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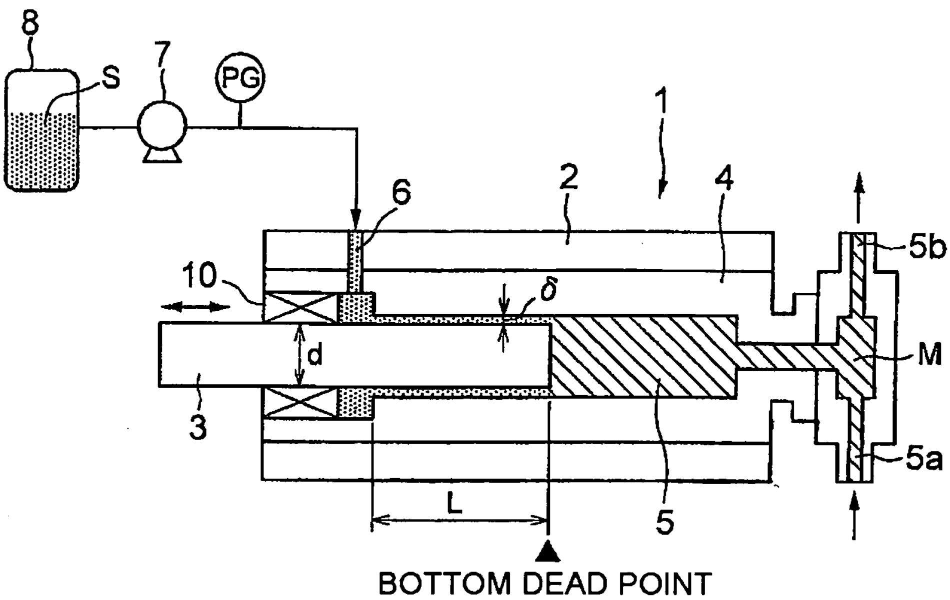
(54) **RECIPROCATION PRESSURE INTENSIFIER**

(57) A reciprocating pressure intensifier that compresses compression-targeted fluid into 20MPa to 400MPa by reciprocation of a piston plunger 3. In the reciprocating pressure intensifier, lubricating oil for axial sealing is injected by a lubricating-oil injection pump 7 into a gap between the piston plunger 3 and a cylinder liner 4 into which the piston plunger is inserted. In order to axially-seal the lubricating oil in the gap, the backward end of the piston plunger 3 is provided with a sealing member, and forward end of the piston plunger 3 is provided with no sealing member adjacent to the compression room.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a reciprocating pressure intensifier suitably used for compressing fluid used as a raw material etc. in a petrochemical industry. More specifically, the present invention relates to a reciprocating pressure intensifier suitably used as a pressure intensifier in a high pressure polyethylene manufacturing process that is a process for reacting a liquid, such as monomer or an organic solvent, in the form of ultra-high-pressure fluid of 20MPa (mega-Pascal) to 400MPa.

BACKGROUND ART

[0002] In a high pressure polyethylene manufacturing process, reaction of ethylene proceeds in an ultra-high pressure of 20MPa to 400MPa. Thus, in a high pressure polyethylene production plant, a large number of compressors (pressure intensifiers) are used that compress the fluid, which is gas or liquid under the normal temperature and normal pressure, into an ultra-high pressure of 20MPa or above. In order to generate such a high pressure, the reciprocating compressor (reciprocating pressure intensifier) is especially suited, and widely used at the site of petrochemical industry. In the reciprocating compressor, the axial seal of a piston plunger is important, and the source gas is likely to leak from the shaft hole for the piston plunger, and leakage of the source gas to the outside may cause a fire or explosion. In addition, since the source material is in a ultra-high pressure, an advanced technique is needed for the sealing thereof.

[0003] Generally, means for sealing the reciprocating compressor employs a technique for injecting the lubricating oil into the axial seal part of the piston plunger for sealing. For example, Patent Publication-1 describes use of an upright reciprocating compressor, wherein lubricating oil is dripped along the inner wall of the cylinder and received in an oil groove that is formed at the forward end of the piston plunger, to thereby supply the lubricating oil between the piston plunger and the cylinder for performing axial seal of the fluid.

[0004] Patent Publication-2 describes a high-pressure plunger pump wherein the lubricating oil is injected into the gap between the cylinder and the piston plunger, and is sealed within the gap by gaskets disposed at the forward side and backward side of the shaft. In this plunger pump, the gaskets and lubricating oil are used for axial seal of the fluid, and it is recited therein that compression of the fluid is achieved at an ultra-high pressure of about 25MPa or above.

[0005] The above publications and the literature described later include:

Patent Publication-1 -----JP-1987-10482A (FIG. 1);
Patent Publication-2 -----JP-1990-95778A (FIG. 1); and
Non-patent Literature-1 ---- "High-pressure physical properties and tribology of lubricating oil" in Science and Technology of a High Pressure, Vol. 11, No. 2 (2001).

[0006] The present inventor conducted investigation as will be described hereinafter, upon design of the ultra-high-pressure reciprocating pressure intensifier of 20 to 400 MPa for use in the high pressure polyethylene manufacturing process. The compressor described in Patent Publication-1 is capable of sealing the fluid by dripping the lubricating oil under a relatively lower pressure such as in a vacuum pump, for example. However, if this reciprocating pressure intensifier is operated at the ultra-high pressure of 20 to 400 MPa that is needed for compressing the fluid such as monomer or organic liquid, there occurs the problem that the lubricating oil mixes into the compression-targeted fluid, and the fluid leaks from the gap that is sealed by the lubricating oil. Thus, it is difficult to use the same under the above ultra-high pressure.

[0007] The ultra-high pressure compressor described in Patent Publication-2 is capable of performing the seal that endures the ultra-high pressure; however, the gasket quipped adjacent to the compression room is subject to a high pressure from the compression room, and the gasket is largely damaged by the mechanical stress occurring due to the reciprocal movement of the piston plunger, thereby raising the problem of insufficient practical endurance.

[0008] Moreover, the high pressure polyethylene manufacturing process includes the process for copolymerizing together ethylene and comonomer, and some of the comonomer is liable to a polymerization reaction. If a mechanical sealing member, such as the gasket, is used for compressing the comonomer, which is liable to the polymerization reaction, the comonomer may polymerize due to generation of heat at the axial seal part, to thereby cause a trouble. Thus, it is also an important factor to prevent generation of heat at the axial-seal part in the reciprocating pressure intensifier used for the polymerization of monomer.

SUMMARY OF THE INVENTION

[0009] It is an object of the present invention to provide a reciprocating pressure intensifier that has a higher durance and thus a superior long-term axial-seal function, and is capable of removing the side reaction caused by the heat generated in the axial-seal part.

[0010] The present invention provides a reciprocating pressure intensifier including: a cylinder; a piston plunger including a forward end that partitions a compression room in association with a forward end of the cylinder and reciprocates within the cylinder; a suction port that communicates to the compression room and inhales a specific fluid in response to the reciprocation of the piston plunger; and a discharge port that communicates to the compression room and discharges the fluid within the compression room, the reciprocating pressure intensifier further comprising: a sealing device that supports the piston plunger for allowing reciprocation thereof at a backward part of the cylinder, and seals a gap between the cylinder and the piston plunger; a lubricating-oil injection port formed on a part of the cylinder that is ahead of the sealing device and adjacent to the sealing device; and a lubricating-oil injection device that injects lubricating oil into the gap between the cylinder and the piston plunger with a specific pressure, wherein at least an interval between a position that is ahead of the lubricating-oil injection port by a specific distance and the compression room is provided with a uniform gap between the cylinder and the piston plunger, and this gap is provided with no sealing device that seals the lubricating oil.

[0011] In accordance with the reciprocating pressure intensifier of the present invention, due to employment of the configuration wherein the uniform gap is formed between a part of the cylinder that is ahead of the lubricating-oil injection port and the piston plunger, and wherein there is no sealing device provided between the cylinder and the piston plunger for sealing the lubricating oil, this structure without the sealing device between the lubricating oil and the compression room minimizes the risk of heavy load of frequent maintenance work due to short life of the sealing device and possibility of fire accident caused by the heat generated in the sealing device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012]

FIG. 1 is a schematic longitudinal-sectional view showing an example of a reciprocating pressure intensifier according to an embodiment of the present invention.

FIG. 2 is a graph showing the relationship between the seal length (L) of lubricating oil and the leakage of the lubricating oil.

DETAILS OF THE INVENTION

[0013] The principle of the present invention will be described hereinafter, before describing the configuration of the embodiment of the present invention. The present invention is directed to an ultra-high-pressure reciprocating pressure intensifier which is a reciprocating pressure intensifier suitable for obtaining an ultra-high-pressure fluid of 20MPa to 400MPa, wherein lubricating oil is injected into the gap between the outer circumferential surface of a piston plunger that moves forward and backward and a cylinder into which the piston plunger is inserted, and wherein no mechanical sealing device that seals the lubricating oil is provided at the forward side of the piston plunger that is ahead of the injection port of the lubricating oil.

[0014] The mechanism employed in the present invention for axially-sealing the lubricating oil has a structure that has never been known in the conventional technique, and does not include an axial-direction sealing device between the gap to which the lubricating oil is injected and the compression room. The principle that omission of the sealing device in this way does not cause leakage of the lubricating oil toward the inside of the compression room during the suction stroke and that the lubricating oil is not blown backward toward the lubricating-oil injection device, which has a lower pressure than the compression room, by the high-pressure compression force during the compression stroke will be described hereinafter. In the following description, Ps, P and Po represent the suction pressure of the fluid in the reciprocating pressure intensifier, discharge pressure of the fluid, and injection pressure of the lubricating oil, respectively.

[0015] During the compression stroke of the reciprocating pressure intensifier, sealing of the lubricating oil is obtained by a pressure dependency of the lubricating oil, which abruptly increases the viscosity thereof along with the increase of pressure and thus hardly flows, and by application of the force in the direction same as the moving direction of the piston plunger due to the friction between the lubricating oil sealed within the narrow gap and the wall surface of the piston plunger. Such a principle of sealing is not known at all heretofore to the persons skilled in the reciprocating pressure intensifier, and in particular, it is beyond imagination of the skilled persons that this principle applies to the reciprocating pressure intensifier having a discharge pressure of 20 to 400 MPa. In the following description, since a cylinder and a cylinder liner are separately manufactured in the configuration of the embodiment of the present invention, these elements are described as separate pieces. However, these elements may be formed in a unitary body.

[0016] During the compression stroke of the reciprocating pressure intensifier, the fluid pressure rises so that $Po<P$ holds due to the thrust-out movement of the piston plunger, whereby the compression-targeted fluid in the compression

room is on the verge of flow back toward the gap between the cylinder liner and the piston plunger. At this moment, the lubricating oil that has flown into the gap between the cylinder liner and the piston plunger is applied with a large differential pressure generated between the compression pressure P of the ultra-high-pressured fluid that is the compression target and the injection pressure Ps of the lubricating oil. Both the viscosity resistance of the lubricating oil that rises under the existence of the large differential pressure and a large pressure loss attributable to the frictional resistance of the lubricating oil applied by the piston plunger which moves toward the direction that is opposite to the direction in which the fluid is to flow backward prevent the backward flow of the fluid, and thus allow the axial seal of the fluid only by the lubricating oil under the presence of the lubricating-oil injection pressure that is significantly lower than the fluid pressure. Note that if the differential pressure between the ultra-high discharge pressure P of the compression-targeted fluid and the injection pressure Ps of the lubricating oil is lower, this backward flow does not occur due to the lower pressure itself.

[0017] During the suction stroke of the reciprocating pressure intensifier, the internal pressure of the compression room reduces contrary to the compression stroke so that Ps<Po results in some case, whereby the sealed lubricating oil is on the verge of flowing into the compression room. However, a force is applied in the direction opposite to the direction of the inflow of the lubricating oil by the viscosity resistance of the lubricating oil itself and the frictional resistance between the piston plunger that moves toward the direction opposite to the direction in which the lubricating oil is to flow and the lubricating oil, whereby the inflow of the lubricating oil is suppressed.

[0018] If the gap (δ) between the cylinder liner and the piston plunger is larger, or if the δ is larger than 30 μm, for example, the frictional resistance applied by the movement of the piston plunger is insufficiently transferred to a part of the lubricating oil near the wall surface of the cylinder liner, thereby causing a risk that the fluid within the cylinder may flow backward between the wall surface of the cylinder liner and the lubricating oil. Moreover, if the length (L) of the cylinder liner that is axially-sealed by the lubricating oil is shorter, the pressure loss caused by the viscosity resistance of the lubricating oil will be insufficient, which may incur the backward flow of the fluid within the cylinder. Thus, a suitable design of the structure of the gap portion between the cylinder liner and the piston plunger will enable the axial seal by the lubricating oil.

[0019] The present inventor, upon investigating the structure that enables the axial seal of the fluid and lubricating oil, reviewed how the lubricating oil behaves if the lubricating oil exists within the gap (δ) between the cylindrical piston plunger having a diameter of "d" and the cylinder liner disposed on the outer circumferential surface thereof, repeating the analysis and experiments thereof.

[0020] In the above analysis, assuming that a Newton fluid flows in a laminar flow between parallel boards, it may be generally considered that the theoretical formula for the leakage of the lubricating oil is expressed by the following formula:

$$Q = \frac{\pi \times \Delta P \times \delta^3 \times d}{12 \times \mu \times L} \qquad (1)$$

where Q, Δ P, δ , d, μ and L are, respectively, the leakage of the lubricating oil, differential pressure between the injection pressure of the lubricating oil and the internal pressure of the compression room, uniform gap formed between the piston plunger and the cylinder liner, diameter of the piston plunger, viscosity of the lubricating oil upon application of the discharge pressure, and length of a part of the cylinder for which the uniform gap is formed, the length being measured at the position of the bottom dead point of the piston plunger.

[0021] However, it was found that the actual measurements obtained by the experiments do not coincide with the above general theoretical formula in a range of smaller value for the gap δ , and for example, at least in the range of δ <100 μm, in which the speed distribution of the fluid can be deemed uniform, whereby a sufficient correlativity was not acquired even in consideration of the pressure dependency of the viscosity. After performing an additional analysis, it was ascertained that although the formula (1) shows a relationship of the inverse proportion of the seal length L with respect to the leakage of the lubricating oil, the result of analysis of the measurement data proved a relationship of the inverse proportion of the leakage of the lubricating oil with respect to about a square of the seal length L, as shown in FIG. 2. FIG. 2 shows the relationship between the seal length L and the leakage of the lubricating oil in the reciprocating compressor of FIG. 1. FIG. 2 is a graph showing the actual measurement data that was obtained by actually measuring the leakage (litter/day) of the lubricating oil "S" exiting from the forward end of the plunger while changing the pressure (oil injection pressure) at the portion of the lubricating-oil injection port and the seal length L, with the diameter d of the plunger and the δ being unchanged, under the condition that the pressure of the reciprocating compressor is an atmospheric pressure.

[0022] As a result of further investigation of a variety of other conditions, it was found that the mixing amount of the lubricating oil into the product is expressed by the following formula:

$$Q' = \frac{\pi \times (Ps - Po) \times \delta^3 \times d \times 3600}{6 \times \mu \times L^2} \quad (2)$$

where Q', Ps, Po, δ , d, μ and L are the leakage index (m^2/h) of the fluid passing through the gap, suction pressure (Pa) of the fluid in the ultra-high-pressure reciprocating pressure intensifier, injection pressure of the lubricating oil for the axial seal, gap (cm) between the piston plunger and the cylinder liner, diameter (cm) of the piston plunger, viscosity (Pa · s) of the lubricating oil upon application of the sealing pressure, and axial length of the uniform gap which is measured at the position of the bottom dead point, as described before. The suction pressure Ps is around 0 to 0.4 MPa, for example, the injection pressure Po of the lubricating oil depends on the performance of the device and is set at around 0.5<P/Po<4, for example.

[0023] For preventing the influence on the quality of the product even if the lubricating oil mixes into the product gas during the suction stroke of the reciprocating pressure intensifier, the value for Q' is to be maintained, for example, in the range of:

$$-100 < Q' < 0.$$

The upper limit, 0, of Q' is a value corresponding to zero of the mixing amount of the lubricating oil into the product, whereas the lower limit, -100, is a value corresponding to the allowable range of the mixing amount of the lubricating oil into the product. The lower limit depends on the product and the required quality thereof.

[0024] For the compression stroke, the following formula:

$$Q'' = \frac{\pi \times (P - Po) \times \delta^3 \times d \times 3600}{6 \times \mu \times L^2}$$

is introduced wherein the suction pressure Ps of the reciprocating pressure intensifier in the Q' is replaced by the discharge pressure P, whereby the design satisfies the following relationship:

$$\frac{\pi \times (P - Po) \times \delta^3 \times d \times 3600}{6 \times \mu \times L^2} < 30 \quad (3)$$

It was found as a result of a variety of experiments that, in the pressure intensifier for which the value of Q" is selected within the upper limit of $30m^2$/h, the pressure increase and pressure fluctuation that occur in the sealing member that axially-seals the lubricating oil and the lubricating-oil injection device are suppressed to a lower value, and the axial seal can be achieved only by the lubricating oil.

[0025] The fact expressed by the above formula (3) is such that suppression of the value of the left side thereof down to equal to or lower than the limit value so that the above formula (3) holds achieves the advantage that the seal provided by the lubricating oil is not substantially affected by the discharge pressure even during the pressure amplification of the fluid. For example, it was found in some case that when the Q" exceeded the above limit value, a larger pressure increase and a larger pressure fluctuation were observed in the sealing member that sealed the lubricating oil and the lubricating-oil injection device. Such a pressure increase and a pressure fluctuation cause a significant reduction in the lifetime of a pump that is pressuring the fluid by using the lubricating oil.

[0026] The reciprocating pressure intensifier that employs the above configuration is capable of axially-sealing for the piston plunger by using the lubricating oil, and does not employ a technique that axially-seals the gap between the lubricating oil and the fluid by using a mechanical member such as a gasket. Thus, the movement of the piston plunger is smooth, to thereby reduce the abrasion and solve the problem of the reduction in the lifetime accompanied by application of the high pressure onto the mechanical sealing member. Moreover, it can be operated for a long period with stability while facilitating the maintenance thereof during compression of the fluid and transfer of a ultra-high-pressure fluid.

[0027] Hereinafter, the present invention will be further described based on an embodiment thereof with reference to the drawing. FIG. 1 shows the configuration of a reciprocating pressure intensifier according to the embodiment of the present invention. The ultra-high-pressure reciprocating pressure intensifier 1 includes a pressure-proof cylinder 2, in which a receiving hole for installing therein a cylinder liner 4 is formed in the axial direction, wherein the cylinder liner 4 is inserted into the receiving hole to be combined with the pressure-proof cylinder 2.

[0028] The cylinder liner 4 is provided with a liner room that extends in the axial direction and is capable of receiving therein a piston plunger 3 for allowing reciprocation movement thereof, and the piston plunger 3 is inserted in the liner room. Note that the cylinder liner 4 has a configuration for preventing leakage of the compressed fluid M, wherein a minimum gap is formed in association with the piston plunger 3 in the range "L" in which the forward end of the piston plunger 3 is capable of reciprocally moving, and the internal surface thereof is mirror-finished to a higher degree.

[0029] The piston plunger 3, upon intensifying the pressure of the fluid M, is reciprocated by a drive unit (not shown) that is installed separately. The forward end of the cylinder liner 4 (shown as a right side in FIG. 1) is provided with a compression room 5 for compressing the fluid M, and the compression room 5 is provided with a suction port 5a and a discharge port 5b in association, that include therein a check valve.

[0030] A lubricating-oil injection port 6 for injecting sealing-use lubricating oil S is formed at the backward part (shown at the left side in FIG. 1) of the cylinder liner, and the lubricating-oil injection port 6 is coupled to a lubricating-oil reservoir 8 via a lubricating-oil injection pump 7. Typically, a part of the cylinder liner at which the lubricating-oil injection port 6 is formed has a larger diameter than the remaining part to provide a larger gap between the piston plunger 3 and the cylinder liner 4 so as to distribute the sealing-use lubricating oil S in the whole circumferential surface of the piston plunger 3.

[0031] A sealing member 10 is installed on a part of the cylinder liner 4 that is located behind the lubricating-oil injection port 6 for preventing backward leakage of the lubricating oil S in the state of the piston plunger 3 being inserted. The sealing member 10 provided on the backward side of the piston plunger 3 may be a mechanical sealing device, such as an ordinary gasket, gland or piston ring. This is because the axial-sealing of the lubricating oil is by far easier to achieve than the axial-sealing of the fluid M that is a reaction raw material used in the ordinary chemical industry etc, and because there is a lower risk of occurring of accident in the event of occurrence of the leakage.

[0032] On the other hand, the fluid M, such as a chemical raw material, is sealed using the lubricating oil S at the forward side of the lubricating-oil injection port 6. Therefore, the gap between the piston plunger 3 and the cylinder liner 4 is reduced in accordance with the above formula (3) and the lubricating oil S is injected into the gap for the sealing, without using a mechanical sealing member, although an auxiliary use thereof is not excluded. This maintains the state of separation between the fluid M and the lubricating oil S without mixing therebetween, whereby the compressed fluid M is sealed by the lubricating oil S. Note that the "auxiliary use of the sealing member" means existence of a large gap between the sealing member and the piston plunger or between the sealing member and the cylinder liner, in a degree of the gap such that the sealing member is not substantially damaged by the reciprocal movement of the piston plunger.

[0033] When the fluid M, such as a chemical raw material, is to be compressed using the reciprocating pressure intensifier 1 of the present invention, the piston plunger 3 is inserted into the cylinder liner 4, and the lubricating oil S is injected from the lubricating-oil injection port 6. The lubricating oil S injected into the gap between the piston plunger 3 and the cylinder liner 4 is preferably maintained so that the discharge pressure of the reciprocating pressure intensifier 1 and the pressure of the lubricating oil S for the axial sealing have therebetween the following relationship:

$$0.5 < P/Po < 4 \qquad (4)$$

where P and Po are the discharge pressure (Pa) of the fluid in the ultra-high-pressure reciprocating pressure intensifier, and injection pressure (Pa) of the lubricating oil for the axial sealing.

[0034] As apparent from the formula (4), the reciprocating pressure intensifier of the present invention can prevent leakage of the fluid M under the condition of $P>Po$, which departs from the common sense, and is capable of axially sealing in the axial direction even in the case of P/Po being as large as $P/Po \fallingdotseq 4$. Except for the case where the obstacle caused by mixing of the lubricating oil S to the process is extremely serious, the condition that P/Po is about 0.5 does not exclude the practical use thereof. Since a smaller P/Po increases the lubricating-oil pressure for the axial sealing to a higher pressure, a high-quality device for increasing the lubricating-oil pressure is needed, whereas a higher P/Po necessitates a larger size for the structure of the pressure intensifier itself. Thus, it is preferable that the design satisfy the formula (3) for this reason again.

[0035] The present invention achieved the design of a new reciprocating pressure intensifier by experiments and analysis, and in order to obtain an ultra-high-pressure reciprocating pressure intensifier having a higher performance, it is desirable to employ the conditions as recited below.

Condition-1: Pressure design

[0036] In the state where the lubricating oil for the axial sealing is introduced within the gap, the outer circumferential surface of the piston plunger 3 that reciprocally moves and the cylinder liner 4 into which the piston plunger 3 is inserted satisfy therebetween the following formula (3):

$$\frac{\pi \times (P - P0) \times \delta^3 \times d \times 3600}{6 \times \mu \times L^2} < 30 \qquad (3)$$

Here, P, Po, δ , d, μ and L are, respectively, the discharge pressure (Pa) of the fluid in the ultra-high-pressure reciprocating pressure intensifier, injection pressure (Pa) of the lubricating oil for the axial sealing, gap (cm) between the piston plunger and the cylinder liner, diameter (cm) of the piston plunger, viscosity (Pa · s) of the lubricating oil in the sealing pressure, and length of a part of the cylinder for which a uniform gap is formed , the length being measured at the position of the bottom dead point of the piston plunger, or in other words, the length (cm) of the cylinder liner for which the lubricating oil performs the axial sealing.

[0037] The pressure characteristic of the viscosity of the lubricating oil S can be measured using a falling-ball high-pressure viscometric technique etc. described in Non-Patent Literature 1. The size of gap, δ , shown in FIG. 1 between the piston plunger 3 and the cylinder liner 4 expands although slightly along with the cylinder liner 4 and pressure-proof cylinder 2 as a whole, due to the pressure of the compressed fluid M. For this reason, it is desirable to correct the value by calculation, wherein the calculation of expansion is performed using the average pressure applied to the cylinder liner 4, which is defined by (discharge pressure of reciprocating pressure intensifier + injection pressure of lubricating oil S for the axial sealing) / 2.

[0038] As the length L of the part of the cylinder liner for which the lubricating oil performs the axial sealing, a length thereof at the moment (bottom dead point) at which the reciprocating pressure intensifier shifts from the suction stroke to the compression stroke is used, for example. Design of the compressor and pump by using the above technique, if employed, allows the compressed fluid M to form a sealing mechanism for the side of fluid M only by the lubricating oil without using a mechanical sealing device, such as a gasket and piston ring. This was ascertained by theoretical analysis and experiments.

Condition-2: Lubricating oil S (viscosity of lubricating oil under the sealing condition)

[0039] The sealing by the lubricating oil in the present invention is targeted to a high-pressure fluid M at 20MPa or above. In this case, the viscosity (Pa · s) of lubricating oil S at the high pressure expressed by the formula (3) can be measured using a falling-ball high-pressure viscometric technique, which is used in the examination of general tribology and described in Non-Patent Literature-1.

[0040] As the lubricating oil used in the present invention, mineral oil, polybutene oil, polyalkylglycol oil etc. are enumerated, without limitation thereto for execution of the present invention. Use of the mineral oil is preferred however, and the kinetic viscosity thereof at the normal pressure and 40°C is preferably in the range of $75mm^2/s$ to $655mm^2/s$.

Condition-3: Materials of the reciprocating pressure intensifier

[0041] As the quality of material for the piston plunger 3 and cylinder liner 4, any material may be used so long as the material has a pressure resistance and an abrasion resistance. Materials that provide a longitudinal elastic modulus of 1.9×10^{11} to 6.5×10^{11} N/m^2 to the outer circumferential surface of the piston plunger 3 and the cylinder liner 4 are preferred, and it is especially preferred to use tungsten carbide (for example, tungsten carbide grain that is sinter-treated using cobalt).

[0042] An example of the actually designed reciprocating pressure intensifier has the specifications as recited hereinafter.

(1) Pump specification:
d= 1.0 μm, L= 5.6cm, and δ = 26.0 μm;
(2) Operating conditions of the pump:
P=280MPa, Po=100MPa, Ps=0.2MPa, and ρ =6.55 μ Pa · s (during application of discharge pressure); and
(3) The value of Q":
Q"=29.0.

[0043] The reciprocating pressure intensifier of the present invention is capable of preventing reduction in the endurance of the pressure intensifier caused by damage on the sealing device, and preventing accidents, such as a fire, occurring due to the side reaction caused by generation of heat in the sealing device. As described above, the configuration wherein the sealing device for the lubricating oil is omitted under presence of a high pressure of 20 to 400 MPa is not known heretofore. Employment of such a structure does not cause any leakage of the lubricating oil toward the outside of the compressor device, and the achievement of the practical advantage that the compressed fluid can be sealed by the lubricating oil departs from the common sense of the skilled persons.

[0044] Although the present invention has been described based on the preferable embodiment thereof, the reciprocating pressure intensifier of the present invention is not limited only to the configuration of the embodiment, and a variety of modifications and alterations from the above embodiment will fall within the scope of the present invention.

Claims

1. A reciprocating pressure intensifier comprising: a cylinder; a piston plunger including a forward end that partitions a compression room in association with a forward end of said cylinder and reciprocates within said cylinder; a suction port that communicates to said compression room and inhales a specific fluid in response to said reciprocation of said piston plunger; and a discharge port that communicates to said compression room and discharges the fluid within said compression room, said reciprocating pressure intensifier further comprising:

   a sealing device that supports said piston plunger for allowing reciprocation thereof at a backward part of said cylinder, and seals a gap between said cylinder and said piston plunger;
   a lubricating-oil injection port formed on a part of said cylinder that is ahead of said sealing device and adjacent to said sealing device; and
   a lubricating-oil injection device that injects lubricating oil into the gap between said cylinder and said piston plunger with a specific pressure,
   wherein at least an interval between a position that is ahead of said lubricating-oil injection port by a specific distance and said compression room is provided with a uniform gap between said cylinder and said piston plunger, and this gap is provided with no sealing device that seals said lubricating oil.

2. The reciprocating pressure intensifier according to claim 1, wherein the relationship of $0.5<P/Po<4$ holds, assuming that P (Pascal: Pa) and Po (Pa) are a discharge pressure of the fluid in said reciprocating pressure intensifier and an injection pressure of said lubricating oil, respectively.

3. The reciprocating pressure intensifier according to claim 2, wherein the gap δ between said cylinder and said piston plunger satisfies $\delta \leqq 30$ μm.

4. The reciprocating pressure intensifier according to claim 3, wherein the discharge pressure P of the fluid is in the range of 20 MPa≦P≦ 400MPa.

5. The reciprocating pressure intensifier according to claim 4, wherein the following relationship:

$$\frac{\pi \times (P - Po) \times \delta^3 \times d \times 3600}{6 \times \mu \times L^2} < 30$$

   holds, assuming that d, δ, L and μ are a diameter of the piston plunger, the uniform gap formed between said piston plunger and said cylinder, a length of a part of said cylinder for which the uniform gap is formed, the length being measured at a position of the bottom dead point, respectively.

6. The reciprocating pressure intensifier according to claim 5, wherein the following relationship:

$$-100 < \frac{\pi \times (Ps - Po) \times \delta^3 \times d \times 3600}{6 \times \mu \times L^2} < 0$$

holds, assuming that Ps is a suction pressure of the fluid in the reciprocating pressure intensifier.

7. The reciprocating pressure intensifier according to any one of claims 2 to 5, wherein the relationship of $Ps<Po<P$ holds assuming that Ps is a suction pressure of the fluid in the reciprocating pressure intensifier.

8. The reciprocating pressure intensifier according to any one of claims 1 to 7, wherein an outer circumferential surface of said piston plunger and said cylinder have a longitudinal elastic modulus that is in a range of 1.9×10^{11} to $6.5 \times 10^{11} N/m^2$.

9. The reciprocating pressure intensifier according to any one of claims 1 to 8, wherein the fluid is a polymerizable monomer or an organic liquid.

FIG.1

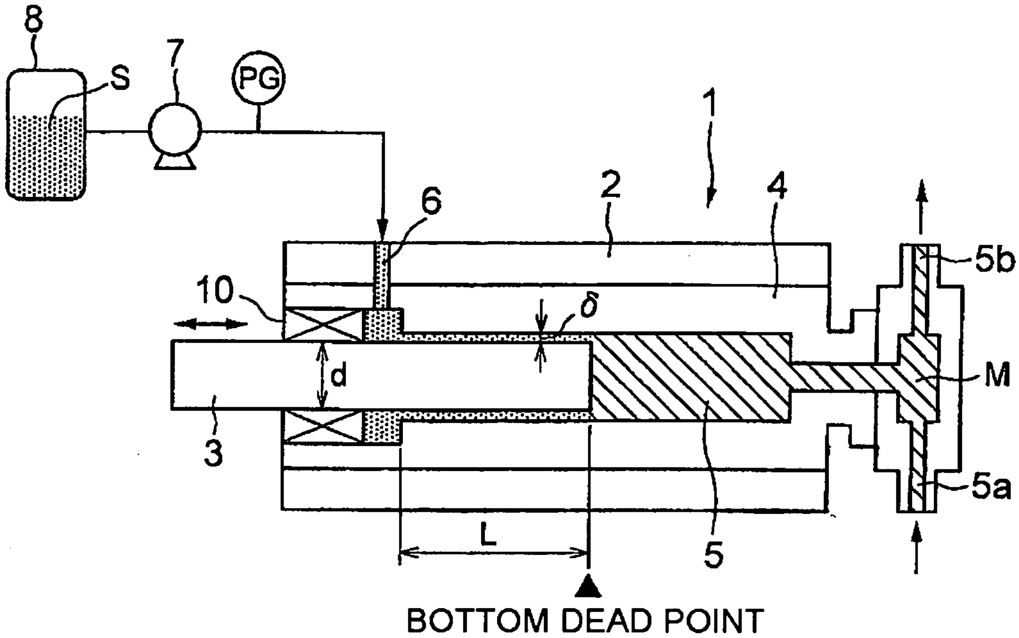
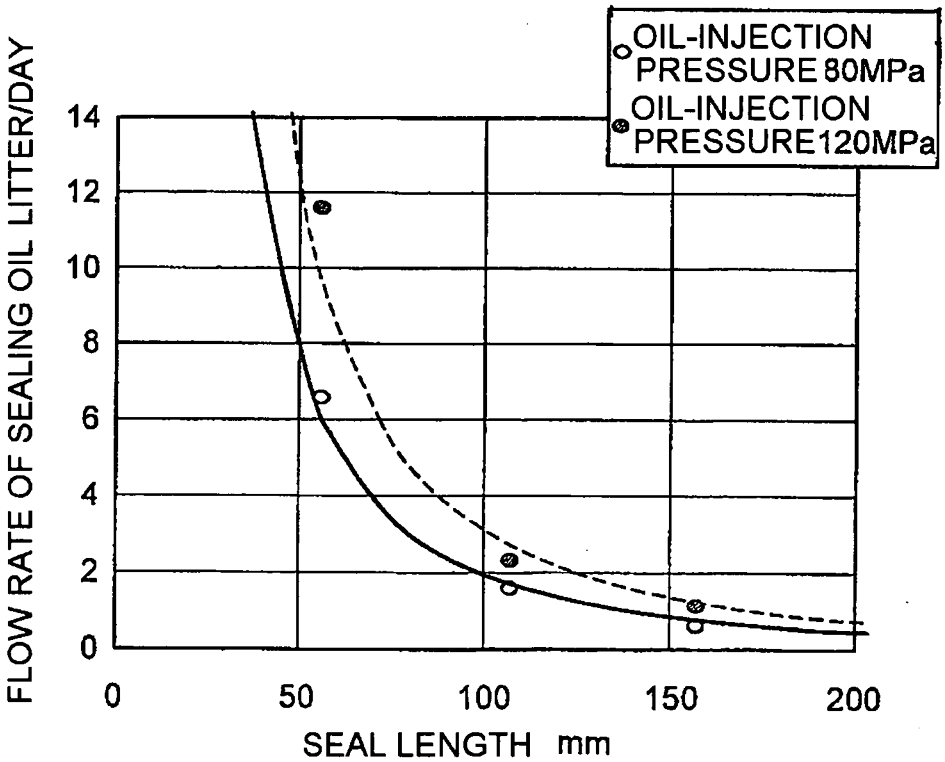

8
S
7
PG
1
2
4
6
10
δ
5b
d
M
3
5a
L
5
BOTTOM DEAD POINT

FIG.2


OIL-INJECTION PRESSURE 80MPa
OIL-INJECTION PRESSURE120MPa
FLOW RATE OF SEALING OIL LITTER/DAY
14
12
10
8
6
4
2
0
0
50
100
150
200
SEAL LENGTH mm

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/062500

A. CLASSIFICATION OF SUBJECT MATTER
F04B39/00(2006.01)i, *F04B53/14*(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04B39/00, F04B53/14, F16J15/40

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2008
Kokai Jitsuyo Shinan Koho	1971-2008	Toroku Jitsuyo Shinan Koho	1994-2008

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 58-183877 A (Nikku Industry Co., Ltd.), 27 October, 1983 (27.10.83), Full text; all drawings (Family: none)	1-4 7-9 5-6
Y A	JP 49-130509 A (Hans Bauer), 13 December, 1974 (13.12.74), Full text; all drawings & DE 2318468 A1	7-9 1

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search 02 October, 2008 (02.10.08)	Date of mailing of the international search report 14 October, 2008 (14.10.08)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2008/062500

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Microfilm of the specification and drawings annexed to the request of Japanese Utility Model Application No. 90319/1983(Laid-open No. 194570/1984) (Toyota Motor Corp.), 24 December, 1984 (24.12.84), Full text; all drawings (Family: none)	1

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 62010482 A **[0005]**
- JP 2095778 A **[0005]**

Non-patent literature cited in the description

- High-pressure physical properties and tribology of lubricating oil. *Science and Technology of a High Pressure,* 2001, vol. 11 (2 **[0005]**