

DESCRIPTION

Title of Invention: PISTON RING AND COMPRESSOR USING THE SAME

Technical Field

[0001]

The present invention relates to a piston ring and a compressor using the same, and in particular, relates to a compressor that reduces wear without degrading performance of a piston ring.

Background Art

[0002]

As a background art in the field of the present technology, Japanese Examined Utility Model Application No. 1-7888 (PTL 1) is known. In this gazette, a structure in which fluid leakage of a piston ring abutment portion is prevented by providing a lip structure below the piston ring abutment portion of a piston ring used in an oilless fluid compressor is described.

Also in Japanese Unexamined Utility Model Application No. 59-21067 (PTL 2), a technology to balance the contact pressure by providing a circumferential groove on an outer circumferential surface of a piston ring for an internal combustion engine and a hole to guide pressure from an inner circumferential surface to the circumferential groove on the outer circumferential surface to prevent wear of the piston ring

is shown.

Citation List

Patent Literature

[0003]

PTL 1: Japanese Examined Utility Model Application No.
1-7888

PTL 2: Japanese Unexamined Utility Model Application No.
59-21067

Summary of Invention

Technical Problem

[0004]

PTL 1 does not describe any structure to balance the sliding portion contact pressure of a piston ring and how to reduce wear of the piston ring is a challenge thereof.

[0005]

PTL 2 does not describe the shape of an abutment portion of a piston ring and how a circumferential groove is provided with respect to the abutment portion. FIG. 32 shows a configuration example of the piston ring of a common internal combustion engine. As shown in FIG. 32, the piston ring for a common internal combustion engine is made of metal such as cast iron and the shape of an abutment is a straight abutment 72 (FIG. 32a) or an angle cut abutment 73 (FIG. 32b) in an oblique shape and because a cylinder and a piston are made of the same

metal, a thermal expansion difference is small and an abutment gap can be set to a few tens of micrometer. Also, oil content is present around the piston ring due to the use for an internal combustion engine and as a result, leakage near the abutment portion including the abutment portion is not so large and the shape of the abutment portion does not affect performance. Therefore, no details of the abutment portion of a piston ring are considered to be provided. However, when used particularly in an oilless compressor, the piston ring is formed from a resin and thus, it is necessary to reduce leakage of an abutment width of a few millimeters, that is, an abutment width of a few tens of times that of the piston ring of an internal combustion engine to prevent the piston ring from creating a strut due to the temperature during operation. Shapes of the piston ring abutment portion corresponding to FIG. 32 and used in an oilless reciprocating compressor are schematically shown by a and b in FIG. 33. As shown in FIG. 33, abutments 76, 77 in FIG. 33 are configured to be larger than the abutments 72, 73 in FIG. 32. The relationship is the same in the case of a step-shaped (step cut) abutment shown in FIG. 3. Therefore, the problem of an oilless reciprocating compressor is to form a circumferential groove on the outer circumferential surface of a piston ring after leakage of the abutment portion is reduced.

[0006]

In view of the above problem, an object of the present

invention is to provide a compressor that reduces wear without causing performance degradation due to leakage from a piston ring abutment portion.

Solution to Problem

[0007]

To solve the above problem, for example, a configuration described in claims is adopted. The present invention includes a plurality of means to solve the above problem and an example thereof is a compressor including a cylinder, a piston, and a piston ring mounted on the piston for sealing between a pressurizing side and a non-pressurizing side in the cylinder to generate a compressed fluid by compressing a fluid in the cylinder by the piston, wherein the piston ring is provided with a first abutment portion overlapping in a step shape in a height direction of the piston ring and a second abutment portion overlapping in a lip shape in a radial direction of the piston ring, an end of the first abutment portion includes a first abutment groove through which an inner circumference and an outer circumference of the piston ring are communicatively connected on the pressurizing side, an end of the second abutment portion includes a second abutment groove through which the inner circumference and the outer circumference of the piston ring are not communicatively connected on the non-pressurizing side with the overlapping lip shape, and a

circumferential groove communicatively connected to the first abutment groove and communicatively not connected to the second abutment groove is provided on the outer circumference of the piston ring.

Advantageous Effects of Invention

[0008]

According to the present invention, a compressor capable of reducing wear of a piston ring sliding surface without causing performance degradation can be provided.

Brief Description of Drawings

[0009]

[FIGS. 1A and 1B] FIGS. 1A and 1B are diagrams showing an outline structure of a reciprocating compressor.

[FIG. 2] FIG. 2 is a diagram showing a sectional shape in which a piston ring is mounted on a conventional piston.

[FIG. 3] FIG. 3 is a diagram showing a common abutment shape (step cut) of the piston ring.

[FIG. 4] FIG. 4 is a diagram showing an A-A cross section in FIG. 3.

[FIGS. 5A and 5B] FIGS. 5A and 5B each show a plan view and a side view of a conventional piston ring provided with a lip shape.

[FIG. 6] FIG. 6 is a perspective view of the piston ring

when FIGS. 5A and 5B are viewed from an inside diameter side.

[FIG. 7] FIG. 7 is a diagram showing a state in which a conventional lip portion is sealed.

[FIG. 8] FIG. 8 is a diagram showing a state in which a sliding surface on the outer circumference of the conventional piston ring is worn out.

[FIG. 9] FIG. 9 is a diagram showing a B-B cross section in FIG. 7.

[FIG. 10] FIG. 10 is a diagram showing a C-C cross section in FIG. 7.

[FIG. 11] FIG. 11 is a diagram showing a D-D cross section in FIG. 7.

[FIG. 12] FIG. 12 is a diagram illustrating a contact pressure balance of the conventional piston ring.

[FIG. 13] FIG. 13 is a diagram showing the structure of the piston ring in Example 1.

[FIG. 14] FIG. 14 is a diagram illustrating the contact pressure balance by a circumferential groove in Example 1.

[FIG. 15] FIG. 15 is a diagram showing the structure of the piston ring in Example 2.

[FIG. 16] FIG. 16 is a diagram showing the structure of the piston ring in Example 2.

[FIG. 17] FIG. 17 is a diagram showing the structure of the piston ring in Example 3.

[FIG. 18] FIG. 18 is a diagram showing the structure of

the piston ring in Example 4.

[FIG. 19] FIG. 19 is a diagram showing the structure of the piston ring in Example 5.

[FIG. 20] FIG. 20 is a diagram showing the structure of the piston ring in Example 6.

[FIG. 21] FIG. 21 is a diagram showing the structure of the piston ring in Example 7.

[FIG. 22] FIG. 22 is a diagram showing the structure of the piston ring in Example 8.

[FIG. 23] FIG. 23 is a diagram showing the structure of the piston ring in Example 9.

[FIG. 24] FIG. 24 is a diagram showing the structure of the piston ring in Example 10.

[FIG. 25] FIG. 25 is a diagram showing the structure of the piston ring in Example 10.

[FIG. 26] FIG. 26 is a diagram showing the structure of the piston ring in Example 10.

[FIG. 27] FIG. 27 is a diagram showing the structure of the piston ring in Example 11.

[FIG. 28] FIG. 28 is a diagram showing a state of the piston on which the piston ring in a cylinder in Example 12 is mounted.

[FIG. 29] FIG. 29 is a diagram showing a relative physical relationship of two piston rings mounted on the piston in Example 12.

[FIG. 30] FIG. 30 is a partial sectional view of the piston

ring in FIG. 28.

[FIG. 31] FIG. 31 is a diagram showing the structure of the piston ring in Example 12.

[FIG. 32] FIG. 32 is a diagram showing a configuration example of the piston ring of an internal combustion engine.

[FIG. 33] FIG. 33 is a diagram showing a configuration example of the piston ring for an oilless reciprocating compressor.

[FIG. 34] FIG. 34 is a diagram showing a configuration example to machine the depth of the circumferential groove of the piston ring in Example 13 with precision.

Description of Embodiments

[0010]

First, the configuration of a reciprocating compressor and a conventional piston ring structure as a premise of the present invention will be described using the drawings.

[0011]

FIGS. 1A and 1B are diagrams showing an outline structure of a reciprocating compressor. FIG. 1A shows an overall configuration diagram and FIG. 1B shows an enlarged view of a compressor main body. In FIGS. 1A and 1B, a motor 2 and a compressor main body 3 are arranged on a tank 1, a compressor pulley 5 is rotated by a belt 4 put on a motor pulley (not shown), the rotation of a crankshaft 6 is converted into reciprocation

by a connecting rod 7, and the air compressed after being sucked in from a suction silencer 11 due to the reciprocation of a piston 8 flows from a discharge opening 12 of the compressor main body to the tank 1 by passing through a pipe (not shown). Here, a piston ring 9 mounted on the piston 8 has a function of sealing between a pressurizing side and a non-pressurizing side inside a cylinder. If the compressor is an oilless reciprocating compressor, the piston ring 9 and a rider ring 10 of the compressor main body are made of a resin such as tetrafluoroethylene resin due to compression without lubricant.

[0012]

FIG. 2 is a diagram showing a sectional shape when the piston ring 9 is mounted on the piston 8. If the compressor is an oilless compressor, the piston ring 9 is made of tetrafluoroethylene resin or the like and has, in contrast to an oiling metal ring, no elasticity in the ring. Thus, a structure to prevent leakage between the piston ring 9 and a sliding surface of a cylinder 13 by providing a back gap on the inside diameter side of the piston ring 9 and guiding an internal cylinder pressure P_c from a top surface gap of the piston ring present originally to a backface of the piston ring 9 to press the piston ring 9 against the inner surface of the cylinder 13 is adopted.

[0013]

On the other hand, the piston ring 9 has an integral shape separated by an abutment portion and can be mounted on the piston due to the abutment portion. In addition, the structure of the abutment portion is devised such that no leakage occurs from the abutment portion when compressed. The most common abutment shape is the step shape (step cut) of abutment portions 14, 15 shown in FIG. 3. In this case, there is no leakage passage directly from above, but a leakage passage is generated, as shown in FIG. 4, in the A-A cross section in FIG. 3 by passing from the backface to the lower portion of the abutment portion and leakage indicated by arrows in FIG. 4 arises, posing a problem of performance degradation.

[0014]

In contrast, as shown in FIGS. 5A and 5B and FIG. 6, a piston ring that reduces leakage by providing a lip shape in the abutment portion on the lower side of the piston ring is known (see, for example, PTL 1). That is, in FIGS. 5A and 5B, FIG. 5A shows the surface to be on the lower side (non-pressurizing side inside the cylinder) when the piston ring is mounted and also shows the shape of the abutment portion on the side face of the piston ring. FIG. 5B similarly shows the surface to be on the upper side (pressurizing side inside the cylinder). Hereinafter, the upper side and the lower side indicate the pressurizing side and the non-pressurizing side inside the cylinder when the piston ring is mounted on the piston.

The piston ring has the abutment portion on the upper side in, as shown in FIG. 5B, a step shape and the abutment portion on the lower side in, as shown in FIG. 5A, a lip shape. FIG. 6 is a perspective view when a lip abutment portion as a lower-side abutment portion and a step abutment portion as an upper-side abutment portion are viewed from the inside diameter side on the lower side. As shown in FIGS. 5A and 5B and FIG. 6, the lip abutment portion is comprised of a lip 21 on the inner side in the radial direction of the piston ring and a lip receiving portion 22 on the outer side.

[0015]

FIG. 7 shows a state in which the lip 21 comes into contact with the lip receiving portion 22 under pressure from the inside diameter side for sealing. FIG. 8 shows a state in which the sliding surface of the outer circumference of the piston ring facing the cylinder is worn out by δ and an abutment portion 25 widens to limits thereof. The wear amount of the outer circumference of the piston ring at this point becomes a limit wear amount δ (that is, the wear amount when the abutment comes off).

[0016]

FIGS. 9 to 11 show B-B to D-D cross sections in FIG. 7 respectively and show that no leakage passage is generated from the piston ring backface in any abutment portion of the piston ring for the piston ring abutment shown in FIG. 4. That is,

FIG. 9 shows the B-B cross section of FIG. 7 and the lip 21 is used for sealing. FIG. 10 shows the C-C cross section of FIG. 7 and the lip 21 and the lip receiving portion 22 are used for sealing. FIG. 11 shows the D-D cross section of FIG. 7 and the lip 21 and the lip receiving portion 22 are also used for sealing.

[0017]

As shown in FIG. 7, the lip shape of the piston ring is such that a lip tip 21a is formed thinner than a lip root 21b. As a result, when the outer circumference of the piston ring 9 is worn out and the abutment widens, the lip tip 21a is easily deformed such that the lip tip 21a is brought into contact with the lip receiving portion 22 to be able to achieve sealing properties.

[0018]

Next, the contact pressure balance of the piston ring will be described using FIG. 12. FIG. 12 shows the pressure balance of a conventional piston ring without a circumferential groove. The internal cylinder pressure P_c acts on the backface of the piston ring 9. On the other hand, the sliding surface of the piston ring has the internal cylinder pressure P_c acting on the upper end thereof and the atmospheric pressure acting on the lower end thereof and thus, the pressure distribution of the sliding surface is, as shown in FIG. 12, a triangular pressure distribution. As a result, an average pressure P_1 of the sliding surface of the piston ring is obtained by dividing the pressure

in a region I by the sliding surface. In this case, the average pressure is obtained as $P_1 = P_c/2$. Therefore, the wear of the sliding surface increases with an increasing contact pressure on the sliding surface and thus, a problem has been how to lower the contact pressure on the sliding surface.

[0019]

Therefore, leakage from the abutment portion of the piston ring can be prevented by adopting a piston ring having a lip shape as shown in FIGS. 5A and 5B and FIG. 6 for the abutment portion, but the challenge has been to reduce wear of the sliding surface of the piston ring by lowering the contact pressure on the sliding surface of the piston ring.

[0020]

Hereinafter, examples of the present invention to solve the above challenge will be described using the drawings.

Example 1

[0021]

FIG. 13 is a diagram showing the structure of a piston ring 30 in the present example. In FIG. 13, the piston ring 30 is provided with a circumferential groove 33 on the outer circumference of the piston ring (sliding surface with the cylinder). The circumferential groove 33 is shown by taking a case when positioned in the center of the piston ring height as an example. Here, the piston ring height refers to the direction parallel to the sliding surface of the piston ring

with the cylinder and the radial direction of the piston ring is called a piston ring thickness.

[0022]

The right side end of the circumferential groove 33 is communicatively connected to an upper abutment groove 34 in the upper portion of the piston ring (pressurizing side in the cylinder) so that a back pressure of the piston ring or internal cylinder pressure can easily be guided to the circumferential groove. Incidentally, a hole may be provided in the circumferential groove 33 so that the back pressure can be guided. The structure in which the hole is provided as described above also applies to other examples described below. The end on the opposite side (left side in FIG. 13) of the circumferential groove 33 is provided up to the neighborhood of a lower abutment groove 35 on the lip receiving portion 32 side of the piston ring, but is not communicatively connected to the lower abutment groove 35. As a result, the compressed air in the cylinder is guided from the upper abutment groove 34 to the circumferential groove 33 without the need to separately machine a communicating hole from the piston ring backface. On the other hand, the opposite side of the circumferential groove 33 is not communicatively connected to the lower abutment groove 35 and thus, performance degradation due to leakage of the air in the circumferential groove can be prevented.

[0023]

Next, FIG. 14 is a diagram illustrating the contact pressure balance by the circumferential groove 33. In FIG. 14, as described above, the internal cylinder pressure P_c is guided into the circumferential groove 33. Thus, the pressure P_c above the circumferential groove 33 acts as a constant pressure and a sliding surface pressure distribution in which the pressure at the lower end of the groove is P_c and the pressure at the lower end of the piston ring is that of the atmosphere is obtained. In this case, the pressure P_c above the circumferential groove 33 and that of the piston ring backface are balanced. Thus, a value P_2 obtained by dividing the pressure in a region II by the sliding surface is the sliding surface contact pressure in the present example and is related with the conventional sliding surface contact pressure P_1 shown in FIG. 12 as $P_2 < P_1$ so that the contact pressure can be reduced by the present example. FIG. 14 is depicted such that the lower end of the circumferential groove is half the piston ring height and in this case, $P_2 = P_1/2$ is obtained and the contact pressure can be reduced by half.

[0024]

The circumferential groove 33 is formed as a groove (in a rectangular shape) having a fixed width in the depth direction. Thus, even if the outer circumference of the ring is worn out, the width of the circumferential groove 33 is maintained constant and so the contact pressure can be balanced in a stable

manner above the circumferential groove 33.

[0025]

Therefore, according to the present example, the wear of the piston ring sliding surface can be reduced by providing a circumferential groove avoiding the abutment portion in the piston ring and balancing the contact pressure of the piston ring without causing performance degradation due to leakage through the abutment portion.

[0026]

The abutment portion of the piston ring 30 in the present example has a shape in which, as shown in FIG. 13, a lip tip 31a and a lip root 31b have substantially the same dimension in thickness and the contact surface of each is formed substantially concentrically. As a result, when the outer circumference of the piston ring 30 is worn out and the lower abutment groove 35 widens, a lip 31 and a lip receiving portion 32 are formed substantially concentrically and thus, the lip 31 has a tip deformed to eliminate the need for sealing, only needs to move by sliding on the backface of the lip receiving portion 32, and has a long contact length due to the line contact as compared with the point contact in the conventional structure so that sealing performance of the abutment portion can be obtained more easily even if the lip tip 31a is thick.

[0027]

Also, by making the lip tip 31a thicker, even when the

piston ring is worn out and the abutment opens like in FIG. 8, the strength near the lip tip portion can be improved.

[0028]

In the present example, as described above, a piston ring is provided with a first abutment portion (step shaped abutment portion) overlapping in a step shape in the height direction of the piston ring and a second abutment portion (lip abutment portion) overlapping in a lip shape in the radial direction of the piston ring in an abutment portion of the piston ring, an end of the first abutment portion includes a first abutment groove (upper abutment groove 34) communicatively connecting the inside and the outside in the radial direction of the piston ring, an end of the second abutment portion includes a second abutment groove (lower abutment groove 35) communicatively non-connecting the inside and the outside in the radial direction of the piston ring with the overlapping lip shape, and a circumferential groove communicatively connected to the first abutment groove and communicatively not connected to the second abutment groove is provided on the outer circumference of the piston ring. In other words, the circumferential groove has one end communicatively connected to the first abutment groove and the other end formed up to just before the second abutment groove. Alternatively, the circumferential groove is provided on the outer circumference by avoiding the second abutment groove.

[0029]

The present example is a compressor including a cylinder, a piston, and a piston ring mounted on the piston for sealing between a pressurizing side and a non-pressurizing side in the cylinder to generate a compressed fluid by compressing a fluid in the cylinder by the piston, wherein the piston ring is provided with a first abutment portion overlapping in a step shape in a height direction of the piston ring and a second abutment portion overlapping in a lip shape in a radial direction of the piston ring in an abutment portion thereof, an end of the first abutment portion includes a first abutment groove through which an inner circumference and an outer circumference of the piston ring are communicatively connected on the pressurizing side, an end of the second abutment portion includes a second abutment groove through which the inner circumference and the outer circumference of the piston ring are not communicatively connected on the non-pressurizing side with the overlapping lip shape, and a circumferential groove communicatively connected to the first abutment groove and communicatively not connected to the second abutment groove is provided on the outer circumference of the piston ring. Accordingly, the wear of the sliding surface of the piston ring can be reduced without degrading sealing performance so that a compressor whose life can be prolonged can be provided.

Example 2

[0030]

Next, the configuration of the piston ring according to the present example will be described using FIGS. 15 and 16. The same reference signs are attached to the same components as those in Example 1 and the description thereof is omitted.

[0031]

In the present example, as shown in FIG. 15, the piston ring height direction of the circumferential groove 33 is moved downward, that is, to the non-pressurizing side and the circumferential groove 33 is formed within the piston ring height where the lower abutment groove 35 exists. Accordingly, as described with reference to FIG. 14, the range in which the contact pressure of the fixed pressure P_c above the circumferential groove 33 is increased with a lower end of the circumferential groove 33 so that the contact pressure can further be reduced. In addition, a communicating groove 36 connecting the upper abutment groove 34 and the circumferential groove 33 is provided in the upper abutment portion to further simplify machining. As a result, the circumferential groove 33 is provided up to near the lower abutment groove 35 and therefore, the contact pressure of the abutment portion can further be reduced.

[0032]

When a problem of lip strength arises, as shown in FIG. 16, the right end of the circumferential groove may be stopped

near the upper abutment groove 34. Accordingly, the strength of the lip portion can be secured.

[0033]

In the present example, as described above, the contact pressure can further be reduced by further providing a communicating groove that sets the piston ring height direction of the circumferential groove to within the height of the lower abutment groove and communicatively connects the circumferential groove and the upper abutment groove.

Example 3

[0034]

Next, the configuration of the piston ring according to the present example will be described using FIG. 17. The same reference signs are attached to the same components as those in Examples 1 and 2 and the description thereof is omitted.

[0035]

In the present example, as shown in FIG. 17, a circumferential groove 33-2 is formed by, like in FIG. 15, lowering the piston ring height direction to reduce the average contact pressure. In addition, a circumferential groove 33-1 is provided in the upper abutment portion. The circumferential groove 33-1 is communicatively connected to the upper abutment groove 34 and a communicating groove 37 that communicatively connects the circumferential grooves 33-1, 33-2 is provided. The reason for providing the circumferential groove 33-1 is that

if the piston ring is high, the pressure P_c above the circumferential groove 33-2 may not be constant with the circumferential groove 33-2 alone due to the height of the piston ring above the circumferential groove 33-2 and thus, by providing the circumferential groove 33-1, the pressure above the circumferential groove 33-2 is maintained constant at P_c . Therefore, the contact pressure can also be reduced effectively for a high piston ring. Incidentally, a hole leading from the circumferential groove to the piston ring backface may be provided as a structure to guide pressure to the circumferential groove 33-1 or the circumferential groove 33-2. The number of circumferential grooves is two in the present example, but the contact pressure may still be made more uniform by providing still more circumferential grooves.

[0036]

According to the present example, as described above, the contact pressure can be reduced effectively also for a high piston ring by providing a plurality of circumferential grooves in the piston ring, wherein both ends of a circumferential groove on the pressurizing side are communicatively connected to an upper abutment groove and a circumferential groove on the non-pressurizing side is not communicatively connected to a lower abutment groove, and connecting a circumferential groove on the pressurizing side and a circumferential groove on the non-pressurizing side by a communicating groove or providing

a hole in a circumferential groove on the pressurizing side to communicatively connect the circumferential groove to the backface thereof.

Example 4

[0037]

Next, the configuration of the piston ring according to the present example will be described using FIG. 18. The same reference signs are attached to the same components as those in Examples 1 to 3 and the description thereof is omitted.

[0038]

In the present example, as shown in FIG. 18, a depth E1 of the circumferential groove 33 is configured so as to satisfy $E1 > \delta$, where δ is the limit wear amount of the piston ring. The limit wear amount δ shows the sliding surface wear amount at the limit when the sealable lip contact length shown in FIG. 8 is obtained.

[0039]

As a result, the contact pressure can be reduced in a stable manner during the life time of the piston ring so that the wear of the piston ring can be reduced. Also, the state of wear of the piston ring can be checked by checking the depth of the circumferential groove 33 of the piston ring during maintenance and as a result, the time of maintenance can be grasped.

Example 5

[0040]

Next, the configuration of the piston ring according to the present example will be described using FIG. 19. The same reference signs are attached to the same components as those in Examples 1 to 4 and the description thereof is omitted.

[0041]

In the present example, as shown in FIG. 19, if the height above the circumferential groove 33, that is, the height from a pressurizing side surface of the piston ring to a pressurizing side end of the circumferential groove is h_4 and the height below, that is, the height from a non-pressurizing side surface of the piston ring to a non-pressurizing side end of the circumferential groove is h_5 to represent the position of the circumferential groove, the position of the circumferential groove satisfies $h_4 > h_5$, that is, the position of the circumferential groove is made lower than the center of the piston ring height. Accordingly, the region II shown in FIG. 14 is made still smaller so that the contact pressure of the sliding surface can be made still smaller.

Example 6

[0042]

Next, the configuration of the piston ring according to the present example will be described using FIG. 20. The same reference signs are attached to the same components as those in Examples 1 to 5 and the description thereof is omitted.

[0043]

In the present example, as shown in FIG. 20, if a lower thickness h_1 of the piston ring abutment portion is smaller than an upper thickness h_2 and the rigidity of the lip is small, the position of the circumferential groove 33 is shifted below in accordance with the lip thickness. In this case, therefore, $h_4 > h_5$ is satisfied and the contact pressure can be reduced still more.

Example 7

[0044]

Next, the configuration of the piston ring according to the present example will be described using FIG. 21. The same reference signs are attached to the same components as those in Examples 1 to 6 and the description thereof is omitted.

[0045]

In the present example, as shown in FIG. 21, the depth E_1 of the circumferential groove 33 is configured to be smaller than a thickness T_1 of the lip receiving portion. As a result, the contact pressure can be reduced without causing the breakage of the groove bottom and leakage from the circumferential groove 33.

Example 8

[0046]

Next, the configuration of the piston ring according to the present example will be described using FIG. 22. The same

reference signs are attached to the same components as those in Examples 1 to 7 and the description thereof is omitted.

[0047]

In the present example, as shown in FIG. 22, the thickness T1 of the lip receiving portion is configured so as to be thicker than a thickness T2 of the lip, that is, $T1 > T2$ is satisfied. A depth E2 of the groove in this case can be made larger than the depth E1 of the groove shown in FIG. 21. That is, $E2 > E1$ is satisfied and the permitted wear amount δ can be set larger. That is, the replacement life of the piston ring can advantageously be prolonged.

Example 9

[0048]

Next, the configuration of the piston ring according to the present example will be described using FIG. 23. The same reference signs are attached to the same components as those in Examples 1 to 8 and the description thereof is omitted.

[0049]

In the present example, as shown in FIG. 23, a communicating hole to communicatively connect the circumferential groove to the backface, that is, a communicating hole 39 to communicatively connect the groove bottom of the circumferential groove and the inner side in the radial direction of the piston ring is provided. As a result, if wear powder arises on the sliding surface, the wear powder

can be discharged from inside the circumferential groove to the backface so that the contact pressure can be reduced without clogging the circumferential groove.

Example 10

[0050]

In the present example, the method of producing piston rings will be described.

[0051]

As processes to produce piston rings in the above examples, in the case of an oilless reciprocating compressor, a resin such as tetrafluoroethylene resin is poured into a mold due to compression without lubricant to form a pipe, which is machined into a ring in a circumferential shape. Next, an abutment portion and a lip portion are machined by a cutter or the like. Then, a circumferential groove is machined on the outer circumferential portion of the ring. That is, one end of the circumferential groove needs to be communicatively connected to the upper abutment groove and the other end needs to be formed up to just before the lower abutment groove and thus, it is necessary to machine the circumferential groove based on the abutment portion and so it is necessary to machine the circumferential groove after the abutment portion is machined.

[0052]

There are mainly two methods of machining the circumferential groove. One method is a case when, as shown

in FIG. 24, the starting point on both sides of the circumferential groove is an arc. A T-type slotting machine is used as a cutter for this machining and machining of the depth E of the groove can be performed by setting a driving depth of the slotting machine to E along the outer circumference of the piston ring. In this case, a distance L1 between the lower abutment groove 35 and an end of the circumferential groove increases with wear of the outer circumference of the piston ring during operation, but the machining speed is advantageously faster.

[0053]

Incidentally, by making a height h_3 of the circumferential groove 33 equal to a cutter thickness h_6 of the T-type slotting machine as shown in FIG. 25, that is, by making the width of the circumferential groove equal to an edge thickness of the cutter for groove machining, machining can be performed by one movement so that machining can be performed in a still shorter time.

[0054]

The other method is a case when, as shown in FIG. 26, the shape in the depth direction of an end of a circumferential groove 38 is machined so as to be perpendicular to a circumferential surface of the piston ring. This machining can be performed by an end mill opposite to the outer circumference of the piston ring. This method is characterized in that even

if the outer circumference of the piston ring is worn out, a distance L2 between the lower abutment groove 35 and an end of the circumferential groove does not change so that a stable reduction of the contact pressure of the abutment portion can be achieved and wear can be prevented. The present machining method is slower than the case when the T type slotting machine is used when machining, but embodies the above features.

Example 11

[0055]

Next, the configuration in the present example will be described using FIG. 27. In FIG. 27, the shape of the piston ring is the step abutment shape shown in FIG. 3. The pressurizing side abutment 15 and the non-pressurizing side abutment 14 each connect communicatively the inner circumferential side of the piston ring to the outer circumferential side. The present example is characterized by the use of a plate 40 as a member that blocks the communicative connection between the outer circumferential side and the inner circumferential side of the piston ring. In the present example, the plate 40 constructed of a steel plate as a thin plate is mounted on the inner circumferential side along the inner circumferential side of the piston ring. The example of FIG. 27 shows about 1.5 turns of the plate 40, but the length thereof is limited by the example. In the present example, the leakage passage indicated by the arrows in FIG. 4 is blocked by the

presence of the plate 40. In this configuration, the backface pressure can be balanced by providing the circumferential groove 33 that is communicatively connected to the pressurizing side abutment 15 and is not communicatively connected to the non-pressurizing side abutment 14 so that the contact pressure of the sliding surface can be reduced. It is needless to say that the technology up to Example 10 can be applied to the idea of the piston ring with respect to the circumferential groove.

[0056]

Incidentally, the plate 40 is not limited to the metal and may be constructed of resin, rubber or the like and only needs to be configurable such that the abutment on the non-pressurizing side is not substantially connected communicatively from the inner circumferential side to the outer circumferential side of the ring.

[0057]

The present piston ring is hard to distinguish between top and bottom before being mounted on the piston, but it is necessary to mount the side on which the abutment and the circumferential groove 33 are communicatively connected above as the abutment 15 on the pressurizing side to obtain the present function.

Example 12

[0058]

Next, the configuration in the present example will be

described using FIGS. 28 to 31. FIG. 29 shows a relative physical relationship of piston rings 53, 54 mounted on a piston 50 and the piston rings are integrated with their abutments displaced 180 degrees from each other. FIG. 30 shows the cross section of a portion indicated by F-F of the piston ring 53 in FIG. 28 and is a diagram showing from above the piston.

[0059]

First, the relationship among the piston 50, a cylinder 60, and the piston rings 53, 54 in the present example will be described. In the present example, the piston 50 is formed from a slidable resin so as to be able to slide by coming into direct contact with a heat resistant cylinder and thus, the rider ring 10 shown in FIG. 1B is not included. In this structure, to prevent the cylinder 60 and the piston 50 from locking due to the rise in temperature during operation, the cylinder 60 and the piston 50 are configured to have a slight gap even at temperature during operation. In this case, as shown in FIGS. 28 and 30, a δ load of a load direction gap during operation is extremely small and a δ anti-load as an anti-load direction gap increases. The two piston rings 53, 54 are provided vertically and the abutment of each of the piston rings 53, 54 is a straight abutment without the pressurizing side and the non-pressurizing side. The piston ring 53 on the pressurizing side is configured such that, as shown in FIG. 30, an abutment 55 of the piston ring 53 is always positioned in the load

direction by a detent 57 formed in the ring groove of the piston. Similarly, the piston ring 54 below is configured such that an abutment 56 is positioned in the anti-load direction in the opposite direction of the piston ring 53 by a detent of the lower ring (not shown).

[0060]

Even if, as shown in a leakage passage 58 of FIG. 30, the abutment 55 is straight and the width of the abutment is large, because the δ load of the gap between a second land portion 51 of the piston 50 and the inner surface of the cylinder is small, the area of the leakage passage 58 of the abutment portion in this structure can be made extremely small so that leakage from the abutment portion can be reduced. Similarly, a channel surrounded by the δ anti-load of the gap between a piston skirt 52 and the inner surface of the cylinder and the abutment becomes a leakage passage for the lower ring 54. While the δ anti-load is larger than the δ load and the δ load < the δ anti-load is satisfied, the abutments are positioned in the opposite directions and the pressure in the piston ring 54 portion is reduced by the piston ring 53 and so is lower than that in the piston ring 53 portion and leakage of the piston ring 54 portion can be decreased.

[0061]

In this structure, therefore, a small leakage passage constructed of the piston rings 53, 54 and the piston 50 can

be formed so that a compressor causing little leakage can be constructed. In FIG. 31, the circumferential groove 33 communicatively connected to the straight abutment portion 55 of piston rings constructed as described above is formed. In the case of the piston 50 and the piston rings 53, 54 constructed as described above, leakage is very small even if a leakage flow passage leading directly to the non-pressurizing side is present and therefore, by forming a circumferential groove communicatively connected to the abutment of each ring, the contact pressure of the sliding surface can be reduced by balancing the back pressure of the piston rings 53, 54 without increasing leakage from the abutment portion.

[0062]

In FIG. 32, examples of the piston ring used in an internal combustion engine are indicated by reference signs 70, 71 and abutment shapes are indicated by abutments 72, 73. These rings can also be used for a compressor if leakage of an abutment portion is permitted. FIG. 33 shows a case when the rings are used in an oilless compressor and abutments 76, 77 are set to a larger abutment gap than that of the rings shown in FIG. 32 to avoid tightening of the abutment portion due to thermal expansion. It is needless to say that leakage can be reduced and also contact pressure of the sliding surface can be reduced by applying the present example to these abutment shapes.

[0063]

FIG. 31 shows an example in which the circumferential groove 33 communicatively connected to both sides of the abutment 55 of the piston ring 53 on the pressurizing side is provided and it is also needless to say that a similar effect is obtained by communicatively connecting the circumferential groove 33 to only one side.

[0064]

When the discharge pressure is small or for a compressor in which the pressure on the suction side is guided into a crankcase to apply the back pressure to the piston, the pressure difference between the pressurizing side and the non-pressurizing side of the ring is small and leakage from the abutment portion is small and therefore, the need for positioning the ring abutment portion in the load direction decreases. In this case, leakage of the abutment portion is small even without the detent 57 of the ring shown in FIG. 30 and thus, the back pressure of the ring can be balanced only by providing the circumferential groove in the piston ring provided rotatably and the sliding contact pressure can be reduced.

[0065]

It is also possible to provide a plurality of rings in a structure in which a piston ring having a detent is provided with a circumferential groove and to reduce the ring back pressure of each ring gradually. Further, it is also possible

to provide a plurality of rings in a structure in which a piston ring having no detent is provided with a circumferential groove and to reduce the ring back pressure of each ring gradually.

Example 13

[0066]

In the present example, a method of machining a circumferential groove with precision will be described. The depth of a circumferential groove is an important dimension that determines the permitted wear amount of a ring. If the depth varies and the groove disappears in a shallow portion after the outer circumference of the ring is worn out, the pressure on the pressurizing side of the ring is not guided from a portion where the groove has disappeared into the groove in a range that is not communicatively connected to the abutment and the back pressure cannot be balanced in this range and as a result, the contact pressure of the sliding surface rises and wear of the portion increases.

[0067]

Thus, it is important to machine the groove depth with precision and the method of machining the groove depth with precision will be described using FIG. 34. In FIG. 34, a receiving jig 80 is finished with a ring receiving portion 81 ensuring circularity in cylinder dimensions. The ring 30 is set such that the ring 30 is uniformly pressed from inside using a tension jig 82 after the receiving surface 81 of the receiving

jig 80 being inserted thereinto.

[0068]

As a result, the outer circumference of the ring 30 is in a state in which circularity is ensured in the cylinder inside diameter dimension. On the other hand, a cutter 83 is positioned precisely with respect to the ring receiving surface 81. Thus, by determining a locus of the cutter 83 with respect to the center of the receiving surface 81, the depth E of the circumferential groove 33 can be machined from the outer circumference of the ring and a partial increase of wear can be prevented.

[0069]

In FIG. 34, the cutter is shown as an example of the T type slotting machine, but machining can also be performed by an end mill or the like using a similar jig.

[0070]

Examples of the present invention have been described above, but the present invention is not limited to the above examples and various modifications thereof are included. For example, the above examples have been described in detail to describe the present invention so as to be understood more easily and all components described above are not necessarily included. Also, a portion of components of a certain example may be replaced by a portion of components of another example or components of a certain example may be added to components

of another example. Also, additions, deletions, or substitutions of other components may be made for a portion of components of each example.

[0071]

In addition to an oilless reciprocating compressor in which a piston ring is formed from a resin member of tetrafluoroethylene resin or the like, the present invention can also support a common compressor that directly sucks in the atmosphere and a booster compressor that pressurizes the air having been primarily pressurized. The gas to be compressed is not limited to the air and a gas compressor for compressing a gas other than the air such as a nitrogen gas can also be supported.

Reference Signs List

[0072]

- 1 tank
- 2 motor
- 3 compressor main body
- 4 belt
- 5 compressor pulley
- 6 crankshaft
- 7 connecting rod
- 8 piston
- 9 piston ring
- 10 rider ring

11 suction silencer
12 discharge opening
13 cylinder
14, 15, 25 abutment portion
21, 31 lip
21a, 31a lip tip
22, 32 lip receiving portion
33, 38 circumferential groove
34 upper abutment groove
35 lower abutment groove
36, 37 communicating groove
39 communicating hole
40 plate
50 piston
51 second land of the piston
52 skirt of the piston
53 piston ring on the pressurizing side (upper)
54 lower piston ring
55 abutment of the upper piston ring
56 abutment of the lower piston ring
57 detent of the ring provided in the piston
58 leakage passage
60 cylinder
70, 71 piston ring for an internal combustion engine
74, 75 piston ring for an oilless reciprocating compressor

72, 76 straight cut abutment
73, 77 angle cut abutment
80 receiving jig
81 ring receiving surface of the receiving jig
82 tension jig
83 cutter
 δ limit wear amount
E, E1, E2 depth of the circumferential groove
L1, L2 distance between the lower abutment groove and an end
of the circumferential groove
Pc internal cylinder pressure
P1, P2 contact pressure of the sliding surface
h1, h2, h4, h5 piston ring height
h3 width of the circumferential groove
h6 cutter thickness
T1 thickness of the lip receiving portion
T2 lip thickness

CLAIMS

[Claim 1]

A compressor having a cylinder, a piston, and a piston ring mounted on the piston for sealing between a pressurizing side and a non-pressurizing side in the cylinder to generate a compressed fluid by compressing a fluid in the cylinder by the piston, wherein

the piston ring includes a first abutment portion provided on the pressurizing side and a second abutment portion provided on the non-pressurizing side, a first abutment groove is formed in a gap of the first abutment portion, a second abutment groove is formed in a gap of the second abutment portion, an inner circumferential side and an outer circumferential side are prevented from being communicatively connected in the second abutment portion, and a circumferential groove that is communicatively connected to the first abutment groove and is not communicatively connected to the second abutment groove is provided on an outer circumference of the piston ring.

[Claim 2]

The compressor according to claim 1, wherein

the first abutment portion has a step shape in which the inner circumferential side and the outer circumferential side are communicatively connected and the second abutment portion has a lip shape in which the inner circumferential side and the outer circumferential side overlap with each other.

[Claim 3]

The compressor according to claim 1, wherein
the piston ring further includes a communicating groove
that sets a piston ring height direction of the circumferential
groove to within a height of the second abutment portion and
communicatively connects the circumferential groove and the
first abutment groove.

[Claim 4]

The compressor according to claim 1, wherein
the piston ring is provided with a plurality of the
circumferential grooves, wherein both ends of the
circumferential groove on the pressurizing side in the cylinder
are communicatively connected to the first abutment groove and
the circumferential groove on the non-pressurizing side in the
cylinder is not communicatively connected to the second
abutment groove, and the circumferential groove on the
pressurizing side and the circumferential groove on the
non-pressurizing side are connected by a communicating groove
or a hole that communicatively connects the circumferential
groove to a backface is provided in the circumferential groove
on the non-pressurizing side.

[Claim 5]

The compressor according to claim 1, wherein
a shape in a depth direction of an end of the
circumferential groove is machined so as to be perpendicular

to an outer circumferential surface of the piston ring.

[Claim 6]

The compressor according to claim 1, wherein

a depth $E1$ of the circumferential groove is configured such that $E1 > \delta$ is satisfied for a limit wear amount δ of the piston ring.

[Claim 7]

The compressor according to claim 1, wherein

the circumferential groove is provided in a position satisfying $h4 > h5$ when a height from a pressurizing side surface of the piston ring to a pressurizing side end of the circumferential groove is $h4$ and the height from a non-pressurizing side surface of the piston ring to a non-pressurizing side end of the circumferential groove is $h5$.

[Claim 8]

The compressor according to claim 1, wherein

the second abutment portion is constructed of a lip portion on an inner side in a radial direction of the piston ring and a lip receiving portion on an outer side and a thickness of the lip receiving portion is configured to be thicker than that of the lip portion.

[Claim 9]

The compressor according to claim 1, wherein

a width of the circumferential groove is configured to be equal to an edge thickness of a cutter for groove machining.

[Claim 10]

The compressor according to claim 1, wherein
the piston ring is provided with a communicating hole that
communicatively connect a groove bottom of the circumferential
groove and an inner side in a radial direction of the piston
ring.

[Claim 11]

The compressor according to claim 8, wherein
the lip portion is configured to have substantially a same
dimension in thickness from tip to root and a contact surface
with the lip receiving portion is formed substantially
concentrically.

[Claim 12]

The compressor according to claim 1, wherein
a member that blocks a communicative connection between
the outer circumferential side and the inner circumferential
side of the piston ring is provided.

[Claim 13]

The compressor according to claim 12, wherein
the first abutment portion and the second abutment
portion have a step shape in which the inner circumferential
side and the outer circumferential side are communicatively
connected.

[Claim 14]

The compressor according to claim 1, wherein

the circumferential groove has a rectangular shape.

[Claim 15]

A piston ring having a first abutment portion on a pressurizing side of the piston ring, and a second abutment portion on a non-pressurizing side of the piston ring, wherein

a first abutment groove is formed in the first abutment portion, a second abutment groove is formed in the second abutment portion, an inner circumferential side and an outer circumferential side are prevented from being communicatively connected in the second abutment portion, and

a circumferential groove that is communicatively connected to the first abutment groove and is not communicatively connected to the second abutment groove is provided on an outer circumference of the piston ring.

[Claim 16]

The piston ring according to claim 15, wherein

the first abutment portion has a step shape in which the inner circumferential side and the outer circumferential side are communicatively connected and the second abutment portion has a lip shape in which the inner circumferential side and the outer circumferential side overlap with each other.

[Claim 17]

The piston ring according to claim 15, wherein

one end of the circumferential groove is communicatively connected to the first abutment groove and the other end is

formed up to just before the second abutment groove.

[Claim 18]

The piston ring according to claim 15, wherein
the circumferential groove is provided on an outer
circumference of the piston ring by avoiding the second abutment
groove.

[Claim 19]

A compressor having a cylinder, a piston, and a piston
ring mounted on the piston for sealing between a pressurizing
side and a non-pressurizing side in the cylinder to generate
a compressed fluid by compressing a fluid in the cylinder by
the piston, wherein

the piston is formed from a resin, and

the piston ring is provided with an abutment portion and
a circumferential groove communicatively connected to the
abutment portion.

[Claim 20]

The compressor according to claim 19, wherein

the abutment portion has a step shape in which an inner
circumferential side and an outer circumferential side are
communicatively connected.

[Claim 21]

The compressor according to claim 19, wherein
a plurality of the piston rings is provided.