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(71) Applicant(s)
SMC Corporation

(Incorporated in Japan)

16-4 Shinbashi 1-chome, Minato-ku, Tokyo, Japan

(72) Inventor(s)
Susumu Takada
Kazuya Tamura
Kunihisa Kaneko
Nobuhiro Fujiwara

(74) Agent and/or Address for Service
Lloyd Wise, Tregear & Co
Commonwealth House, 1-19 New Oxford Street,
LONDON, WC1A 1LW, United Kingdom

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(54) **Air cylinder device**

(57) An air cylinder device is provided with air bearings 16a,16b for supporting the sliding portion of a cylinder body, a piston, and a rod in substantially non-contact state by the intervention of compression air; and an air supply means for supplying compression air to the air bearings, the air supply means being connected respectively to two pressure chambers 12a,12b which are located one on each side of the piston and to each bearing through an air flow path, and that one of the pressure chambers to which compression air has been supplied is connected to each air bearing automatically and selectively by means of the action of air pressure. The automatic connection may be effected by a shuttle valve 18 or by a pair of check valves in the connections 19a,19b to the chambers.

FIG. 1

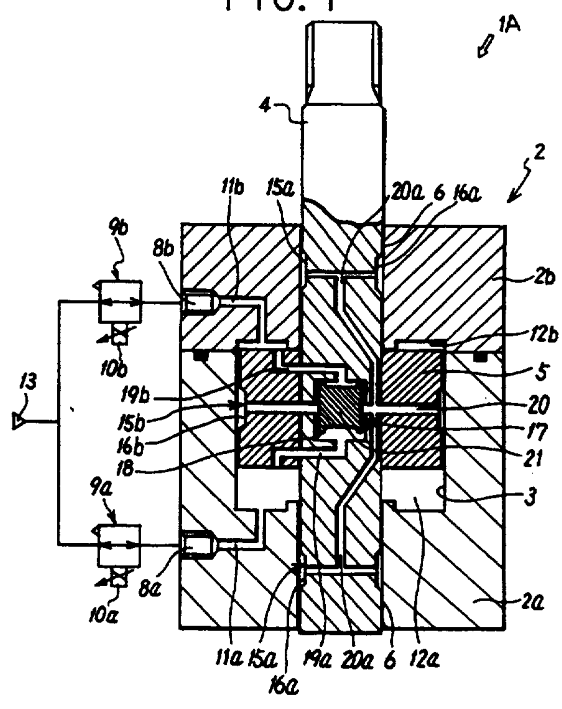

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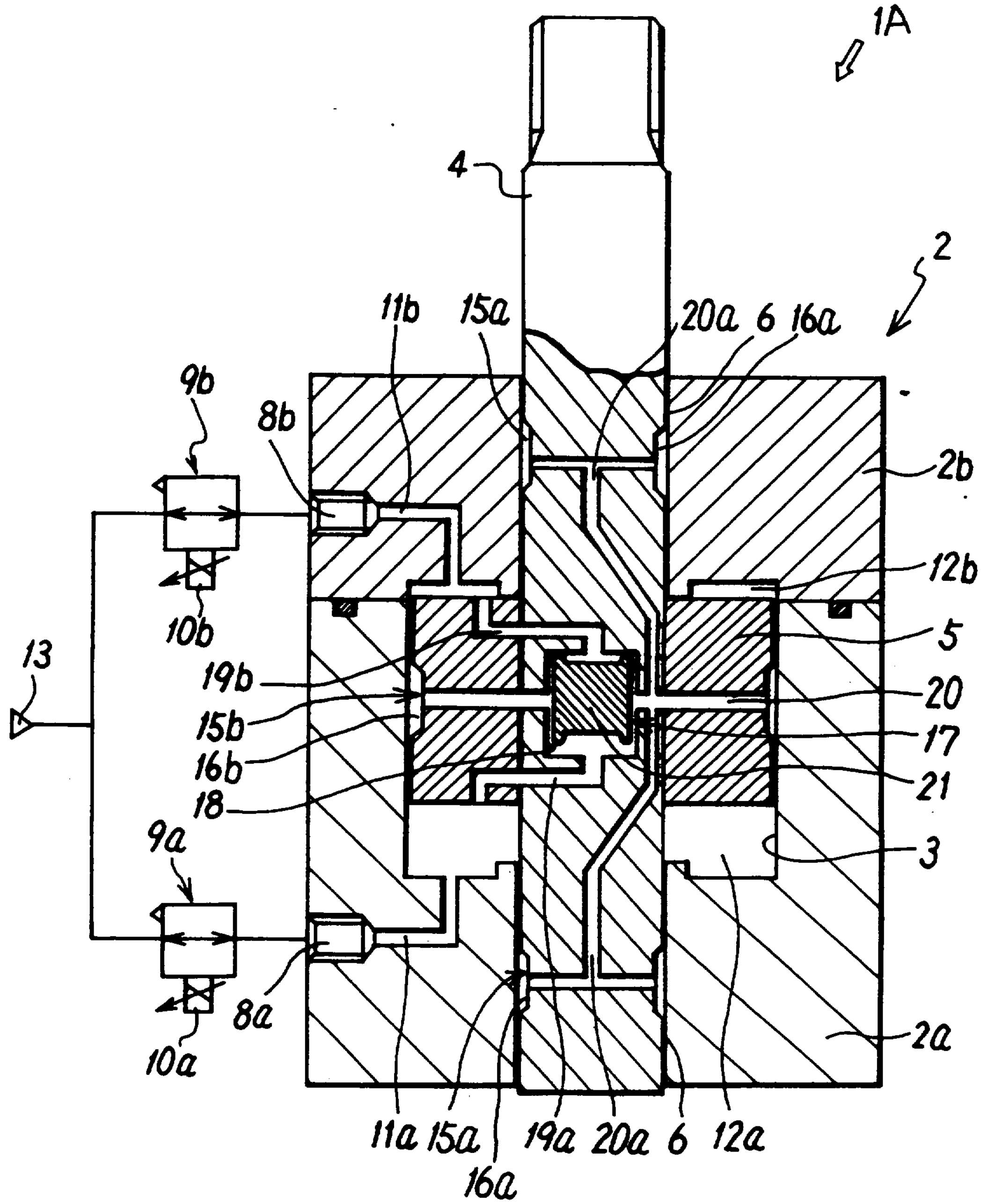
FIG. 1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2
4
2b
2a
5
20
17
21
3
12b
11b
15a
20a
6
16a
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9b
10b
13
19b
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11a
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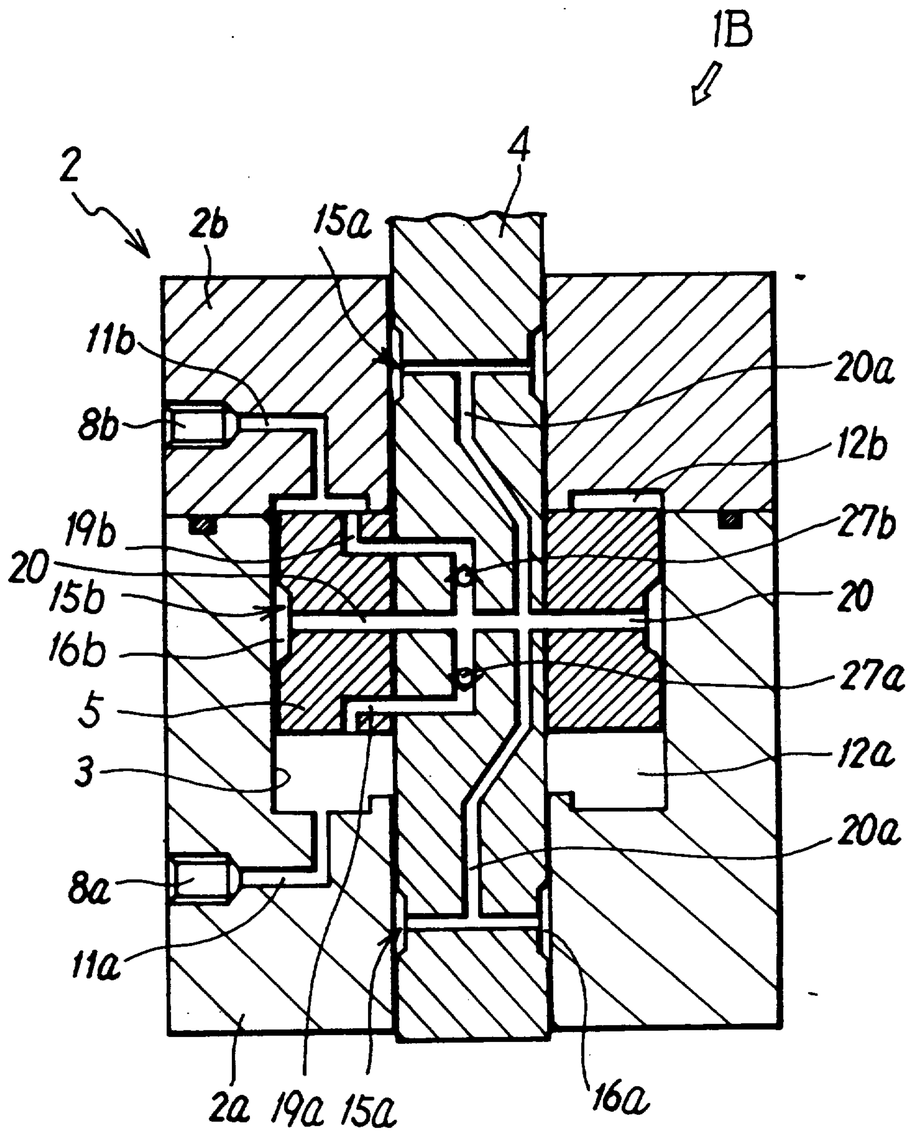
16a
19a
20a
6
12a

FIG. 2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4
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15a
11b
8b
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12b
19b
27b
20
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19a
15a
16a

FIG. 3

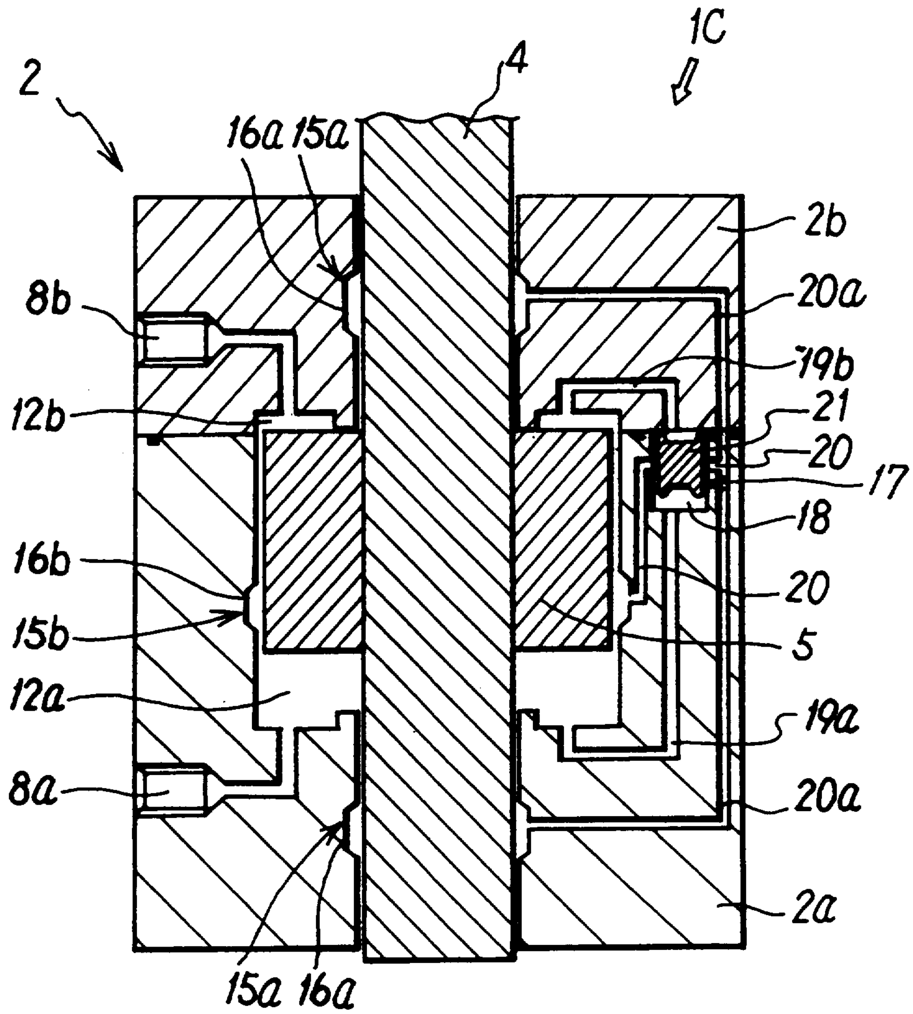
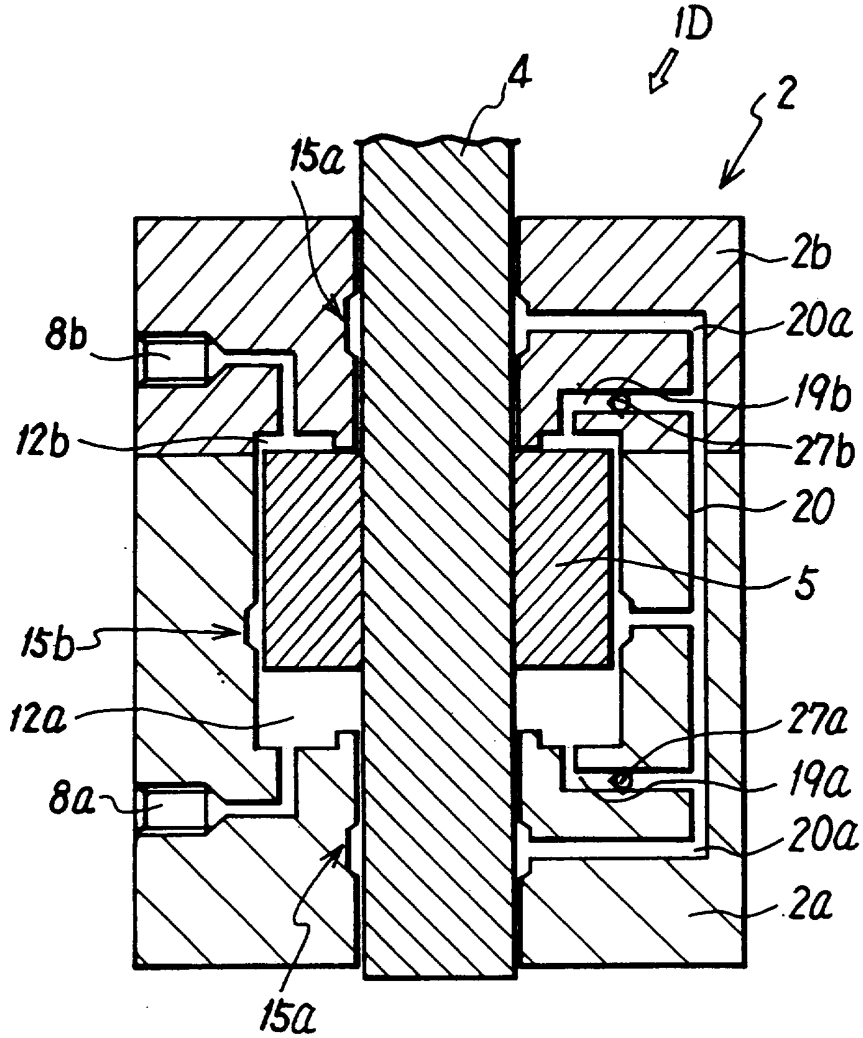

2
4
1C
16a
15a
2b
20a
8b
19b
12b
21
20
17
18
16b
20
15b
5
12a
19a
8a
20a
2a
15a
16a

FIG. 4



AIR CYLINDER DEVICE

The present invention relates to an air cylinder device with a piston and a rod featuring low sliding resistance.

Conventional air cylinder devices are provided with a piston and a rod slidably incorporated in a cylinder body, and a pair of ports to supply and discharge compression air to a cylinder chamber on each end of the piston. The piston and rod are driven by means of compression air which is alternately supplied and discharged from these ports to the cylinder chambers.

However, such conventional air cylinders have the disadvantage that their sliding resistance is large because the sliding portion between the cylinder body on the one hand, and the piston and the rod, on the other, is sealed with synthetic rubber packing. Also, it is difficult to stop the piston and rod in a precise position.

Air bearings have been used to reduce the sliding resistance of the sliding portion by intervening compression air thereat, but they have required specific piping for supplying the compression air. Therefore, if such an air bearing is installed in an air cylinder as is, the number of pipes increases, whereby the device becomes complicated, and moreover the expansion or contraction of the piping in response to rod expansion and contraction, cylinder movement, or the like has proven an obstacle to smooth operation.

Accordingly, it would be desirable to provide an air cylinder device having an improved air bearing arrangement for reducing the sliding resistance of the piston and rod.

The air cylinder device in accordance with the present invention comprises a piston slidably incorporated in a cylinder body and a rod coupled to the piston; a pair of ports for alternately supplying and discharging compression air to two pressure chambers one on each side of said piston for moving said piston and attached rod; an air bearing for supporting each of the piston and rod in a substantially non-contact state at the sliding portion between said piston and rod, and the cylinder body; an air flow path for connecting each said pressure chamber and each air bearing; and an air supply means provided in said air flow path and automatically and selectively connecting the pressure chamber to which compression air has been supplied and each air bearing by means of air pressure.

According to one preferred embodiment of the present invention, the air supply means comprises a shuttle valve having a valve chamber connected to each of the two pressure chambers through an individual air supply flow path, and connected also to each air bearing through an output air flow path. A valve body in the valve chamber of the shuttle valve is adapted to close the air supply flow path on the low-pressure side by the action of the air pressure supplied into the valve chamber through the air supply flow path on the high pressure side and to connect the air supply flow path on the high-pressure side to the output air flow path.

According to another preferred embodiment of the present invention, the air supply means is constituted by two check valves. One of the two check valves is provided between one of the two pressure chambers and each air bearing, and the other check valve is provided between the other pressure chamber and each air bearing.

In one specific example of the present invention, the air supply means is incorporated into the piston or rod.

In another specific example of the present invention, said air supply means is incorporated in the cylinder body.

In the air cylinder device of the present invention, since the air bearings reduce the sliding resistance between the piston and the rod, the sliding action is smooth, and as a result, the stopping position of the piston and rod can be controlled with high precision.

In addition, since compression air can be supplied to the air bearings through internal flow paths provided within the piston, rod, or cylinder body, there is no need for dedicated external piping. Therefore, the number of pipes need not increase, the device need not become complicated through the addition of pipework, and pipe expansion or contraction due to rod expansion or contraction, cylinder movement, or the like does not become an obstacle to smooth operation.

Embodiments of the air cylinder device of the present invention will now be described in detail with reference to the accompanying drawings, in which:

Fig. 1 is a sectional view illustrating a first embodiment of the present invention;

Fig. 2 is a sectional view illustrating a second embodiment of the present invention;

Fig. 3 is a sectional view illustrating a third embodiment of the present invention; and

Fig. 4 is a sectional view illustrating a fourth embodiment of the present invention.

Fig. 1 illustrates a first embodiment of an air cylinder device of the present invention, where the air cylinder device 1A has a cylinder body 2 provided with a piston chamber 3 inside the body. The cylinder body 2 is formed of a first portion 2a providing a recess defining the piston chamber 3, and a second portion 2b closing the recess of the first portion 2a, and both portions 2a and 2b thereof are made airtight via coupling means such as bolts (not shown).

A through hole 6 passing through the centre of the piston chamber 3 is formed in the first and second portions 2a and 2b of the cylinder body 2. A rod 4 is inserted in this through hole 6 in a slidable manner, with a slight clearance between the hole faces and the rod, and on the rod 4 is integrally mounted an annular piston 5 so as to slide in the piston chamber 3 with a slight clearance between the faces thereof and the piston. First and second pressure chambers 12a, 12b, respectively, are formed on each side of the piston 5 within the piston chamber 5.

Ports 8a and 8b individually communicating with the first pressure chamber 12a and the second pressure chamber 12b, respectively, through air flow paths 11a and 11b are provided on the outer face of the cylinder body 2. These ports 8a and 8b are connected, respectively, to a compression air source 13 via solenoid-type pressure proportional control valves 9a and 9b, which act as air pressure control means.

By controlling the value of the current which passes through the proportional solenoids 10a and 10b of the control valves 9a and 9b, the pressure of the compression air to be supplied from the compression air source 13 to the pressure chambers 12a and 12b can be controlled at a desired level.

Circumferential grooves 16a and 16b constituting air bearings 15a and 15b are formed, respectively, on the outer circumferential faces of the rod 4 and of the piston 5. These air bearings 15a and 15b permit the rod 4 and the piston 5 to be supported by means of air substantially out of contact with the faces of the through hole 6 and piston chamber 3, respectively, whereby the sliding resistance on movement of the rod 4 and piston 5 can be substantially reduced.

The grooves 16a providing the air bearings for the rod 4 are positioned such that they are always located in the through hole 6 as the rod 4 moves.

In the illustrated example, a single air bearing 15a is provided, for the rod 4 on each side of the piston 5; however, two or more air bearings may be provided on the respective sides. Similarly, the piston 5 may be provided with two or more air bearings 15b, although in the illustrated embodiment only a single bearing 15b is shown.

Inside the section of the rod 4 adjacent to where the piston 5 has been mounted, a shuttle valve 17 is incorporated as a means to supply compression air to the air bearings 15a and 15b.

The shuttle valve 17 has a valve chamber 18 and a valve body 21 arranged therein. One of the sides of the valve chamber 18 in its axial direction communicates with the first pressure chamber 12a by means of a first air supply flow path 19a formed in the rod 4 and the piston 5, and the opposite side of the valve chamber 18 likewise communicates with the second pressure chamber 12b by means of second air supply flow path 19b. Further, in this valve chamber 18, a plurality of output air flow paths 20 open radially at a position between the two air flow paths 19a and 19b. Some of these output air flow paths 20 communicate with the two air bearings 15a, 15a of the rod 4 by means of air flow paths 20a, 20a provided in the rod 4, and the remaining output air flow paths 20 penetrate the rod 4 and the piston 5 and communicate with the air bearing 15b of the piston 5.

A plurality of such output radial air flow paths 20 does not always need to be provided for and in some instances only one path 20, having communicating air flow paths 20a, 20a for the air bearings 15a, 15a, will suffice.

In the air cylinder device 1A of this first embodiment, when power is supplied to the proportional solenoid 10a of the first proportional control valve 9a and the proportional solenoid 10b of the second proportional control valve 9b is made non-conductive, compression air at a pressure proportional to the conduction quantity is supplied from the first proportional control valve 9a to the first pressure chamber 12a, and the compression air in the second pressure chamber 12b is discharged to the outside from the second proportional control valve 9b. Therefore, the rod 4 and the piston 5 move to the position illustrated in Fig. 1.

At this time, in the shuttle valve 17, the high-pressure compression air in the first pressure chamber 12a flows into the valve chamber 18 through the first air supply flow path 19a, moves the valve body 21 (upwards as shown in Fig. 1), and closes the second air supply flow path 19b on the low-pressure side. At the same time, compression air flows into grooves 16a and 16b of air bearings 15a and 15b through the radial air flow paths 20 and air flow paths 20a. Therefore, the rod 4 and the piston 5 are supported in a substantially non-contact state in the through hole 6 and piston chamber 3, respectively, by means of the compression air passing through the clearances between the rod 4 and the faces of through hole 6, and between the piston 5 and the faces of the piston chamber 3. The rod 4 and piston 5 then move to the position shown on air bearings. Consequently, the sliding resistance encountered by the rod 4 and piston 5 is very low, and the sliding thereof is performed smoothly.

The compression air supplied to the grooves 16a and 16b of the air bearings 15a and 15b leaks slightly to the outside from the clearances. However, since these clearances are much smaller than the capacitance of the pressure chamber 12a, this leakage quantity is small, and the air pressure in the pressure chamber 12a is usually maintained. If however it is significantly lowered, the air pressure is increased by the operation of the proportional control valve 9a.

The rod 4 and piston 5 stop at a position at which the force of the compression air supplied to the pressure chamber 12a balances the self-weights of the rod 4 and the piston 5 plus the weight of the load (not shown) mounted on the rod 4. This stopping position can be controlled by the current value to the proportional solenoid 10a of the proportional control valve 9a. Since the sliding resistance encountered by the rod 4 and the piston 5 is very low, the stopping position can be controlled precisely.

Conversely, in the case where the first proportional control valve 9a is made non-conductive and power is supplied to the second proportional control valve 9b, compression air is supplied to the second pressure chamber 12b and the piston 5 and the rod 4 move back to their original positions. Also at the same time, in the shuttle valve 17, the valve body 21 moves down (as shown in Fig. 1) as a result of compression air flowing into the valve chamber 18 from the second air supply flow path 19b, and the first air supply flow path 19a is closed. However, compression air from the second air supply flow path 19b is supplied to the air bearings 15a and 15b, through the air flow paths 20 and 20a as before. As a result, the movement and stoppage of said piston 5 and rod 4 can be performed smoothly and precisely.

Thus, since part of the compression air supplied to the two pressure chambers 12a and 12b is always supplied to the air bearings 15a and 15b, the rod 4 and the piston 5 move lightly and smoothly and the stopping position can be controlled smoothly and precisely. Moreover, since compression air is supplied to each air bearing through the air flow paths provided in the rod 4 and the piston 5, specific additional piping is not required, a simple structure is maintained, and expansion and contraction of the piping do not influence operation.

Furthermore, since the shuttle valve 17 is incorporated in the centre portion of the rod 4, the weight balance in the radial direction of said rod is substantially the same. As a result, an eccentric load acting on the rod 4 or the piston 5 is avoided.

Fig. 2 illustrates a second embodiment of the present invention, which is essentially identical to said first embodiment except that the air supply means is constituted by a check valve instead of a shuttle valve. That is, in an air cylinder device 1B of the second embodiment, the first supply air flow path 19a communicating with the first pressure chamber 12a meets the output air flow path 20 communicating with each air bearing 15a and 15b at a junction, and a first check valve 27a is installed upstream of the junction of the air flow paths so that compression air can flow only in a direction from the first pressure chamber 12a to the air bearings 15a and 15b. Similarly, the second air supply flow path 19b communicating with the second pressure chamber 12b meets the output air flow path 20 at the same junction, and a second check valve 27b is installed upstream of the junction so that compression air can flow only in a direction from the second pressure chamber 12b to the air bearings 15a and 15b.

In other respects the construction and operation of the air cylinder device of the second embodiment are substantially identical to those of the first embodiment, and the same reference numerals as those of Fig. 1 are therefore used in Fig. 2, and a detailed description of the second embodiment is omitted here.

In the first and second embodiments, since the rod 4 and the piston 5 are coupled in a form in which the rod 4 penetrates the centre of the annular piston 5, the shuttle valve 17 and check valves 27a and 27b are provided inside the rod 4 as the air supply means. However, in cases where each half portion of the rod 4 is mounted on the end face of a non-annular piston 5, it is convenient that the air supply means is then provided inside the piston 5.

Fig. 3 illustrates a third embodiment of the present invention, in which an air cylinder 1C differs from that in the first embodiment in the fact that the shuttle valve 17 is incorporated in the cylinder body 2. That is, the valve chamber 18 is formed between the first and second portions 2a and 2b of the cylinder body 2; the valve body 21 is housed in the valve chamber 18; and the air supply flow path 19a and 19b, the output air flow path 20, and the air flow path 20a are all formed in the cylinder body 2. Furthermore, the grooves 16a and 16b in the circumferential direction constituting the air bearings 15a and 15b are also formed on the side of the cylinder body 2.

Therefore, in this embodiment there is no need to form air flow paths in the rod 4 and the piston 5, and the manufacturing process is simplified.

In other respects the construction and operation of the air cylinder device of the third embodiment are substantially identical to those in the first embodiment, and accordingly in Fig. 3 the same reference numerals as those in Fig. 1 are given to the main items, and a detailed description of the third embodiment is omitted.

Fig. 4 illustrates the fourth embodiment of the present invention, in which the air cylinder device 1D differs from that of the third embodiment in that a check valve is used as an air supply means. That is, the first air supply flow path 19a communicating with the first pressure chamber 12a meets the output air flow path 20 communicating with each of the air bearings 15a and 15b at a junction, and a first check valve 27a is installed upstream of the junction so that compression air can flow only in the direction from the first pressure chamber 12a to the air bearings 15a and 15b. Similarly, a second check valve 27b is installed upstream of the junction between the output air flow path 20 and the second supply air flow path 19b communicating with the second pressure chamber 12b, so that compression air can flow only in the direction from the second pressure chamber 12b to the air bearings 15a and 15b.

In other respects the construction and operation of this fourth embodiment are substantially identical to those of the third embodiment, and accordingly the same reference numerals are used in Fig. 4 as in Fig. 3, and a detailed description of the fourth embodiment is omitted here.

In the third and fourth embodiments, since the cylinder body 2 can be provided with all of the air supply means, air flow paths, and air bearing grooves, the construction is simple and manufacturing is simplified. These embodiments are particularly effective in cases where the piston strokes are short.

The air cylinder device of each of the illustrated embodiments is nt limited to the case in which the rod 4 and the piston 5 are used for vertical movement as illustrated. For example, instead the air cylinder device be installed horizontally, and the rod and the piston can be used for horizontal movement. In this case, the rod and the piston can be stopped at a specified position by equalizing the air pressure in the pressure chambers 12a and 12b and can be positioned precisely because little sliding resistance is generated by means of the air bearings 15a and 15b.

In addition, in each of the illustrated embodiments, although not shown in the drawings, a positioning sensor such as potentiometer or linear encoder may be installed on the rod, and the conduction quantity of the proportional solenoids 10a and 10b is adjusted, or the air pressure of the compression air for driving the cylinder is controlled by means of an air servo valve, in response to the displacement distance of the rod. Accordingly, the stop position of the rod and the piston can be controlled precisely.

In an experiment, it was found in the case of a conventional air cylinder device using synthetic rubber packing, that positioning could only be performed in units of 0.1 mm; however, in the case of an air cylinder device of the present invention using air bearings, precise positioning could be performed in units of 0.001 mm.

CLAIMS

1. An air cylinder device comprising a piston slidably incorporated in a cylinder body and a rod coupled to the piston; a pair of ports for alternately supplying and discharging compression air to two pressure chambers one on each side of said piston for moving said piston and attached rod; an air bearing for supporting each of the piston and rod in a substantially non-contact state at the sliding portion between said piston and rod, and the cylinder body; an air flow path for connecting each said pressure chamber and each air bearing; and an air supply means provided in said air flow path and automatically and selectively connecting the pressure chamber to which compression air has been supplied and each air bearing by means of air pressure.

2. An air cylinder device as claimed in Claim 1, wherein said air supply means comprises a shuttle valve having a valve chamber connected to each of said two pressure chambers through an individual air supply flow path, and also connected to each air bearing through an output air flow path, the shuttle valve including a valve body in the valve chamber adapted to close the air supply flow path on the low-pressure side by the action of air pressure supplied to the valve chamber through the air supply flow path on the high-pressure side and to connect the air supply flow path on the high-pressure side to said output

air flow path.

3. An air cylinder device as claimed in Claim 1, wherein said air supply means is constituted by two check valves, one check valve being installed between one pressure chamber and each air bearing, and the other check valve being installed between the other pressure chamber and each air bearing.

4. An air cylinder device as claimed in Claim 2 or 3, wherein said air supply means is incorporated in said piston or said rod.

5. An air cylinder device as claimed in any preceding Claim, wherein said air supply means is incorporated in the cylinder body.

6. An air cylinder device substantially as hereinbefore described with reference to Fig. 1, Fig. 2, Fig. 3 or Fig. 4 of the accompanying drawings.

17

Application No: GB 9724152.5
Claims searched: 1 to 6
Examiner: Trevor Berry
Date of search: 11 December 1997

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): F1D (DA2, DH)

Int Cl (Ed.6): F15B 15/08, 15/14, 15/20

Other: ONLINE: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
	NONE	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
		E	Patent document published on or after, but with priority date earlier than, the filing date of this application.
&	Member of the same patent family		