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(54) Motor-compressor unit.

(57) A motor-compressor unit comprising a vibration motor having two or more coils around a stator core (1), parallel to which is arranged a magnet (3,4) with a stator part (2A,2B) above it, one of the poles of this magnet being directed to the core and circularly bent air gaps being present between the stator core and the stator part, while slide elements (7,8,9,10) of an armature (11,12) traverse in these air gaps a part of an arc of a circle and the armature is rotatable about a motor shaft (13), this armature (11,12) being coupled with a piston body (16) linearly movable in a cylinder (17), which piston body (16) can vary with one side the volume of a compression space (21) with inlet and outlet valves and can vary with its other side the volume of a gas spring space (24), the gas spring space (24) being solely provided with an inlet valve (23), which adjoins the same medium supply as the inlet valve (19) of the compression space (21) and at nominal power and nominal delivery pressure and suction pressure the volume of the gas spring space (24) exceeds that of the compression space (21) by such an amount that the spring stiffness of the gas in the gas spring space (24) is equal to the spring stiffness of the gas in the compression space (21), while the piston body (16) performs during operation a vibration about a central position corresponding to the central position of the armature (11,12).

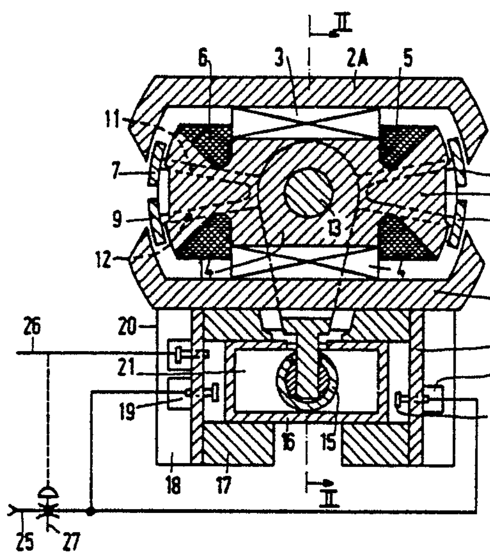

FIG. 1

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Motor-compressor unit.

The invention relates to a motor-compressor unit comprising a vibration motor having two or more coils around a stator core, parallel to which is arranged a magnet with a stator part above it, one of the poles of said magnet being directed to the core and circularly bent air gaps being present between the stator core and the stator part, while slide elements of an armature traverse in said air gaps a part of an arc of a circle and the armature is rotatable about a motor shaft, which is coupled with a piston body linearly movable in a cylinder, which piston body can vary with one side the volume of a compression space with inlet and outlet valves and can vary with its other side the volume of a gas spring space.

A motor-compressor unit of the kind described above is known from EP A 0155057. In this motor-compressor unit, the vibrating rotary movement of the armature is converted by means of a transmission into a linear reciprocating movement of the piston-shaped body. Such a motor-compressor unit forms a mass spring system, in which the springs are formed by the gas pressures on either side of the piston body and the mass is formed by the mass of the piston body and by the masses of the moving parts of the motor.

The present invention has for its object to provide a motor-compressor unit of the kind described having an optimum efficiency. The invention is based on the recognition of the fact that one of the requirements for an optimum efficiency is that the piston-shaped body performs a reciprocating movement about a central position, which corresponds approximately to the central position of the armature of the motor.

In order to achieve this object, the motor-compressor unit according to the invention is characterized in that the gas spring space is solely provided with an inlet valve, which is connected to the same medium supply as the inlet valve of the compression space, while at nominal power and nominal delivery pressure and suction pressure the volume of the gas spring space exceeds the volume of the compression space by such an amount that the spring stiffness of the gas in the gas spring space is equal to the spring stiffness of the gas in the compression space and the piston body performs during operation a vibration about a central position corresponding to the central position of the armature. Thus, a motor-compressor unit is obtained which in the nominal operating conditions has an optimum efficiency. Some deviation from the nominal operating conditions will result in only a small displacement of the central position of the moving piston so that even in this case a reasonable efficiency is guaranteed. The influence of any leakage of gas along the piston from the gas spring space to the suction space can be compensated for by drawing gas along the inlet valve so that a stable situation is obtained for the piston-shaped body.

If now the motor is driven at a frequency corresponding to the natural frequency of the mass spring system, an optimum situation with respect to effeciency is obtained. However, in practice both the delivery pressure and the suction pressure will vary when the motor-compressor unit is used, for example, in a refrigerating system. The spring stiffness of the gas in the compression space and in the gas spring space strongly depends upon the delivery pressure and suction pressure so that the natural frequency of the system will also vary with varying delivery pressure and suction pressure. Without any control the maximum efficiency will then consequently be rarely attained.

It is possible to adapt by means of an electronic control the frequency at which the motor is operated to the varied natural frequency of the system.

However, it has been found that it is also possible by manipulation of suction pressure and delivery pressure to act upon the spring stiffness of the gas in the compression space and the gas spring space in such a manner that the natural frequency of the system remains substantially constant and the central position of the vibrating system remains unchanged.

A favourable embodiment of the motor-compressor unit according to the invention is characterized in that the suction and/or delivery lead accommodates a controllable restriction, which can be controlled so that with increasing delivery pressure the suction pressure decreases and conversely.

The invention is based on the recognition of the fact that, when the delivery pressure in the compression space increases, the spring stiffness of the gas in this space increases. When the suction pressure is decreased, the spring stiffness will decrease. When these possibilities are combined, the resulting spring stiffness and hence the natural frequency of the system will remain substantially constant.

Although it is possible to manipulate both the suction pressure and the delivery pressure, it is to be preferred to adapt only the suction pressure to a varied delivery pressure in such a manner that the suction pressure decreases with increasing delivery pressure and increases with decreasing delivery pressure.

A motor-compressor unit according to the invention, in which some variation in natural fre-

quency and central position of the moving system is taken into the bargain, is characterized in that solely the suction lead is provided with a controllable restriction, which keeps the suction pressure constant independently of the delivery pressure.
A further favourable embodiment of the motor-compressor unit according to the invention is characterized in that the suction-and delivery leads both accommodate a controllable restriction which independently keep the suction pressure and the delivery pressure at a constant low pressure.

The invention will be described more fully with reference to the drawing.

For an extensive description of the motor-compressor as shown diagrammatically in Figures 1 and 2, reference may be made to EP A 0155057. The motor-compressor comprises a stator core 1 and stator parts 2A and 2B. Between the core 1 and the part 2 is provided a gap in which magnets 3 and 4 are arranged, one of whose poles faces the core. Further, two coils 5 and 7 wound on the stator are present, which can be connected to an alternating voltage.

In the air gaps between the stator core 1 and the stator part 2 are provided four slide elements 7,8 and 9,10, which can rotate about a motor shaft 13 via armature parts 11 and 12.

The parts 11 and 12 are connected via a part 14 and a Scottish yoke construction 15 to a piston 16, which is accommodated in a cylinder 17 ao as to be capable of performing a linear reciprocating movement.

The cylinder 17 is provided on one side with a plate 18, in which an inlet valve 19 and an outlet valve 20 are included, through which gas can flow into and out of a compression space 21.

On the other side a plate 22 including an inlet valve 23 limits a gas spring space 24.

The inlet valves 19 and 23 adjoin a common suction lead 25, through which working medium can flow to the relevant spaces.

The outlet valve 20 adjoins a delivery lead 26, to which compressed working medium is supplied by the compressor.

The leads 25 and 26 may form part, for example, of a cooling circuit in which further a condensor (not shown), a choke valve and an evaporator are arranged.

A controllable restriction 27 is provided in the suction lead 25.

The operation is briefly as follows. An alternating current through the coils 5 and 6 results in an oscillating rotary movement of the armature parts 11,12 about the motor shaft 13. The slide parts 7,8,9,10 of the armature are shown in the Figure in their central position, one half of each of the slide parts projecting into and the other half projecting out of the air gap between the stator core and the relevant stator part.

During operation, the alternating magnetic field generated by the coils 5 and 6 is superimposed on the magnetic field of the permanent magnets 2A and 2B. Consequently, the magnetic flux density in each slide part 7,8,9,10 alternately assumes a high and a low value. The magnets 3,4 are magnetized so that their direction of magnetization is the same, while further the coils 5 and 6 are interconnected so that the direction of rotation of the current through these coils is also the same so that two slide parts 7,8 and 9,10 arranged diagonally opposite to each other are subjected at the same instant to a high magnetic flux so that they are drawn into the air gap, whereas the remaining two slide parts are subjected to a low flux density and are located outside the gap. This leads to an oscillatory movement of the slide parts and of the armature.

This oscillatory movement of the armature is transmitted via the armature part 14 and the Scottish yoke construction 15 to the piston 16. The piston 16 influences with one side the volume of the compression space 21 and with its other side the volume of the gas spring space 24. The gas in these two spaces then acts as two springs so that a real mass spring system is obtained having as mass the mass of the piston with the parts connected thereto, such as the yoke 15 and the armature 11,12 with slide parts 7,8,9 and 10.

The piston 16 will then perform a reciprocating movement about a given central position, which is for a large part dependent upon the power supplied to the motor, upon the delivery pressure and suction pressure and upon the spring stiffness of the gas in the compressor space and the gas spring space.

A feature of the electric motor is that is operates with an optimum efficiency when the armature performs a vibrating osciallatory movement about a central position, the slide parts 7,8 and 9,10 being located by half in their respective air gaps and by half outside these gaps. Since the armature is fixedly coupled with the piston 16, the optimum central position of the piston 16 is thus also fixed and this position is obtained according to the invention in that the cylinder is constructed so that the gas spring space 24 is slightly larger than the compression space, as a result of which it is achieved that the spring stiffness of the gas in the two spaces is substantially the same. Any leakage along the piston etc. is compensated for by providing the gas spring space with solely an inlet valve, so that the suction pressures on both sides of the piston are equal.

Thus, a mass spring system is obtained which performs an oscillatory movement about the said central position. Such a motor-compressor has an optimum efficiency when it performs a movement about the central position and is driven by the motor at a frequency approximately corresponding to the resonance frequency of the vibrating mass spring system.

In such a compressor, in general both the delivery pressure and the suction pressure will vary due to conditions occurring in the system, which is connected to the delivery and suction valves; this may be, for example, a cooling circuit, in which the pressure varies with the ambient temperature.

Upon variation of the delivery pressure and suction pressure, the spring stiffness of the gas in the compression space and the gas spring space will also vary so that the resonance frequency of the system may also vary. When now the delivery pressure and suction pressure are adapted, it has nevertheless proved to be possible to keep the effective spring stiffness and hence the resonance frequency equal.

For this purpose, in the compressor shown in the drawing the suction lead accommodates a controllable restriction 27, which is controlled in dependence upon the pressure in the delivery lead 26 in such a manner that with increasing delivery pressure the restriction is narrowed and the suction pressure decreases. Thus, the spring stiffnesses and hence the resonance frequency remain unchanged so that in every operating condition the motor-compressor operates with an optimum efficiency, the optimum central position of the piston also remaining unchanged. The extent to which the delivery pressure and the suction pressure are controlled with respect to each other depends upon the compressor dimensions. In a compressor with a cylinder bore having a diameter of 25 mm and a piston stroke of 14 mm, the pressures are controlled so that, when the delivery pressure increases by a value P, the suction pressure decreases by a value $\frac{1}{6}$ P.

In a further embodiment shown in Fig. 3 both the suction lead 25 and the delivery lead 26 accommodate a controllable restriction 27 and 28 respectively. In this case the restriction 27 is controlled in dependence upon the pressure prevailing in the suction lead and keeps this pressure at a constant low value e.g. equal to the minimum pressure which may occur during operation in the evaporates of a cooling circuit connected to the compressor. The restriction 28 is controlled in dependence upon the pressure prevailing in the delivery lead 26 and keeps this pressure at a constant low value e.g. equal to the condensation pressure at normal ambient temperature of the cooling medium used in a refrigeration circuit connected to the compressor. Due to the fact that in this embodiment the compressor operates with a constant suction and delivery pressure the resonance frequency will always be the same and thus in every operating condition the compressor unit operates with maximum efficiency.

Claims

1. A motor-compressor unit comprising a vibration motor having two or more coils around a stator core, parallel to which is arranged a magnet with a stator part above it, one of the poles of this magnet being directed to the core and circularly bent air gaps being present between the stator core and the stator part, while slide elements of an armature in these air gaps traverse a part of an arc of a circle and the armature is rotatable about a motor shaft, this armature being coupled with a piston body linearly movable in a cylinder, which piston body can vary with one side the volume of a compression space with inlet and outlet valves and can vary with its other side the volume of a gas spring space, characterized in that the gas spring space is solely provided with an inlet valve which adjoins the same medium supply as the inlet valve of the compression space and at nominal power and nominal delivery pressure and suction pressure the volume of the gas spring system exceeds that of the compression space by such an amount that the spring stiffness of the gas in the gas spring space is equal to the spring stiffness of the gas in the compression space, while the piston body performs during operation an oscillatory movement about a central position corresponding to the central position of the armature.

2. A motor-compressor unit as claimed in Claim 1, characterized in that the suction and/or delivery lead accommodates a controllable restriction, which can be controlled so that with an increasing delivery pressure the suction pressure decreases or conversely.

3. A motor-compressor unit as claimed in Claim 1, characterized in that solely the suction lead is provided with a controllable restriction, which keeps the suction pressure constant independently of the delivery pressure.

4. A motor-compressor unit as claimed in Claim 1, characterized in that the suction-and delivery leads both accommodate a controllable restriction which independently keep the suction pressure and delivery pressure at a constant low pressure.

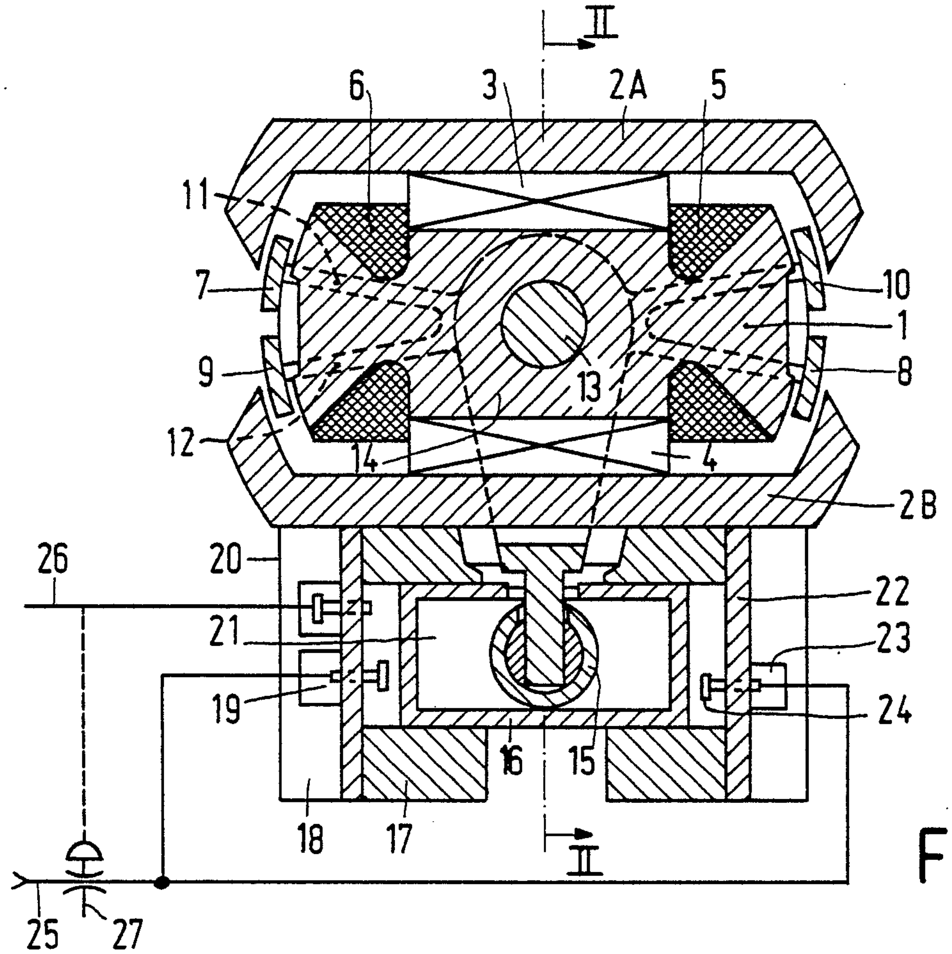
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FIG.1

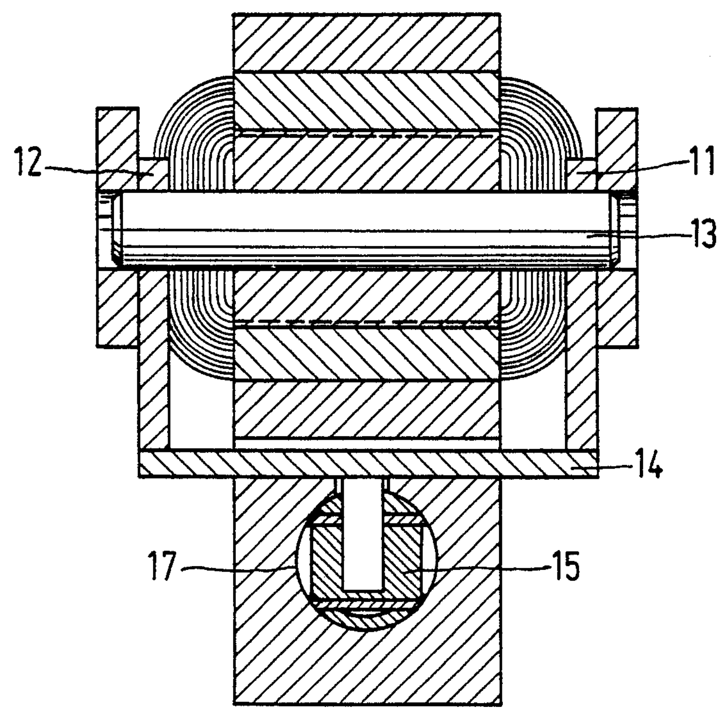
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FIG.2

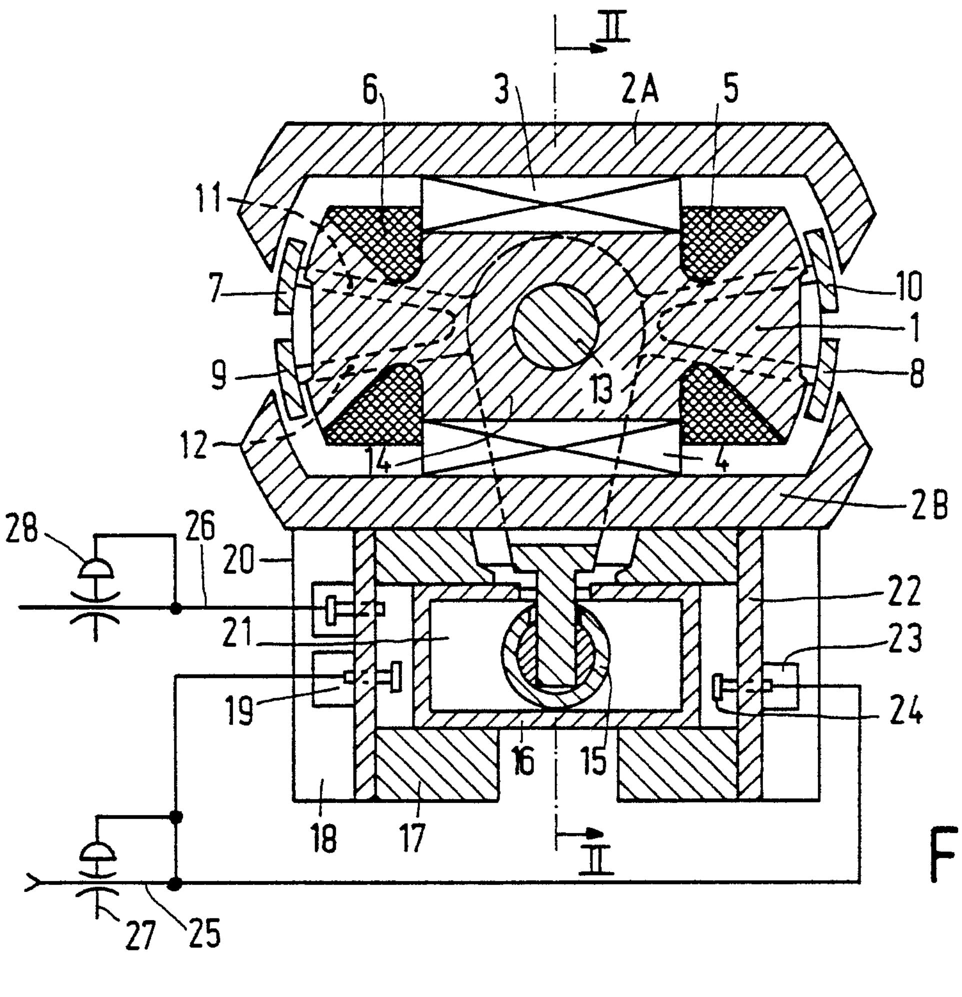
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FIG. 3

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EUROPEAN SEARCH REPORT

Application Number

EP 87 20 2579

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
D,A	EP-A-0 155 057 (PHILIPS) * Page 7, line 20 - page 8, line 17; figures 7-9 * ---	1	F 04 B 35/04 F 04 B 39/00
A	DE-C- 408 499 (D.M.F.) * Whole document * -----	1	
			TECHNICAL FIELDS SEARCHED (Int. Cl.4)
			F 04 B H 02 K F 01 B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	31-03-1988	VON ARX H.P.

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