A piston is used in a fluid machine. The fluid machine has a drive shaft and a cam plate operatively connected to the drive shaft. The drive shaft integrally rotates with the cam plate in a housing. The piston has a head portion, a neck portion, a receiving wall and a guide wall. The head portion is accommodated in a cylinder bore in the housing. The neck portion is operatively connected to the cam plate. The receiving wall integrally connects the head portion and the neck portion on the drive shaft side. The receiving wall is formed substantially on a preceding side in a rotating direction of the cam plate. The guide wall integrally connects the head portion and the neck portion on an opposite side of the drive shaft side. The guide wall is formed substantially on a following side in the rotating direction of the cam plate.
FIG. 5A

FIG. 5B
PISTON FOR FLUID MACHINE AND THE FLUID MACHINE HAVING THE SAME

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a piston for a fluid machine and to the fluid machine. The piston has a receiving wall for receiving side force and a guide wall between a head portion in a cylinder bore and a neck portion that is operatively connected to a cam plate.

[0002] For example, in a piston type compressor that compresses a refrigerant by a reciprocation of a piston in a cylinder bore, a cavity is conventionally formed in a connecting portion between a head portion and a neck portion of the piston to reduce the weight of the piston. Japanese Unexamined Patent Publication No. 2000-274350 discloses the above type of piston in which a cavity is formed in a portion corresponding to the connecting portion of the piston. In addition, a receiving wall for receiving side force is formed at the connecting portion on the downside of the head portion. A guide wall is formed at the connecting portion on the upside of the head portion. The receiving wall is formed on a preceding side in a rotating direction of a swash plate. The swash plate functions as a cam plate that reciprocates the piston. Thereby, the receiving wall effectively receives the side force from the inner circumferential surface of a cylinder bore.

[0003] Note that the upside of the head portion is further away from a drive shaft of a fluid machine while the downside is closer to the drive shaft. In the above structure, however, the receiving wall is not formed on a following side in the rotating direction of the swash plate. In other words, the receiving wall and the guide wall are not satisfactorily balanced with respect to a central axis of the head portion. Therefore, in the above structure, if the piston is polished and ground by a centerless machining process, it is hard to ensure the accuracy of machining. The centerless machining is a machining method of polishing and grinding by contacting a machining tool such as a grind stone with the piston under the condition that the rotary center of the piston as a work piece is not checked but the outer circumferential surface of the piston is radially pressed by using a support member such as a roller. As a result, it is hard to accurately hold the piston. In contrast, as pressing force or contact pressure that is applied from the support member such as a roller and the machining tool to the piston is close to each other, the accuracy of machining is improved. In the above improved structure, however, the receiving wall and the guide wall are imbalanced with respect to the central axis of the head portion. Therefore, the pressing force of the support member and the machining tool hardly become equal to each other. Consequently, it becomes hard to ensure the accuracy of machining.

SUMMARY OF THE INVENTION

[0004] The present invention is directed to a piston for a fluid machine and the its reduced manufacturing cost due to not only the reduced weight of the piston but also a centerless machining.

[0005] According to the present invention, a piston is used in a fluid machine. The fluid machine has a drive shaft and a cam plate that is operatively connected to the drive shaft. The drive shaft integrally rotates with the cam plate in a housing. The piston has a head portion, a neck portion, a receiving wall and a guide wall. The head portion is accommodated in a cylinder bore that is formed in the housing. The neck portion is operatively connected to the cam plate through a pair of shoes. The receiving wall integrally connects the head portion and the neck portion on the opposite side of the drive shaft side. The receiving wall is formed substantially on a preceding side in a rotating direction of the cam plate. The guide wall integrally connects the head portion and the neck portion on the opposite side of the drive shaft side. The guide wall is formed substantially on a following side in the rotating direction of the cam plate.

[0006] Furthermore, the present invention has a following second feature. A fluid machine has a housing, a drive shaft and a piston. The drive shaft is rotatably supported in the housing. The piston is operatively connected to the drive shaft and exerts pressure on fluid. The piston includes a head portion, a neck portion, a receiving wall and a guide wall. The head portion is accommodated in a cylinder bore that is formed in the housing. The neck portion is operatively connected to the drive shaft. The receiving wall integrally connects the head portion and the neck portion on the drive shaft side. The receiving wall is formed substantially on a preceding side in a rotating direction of the drive shaft. The guide wall integrally connects the head portion and the neck portion on the opposite side of the drive shaft side. The guide wall is formed substantially on a following side in the rotating direction of the drive shaft.

[0007] Furthermore, the present invention has a following third feature. A piston type compressor has a housing, a drive shaft, a cam plate and a plurality of pistons. The drive shaft is rotatably supported in the housing. The cam plate is supported by the drive shaft. The cam plate is rotated by the rotation of the drive shaft. The plurality of pistons is operatively connected to the cam plate and compresses refrigerant gas. The rotation of the cam plate is converted into a reciprocating movement of the piston. The piston includes a head portion, a neck portion, a receiving wall and a guide wall. The head portion is accommodated in a cylinder bore that is formed in the housing. The neck portion is operatively connected to the cam plate. The receiving wall integrally connects the head portion and the neck portion on the side of the drive shaft. The receiving wall is formed substantially on a preceding side in a rotating direction of the cam plate. The guide wall integrally connects the head portion and the neck portion on the opposite side of the drive shaft. The guide wall is formed substantially on a following side in the rotating direction of the cam plate.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The features of the present invention that are believed to be novel are set forth with particularity in the appended claims. The invention together with objects and advantages thereof, may best be understood by reference to the following description of the presently preferred embodiments together with the accompanying drawings in which:

[0009] FIG. 1 is a cross-sectional view of a variable displacement single-head piston type compressor according to a preferred embodiment of the present invention;

[0010] FIG. 2 is a perspective view of a piston for use in the variable displacement single-head piston type compressor according to the preferred embodiment of the present invention;
FIG. 3 is an enlarged cross-sectional view of the piston taken along the line III-III in FIG. 1;

FIG. 4A is a partial side view of a swash plate, a pair of shoes and the piston according to the preferred embodiment of the present invention. The piston is positioned near the top dead center while the piston is in transition from a bottom dead center toward a top dead center;

FIG. 4B is a partial top view of the swash plate, the pair of shoes and the piston according to the preferred embodiment of the present invention. The piston is positioned near the top dead center while the piston is in transition from the bottom dead center toward the top dead center;

FIG. 5A is a partial side view of the swash plate, the pair of shoes and the piston according to the preferred embodiment of the present invention. The piston is positioned at an early stage while the piston is in transition from the top dead center toward the bottom dead center;

FIG. 5B is a partial top view of the swash plate, the pair of shoes and the piston according to the preferred embodiment of the present invention. The piston is positioned at the early stage where the piston is in transition from the top dead center to the bottom dead center;

FIG. 6 is a cross-sectional view of a connecting portion of the piston according to another preferred embodiment of the present invention;

FIG. 7 is a cross-sectional view of a connecting portion of the piston according to yet another preferred embodiment of the present invention; and

FIG. 8 is an enlarged cross-sectional view of the piston taken in FIG. 3, which is manufactured by using movable dies and a stationary die.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

A piston for a fluid machine according to a preferred embodiment of the present invention will now be described with reference to FIGS. 1 through 8.

FIG. 1 illustrates a variable displacement single-head piston type compressor (hereinafter a compressor) or a fluid machine that is applied to a vehicle air conditioner. In the drawing, left and right sides of FIG. 1 respectively represents front and rear. A front housing 11, a cylinder block 12 and a rear housing 13 form a housing of a compressor C or a compressor housing. The rear end of the front housing 11 is fixedly secured to the front end of the cylinder block 12 that is a center housing. The front end of the rear housing 13 is fixedly secured to the rear end of the cylinder block through a valve plate assembly 14. Although only one blot is illustrated in FIG. 1, the compressor housing and the valve plate assembly 14 are fixedly secured by bolting the rear housing 13 with a plurality of bolts 10 through the front housing 11, the cylinder block 12 and the valve plate assembly 14. The front housing 11 and the cylinder block 12 define a crank chamber 15. A drive shaft 16 that drives the compressor C is rotatably supported by the front housing 11 and the cylinder block 12 so as to pass through the crank chamber 15. Although not shown in the drawing, the drive shaft 16 is operatively connected to a vehicle engine that is an external drive source through a clutch mechanism such as an electromagnetic clutch.

Still referring to FIG. 1, rotation is converted into reciprocating motion. A lug plate 17 is fixedly mounted on the drive shaft 16 in the crank chamber 15. A cam plate or a swash plate 18 is connected to the drive shaft 16 so that the swash plate 18 integrally rotates with the drive shaft 16 through a hinge mechanism 19 and inclines with respect to a central axis L of the drive shaft 16. A plurality of cylinder bores 12A is formed in the cylinder block 12 around the axis L of the drive shaft 16 although only one cylinder bore is illustrated in the drawing. Also, a piston for a fluid machine or a single-head piston 20 is accommodated in each cylinder bore 12A. Each piston 20 is engaged with the swash plate 18 through a pair of shoes 21. The rotary motion of the drive shaft 16 is converted into the reciprocation of each piston 20 along the respective cylinder bores 12A through the lug plate 17, the hinge mechanism 19, the swash plate 18 and the shoes 21. The drive shaft 16, the lug plate 17, the hinge mechanism 19 and the shoes 21 constitute a driving unit of the piston 20.

Refrigerant gas is compressed by the reciprocating motion. A suction chamber 22 and a discharge chamber 23 are defined between the rear housing 13 and the valve plate assembly 14. The valve plate assembly 14 further includes a suction port 24, a suction valve 25, a discharge port 26 and a discharge valve 27. The refrigerant gas in the suction chamber 22 is drawn into the corresponding cylinder bore 12A through the associated suction port 24 by pushing away the associated suction valve 25 while the piston 20 moves forward (or from right to left in FIG. 1). The refrigerant gas drawn into the cylinder bore 12A is compressed to a predetermined pressure level and is discharged into the corresponding discharge chamber 23 through the associated discharge port 26 by pushing away the associated suction valve 27 while the piston 20 moves rearward (or from left to right in FIG. 1). A supply passage 28 connects the discharge chamber 23 with the crank chamber 15. A bleed passage 29 connects the crank chamber 15 with the suction chamber 22. A displacement control valve 30 is placed in the supply passage 28. A pressure sensing passage 31 connects the displacement control valve 30 with the suction chamber 22.

Still referring to FIG. 1, the compression is controlled by the displacement control valve 30. The displacement control valve 30 further includes a diaphragm 30A and a valve body 30B. The valve body 30B is opened and closed by diaphragm 30A that reacts to the pressure in the suction chamber 22 through the pressure sensing passage 31. Thereby, the opening degree of the supply passage 28 is varied to control the amount of the refrigerant gas that is introduced into the crank chamber 15. On the other hand, the refrigerant gas in the crank chamber 15 is introduced into the suction chamber 22 through the bleed passage 29. Therefore, the pressure in the crank chamber 15 is varied. Since the pressure differential between the crank chamber 15 and the cylinder bore 12A applied to the piston 20 changes, the inclination angle of the swash plate 18 is also varied. Consequently, a piston stroke is varied, and a displacement is adjusted.

In the present embodiment, a spring is placed between the lug plate 17 that is mounted on the drive shaft 16 and the swash plate 18 although not shown in the
drawing. On the other hand, a circular clip 16A is fixedly mounted on the drive shaft 16 behind the swash plate 18. Thereby, a minimum inclination angle of the swash plate 18 is restricted with respect to the perpendicular plane to the axis L of the drive shaft 16. At the minimum inclination angle of the swash plate 11 as shown in hypothetical two-dotted lines, the swash plate 18 contacts with the circular clip 16A, which is fixedly mounted on the drive shaft 16. In addition, the compressor C is constructed in a such manner that the output displacement of the piston 20 is approximately zero per rotation of the drive shaft 16.

[0025] Next, the constitution of the piston 20 will be described in detail. As shown in FIGS. 1 and 2, the piston 20 has a head portion 40 accommodated in the cylinder bore 12A and a neck portion 41 connected to a distal portion of the swash plate 18 through the shoes 21. The head portion 40 and the neck portion 41 are designed to have a predetermined distance in the axial direction of the piston 20. The head portion 40 and the neck portion 41 are connected by and integrally formed with a connecting portion 42.

[0026] The head portion 40 is formed in a such manner that its outside cross-sectional diameter is approximately equal to the inside diameter of the cylinder bore 12A. The neck portion 41 further includes a coupler 41A, which partially forms a shoe inserted portion 41B and a partially cut disk 41C, which defines the outside diameter to approximately match the inside diameter of the cylinder bore 12A. The outer circumferential surface between the head portion 40 and the partially cut disk 41C constitute an outer circumferential surface of a hypothetical cylinder.

[0027] Still referring to FIGS. 1 and 2, a pair of concave spherical surfaces 41D is provided at the front and rear sides of the piston 20 so as to face each other in the shoe inserted portion 41B. The pair of shoes 21 is substantially in the shape of hemisphere and sandwiches the front and rear surfaces of the distal portion of the swash plate 18. The shoes 21 are received respectively by the corresponding concave spherical surfaces 41D in the shoe inserted portion 41B so as to freely slide. Thus, the shoes 21 slide relative to the front and rear surfaces of the swash plate 18 and enable the piston 20 to reciprocate in the axial direction of the piston 20 based on the rotary motion of the swash plate 18, which is integrally rotated with the drive shaft 16.

[0028] Since the piston 20 is connected to the swash plate 18 through the shoes 21, the piston 20 is not prevented from rotating around the axis of the piston 20 or around a central axis of the head portion 40. In the present embodiment, the piston 20 has a rotation restricting portion 41E for restricting the rotation of the piston 20 around the axis of the piston 20 due to the contact with an inner circumferential surface 11A of the front housing 11 as shown in FIG. 1. For this reason, the rotation restricting portion 41E is designed in a such manner that one of the circumferential ends of the rotation restricting portion 41E contacts the inner circumferential surface 11A of the front housing 11 as the piston 20 is about to rotate around the axis of the piston 20.

[0029] As shown in FIGS. 1 through 3, the connecting portion 42 has a receiving wall 42A for receiving side force that extends from the downside of the head portion 40 to the partially cut disk 41C of the neck portion 41 and a guide wall 42B that extends from the upper side of the head portion 40 to the partially cut disk 41C. The receiving wall 42A and the guide wall 42B are formed in a such manner that the outer circumferential surfaces of the receiving wall 42A and the guide wall 42B around the axis of the piston 20 constitute an outer circumferential surface of the hypothetical cylinder as previously described. Note that the upside of the head portion 40 is further away from the drive shaft 16 while the downside is closer to the drive shaft 16.

[0030] FIG. 3 illustrates the connecting portion 42 in a cross-sectional view in which a rotating direction of the drive shaft 16 or the swash plate 18 is clockwise. The receiving wall 42A is formed on a preceding side in the rotating direction of the swash plate 18 or in the direction indicated by an arrow in FIG. 3. A hypothetical straight line L1 extends through the central axes of the drive shaft 16 and the head portion 40 as indicated in a dotted line in FIG. 3. The hypothetical straight line L1 and the outer circumferential surface of the head portion 40 intersect at intersectional points P1 and P2. The intersectional point P1 is further from the axis of the drive shaft 16 than the intersectional point P2. In the present embodiment, when the position of the intersectional point P1 is referred to as 12 o’clock, the outer circumferential surface of the receiving wall 42A is formed substantially over a range of 3 o’clock to 6 o’clock. On the other hand, the guide wall 42B is formed on a following side in the rotating direction of the swash plate 18 or on an opposite side to the preceding side in the rotating direction of the swash plate 18. In the present embodiment, the outer circumferential surface of the guide wall 42B is formed substantially over a range of a 9 o’clock position to a 12 o’clock position.

[0031] The receiving wall 42A is connected to the guide wall 42B by a flat reinforcement 42C. The reinforcement 42C is formed in a such manner that it extends from the end of the receiving wall 42A at the position of 3 o’clock to the end of the guide wall 42B at the position of 9 o’clock. The reinforcement 42C also extends from the head portion 40 to the partially cut disk 41C. The connecting portion 42 includes the receiving wall 42A, the guide wall 42B and the reinforcement 42C. In addition, a cross section of the connecting portion 42 is substantially in the shape of S as shown in FIG. 3.

[0032] The piston 20 is integrally molded with an aluminum alloy by die casting. In the present embodiment, as shown in FIG. 8, the piston 20 is as a whole molded by a die unit during the molding process by die casting. The die unit includes a first movable die 43, a second movable die 44, a third movable die 45 and a stationary die 46. The first movable die 43, the second movable die 44 and the third movable die 45 are movable only in a direction between 3 o’clock and 9 o’clock and are drawn in turn. Therefore, each end of the receiving wall 42A and the guide wall 42B is formed so as not to prevent the dies from being drawn. Then, the concave spherical surfaces 41D is formed by cutting, and the outer circumferential surfaces of the head portion 40, the neck portion 41 and the connecting portion 42 are ground or polished.

[0033] Next, side force acting on the piston 20 will be described in detail. The piston 20 experiences forces that include compression reactive force caused by the compression work of the refrigerant gas, inertia force caused by the reciprocating motion of the piston 20 and rotational force of the swash plate 18 caused by friction between the rotating
swash plate 18 and the shoes 21. Based on these forces, reactive force from the inner circumferential surface of the cylinder bore 12A or side force also acts on the piston 20.

[0034] FIGS. 4A and 4B show a state in which the piston 20 is positioned near the top dead center and the piston 20 has moved the most rightward position in FIG. 1. In detail, FIGS. 4A and 4B show the state in which the piston 20 is moving from the bottom dead center side toward the top dead center side. The piston 20 receives the largest compression reactive force near the above-described top dead center.

[0035] As shown in FIG. 4A, the piston 20 receives a reactive force Fr as shown in an arrow from the swash plate 18 through the shoe 21 in a perpendicular direction to a sliding surface between the swash plate 18 and the shoe 21. A magnitude of the reactive force Fr meets the magnitude of the compression reactive force and the inertia force. The reactive force Fr is based on the inclining state of the swash plate 18. The reactive force Fr is decomposed into a first component of force Fr1 and a second component of force Fr2 as shown by arrows on a plane that includes the hypothetical straight line L1 and the longitudinal axis of the piston 20 in FIG. 4A. The first component force Fr1 as indicated in the arrow acts in parallel to the longitudinal axis of the cylinder bore 12A, although the cylinder bore 12A is not illustrated in FIG. 4A but in FIG. 1. The second component force Fr2 as shown by the arrow acts in parallel to the hypothetical straight line L1 on a plane perpendicular to the longitudinal axis of the cylinder bore 12A. In other words, the piston 20 receives a reactive force whose magnitude is equal to that of the second component force Fr2 in the opposite direction to the second component force Fr2 from the inner circumferential surface of the cylinder bore 12A. Namely, the second component force Fr2 is in the direction of the straight line that connects 12 o’clock to 6 o’clock.

[0036] Also, as shown in a top view in FIG. 4B, the reactive force Fr is decomposed into a third component of force Fr3 and a fourth component of force Fr4 as shown by arrows on a plane that includes a straight line connecting 3 o’clock to 9 o’clock and the longitudinal axis of the piston 20 or in FIG. 4B. The third component force Fr3 acts in the axial direction of the cylinder bore 12A. The fourth component force Fr4 acts in a perpendicular direction to the hypothetical straight line L1 in the plane perpendicular to the axial direction of the cylinder bore 12A. In other words, the piston 20 receives a reactive force whose magnitude is equal to that of the fourth component force Fr4 in the opposite direction to the fourth component force Fr4 from the inner circumferential surface of the cylinder bore 12A. Namely, the fourth component force Fr4 is in the direction of the straight line that connects 3 o’clock to 9 o’clock. Furthermore, the frictional force caused by the rotating swash plate 18 and the shoes 21 is applied to the piston 20 in the rotating direction of the swash plate 18. Namely, the frictional force is substantially in the direction from 9 o’clock toward the 3 o’clock.

[0037] The second component force Fr2, the fourth component force Fr4 and the above frictional force function to incline the piston 20 with respect to the axis of the cylinder bore 12A. Reactive force generated from the inner circumferential surface of the cylinder bore 12A due to the above combined force is effectively received by the receiving wall 42A, which is formed on the preceding side in the rotating direction of the swash plate 18 on the lower portion of the head portion 40. Thereby, the inclination of the piston 20 is substantially restrained.

[0038] Furthermore, a magnitude of the above reactive force that is applied from the inner circumferential surface of the cylinder bore 12A to the piston 20 has a maximum value near the top dead center while the piston 20 moves from the bottom dead center to the top dead center. In addition, it is clearly confirmed by an experiment that the above reactive force is mainly applied to the outer circumferential surface of the receiving wall 42A in a range of 4 o’clock to 6 o’clock. In the present embodiment, the outer circumferential surface of the receiving wall 42A over the range of 4 o’clock to 6 o’clock substantially extends towards the position of 3 o’clock for reinforcement.

[0039] FIGS. 5A and 5B show another state in which the piston 20 starts to move from the top dead center toward the bottom dead center so as to perform a suction work. While the piston 20 moves from the top dead center toward the bottom dead center, the refrigerant gas is drawn from the suction chamber 22 into the cylinder bore 12A. In an early stage of the movement until inertia force of the piston 20 exceeds in tensile force that is applied to the piston 20 rearward due to negative pressure in the cylinder bore 12A, the piston 20 experiences force that meets the tensile force and the inertia force rearward. That is, as shown in FIG. 5A, the piston 20 receives a reactive force Fp from the swash plate 18 through the shoe 21 in a perpendicular direction to a sliding surface between the swash plate 18 and the shoes 21 as shown by an arrow. A magnitude of the reactive force Fp meets that of the rearward force.

[0040] Still referring to FIG. 5A, the reactive force Fp is based on an inclining angle of the swash plate 18. The reactive force Fp is decomposed into a first component of force Fp1 and a second component of force Fp2 as shown by arrows on a plane that includes the hypothetical straight line L1 and the longitudinal axis of the piston 20 in FIG. 5A. The first component force Fp1 as indicated in the arrow acts in parallel to the longitudinal axis of the cylinder bore 12A, although the cylinder bore 12A is not illustrated in FIG. 5A but in FIG. 1. The second component force Fp2 as shown by the arrow acts in parallel to the hypothetical straight line L1 on a plane perpendicular to the longitudinal axis of the cylinder bore 12A. In other words, the piston 20 receives a reactive force whose magnitude is equal to that of the second component force Fp2 in the opposite direction to the second component force Fp2 from the inner circumferential surface of the cylinder bore 12A. Namely, the second component force Fp2 is in the direction of the straight line that connects 12 o’clock to 6 o’clock.

[0041] The reactive force Fp1 functions as a tensile force to pull the connecting portion 42 through the coupler 41A and an upper region of the partially cut disk 41C frontward along the longitudinal axis of the piston 20. The tensile force is effectively received by the guide wall 42B.

[0042] Also, as shown in a top view in FIG. 5B, the reactive force Fp is decomposed into a third component of force Fp3 and a fourth component of force Fp4 as shown by arrows on a plane that includes a straight line connecting 3 o’clock to 9 o’clock and the longitudinal axis of the piston
FIG. 5B. The third component force $F_{p3}$ acts in the axial direction of the cylinder bore 12A. The fourth component force $F_{p4}$ acts in the perpendicular direction to the hypothetical straight line L1 in the plane perpendicular to the axial direction of the cylinder bore 12A. In other words, external force acts on the piston 20 in a such manner that the neck portion 41 is pulled downward in FIG. 5B by the fourth component force $F_{p4}$. In this state, the fourth component force $F_{p4}$ functions as a tensile force. The tensile force is applied to the connecting portion 42 substantially at the position of 9 o'clock of the piston 20. The tensile force is effectively received by the guide wall 42B, which is formed substantially at the position of 9 o'clock on the following side in the rotating direction of the swash plate 18. Furthermore, the frictional force generated between the rotating swash plate 18 and the shoes 21 is further applied to the piston 20 in the rotating direction of the swash plate 18 or substantially in the direction from 9 o'clock toward 3 o'clock.

In the present embodiment, when the compressor C does not require discharge or compression of the refrigerant, the inclination angle of the swash plate 18 approaches to the minimum inclination angle by an urging force of the spring that is not illustrated in the drawings. As a result, the displacement approaches to zero. At this time, the swash plate 18 pushes the piston 20 to move from the bottom dead center toward the top dead center. Thereby, as the swash plate 18 is urged by the spring, the urge generates a component of force that pushes the piston 20 in an upward direction. The component force is effectively received by the guide wall 42B substantially at the position of 12 o'clock. In a sense, the above component force could generate a twist of the piston 20 with respect to the cylinder bore 12A. However, since the guide wall 42B longitudinally extends from the upside of the head portion 40 toward the neck portion 41, the twist does not tend to occur. Therefore, the piston 20 smoothly moves toward the top dead center, and the swash plate 18 is also moved toward the minimum inclination angle. While the compressor C does not require the discharge or the compression of the refrigerant, the compressor C is stopped. In this state, the swash plate 18 is moved toward the minimum inclination angle to prepare for the next activation of the compressor C.

In the present embodiment, the outer circumferential surface of the guide wall 42B of the piston 20 is formed so as to substantially extend from 12 o'clock to 9 o'clock. The strength of the connecting portion 42 against the tensile force is sufficiently ensured by the guide wall 42B. In addition, the outer circumferential surface of the connecting portion 42 of the piston 20 is formed to be substantially symmetrical with respect to the axis of the piston 20 by the guide wall 42B. Thereby, the guide wall 42B effectively functions when the piston 20 is machined by centerless machining.

In the present embodiment, the following advantageous effects are obtained. (1) The connecting portion 42 that connects the head portion 40 to the neck portion 41 is formed by the receiving wall 42A, the guide wall 42B and the flat reinforcement 42. In the above structure, the weight of the piston 20 is reduced in comparison to another structure whose connecting portion is formed to be a solid cylinder.
may not be necessarily formed so as to connect the receiving wall 42A to the guide wall 42B. In other words, the receiving wall 42A, the guide wall 42B and the reinforcement 42C may be formed so as to leave a space between the receiving wall 42A and the reinforcement 42C and a space between the guide wall 42B and the reinforcement 42C. If the piston 20 maintains a predetermined strength level, the piston 20 does not necessarily require the reinforcement 42C. In the above structure, the connecting portion 42 is constituted as shown in FIG. 6. A cross-sectional view of a connecting portion 42 is viewed in a such manner that the rotating direction of the drive shaft 16 is clockwise. In FIG. 6, the connecting portion 42 further includes only the receiving wall 42A and the guide wall 42B. In the structure of FIG. 6, the receiving wall 42A and the guide wall 42B are formed in a such manner that a top-end surface 42D of the receiving wall 42A at the position of 3 o'clock does not exceed a bottom-end surface 42E of the guide wall 42B at the position of 9 o'clock. Thereby, if the dies are movable only in a direction, the whole piston 20 is integrally molded in the process of die casting. Note that the above direction of the die movement corresponds to the direction of the straight line that connects 3 o'clock to 9 o'clock. The direction of the die movement may not necessarily correspond to the direction of the straight line that connects 3 o'clock to 9 o'clock.

[0053] As shown in FIG. 7, a reinforcement 42C may be formed in a such manner that an end of the receiving wall 42A at the position of 6 o'clock is connected to an end of the guide wall 42B at the position of 12 o'clock. FIG. 7 is a cross-sectional view of the connecting portion 42 that is viewed in a such manner that the rotating direction of the drive shaft 16 is clockwise. The cross section of the connecting portion 42 is substantially in the shape of Z. When the connecting portion 42 is viewed in a such manner that the rotating direction of the drive shaft 16 is counterclockwise, the cross section is substantially in the shape of S. In the above structure of FIG. 7, the reinforcement 42C is formed in a such manner that the top end of the reinforcement 42C at the position of 12 o'clock does not exceed to the right of the bottom end of the reinforcement 42C at the position of 6 o'clock. The reinforcement 42C is not angled with respect to the straight line that connects 12 o'clock to 6 o'clock. Thereby, if the dies are movable only in a direction, the whole piston 20 is integrally molded in the process of die casting. Note that the above direction of the die movement corresponds to the direction of the straight line that connects 6 o'clock to 12 o'clock.

[0054] The piston 20 may be integrally molded by a molding device that includes a plurality of dies that is movable in different directions from each other. In this case, since the piston 20 is not necessarily integrally molded by the dies that are movable only in a direction, the shape of the piston 20 is not restricted. For example, a connecting portion includes a receiving wall, a guide wall and a reinforcement, and the cross-sectional shape of the connecting portion along the plane perpendicular to the axis of the piston 20 has an increased degree of freedom.

[0055] In another alternative embodiment, the piston 20 is not necessarily integrally formed as a whole. That is, the piston 20 includes a plurality of members. In this case, the weight of the piston 20 is also reduced in comparison to another piston whose connecting portion is formed to be substantially solid. Also, in comparison to a structure whose

that the receiving wall is formed on the preceding side of the rotating direction of the swash plate 18 and that the guide wall is not formed on the following side of the rotating direction of the swash plate 18, the piston 20 is accurately held when the piston 20 is machined by centerless machining.

[0056] In yet another alternative embodiment, the piston 20 is not molded by die casting. The piston 20 is formed, for example, by casting, forging or cutting. The receiving wall 42A is not formed over the range of 3 o'clock to 6 o'clock. The receiving wall 42A is formed, for example, over a range of 4 o'clock to 6 o'clock. As long as a predetermined strength of the piston 20 is maintained, the receiving wall 42A may be formed over a narrower range than the range of 3 o'clock to 6 o'clock. Similarly, the guide wall 42B is not formed over the range of 9 o'clock to 12 o'clock. The guide wall 42B may be formed, for example, over a range of 10 o'clock to 12 o'clock. As long as a predetermined strength of the piston 20 is maintained, the guide wall 42B may be formed over a narrower range than the range of 10 o'clock to 12 o'clock. The piston 20 may be constituted of metal such as an iron other than aluminum.

[0057] In other alternative embodiments, the displacement control valve 30 is replaced by another displacement control valve whose opening degree of the supply passage 28 is variable by controlling an external control device. In this case, a stroke volume of the piston 20 is reduced, for example, by completely opening the supply passage 28 by controlling the control device.

[0058] There are other alternative embodiments. The compressor C is designed that a displacement of the refrigerant is substantially zero per revolution of the drive shaft 16. However, the compressor C is also designed that the displacement of the refrigerant is not substantially zero per revolution of the drive shaft 16 when the displacement of the refrigerant is close to zero. A double-headed piston type compressor is employed in place of the single-headed piston type compressor C whose single-headed piston performs a compression work. The double-headed piston performs a compression work in cylinder bores formed on the front and rear sides of a crank chamber. Furthermore, the compressor C may be a fixed displacement type of which stroke volume of the piston 20 is fixed.

[0059] In the above-described embodiment, the compressor C is employed as a fluid machine. However, an oil pump and an air pump may be employed in place of the compressor C. The present examples and embodiments are to be considered as illustrative and not restrictive and the invention is not to be limited to the details given herein but may be modified within the scope of the appended claims.

What is claimed is:

1. A piston to be used in a fluid machine, the fluid machine having a drive shaft and a cam plate operatively connected to the drive shaft, the drive shaft integrally rotating with the cam plate in a housing, the piston comprising:
   a. a head portion accommodated in a cylinder bore formed in the housing;
   b. a neck portion operatively connected to the cam plate through a pair of shoes;
a receiving wall integrally connecting the head portion and the neck portion on the drive shaft side, the receiving wall being formed substantially on a preceding side in a rotating direction of the cam plate; and

a guide wall integrally connecting the head portion and the neck portion on an opposite side of the drive shaft side, the guide wall being formed substantially on a succeeding side in the rotating direction of the cam plate.

2. The piston according to claim 1 wherein the piston is integrally molded as a whole by a die unit that includes a movable die, which is movable only in a direction.

3. The piston according to claim 1 further comprising a reinforcement for connecting the receiving wall to the guide wall.

4. The piston according to claim 3 wherein the receiving wall, the guide wall and the reinforcement substantially define a shape of S in a cross section along a plane perpendicular to a longitudinal axis of the piston.

5. The piston according to claim 1 wherein the piston is viewed in a cross section along a plane perpendicular to the axial direction of the drive shaft in a such manner that the drive shaft is rotated clockwise, an outer circumferential surface of the receiving wall being formed at least over a range of 4 o’clock to 6 o’clock, an outer circumferential surface of the guide wall being formed at least over a range of 10 o’clock to 12 o’clock, the 12 o’clock being located at the top of the cross section.

6. The piston according to claim 5 wherein the outer circumferential surface of the receiving wall is formed substantially over a range of 3 o’clock to 6 o’clock, the outer circumferential surface of the guide wall being formed substantially over a range of 9 o’clock to 12 o’clock.

7. The piston according to claim 6 further comprising a reinforcement for connecting the receiving wall at the position of 3 o’clock to the guide wall at the position of 9 o’clock.

8. The piston according to claim 6 further comprising a reinforcement for connecting the receiving wall at the position of 6 o’clock to the guide wall at the position of 12 o’clock.

9. The piston according to claim 1 wherein the receiving wall and the guide wall are formed substantially symmetrically with respect to a longitudinal axis of the piston.

10. The piston according to claim 1 wherein an outer circumferential surface of the receiving wall and the guide wall is slidable relative to an inner circumferential surface of the cylinder bore.

11. The piston according to claim 1 wherein the piston as a whole is made of aluminum.

12. A fluid machine comprising:

a housing;

a drive shaft rotatably supported in the housing; and

a piston operatively connected to the drive shaft for exerting pressure on fluid, the piston further including:

a head portion accommodated in a cylinder bore formed in the housing;

a neck portion operatively connected to the drive shaft;

a receiving wall connecting the head portion and the neck portion on the drive shaft side, the receiving wall being formed substantially on a preceding side in a rotating direction of the drive shaft; and

a guide wall connecting the head portion and the neck portion on an opposite side of the drive shaft side, the guide wall being formed substantially on a following side in the rotating direction of the drive shaft.

13. The piston according to claim 12 wherein the piston is integrally molded as a whole by a die unit that includes a movable die, which is movable only in a direction.

14. The piston according to claim 12 further comprising a reinforcement for connecting the receiving wall to the guide wall.

15. The piston according to claim 14 wherein the receiving wall, the guide wall and the reinforcement substantially define a shape of S in a cross section along a plane perpendicular to a longitudinal axis of the piston.

16. The piston according to claim 12 wherein the piston is viewed in a cross section along a plane perpendicular to the axial direction of the drive shaft in a such manner that the drive shaft is rotated clockwise, an outer circumferential surface of the receiving wall being formed at least over a range of 4 o’clock to 6 o’clock, an outer circumferential surface of the guide wall being formed at least over a range of 10 o’clock to 12 o’clock, the 12 o’clock being located at the top of the cross section.

17. The piston according to claim 12 wherein the piston as a whole is made of aluminum.

18. A piston type compressor comprising:

a housing;

a drive shaft rotatably supported in the housing;

a cam plate supported by the drive shaft, the cam plate being rotated by the rotation of the drive shaft; and

a plurality of pistons operatively connected to the cam plate for compressing refrigerant gas, the rotation of the cam plate being converted into a reciprocating movement of the piston, the piston further including:

a head portion accommodated in a cylinder bore formed in the housing;

a neck portion operatively connected to the cam plate;

a receiving wall connecting the head portion and the neck portion on the drive shaft side, the receiving wall being formed substantially on a preceding side in a rotating direction of the cam plate; and

a guide wall connecting the head portion and the neck portion on an opposite side of the drive shaft side, the guide wall being formed substantially on a following side in the rotating direction of the cam plate.

19. The piston according to claim 18 wherein the piston is as a whole integrally molded by a die unit that includes a movable die, which is movable only in a direction.

20. The piston according to claim 18 further comprising a reinforcement for connecting the receiving wall to the guide wall.

21. The piston according to claim 20 wherein the receiving wall, the guide wall and the reinforcement substantially define a shape of S in a cross section along a plane perpendicular to a longitudinal axis of the piston.

22. The piston according to claim 18 wherein the piston is viewed in a cross section along a plane perpendicular to the axial direction of the drive shaft in a such manner that the drive shaft is rotated clockwise, an outer circumferential surface of the receiving wall being formed at least over a
range of 4 o'clock to 6 o'clock, an outer circumferential surface of the guide wall being formed at least over a range of 10 o'clock to 12 o'clock, the 12 o'clock being located at the top of the cross section.

23. The piston according to claim 22 wherein the outer circumferential surface of the receiving wall is formed substantially over a range of 3 o'clock to 6 o'clock, the outer circumferential surface of the guide wall being formed substantially over a range of 9 o'clock to 12 o'clock.

24. The piston according to claim 23 further comprising a reinforcement for connecting the receiving wall at the position of 3 o'clock to the guide wall at the position of 9 o'clock.

25. The piston according to claim 23 further comprising a reinforcement for connecting the receiving wall at the position of 6 o'clock to the guide wall at the position of 12 o'clock.

26. The piston according to claim 18 wherein the piston as a whole is made of aluminum.

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