rotor blades 4 and two shorter stabilizer blades 5 supported by a main rotor shaft 6 (see FIG. 14) aligned with main rotor axis of rotation 3. In operation, main rotor 2 rotates rapidly about main rotor axis of rotation 3 in rotation direction 8. As main rotor 2 rotates, main rotor blades 4 and subrotor blades 5 act like propellers or fans moving large amounts of air downward thereby creating an aerodynamic force that lifts helicopter 1 upward. This force can be directed straight down or in various directions by main rotor 2 to make the helicopter 1 fly forwards, backwards or sideways. When a helicopter moves forwards, backwards or sideways it is said to be "translating" and in a state of "translating flight." When a helicopter is flying nearly motionless in the air over a spot on the ground it is said to be "hovering" over the spot.

Angular motions of helicopter 1 about main rotor axis 3 are called "yaw motions," and forces that tend to rotate

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helicopter 1 about main rotor axis 3 are called "yaw moments" or "yaw torques." The yaw torque (reaction force) created by rotating main rotor 1 in rotation direction 8 tends to cause helicopter 1 to swing about main rotor axis of rotation 3 in yaw direction 9. When trimmed for steady hovering flight, tail rotor 13 propels air in direction 17 creating enough thrust force in direction 17 to cancel the yaw torque produced by main rotor 2 exactly so that helicopter 1 maintains a constant heading in flight.

Decreasing or increasing the thrust force of tail rotor 13, as by increasing or decreasing the collective pitch of tail rotor blades 14 or the speed of rotation of tail rotor 13, will cause helicopter 1 to turn in yaw directions 8 or 9 respectively. Typically, the pilot of a full-sized helicopter (not shown) controls the collective pitch of tail rotor blades 14 by manipulating foot pedals located within the cockpit (not shown). Cables, push-pull rods, mixing arms, and bellcranks connect the pedals to the pitch controls of tail rotor blades 14. As the pilot adjusts the pedal position, the change in angle-of-attack (pitch) and associated thrust force of the rotating tail rotor blades results in a yaw moment about the main rotor axis. This yaw moment is directed to maneuver the helicopter, or to oppose any destabilizing yaw moment sensed by the pilot.

Tail rotors of radio-controlled model helicopters are usually designed to operate in a manner identical to full-sized helicopters. The pilot manipulates small joysticks on a hand-held radio transmitter (not shown) which in turn sends commands to electromechanical servo actuators located within the flying model. Push-pull rods, mixing arms, and bellcranks connect the servos to the collective pitch controls of the tail rotor blades. Alternatively, tail rotors can be operated, for instance, by a motor (not shown) mounted at the end of a tail boom of the helicopter and connected to the tail rotor blades. Changes in the speed of the electric motor (not shown) change the speed and vary the thrust of the tail rotor.

As shown in more detail in FIG. 2, which is an enlarged view of a tail assembly of helicopter 1 having a tail rotor system in accordance with the present disclosure, tail rotor blades 14 are fixedly secured to reach-around blade grips 24. Axial motion of push-pull rod 32 along axis 15 (as caused by operation of bellcrank 33) moves spider 34 along tail rotor axis 15 thereby varying collective pitch angle 37 of tail rotor blades 14 and the thrust of tail rotor 13.

Now referring to FIG. 3, which is an exploded view of the tail boom assembly of helicopter 1, crown gear 50 is fixed to rotate with main rotor shaft 6 (not shown) about main rotor axis 3 and drives front pinion gear 51. Front pinion gear 51 is fixedly coupled to rotatable drive shaft 53 by gear retainer 52. Rotatable drive shaft 53 is located within tail boom 16 (shown in sections) and transmits power from crown gear 50 to tail rotor 13. Gear box housing 55 is mounted at the end of tail boom 16 and encloses ball bearings 56, 57, rotatable bevel gears 59, 60, and hollow tail rotor shaft 61 that together support and drive tail rotor 13 (shown in FIG. 1,2). Bearing collar 69 is fixedly secured to one end 75 of tail rotor shaft 61 by force receivers, or setscrews 74 and retains bearing 56 in gear box housing 55.

Rotational motion from power plant 7 of helicopter 1 is transmitted to tail rotor 13 through front crown gear 50, front pinion gear 51 (which is appended to rotatable drive shaft 53), rotatable bevel gears 59, 60, tail rotor shaft 61, and tail rotor hub 63. In the embodiment shown in the figures, tail rotor 13 is driven at a rotational speed of about 2 to 3 times that of main rotor 2. Pinion gear 51 and bushing 70, and

rotatable bevel gear **59** and bushing **71** are separated by drive washers **73** which are made of a low-friction material such as Teflon.

Because tail rotor blades **14** are fixedly coupled to reach-around grips **24**, and not coupled by a pivot mechanism as are the tail rotor blades on some helicopters (not shown), impact of tail rotor blades **14** on the ground or other obstruction (not shown) can induce damaging forces in the tail rotor drive train (which is also known as the tail rotor power transmission system). In one embodiment of the current disclosure, crown gear **50** contains a slip-clutch **82** (see, for example, FIG. **15**) or other torque-limiting or power-limiting device to limit the torque or power transmitted through the tail rotor drive train to tail rotor blades **14**. When, for instance, tail rotor blades **14** strike an obstruction, the slip-clutch **82** reduces the power available to tail rotor **13** by disconnecting the tail rotor drive train from power plant **7** thereby minimizing damage done by tail rotor blades **14** on the obstruction, and the damage done to tail rotor blades **14** by the obstruction.

For model helicopters configured according to the current disclosure, tail boom **16** (shown in sectioned cut-away) is made of a deformable material such as aluminum, has a center bushing **69** and end bushings **70,71** at each end made of a plastics material such as Delrin which take the place of expensive ball bearings. When installed, gear box housing retainer **54** extends into the interior of gear box housing **55** near the end of tail boom **16** and sets securely against the outer surface of tail boom **16**. Bushing channel **72** is formed in end bushings **71** to accommodate deformation of tail boom **16** by the end of gear box housing retainer **54** which secures gear box housing **55** against rotation or axial motion relative to tail boom **16**.

Tail boom bracket **66** is provided to mount tail boom **16** to the fuselage structure of helicopter **1** (as shown in FIG. **13**). A gear box housing retainer **54** (not shown) is incorporated into tail boom bracket **66** to deform the wall of tail boom **16** adjacent to tail boom bracket **66** to prevent tail boom **16** from moving relative to tail boom bracket **66** (using the method herein disclosed to secure gear box housing **55** to tail boom **16**).

Tail rotor pushrod **76** extends rearward from the pilot controls of helicopter **1** and is operably coupled to bellcrank **33**. Bellcrank **33** is operably coupled to one end of push-pull rod **32** which extends transversely through the interior of gear box housing **55** and tail rotor hub **63** to exit tail rotor hub **63** through hole **64**. Tail rotor axle screws **18** secure tail rotor hub **63** to hollow shaft **61**.

As shown in FIGS. **4** and **5**, tail rotor **13** comprises two opposing tail rotor blades **14** pivotable about axle screws **18** and fixedly coupled to blade grips **24**. FIGS. **4** and **5** are drawn to scale, and axle screws **18** are shown about $\frac{5}{8}$ inches (0.625") long. Grip **24** comprises distal finger portion **25** located away from blade **14**, base portion **27** located adjacent to blade **14**, and intermediate link portion **26** located between finger portion **25** and base portion **27**. Co-axial outer pivot holes **20** and inner pivot holes **21** extend through base portion **27** and finger portion **25** and are receptive to axle screws **18** for rotation about pitch axis **23**. Tail rotor axle screws **18** extend through the smooth interiors **35,36** of outer pivot holes **20** and inner pivot holes **21**, thread into holes **65** in tail rotor hub **63** (see FIG. **6**) and engage hollow shaft **61** thereby securing tail rotor hub **63** to hollow shaft **61**. Thrust washers **19** abut the inner faces of finger portion **25** and the exterior of hub **63**, and are manufactured of a low-friction material such as Teflon.

Link portion **26** of grip **24** has link opening **28** extending completely through link portion **26** along axis **15** formed by outer cross-member **83** and inner cross-member **84**. Spider pin **31** extends through the middle of opening **28** and into pin holes **29** in finger portion **25** and base portion **27** of blade grip **24**. Axle screw recess **30** in blade **14** is slightly larger in diameter than axle screws **18** and facilitates insertion of axle screw **18** during assembly of tail rotor blade **14** to tail rotor hub **63**. In one embodiment, tail rotor blade **13** is injection molded from a plastics material such as nylon or polycarbonate. Plastics materials such as nylon and polycarbonate have the strength and stiffness needed for proper operation of tail rotor blade **14** in flight. In addition, plastics materials such as nylon have an abrasion resistance property which enables these materials to act as bearing surfaces at **35,36** when in contact with the exterior of axle screws **18**.

A feature of the current disclosure when molded from a plastics material is that pivot holes **20,21** are of a slightly larger diameter than axle screws **18**, and extend completely through finger portion **25** and base portion **27** into blade **14** thereby forming axle screw recess **30**. When molded in a plastics injection mold with a movable core pin (as would be understood by one skilled in the art of plastics molding), the core pin extends through blade grip **24** and into tail rotor blade **14** simultaneously forming not only axle screw pivot holes **20,21**, but also screw recess **30** in blade **14** which is needed for proper insertion of axle screw **18** during assembly of tail rotor blade **13** to hub **63**. Having a mold core pin along the mold parting line simplifies mold construction and operation.

Referring now to FIG. **6**, tail rotor hub **63** is generally hollow, has through hole **67** to accept tail rotor shaft **61**, and has two threaded cross holes **65** receptive to axle screws **18**. In one embodiment of the current disclosure, axle screws **18** act both as pivot axles for tail rotor blades **14** and as attachment screws to secure hub **63** to hollow shaft **61**. While hub **61** can be manufactured from a metal material, in one embodiment of the current disclosure, hub **63** is injection molded from a plastics material such as Delrin or Acetyl as would be understood by one skilled in the art of plastics manufacturing. Plastics materials such as Delrin or Acetyl have the combined physical properties of strength and toughness to withstand the severe operating conditions of tail rotor hub **63**, but also have thread locking properties to prevent axle screws **18** from loosening in flight and being ejected radially from spinning tail rotor **13**. In addition, the complex geometry of tail rotor hub **63** is well suited for manufacture by multi-cavity injection molding techniques wherein a molten plastics material is forced into several mold cavities simultaneously in order to make many parts simultaneously.

A feature of the current disclosure is that rotatable bevel gear **59** is injection molded of a plastics material such as Delrin or Acetyl in one piece around the end of rotatable drive shaft **53** which is configured at one end in a serpentine shape **62** to retain rotatable bevel gear **59**. Rotatable bevel gear **60** is injection molded of a plastics material such as Delrin or Acetyl in one piece around drive tail rotor shaft **61** which has notch **58** to retain gear **60**.

Referring to FIG. **6a** which illustrates a manufacturing process for rotatable drive shaft **53** and rotatable bevel gear **59**, rotatable drive shaft **53** is made of high strength steel such as ASTM-A-228 piano wire. During manufacture, rotatable drive shaft **53** undergoes a first operation to create a holding geometry **105** on rotatable drive shaft **53** which protrudes from the outer radius of rotatable drive shaft **53** by an arm distance **111** to retain rotatable bevel gear **59**. During

said first operation, rotatable drive shaft **53** is forcibly pressed between upper steel die **101** and lower steel die **102** as they close in die directions **112,113** to form serpentine shape **62**. Upper die **101** has recess **103**, and lower die **102** has boss **104** which cooperate to form the reverse image of serpentine shape **62** when pressed against rotatable drive shaft **53**.

After being formed in the first operation, rotatable drive shaft **53** is transferred to a molding station where first mold half **106** and second mold half **107** have interior cavities **108,109** defining rotatable bevel gear **59**. In a second operation, serpentine shape **62** of rotatable drive shaft **53** is transferred to a mold cavity **108,109** in an injection molding machine, mold halves **106,107** are closed in mold directions **114,115** and a liquid plastics material such as Acetyl is injected into the mold cavity through sprue passage **110** thereby encapsulating serpentine shape **62** and forming rotatable bevel gear **59**.

After molding, rotatable bevel gear **59** and rotatable drive shaft **53** form a single integral part that will not slip or fail for the useful life of rotatable bevel gear **59**. Arm distance **111** is set to accommodate the size of rotatable bevel gear **59** and the diameter of rotatable drive shaft **53** which can include very small diameters. A feature of the manufacturing method of the current disclosure is that rotatable bevel gear **59** is low weight and compact to reduce the possibility of a tail-heavy condition of helicopter **1**. It will be understood by one skilled in the art of manufacturing that dies **101,102** and mold halves **106,107** are shown in FIG. **6a** to illustrate the method of the current disclosure, and said dies and molds can vary in form while producing the same results in practice. It will be further understood that other drive train components can be appended rotatable drive shaft **53** using the method disclosed.

As shown in FIGS. **7, 8**, a gear box housing **55** is formed to include a tail boom receiver **100**, and is secured to tail boom **16** by housing retainer **54** configured to move in a retainer aperture **101** into deformation **78** of the surface of tail boom **16**. Tip **77** of housing retainer **54** is pointed to concentrate force on tail boom **16** to deform the surface of tail boom **16** into bushing channel **72** in bushing **71**. Tip **77** acts as a key inside of deformation **78** to prevent gear box housing **55** from rotating or moving axially relative to tail boom **16**. A feature of the current disclosure is that no special manufacturing operations such as slotting or drilling are required to prepare tail boom **16** for assembly to gear box housing **55**.

Referring now to FIG. **9**, spider eyelet **40** extends through eyelet hole **42** and into eyelet collar **41**. Setscrew **43** extends through threaded hole **44** in collar **41** and into clearance hole **45** to secure eyelet **40** to push-pull rod **32** (see FIG. **10**). When assembled, eyelet **40** and collar **41** together define an annular recess **46** in which spider **34** can rotate freely.

As shown in FIGS. **4, 5, 9** and **10**, push-pull rod **32** extends through the center of spider eyelet **40** which is fixedly secured to push-pull rod **32** by collar **41** and collar setscrew **43**. Pitch pins **31** extend through pitch pin holes **29** in reach-around grips **32**, and are pressed into and secured within spider pitch pin holes **39** in spider **34**. Operation of push-pull rod **32** in the direction of arrow **17** pitches tail rotor blade **11** to a lower angle-of-attack **37**.

As shown in FIGS. **10-12**, a feature of the current disclosure is that pitch control linkages such as spider **34** can be operably connected to link portion **26** of blade grip **24** from either side of link opening **28** to allow tail rotor blade **14** to be mounted in either a “pusher” or “puller” configu-

ration. When tail rotor thrust is directed away from tail boom **16** in direction **17**, tail rotor **13** is called a “pusher” type tail rotor as shown in FIGS. **1, 2, 10, 12** and **13**. When the tail rotor thrust force is directed toward tail boom **16** as in FIG. **12**, the tail rotor is called a “puller” type tail rotor. Another feature of the current disclosure shown in FIG. **11** is that multiple tail rotor blades **14** can be linked together with the pitch control linkage **81** extending from one blade to the next in series. This allows for multi-bladed tail rotor configurations having two or more tail rotor blades connected together.

Referring now to FIG. **15** through FIG. **17**, power limiting device means includes a slip-clutch **82** in accordance with the current disclosure, an upper clutch plate **89** having gear teeth **90** and flexible tabs **91**, a clutch eyelet **93** having an eyelet opening **94**, and clutch hub **85** having radially extending clutch ridges **95** around its upper periphery. Clutch eyelet **93** passes through center hole **96** in upper clutch plate **89** and into clutch hub hole **99** in clutch hub **85** where it is secured by setscrew **97** in clutch hub **85**. Clutch hub **85** secures slip-clutch **82** to main rotor shaft **6** by clutch setscrew **86** which passes through eyelet opening **94** in clutch eyelet **93** and presses against main rotor shaft **6** which extends through clutch eyelet **93**.

Each clutch ridge **95** operates against the end portion **98** of a flexible tab **91** on upper clutch plate **89** thereby transferring rotational motion of main rotor shaft **6** to upper clutch plate **89**. Clutch gear teeth **90** on upper clutch plate **89** engage the gear teeth of front pinion gear **51** which is connected to rotatable drive shaft **53** and transmits power from power plant **7** to tail rotor **13** (see FIG. **3**). Application of a force beyond a pre-set limit to tail rotor **13** causes flexible tabs **91** to flex or bend.

This flexing action shortens the length of flexible tabs **91** until flexible tabs **91** slide over clutch ridges **95** allowing upper clutch plate **89** and clutch hub **85** to slip past one another thereby limiting the amount of power from the plant power available to tail rotor **13**. This can limit the amount of damage done to tail rotor **13** when, for instance, tail rotor blades **14** strike the ground or another obstacle.

An alternative embodiment (not shown) of slip-clutch **82** has clutch plates that are pressed together by a spring mechanism to develop adjustable friction between the plates. Application of a force beyond a pre-set limit causes the plates to slip past one another thereby limiting the amount of power plant power available to tail rotor **13**.

While a clutch system such as slip-clutch **82** may be located anywhere along the tail rotor power transmission system (for example, by tail rotor **13** or in tail rotor hub **63**), slip-clutch **82** in accordance with the current disclosure is located forward of tail rotor **13** on or near main rotor shaft **6** to reduce the weight of tail rotor **13** and prevent a tail-heavy condition of helicopter **1**. Regardless of the physical location of slip-clutch **82**, slip-clutch **13** and tail rotor **13** cooperate to form a low weight, durable tail rotor system.

As described herein, an improved tail rotor system includes a tail rotor spaced apart from the body of the helicopter to control the flight direction of the helicopter, a tail boom assembly supporting the tail rotor and connecting the tail rotor to the body, and a tail rotor drive mechanism for transmitting motive power from a power source to the tail rotor to rotate the tail rotor about a tail rotor axis of rotation which, in one embodiment, is substantially perpendicular to the main rotor axis of rotation. While the power source is usually located inside the body of the helicopter, in one embodiment it is located at the end of a helicopter tail

boom near the tail rotor, or on the end of a wing on a tilt-rotor aircraft. The tail rotor comprises one-piece molded rotor blades that can be configured to operate in either a “pusher” or “puller” configuration without structural modification, and a simplified one-piece tail rotor hub that is easy to manufacture and resistant to damage from crashes. The tail boom assembly includes a simplified and improved gear box design that provides a positive attachment to the tail boom through mechanical deformation of the tail boom tube. The tail rotor drive means includes a torque-limiting device such as a slip-clutch to reduce tail rotor and drive train damage in the event of a tail blade strike on the ground or other obstruction.

A tail rotor system in accordance with this disclosure includes tail rotor elements with low cost reversible rotor blades, mechanical drive elements including, for instance, a slip-clutch that resist damage due to crashes, and simplified supporting structure that is inexpensive to manufacture. While the current disclosure has significant applications in model helicopters, many aspects of the current disclosure can also be used in full-size man-carrying helicopters and similar aircraft such as, for instance, tilt-rotor aircraft. When used on helicopters, a tail rotor system increases tail rotor effectiveness and durability, and reduces manufacturing and operating costs.

What is claimed is:

1. An aircraft rotor system comprising
 - a tail boom made of a deformable material and formed to include an interior region containing a rotatable drive shaft,
 - a gear box associated with the tail boom, the gear box including a housing formed to include a tail boom receiver and a retainer aperture opening into the tail boom receiver, a rotatable bevel gear mounted for rotation in an interior region of the housing and in spaced-apart relation to the tail boom and adapted to rotate tail rotor blades associated with the rotatable bevel gear, and a bushing arranged to support the drive shaft for rotation inside the tail boom receiver, a portion of the tail boom being located to lie between the bushing and the tail boom to confront the opening of the retainer aperture, and
 - a housing retainer configured to move in the retainer aperture in a direction toward the bushing located in the tail boom receiver, the housing retainer including a force receiver adapted to mate with a force-producer tool and means for engaging an exterior surface of the tail boom and deforming the tail boom to move a deformed portion of the tail boom toward the bushing into a bushing channel formed in the bushing in response to movement of the housing retainer in the retainer aperture toward the bushing so that the housing is retained in a fixed position on the tail boom without hindering rotation of the drive shaft, and bevel gear within the housing.
2. A rotor system for an aircraft having a fuselage, a rotor for moving air, the rotor system comprising
 - a housing for supporting the rotor for rotation about a rotor rotation axis and a tail boom for supporting the housing in spaced-apart relation to the body, and
 - retainer means for securing the housing to the tail boom, the retainer means comprising at least one retaining screw engaging a wall of the housing in perpendicular relation to the tail boom and one end of the retaining screw presses against the surface of the tail boom to secure the housing to the tail boom and the retaining

- screw deforms the surface of the tail boom inward into a bushing channel in an interior portion of the tail boom to produce a retainer indentation in the tail boom.
3. In a rotor system for an aircraft having a body, a rotor for moving air, a housing for supporting the rotor for rotation about a rotor rotation axis, and a tail boom for supporting the housing in spaced-apart relation to the body,
 - a method for fixedly coupling the housing to the tail boom comprising the steps of moving a retaining mechanism to engage a wall of the housing abutting the tail boom, to cause the tail boom to deform the surface of the tail boom into a bushing channel and create a recess in the tail boom receiving the retaining mechanism therein to secure the housing to the tail boom against axial and rotational motion of the housing relative to the tail boom.
4. A rotor system for an aircraft having a rotor for moving air, the rotor system comprising
 - a rotor hub connected to a rotor shaft and supported for rotation about a rotor axis of rotation, the rotor hub having a first side and a second side located in spaced-apart relation to the rotor axis of rotation and diametrically opposed to each other,
 - a first rotor blade grip extending in perpendicular relation to the rotor axis of rotation and having a finger part abutting a first side of the rotor hub, a root part in proximity to a second side of the rotor hub, and the root part and finger part of the first rotor blade grip each contain a coaxial passage receptive to a pitch axle,
 - a second rotor blade grip extending in perpendicular relation to the rotor axis of rotation and having a finger part abutting the second side of the rotor hub, a root part in proximity to the first side of the rotor hub, and the root part and finger part of the second rotor blade grip each contain a coaxial passage receptive to a pitch axle,
 - a pitch axle extending through the root part of the first rotor blade and the finger part of the second rotor blade and into a side of the rotor hub and the first and second rotor blade grips are rotatable on the pitch axle for rotation about a rotor blade pitch axis, the pitch axle being fixedly coupled to the rotor hub and free of rotation about its longitudinal axis.
5. A rotor system for an aircraft, the rotor system comprising
 - a rotor for moving air,
 - a power plant for driving the rotor about a rotor axis of rotation, and
 - a power transmission system for transmitting power from the power plant to the rotor, the power transmission system including power-limiting device means for disconnecting the power plant from the rotor in response to application of a force to the rotor above a desired value as by impact of the rotor against an obstacle or the ground to cause the power plant to disconnect from the rotor so that power available from the power plant to the rotor is reduced.
6. The rotor system of claim 5, wherein the power-limiting device means includes a clutch, and application of a torque force to the rotor above a desired value as by impact of the rotor with the ground causes the clutch to slip relative to the power plant thereby limiting the torque available to drive the rotor.
7. The rotor system of claim 4, wherein the pitch axle abuts the rotor shaft and fixedly secures the rotor hub to the rotor shaft.
8. The rotor system of claim 7, wherein the pitch axle is a setscrew having a threaded exterior and the rotor hub has

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at least one threaded cross hole in one of the first side and second side and the pitch axle screws into the threaded cross hole and against the rotor shaft.

9. The rotor system of claim 5, wherein the power-limiting device means includes a clutch coupled to the rotors and configured to slip relative to the power plant in response to application of a torque force to an affected rotor above a desired value as by impact of the rotor with the ground thereby limiting the torque available to drive the affected rotor without limiting the torque available to drive the remaining rotors.

10. A rotor system for an aircraft, the rotor system comprising

a rotor for moving air,

a power plant for driving the rotor about a rotor axis of rotation, and

the power transmission system including power-limiting device means for disconnecting the power plant from at least one affected rotor in response to application of a force to the affected rotor above a desired value as by impact of the affected rotor against an obstacle or the ground to cause the power plant to disconnect from the affected rotor so that power available from the power plant to the affected rotor is reduced while the power available to the remaining rotors is not substantially reduced.

11. The rotor system of claim 9 wherein the aircraft is a helicopter having a main rotor supported for rotation about a main rotor axis by a main rotor shaft, a tail rotor supported

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for rotation about a tail rotor axis by a tail rotor shaft, a tail rotor drive shaft operably connecting the main rotor shaft and tail rotor shaft to transmit motive power from the main rotor shaft to the tail rotor shaft, and the power-limiting device means is a slip-clutch located between the main rotor shaft and the tail rotor drive shaft and configured to disconnect the tail rotor drive shaft from the main rotor shaft upon application of a force to the tail rotor above a desired value as by impact of the tail rotor with the ground.

12. An aircraft rotor system comprising

a main rotor supported for rotation about a main rotor axis and driven by a power plant to lift the helicopter into the air,

a tail rotor supported for rotation about a tail rotor axis substantially perpendicular to and in spaced apart relation to the main rotor axis and driven by a power plant to counter the torque produce by the main rotor,

a tail rotor power transmission system for transmitting power from the power plant to the tail rotor, and

power-limiting device means for disconnecting the tail rotor from the power plant in response to application of a force to the tail rotor above a desired value as by impact of the tail rotor against an obstacle or the ground to cause the tail rotor to disconnect from the power plant to reduce damage to the tail rotor and tail rotor power transmission system.

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