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(56) Documents Cited:
EP 1865590 A1 **US 4607180 A**
US 2860266 A **US 20060266146 A1**
US 20050269887 A1

(58) Field of Search:
INT CL **B64C, F16H**
Other: **WPI, EPODOC**

(54) Title of the Invention: **High integrity linear actuator and method of operation**
Abstract Title: **High integrity linear actuator**

(57) A linear actuator 1 comprises first and second casing sections 2,3 which are slidable relative to one another. Inside the casing sections 2,3 there are provided first and second motors 6,16 each of which can drive a screw-threaded rod 4. If one of the motors becomes jammed, the other can drive the rod 4.

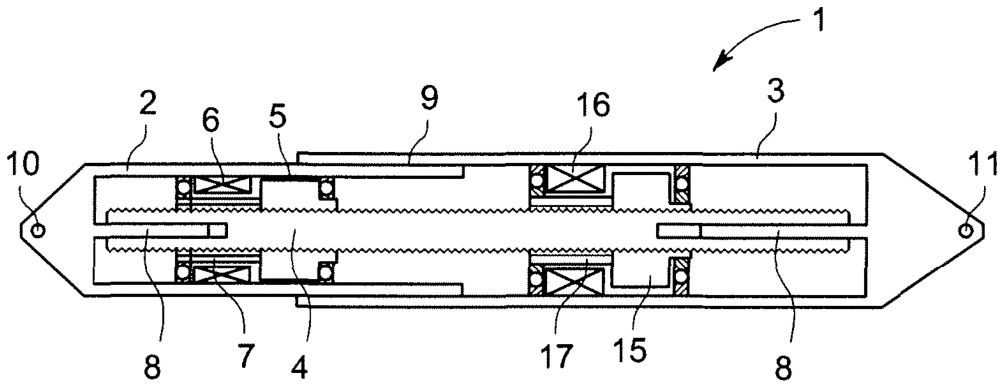

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

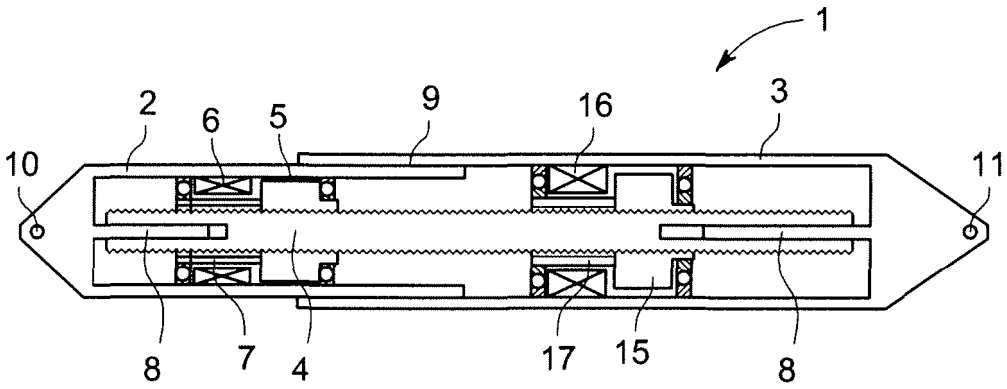

FIG. 1

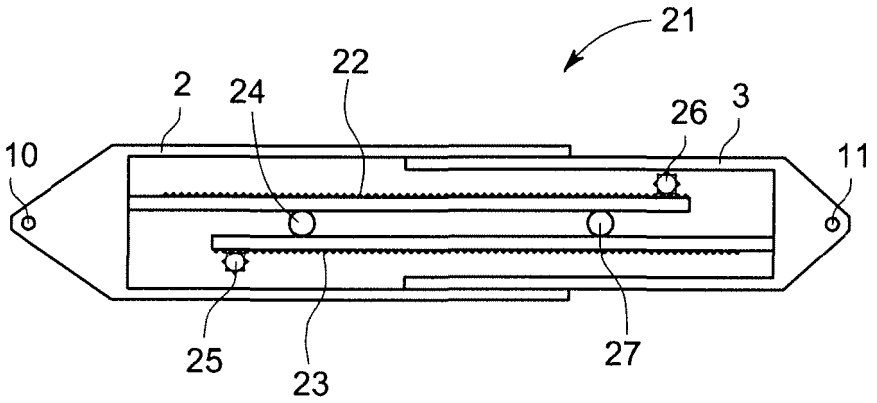

FIG. 2

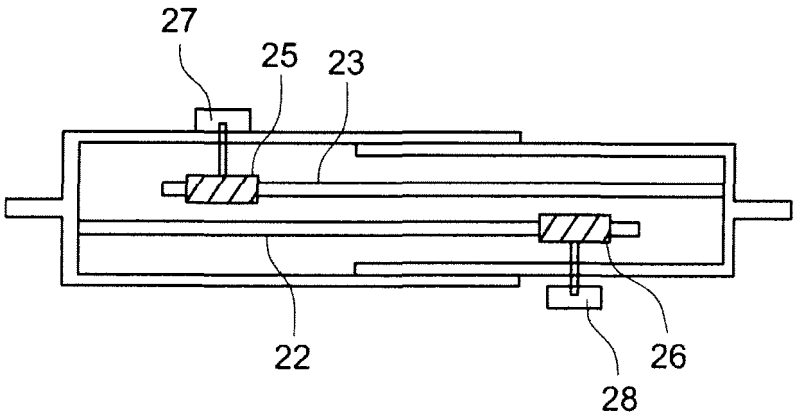

FIG. 3

HIGH INTEGRITY LINEAR ACTUATOR AND METHOD OF OPERATION

The present invention relates to linear actuators and methods of their operation, in particular, the invention relates to linear actuators and methods of their operation that are suitable for use in aircraft.

Actuation of safety critical mechanisms in safety critical systems or equipment needs to achieve a high level of reliability. It is generally known to use hydraulic actuators in aircraft, for example to operate landing gears and/or flaps and ailerons and so on, due to their reliability. Hydraulic system failure is usually caused by leakage of hydraulic fluid, and the system fails to a freely moveable state without jamming. In the case of hydraulically actuated landing gears, this fact allows the gears to be lowered for landing in spite of a system failure.

The utilization of electromechanical actuators is advantageous, because they are light in weight and can be incorporated into an aircraft simply and powered using the electric power distribution system within the aircraft. However, electric motors have a significant seizure failure mode, whereby they tend to fail to a jammed state, preventing backup systems becoming effective.

Aircraft safety regulations require high integrity and invulnerability to single failures for those items of equipment whose failure could lead to catastrophic consequences. Landing gear actuators must meet this criterion and jam vulnerability has prevented electric actuation being used.

Known failure-tolerant linear actuators require two separate actuators each having a disconnect device, wherein in the event of a jam the jammed actuator can be disengaged and the other actuator can be used.

The present invention provides a linear actuator for an aircraft comprising a casing including first and second casing sections, which are extendible and retractable with respect to one another and in which are disposed first and second drive means operable independently of one another to drive one or more transmission elements connected to the interior of the casing sections.

Apart from control and power inputs of the actuator, the actuator is self-contained, ie all of its components are housed within the casing sections, whereby the actuator can be particularly well sealed against environmental ingress, improving the lifetime of the actuator and its internal components. The actuator also has few parts, thus providing a simple and reliable structure of low weight.

The drive means can be concentric with the transmission element or elements. Where a large actuation force is needed, a reduction gearing can be interposed between the drive means and the transmission element.

In one embodiment, the casing sections have a substantially constant cross-section. Advantageously, the linear actuator according to the invention thereby has no projecting parts vulnerable to damage.

Advantageously, the actuator according to the invention is continuously operable in the event of a failure of either of the drive means or jamming of the gear assembly. Further, the gear assembly avoids the use of disconnect clutches, whereby the actuator has a low weight and size and increased reliability.

There follows a detailed description of embodiments of the invention by way of example only and with reference to the accompanying schematic drawings, in which:

Fig. 1 is a cross-sectional view of an actuator according to a first embodiment of the invention;

Fig. 2 is a cross-sectional view of an actuator according to a second embodiment of the invention; and

Fig. 3 is a further cross-sectional view of the second embodiment of the actuator.

Fig. 1 shows a linear actuator 1 comprising a casing including a first casing section 2 and a second casing section 3. The casing sections 2,3 have a region 9 of overlap in which the sections are slidable relative to one another. Inside the first casing section 2 there is provided a first drive means comprising an electric motor including a stator 6 fast with the casing section 2 and a rotor 7 fast with a roller screw 5. The roller screw

5 is journalled in the casing section 2. In operation, the electric motor rotates the roller screw 5 causing a transmission element 4 comprising a screw-threaded rod to move linearly. The motion of the transmission element 4 causes the casing sections 2,3 to slide relative to one another. Each end of the casing has a spline or key 8 upon which the transmission element 4 is splined or keyed to allow relative movement between the casing sections 2,3 even in the event of a jam in one drive means. In the second casing section 3, a second drive means is provided comprising an electric motor including a stator 16 and a rotor 17 which drives a roller screw 15 to move the screw-threaded rod 4. In the event of one of the first and second drive means failing or jamming, the other drive means can drive the actuator. Thus the actuator is immune to single failures. The actuator is symmetrical which helps to prevent twisting loads on the end mountings.

A first end 10 of the actuator can be attached to an aircraft structure such as part of the frame, whilst a second end 11 of the actuator 1 can be connected to the object that is being actuated, e.g. a landing gear.

Fig. 2 shows a second embodiment of the invention wherein like parts are designated by the same reference numerals as before. The actuator 21 comprises first and second casing sections 2,3 which are slidably connected to one another. The transmission elements comprise racks 22,23 which are driven by pinions 25,26. The pinions are connected to respective electric motors 27,28 which are shown in Fig. 3 on the outside of the casing. However, in accordance with the invention, the motors can also be provided inside the casing. Idler gears 24 and 27 are disposed adjacent to each rack 22,23 to support the rack and ensure good driving engagement between the racks and pinions. In the event of a jam affecting one of the racks or pinions and/or one of the electric motors, the actuator can still function by virtue of the others.

Other types of connection between the electric motors and the transmission elements can be used in the present invention without departing from the scope of the claims. For example, roller screws, ball screws, lead screws and rack and pinion arrangements are all usable. Independence of actuation could also be achieved using other forms of electro-magnetic actuation or hydraulics.

In normal operation, the first and second drive means are used alternately, so that the functionality of each drive means is demonstrated with each alternate use. Alternatively, in operation of both the first and second drive means at the same time, the speed of actuation provided by each drive means is added together, whereby the actuator can be operated at double speed if desired.

CLAIMS:

1. A linear actuator for an aircraft comprising a casing including first and second casing sections, which are extendible and retractable with respect to one another and in which are disposed first and second drive means operable independently of one another to drive one or more transmission elements connected to the interior of the casing sections.

2. A linear actuator according to claim 1, wherein the first and second drive means comprise electric motors.

3. A linear actuator according to claim 1 or 2, wherein the casing sections have a substantially constant cross-section.

4. A linear actuator according to any of the preceding claims, wherein the transmission element comprises a screw-threaded rod.

5. A linear actuator according to any of the preceding claims, wherein the drive means drives the screw-threaded rod via a roller screw.

6. A linear actuator according to any of the preceding claims, wherein the screw-threaded rod is splined to the interior of each of the first and second casing sections.

7. A linear actuator according to any of claims 1 to 3, wherein the transmission element comprises a rack which is driven via a pinion.

8. A linear actuator according to any of the preceding claims, wherein the drive means are concentric with the transmission element.

9. A method of operating the linear actuator according to any of the preceding claims, comprising using the first and second drive means alternately with each use of the actuator.

10. A linear actuator substantially as herein described with reference to the accompanying drawings.

11. A method of operating a linear actuator substantially as herein described with reference to the accompanying drawings.

Application No: GB1108483.7 **Examiner:** Mr Hal Young

Claims searched: 1-11 **Date of search:** 30 August 2011

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-11	US4607180 A (GEN DYNAMICS) see fig 1 and column 2 lines 18-43.
X	1-11	US2005/269887 A1 (BOEING) see fig 1 and paragraphs 0007-0008.
X	1-11	US2006/266146 A1 (WAIDE) see figs and paragraphs 0007-0018.
X	1-11	US2860266 A (AMERICAN METAL) see fig.
A		EP1865590 A1 (GOODRICH)

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

B64C; F16H

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
B64C	0013/50	01/01/2006
F16H	0025/24	01/01/2006