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54 **Linear actuator for antenna pointing, particularly suitable for space applications.**

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GB-A- 2 127 624
US-A- 4 652 887
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Description

The invention presented concerns an electromechanical device which is referred to in the following as "linear actuator", in its best application used within a satellite-borne antenna system, achieving fine pointing of an antenna determining by linear displacement of one of its points, rotation of the antenna around a hinge.

The preamble of claim 1 is based on US-A 4 652 887. This prior art discloses an antenna which is pivoted on a mounting about a first axis and is driven by a screw threaded drive member to which it is pivoted about a second axis. The drive member is a screw gear which engages a jack gear pivoted about a third axis, all the axes being parallel. However, in the whole document there is no hint as to the materials used for the screw gear and the jack gear.

GB-A 2 127 624 refers to an antenna mounting system having a reflector 12 which is secured to an end of an arm 14 which is secured at its opposite end by a hinge assembly 16 to a mounting platform 18. By means not shown, the reflector is moveable from a stowed position to its operating position. Obviously, said means not described consists of a linear actuator which may be of the type described in US-A-4 652 887 and in the preamble of claim 1.

It is the object of the invention to provide a linear actuator for space applications, particularly for antenna pointing systems, which is of high accuracy and reliability and guarantees a continuous operation for several years, yet having an extremely low weight.

The actuator according to the invention consists basically (figure 2) of a rotating motor 8, a screw gear 11 connected to the motor shaft, a screw jack 13 connected to the gear to achieve linear motion.

Figure 1 shows how the linear actuator 1 is fitted. It is connected to a supporting arm 2 and it transmits linear motion to a reflector 3 hinged at point 6.

The reflector (or paraboloid) shown in Figure 1 is shown in take-off configuration connected to satellite body 5 by means of frangible connectors 4. Upon completion of the launch phase, the reflector is freed from connectors 4 and by rotating arm 2 around hinge 7, it is moved to its operating configuration.

The innovative aspects of this linear actuator are:
a) kinematic couplings which do not make use of roller bearings, using hard material against soft self lubricating material having low friction and wear characteristic. In particular, adoption of metal for the screw gear and of teflon, or derivatives, for the screw jack.

b) adoption of metal casings for the chassis and parts interconnection by means of soft material, configured so as to achieve geometric invariance with sufficient accuracy with varying temperature, resulting in uniform stress distribution over extended surfaces within the working couplings.

Together with the above dimensioning of screw and jack gears with minimum axial and radial backlash which ensure in all cases total absence of interference on the kinematic couplings.

c) adoption of a passive device to isolate against mechanical stressing at take off.

d) adoption of a preloading system to absorb overall backlash, with further task of providing constant force and of providing and maintaining the kinematic connection closed after releasing and opening of the antenna reflector.

The invention pertains to the electromechanical field, more specifically to that for satellite-borne antenna pointing.

Defective pointing of an antenna invalidates the mission of a telecommunication satellite, making void the scope for which the satellite is placed in orbit.

The pointing mechanism must satisfy high accuracy, reliability, continuous operation for several years, yet have an extremely low weight.

The innovations presented above were introduced to overcome the problems which normally arise in a device for space applications and of great relevance in terms of satellite economics.

The invention is meant to provide an optimum solution to these requirements, in terms of technologies (a and b) of materials use and selection and in terms of actuator design within the satellite system (c and d), achieving essential performance such as isolation at take off and high accuracy during operation.

As regards the mechanical couplings, existing solutions adopt rolling mechanism at the interface between screw and jack gears, using hard materials against hard materials (metals).

Rolling elements are not suitable for the operating cycle required for antenna pointing; metal to metal contact with concentrated loads and limited displacements in both directions over one same area, destroy the lubricating film required between metal parts.

One of the most innovative aspects of this invention, referred to at point a, is the use of hard metal for the screw gear and soft material for the jack (such as teflon or equivalent materials) without the need for any intermediate rolling element.

The following advantages ensue:

- the metal screw acts as a shaping former, while the jack screw adapts to it by expanding its contact area;
- no deformation of the jack screw is required by relative displacement, either large or small;
- no lubricant is required because of the self lubricating properties of teflon;
- the very low friction factor keeps torque required low;
- due to the low friction, low specific load and extended contact area, good dimensional stability and low wear characteristics are achieved.

The innovations at point b are due to the jack

screw soft material. Such material is contained within a metal container which acts as a cage with a sufficiently tight grid to guide the soft material geometry so that the stress on the coupling surfaces with the screw gear is kept uniform. The guiding function of the metal cage reduces to a minimum the thermal expansion of teflon, which is normally high.

Figure 4 shows, for illustrative and not limiting purposes, an example of implementation, where the jack screw includes the metal casing in figure 4, the threaded insert of figure 5 and the insert of figure 6, all made of teflon.

The jack screw configuration provides for axial connection between metal casing and jack screw insert by means of a deep thread with a rectangular profile.

The radial connection is provided by pins, parallel to the jack screw axis, inserted into holes 24 (fig. 5), which cross the metal casing thread and the corresponding thread within the teflon insert.

The radial connection is improved by reducing the circumferential friction of the teflon insert by means of cuts 25 (fig. 5) which partially interrupt the circumferential continuity of the insert itself. This characteristic allows to reduce the radial shrinkage which arises at low temperature.

Noteworthy is the asymmetric partitioning of the thread pitch between thinner metal tooth and thicker teflon tooth, provided for the connecting thread between casing and insert and that between insert and screw gear. This feature provides greater strength of the screw gear - jack gear coupling and improved tooling of metal parts.

No comparisons with previous solutions are made because the screw/jack transmission did not make use of non metal materials.

As regards the innovation at point c previous solutions provide protection from take off stressing by means of parallel connecting structures which absorb greater part of such stresses.

The elimination of these structures requires active devices to free the actuator passing into the operating configuration. Such conventional devices are of great design complexity, high mass and limited reliability.

The proposed solution offers protection against take off loads by keeping the motion transmission gear open at take off and closing it once in operation. Opening is maintained by frangible supports 4 (fig. 1) which determine the position of the paraboloid by connecting it to the satellite body at take off.

Closing of the gear takes place upon freed paraboloid due to the pre-loading system which pushes flange 16, which is part of the paraboloid, against jack gear 13 (fig. 5).

A coaxial guide between flange and jack screw gear follows displacement and an axial end of run stops determines displacement transmission during

operation.

The protective device consists therefore of the coaxial rail with axial end of run stop and of the pre-loading device, which produces the displacement and maintains contact of the axial stop to achieve motion transmission.

The innovative aspect at point d regards the pre-loading system which performs the following functions simultaneously:

F 1 closing and maintenance of the connection for motion transmission as already seen at the point above;

F 2 recovery of backlash throughout the entire transmission;

F 3 compensation to eliminate the force variations due to hinge 6 (fig. 1) which is made of elastic elements.

The preloading system, shown in Fig. 3, consists of a preloaded spring 20, struts 21 and levers 22.

Further to performing additional specific functions F 1 and F 3, this preloading system performs the function of eliminating any backlash, producing further advantages compared to previous solutions:

- less torque required of the motor;
- simplification of the jack screw gear design, which is made in one single section;
- recovery of backlash of the entire kinematic chain.

The invention is now described with illustrative and non limiting purposes with reference to the figures attached.

Figure 1 shows the antenna system configured for take-off, where 1 shows the linear actuator. Also visible are the following:

- 2 antenna supporting arm
- 3 antenna reflector
- 4 frangible supports
- 5 satellite body
- 6 pointing hinge
- 7 unfolding hinge.

Figure 2 shows the linear actuator assembly. It shows:

- 8 rotating motor
- 9 supporting stand
- 10 joint
- 11 screw gear
- 12 end of run mechanical system
- 13 jack screw gear assembly
- 14 rail which prevents rotation of the jack screw gear
- 16 flange
- 17 articulated joint between connecting element and reflector
- 18 reflector connecting element
- 19 connector
- 20 spring
- 21 strut
- 22 lever

(parts 20, 21 and 22 form the preloading system).

Figure 3 shows the schematic outline of the linear actuator and also provides visibility of the kinematic coupling configuration. It shows:

- 8 rotating motor
- 9 supporting stand
- 10 joint
- 11 screw gear
- 13 jack gear
- 14 rail which prevents rotation of the jackgear
- 20 pre-loaded gear
- 21 struts
- 22 levers

(parts 20, 21 and 22 form the preloading system as mentioned for figure 2)

- 26 end of run stop

Figure 4 shows the metal casing of the jack screw gear. It shows the containing structure of the teflon insert which forms the jack screw gear.

Figure 5 shows an enlargement of the teflon insert which forms the jack screw with its internal threading.

Figure 5.1. shows the teflon insert in the same scale as the metal housing, while

Figure 5.2. shows an enlargement of the teflon insert with the internal threading for the kinematic coupling with the screw and the external thread for coupling with the metal casing.

The connection with the metal casing is completed, for radial containment, by holes 24, into which axial metal pins are inserted.

The effectiveness of such locking pins is improved by partial interruption of the circumferential continuity of the teflon insert provided with radial cuts 25.

Figure 6 shows a second teflon insert fitted into the upper part of the metal casing and which, together with the first insert, provides a suitable coaxial rail between screw gear and jack gear.

The linear actuator, subject of this invention, as already mentioned, provides the performance required for space application with simple build, low cost and high reliability.

The invention is summarised as follows :

The linear actuator for antenna pointing, particularly indicated for space-borne satellite antennae according to the invention belongs to the electromechanical field of application related to space borne antennae.

The actuator is adopted by antenna systems on board satellites to achieve R.F. sensing (antenna fine pointing) so that by moving one of its points linearly, rotation of the antenna around a hinge takes place.

The actuator consists essentially (figure 2) of a rotating motor 8, a screw gear 11 connected to the motor shaft, a screw jack 13 coupled to the screw gear to obtain a linear motion. Kinematic couplings are obtained by means of hard materials in contact with soft materials in absence of rolling elements. In

particular, the coupling between screwgear and screwjack consists of a metal screw and teflon (or similar) jack, enclosed in a metal case which provides for guidance and geometric configuration stability even under critical temperature extremes so as to maintain a wide coupling surface with a uniform distribution of stresses. The displacement coupling, with an end of run stop, present between the element firmly connected to antenna reflector 16 and screw jack 13, lets free relative axial displacement during launch, while the pre-loading device ensures that contact with the end of run stop is maintained; all above resulting in movement transmission from actuator to reflector when the latter separates from the satellite body.

The pre-loading device, consisting of parts 20, 21 and 22, finally recovers the backlash of the entire kinematic chain, thus simplifying the screw gear/jack coupling and also achieving a constant pre-load throughout the entire run and a reduction of the reaction torque of the motor.

Claims

1. Linear actuator for space applications, comprising a rotating motor (8), a screw gear (11) connected to the motor shaft, and a jack gear (13) coupled to said screw gear (11), characterised in that the jack gear (13) consists of a metal casing and of an insert of self-lubricating soft material such as teflon or the like, having an internal screw thread, whereas the material of the screw gear (11) is harder than that of the insert.
2. Linear actuator according to claim 1, wherein the screw gear (11) is configured with a thread having a thickness which is half the thread pitch.
3. Linear actuator according to claim 1 or 2, characterised by an asymmetric partitioning of the thread pitch between the thinner metal teeth of the casing and the thicker teeth of the insert and of the thread pitch between the insert and the screw gear (11).
4. Linear actuator according to anyone of the preceding claims, wherein the insert is fixed in the casing of the jack gear (13) by means of pins running parallel to the jack screw axis.
5. Linear actuator according to claim 4, wherein the circumferential continuity of the insert is partially interrupted by radial cuts (25).
6. Linear actuator according to anyone of the preceding claims, wherein a preloading device (20,21,22) is provided between the jack gear (13)

and an antenna reflector (3) or the like.

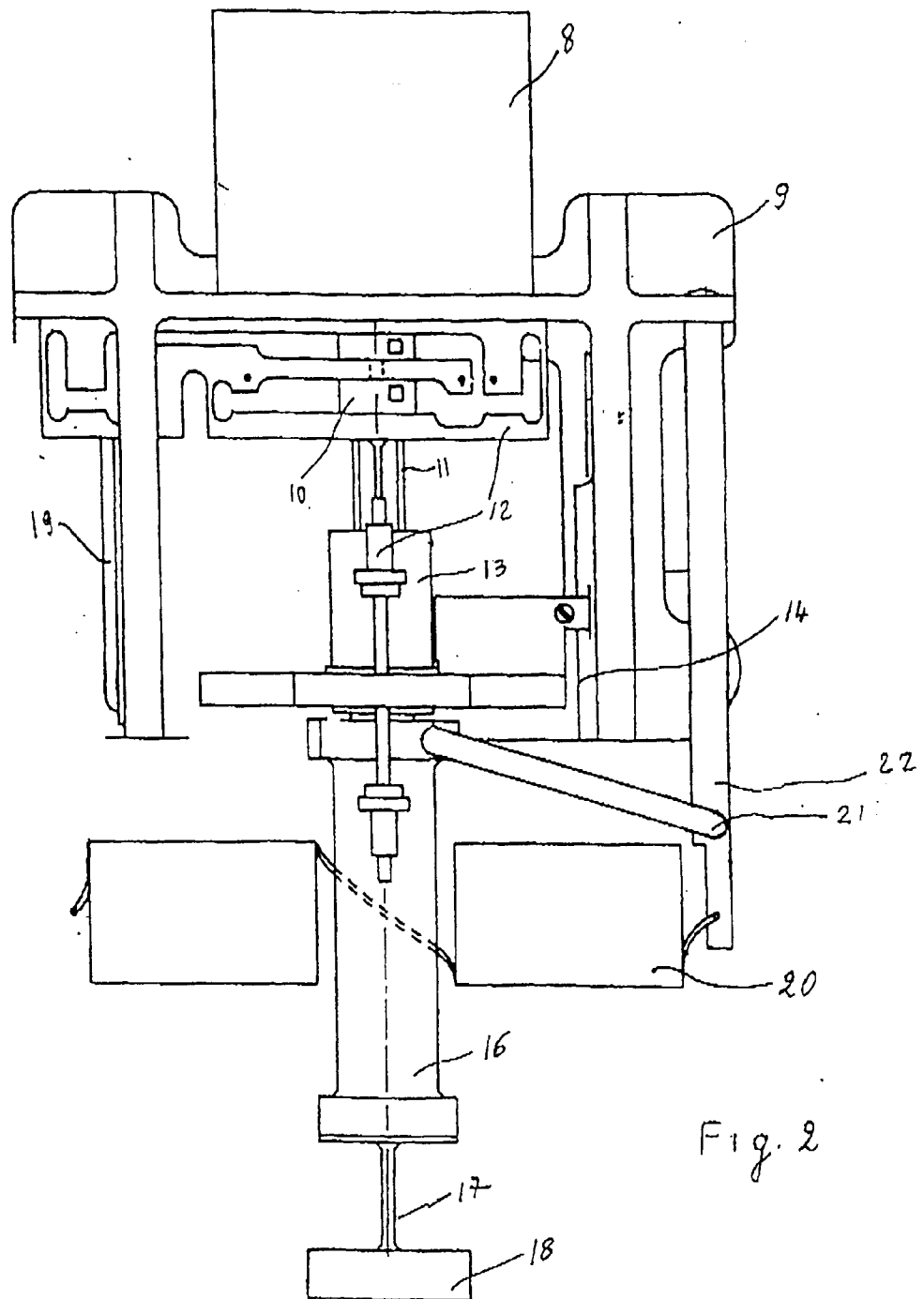
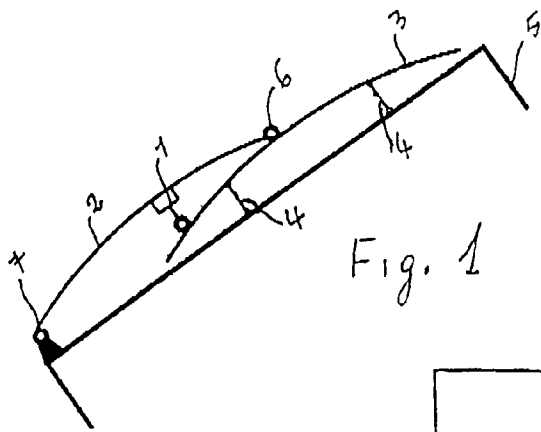
7. Linear actuator according to claim 6, wherein the preloading device comprises a preloaded spring (20) set perpendicularly with respect to the actuator axis by means of struts (21) and levers (22).

Patentansprüche

1. Linearantrieb für Weltraumanwendungen, umfassend einen Drehantriebsmotor (8), eine mit der Motorwelle verbundene Schraubspindel (11), die mit einer Spindelmutter (13) in Eingriff ist, **dadurch gekennzeichnet**, daß die Spindelmutter (13) aus einem Metallgehäuse und einem Einsatz aus weichem, selbstschmierendem Material wie Teflon oder dgl. besteht, der ein Innengewinde aufweist, während das Material der Schraubspindel (11) härter als das des Einsatzes ist.
2. Linearantrieb nach Anspruch 1, **dadurch gekennzeichnet**, daß die Schraubspindel (11) ein Gewinde hat, dessen Dicke kleiner als die Hälfte der Gewindesteigung ist.
3. Linearantrieb nach Anspruch 1 oder 2, **gekennzeichnet durch** eine asymmetrische Verteilung der Gewindesteigung zwischen den dünneren, metallischen Gewindegängen des Gehäuses und den dickeren Gewindegängen des Einsatzes und der Gewindesteigung zwischen dem Einsatz und der Schraubspindel (11).
4. Linearantrieb nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet**, daß der Einsatz im Gehäuse der Spindelmutter (13) durch Stifte befestigt ist, die parallel zur Schraubspindel verlaufen.
5. Linearantrieb nach Anspruch 4, **dadurch gekennzeichnet**, daß der Einsatz an seinem Umfang teilweise durch radiale Einschnitte (25) unterbrochen ist.
6. Linearantrieb nach einem der vorhergehenden Ansprüche, **dadurch gekennzeichnet**, daß zwischen der Spindelmutter (13) und einem Antennenreflektor (3) oder dgl. eine Vorspanneinrichtung (20, 21, 22) angebracht ist.
7. Linearantrieb nach Anspruch 6, **dadurch gekennzeichnet**, daß die Vorspanneinrichtung eine vorgespannte Feder (20) aufweist, die durch Streben (21) und Hebel (22) rechtwinklig zur Achse des Linearantriebs gehalten wird.

Revendications

1. Actionneur linéaire pour applications spatiales, comprenant un moteur rotatif (8), un engrenage à vis (11) relié à l'arbre du moteur, et un vérin à vis (13) associé audit engrenage à vis (11), caractérisé en ce que le vérin à vis (13) se compose d'une enveloppe métallique et d'un élément encastré en matériau doux autolubrifiant, tel que le Téflon ou analogue, ayant un filetage intérieur, tandis que le matériau de l'engrenage à vis (11) est plus dur que celui de l'élément encastré.
2. Actionneur linéaire selon la revendication 1, dans lequel l'engrenage à vis (11) présente un filetage ayant une épaisseur qui représente la moitié du pas de vis.
3. Actionneur linéaire selon la revendication 1 ou 2, caractérisé par une distribution asymétrique du pas de vis entre les dents métalliques plus minces de l'enveloppe et les dents plus épaisses de l'élément encastré et du pas de vis entre l'élément encastré et l'engrenage à vis (11).
4. Actionneur linéaire selon l'une quelconque des revendications précédentes, dans lequel l'élément encastré est fixé dans l'enveloppe du vérin à vis (13) au moyen de goujons s'étendant parallèlement à l'axe de la vis du vérin.
5. Actionneur linéaire selon la revendication 4, dans lequel la continuité circonférentielle de l'élément encastré est partiellement interrompue par des découpes radiales (25).
6. Actionneur linéaire selon l'une quelconque des revendications précédentes, dans lequel il est prévu un dispositif de mise en charge préalable (20, 21, 22) entre le vérin à vis (13) et un réflecteur d'antenne (3) ou analogue.
7. Actionneur linéaire selon la revendication 6, dans lequel le dispositif de mise en charge préalable comprend un ressort précontraint (20) fixé perpendiculairement à l'axe de l'actionneur au moyen de contrefiches (21) et de leviers (22).



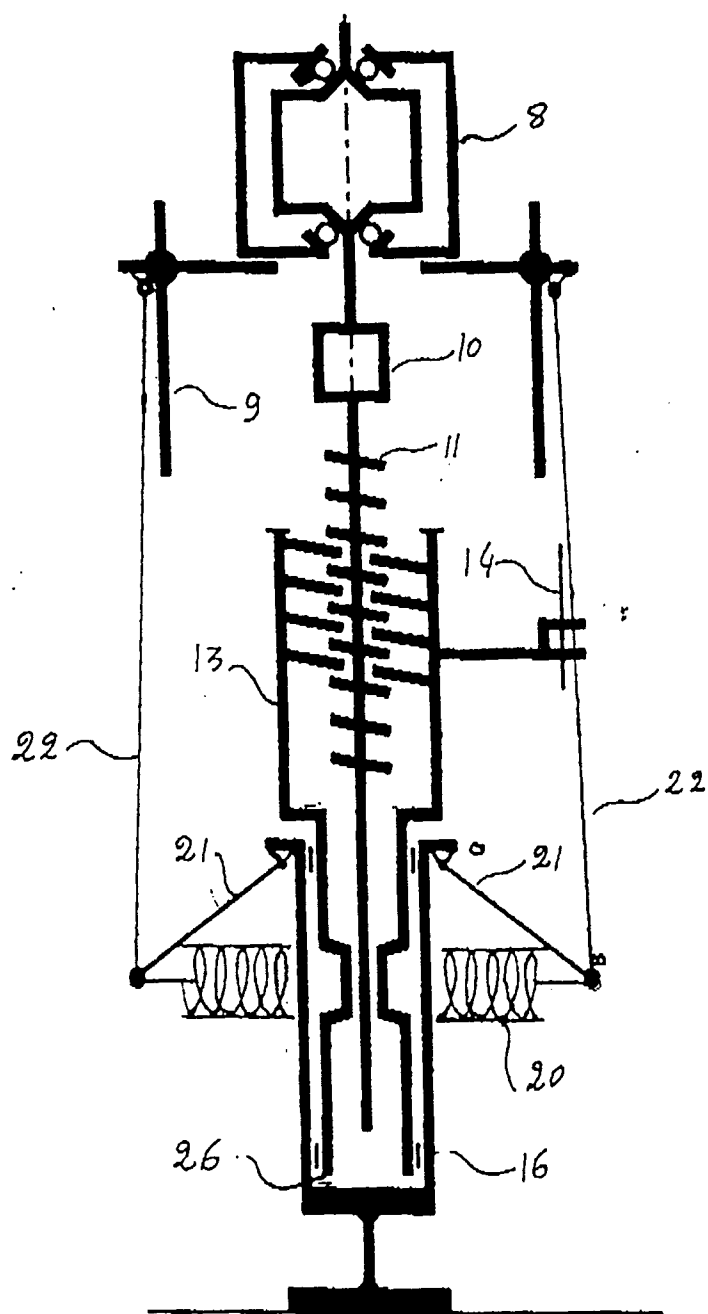


Fig. 3

