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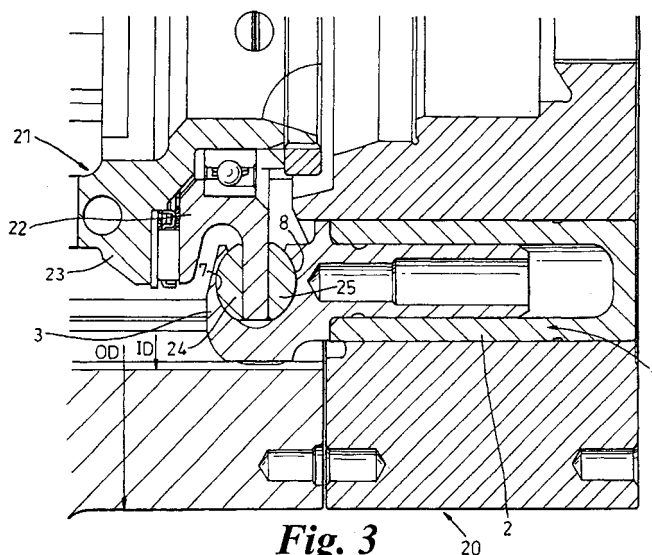
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(54) **A piston for a compressor**

(57) A piston (1) is provided for use in a compressor (20), primarily but not exclusively a swash plate CO₂ compressor for a vehicle air-conditioning system. The piston (1) comprises a cylindrical portion (2) at one end and a foot portion (3) at its other end. The foot portion (3) can accommodate a bearing for a swash or wobble plate arrangement (21) of the compressor (20). In particular, the piston (1) is made from at least two individual

parts (2, 3) which have been joined together after separate manufacture. The cylindrical portion (2) and the foot portion (3) are two of these parts and are made of different materials from one another. Preferably, the cylindrical portion (2) is made from aluminum and the foot portion (3) is made from steel, the two portions having been joined together by a friction fusion process or a magnetic pulse welding process.



Description

[0001] The present invention relates to a piston for use in a compressor, particularly but not exclusively a swash plate CO₂ compressor for a vehicle air-conditioning system, and to a compressor incorporating such a piston.

[0002] US 5,387,091 describes a variable capacity type swash plate compressor for an air-conditioning system in a vehicle having a drive shaft and at least one piston movable in a cylinder. A swinging swash plate of the compressor is provided on each side with an annular rail over which is fitted a semi-spherical inner sliding shoe. The inner sliding shoes engage semi-spherical outer shoes machined on inner surfaces of a swash plate receiving groove at the neck of a piston of the compressor. This arrangement allows a separation between the rotational movement that takes place between the swash plate and the inner sliding shoes, and the translational movement of the outer shoes and the piston.

[0003] In US 5,826,490 is also described a swash plate compressor but here a wobble plate arrangement is used between the piston and the drive shaft. The wobble plate arrangement comprises a swash plate on which a wobble plate is rotatably mounted and between the wobble plate and the piston is arranged a bearing which allows movements of the wobble plate relative to the piston in a circumferential direction. The wobble plate is able to rotate freely both with respect to the swash plate and with respect to the piston. The bearing comprises a slider shoe arrangement in which a pair of part-spherical sliding shoes are swivel mounted between two complementarily formed outer shoes located in a recess of the piston, the wobble plate being received between two opposed smooth sliding surfaces of the sliding shoes respectively. The two outer shoes are provided by bearing shells which are fixed in the piston.

[0004] The use of bearing shells to form the outer shoes attached to the piston in this compressor provides several advantages, as follows.

- It enables the piston to be hollowed out from its bottom end so that its bulk is greatly reduced, enabling the compressor to be optimally designed. As the pistons are made of steel rather than aluminum, which would be unsuitable for this design of compressor, weight reduction becomes an important design consideration.
- The shells have a simple shape and are relatively easy to produce by machining.
- If a regulating screw is provided for adjustment of the position of the piston-side bearing shell, the axial clearance or play of the shells can be adjusted. Hence, as the shells wear owing to the action of the sliding shoes, the end play of the shells can be adjusted.

- The fact that the position of the shells can be adjusted permits adjustment to take place to compensate for less than precise manufacturing tolerances.

[0005] More generally, because wear takes place in the bearing arrangement, the bearing shells have to be appropriately designed by a suitable choice of materials and optionally by a subsequent thermal treatment or coating.

[0006] It should be appreciated that pressure is applied to the piston-side bearing shell mainly during piston movement on the compression stroke when the piston rises from the bottom to the top of the cylinder. In contrast, pressure is applied to the regulating-side bearing shell mainly during the intake stroke, when the piston descends from the top of the cylinder to the bottom. The characteristic of the gas forces acting on the piston is such that during the compression stroke, when the crank angle of the piston is between 180° to 360°, the force acting on the piston-side bearing shell is significantly greater than that applied to the regulating-side bearing shell during the intake stroke, when the crank angle of the piston is approximately in the range 50° to 200°. In addition to the gas forces, other forces caused by overshooting losses, and inertial losses will also act on the bearing shells to produce wear.

[0007] A critical factor in the design of bearing arrangements for swash plate compressors is the so-called *p_v* value, which is the product of the applied surface pressure and the velocity. As the wobble plate of a compressor of the type disclosed in US 5,826,490 performs only small rotational movements, the product of the surface pressure and the velocity is small and the bearing shells can be made with small dimensions, mainly taking into account only the surface pressure. Essentially, therefore, the size of the sliding shoes determines the size of the complementarily formed bearing shells.

[0008] However, the arrangement described in US 5,826,490 has several drawbacks, in particular with regard to the nature and design of the bearing shells. These drawbacks have been primarily brought about by the desire to mass produce the compressor, which involves changing from steel to aluminum pistons. These drawbacks include the following.

- The bearing shells may, and in fact do, rotate in their seating in the piston. This causes wear in the seating, which is especially pronounced when the piston is made of aluminum.
- Rotation of the bearing shells in their seatings causes friction so that the mechanical losses of the driving mechanism are increased.
- If aluminum is used as the piston material, then bearing shells of the type described will create an unacceptably high surface pressure on the piston-

side seating of the shells.

- The aforementioned drawback is increased in severity if the piston is made hollow as described in US 5,826,490 as here only an annular rim of the piston is available as the seating surface for the piston-side bearing shell.
- The use of a regulating screw to adjust the position of the piston-side bearing shell increases the length of the piston required and thus results in a increased overall length for the driving mechanism, and hence the compressor as a whole.
- An increased overall length of the driving mechanism of the compressor, in particular an increased length of the swash plate and wobble plate, leads to a greater variability of the centre of gravity of the compressor when it is tilted, as happens for the purposes of power control, and thus causes imbalance and noise, especially at higher speeds.
- Whilst the use of a piston-side bearing shell is useful because it can be manufactured with a view to minimizing wear resistance by a suitable choice of materials and the use of hardening techniques and wear-resistant coatings, the use of a regulating-side bearing shell is not as useful. This is because the surface pressures occurring on this side of the bearing arrangement are normally significantly smaller than that on the piston-side. In addition, the provision of a regulating-side bearing shell increases the length of the piston and therefore of the driving arrangement of the compressor.
- If regulating screws are employed in compressors comprising a larger number of pistons, for example those with seven pistons, the quantity of assembly work required to mass produce the compressor becomes excessive. However, without the use of regulating screws and the associated drilling through the bottom of the piston necessitated thereby, insertion of the bearing shells into the piston is very difficult and, in the embodiment illustrated in US 5,826,490, is practically impossible.

[0009] The object of the present invention is to provide a piston for use in a compressor, in particular as described above, which overcomes or substantially mitigates the aforementioned disadvantages.

[0010] In particular, it is intended that in a preferred embodiment of piston according to the present invention, the use of bearing shells or shoes is eliminated and a more compact piston geometry can be adopted to save space.

[0011] According to a first aspect of the present invention there is provided a piston for use in a compressor for a vehicle air conditioning system comprising a cylin-

drical portion at one end and a foot portion at its other end, which foot portion can accommodate a bearing for a swash or wobble plate arrangement of a compressor, characterised in that the piston has been made from at least two individual parts which have been joined together after separate manufacture, the cylindrical portion and the foot portion being two of these parts and being made of different materials from one another.

[0012] Preferably, at least one of the parts is made from steel and at least one other is made from a lighter-weight metal. Advantageously, the part made from steel is made from a high-strength steel and the other part is made from aluminum.

[0013] Preferably also, the part made from steel has been surface hardened.

[0014] Preferably also, the piston comprises only two parts in the form of the cylindrical portion and the foot portion which are joined together after separate manufacture.

[0015] Alternatively, a further part comprising an anti-rotation lock means is located between the foot portion and the cylindrical portion. This anti-rotation lock means preferably comprises a ring provided with a radial projection.

[0016] Preferably also, the cylindrical portion is hollow.

[0017] Preferably also, the foot portion comprises an annular cap which closes an open end of the hollow cylindrical portion when joined thereto.

[0018] Preferably also, the foot portion comprises a skirt which is fitted inside the hollow cylindrical portion.

[0019] Preferably also, the foot portion defines a recess into which a swash or wobble plate arrangement can extend.

[0020] Preferably also, the foot portion defines a part-spherical, pressure-bearing surface on a side of the recess opposite to that adjacent the cylindrical portion, which pressure-bearing surface transmits translational forces to the piston in a direction away from the cylindrical portion.

[0021] Preferably also, the foot portion defines a second part-spherical, pressure-bearing surface on a side of the recess adjacent the cylindrical portion, which pressure-bearing surface transmits translational forces to the piston in a direction towards the cylindrical portion.

[0022] Preferably also, the second part-spherical pressure-bearing surface has a surface area which is substantially smaller than the cross-sectional surface area of the cylindrical portion.

[0023] Preferably also, the second part-spherical, pressure-bearing surface has a surface area that is commensurate with that of the first part-spherical, pressure-bearing surface.

[0024] Preferably also, the piston comprises two parts which have been joined together by force fitment. Alternatively or in addition, the two parts have been bonded together to integrate the two parts into a unitary whole.

[0025] Preferably also, the piston comprises two parts

which have been joined together by the use of an adhesive material applied between the two parts. Advantageously, the adhesive material comprises a cementitious material.

[0026] Alternatively, the two parts have been joined together by brazing.

[0027] In a further alternative, the two parts have been joined together by a friction fusion process.

[0028] In another alternative, the two parts have been welded together, preferably by magnetic pulse welding.

[0029] In yet a further alternative, the piston comprises two parts which have been joined together by a mechanical means. This may take the form of a threaded engagement with one another or be accomplished by the use of mechanical fasteners.

[0030] Preferably also, the piston comprises two parts which have been joined together and which have subsequently been at least partially coated with a friction-reducing coating. Such a coating may comprise a polytetrafluoroethylene (PTFE) coating or an anti-friction lacquer coating.

[0031] According to a second aspect of the present invention there is provided a swash or wobble plate compressor for a vehicle air conditioning system comprising a piston according to the first aspect of the invention.

[0032] According to a third aspect of the present invention there is provided a compressor for a vehicle air conditioning system comprising a drive shaft, a swash or wobble plate arrangement operatively connected to the drive shaft, a piston with a cylindrical portion at one end and a foot portion at its other end, a cylinder in which the cylindrical portion can be reciprocated, and a bearing accommodated in the foot portion that cooperates with the swash or wobble plate arrangement to reciprocate the piston as the drive shaft rotates, and characterised in that the piston has been made from at least two individual parts which have been joined together after separate manufacture, the cylindrical portion and the foot portion being two of these parts and being made of different materials from one another.

[0033] Preferably, the compressor comprises a wobble plate arrangement comprising a swash plate on which a wobble plate is rotatable mounted.

[0034] Preferably also, the wobble plate has two degrees of rotary freedom so that it can rotate jointly with the swash plate and rotate relative to the swash plate.

[0035] Preferably also, the compressor has been designed for the compression of CO₂. Alternatively, the compressor has been designed for the compression of R134A.

[0036] In all of the aforementioned embodiments, preferably the cylindrical portion of the piston is made of aluminum and the foot portion of the piston is made of steel. Such an arrangement enables a piston to be produced which has significant advantages over the prior art.

[0037] First, the fact that the foot portion is made of

steel, it can be made much more compact in size and shape than one made of aluminum because steel can better withstand the forces to which the foot portion is subjected. In particular, the first and second part-spherical, pressure-bearing surfaces provided in the foot portion can be made up to 50% smaller in area than those provided in an aluminium foot portion and the use of bearing shoes or shells can be dispensed with. Typically, the diameters of the part-spherical, pressure-bearing surfaces will be in the range 8 mm to 12 mm inclusive. This also means that the hemi-spherical sliding shoes against which a swash or wobble plate arrangement of the compressor acts and which are seated against the first and second part-spherical, pressure-bearing surfaces can also be made correspondingly smaller in size. In fact, typically the sliding shoes in a piston according to the present invention have a weight in the region of 1.5 g whereas those for use in conventional aluminium piston foot portions have a weight in the region of 7.0 g.

[0038] The *p**v* value is relevant here as preferably the piston according to the invention is used in a compressor with a the wobble plate arrangement that performs only small rotational movements so that the product of the surface pressure and the velocity is small. Such a wobble plate arrangement comprises a wobble plate that has two degrees of rotary freedom so that it can rotate jointly with the swash plate and rotate relative to the swash plate. A consequence of the *p**v* value being small is that the hemi-spherical sliding shoes can be made with small dimensions, mainly taking into account only the surface pressure. The size of the sliding shoes also determines the size of the complementarily formed part-spherical, pressure-bearing surfaces provided in the foot portion, which as indicated above can be made significantly smaller than those in an aluminum foot portion, thus reducing the machining operation time required to produce them with consequent cost savings.

[0039] Second, as the foot portion of the piston 1 must be dimensioned so that it is capable of withstanding the forces which it must carry without deformation or cracking, the capability of making it from steel rather than aluminum enable its dimensions to be kept to a minimum. In this regard, the dimensions of a steel foot portion can be made considerably smaller than an equivalent foot portion made of aluminum in terms of width, length, and depth. The depth of the foot portion relates to the degree to which the foot portion protrudes radially beyond the cylindrical portion.

[0040] Third, the use of an aluminum cylindrical portion is also advantageous because they are lighter in weight than steel cylindrical portions and can, in the present invention, be made hollow. In addition, because it is advantageous to use a cylinder block made of aluminium for similar weight-saving reasons, the use of a piston with a cylindrical portion made of aluminium means that both the cylindrical portion and the cylinder bore in which it reciprocates exhibit the same tribological behaviour. In particular, it is advantageous in compres-

sors used in vehicle air conditioning systems with pistons without rings for there to exist a slight gap between the cylindrical portion of the piston and the cylinder bore to permit a slight leakage of gas to occur into the compressor casing. If the cylindrical portion and the cylinder bore are made of the same material, they have the same coefficient of thermal expansion so that the gap will be constant along the length of the cylindrical portion and under all thermal operating conditions.

[0041] A further advantage arises when the cylinder block and the cylindrical portion are made of the same material because they both exhibit the same modulus of elasticity. The forces transmitted to the piston during use are not exclusively axial forces but comprise a substantial radial component, which is dependent on the angle of inclination of the swash or wobble plate arrangement. The radial force component causes contact to occur between the cylindrical portion of the piston and the cylinder bore that leads to wear in the bore and consequent compression and wear of the cylindrical portion of the piston. If both of these components are made of the same material and therefore with the same modulus of elasticity the effects of the wear can be more controlled.

[0042] The present invention will now be described by way of example with reference to the accompanying drawings, in which:-

Fig. 1 is a perspective side view of a conventional aluminum piston

Fig. 2 is a perspective view similar to that of Fig. 1 but of a piston according to the present invention;

Fig. 3 is a partial longitudinal cross-sectional view of a piston according to the present invention in situ in a swash plate compressor;

Fig. 4 is a longitudinal cross-section of the piston shown in Fig. 3;

Fig. 5 is a view similar to that of Fig. 4 but to a smaller scale and showing an alternative means of joining the components of the piston together; and

Fig. 6 is a view similar to that of Fig. 5 but showing another means of joining the components of the piston together and a further modification.

[0043] In all the drawings, the same components or components with the same function have been given the same reference numeral.

[0044] A piston 1 for use in a compressor and as shown in Figs. 2 to 5 the drawings comprises a cylindrical portion 2 at one end and a foot portion 3 at its other end. The foot portion 3 comprises a first part which forms an annular cap 4 joined to an end of the cylindrical portion and bridge 5 which defines a recess 6 that can ac-

commodate a bearing (not shown) for a swash or a wobble plate arrangement of the compressor. On either side of the recess 6, are formed first and second part-spherical, pressure-bearing surfaces 7 and 8 to transmit translational forces to the piston 1 from the swash or wobble plate arrangement. The translational forces transmitted to the first surface 7 (see Fig. 3) are in a direction away from the cylindrical portion 2 in order, in use, to pull the piston out of a cylinder bore of the compressor whereas those transmitted to the second surface 8 are in a direction towards the cylindrical portion 2 in order to push the piston 1 into the bore on the compression stroke of the piston.

[0045] In accordance with the invention, the portions 2 and 3 are made of different materials and have been separately manufactured and have been joined together into a unitary whole to form the piston 1, preferably a high strength steel, by working or by deformation. The cylindrical portion 2 is made of aluminum (Al) and the foot portion 3 is made of steel (St), preferably a high-strength steel. As both the first and second bearing surfaces 7 and 8 are formed in the steel foot portion, their surface areas can be made of commensurate size with one another and also significantly smaller than the cross-sectional surface area of the cylindrical portion 2.

[0046] As indicated above, if the relative sizes of the first and second pressure-bearing surfaces 7 and 8 are compared to those of a conventional solely aluminium piston, as shown in Fig. 1, in which comparable parts have been given the same reference numerals but with a suffix 'A', it can be seen that they are approximately 50% smaller. Also, the width W, length L, and depth D of the foot portion are considerably smaller than those (WA, LA, DA) of the foot portion in the conventional piston.

[0047] As previously explained, in a swash plate compressor 20, as shown in Fig. 3, comprising a wobble plate arrangement 21 wherein the wobble plate 22 of the arrangement has two degrees of rotary freedom so that it can rotate jointly with a swash plate 23 and also rotate relative to the swash plate 23, the size of the hemispherical sliding shoes 24 and 25 can be considerably reduced. This means, as indicated above, that the first and second pressure-bearing surfaces 7 and 8 in contact with the sliding shoes 24 and 25 respectively are also reduced in size. This has considerable advantages for the compressor 20 because the inner and outer diameters, ID and OD respectively, of the compressor housing 26 can also be reduced with consequent cost and space savings.

[0048] Making the piston 1 in at least two portions 2 and 3 has the considerable further advantage that it enables the most suitable form of manufacture to be used for each part. In particular, the cylindrical portion 2 of the piston 1 is best produced using turning machinery as accuracy of its cylindrical surface is most important. In contrast, the foot portion 3 is best produced using milling machinery because of the various surfaces, such as the

surfaces 7 and 8, which must be accurately defined. Also, the foot portion 4 can be manufactured initially with a relatively accurate shape by casting or forging before being subject to a finishing machining operation to define the various surfaces accurately. Such machining is much more difficult to accomplish if the piston 1 is manufactured as a unitary whole rather than in the various parts as proposed by the present invention. The part or parts of the piston made from steel, which is primarily the foot portion 3 but may also include an anti-rotation locking means (see below) may also be surface hardened prior to being joined to the other piston parts to form the finished piston 1.

[0049] In a first embodiment, as shown in Figs. 3 and 4, the cylindrical portion 2 comprises a hollow aluminum cylinder which is closed at its head 9 but closed by the annular cap 4 of a steel foot portion 3 at its other end. In this embodiment, the foot portion 3 is provided with a skirt 10 that is force- or press-fitted into the hollow cylindrical portion 2 so that the foot portion 3 is joined to the cylindrical portion 2 around the cap 4. Alternatively or in addition, the foot portion 3 may be bonded to the cylindrical portion 2, for example by fusion, welding, brazing or by application of a suitable adhesive or cementitious material in the joint between the annular cap 4 and the end of the cylindrical portion 2.

[0050] In a second embodiment, as shown in Fig. 5, the skirt 10 of the foot portion 2 comprises a slotted spring member defining axial slots 11 which is force fitted into the hollow cylindrical portion 2 and thereafter exerts outward radial forces on the cylindrical portion 2 to retain itself in position.

[0051] As a result of the differences in the coefficient of thermal expansion between the different materials used for the parts of the piston 1, such as the cylindrical portion 2 and the foot portion 3, it is preferable in both of the above embodiments if, after these two portions have been force fitted together, they can be integrated more closely by some form of metallurgical bonding process. The most suitable bonding process are a friction fusion process or a magnetic pulse welding. Both of these processes are highly suitable for joining a component made of aluminum to one made of steel because they can cope with high loads.

[0052] Friction fusion is not friction welding in the conventional sense. In this process rotation-symmetric aluminum and steel components of tubular or full cross-sections are joined using friction at a temperature below the melting point of aluminum while the aluminium component is still solid but in a plasticized state. When in this state, the two components can then be joined by force. The fact that this process does not rely on a molten phase between the two components makes it highly suitable for a piston, which after joining must retain with some accuracy the previously machined surfaces of the two components. The effective friction time, from component contact to the halting of the rotational movement, may only amount to 0.3 seconds, which corresponds to

between 1 and 4 component revolutions.

[0053] The joint between the steel skirt 10 of the foot portion 3 and the inner surface defined by the aluminum cylindrical portion 2 of a piston 1 as described above is eminently suitable for being joined by a friction fusion process. The aluminum cylindrical portion 2 expands during plasticization and fuses solidly on the inner steel skirt 10.

[0054] Tests have been carried out using various aluminum alloys and 42CrMo4 steel. Good results were found with AlMgSi1 aluminum, as would be expected, but surprisingly good results were also found with AHS-2 and AlCuMg2 aluminum alloys, where the tensile strength of the steel/aluminum joints were found respectively to be 220 N/mm² and 336 N/mm².

[0055] Also, friction fusion permits materials other than aluminum and steel to be used for the portions 2 and 3. For example, friction fusion can be used to join components made of austenitic and ferritic steel, and to produce joints between ferrous and non-ferrous materials, such as steel and any of the following materials: aluminum, copper, lead, nickel-based alloys, metal carbides, magnesium, tungsten, and zirconium oxide. Joints between non-ferrous metals are also possible, for example between aluminum and copper. Frictionally fused joints between other material combinations, in particular non-metal materials, are currently being developed which may also be suitable for use in a piston according to the present invention, for example ceramic-metal joints.

[0056] As indicated above, an alternative to friction fusion is magnetic pulse welding. This is a cold welding process that again offers the advantage of not requiring a molten phase between the two components, which can again be of different materials. Also, the welded joint is stronger than the weaker of the two materials being joined.

[0057] In magnetic pulse welding, the welded joint is formed between two overlapping tubes, one being at least partially inserted into the other. It will be appreciated that it is therefore suitable for an arrangement as shown in Fig. 5 where the steel skirt 10 of the foot portion 3 is inserted into the hollow aluminum cylindrical portion 2 of the piston 1. The process involves the discharge of a very high current, which may be up to 2 million amps in some instances, in an extremely short period of time, for example in less than 100 microseconds, through a coil that surrounds the components to be welded. The coil does not contact the components but the discharged current induces a very high eddy current in the outer component, in this case the aluminum cylindrical component 2, which as a result collapses and welds itself to the inner component, in this case the skirt 10. It will be appreciated that both the current in the coil and the eddy current in the outer component create very strong magnetic fields but in opposing directions so that they repel one another. As the coil is stronger than the cylindrical portion 2, the portion 2 moves away from the coil at a

high velocity, which is above its elastic limit, so that it becomes plastic and as a result collapses onto the inner tube to form the welded joint. The actual welding process last less than 100 microseconds and as a gap is needed between the components for the process to work, tight tolerances between the skirt 10 and the cylindrical portion 2 are not required.

[0058] Magnetic pulse welding is a cold process because it happens so rapidly. As a result, the components are heated to no more than 30°C, which is too low to cause any degradation of the metals involved. Also, the welded joint becomes the strongest part of the assembly. It can be used with any material that is conductive and is therefore eminently suitable to weld aluminum to steel. However, many other dissimilar and similar metals can be successfully welded, as well as the joining of metals to non-metals, where a metallurgical bond is not required, for example a ceramic/metal joint as indicated above with reference to the friction fusion process.

[0059] Friction welding could also be used to join a hollow or solid cylindrical portion 2 to the cap 4 of a foot portion 3, each defining a complementary flat, cross-section surface 13, as shown in Fig. 6. In this case the two flat, apposed surfaces 13, perpendicular to the longitudinal axis of the piston, are joined as shown. Friction welding can cope with high loads and also has the advantage that it does not rely on a molten phase between the two components. The join between the annular cap 4 of the foot portion 3 and the annular edge defined by the cylindrical portion 2 of a piston 1 is eminently suitable for being welded by a friction welding process, small beads (not shown) forming in the process on the inside, if the cylinder is hollow, and on outside of the joint.

[0060] Fig. 7 shows a different method of joining the cylindrical portion 2 to the foot portion 3 in which the skirt 10 of the foot portion 3 and the interior cylindrical surface of the hollow cylindrical portion 2 are provided with complementary screw threads 12 so that the two portions 2 and 3 can be screwed together. Alternatively, the annular cap 4 and the cylindrical portion 2 may be tapped in order that the two portions 2 and 4 can be joined together by the use of mechanical fasteners, such as screws.

[0061] A piston according to the invention can also be further modified, as also shown in Fig. 7, by the addition of an additional part 14 comprising an anti-rotation lock means located between the foot portion 3 and the cylindrical portion 2. The lock means comprises a ring 14 provided with at least one and preferably two lateral projections 15, which may comprise symmetrical wings, that support the piston 1 against an adjacent wall surface of a casing of the compressor and thereby inhibit rotation of the piston about its longitudinal axis. The projections 15 need not be made excessively thick as they will not be subjected to bending moments because they project outwards from the main body of the piston 1. This helps to keep the overall weight of the piston 1 low.

[0062] The ring comprising the lock means 14 is preferably fitted to the foot portion 3 of the piston 1 in the

same manner as the cylindrical portion 2. In the illustrated example, the inner annular face of the ring 3 is also provided with a screw thread in order that it can be screwed onto the skirt 10 of the foot portion 3. Alternatively, it could be force fitted on to a slotted spring skirt 10 prior to the cylindrical portion 2, as described above with reference to Fig. 5, and, if necessary, thereafter friction fused to both the cylindrical and foot portions 2 and 3.

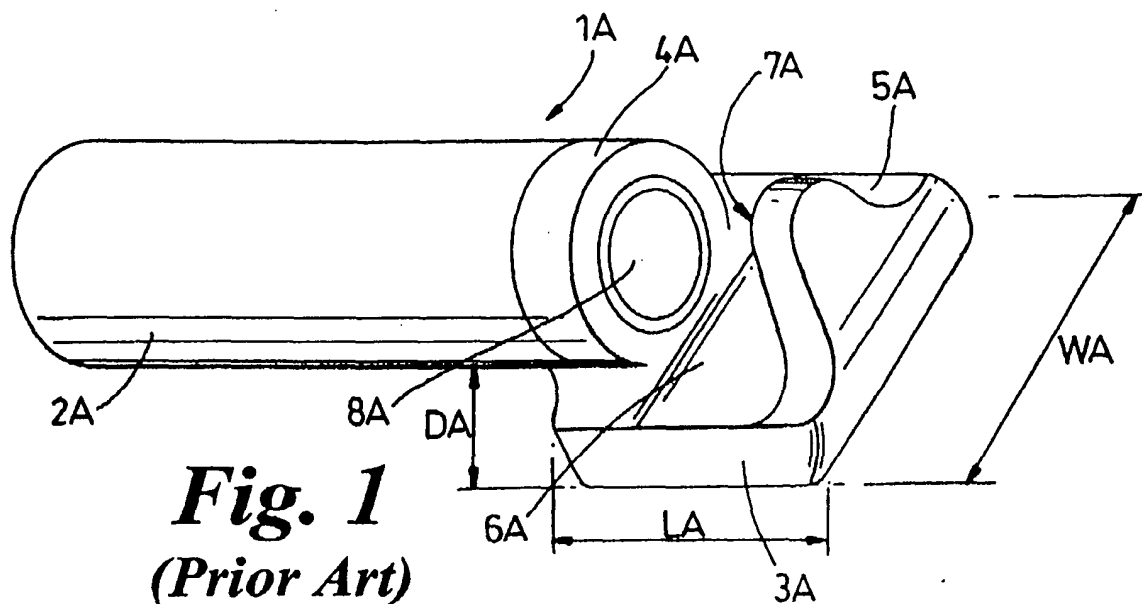
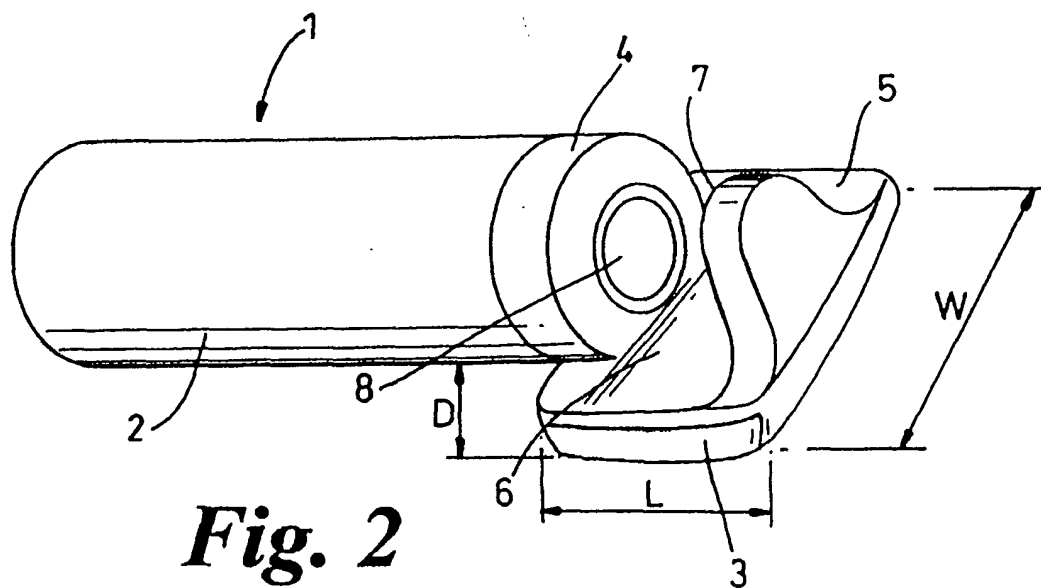
[0063] The ring 14 can be made of either aluminium or steel but should preferably be made of the same material as the casing of the compressor in order to reduce wear between those parts of the ring 13, such as the projections 15, which will contact the surface of the casing. In any event, in order to keep frictional forces between the foot portion 3 and the casing to a minimum, at least the foot portion 3 and, if provided, the ring 14 can be provided with a friction-reducing coating, such as a polytetrafluoroethylene (PTFE) coating or an anti-friction lacquer coating.

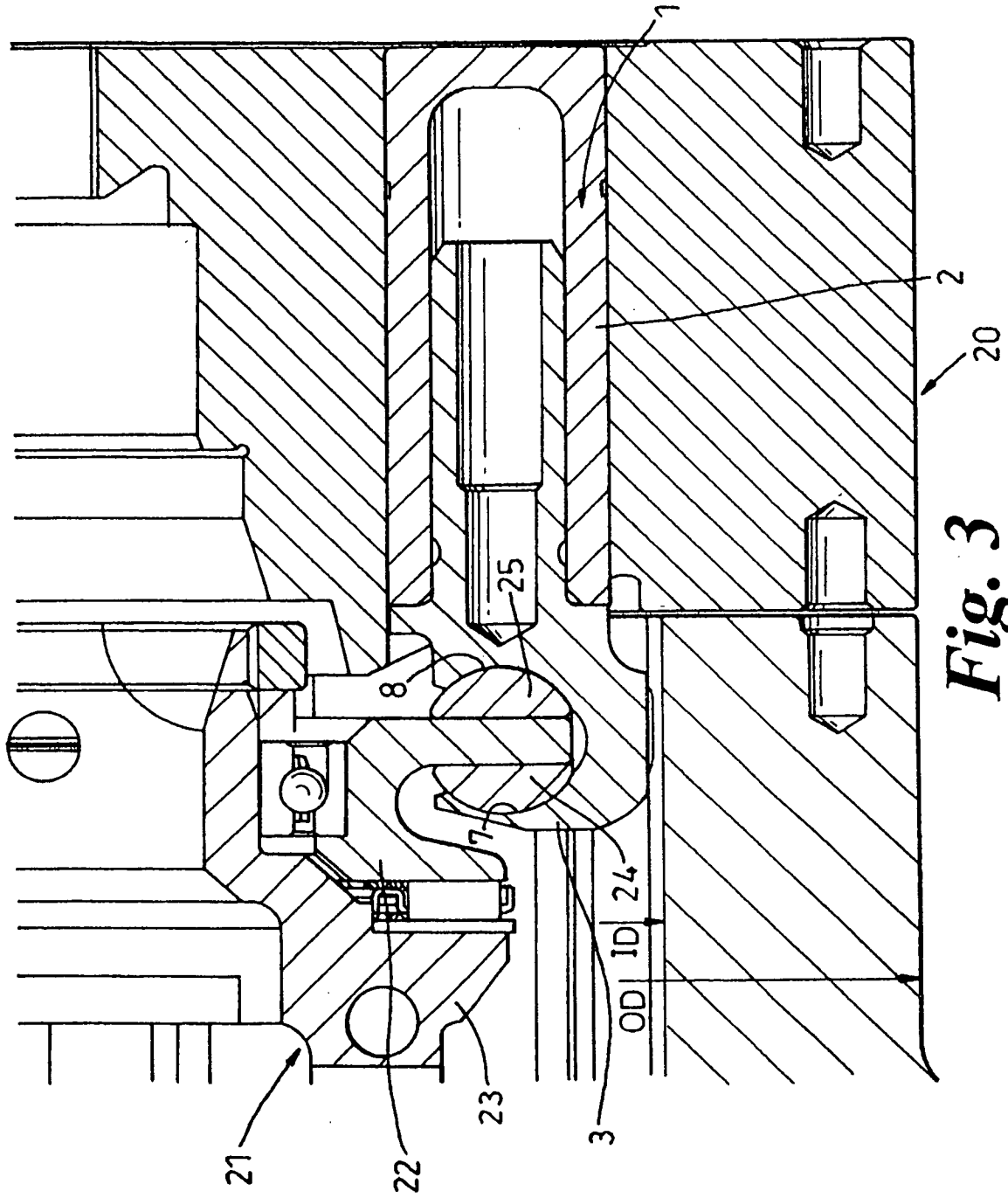
Claims

1. A piston (1) for use in a compressor for a vehicle air conditioning system comprising a cylindrical portion (2) at one end and a foot portion (3) at its other end, which foot portion (3) can accommodate a bearing for a swash or wobble plate arrangement (21) of a compressor (20),
characterised in that
the piston (1) has been made from at least two individual parts which have been joined together after separate manufacture, the cylindrical portion (2) and the foot portion (3) being two of these parts and being made of different materials from one another.
2. A piston (1) as claimed in Claim 1,
characterised in that
at least one of the parts (2, 3) is made from steel and at least one other is made from a lighter-weight metal.
3. A piston (1) as claimed in Claim 2,
characterised in that
the one part made from steel is made from a high-strength steel and the other part is made from aluminium.
4. A piston as claimed in Claim 2 or Claim 3,
characterised in that
the part made from steel has been surface hardened.
5. A piston (1) as claimed in any of Claims 1 to 4,
characterised in that
the cylindrical portion (2) is made for aluminum and the foot portion (3) is made from steel.

6. A piston (1) as claimed in any of Claims 1 to 5,
characterised in that
it comprises only two parts in the form of the cylindrical portion (2) and the foot portion (3) which are joined together after separate manufacture.
7. A piston (1) as claimed in any of Claims 1 to 5,
characterised in that
a part comprising an anti-rotation lock means (13) is located between the foot portion (3) and the cylindrical portion (2).
8. A piston (1) as claimed in Claim 7,
characterised in that
the anti-rotation locking means (13) comprises a ring provided with a radial projection (14).
9. A piston (1) as claimed in any of Claims 1 to 8,
characterised in that
the cylindrical portion (2) is hollow.
10. A piston (1) as claimed in Claim 9,
characterised in that
the foot portion (3) comprises an annular cap (4) which closes an open end of the hollow cylindrical portion (2) when joined thereto.
11. A piston (1) as claimed in Claim 9 or Claim 10,
characterised in that
the foot portion (3) comprises a skirt (10) which is fitted inside the hollow cylindrical portion (2).
12. A piston (1) as claimed in any of Claims 1 to 11,
characterised in that
the foot portion (3) defines a recess (6) into which a swash or wobble plate arrangement can extend.
13. A piston (1) as claimed in Claim 12,
characterised in that
the foot portion (3) defines a part-spherical, pressure-bearing surface (7) on a side of the recess (6) opposite to that adjacent the cylindrical portion (2), which pressure-bearing surface (7) transmits translational forces to the piston (1) in a direction away from the cylindrical portion (2).
14. A piston (1) as claimed in Claim 13,
characterised in that
the foot portion (3) defines a second part-spherical, pressure-bearing surface (8) on a side of the recess (6) adjacent the cylindrical portion (2), which pressure-bearing surface (8) transmits translational forces to the piston (1) in a direction towards the cylindrical portion (2).
15. A piston (1) as claimed in Claim 14,
characterised in that
the second part-spherical pressure-bearing surface (8) has a surface area which is substantially smaller than the cross-sectional surface area of the cylindrical portion (2).
16. A piston (1) as claimed in Claim 14 or Claim 15,
characterised in that
the second part-spherical, pressure-bearing surface (8) has a surface area that is commensurate with that of the first part-spherical, pressure-bearing surface (7).
17. A piston (1) as claimed in any of Claims 1 to 16,
characterised in that
it comprises two parts (2, 3) which have been joined together by force fitment.
18. A piston (1) as claimed in any of Claims 1 to 17,
characterised in that
it comprises two parts (2, 3) which have been bonded together to integrate the two parts into a unitary whole.
19. A piston (1) as claimed in Claim 18,
characterised in that
the two parts (2, 3) have been bonded together by the use of an adhesive material applied between the two parts (2, 3).
20. A piston (1) as claimed in Claim 19,
characterised in that
the adhesive material comprises a cementitious material.
21. A piston (1) as claimed in Claim 18,
characterised in that
the two parts (2, 3) have been joined together by brazing.
22. A piston (1) as claimed in Claim 18,
characterised in that
the two parts (2, 3) have been joined together by a friction fusion process.
23. A piston (1) as claimed in Claim 18,
characterised in that
the two parts (2, 3) have been joined together by a welding process.
24. A piston (1) as claimed in Claim 23,
characterised in that
the two parts (2, 3) have been joined together by magnetic pulse welding.
25. A piston (1) as claimed in any of Claims 1 to 17,
characterised in that
it comprises two parts (2, 3) which are joined together by a mechanical means (12).

26. A piston (1) as claimed in Claim 25,
characterised in that
the two parts (2,3) are joined together by a threaded engagement (12).
27. A piston (1) as claimed in Claim 25,
characterised in that
the two parts (2, 3) are joined together by mechanical fasteners.
28. A piston (1) as claimed in any of Claims 1 to 27,
characterised in that
it comprises two parts (2, 3) which have been joined together and which have subsequently been at least partially coated with a friction-reducing coating.
29. A piston (1) as claimed in any of Claim 28,
characterised in that
the coating comprises a polytetrafluoroethylene (PTFE) coating or an anti-friction lacquer coating.
30. A swash or wobble plate compressor (20) for a vehicle air conditioning system comprising a piston (1) as claimed in any of Claims 1 to 29.
31. A compressor (20) for a vehicle air conditioning system comprising a drive shaft, a swash or wobble plate arrangement (21) operatively connected to the drive shaft, a piston (1) with a cylindrical portion (2) at one end and a foot portion (3) at its other end, a cylinder in which the cylindrical portion (2) can be reciprocated, and a bearing (24, 25) accommodated in the foot portion (3) that cooperates with the swash or wobble plate arrangement (21) to reciprocate the piston (1) as the drive shaft rotates,
characterised in that
the piston (1) has been made from at least two individual parts (2, 3) which have been joined together after separate manufacture, the cylindrical portion (2) and the foot portion (3) being two of these parts and being made of different materials from one another.
32. A compressor (20) as claimed in Claim 31,
characterised in that
it comprises a wobble plate arrangement (21) comprising a swash plate (23) on which a wobble plate (22) is rotatable mounted.
33. A compressor (20) as claimed in Claim 32,
characterised in that
the wobble plate (22) has two degrees of rotary freedom so that it can rotate jointly with the swash plate (23) and rotate relative to the swash plate (23).
34. A compressor (20) as claimed in any of Claims 31 to 33,
- characterised in that**
it has been designed for the compression of CO₂.
35. A compressor (20) as claimed in any of Claims 31 to 33,
characterised in that
it has been designed for the compression of R134A.





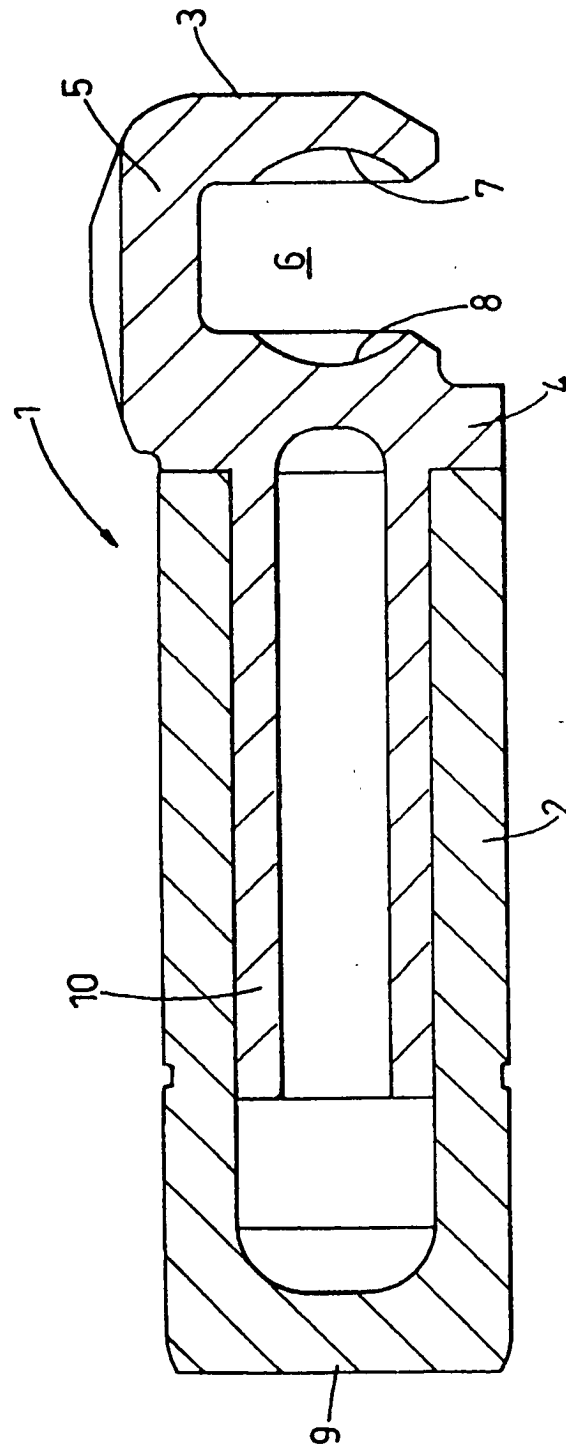


Fig. 4

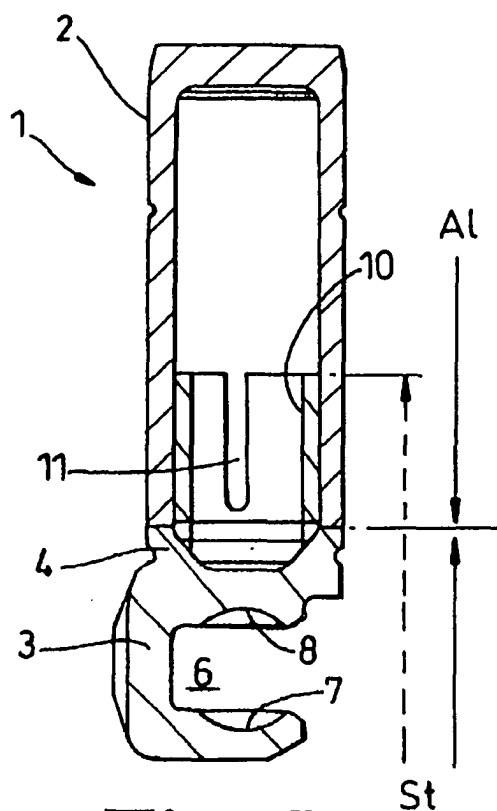


Fig. 5

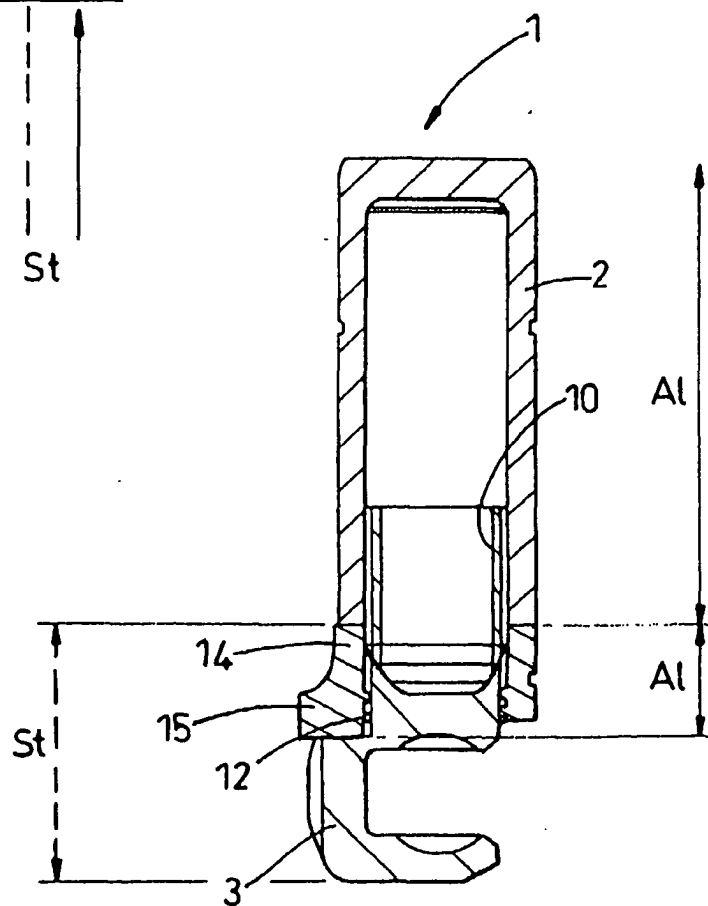


Fig. 7

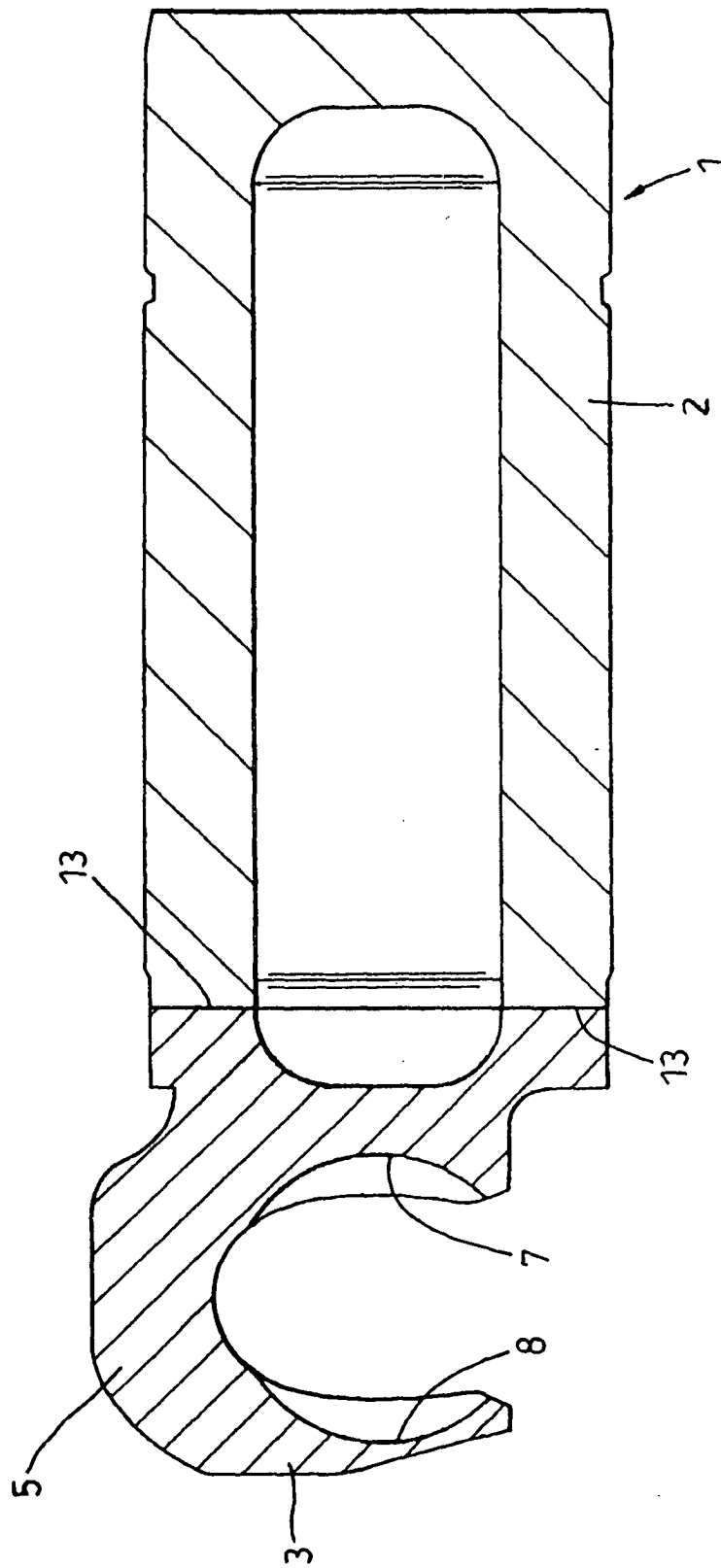


Fig. 6



European Patent
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EUROPEAN SEARCH REPORT

Application Number
EP 02 01 6798

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			F04B
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 13 January 2003	Examiner Ingelbrecht, P
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons</p> <p>& : member of the same patent family, corresponding document</p>			

EPO FORM 1503 03/82 (P04C01)

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EP 02 01 6798

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13-01-2003

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