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Angle transmission device.

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Angle transmission device

Field of the invention

[0001] The present invention concerns an angle transmission device and a method using said device.

Description of related art

[0001] Angle transmission devices are mechanical devices allowing the transmission of rotation motion between two shafts each shaft rotating around a rotation axis. In most cases, angle transmission devices are right angle transmission devices, where the first and second shaft are perpendicular.

[0002] Worm transmission are one of the known solutions for angle transmission device. A classic worm transmission is showed in figure 1. In this example, the transmission have two main components, the worm 1000 and the gear 2000, in other word a toothed wheel, the helical shaped teeth of the worm 1000 being meshed with the external teeth of the wheel 2000. When the worms 1000 turns, the teeth of the worms slide engage the gear teeth of the gear to drive the rotation of the gear 2000. During motion, there is a continuous sliding of the worm and gear teeth. For this, the transmission requires sustained lubrication for minimizing the friction and reduced wear of the teeth in contact. Lubricant also helps absorbing the heat generated during the continuous sliding of the teeth in contact.

[0003] The gap between the teeth of the worm teeth and the gear teeth depends on the distance between the axes of the worm 1000 and gear 2000. Ideally, the distances between axes is set so that the gap between the teeth is zero. In practice, this perfect condition is impossible to achieve due to misalignment and manufacturing errors or tolerances. In addition, a perfect condition, if any, is impossible to maintain because of the wear of the teeth surfaces in contact in motion. If there is clearance between the teeth, there is backlash between the teeth and the

transmission plays. On the contrary, in case of interference, the friction creates an important wear of the surfaces in contact, the transmission is either blocked or very inefficient. Also, such transmission are generally made with heavy material capable of resisting to wear, but also increasing the inertia forces of the system.

[0004] Alternatively, ball worm transmission are also used for angle transmission. The document US20030115981 describes a ball worm transmission illustrated in figure 2. In such system, balls 3000 are at the interface between the worm 1001 and the gear 2001 to transmit the torque. The balls ensure a higher efficiency than worm transmission. The backlash is also significantly reduced. But ball worm transmission suffers from a poor load capacity because of the few number of balls taking the load during the motion.

[0005] A similar solution is used for steering shafts in vehicles, having as input shaft a ballscrew that drives linearly the nut sub-assembly that has a bushing with a rack. The rack drives in rotation the output shaft.

[0006] There is a need to provide an angle transmission limiting the drawbacks of the existing solutions.

Brief summary of the invention

[0007] According to the invention, these aims are achieved by means of an angle transmission device comprising :

- An input shaft rotating around a first rotation axis and an output shaft rotating around a second rotation axis,

- An assembly arranged for coupling the input shaft with the output shaft so that the output shaft can be rotationally driven by the input shaft, said assembly allowing transforming the rotation of the input shaft around said first rotation axis into the rotation of the output shaft around the second rotation axis;

- the assembly comprising a rotary actuator and a linear mobile, the rotary actuator being coupled with the input shaft and moves the linear mobile in a translation motion relative to the actuator, the linear mobile being coupled with the output shaft so that the rotation of the input shaft drives the rotation of the output shaft;

The device being characterized in that the assembly further comprises a flexible blade fixed to said linear mobile and looped around the output shaft, so that when the actuator moves the linear mobile, the flexible blade drives the rotation of the output shaft.

[0008] The claimed angle transmission device differs from the existing solutions at least in that it comprises a flexible blade that controls the rotation of the output shaft. The blade is fixed to a mobile that cooperates with the input shaft. The rotation of the input shaft moves the mobile in a translation motion: the motion of the mobile drives the motion of the blade that is fixed thereon. The blade is looped around the output shaft, so that said blade is integral with the output shaft.

[0009] The mobile moves in a translation motion along the first rotation axis of the input shaft upon rotation of said input shaft. The translation of the mobile induces the rotation of the output gear that is driven by the flexible blade.

[0010] Advantageously, the blade provides a high efficiency of transmission, in particular a higher efficiency that the existing solutions, whether worm transmission or ball worm transmission that have an efficiency between about 50% and 90%.

[0011] The efficiency of the blade is 100%, or very close to 100%, for instance at least 95%, preferably 98%. Thus, there is no or a negligible lost in transmission between the input shaft and the output shaft, for instance torque or speed lost. This is particularly advantageous for application where there is a small available volume or a limited energy supply, such as

fin and flap actuators, lens and mirror steerers/shifters, portative instruments, etc...

[0012] Worm transmission devices suffer from clearance or interference issues that significantly impact the accuracy of these devices because the worm and wheel teeth are either to close or too far apart. In the claimed angle transmission device, the blade is looped in tension around the output shaft so that there is no interference or clearance issues. On the contrary, there is a continuous contact between the blade and the output shaft, the blade is integral with the output shaft thereby providing an increased accuracy of the angular position of the output shaft.

[0013] The increased angular positioning accuracy is particularly advantageous for applications requiring very specific angular positioning, for example optical devices with lens such as telescope, guiding instruments such as satellites.

[0014] The claimed device is lighter than existing solution for instance worm or worm ball transmission. The inertia force is lower providing an improved performance for high acceleration transmission.

[0015] The claimed invention is also compact, in other word a low footprint. This facilitates the integration of the claimed device in a system or an instrument.

[0016] In worm transmission device, the contact or friction between the worm and wheel teeth induces wear of the contact surfaces. In the present invention, the wheel teeth is replaced by a blade to overcome the wear issues. Therefore, the claimed device has an improved lifetime.

[0017] The blade is made of material with a predetermined fatigue. In particular, the material of the blade is chosen depending on its theoretical fatigue limit so that the stress on the blade is below this fatigue limit. The goal is to provide a blade allowing a high and unlimited number of loading cycles.

[0018] In an embodiment, the rotary actuator comprises a ball screw and the mobile comprises a ball nut, the device comprising a plurality of balls circulating between the ball screw and the ball nut so that the balls transmit the torque between the ball screw to the ball nut to move the ball nut in a linear motion, the rotation of the input shaft drives the ball screw and generates the linear motion of the ball nut that drives the rotation of the output shaft.

[0019] Alternatively, the opposite configuration (described in [0017]) can also be made in another embodiment. When rotating the ball nut sub-assembly, as input shaft, the ball screw becomes the linear mobile, on which will be fixed the flexible blade that drives, in rotation, the output shaft. Such linear motion driving system is called "non-captive" ball screw (or leadscrew) actuator.

[0020] Advantageously, balls circulating between the ball screw and the ball nut allow providing a coupling free from play between the nut and the screw.

[0021] Besides, recirculating balls screw provides a transmission free from lubricant or almost free from lubricant, contrary to the worm transmission where the teeth in contact are typically in a lubricant bath. In particular, ceramic balls can be used for a lubricant free coupling.

[0022] Recirculating ball screw also provides a relevant efficiency for a transmission device, typically above 90 %.

[0023] According to an embodiment, the actuator comprises a lead screw or ball screw and the linear mobile comprises at least a nut or ball nut, the screw being coupled with said nut to move said nut in a linear motion relative to the screw, the rotation of the input shaft drives the screw and generates the linear motion of the nut that drives the rotation of the output shaft. As mentioned previously (see [0019]) screw and nut can be reversed to provide the same result that is transforming a rotational to a linear motion.

[0024] In an embodiment, the linear mobile comprises at least a nut and a housing integral with said nut, the flexible blade being fixed on said housing. Preferably, the nut is a ball nut when the actuator comprises a ball screw. The housing is used to ensure the mechanical link between the nut and the flexible blade.

[0025] According to an embodiment, the rotary actuator comprises a rotary motor, preferably a brushless motor, a DC motor, a stepper motor, a piezo motor or a voice coil.

[0026] In an embodiment, the flexible blade comprises two ends and a loop, said loop being between said two ends, said ends being fixed to the linear mobile.

[0027] In an embodiment, the blade could be replaced by a flexible cable, which could be winded around the said output shaft and fixed on both ends on the said housing.

[0028] According to an embodiment, the device is arranged to be in contact or to have a gap between the flexible blade and the linear mobile. The gap is used to compensate a possible inconstant misalignment. During the linear movement of the mobile, a variable radial force will be applied on the ball screw, through the ball nut and the housing.

[0029] In an embodiment, the flexible blade is made or mainly made of metal. In another embodiment, the flexible blade could also be made or mainly made of composite material or polymer.

[0030] According to an embodiment, the input shaft and/or the output shaft, preferably the input shaft and the output shaft, are mounted on at least one ball bearing and configured to tolerate thermal expansion.

[0031] In an embodiment, the flexible blade allows angular rotation of the output shaft between -1000° and 1000°, preferably between about -

180° and +180°, more preferably between -30° and +30°. Generally, the angular rotation range varies depending on the application :

- Large angular range are used for example in telemetry, turrets for solar panels, radars and telescopes on ground or on satellite.

- Limited angular range are used in lens and mirror angular positioners such for laser welding, cutting and graving applications, ophthalmology, additive manufacturing, fin and flap actuators (fluid deflectors), steering shafts in vehicles, etc...

[0032] According to an embodiment, the flexible blade allows controlling the angular position of the output shaft between a plurality of discrete indexed positions. For instance, the output shaft operates three distinct positions, in other words discrete positions, for instance a first position at X degree, then a second position at Y degree and a final position at Z degree. This could be used for an automation process such as palletization (pick'n place).

[0033] In an embodiment, the flexible blade allows controlling the angular position of the output shaft on an operational range comprised between a first angular position and a second angular position. For instance, the output shaft can operate between a position at X degree and a position ad Y degree, for instance between -50° and + 50°. This could be used for a solar panel or a flap actuator.

[0034] According to an embodiment, the device is a reducer for reducing the torque and/or the speed between the input shaft and the output shaft, preferably with a reduction ratio comprised between 1:1 and 1:20000, more preferably between about 1:1 and 1:2000, in particular between 1:1 and 1:200.

[0035] In an embodiment, the first rotation axis being perpendicular to the second rotation axis. Many applications requires right angle transmission devices, for instance in automotive, machine tools, conveyors,

guillotine doors,.... Right angle means that the angle between the input shaft and the output shaft is equal to 90°. However, the present application is not limited to right angle transmission device.

[0036] According to an embodiment, the device could comprise an adjustment screw to define a precise preload on the flexible blade. This preload will have an impact on the radial force on the ball screw due to the inconstant misalignment.(See [0028]).

[0037] The invention also concerns a method for transforming a rotation around a first axis into a rotation into a second axis, the method using a device according to the invention.

[0038] In the present invention, the terms "the flexible blade fixed on the mobile" refer to a blade mounted on or coupled to the mobile. The blade is integral with the mobile, in other word if the mobile moves, the blade moves, and the motion of the blade correlates with the motion of the mobile.

[0039] In the present invention, the term "housing" designates a component arranged for receiving the nut and for being coupled with the flexible blade. The housing comprises an external surface with a portion opposite the output shaft on which the blade is fixed.

[0040] In the present invention, the term "reducer" refers to a device for reducing the torque and/or between the input shaft and the output shaft. The reducer is in particular a speed reducer for reducing the rotation speed of the output shaft compared to the rotation speed of the input shaft.

[0041] In the present invention, the terms "flexible blade" define a blade made of a material having a flexibility allowing the motion of the mobile relative the output shaft when the blade is looped around said output shaft. The motion of the mobile unwinds a portion of the blade and winds another portion of the blade so that the blade follows the outline of

the output shaft. The blade needs to be made of a flexible material allowing unwinding and winding said blade around the output shaft depending on the motion of the mobile. The terms "blade" or "flexible blade" are synonyms and interchangeable.

[0042] In the present invention, the word "device" designated the "angle transmission device" according to the invention, to simplify the reading of the text.

[0043] In the present invention, the word "mobile" designated the "linear mobile" to simplify the reading of the text.

[0044] The embodiments of the angle transmission device also apply to the method according to the present invention mutatis mutandis.

Brief Description of the Drawings

[0045] The invention will be better understood with the aid of the description of embodiments given by way of example and illustrated by the figures, in which:

Figures 1 and 2 show overviews of angle transmission devices according to the prior art;

Figures 3a,b illustrates the device according to a first embodiment;

Figure 4 illustrates a flexible blade for a device according to the invention;

Figures 5a to c illustrates a device according a second embodiment;

Detailed Description of possible embodiments of the Invention

[0046] Figures 3 to 5 illustrates some embodiments of the present invention but the invention is not limited to the disclosed embodiments.

[0047] Figures 3a,b show a device 1 according to a first embodiment. In particular, figures 3 a,b illustrates the functioning, i.e the concept, of the angle transmission device 1 according to the invention.

[0048] The device 1 comprises an input shaft 2 rotating around a first rotation axis A and an output shaft 3 rotating around a second rotation axis B. In the present embodiment, the first axis A is perpendicular to the second rotation axis B.

[0049] The device further comprises an assembly 4 arranged for coupling the input shaft 2 with the output shaft 3. The assembly 4 allows transforming the rotation of the input shaft 2 around said first rotation axis A into the rotation of the output shaft 3 around the second rotation axis B.

[0050] The assembly 4 comprises a rotary actuator 5 and a linear mobile 6 coupled to said rotary actuator 5. The rotation of the rotary actuator 5 drives the linear mobile 6 in a translation motion. The role of the assembly 4 is to ensure the transmission of the force, i.e. torque force or the speed, between the input shaft 2 and the output shaft 3.

[0051] In the present embodiment, the rotary actuator 5 is a ball screw 7 and the linear mobile 6 comprises two ball nuts 8 received in a housing 9, said nuts 8 being integral with said housing 9, so that when the screw 7 drives the nuts 8, the housing 9 moves accordingly.

[0052] The screw 7 is coupled to the input shaft 2; and the housing 9 is coupled to the output shaft 3.

[0053] Alternatively, the screw is a lead screw coupled to at least a corresponding nut (not represented in figures).

[0054] The assembly 4 further comprises a coupling element for coupling element for transmitting the motion of the mobile 6 to the output shaft 3. In other words, in this example, the coupling element is flexible blade 10 ensuring the transmission of the forces between the mobile 6 and the output shaft 3, and thus between the input shaft 2 and the output shaft 3. The flexible blade 10 is fixed to the housing 9 and looped around the output shaft 3.

[0055] In figure 3a, the device 1 is in an initial position where the input shaft 2 and the output shaft 3 are immobile, i.e. motion less.

[0056] In figure 3b, the screw 7 is rotating. The rotation of the screw 7 drives the nuts 8 and the housing 9 in a linear motion in a direction parallel with the first rotation axis of the axis of the ball screw 7. While the housing 9 is displacing in translation motion, the flexible blade 10, looped around the output shaft 3, drives the rotation of the output shaft 3.

[0057] Figure 4 illustrates an embodiment of a flexible blade 100 that can be used in the claimed device 1,201. The blade 100 is a strip made of 301 stainless steel. In the present embodiment, the strip has 6.5 mm width, 80 mm length, 0.1 mm thick but the invention is not limited to these dimensions. Advantageously, the dimensions are comprised:

- Between 0.5 and 1000mm width;
- Between 1 and 5000mm length;
- Between 0.01 and 2mm thick.

[0058] The flexible blade 100 comprises a flexible ribbon 101 comprising an aperture 102 and a narrow portion 103. The narrow portion 103 is inserted into the aperture 102 to form a loop 104, said loop 104 being designed to circle or loop around the output shaft (not represented in figure 4). The ribbon 103 comprises two ends 105 each equipped with

traversing holes 106 to fix said blade 100 onto the mobile. For instance, the blade 100 is screwed on the mobile via the holes 106.

[0059] Figures 5 a-c show a device 201 according to a second embodiment. The device 201 comprises an input shaft 202 coupled to an output shaft 203 via an assembly 204. Advantageously, the device 201 reducer allowing a reduction ration of 56 between the input shaft 201 and the output shaft 202.

[0060] The device 201 comprises a rotatory actuator 205 and a linear mobile 206:

- The rotatory actuator 205 comprising a ball screw 207;
- The linear mobile 206 comprising two ball nuts 208 received and integral with a housing 209.

[0061] The device 201 is received in a casing 210, for instance a polygonal casing as illustrated in figures 5. The casing 210 comprises a input face 211 and an output face 212 :

- The input face 211 comprising an input window 213 for operating the input shaft 202; for instance for coupling the input shaft 202 with a rotary motor (not represented in figures);
- The output face 212 comprising an output window 214 for operating the output shaft 212; for instance for coupling the output shaft 212 with an instrument and controlling the angular position of instrument, for instance a solar panel, optical devices etc... (not represented in figures);

[0062] The ball screw 207 is mounted on two balls bearings 215. Preferably, the output shaft 203 is also mounted on ball bearing (not represented in figures).

[0063] A flexible blade 216 is fixed to the housing 209. In the present example, the blade 216 is screwed on the housing with four fixing screws 217 after having adjusted the preload force on the flexible blade using the preloading screws. Once the fixation screw are tighten with a given torque and using thread lock glue, the preloading screws can be removed.

[0064] In the present embodiment, the device 201 can adopt three configurations illustrated in figures 5a-c:

- A initial configuration P0 before the rotation of the input shaft 202, shown in figure 5a;
- A first configuration P1 after the rotation of the input shaft with an angle of +α (plus alpha), shown in figure 5b;
- A second configuration P2 after the rotation of the input shaft with an angle of +α (plus alpha) shown in figure 5c;

[0065] The rotation of the input shaft with an angle of +α (plus alpha) moves the mobile in a linear translation so that the flexible blade drives the rotation of the output shaft with an angle of +β (plus beta).

[0066] The rotation of the input shaft with an angle of -α (minus alpha) moves the mobile in a linear translation so that the flexible blade drives the rotation of the output shaft with an angle of -β (minus beta).

[0067] In the present embodiment, the angular position of the output shaft 203 varies on an operational range comprised between a first angular position –β (minus beta) and a second angular position +β (plus beta). The output shaft can adopt any angular position within the interval defined by the first angular position and the second angular position.

[0068] In other embodiment (not illustrated), the device can also be configured to limit the angular positions of the output shaft to a plurality of discrete indexed position X1, X2, Xn. For instance, the output shaft is

either in a position X1 corresponding to an angle beta of X degree, or position X2 corresponding to an angle beta of X degree.

Claims

1. Angle transmission device (1,201) comprising :

- An input shaft (2, 202) rotating around a first rotation axis and an output shaft (3,203) rotating around a second rotation axis,

- An assembly (4, 204) arranged for coupling the input shaft (2,202) with the output shaft (3,203) so that the output shaft (3,203) can be rotationally driven by the input shaft (2,202), said assembly (4,204) allowing transforming the rotation of the input shaft (2,202) around said first rotation axis into the rotation of the output shaft (3,203) around the second rotation axis;

- the assembly (4,204) comprising a rotary actuator (5, 205) and a linear mobile (6,206), the rotary actuator (5,205) being coupled with the input shaft (2,202) and moves the linear mobile (6,206) in a translation motion relative to the actuator (5,205), the linear mobile (6,206) being coupled with the output shaft (3,203) so that the rotation of the input shaft (2,202) drives the rotation of the output shaft (3,203);

the device (1,201) being characterized in that the assembly (4,204) further comprises a flexible blade (10,100,216) fixed to said linear mobile (6,206) and looped around the output shaft (3,203), so that when the actuator (5,205) moves the linear mobile (6,206), the flexible blade (10,100,216) drives the rotation of the output shaft (3,203).

2. Device (1,201) according to claim 1, wherein the rotary actuator (5,205) comprises a ball screw (7,207) and the mobile (6,206) comprises a ball nut (8,208), the device (1,201) comprising a plurality of balls circulating between the ball screw (7,207) and the ball nut (8,208) so that the balls transmit the torque between the ball screw (7,207) to the ball nut (8,208)

to move the ball nut (8,208) in a linear motion, the rotation of the input shaft (2,202) drives the ball screw (7,207) and generates the linear motion of the ball nut (8,208) that drives the rotation of the output shaft (3,203).

3. Device (1,201) according to claim 1, wherein the actuator (5,205) comprises a lead screw and the linear mobile (6,206) comprises at least a nut, the lead screw being coupled with said nut to move said nut in a linear motion relative to the lead screw, the rotation of the input shaft (2,202) drives the lead screw and generates the linear motion of the nut that drives the rotation of the output shaft (3,203).

4. Device (1,201) according to any one of claims 1 to 3, wherein the linear mobile (6,206) comprise at least a nut (8,208) and a housing (9,209) integral with said nut (8,208), the flexible blade (10,100,216) being fixed on said housing (9,209).

5. The device (1,201) according to any one of claims 1 to 4, wherein the rotary actuator (5,205) comprises a rotary motor, preferably a brushless motor, a stepper motor, a piezo motor, a voice coil or a DC motor.

6. Device (1,201) according to any one of claims 1 to 5, wherein the flexible blade (10,100,216) comprises two ends (105) and a loop (104), said loop (104) being between said two ends (105), said ends (105) being fixed to the linear mobile (6,206).

7. Device (1,201) according to any one of claims 1 to 6, wherein the device is arranged to be in contact or to have a gap between the flexible blade (10,100,216) and the linear mobile (6,206).

8. Device (1,201) according to any one of claims 1 to 7, wherein the flexible blade (10,100,216) is made of metal or polymer.

9. Device (1,201) according to any one of claims 1 to 8, wherein the input shaft (2,202) and/or the output shaft (3,203) is mounted on at least one ball bearing (215).

10. Device (1,201) according to any one of claims 1 to 9, wherein the flexible blade (10,100,216) allows angular rotation of the output shaft (2,202) between -1000° and 1000°, preferably between about -180° and +180°, more preferably between -30° and +30°.

11. Device (1,201) according to any one of claims 1 to 10, wherein the flexible blade (10,100,216) allows controlling the angular position of the output shaft (3,203) between a plurality of discrete indexed positions.

12. Device (1,201) according to any one of claims 1 to 11, wherein the flexible blade (10,100,216) allows controlling the angular position of the output shaft (3,203) on an operational range comprised between a first angular position and a second angular position.

13. Device (1,201) according to any one of claims 1 to 12, wherein the device is a reducer for reducing the torque and/or the speed between the input shaft (2,202) and the output shaft (3,203), preferably with a reduction ratio comprised between 1:1 and 1:20000, more preferably between about 1:1 and 1:2000, in particular between 1:1 and 1:200.

14. Device (1,201) according to any one of claims 1 to 13, wherein the first rotation axis being perpendicular to the second rotation axis.

15. Method for transforming a rotation around a first axis into a rotation into a second axis, the method using a device (1,201) according any one of claims 1 to 14.

Abstract

The present invention concerns angle transmission device comprising :

- An input shaft and an output shaft,
- An assembly arranged for coupling the input shaft with the output shaft so that the output shaft can be rotationally driven by the input shaft,
- the assembly comprising a rotary actuator and a linear mobile, the rotary actuator being coupled with the input shaft and moves the mobile in a translation motion relative to the actuator, the mobile being coupled with the output shaft so that the rotation of the input shaft drives the rotation of the output shaft;
- the assembly further comprises a flexible blade fixed to said mobile and looped around the output shaft, so that when the actuator moves the mobile, the flexible blade drives the rotation of the output shaft.

The invention also comprises a method using said device.

(Fig. 1)

PRIOR ART

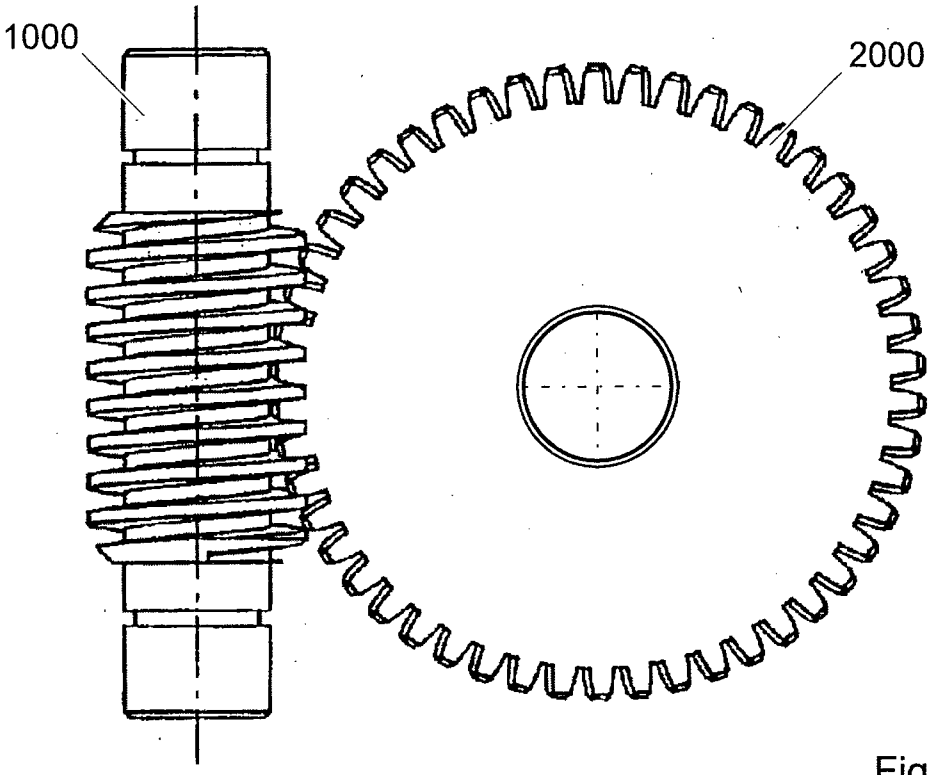

Fig. 1

PRIOR ART

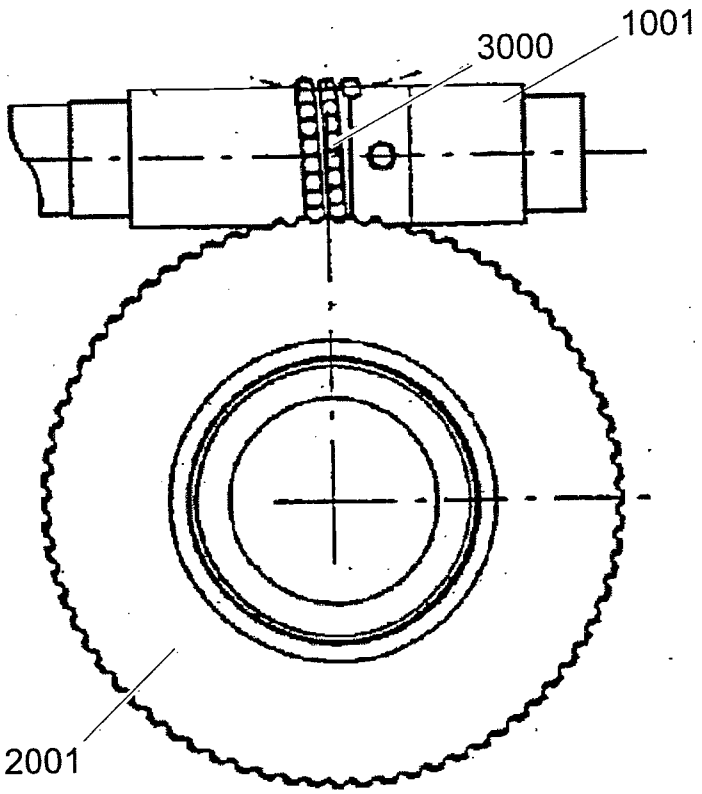

Fig. 2

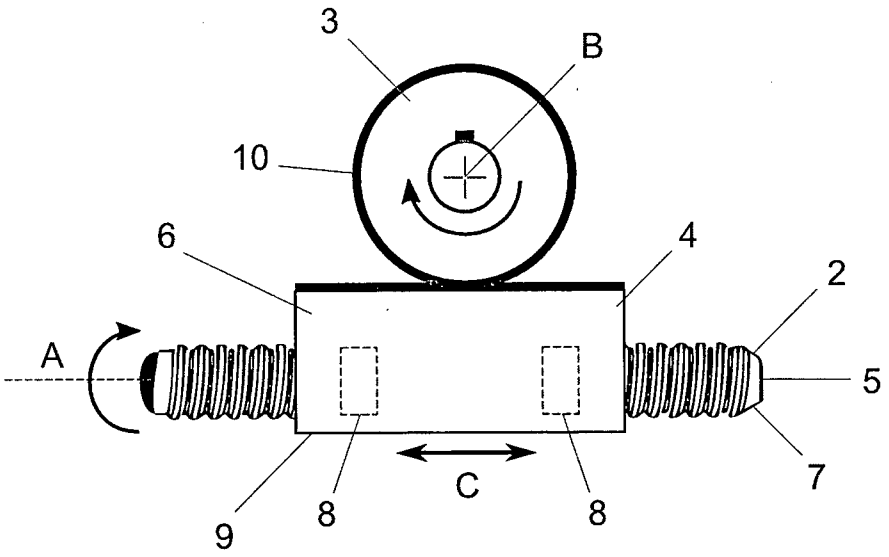

Fig. 3a

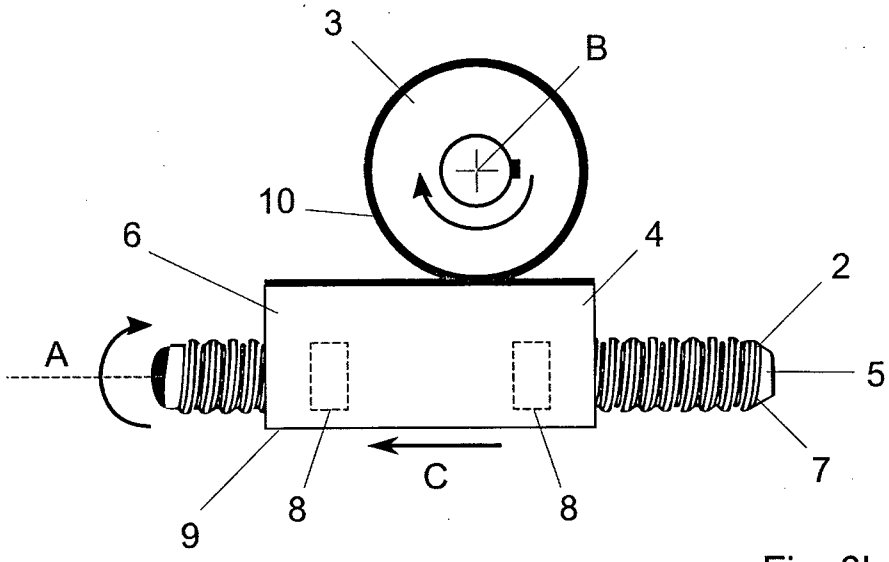

Fig. 3b

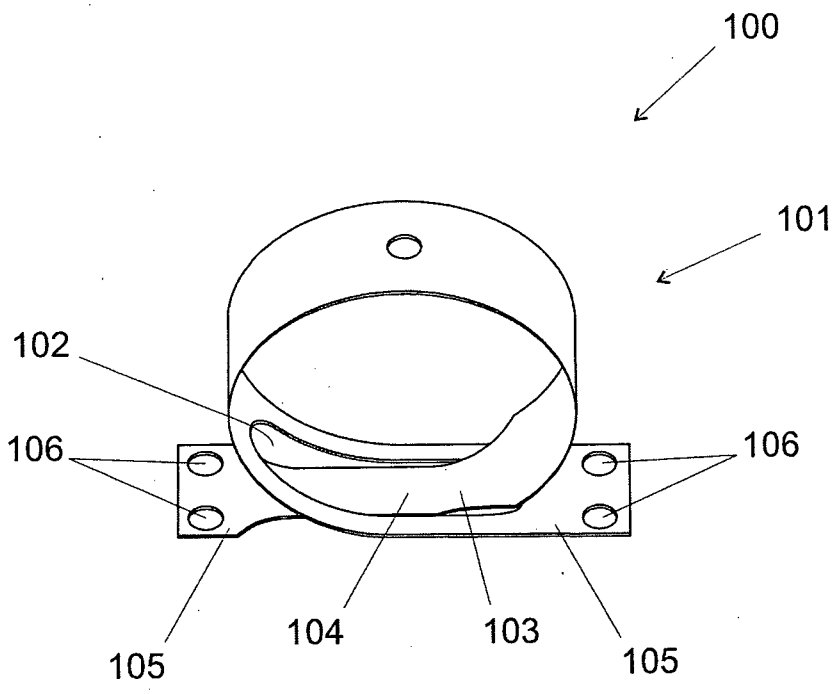

Fig. 4

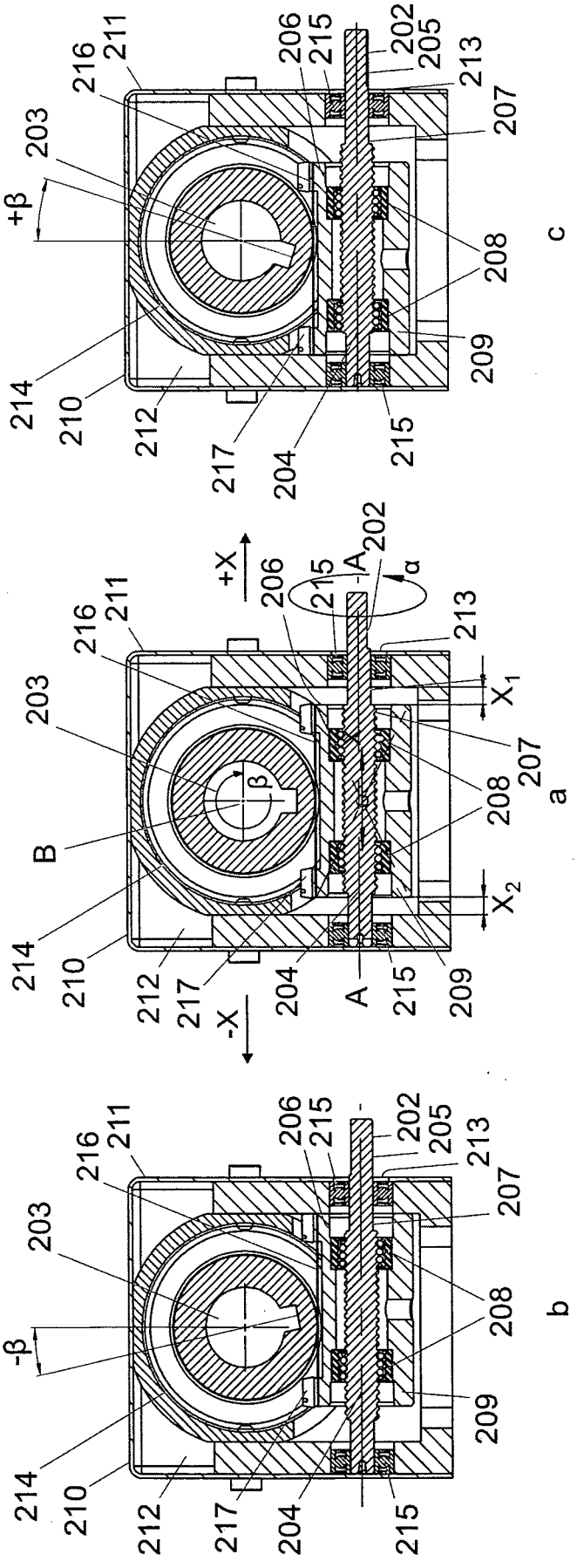

Fig. 5