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(54) **LINEAR COMPRESSOR WITH PRELOADED SPRING PISTON ROD, AND REFRIGERATING MACHINE**

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(57) **ABSTRACT**

A linear compressor including a piston housing, a compressor piston movable in a reciprocating manner along an axis within the piston housing, a drive mechanism for driving the reciprocating movement, a linkage for connecting the compressor piston to the drive mechanism, and a helical spring operable within the linkage.

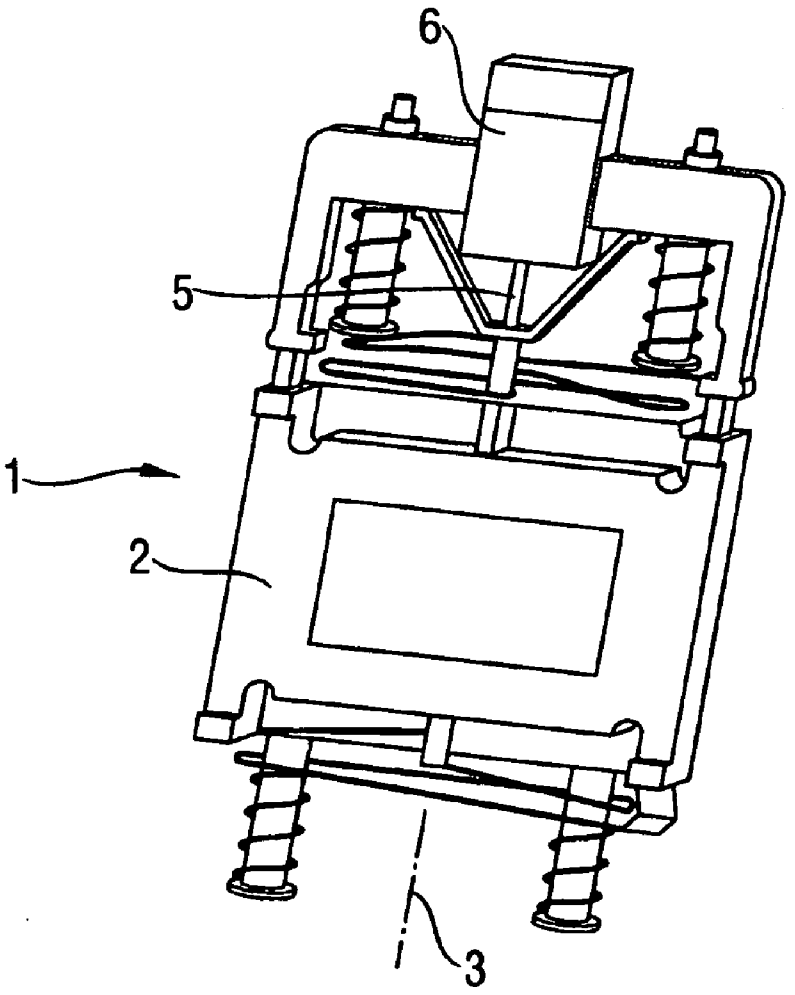


Fig. 1

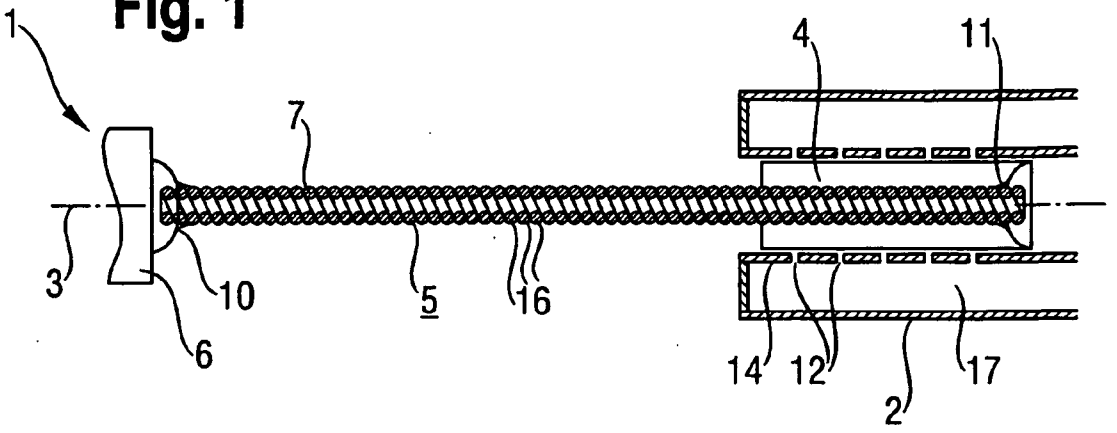


Fig. 2

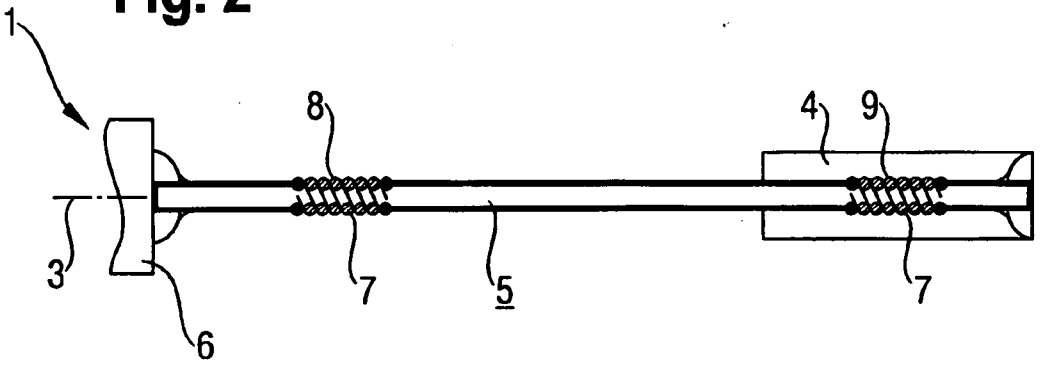


Fig. 3

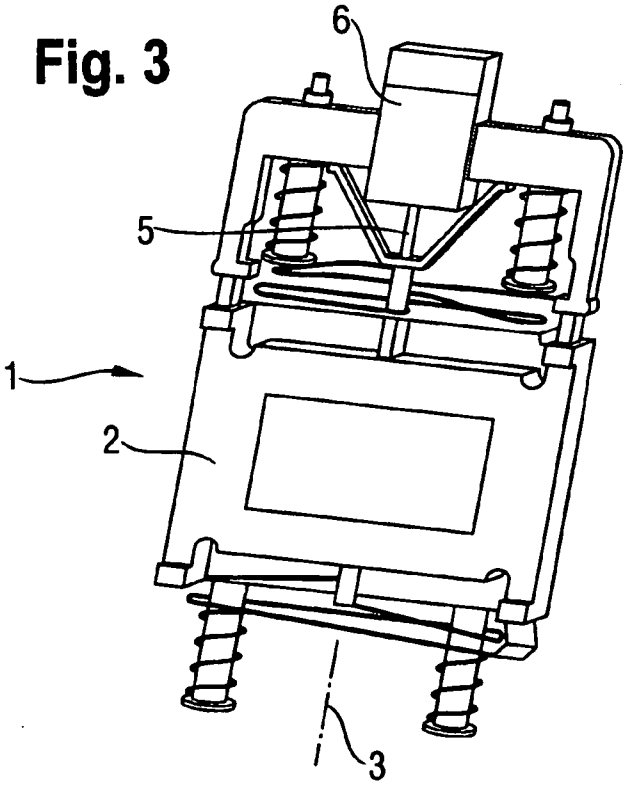
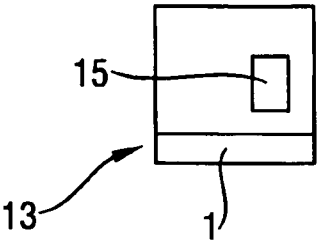


Fig. 4



LINEAR COMPRESSOR WITH PRELOADED SPRING PISTON ROD, AND REFRIGERATING MACHINE

[0001] The invention relates to a linear compressor comprising a piston housing and a compressor piston movable in a reciprocating manner therein, wherein the compressor piston is connected via a linkage to a drive for the reciprocal movement, a refrigerating machine and a method for cooling or freezing a product.

[0002] It is known how to support and guide a compressor piston in the case of oil-free linear compressors, using a cushion of coolant in gaseous form which streams through micro-openings through a housing wall of a piston housing inward to the compressor piston. To maintain the gas pressure bearing effected by the cushion, a continuous feed of gas is necessary, because otherwise the compressor piston comes into contact with the housing wall, which produces friction and thus leads to wear of the linear compressor. It follows from DE 695.26 217 T2 that, especially in the case of gas pressure bearings, touching of the piston and the cylinder should be avoided in the working state, to minimize the friction and hence the wear of the linear compressor.

[0003] In order to keep the consumption of gas as small as possible and to extend the service life of the linear compressor, for a linear compressor, in particular one with a gas pressure bearing of such a type, the transmission of the linear movement of the linear drive to the piston by a piston rod must be as free as possible of transverse forces.

[0004] The piston rod known from DE 695 26 217 T2 provides a sprung bar or a tube, by which forces are transmitted. However, a simple tube or a simple sprung bar is not adequate to provide the necessary combination of low transverse rigidity, to absorb the unwanted transverse forces, and high axial rigidity for the transmission of a working stroke. For this reason, known solutions provide special bar-shaped spring elements having two narrow points which serve as bending points and ensure the lowest possible transverse rigidity.

[0005] A disadvantage of the known solutions is that, because of the thin bending points, the probability of buckling is comparatively high, even during normal operation. It is consequently necessary to develop a separate specially adapted piston rod for each application situation, i.e. for each compressor variant, so that the sensitive balance between transverse and axial rigidity can be maintained as required by the design. Over and above this, an attachment of the piston rod to the piston and to the linear drive is expensive, due to the small diameter of the narrow points.

[0006] The solution known from DE 695 26 217 T2 has too low axial rigidity. This can result in loss of performance and disturbances during operation, so that under some circumstances the linear compressor works less efficiently and less reliably.

[0007] It is therefore the object of the present invention to specify a linear compressor or a refrigerating machine in which it is possible to realize a coupling, of the compressor piston to a drive, which is axially rigid but pliant against transverse forces. A further object is to specify a method of cooling or freezing a product which works reliably, with a high efficiency, and is in a position to cool goods down rapidly and efficiently.

[0008] These objects are achieved according to the invention by the linear compressor, by the refrigerating machine and by the method, as specified in the independent claims. Further advantageous embodiments and developments which can each be applied individually or in any desired combination, are the subject of the relevant dependent claims.

[0009] The linear compressor according to the invention incorporates a piston housing and a compressor piston which can move reciprocally along an axis within the housing, wherein the compressor piston is connected via a linkage to a drive for the reciprocal movement, wherein the linkage has a preloaded spring, in particular a helical spring.

[0010] The linkage can be formed by one or more piston rods. Several piston rods can be joined together in parallel and/or in series with each other.

[0011] The linear compressor can be oil-free. In particular, it has a gas pressure bearing by which the compressor piston is located in the piston housing without making contact during the reciprocal movement.

[0012] The linkage for transmitting a force from the drive to the compression piston has a preloaded spring, i.e. a spring which does not change in length until a prescribed threshold is exceeded for a level of force.

[0013] The spring can be manufactured from a metal, in particular steel, or even from plastics or composite materials. In particular, it is possible to use fiber-reinforced springs, such as for example carbon-, glass- or polyaramide-fiber reinforced springs.

[0014] It is advantageous if the spring is a close-coiled helical spring, i.e. neighboring turns touch each other, wherein it is advantageous if the surfaces of neighboring turns lie against each other under pressure. With a spring of this type, a prescribed threshold of force, that is a certain prescribed amount of force, must be exceeded to separate the neighboring turns of the spring from each other. A compression force which is greater than zero can be exerted between two turns of the spring, along the contact area.

[0015] With a linkage of this type, it is possible to take up comparatively large axial forces, while comparatively small transverse forces can be gently cushioned. If the spring is close coiled, then a compression force in the longitudinal direction can be taken up by the side surfaces of the turns lying against each other, so that a high longitudinal rigidity is achieved. With a preloaded spring, a high longitudinal rigidity is achieved by the preloading. However, comparatively small transverse forces can be absorbed and balanced out as a result of a lever effect. Due to this lever effect, and the possibility that a turn can unilaterally lift off the turn adjacent to it, the spring is very pliant in the transverse direction.

[0016] Due to the preloading, forces in the longitudinal direction lead to less destabilization of the spring in the transverse direction than is the case with known piston rods.

[0017] It is advantageous if the preloading of the spring is greater than any tensile stress which can be created in the linkage by the drive. This ensures that the spring is not further compressed or stretched, as applicable, so that a hard coupling is effected between the drive and the compression piston. In particular, this ensures that the linkage does not become an inherently oscillatory system because of the spring.

[0018] In a special form of embodiment the linkage has, at each of at least two sections, a preloaded spring. However, it is especially preferred that the linkage as such is formed by the spring. By this means, a coupling is effected which is

especially pliant in the transverse direction, which can absorb the most diverse modes of oscillation, in particular S-shaped deformations of the linkage.

[0019] In a particularly advantageous embodiment of the invention the linkage is screwed, in particular by a section of spring, to the drive and/or the compressor piston. In particular, due to the particular geometry of a close-coiled helical spring, there is the possibility of implementing the connection between the compressor piston and the drive in each case as a screwed connection, by using the turns at the ends of the helical spring as a thread, which is more reliable and more cost-effective by comparison with the known attachment techniques, by gluing or clamping.

[0020] The ratio of axial to transverse rigidity for the spring or the linkage according to the invention, as applicable, is at least 20:1, in particular at least 50:1, preferably at least 200:1. Due to its construction, the linkage described has a particularly good ratio of axial to transverse rigidity. Consequently the same component can be used for different linear compressors, in particular linear compressors with different power levels, e.g. 40 Watt, 80 Watt, 120 Watt or 160 Watt. Special modification of the linkage for the linear compressor type concerned is no longer necessary. This further reduces the manufacturing costs of the linear compressor.

[0021] In an advantageous embodiment of the invention, the compressor piston is guided in the piston housing by means of a housing wall which has openings and a gaseous fluid, in particular a coolant, which streams through the openings.

[0022] All in all, it is possible with the linear compressor according to the invention to realize reliable operation with a high efficiency. Power losses due to a piston rod which is excessively pliant in the longitudinal direction are avoided. Also avoided are power losses due to skewing of the compressor piston in the piston housing because of excessive rigidity of the piston rod or buckling of the piston rod at a narrow point. Overall, the wear on the linear compressor is thus reduced, and the susceptibility of the linear compressor to faults is further reduced.

[0023] The refrigerating machine according to the invention, in particular a refrigerator and/or freezer or an air conditioning system for vehicles, incorporates the linear compressor according to the invention. The advantageous characteristics of the linear compressor according to the invention thus carry over to the refrigerating machine, and thus permit an especially reliable, as well as energy-saving, operation of the refrigerating machine which extends the application possibilities of the refrigerating machine, particularly in relation to mobile application areas.

[0024] The method according to the invention for cooling or freezing a product incorporates the refrigerating machine according to the invention. Due to the high reliability together with the high efficiency of the refrigerating machine, especially reliable and energy-saving cooling or freezing of a product is possible. This makes possible especially rapid and cost-effective cooling or freezing of a product.

[0025] Further particular advantages or details are explained in more detail by reference to the following drawing, which is not intended to restrict the invention but merely to illustrate it by examples. Shown in schematic form are:

[0026] FIG. **1** a cross-sectional view of a linear compressor according to the invention,

[0027] FIG. **2** a cross-sectional view of a section of another linear compressor according to the invention,

[0028] FIG. **3** a perspective view of a linear compressor according to the invention, and

[0029] FIG. **4** a refrigerating machine according to the invention.

[0030] FIG. **1** shows a longitudinal section through a linear compressor **1** according to the invention, with a compressor piston **4**, which has a'drive **6** and a linkage **5**, for connecting the compressor piston **4** with the drive **6**, within a housing wall **14** which has openings **12** through which fluid streams to provide a bearing. The linkage **5** which takes the form of a piston rod is formed by a close-coiled helical spring **7** which is subject to preloading. The preloading amounts to some 5 to 50 Newtons, i.e. at least 5 to 50 Newtons must be applied to the linkage **5** in its axial direction to separate neighboring turns **16** from each other. Due to the lever effect however, only 0.14 to 1.4 Newtons are necessary in the transverse direction with the leverage shown here to effect the lifting of one turn off its neighboring turn. The compressor piston **4** moves reciprocally along an axis **3** in the housing wall **14**, which is in the form of a cylindrical sleeve. The bearing for the piston **4** is effected with the help of a fluid **17**, which flows between the housing wall **14** and the piston housing **2** and through the openings **12**. The fluid stream forms a gas cushion, so that a gas pressure bearing is created.

[0031] FIG. **2** shows a longitudinal section through a section of another linear compressor **1** according to the invention, wherein the linkage **5** is tubular in form and on a first section **8** and on a second section **9** are arranged close-coiled preloaded springs. The two sections **8**, **9** permit bending of the linkage **5** in these regions, and thus an especially low transverse rigidity.

[0032] FIG. **3** shows a perspective view of a linear compressor **1** according to the invention, with a drive **6**, a piston housing **2**, wherein a compressor piston (not shown) is driven by the drive **6** with the help of a linkage **5**.

[0033] The compression pressure is 9 to 10 bar. The mass of the compressor piston **6** is 50 g. The working frequency is somewhat below 50 Hz. The stroke of the compressor piston is about 20 mm and the volume which is compressed is from 1 to 9 cm^3.

[0034] FIG. **4** shows the refrigerating machine **13** according to the invention, with the linear compressor **1** according to the invention and goods **15** which are being cooled. Especially reliable, rapid and energy saving cooling of the goods **15** is made possible by the high reliability and high efficiency of the linear compressor **1** according to the invention.

[0035] The invention relates to a linear compressor **1** comprising a piston housing **2** and a compressor piston **4** movable in a reciprocating manner therein along an axis **3**, wherein the compressor piston **4** is connected via a linkage **5** to a drive **6** for the reciprocating movement, wherein the linkage **5** has a preloaded spring **7**, together with a refrigerating machine and a method of cooling or freezing a product comprising the linear compressor **1** according to the invention. The invention is distinguished by the fact that, on account of the type of construction of the preloaded spring, an especially good ratio of axial to transverse rigidity of the coupling between drive **6** and compressor piston **4** can be achieved and therefore one and the same component can be used for various linear compressors having different output stages. This reduces not only the variance in the piston rods but also the number of fastening parts at the piston and the drive ends.

LIST OF REFERENCE CHARACTERS

[0036] **1** Linear compressor

[0037] **2** Piston housing

[0038] **3** Axis
[0039] **4** Compressor piston
[0040] **5** Linkage
[0041] **6** Drive
[0042] **7** (Helical) spring
[0043] **8** First section
[0044] **9** Second section
[0045] **10** First section of spring
[0046] **11** Second section of spring
[0047] **12** Openings
[0048] **13** Refrigerating machine
[0049] **14** Housing wall
[0050] **15** Goods
[0051] **16** Turns
[0052] **17** Fluid

1-10. (canceled)

11. A linear compressor comprising:
a piston housing;
a compressor piston movable in a reciprocating manner along an axis within the piston housing;
a drive mechanism that drives the reciprocating movement;
a linkage that connects the compressor piston to the drive mechanism; and
a helical spring within the linkage.

12. The linear compressor according to claim **11**, wherein the spring is a close coiled helical spring.

13. The linear compressor according to claim **11**, wherein the preloading of the spring is greater than any tensile stress which can be produced in the linkage by the drive mechanism.

14. The linear compressor according to claim **11**, wherein a preloaded spring is at each of two sections of the linkage.

15. The linear compressor according to claim **11**, wherein the linkage comprises the spring.

16. The linear compressor according to claim **11**, wherein a section of the linkage with a section of spring has a screwed fixing the linkage to one of the drive mechanism and the compressor piston.

17. The linear compressor according to claim **11**, wherein the ratio of axial to transverse rigidity for the spring is at least 20:1, in particular at least 50:1, preferably at least 200:1.

18. The linear compressor according to claim **11**, wherein the compressor piston is guided in the piston housing by a housing wall which has openings and a coolant, which enters the housing through the openings.

19. A refrigerating machine including one of a refrigerator, a freezer and an air conditioning system with the refrigerating machine comprising:
a linear compressor including a piston housing;
a compressor piston movable in a reciprocating manner along an axis within the piston housing;
a drive mechanism for driving the reciprocating movement;
a linkage that connects the compressor piston to the drive mechanism; and
a helical spring within the linkage.

20. A method for cooling or freezing a product by the use of a refrigerating machine, the method comprising:
providing a refrigerating machine having:
a linear compressor including a piston housing;
a compressor piston movable in a reciprocating manner along an axis within the piston housing;
a drive mechanism that drives the reciprocating movement;
a linkage that connects the compressor piston to the drive mechanism; and
a helical spring within the linkage, and
exposing the product to the atmosphere within the refrigerating machine for a predetermined time duration.

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