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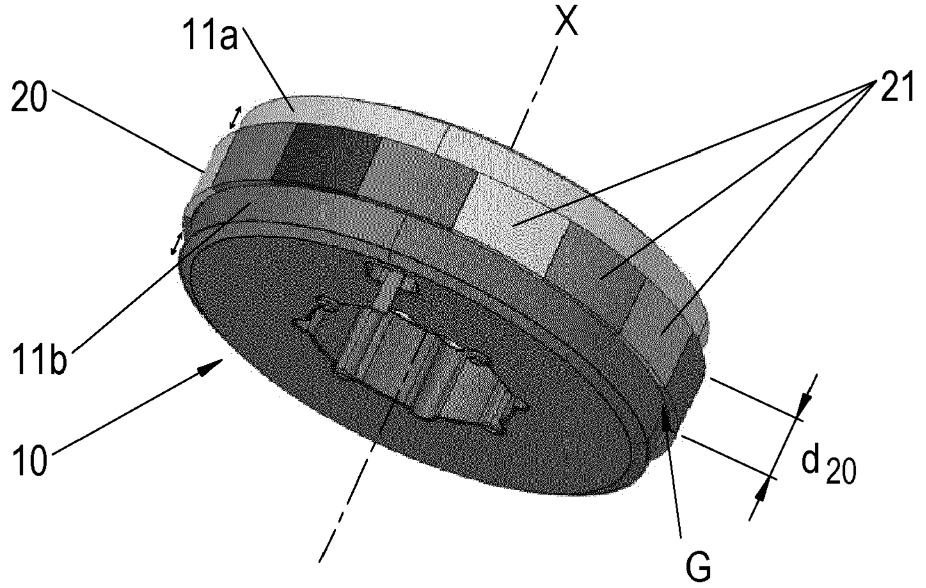
(54) LINEAR ACTUATOR, COMPRESSOR, PUMP, AND HOUSEHOLD APPLIANCE

(57) Disclosed is a linear actuator 1 comprising a stator 10, an annular yoke 30, and an annular magnet component 20. The stator 10 comprises two annular iron core elements 11a, 11b and a solenoid coil 12 having a common centre axis X, wherein the iron core elements 11a, 11b are spaced apart from each other. The annular yoke 30 is assembled coaxial to and radially outwards of the iron core elements 11a, 11b. The annular magnet component 20 comprises a plurality of radially oriented permanent magnet segments 21 and is collocated radially between the stator 10 and the annular yoke 30 so as to be movable in axial direction.

Further disclosed are a pump and a compressor respectively comprising such linear actuator 1, and a household appliance comprising such pump and/or such compressor.

Fig. 1b:



EP 4 571 107 A1

Description

[0001] The present invention concerns a linear actuator, a compressor comprising such linear actuator, a pump comprising such linear actuator, and a household appliance including such compressor and/or pump.

[0002] Linear actuators are machine components which produce a usually reciprocating linear motion from energy, in particular from electrical input supplied thereto. In particular, they may be included in compressors and/or pumps as those integrated in household appliances, for example.

[0003] From US 2020/0260628 A1, a linear compressor is known which comprises a piston configured to linearly reciprocate in a cylinder so as to compress a refrigerant. For driving the motion, the compressor comprises an inner and an outer stator arranged with an interspace in-between, and a permanent magnet connected to the piston and positioned in the interspace. Mutual electromagnetic force between the permanent magnet, the inner stator, and the outer stator causes a linear motion of the permanent magnet and, therewith, of the piston connected thereto.

[0004] US 2020/0395836 A1 discloses a compressor having a linear motor comprising an outer stator, an inner stator, and a mover which is located between the outer and the inner stator and coupled to a piston. The outer stator includes a plurality of laminated blocks, on which a coil is wound. Two magnets are coupled to the inner stator.

[0005] It is an object of the present invention to provide an improved linear actuator, an improved compressor, an improved pump, and an improved household appliance.

[0006] The object is achieved by a linear actuator according to claim 1, by a compressor according to claim 6, by a pump according to claim 7, and by a household appliance according to claim 8. Advantageous embodiments are disclosed in the dependent claims, in the description, and in the drawings.

[0007] A linear actuator according to the present invention comprises a stator, an annular (in particular, cylindric) magnet component, and an annular (in particular, cylindric) yoke.

[0008] The stator comprises two annular (in particular, cylindric) iron core elements and a solenoid coil which are arranged about a common centre axis (thus, coaxial to each other). Therein, the iron core elements are spaced apart from each other in axial direction, i.e., an annular interspace is formed axially between the iron core elements; as is to be noted, if not explicitly noted otherwise, in this document, the terms "axial", "coaxial", "radial", "circumferential", and their derivatives relate to said common centre axis.

[0009] In particular, (with respect to said centre axis) the iron core elements are preferably arranged at least partially radially outwards of the solenoid coil (e.g., so as to surround at least a portion of the solenoid coil), and/or said annular interspace may surround at least a part of the solenoid coil. In advantageous embodiments, the iron core elements have the same diameter or even are equally shaped. In particular, one or both of the iron core elements may be formed as a cylindric piece of a pipe.

[0010] The annular yoke of the linear actuator according to the present invention is arranged coaxial to the iron core elements and radially outwards thereof. It may preferably have an axial extension which is equal to or larger than an axial extension of the stator. In particular, it may ensheathe (thus, surround) both annular iron core elements thereof. Preferably, the annular yoke is arranged stationary relative to the stator.

[0011] The annular magnet component comprises a plurality of radially oriented permanent magnet segments. It resides between the stator and the annular yoke and is movable relative to them in axial direction. In particular, the annular magnet component is arranged in a circumferential gap between the stator and the annular yoke. Preferably, the annular magnet component is coaxial to the annular yoke (and therewith, also to the annular iron core elements).

[0012] In this way, the linear actuator according to the present invention is configured to generate an alternating magnetic flux in response to alternately poled electric power input to the solenoid coil. In particular, a magnetic circuit thus is at least partially formed by the stator, the annular magnet component, and the annular yoke providing permeability paths for the magnetic flux. As a consequence, the annular magnet component is caused to linearly reciprocate relative to the stator (and to the annular yoke). Therein, the annular shape and the arrangement of the iron core components cause the generation of magnetic flux in a full circumferential area, such that an increased efficiency and electromagnetic force of the linear actuator can be achieved. Moreover, due to the reduced number of its components, the linear actuator according to the present invention advantageously has a reduced complexity and an improved resilience, and it requires a reduced assembling effort when it is manufactured.

[0013] According to advantageous embodiments, the iron core elements are made of a soft magnetic composite. Such soft magnetic composite material comprising isolated particles provides for reduction of iron losses and, thereby, further increases efficiency of the linear actuator.

[0014] The coil may preferably be wound on a bobbin which in particular may be made of plastics. Thereby, an assembling effort is further reduced when the linear actuator is manufactured, in particular, as the completed solenoid coil and the annular iron core elements can be easily combined to each other.

[0015] According to advantageous embodiments, an axial extension of one or both of the iron core elements may preferably be equal to or larger than an axial extension of the annular interspace there-between. Additionally or alternatively, an axial extension of the annular magnetic component may preferably be smaller than an axial extension of the stator, preferably even smaller than a half of the axial extension of the stator. By such dimensions, a magnetic circuit being particularly advantageous with regard to the efficiency and electromagnetic force of the linear actuator can be established.

[0016] The linear actuator according to the present invention may further comprise a piston which may be connected (e.g., by means of an inflexible connection component possibly further comprised by the linear actuator) to the annular magnet component. Alternatively, the linear actuator may further comprise a cylinder component connected (e.g., by means of an inflexible connection component possibly further comprised by the linear actuator) to the annular magnet component. Accordingly, in these embodiments, when the annular magnet component is linearly reciprocating in axial direction relative to the stator and to the annular yoke, so is the piston or cylinder component, respectively. The thus moving piston and/or the thus moving cylinder component may thus serve to vary the volume of a chamber, such as to compress a gas contained therein, or to pump a fluid into a desired path, as respectively detailed below.

[0017] A compressor according to the present invention comprises a housing and a linear actuator according to an embodiment of the present invention, the stator and the annular yoke of which are fixed (stationary) to the housing. Therein, the linear actuator is preferably configured to vary a volume of a compression chamber formed by the compressor.

[0018] Likewise, a pump according to the present invention comprises a housing and a linear actuator according to an embodiment of the present invention, the stator and the annular yoke of which are fixed (stationary) to the housing.

[0019] The annular magnet component of the linear actuator comprised by such compressor or pump, respectively, may advantageously be (rigidly) connected to a piston or to a cylinder component as mentioned above.

[0020] In the former case, i.e., if the annular magnet component is connected to a piston, the compressor or pump, respectively, may preferably further comprise a cylinder component which encompasses the piston and which is arranged stationary relative to the housing. Accordingly, in such embodiments, the piston is linearly movable within the cylinder component.

[0021] If, however, the annular magnet component is connected to a cylinder component, the compressor or pump, respectively, may preferably further comprise a piston which is encompassed by the cylinder component and which is arranged stationary relative to the housing. Accordingly, in such embodiments, the cylinder component is linearly movable around the immobile piston arranged therein. Such embodiments facilitate a particularly compact construction of the compressor or pump.

[0022] A household appliance according to the present invention comprises a compressor and/or a pump respectively in accordance with an embodiment of the present invention. The household appliance in particular may be a major appliance such as a washing machine, a tumble drier, a dishwater, a refrigerator, or a freezer.

[0023] In what follows, an exemplary embodiment of the present invention is explained with respect to the accompanying drawings. As is to be understood, the various elements and components are depicted as examples only, may be facultative and/or combined in a manner different than that depicted. Reference signs for related elements are used comprehensively and not defined again for each figure.

[0024] Shown is schematically in

Fig. 1a: a stator of an exemplary embodiment of a linear actuator according to the present invention;

Fig. 1b: the stator of Figure 1a with the annular magnet component assembled around the stator; and

Fig. 1c: the stator of Figures 1a, 1b with the annular yoke of the linear actuator assembled around.

[0025] The successive Figures 1a - 1c illustrate steps of installation of the components of a linear actuator 1 according to the present invention.

[0026] Therein, Figure 1a depicts a stator 10 of the linear actuator in perspective view. The stator 10 comprises two annular iron core elements 11a, 11b and a solenoid coil 12 which are arranged about a common centre axis X. Therein, the solenoid coil 12 is wound on a bobbin 13 which preferably is made of plastics. The iron core elements 11a, 11b are arranged radially outwards (with respect to the centre axis X) of the solenoid coil 12 which thus is partially surrounded by the iron core elements 11a, 11b. Preferably, at least one or both of the iron core elements 11a, 11b are made of soft magnetic composite (not visible in the figures).

[0027] In axial direction, the iron core elements 11a, 11b are separated from each other by an annular interspace I which surrounds a part of the solenoid coil 12. As a consequence, in Figure 1a, the solenoid coil 12 is visible through the interspace I. In particular, the iron core elements 11a, 11b are spaced apart from each other in axial direction.

[0028] In the embodiment shown, the iron core elements 11a, 11b are equally shaped, both forming a cylindric piece of a pipe whose edge which respectively faces away from the interspace is chamfered.

[0029] In particular, an axial extension d_{11a} of iron core element 11a is equal to an axial extension d_{11b} of iron core element 11b, and each of the axial extensions d_{11a}, d_{11b} is larger than an axial extension d_I of the interspace I.

[0030] In Figure 1b, the stator 10 is shown with an annular magnet component 20 arranged coaxial to the stator 10, with a circumferential gap G in-between, such that the annular magnet component 20 is radially spaced apart from the stator 10. As a consequence, the annular magnet component 20 can move, relative to the stator 10, in axial direction, as indicated by the double arrows and detailed below.

[0031] In the situation shown in Figure 1b, the annular magnet component 20 surrounds the interspace I and a respective part of each of the iron core elements 11a, 11b. Its axial extension d_{20} is larger than than the axial extension d_I of the interspace I and also thant the axial extensions d_{11a}, d_{11b} of the iron core elements 11a, 11b.

[0032] The annular magnet component 20 comprises plurality of permanent magnet segments 21 which are radially oriented (not visible in the figures), only three of which are referenced in Figure 1b.

[0033] Figure 1c depicts the linear actuator 1 with an annular yoke 30 assembled around the stator 10, with the annular magnet component 20 residing in-between. Therein, the annular yoke 30 encompasses both iron core elements 11a, 11b and the annular magnet component 20. In particular, an axial extension d_{30} of the annular yoke is larger than an axial extension d_{10} of the stator (referenced in Figure 1a), such that in the perspective of Figure 1c, the iron core element 11a and the annular magnet component 20 are hidden by the annular yoke 30. The annular yoke 30 is radially spaced away from the annular magnet component 20 (not visible in the figures), such that the annular magnet component can freely move, in axial direction, between the stator 10 and the yoke 30.

[0034] The linear actuator 1 assembled in this manner thus forms a magnetic circuit. Accordingly, in response to alternating electrical input, as realised by connection of the solenoid coil 12 to an electric power source and varying a current direction (not shown in the figures), an alternating magnetic flux is generated which produces a linearly reciprocating motion of the annular magnet component 20 between the stator 10 and the annular yoke 30, and in axial direction as indicated, in Figure 1b, by double arrows.

[0035] Accordingly, when a component part such as a piston or a cylinder component is connected (not shown) to the annular magnet component 20, such as by means of a connection component, said component part can be moved, along with the annular magnet component 20. In particular, the linear actuator 1 may be integrated into a compressor or pump and thus serve to drive a compression or pump action thereof.

[0036] Disclosed is a linear actuator 1 comprising a stator 10, an annular yoke 30, and an annular magnet component 20. The stator 10 comprises two annular iron core elements 11a, 11b and a solenoid coil 12 having a common centre axis X, wherein the iron core elements 11a, 11b are spaced apart from each other. The annular yoke 30 is assembled coaxial to and radially outwards of the iron core elements 11a, 11b. The annular magnet component 20 comprises a plurality of radially oriented permanent magnet segments 21 and is collocated radially between the stator 10 and the annular yoke 30 so as to be movable in axial direction.

[0037] Further disclosed are a pump and a compressor respectively comprising such linear actuator 1, and a household appliance comprising such pump and/or such compressor.

Reference signs

[0038]

1	linear actuator
10	stator
11a, 11b	annular iron core element
12	coil
13	bobbin
20	annular magnet component
21	permanent magnet segments
30	annular yoke
d_{10}	axial extension of stator 10
d_{11a}	axial extension of annular iron core element 11a
d_{11b}	axial extension of annular iron core element 11b
d_{20}	axial extension of annular magnet component 20
d_{30}	axial extension of annular yoke 30
d_I	axial extension of interspace I
I	interspace
X	centre axis

Claims

1. Linear actuator (1) comprising a stator (10), an annular yoke (30), and an annular magnet component (20), wherein

   - the stator (10) comprises two annular iron core elements (11a, 11b) and a solenoid coil (12) having a common centre axis (X), wherein the iron core elements (11a, 11b) are spaced apart from each other in axial direction,
   - the annular yoke (30) is assembled coaxial to and radially outwards of the iron core elements (11a, 11b); and
   - the annular magnet component (20) comprises a plurality of radially oriented permanent magnet segments (21) and is collocated radially between the stator (10) and the annular yoke (30) so as to be movable in axial direction.

2. Linear actuator according to claim 1, wherein the iron core elements (11a, 11b) are made of a soft magnetic composite.

3. Linear actuator according to one of claims 1 or 2, wherein the coil (12) is wound on a plastic bobbin (13).

4. Linear actuator according to one of the preceding claims, wherein the annular yoke (30) is arranged so as to encompass both annular iron core elements (11a, 11b).

5. Linear actuator according to one of the preceding claims, further comprising a piston or a cylinder component respectively connected to the annular magnet component (20).

6. Compressor comprising a housing and a linear actuator (1) according to one of the preceding claims, wherein the stator (10) and the annular yoke (30) of the linear actuator are fixed to the housing.

7. Pump comprising a housing and a linear actuator (1) according to one of the preceding claims, wherein the stator (10) and the annular yoke (30) of the linear actuator are fixed to the housing.

8. Household appliance comprising a compressor according to claim 6 and/or a pump according to claim 7.

9. Household appliance according to claim 8 which is a washing machine, a tumble drier, a dishwater, a refrigerator, or a freezer.

Fig. 1a:

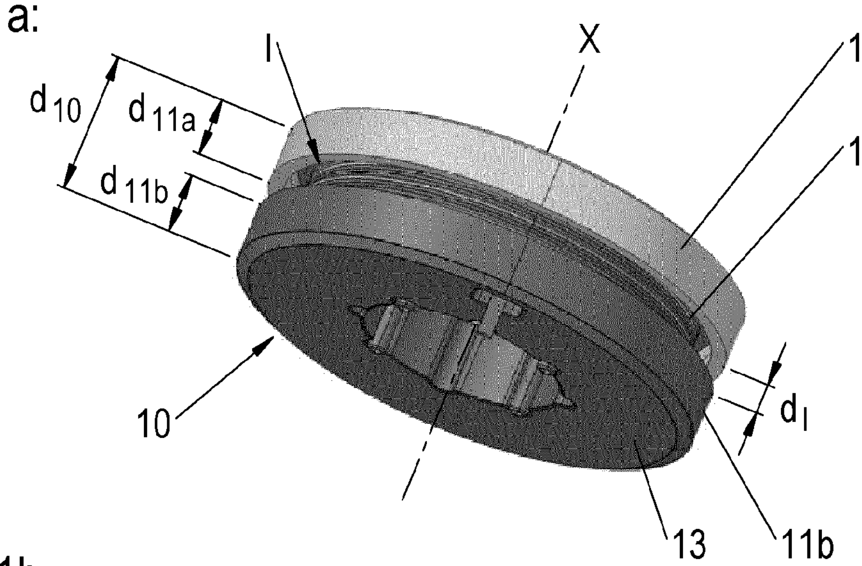


Fig. 1b:

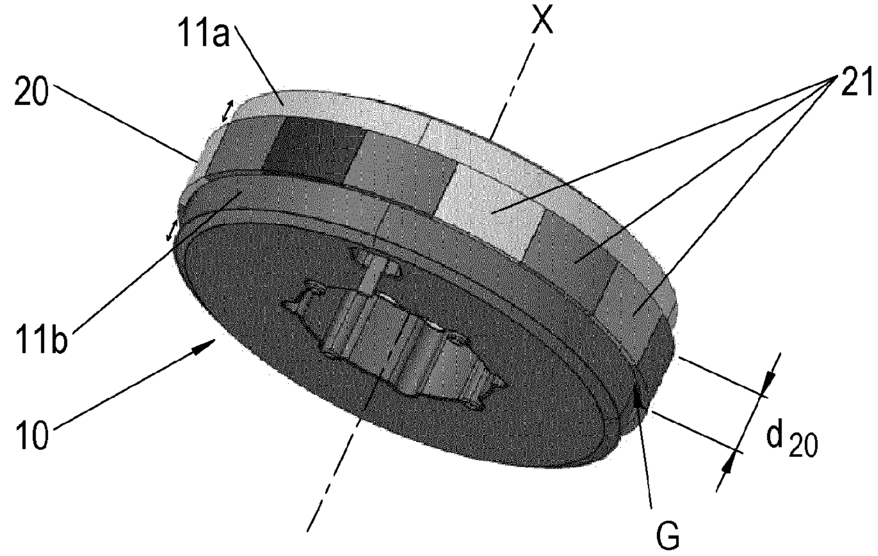
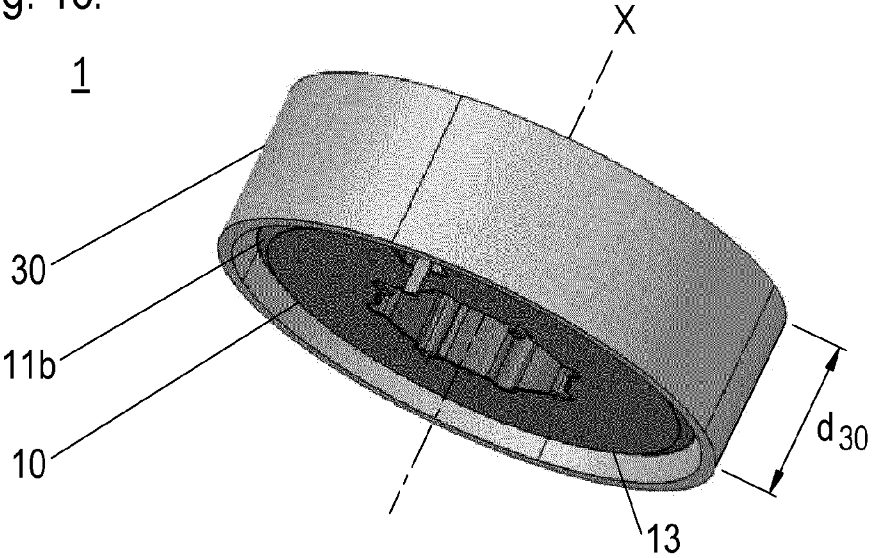


Fig. 1c:



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EUROPEAN SEARCH REPORT

Application Number
EP 23 21 6498

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A	US 5 945 748 A (PARK JUNG SIK [KR] ET AL) 31 August 1999 (1999-08-31) * column 4, line 45 - column 5, line 13 * * figure 13 *	1-9	TECHNICAL FIELDS SEARCHED (IPC) F04B

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
Munich	28 May 2024	Lange, Christian

CATEGORY OF CITED DOCUMENTS

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