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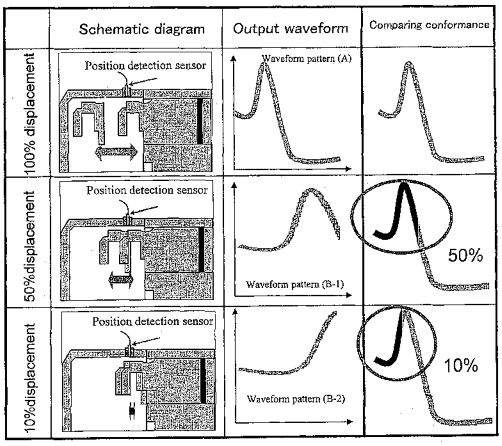
(54) DISPLACEMENT DETECTION DEVICE FOR VARIABLE DISPLACEMENT COMPRESSOR, AND VARIABLE CAPACITY COMPRESSOR EQUIPPED WITH SAME

(57) Provided is a displacement detection device for a variable displacement compressor which has a configuration such that the displacement detection device can estimate the displacement with little effect from external disturbances, and can be used with pistons that do not require a high degree of machining precision, thus allowing for a greater degree of freedom in the shape of the surface to be detected. Also provided is a variable displacement compressor provided with the displacement detection device. The displacement detection device for a variable displacement compressor is equipped with: a position detection sensor, which is disposed laterally to the piston and outputs a surface displacement signal for the surface to be detected when the piston moves in a reciprocating manner; and an estimation means that measures and stores the waveform pattern (A) of the displacement signal for a stroke of the piston during operation at maximum displacement, detects the waveform pattern (B) of the displacement signal for one stroke of the piston in the current operating state, and estimates the displacement of one stroke of the piston in the current operating state from a comparison of waveform pattern (A) and waveform pattern (B).

FIG. 2



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Description

Technical Field of the Invention

[0001] The present invention relates to a variable displacement compressor which can vary its discharge displacement by changing the piston stroke, and specifically relates to a displacement detection device which is applicable to a variable displacement compressor and is capable of appropriately detecting the displacement of the compressor.

Background Art of the Invention

[0002] A variable displacement compressor, of which discharge displacement can be controlled variably and which will also be called merely "compressor" hereinafter, is generally known as a compressor used in air conditioning system for vehicles, etc. In a piston type compressor, a swash plate which can be inclined with respect to a drive shaft may be housed in a crank chamber. The higher a pressure in the crank chamber is, the smaller the inclination angle of the swash plate is, as the swash plate gets more perpendicular to the axis of the drive shaft. On the other hand, the lower the pressure in the crank chamber is, the greater the inclination angle of the swash plate is, as the swash plate approaches the axis of the drive shaft. The stroke of a piston of the compressor is varied depending on an inclination condition of the swash plate. For example, the stroke of the piston is less, when the pressure in the crank chamber is higher and the inclination angle of the swash plate is smaller. In contrast, the stroke of the piston is greater, when the pressure in the crank chamber is lower and the inclination angle of the swash plate is greater. Therefore the smaller the stroke of the piston is, the less a discharge displacement is. And the greater the stroke is, the greater the discharge displacement is.

[0003] In such a variable displacement compressor, it is often demanded to perceive a current displacement of the compressor in operation for controlling the compressor itself and a refrigeration circuit of an air conditioning system in which the compressor is mounted. Patent document 1 discloses a conventional technology in which a piston is provided with a surface to be detected, which is formed as tapered toward its axis direction. A contactless type position detection sensor is placed laterally to the piston as facing the surface to be detected. The position detection sensor detects the distance between the position detection sensor and the surface (detection point) to be detected, which approaches and leaves by stroke changes of the piston. An air-conditioning ECU measures the stroke of the piston as based on detected distance information transmitted from the position detection sensor, and accordingly perceives the displacement of the compressor.

Prior art documents

Patent documents

[0004]

Patent document 1: JP2003-148357-A

Summary of the Invention

Problems to be solved by the Invention

[0005] Such a method as shown in Patent document 1 to obtain a discharge displacement according to the distance from the surface (detection point) to be detected, which approaches and leaves corresponding to the piston stroke change, has the following problems as the shape of the piston is subject to a great restriction. Problems:

- Because a tapered shape or a stepped shape is required to form with a high dimensional accuracy on a back side of a neck part of the piston as a surface to be detected, the cost may be increased.
- Even if it is formed in the most practical tapered shape of which width is monotonically extended (or, monotonically narrowed) the thickness of the piston neck part is increased and the weight is increased.

[0006] In addition, there may be the following problems even if the displacement is calculated from the distance between the surface to be detected and the position detection sensor. Problems:

- When foreign substances pass between the sensor and the surface to be detected or when an abrasion or a crack appears on the surface to be detected, the influence may directly affect the calculation to make an outlier for a discharge displacement value. That means it is sensitive to disturbances.

- If there is a substantive backlash of a clearance between the piston and a cylinder bore, the same piston stroke might make a difference of the distance to the surface to be detected in different operation conditions.

Such a difference of the distance may cause a detection error, and eventually a calculation error of the displacement. Further, there might be caused a problem of a temperature drift about calculating the displacement, in case that the temperature fluctuates the distance between the surface to be detected and the position detection sensor or that the temperature is fluctuated by the detectivity.

[0007] Accordingly, an object of the present invention is to provide a displacement detection device for a variable displacement compressor and a variable displacement compressor provided with the displacement detection device, which can be used with pistons that do not require a high degree of machining precision so as to allow a greater degree of shape freedom of the surface to be detected, and which can estimate the displacement with a little effect from external disturbances even if an abrasion or a crack appears on the surface to be detected or even if the clearance between the piston and the cylinder bore fluctuates detection signal.

Means for solving the Problems

[0008] To achieve the above-described object, a displacement detection device for a variable displacement compressor is a displacement detection device for a variable displacement compressor, wherein a piston reciprocates to compress gas and a stroke of the piston is changed to vary a displacement, comprising
a position detection sensor, which is disposed laterally to the piston and which outputs a displacement signal indicating that a detection point, which is a part of a surface to be detected facing the position detection sensor as a shape of the piston which moves in a traverse direction in front of the position detection sensor by a reciprocation motion of the piston, approaches and leaves the position detection sensor at a time of the reciprocation motion of the piston, and
an estimation means for estimating a current operational displacement corresponding to a current operational piston stroke by comparing waveform pattern (A) to waveform pattern (B), wherein the waveform pattern (A) of the displacement signal corresponding to one piston stroke in operation with a maximum displacement is measured and stored and the waveform pattern (B) of a current operational displacement signal corresponding to one current operational piston stroke is detected.

[0009] In such a displacement detection device, the position detection sensor is placed laterally to the piston and a side surface of the piston moving in the traverse direction in front of the position detection sensor (at the side of measuring a distance with the position detection sensor) becomes the surface to be detected. Therefore, the detection point as a part, which faces the position detection sensor, of the surface to be detected is sequentially changed as corresponding to the piston reciprocation motion on the surface to be detected. The surface to be detected is formed such that the displacement signal indicating that the detection point comes close to the position detection sensor and goes away therefrom as corresponding to the piston stroke is output as a waveform pattern. Therefore, all of waveform patterns of the detected displacement signals of one piston stroke can be obtained as a whole between the top dead center and the bottom dead center by outputting the displacement signal in the one piston stroke. Such a waveform pattern of the displacement signal for one piston stroke can be regarded as corresponding to a compressor displacement at the time. The present invention utilizes the fact that waveform pattern (A) of a displacement signal for one piston stroke in operation with the maximum displacement completely includes waveform pattern (B) of another displacement signal for one piston stroke in operation with another displacement value, as being based on the correspondence between the displacement signal waveform pattern and the compressor displacement. In other words, the measured and stored waveform pattern (A) and the detected waveform pattern (B) are compared to perceive what part of the waveform pattern (A) the waveform pattern (B) corresponds to, so that the proportion of one current operational piston stroke to one piston stroke in operation with the maximum displacement operation is perceived and the current operational displacement corresponding to the current operational piston stroke is estimated. Because the back face of the piston forming the surface to be detected has a complicated shape through the head part, neck part and cylinder part, the detected signal pattern obtained in operation with each stroke of discharge displacement contains sufficient variation. By a method of displacement estimation of the present invention, the detection surface formed on the piston is not required to correspond to the discharge displacement one-on-one with such a high accuracy as shown in Patent document 1. Therefore, the flexibility of the piston shape as a detection surface of the displacement detection device is improved so that its shape is made lighter and is easily formed with low cost. In a structure disclosed in Patent document 1, there is a great sensitiveness to disturbances because it is likely that the influence directly affects the calculation to make an outlier for a discharge displacement value when foreign substances pass between the sensor and the surface to be detected or when an abrasion or a crack appears on the surface to be detected. On the other hand, because the present invention employs a determination with the detected waveform pattern for one piston stroke as a whole, there is a great robustness against disturbances while it is not likely that the calculation is affected with noises caused by an abrasion or a crack on the surface to be detected and by a foreign substance passing by. Therefore, a current compressor displacement can be estimated more properly with a higher accuracy.

[0010] In the displacement detection device according to the present invention, it is possible that the estimation means estimates the current operational displacement by comparing the waveform pattern (A) and the waveform pattern (B) based on a comparative standard consisting of an one turn cycle signal of the compressor, a top dead center signal of the piston or both of the signals, so that the waveform pattern (A) of the displacement signal corresponding to one piston stroke in operation with the maximum displacement as well as the waveform pattern (B) of the displacement signal corresponding to one current operational piston stroke is precisely perceived as a waveform corresponding to one piston stroke. A half of the one turn cycle of the compressor can be recognized as one piston stroke, so as to precisely perceive an entering timing of the one piston stroke based on the top dead center signal of the piston.

[0011] In the displacement detection device according to the present invention, various methods can be employed as an estimation method of the compressor displacement by the estimation means, as follows. For example, it is possible that the estimation means estimates the current operational displacement at a displacement value corresponding to a maximum cross-correlation coefficient which is calculated by comparing a plurality of waveform patterns carved out from the waveform pattern (A) by a predetermined step with the waveform pattern (B). The displacement for the maximum cross-correlation coefficient is regarded as an estimated displacement so that the current operational displacement is estimated more properly. For example, the cross-correlation coefficient is calculated as detected signal pattern of waveform pattern (B) to be sought is compared in turn to displacement signal patterns which have been carved out by a predetermined step from 0% to 100% of displacement from the waveform pattern (A). The displacement of which cross-correlation coefficient is the highest among them is regarded as an estimated displacement of the detected signal pattern to be sought. Concrete arithmetic expression of the cross-correlation coefficient will be explained later.

[0012] It is also possible that the estimation means estimates the current operational displacement at a displacement value corresponding to a minimum cumulative residual sum calculated by comparing a plurality of waveform patterns carved out from the waveform pattern (A) by a predetermined step with the waveform pattern (B). The displacement for the minimum cumulative residual sum is regarded as an estimated displacement so that the current operational displacement is estimated more properly. For example, the cumulative residual sum is calculated as detected signal pattern of subject waveform pattern (B) is compared in turn to displacement signal patterns which have been carved out by a predetermined step from 0% to 100% of displacement from the waveform pattern (A). The displacement of which cumulative residual sum is the lowest among them is regarded as an estimated displacement of the detected signal pattern to be sought. Concrete arithmetic expression of the cumulative residual sum will be explained later.

[0013] It is also possible that the estimation means estimates the current operational displacement at a displacement value corresponding to a minimum cumulative sum of differences between deviations of the waveform pattern (A) from its average and deviations of the waveform pattern (B) from its average. In an actual operation of the compressor, ambient temperatures of the compressor including sensors vary greatly depending on operation environments and operation conditions. Therefore, there may be a substantial influence from temperature dependency of sensitivity/output of sensors. In a case where the ambient temperatures differ greatly when the waveform pattern (A) and the waveform pattern (B) are obtained, the absolute value of the same waveform pattern shape may vary as affected by the temperature drift, and therefore the residual error level to be obtained fluctuates. If the estimation is performed with the cumulative sum of the differences of detected signals of pattern (A) and (B) in its state from each average, such an influence from the operation condition can be offset, so that conformance is calculated more precisely and more quickly. Concrete arithmetic expression of the cumulative sum of differences of deviations from averages will be explained later.

[0014] In a case where the current operational displacement is estimated on the basis of the cumulative residual sum or the cumulative sum of differences of deviations, it is possible that the estimation means stops calculating the cumulative sum when a calculated result exceeds a minimum value during a calculation, and the minimum value is updated if a calculated result is less than the minimum value at an end of the calculation. Because the minimum value is ready to be perceived if the halfway calculated result exceeds the minimum value, further calculation is not necessary. Therefore, total time required for the calculation can be shortened by stopping the calculation at the time. If the minimum value of the cumulative sum is less than the last minimum value, the current operational displacement can be output more properly and more precisely by updating the minimum value. More concretely, computation load is demanded to be reduced in case of great practical troubles because CPU capable of operating in a high speed is required if the discharge displacement is calculated by calculating the conformance to the detected signal pattern by all steps from 0 to 100% through all the cycle on a real-time basis. Such a computation load concerning the conformance calculation can be greatly reduced by the method of the present invention, so that the real-time measurement is enabled. Besides, even if the calculation stops when the calculated result has exceeded the minimum value, the accuracy of the conformance calculation to seek the minimum does not decrease.

[0015] In order to estimate the current operational displacement by the estimation means, an interpolation operation can estimate the current operational displacement more precisely in a case that a further appropriate estimated value seems to exist between discrete estimated values. Namely, it is possible that the estimation means interpolates a displacement region of between either the maximum cross-correlation coefficient or an estimated displacement value exhibiting the minimum cumulative sum and an adjacent calculated displacement value, and if a value, which is greater than the maximum cross-correlation coefficient or which is smaller than an already calculated cumulative sum, exists in the displacement region interpolated, the value is regarded as an estimated current operational displacement. Namely in a case where the detected signal pattern of waveform pattern (B) to be sought is compared in turn to the displacement signal pattern carved out by a certain step from 0% to 100% displacement from waveform pattern (A), if the estimation is performed with a wider step (by 1%, for example), the calculation time is shortened and the estimation accuracy becomes worse. On the contrary, if the step is narrowed (by 0.1%, for example), the calculation time is elongated and the accuracy is improved. That makes a relation of trade-off. Therefore, such an interpolation method can save the calculation time and improve the accuracy. For example, values around the displacement value with the highest conformance are approximated with a certain function, of which local extremum of the approximate curve is updated with a value with the highest conformance. The approximate curve should be drawn by a function having an extremum. Spline curves or other curves obtained by high-degree method of least squares can be employed, for example. The interpolation can be performed by any general methods as described later in details.

[0016] It is possible that the one turn cycle signal of the compressor is obtained from a rotation signal of a compressor drive source. It is possible that the top dead center signal of the piston is obtained with a body to be detected which is provided at a part corresponding to a top dead center of the piston of a rotating body for driving the compressor, such as a pulley for transmitting a drive power and a drive section of clutch or torque limiter, and with a detection means which is provided at a position facing the body to be detected. The current operational displacement can be estimated from such a signal and a detected signal pattern which is transmitted from the position detection sensor.

[0017] In the present invention, waveform patterns (A) and (B) of the displacement signal corresponding to one piston stroke should be compared. It is possible that a waveform pattern of the displacement signal for the one piston stroke is obtained from a waveform pattern at the time of the reciprocation motion of the piston, and alternatively, that waveform patterns corresponding to one turn cycle of the compressor (corresponding to a reciprocation motion of the piston) are compared to each other. In other words, the detected signal pattern for one cycle of the compressor is symmetric about the center of the top dead center and the bottom dead center, and therefore the current operational displacement can be calculated with the detected signal pattern for the one cycle. Because the information amount of the signal pattern increases by comparing the detected signal patterns for one cycle to each other, the accuracy in seeking the conformance can be improved.

[0018] In the present invention, it is possible that the position detection sensor detects at least any of distributions, such as a distribution of an unevenness on the surface to be detected of the piston, a distribution of electromagnetic characteristics and a distribution of light reflection characteristics. In either case, it is preferable that signals obtained from the position detection sensor vary widely in order to estimate precisely the current operational displacement in a wider range from 0% to 100% of waveform pattern (A).

[0019] It is preferable that the position detection sensor is any of sensors including of an eddy current type sensor, an electromagnetic induction type sensor, a capacitance type sensor and a photoelectric reflection type sensor, from a viewpoint of ensuring a clear signal waveform.

[0020] In a case where the electromagnetic induction type sensor is employed as the position detection sensor, it is possible that a magnetic coating material is applied to the surface to be detected of the piston or that a magnet is buried therein. Namely, coating material or resin containing metal powder which exhibit magnetic characteristics is applied to the surface to be detected, or plating is performed, and alternatively, magnets are buried in the surface to be detected so as to exhibit magnetic characteristics.

[0021] In a case where the photoelectric reflection type sensor is employed as the position detection sensor, it is possible that an optical coating material is applied to the surface to be detected of the piston in order to obtain more clear detected signal.

[0022] Further, it is possible that the estimation means estimates the current operational displacement as removing an influence which has fluctuated a detected signal of the position detection sensor from an initial value, through a crack or an abrasion of the surface to be detected of the piston, by recording the waveform pattern (A) again in its state. Even when the distribution shape of the reflection media having high definition from the surface to be detected fluctuates from the initial value by a crack or an abrasion, the detected signal pattern obtained at the time of the maximum displacement operation is reacquired in its state, so that the influence of the fluctuation of the distribution pattern of the reflection media is corrected to improve the accuracy at the time of degradation. The detected signal pattern obtained at the time of the maximum displacement operation can be easily obtained in operation without stopping and removing the compressor.

[0023] The present invention also provides a variable displacement compressor provided with the above-described displacement detection device. In the compressor, it is possible that a torque of the compressor is estimated from an estimated displacement and at least a discharge pressure and a suction pressure of the compressor. It is also possible that a valve opening of a displacement control valve for varying a displacement of the compressor is controlled with an estimated displacement as an input information.

Effect according to the Invention

[0024] Thus, the variable displacement compressor and its displacement detection device make it possible that the surface to be detected of the piston is enhanced in flexibilities of its shape and structure from a conventional technology disclosed in Patent document 1. Further, high accuracy is not required in processing the piston so as to achieve great reduction in cost. In addition, even if the abrasion or the crack on the surface to be detected and the clearance between the piston and the cylinder bore fluctuate the detected signal, the influence can be minimized so that the displacement is properly estimated as being robust against disturbances.

Brief explanation of the drawings

[0025]

[Fig. 1] Fig. 1 is a longitudinal cross section of a variable displacement compressor provided with a displacement detection device according to an embodiment of the present invention.
[Fig. 2] Fig. 2 is an explanatory diagram showing an example of methods to estimate a displacement by a displacement detection device according to the present invention.
[Fig. 3] Fig. 3 is a control flow chart showing an example of methods to estimate a displacement by a displacement detection device according to the present invention.
[Fig. 4] Fig. 4 is a relationship diagram between cumulative residual sums and the number of processed data, showing an example of methods of a repeat operation in estimating a displacement of a displacement detection device according to the present invention.
[Fig. 5] Fig. 5 is an explanatory diagram showing an example of methods of interpolation processing in estimating a displacement of a displacement detection device according to the present invention.

Embodiments for carrying out the Invention

[0026] Hereinafter, the present invention will be explained as an embodiment of a displacement detection device for a swash plate type variable displacement compressor applicable to an air conditioning system for vehicles. Fig. 1 shows variable displacement compressor 1 provided with displacement detection device 2 according to an embodiment of the present invention, and specifically shows a longitudinal section of compressor 1 in the minimum displacement state. In variable displacement compressor, the rotation drive force input from an external drive source is transmitted to pulley 3 through a belt, etc., and then is transmitted to drive shaft of the compressor through torque limiter mechanism 4. Inside crank chamber 8 which has been made with front housing 6 and cylinder block 7, provided are rotor 9 to rotate together with drive shaft 5 and swash plate 11 which has been connected to rotor 9 through link mechanism 10 and is capable of varying its inclination angle with respect to drive shaft 5, while swash plate 11 is rotated as being synchronized with drive shaft 5. Cylinder block 7 is provided with a plurality of cylinder bores 12 (only 1 cylinder is illustrated), and piston 13 is reciprocably inserted in each cylinder bore 12. One end part 13a (neck part) of piston 13 is connected to swash plate 11 through a pair of shoes 14 which contact slidably to both sides of swash plate 11, and the rotation motion of swash plate 11 is converted into the reciprocation motion of piston 13. The stroke of the reciprocation motion of piston 13 is varied corresponding to the inclination angle of swash plate 11, and the inclination angle of swash plate 11 is varied corresponding to inner pressure of crank chamber 8 as described above. Corresponding to the reciprocation motion of piston 13, fluid, such as refrigerant, to be compressed is sucked from suction chamber 16 formed in cylinder head 15 into cylinder bore 12, and compressed fluid which has been compressed in cylinder bore 12 is discharged to an external circuit through discharge chamber 17.

[0027] In such variable displacement compressor 1, the discharge displacement is determined according to a displacement volume of piston 13, namely the stroke of piston 13. Displacement detection device 2 estimates current operating displacement corresponding to the stroke of piston 13, and is constituted as follows.

[0028] A back side of piston 13 which is one of pistons 13 shown in Fig. 1, becomes surface 21 to be detected. Surface 21 to be detected is shaped such that the distance between surface 21 to be detected and a position detection sensor is varied, when piston 13 reciprocates for one cycle. Because the back side of piston 13, which is used for a typical swash plate type variable displacement compressor, becomes a back side of head part, neck part and cylinder part , the distance between surface 21 to be detected and the position detection sensor continues to change obviously. Because the estimation can be done with a higher accuracy when the trace of detected signals in operation by each discharge displacement varies widely, surface 21 to be detected is sometimes slit so as to more vary in a direction of the reciprocation motion. However, there are not any particular restriction of accuracy and shape, even in such a case. Surface 21 to be detected is placed at a side opposite to drive shaft 5 around axis line S, as partially facing inner periphery 6a of front housing 6.

[0029] On inner periphery 6a of front housing 6, detection head 22a of contactless position detection sensor 22 is disposed as facing surface 21 to be detected of piston 13 in the circumference side of neck part 13a of piston 13, namely in the lateral side of neck part 13a. Position detection sensor 22 may be the one of eddy current loss detection type.

[0030] When piston 13 reciprocates, surface 21 to be detected is moved in a traverse direction in front of position detection sensor 22 (detection head 22a) at the lower side of Fig. 1, namely at the side of measuring distance by detection head 22a. Therefore, detection object point K, which is a part confronting detection head 22a on surface 21 to be detected, moves sequentially along the shape on surface 21 to be detected as depending on the reciprocation motion of piston 13, and distance L between detection object point K and detection head 22a changes. Position detection sensor 22 detects distance L between detection head 22a and surface 21 to be detected (detection object point K) and outputs detected distance information L from controller 23 to air-conditioner ECU24.

[0031] Air-conditioner ECU 24, which is an electronic control unit like a computer, estimates and perceives a discharge displacement of the compressor based on detection distance information L from position detection sensor 22. Namely, air-conditioner ECU 24 constitutes a displacement estimation means. Air-conditioner ECU 24 transmits perceived displacement information of the compressor to an engine ECU which is not shown in Fig. 1. Therefore, the idling control of the engine by an engine ECU can be made desirable by considering the load torque of the compressor.

[0032] While piston 13 reciprocates by one stroke, surface 21 to be detected is moved to change distance L from detection head 22a which detects the displacement of surface 21 to be detected, and the displacement signal is output from position detection sensor 22. This displacement signal as a displacement signal of a waveform pattern is output from position detection sensor 22 to air-conditioner ECU 24 as shown in Fig. 2 while piston 13 moves in one stroke of piston 13 between the top dead center position and the bottom dead center position. The detected signal patterns, which are waveform patterns of displacement signals, of distance information L differ depending on discharge displacements in operation.

[0033] In this embodiment, three kinds of information are required for detecting the discharge displacement. The first one is a detected signal pattern, which is a waveform pattern of displacement signal, of distance information L obtained from position detection sensor 22. The second one is a detected signal of the top dead center position in piston reciprocation motion. The third one is periodic information of the piston reciprocation motion or information corresponding to one stroke.

[0034] As for a pulley section of a torque limiter corresponding to the top dead center position of the compressor or a clutch, the top dead center position and the periodic information of the piston reciprocation motion are detected with a contactless type detection sensor 26 placed as facing to surface 21 to be detected, of reflection type part 25 to be detected provided in an armature section. Detection sensor 26 may be the one of photoelectric reflection type.

[0035] Fig. 3 is a flow chart showing an example of processing method in a displacement estimation according to this embodiment. The example of processing method in the displacement estimation will be explained as referring to Fig. 2 and Fig. 3.

[0036] In this embodiment, at first the detected signal pattern (waveform pattern of the displacement signal) of position detection sensor 22 is recorded as a standard output waveform for a comparison to estimate current operational displacement while piston 13 moves by one piston stroke between the top dead center position and the bottom dead center position according to the detected signal pattern of distance information L from position detection sensor 22 in operation with the maximum displacement, the top dead center position information from detection sensor 26, and the periodic information. Hereinafter, such a detected signal pattern will be called displacement signal waveform pattern (A) corresponding to one piston stroke in operation with the maximum displacement.

[0037] Next, the detected signal pattern (waveform pattern of the displacement signal) of position detection sensor 22 is recorded as an output waveform to estimate current operational displacement while piston 13 moves by one piston stroke between the top dead center position and the bottom dead center position according to the detected signal pattern of distance information L from position detection sensor 22 in operation with current displacement to be measured, the top dead center position information from detection sensor 26, and the periodic information. Hereinafter, such a detected signal pattern will be called output waveform pattern (B) to estimate the current operational displacement.

[0038] Because the displacement to be measured is below the maximum displacement, displacement signal waveform pattern (A) (output waveform at 100% displacement in Fig. 2) in operation with the maximum displacement includes the output waveform pattern (output waveform pattern (B) of the displacement signal corresponding to one piston stroke) to estimate the current operational displacement, as namely including the output waveform at 50% or 10% displacement in Fig. 2.

[0039] The detected signal pattern of distance information L in operation with the maximum displacement (displacement signal waveform pattern (A) corresponding to one piston stroke in operation with the maximum displacement) is carved out by a certain step (every 1%, for example) from the top dead center, so as to be compared to the detected signal pattern of the distance information in operation with "displacement to be measured" (Namely, displacement signal waveform pattern (B) corresponding to one piston stroke in operation with current displacement) in conformance. Such a comparison of the conformance is continued from 0% to the maximum displacement 100%, for example. Above all, the displacement closest (conformed) to the detected signal pattern of the distance information of "displacement to be measured" is selected as an estimated displacement in operation with "displacement to be measured".

[0040] The detected signal pattern of distance information L in operation with the maximum displacement, which has been carved up at a certain displacement, can be evaluated in a conformance to the detected signal pattern of the distance information in operation with "displacement to be measured", by using a parameter, such as cross-correlation coefficient as described above, cumulative residual sum and cumulative sum of deviations from an average.

[0041] In a case of using the cross-correlation coefficient, a displacement of which the cross-correlation coefficient r calculated with Formula 1 is the highest, namely closest to 1, becomes a discharge displacement to be measured. In a case of using the cumulative residual sum or the cumulative sum of deviations from the average, a displacement of which cumulative sum I calculated with Formula 2 (in case of using the cumulative residual sum) or Formula 3 (in case of using the cumulative sum of deviations from the average) is the lowest, namely closest to 0, becomes a discharge displacement to be measured. In Formula1 - Formula 3, ai implies a value at a certain point of waveform pattern in operation with "displacement to be measured", a with bar implies an average at each point of the waveform pattern, bi implies a value at a certain point of waveform pattern in operation with the maximum displacement, and b with bar implies an average at each point of the waveform pattern.

[0042]

[Formula 1]

$$r = \frac{\sum_{i=0}^{N-1}(a_i - \bar{a})(b_i - \bar{b})}{\sqrt{\left(\sum_{i=0}^{N-1}(a_i - \bar{a})^2\right)}\sqrt{\left(\sum_{i=0}^{N-1}(b_i - \bar{b})^2\right)}}$$

[0043]

[Formula 2]

$$I = \sum_{i=0}^{N-1}\left|a_i - b_i\right|$$

[0044]

[Formula 3]

$$I = \sum_{i=0}^{N-1}\left|\left(a_i - \bar{a}\right) - \left(b_i - \bar{b}\right)\right|$$

[0045] Further, unnecessary calculation may be omitted in the middle in order to achieve an efficiency of the calculation and to shorten the calculation time. In other words, in a case of using the cumulative residual sum or the cumulative sum of deviations to estimate a current displacement in operation, the displacement estimation means can stop calculating at the time when a calculated result exceeds the minimum cumulative sum in the middle of calculating the cumulative sum. As shown in Fig. 4, when the calculated result exceeds the minimum cumulative sum in the middle of repeated calculation, additional calculation is not necessary because the minimum value can already be perceived. If the calculation is stopped at the time, the number of processed data in the signal pattern to be calculated can be reduced and total time required for the calculation can be shortened.

[0046] Furthermore, in a case that more appropriate estimated value seems to exist between discrete estimated displacement values in estimating a current operational displacement, the method of interpolation can be employed for estimating current operational displacement more accurately. Even in the control flow chart shown in Fig. 3, such a step of the interpolation is provided before the final step. This interpolation can be achieved with a general method of interpolation. As shown in Fig. 5, if a virtual datum with a higher conformance around some most conformed data (in a neighborhood of a local minimal value in Fig. 5) seem to exist in a column of processed data concerning an estimated displacement (indicated with open circles in Fig. 5), the data column is approximated with a approximate curve as interpolating between certain data, and a local minimal value of the interpolated approximate curve is obtained in a region of the interpolation, for example. Thus an estimated displacement datum with a higher conformance is obtained and employed as an estimated current operational displacement, so that the current operational displacement can be estimated more accurately.

[0047] In this embodiment, as shown in Fig. 2, the conformance is compared by using the detected signal pattern (displacement signal waveform pattern) of distance information L corresponding to one piston stroke between the top dead center position and the bottom dead center position. Alternatively, the discharge displacement can be estimated based on information of one cycle between a bottom dead center position to the next bottom dead center position with the center of the top dead center position. Also, a displacement signal waveform pattern corresponding to one piston stroke can be obtained from a half part of the information of one cycle.

[0048] Furthermore, even if the detected signal, such as signal with a distribution of reflection medium with a high definition, from surface 21 to be detected of the piston varies greatly from the initial value by crack or abrasion when the compressor is in operation, the detected signal pattern in operation with the maximum displacement is obtained again, so that the influence from fluctuated detected signal pattern of the reflection medium is corrected and that accuracies of the detection and the displacement estimation are improved in a degraded condition. The detected signal pattern in operation with the maximum displacement can easily be obtained even in operation without stopping or removing the compressor.

Industrial Applications of the Invention

[0049] The displacement detection device of the present invention is applicable to any piston type variable displacement compressor, in which a displacement can easily be estimated with low cost and high accuracy, so that a torque of the variable displacement compressor is estimated through estimating the displacement, for example.

Explanation of symbols

[0050]

1: variable displacement compressor
2: displacement detection device
3: pulley
4: torque limiter mechanism
5: drive shaft
6: front housing
6a: inner periphery of front housing
7: cylinder block
8: crank chamber
9: rotor
10: link mechanism
11: swash plate
12: cylinder bore
13: piston
13a: neck part of piston
14: shoe
15: cylinder head
16: suction chamber
17: discharge chamber
21: piston surface to be detected
22: position detection sensor
22a: detection head of position detection sensor

23: controller
24: air-conditioner ECU
25: part to be detected
26: detection sensor

Claims

1. A displacement detection device for a variable displacement compressor, wherein a piston reciprocates to compress gas and a stroke of said piston is changed to vary a displacement, comprising
a position detection sensor, which is disposed laterally to said piston and which outputs a displacement signal indicating that a detection point, which is a part of a surface to be detected facing said position detection sensor as a shape of said piston which moves in a traverse direction in front of said position detection sensor by a reciprocation motion of said piston, approaches and leaves said position detection sensor at a time of said reciprocation motion of said piston, and
an estimation means for estimating a current operational displacement corresponding to a current operational piston stroke by comparing waveform pattern (A) to waveform pattern (B), wherein said waveform pattern (A) of said displacement signal corresponding to one piston stroke in operation with a maximum displacement is measured and stored and said waveform pattern (B) of a current operational displacement signal corresponding to one current operational piston stroke is detected.

2. The displacement detection device according to claim 1, wherein said estimation means estimates said current operational displacement by comparing said waveform pattern (A) and said waveform pattern (B) based on a comparative standard consisting of an one turn cycle signal of said compressor, a top dead center signal of said piston or both of said signals.

3. The displacement detection device according to claim 1 or 2, wherein said estimation means estimates said current operational displacement at a displacement value corresponding to a maximum cross-correlation coefficient which is calculated by comparing a plurality of waveform patterns carved out from said waveform pattern (A) by a predetermined step with said waveform pattern (B).

4. The displacement detection device according to claim 1 or 2, wherein said estimation means estimates said current operational displacement at a displacement value corresponding to a minimum cumulative residual sum calculated by comparing a plurality of waveform patterns carved out from said waveform pattern (A) by a predetermined step with said waveform pattern (B).

5. The displacement detection device according to claim 1 or 2, wherein said estimation means estimates said current operational displacement at a displacement value corresponding to a minimum cumulative sum of differences between deviations of said waveform pattern (A) from its average and deviations of said waveform pattern (B) from its average.

6. The displacement detection device according to claim 4 or 5, wherein said estimation means stops calculating said cumulative sum when a calculated result exceeds a minimum value during a calculation, and said minimum value is updated if a calculated result is less than said minimum value at an end of said calculation.

7. The displacement detection device according to any of claims 3-6, wherein said estimation means interpolates a displacement region of between either said maximum cross-correlation coefficient or an estimated displacement value exhibiting said minimum cumulative sum and an adjacent calculated displacement value, and if a value, which is greater than said maximum cross-correlation coefficient or which is smaller than an already calculated cumulative sum, exists in said displacement region interpolated, said value is regarded as an estimated current operational displacement.

8. The displacement detection device according to any of claims 2-7, wherein said one turn cycle signal of said compressor is obtained from a rotation signal of a compressor drive source.

9. The displacement detection device according to any of claims 2-8, wherein said top dead center signal of said piston is obtained with a body to be detected which is provided at a part corresponding to a top dead center of said piston of a pulley for driving said compressor, and with a detection means which is provided at a position facing said body

to be detected.

10. The displacement detection device according to any of claims 1-9, wherein a waveform pattern of said displacement signal for said one piston stroke is obtained from a waveform pattern at said time of said reciprocation motion of said piston.

11. The displacement detection device according to any of claims 1-10, wherein said position detection sensor detects at least any of distributions, among a distribution of an unevenness on said surface to be detected of said piston, a distribution of electromagnetic characteristics and a distribution of light reflection characteristics.

12. The displacement detection device according to claim 11, wherein said position detection sensor is any of sensors including an eddy current type sensor, an electromagnetic induction type sensor, a capacitance type sensor and a photoelectric reflection type sensor.

13. The displacement detection device according to claim 12, wherein a magnetic coating material is applied to said surface to be detected of said piston or a magnet is buried therein.

14. The displacement detection device according to claim 12, wherein an optical coating material is applied to said surface to be detected of said piston or a light reflective body is buried therein.

15. The displacement detection device according to any of claims 1-14, wherein said estimation means estimates said current operational displacement as removing an influence which has fluctuated a detected signal of said position detection sensor from an initial value, through a crack or an abrasion of said surface to be detected of said piston, by recording said waveform pattern (A) again in its state.

16. A variable displacement compressor provided with said displacement detection device according to any of claims 1-15,

17. The variable displacement compressor according to claim 16, wherein a torque of said compressor is estimated from said estimated displacement and at least a discharge pressure and a suction pressure of said compressor.

18. The variable displacement compressor according to claim 16 or 17, wherein a valve opening of a displacement control valve for varying a displacement of said compressor is controlled with an estimated displacement as an input information.

FIG. 1

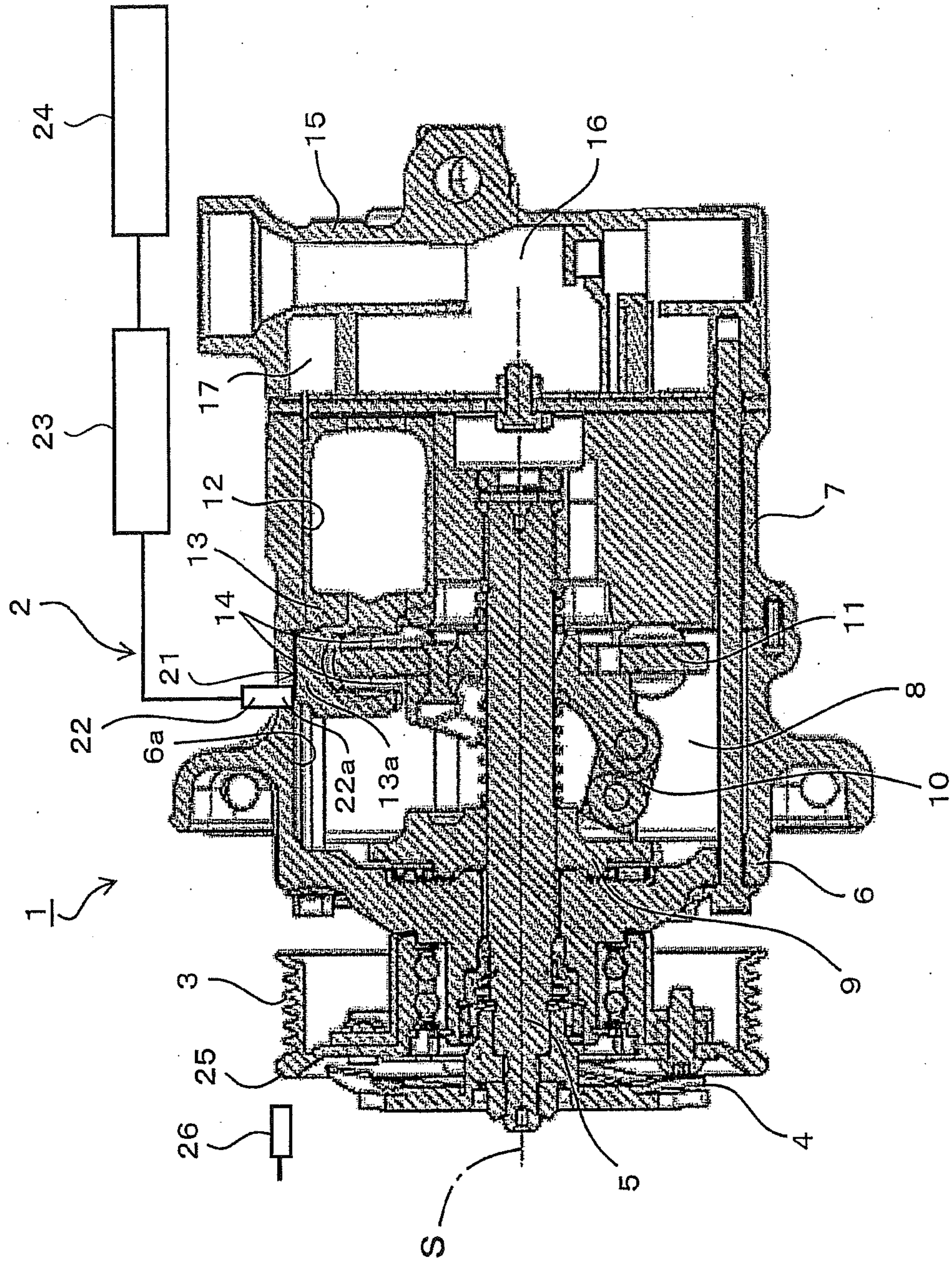


FIG. 2

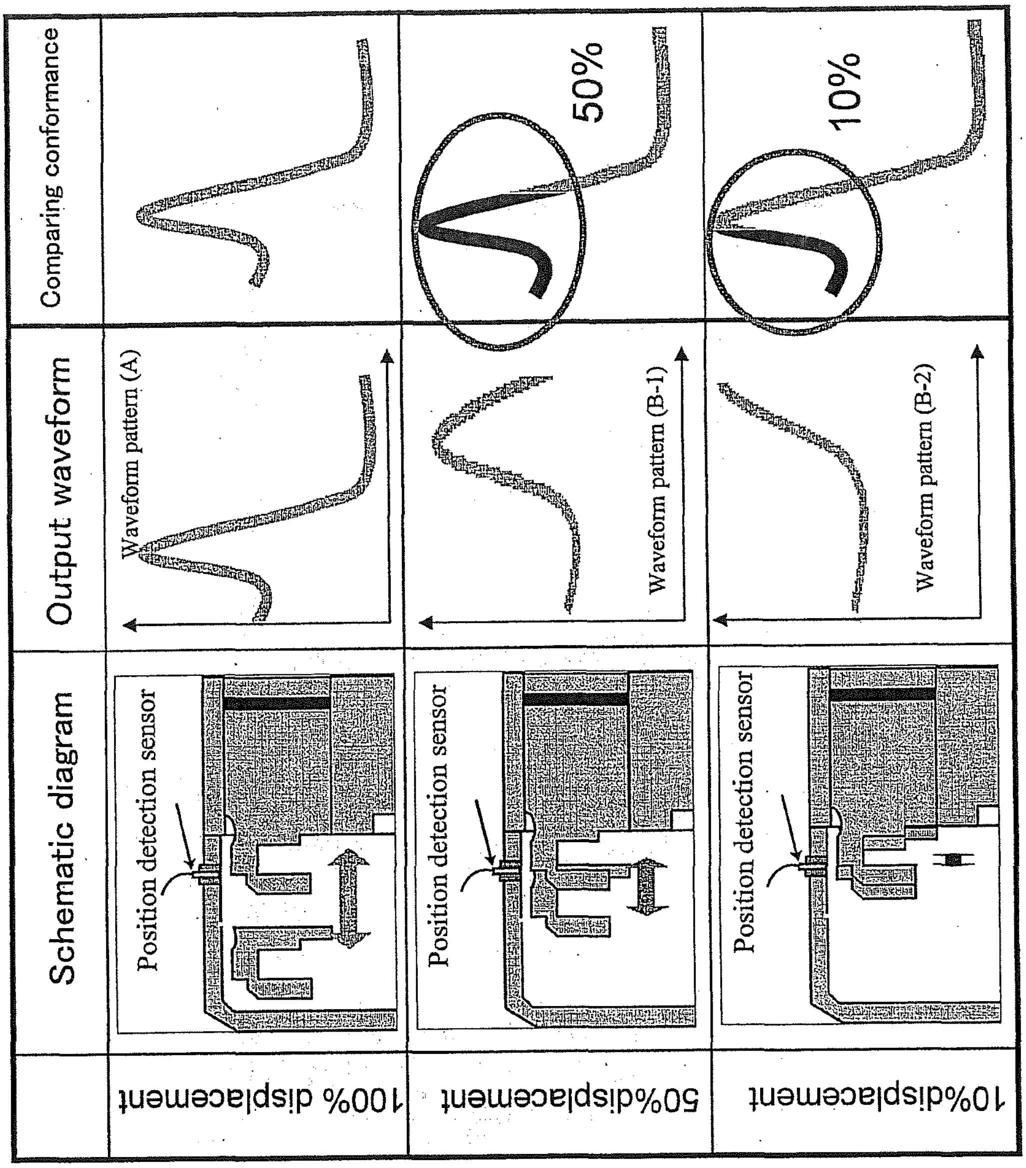

Schematic diagram
Output waveform
Comparing conformance
100% displacement
Position detection sensor
Waveform pattern (A)
50%displacement
Position detection sensor
Waveform pattern (B-1)
50%
10%displacement
Position detection sensor
Waveform pattern (B-2)
10%

FIG. 3

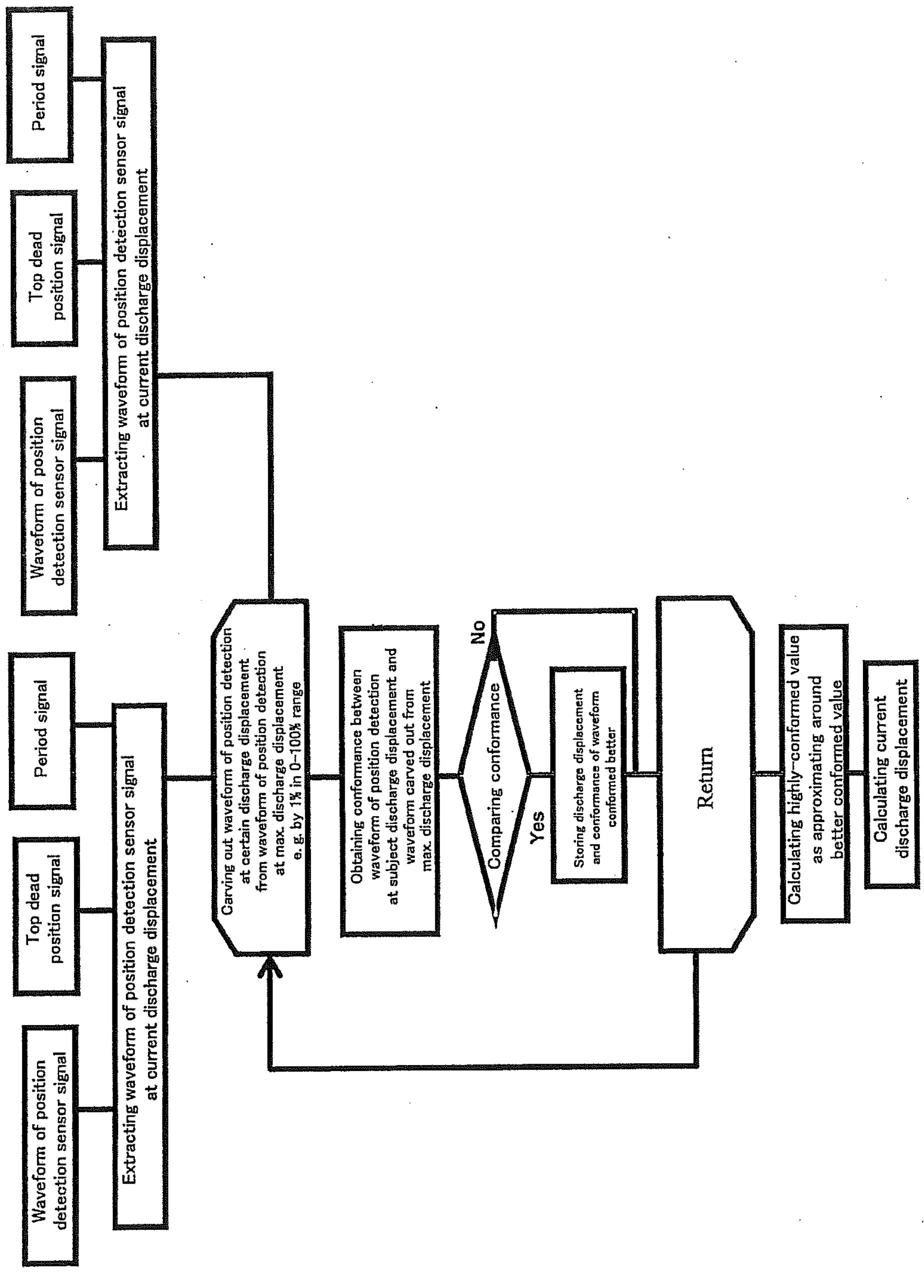
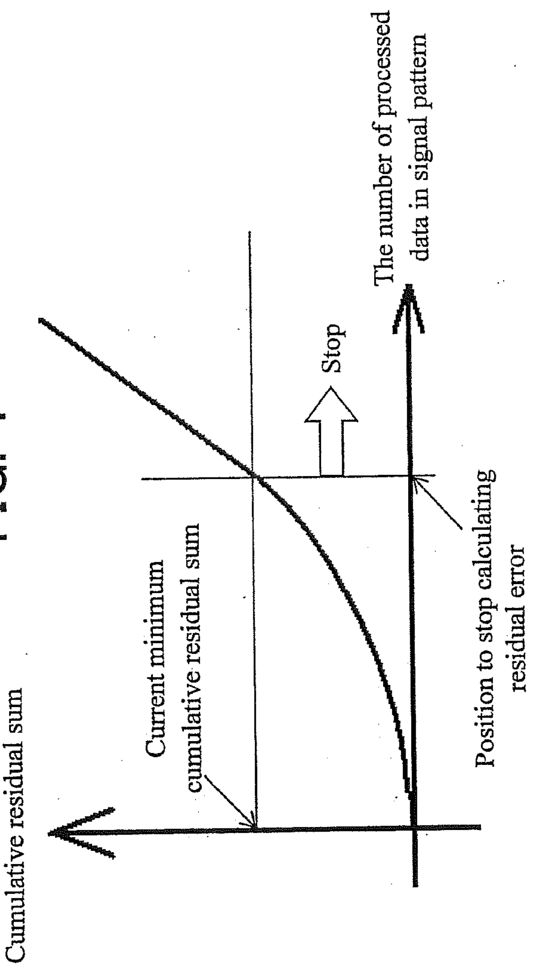
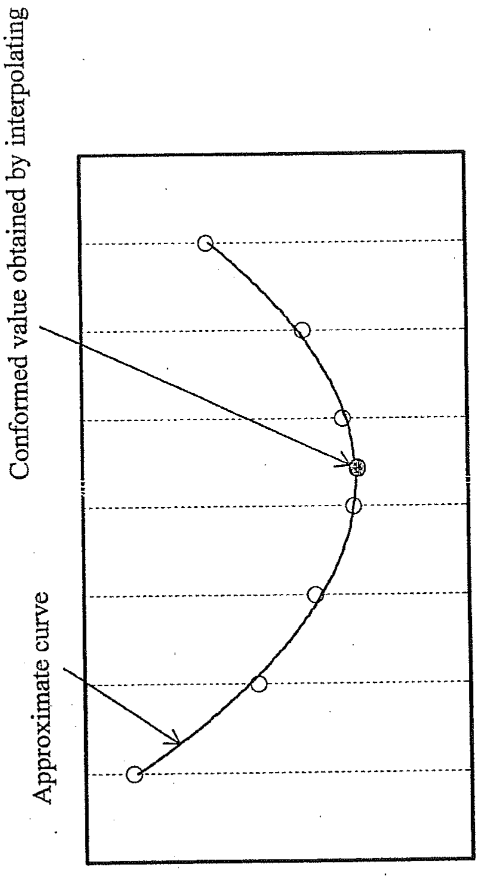

Waveform of position detection sensor signal
Top dead position signal
Period signal
Extracting waveform of position detection sensor signal at current discharge displacement
Waveform of position detection sensor signal
Top dead position signal
Period signal
Extracting waveform of position detection sensor signal at current discharge displacement
Carving out waveform of position detection at certain discharge displacement from waveform of position detection at max. discharge displacement e. g. by 1% in 0~100% range
Obtaining conformance between waveform of position detection at subject discharge displacement and waveform carved out from max. discharge displacement
Comparing conformance
No
Yes
Storing discharge displacement and conformance of waveform conformed better
Return
Calculating highly-conformed value as approximating around better conformed value
Calculating current discharge displacement

FIG. 4



Cumulative residual sum
Current minimum
cumulative residual sum
Stop
The number of processed
data in signal pattern
Position to stop calculating
residual error

FIG. 5



Conformed value obtained by interpolating
Approximate curve

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/000231

A. CLASSIFICATION OF SUBJECT MATTER
F04B27/10(2006.01)i, *F04B27/08*(2006.01)i, *F04B27/14*(2006.01)i, *F04B39/00*(2006.01)i, *F04B49/00*(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
F04B27/10, F04B27/08, F04B27/14, F04B39/00, F04B49/00

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

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2011
Kokai Jitsuyo Shinan Koho	1971-2011	Toroku Jitsuyo Shinan Koho	1994-2011

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2003-148357 A (Toyota Industries Corp.), 21 May 2003 (21.05.2003), paragraphs [0026] to [0050]; fig. 1 to 6 (Family: none)	1-18
A	JP 2003-148355 A (Sanden Corp.), 21 May 2003 (21.05.2003), paragraphs [0007] to [0014]; fig. 1, 3 (Family: none)	1-18
A	JP 11-093846 A (Daikin Industries, Ltd.), 06 April 1999 (06.04.1999), paragraph [0028]; fig. 1, 2 (Family: none)	1-18

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
02 May, 2011 (02.05.11)	17 May, 2011 (17.05.11)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2011/000231

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 02-064275 A (Nippon Soken, Inc., Nippondenso Co., Ltd.), 05 March 1990 (05.03.1990), page 9, lower left column, line 9 to page 10, lower left column, line 13; fig. 6 to 11 (Family: none)	1-18

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2003148357 A **[0004]**