An actuator includes a housing assembly, a ball nut, a ball screw, and a ball screw stop. The ball nut is rotationally mounted in the housing assembly, is adapted to receive an input torque, and is configured, upon receipt thereof, to rotate and supply a drive force. The ball screw is mounted within the housing assembly and extends through the ball nut. The ball screw has a first end and a second end, and is coupled to receive the drive force from the ball nut. The ball screw is configured, upon receipt of the drive force, to selectively translate between a stow position and a deploy position. The ball screw stop is mounted on the ball screw to translate therewith and is configured to selectively engage the housing assembly while the ball screw is translating, and engage the ball nut when the ball screw is in the deploy position.

16 Claims, 5 Drawing Sheets
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BALL SCREW ACTUATOR INCLUDING A STOP WITH AN INTEGRAL GUIDE

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

This invention was made with Government support under contract number NAS15-10000 awarded by NASA. The Government has certain rights in this invention.

TECHNICAL FIELD

The present invention generally relates to actuators, and more particularly relates to linear, ball screw actuators that include stops with integral guides.

BACKGROUND

Actuators are used in myriad devices and systems. For example, many vehicles including, for example, aircraft, spacecraft, watercraft, and numerous other terrestrial and non-terrestrial vehicles, include one or more actuators to effect the movement of various control surfaces or components. Many different types of actuator configurations presently exist. One particular type of actuator is a linear electro-mechanical actuator (EMA). A typical linear EMA includes a power drive unit, an actuation member, and a translation member. The power drive unit, such as a motor, is configured to supply a drive torque to the actuation member, which in turn causes the translation member to translate.

One particular type of linear EMA is a ball screw actuator. This type of actuator includes a ball screw and a ball nut. The ball nut is mounted on, and is configured to rotate relative to, the ball screw. In some configurations, the ball screw is the actuation member, and the ball nut is the translation member. With these configurations, the power drive unit drives the ball screw, which causes the ball nut to translate. In other configurations, the ball nut is the actuation member, and the ball screw is the translation member. With these configurations, the power drive unit drives the ball nut, which causes the ball screw to translate.

With the latter configuration, in which the ball screw is the translation member, the ball screw can vibrate while it is translating, and also deflect at the limits of translational stroke. These factors, both individually and collectively, can deleteriously impact overall actuator assembly performance and lifetime.

Hence, there is a need for mechanism that at least inhibits ball screw vibration during translation and/or minimizes ball screw deflection at the limits of translation stroke. The present invention addresses at least these needs.

BRIEF SUMMARY

In one embodiment, an actuator includes a housing assembly, a ball nut, a ball screw, and a ball screw stop. The ball nut is rotationally mounted in the housing assembly, is adapted to receive an input torque, and is configured, upon receipt thereof, to rotate and supply a drive force. The ball screw is mounted within the housing assembly and extends through the ball nut. The ball screw has a first end and a second end, and is coupled to receive the drive force from the ball nut. The ball screw is configured, upon receipt of the drive force, to selectively supply the drive torque thereto. The motor is coupled to the ball nut and is configured to selectively supply the drive torque thereto. The ball screw is configured, upon receipt of the drive force, to selectively translate between a stow position and a deploy position.

In another embodiment, an actuator includes a housing assembly, a ball nut, a motor, a ball screw, and a ball screw stop. The ball nut is rotationally mounted in the housing assembly and has a first dog stop formed on an end thereof. The ball nut is adapted to receive an input torque and is configured, upon receipt thereof, to rotate and supply a drive force. The motor is coupled to the ball nut and is configured to selectively supply the drive torque thereto. The motor is coupled to the ball nut and is configured to selectively translate between a stow position and a deploy position.

In yet another embodiment, an actuator includes a housing assembly, a ball nut, a motor, a ball screw, and a ball screw stop. The ball nut is rotationally mounted in the housing assembly and has a first dog stop formed on a first end thereof. The ball nut is adapted to receive an input torque and is configured, upon receipt thereof, to rotate and supply a drive force. The motor is coupled to the ball nut and is configured to selectively supply the drive torque thereto. The ball screw is mounted within the housing assembly and extends through the ball nut. The ball screw has a first end and a second end, and is coupled to receive the drive force from the ball nut. The ball screw is configured, upon receipt of the drive force, to selectively translate between a stow position and a deploy position.

In still another embodiment, an actuator includes a housing assembly, a ball nut, a motor, a ball screw, and a ball screw stop. The ball nut is rotationally mounted in the housing assembly and has a first dog stop formed on an end thereof. The ball nut is adapted to receive an input torque and is configured, upon receipt thereof, to rotate and supply a drive force. The motor is coupled to the ball nut and is configured to selectively supply the drive torque thereto. The ball screw is mounted within the housing assembly and extends through the ball nut. The ball screw has a first end and a second end, and is coupled to receive the drive force from the ball nut. The ball screw is configured, upon receipt of the drive force, to selectively translate between a stow position and a deploy position.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will hereinafter be described in conjunction with the following drawing figures, wherein like numerals denote like elements, and wherein:

FIG. 1 depicts a plan view of one embodiment of a ball screw actuator assembly;

FIG. 2 depicts a cross section view taken along line 2-2 in FIG. 1;

FIG. 3 depicts a close-up cross section view of a ball nut and a portion of a ball screw that may be used to implement the actuator assembly of FIGS. 1 and 2;

FIG. 4 depicts a close-up plan view of an embodiment of a ball screw stop mounted on a ball screw; and
FIGS. 5 and 6 depict cross section plan views of the ball screw stop depicted in FIG. 3.

DETAILED DESCRIPTION

The following detailed description is merely exemplary in nature and is not intended to limit the invention or the application and uses of the invention. As used herein, the word "exemplary" means "serving as an example, instance, or illustration." Thus, any embodiment described herein as "exemplary" is not necessarily to be construed as preferred or advantageous over other embodiments. All of the embodiments described herein are exemplary embodiments provided to enable persons skilled in the art to make or use the invention and not to limit the scope of the invention which is defined by the claims. Furthermore, there is no intention to be bound by any expressed or implied theory presented in the preceding technical field, background, brief summary, or the following detailed description.

Referring to FIGS. 1 and 2, an exemplary ball screw actuator 100 is depicted. The depicted actuator 100 is a linear electromechanical (EMA) actuator and includes a pair of motors 102 (102-1, 102-2), a ball nut 104, and a ball screw 106, disposed within the ball nut passageway 216 of the housing assembly 112. The ball screw 106 includes a first end 118, a second end 122, and an inner surface 114 of the housing assembly 112. The actuator housing assembly 112 defines a passageway 216 that extends through the housing assembly 112 and extends through the ball nut passageway 216. The ball screw stop 120 is mounted on the ball screw 106 and is configured, upon receipt thereof, to selectively translate between a stow position and deploy position. The ball screw 106 includes a first end 118, a second end 122, and an outer surface 124. The ball screw outer surface 124 has a single or a plurality of ball grooves (or "threads") 126 formed thereon. A plurality of non-illustrated recirculating balls are disposed within the ball nut ball grooves 218, and in selected ones of the ball screw ball grooves 126. The balls, in combination with the ball grooves 126, 218, convert the rotational movement of the ball nut 104 into the translational movement of the ball screw 106. It will be appreciated that the direction in which the ball screw 106 travels will depend on the direction in which the ball nut 104 rotates.

As FIG. 2 further depicts, a ball screw stop 120 is mounted on the ball screw 106 in a manner that causes the ball screw stop 120 to translate with ball screw 106. The ball screw stop 120 may be variously implemented, but is configured to at least selectively engage the housing assembly 112, and more particularly the housing assembly inner surface 114, while the ball screw 106 is translating between the stow position and deploy position. The ball screw stop 120 is additionally configured to engage the ball nut 104 when the ball screw 106 is in the deploy position. The ball screw stop 120, upon engaging the ball nut 104, prevents rotation of the ball nut in one direction, while allowing the rotation of the ball nut in an opposite direction. It will be appreciated that the ball screw stop 120 may be variously configured to implement this functionality. One particular embodiment of the ball screw stop 120 is depicted more clearly in FIG. 4, and with reference thereto will now be described.

The depicted ball screw stop 120 includes a stop structure 302 and a guide structure 304. The stop structure 302 is mounted directly on the ball screw 106, proximate its first end 118, and has a first end 306 (see FIG. 6), a second end 308, and an outer surface 312. The second end 308 has a second dog stop 314 formed thereon. The second dog stop 314 is configured to mate with the first dog stop 214 that is formed on the ball nut 104 when the ball screw stop 120 engages the ball nut 104. The guide structure 304 is mounted directly on, and surrounds at least a portion of, the outer surface 312 of the stop structure 120. As shown even more clearly in FIGS. 5 and 6, the ball screw stop 120 is mounted on the ball screw 106 via a fastener 402 that extends through the stop structure 302, the guide structure 304, and the ball screw 106, and is held in place via a nut 404.

The ball screw stop 120 is configured such that there is a slight gap between the guide structure 304 and the inner surface 114 of the housing assembly 112. Thus, the guide structure 304 will only selectively engage the inner surface 114 while the ball screw 106 is translating and will minimize deflection of the ball screw 106 at the limits of its stroke (i.e., the stow position and deploy position). The first and second dog stops 214, 314, as noted above, will mate and engage each other when the ball screw 106 is moved to the fully deployed position, and will prevent further rotation of the ball nut 104.
between different elements do not imply that a direct physical connection must be made between these elements. For example, two elements may be connected to each other physically, electronically, logically, or in any other manner, through one or more additional elements.

While at least one exemplary embodiment has been presented in the foregoing detailed description of the invention, it should be appreciated that a vast number of variations exist. It should also be appreciated that the exemplary embodiment or exemplary embodiments are only examples, and are not intended to limit the scope, applicability, or configuration of the invention in any way. Rather, the foregoing detailed description will provide those skilled in the art with a convenient road map for implementing an exemplary embodiment without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. An actuator, comprising:
   a housing assembly;
   a ball nut rotationally mounted in the housing assembly, the ball nut adapted to receive an input torque and configured, upon receipt thereof, to rotate and supply a drive force;
   a ball screw mounted within the housing assembly and extending through the ball nut, the ball screw having a first end and a second end, and coupled to receive the drive force from the ball nut, the ball screw configured, upon receipt of the drive force, to selectively translate between a stow position and a deploy position; and
   a ball screw stop mounted on the ball screw to translate therewith, the ball screw stop (i) selectively engaging the housing assembly while the ball screw is translating between the stow position and deploy position, and (ii) engaging the ball nut when the ball screw is in the deploy position,
   wherein the ball screw stop comprises:
   a stop structure having a first end, a second end, and an outer surface;
   a guide structure mounted directly on and surrounding at least a portion of the outer surface of the stop structure, and
   a fastener extending through the stop structure, the guide structure, and the ball screw.

2. The actuator of claim 1, wherein:
   the ball screw comprises a first dog stop formed on a first end thereof; and
   the ball screw stop comprises a second dog stop formed on a second end thereof, the first dog stop and the second dog stop configured to mate when the ball screw stop engages the ball nut.

3. The actuator of claim 2, wherein the ball screw stop, upon engaging the ball nut, prevents rotation of the ball nut in one direction while allowing the rotation of the ball nut in an opposite direction.

4. The actuator of claim 1, wherein:
   the housing assembly includes an inner surface that defines a cavity;
   the ball screw includes a first end and a second end, the first end disposed within the cavity, the second end disposed outside the cavity; and
   the ball screw stop is disposed at least proximate the first end.

5. The actuator of claim 1, wherein the guide structure selectively engages the inner surface of the housing while the ball screw is translating.

6. The actuator of claim 1, further comprising:
   a motor coupled to the ball nut and configured to selectively supply the drive torque thereto.

7. The actuator of claim 6, further comprising:
   a gear set coupled between the motor and the ball nut.

8. An actuator, comprising:
   a housing assembly;
   a ball nut rotationally mounted in the housing assembly and having a first dog stop formed on an end thereof, the ball nut adapted to receive an input torque and configured, upon receipt thereof, to rotate and supply a drive force;
   a motor coupled to the ball nut and configured to selectively supply the drive torque thereto;
   a ball screw mounted within the housing assembly and extending through the ball nut, the ball screw having a first end and a second end, and coupled to receive the drive force from the ball nut, the ball screw configured, upon receipt of the drive force, to selectively translate between a stow position and a deploy position; and
   a ball screw stop mounted on the ball screw to translate therewith and having a second dog stop formed on an end thereof, the ball screw stop configured to at least selectively engage the housing assembly while the ball screw is translating between the stow position and deploy position, the second dog stop configured to mate with and engage the first dog stop when the ball screw is in the deploy position,
   wherein the ball screw stop comprises:
   a stop structure mounted directly on the ball screw, the stop structure having a first end, a second end, and an outer surface;
   a guide structure mounted directly on and surrounding at least a portion of the outer surface of the stop structure, and
   a fastener extending through the stop structure, the guide structure, and the ball screw.

9. The actuator of claim 8, wherein the ball screw stop, upon engaging the ball nut, prevents rotation of the ball nut in one direction while allowing the rotation of the ball nut in an opposite direction.
10. The actuator of claim 8, wherein:
the housing assembly includes an inner surface that defines a cavity;
the ball screw includes a first end and a second end, the first end disposed within the cavity, the second end disposed outside the cavity; and
the ball screw stop is disposed at least proximate the first end.
11. The actuator of claim 8, wherein the guide structure selectively engages the inner surface of the housing while the ball screw is translating.
12. An actuator, comprising:
a housing assembly;
a ball nut rotationally mounted in the housing assembly and having a first dog stop formed on a first end thereof, the ball nut adapted to receive an input torque and configured, upon receipt thereof, to rotate and supply a drive force;
a motor coupled to the ball nut and configured to selectively supply the drive torque thereto;
a ball screw mounted within the housing assembly and extending through the ball nut, the ball screw having a first end and a second end, and coupled to receive the drive force from the ball nut, the ball screw configured, upon receipt of the drive force, to selectively translate between a stow position and a deploy position;
a ball screw stop mounted on the ball screw to translate therewith, the ball screw stop configured to (i) at least selectively engage the housing assembly while the ball screw is translating between the stow position and deploy position and (ii) engage the ball nut when the ball screw is in the deploy position, the ball screw stop comprising:
a stop structure mounted directly on the ball screw, the stop structure having a first end, a second end, and an outer surface,
a guide structure mounted directly on and surrounding at least a portion of the outer surface of the stop structure, and
a fastener extending through the stop structure, the guide structure, and the ball screw.
13. The actuator of claim 12, wherein:
the ball nut comprises a first dog stop formed on a first end thereof; and
the ball screw stop comprises a second dog stop formed on a second end thereof, the first dog stop and the second dog stop configured to mate when the ball screw stop engages the ball nut.
14. The actuator of claim 12, wherein the ball screw stop, upon engaging the ball nut, prevents rotation of the ball nut in one direction while allowing the rotation of the ball nut in an opposite direction.
15. The actuator of claim 12, further comprising:
a gear set coupled between the motor and the ball nut.
16. The actuator of claim 12, wherein:
the housing assembly includes an inner surface that defines a cavity;
the ball screw includes a first end and a second end, the first end disposed within the cavity, the second end disposed outside the cavity;
the ball screw stop is disposed at least proximate the first end; and
the guide structure selectively engages the inner surface of the housing while the ball screw is translating.