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Son et al.

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(54) **VALVE DURATION CONTROL APPARATUS AND ENGINE PROVIDED WITH THE SAME**

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(52) **U.S. Cl.**
CPC ***F01L 1/356*** (2013.01)

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CPC F01L 1/356; F01L 2001/0476; F01L 2001/0537; F01L 2820/032
USPC 123/90.15, 90.16
See application file for complete search history.

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Assistant Examiner — Paul W Thiede
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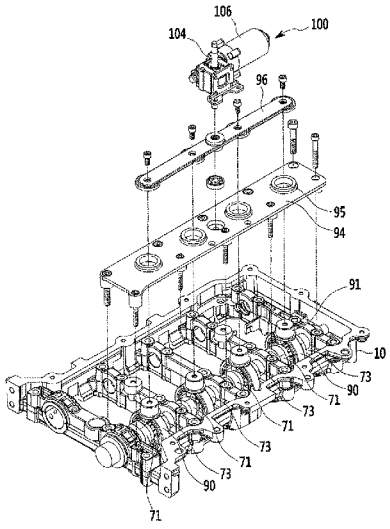
(57) **ABSTRACT**

A continuously variable valve duration apparatus may include a camshaft, a plurality of first cams and second cams of which a cam key is formed respectively thereto, and of which relative phase angles with respect to the camshaft are variable, a plurality of rotation rings mounted to the camshaft and of which a ring key is formed thereto respectively, a plurality of inner brackets transmitting rotation of the camshaft to the cam keys of the first cams and the seconds respectively, a plurality of slider housings of which each inner bracket is rotatable inserted therein, a support bracket connecting the slider housings and a control portion selectively moving the support bracket and moving positions of the slider housings so as to change rotation centers of the inner brackets.

20 Claims, 10 Drawing Sheets



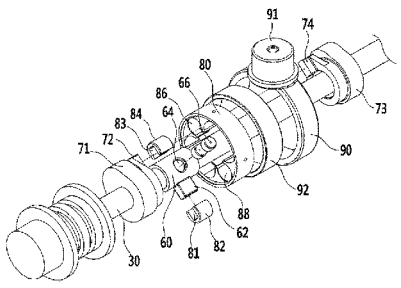


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FIG. 1

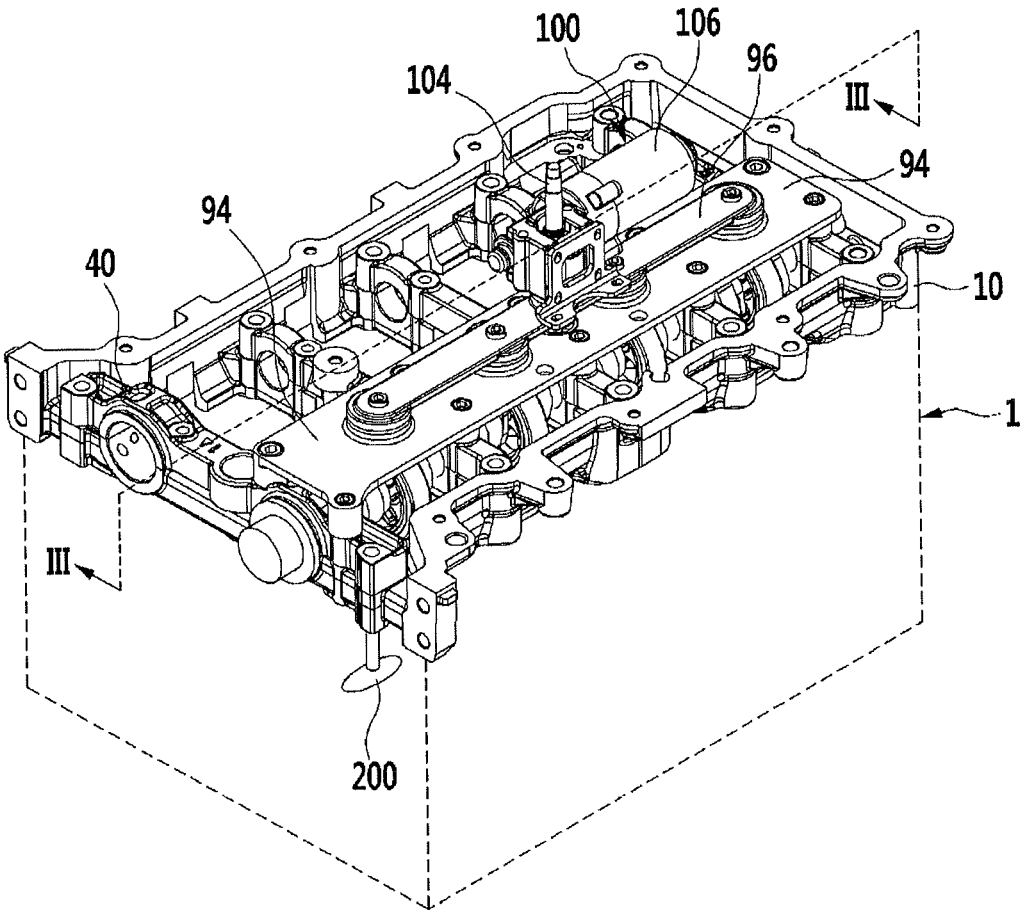


FIG. 2

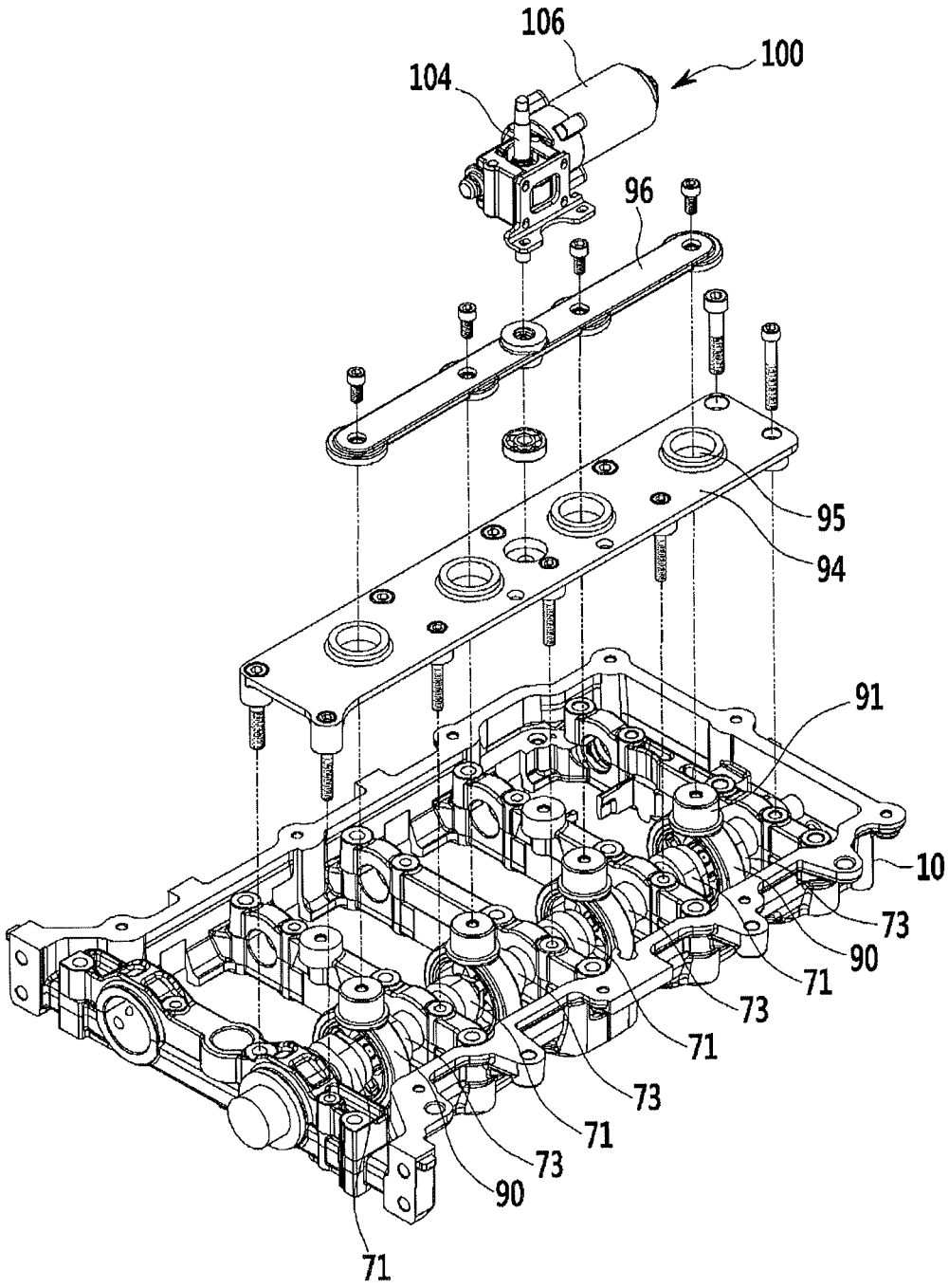


FIG. 3

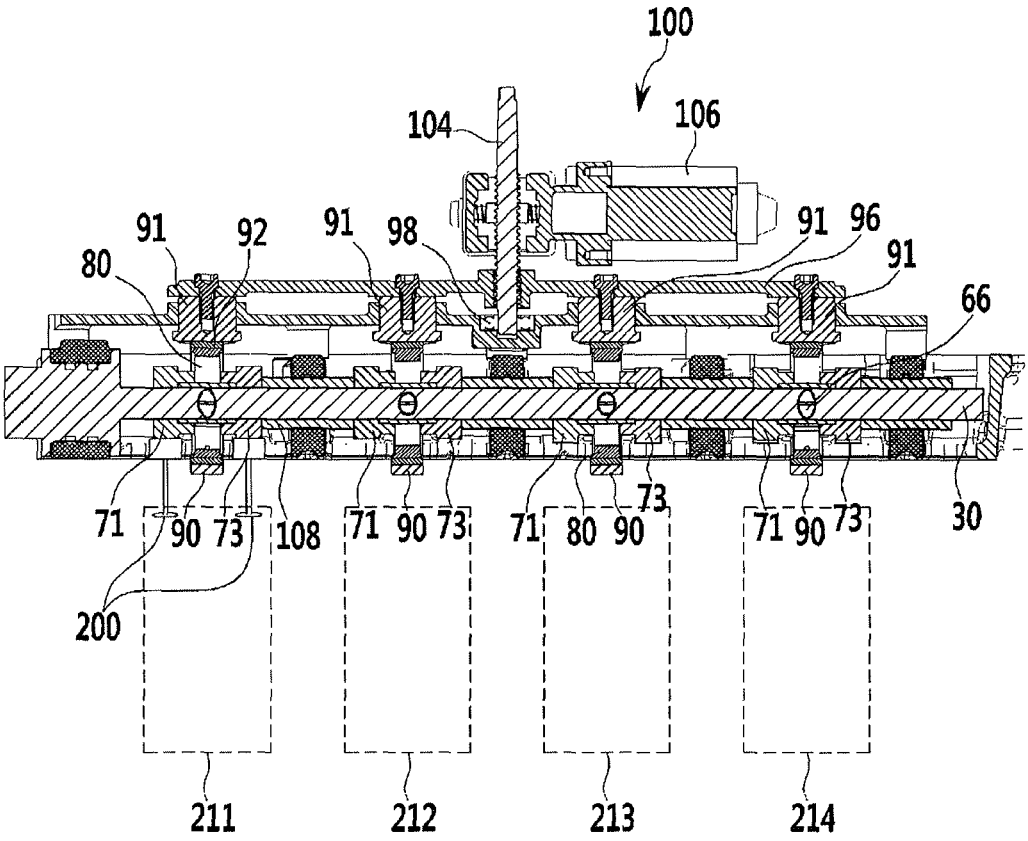

100
104
106
91
92
91
98
91
96
91
80
66
71
90
73
108
71
90
73
71
80
90
73
71
90
73
30
200
211
212
213
214

FIG. 4

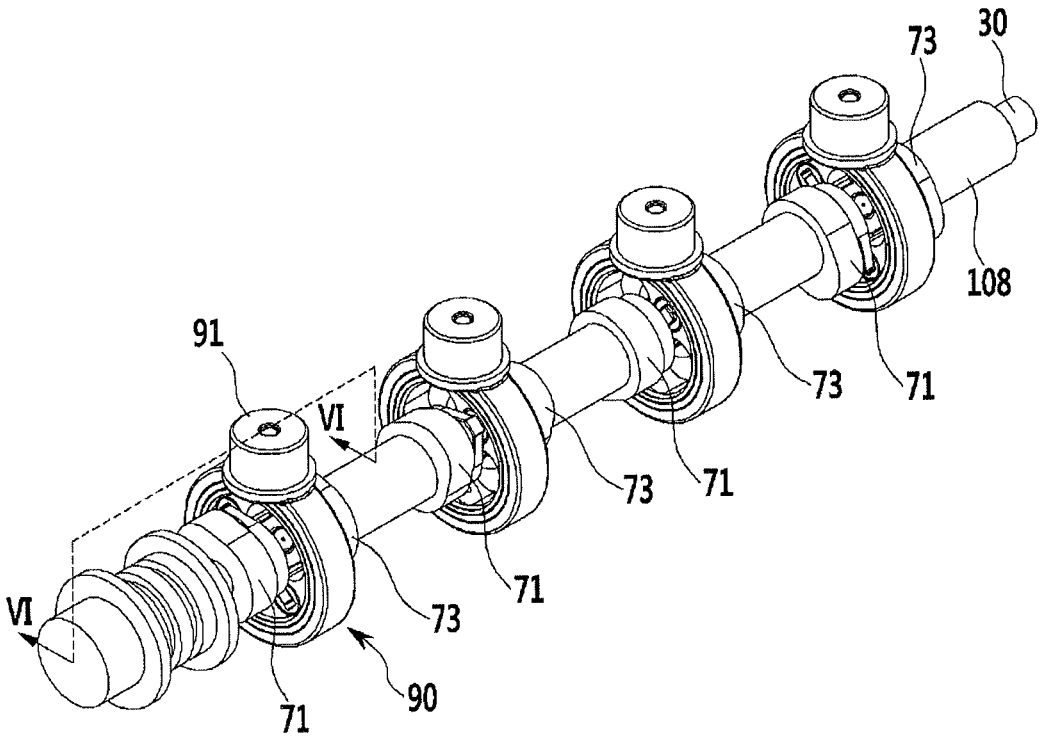


FIG. 5

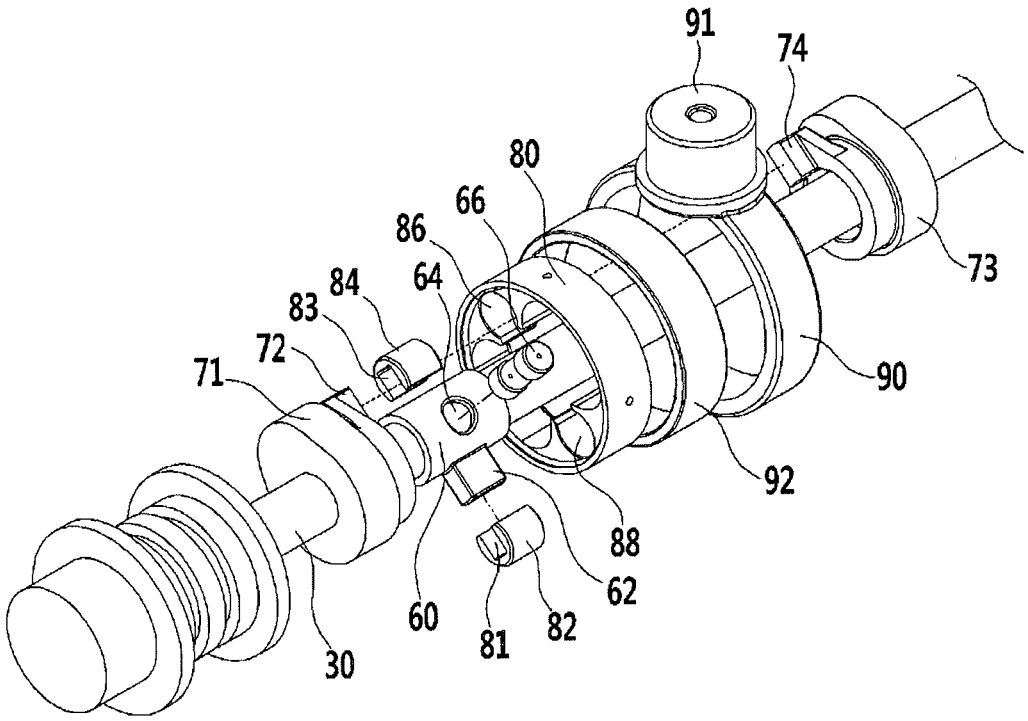


FIG. 6

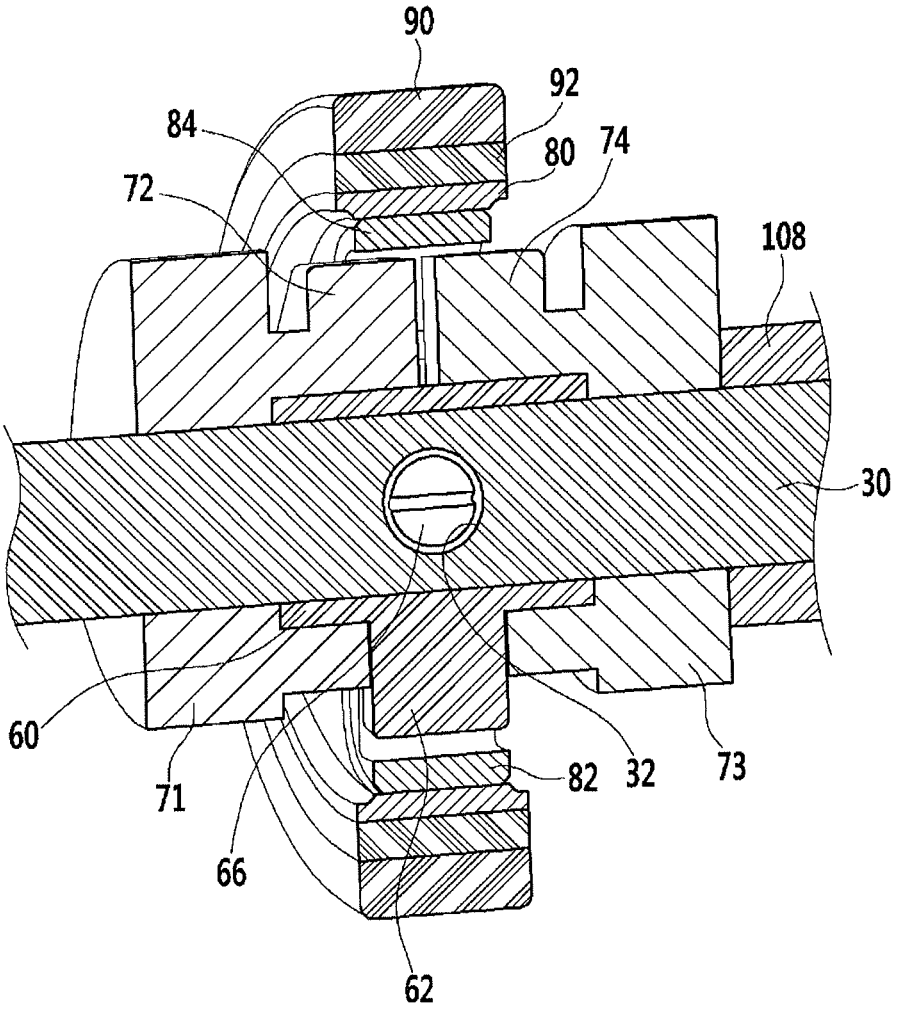


FIG. 7

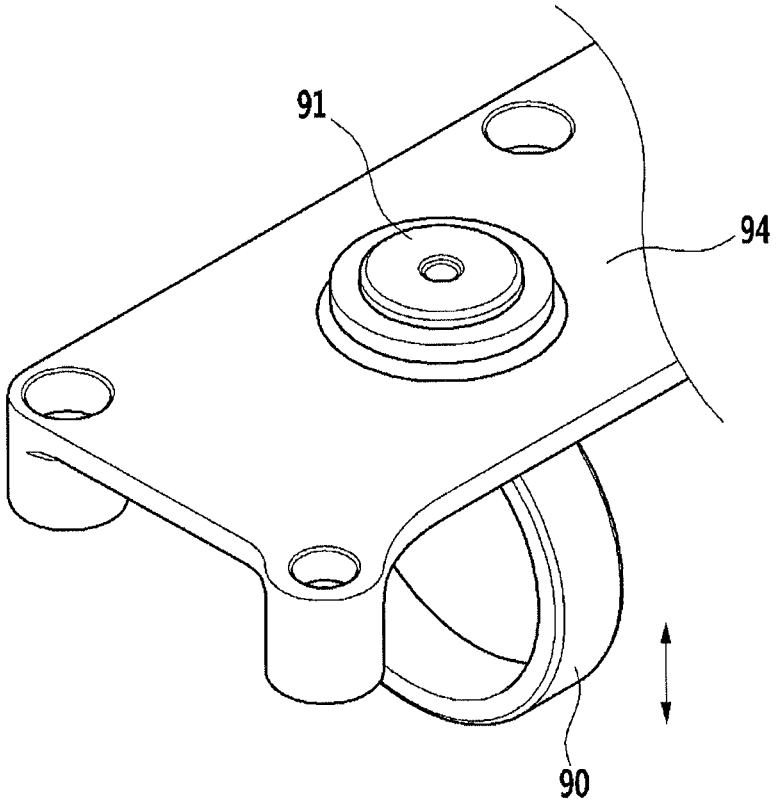


FIG. 8

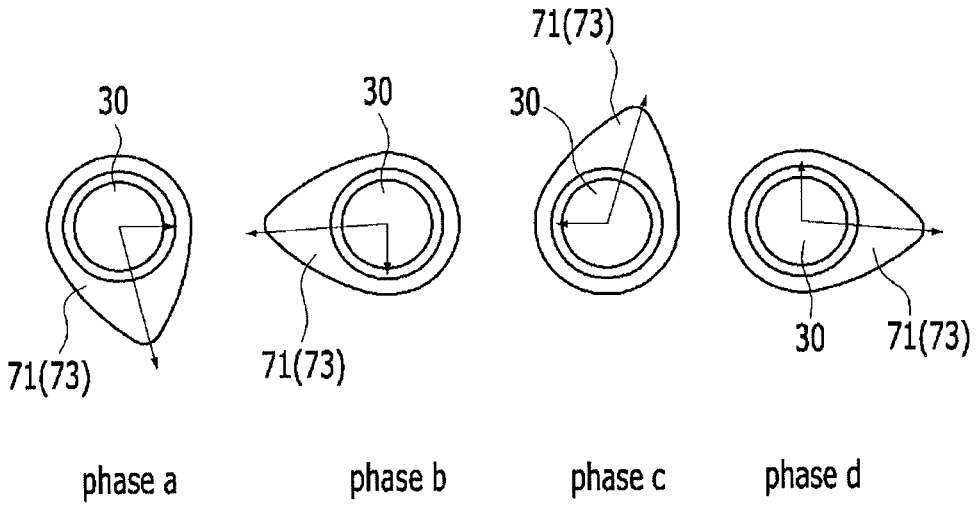


FIG. 9

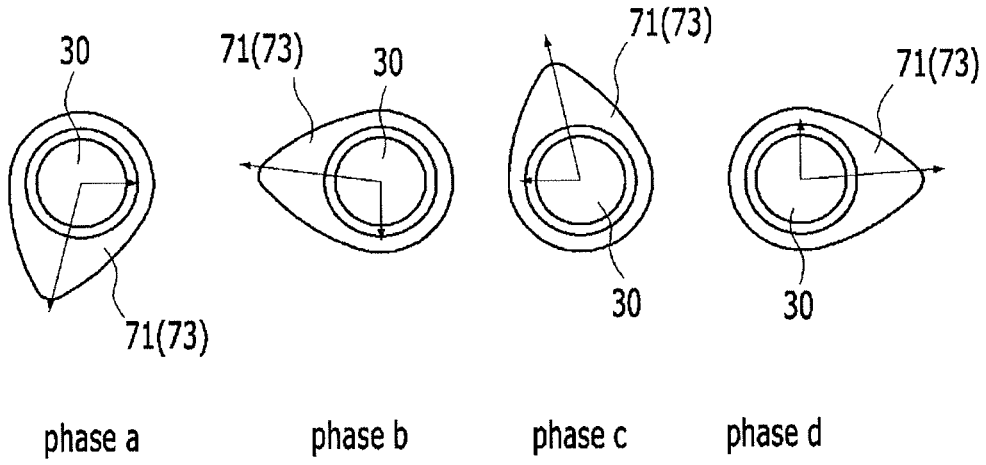
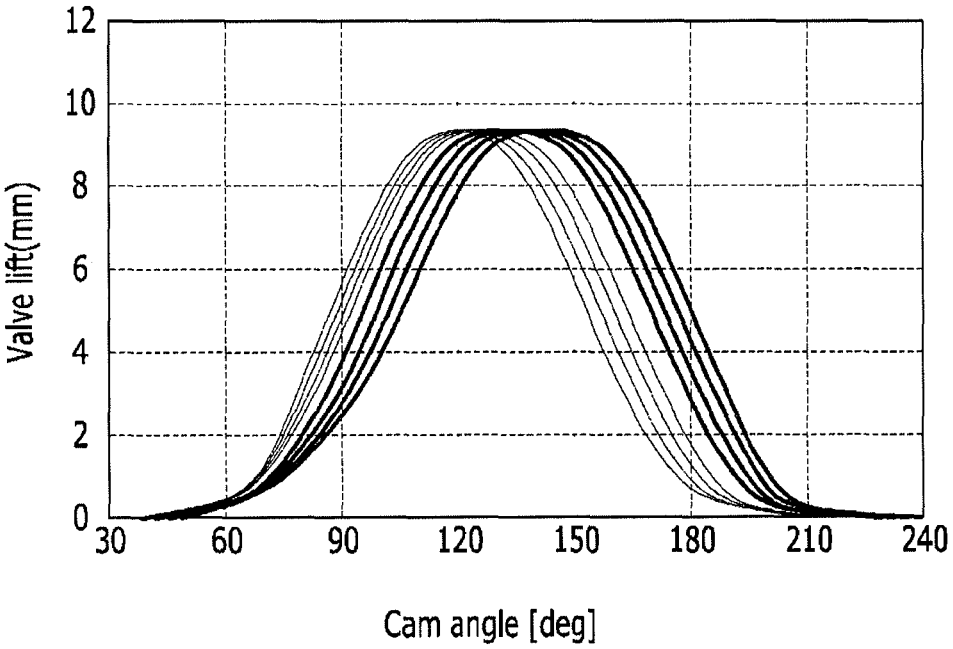


FIG. 10


12
10
8
6
4
2
0
Valve lift(mm)
30
60
90
120
150
180
210
240
Cam angle [deg]

VALVE DURATION CONTROL APPARATUS AND ENGINE PROVIDED WITH THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

The present application claims priority to and the benefit of Korean Patent Application No. 10-2015-0096266 filed on Jul. 7, 2015, the entire contents of which is incorporated herein for all purposes by this reference.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a continuous variable valve duration apparatus and an engine provided with the same. More particularly, the present invention relates to a continuous variable valve duration apparatus an engine provided with the same which may vary opening duration of a valve according to operation conditions of an engine with a simple construction.

Description of Related Art

An internal combustion engine generates power by burning fuel in a combustion chamber in an air media drawn into the chamber. Intake valves are operated by a camshaft in order to intake the air, and the air is drawn into the combustion chamber while the intake valves are open. In addition, exhaust valves are operated by the camshaft, and a combustion gas is exhausted from the combustion chamber while the exhaust valves are open.

Optimal operation of the intake valves and the exhaust valves depends on a rotation speed of the engine. That is, an optimal lift or optimal opening/closing timing of the valves depends on the rotation speed of the engine. In order to achieve such optimal valve operation depending on the rotation speed of the engine, various researches, such as designing of a plurality of cams and a continuous variable valve lift (CVVL) that can change valve lift according to engine speed, have been undertaken.

Also, in order to achieve such an optimal valve operation depending on the rotation speed of the engine, research has been undertaken on a continuously variable valve timing (CVVT) apparatus that enables different valve timing operations depending on the engine speed. The general CVVT may change valve timing with a fixed valve opening duration.

However, the general CVVL and CVVT are complicated in construction and are expensive in manufacturing cost.

The information disclosed in this Background of the Invention section is only for enhancement of understanding of the general background of the invention and should not be taken as an acknowledgement or any form of suggestion that this information forms the prior art already known to a person skilled in the art.

BRIEF SUMMARY

Various aspects of the present invention are directly providing a continuous variable valve duration apparatus and an engine provided with the same which may vary opening duration of a valve according to operation conditions of an engine, with a simple construction.

According to various aspects of the present invention, a continuously variable valve duration apparatus may include a camshaft, a plurality of first cams and second cams of which a cam key is formed respectively thereto, and of which relative phase angles with respect to the camshaft are variable, a plurality of rotation rings mounted to the camshaft and of which a ring key is formed thereto respectively, a plurality of inner brackets transmitting rotation of the camshaft to the cam keys of the first cams and the seconds respectively, a plurality of slider housings of which each inner bracket is rotatable inserted therein, a support bracket connecting the slider housings and a control portion selectively moving the support bracket and moving positions of the slider housings so as to change rotation centers of the inner brackets.

The continuously variable valve duration apparatus may further include a first pin of which a ring key slot where the ring key is slidably inserted thereto is formed thereto and a second pin of which a cam key slot where the cam key is slidably inserted thereto is formed thereto and wherein a first and a second sliding pin holes where the first pin and the second pin are inserted thereto respectively may be formed to the inner brackets respectively.

The first pin and the second pin may be formed as a circular cylinder shape and the first sliding pin hole and the second sliding pin hole may be formed for the first pin and the second pin to be rotated within thereto.

Parts of the first sliding pin hole and the second sliding pin hole may be opened for movements of the ring key and the cam key not to be interrupted.

The continuously variable valve duration apparatus may further include a bearing inserted between the slider housing and the inner bracket.

The continuously variable valve duration apparatus may further include a guider mounted to a cylinder head of which a guide hole is formed thereto, and wherein a guide protrusion may be formed to the slider housing, the guide protrusion may be inserted into the guide hole and the guide hole may guide movements of the guide protrusion.

The control portion may include a ball screw engaged with the support bracket and a control motor selectively rotating the ball screw.

The continuously variable valve duration apparatus may further include a screw bearing mounted to the support bracket for rotatably supporting the ball screw.

The camshaft and the rotation ring may be connected through a connecting pin.

The continuously variable valve duration apparatus may further include a spacer disposed to the camshaft for maintaining distances between one cylinder and neighboring cylinder.

According to various aspects of the present invention, an engine may include a camshaft, a plurality of first cams and second cams of which a cam key is formed respectively thereto, of which relative phase angles with respect to the camshaft are variable, and disposed on a corresponding cylinder respectively, a plurality of rotation rings mounted to the camshaft, of which a ring key is formed thereto respectively, and disposed on the corresponding cylinder respectively, a plurality of inner brackets transmitting rotation of the camshaft to the cam keys of the first cams and the seconds respectively, a plurality of slider housings of which each inner bracket is rotatable inserted therein, a support bracket connecting the slider housings and a control portion selectively moving the support bracket and moving positions of the slider housings so as to change rotation centers of the inner brackets.

The engine may further include a first pin of which a ring key slot where the ring key is slidably inserted thereto is formed thereto and a second pin of which a cam key slot where the cam key is slidably inserted thereto is formed thereto and wherein a first and a second sliding pin holes

where the first pin and the second pin are inserted thereto respectively may be formed to the inner brackets respectively.

The first pin and the second pin may be formed as a circular cylinder shape and the first sliding pin hole and the second sliding pin hole may be formed for the first pin and the second pin to be rotated within thereto.

Parts of the first sliding pin hole and the second sliding pin hole may be opened for movements of the ring key and the cam key not to be interrupted.

The engine may further include a bearing inserted between the slider housing and the inner bracket.

The engine may further include a guider mounted to a cylinder head of which a guide hole is formed thereto, and wherein a guide protrusion may be formed to the slider housing, the guide protrusion may be inserted into the guide hole and the guide hole may guide movements of the guide protrusion.

The control portion may include a ball screw engaged with the support bracket and a control motor selectively rotating the ball screw.

The engine may further include a screw bearing mounted to the support bracket for rotatably supporting the ball screw.

The camshaft and the rotation ring may be connected through a connecting pin.

The engine may further include a spacer disposed to the camshaft for maintaining distances between one cylinder and neighboring cylinder.

As described above, a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention may vary an opening duration of a valve according to operation conditions of an engine, with a simple construction.

The continuous variable valve duration apparatus according to an exemplary embodiment of the present invention may be reduced in size and thus the entire height of a valve train may be reduced.

Since the continuous variable valve duration apparatus may be applied to an existing engine without excessive modification, thus productivity may be enhance and production cost may be reduced.

The methods and apparatuses of the present invention have other features and advantages which will be apparent from or are set forth in more detail in the accompanying drawings, which are incorporated herein, and the following Detailed Description, which together serve to explain certain principles of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an engine provided with a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention.

FIG. **2** is a partial exploded perspective view of an engine provided with a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention.

FIG. **3** is a cross-sectional view along line III-III of FIG. **1**.

FIG. **4** is a partial perspective view of a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention.

FIG. **5** is a partial exploded perspective view of a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention.

FIG. **6** is a partial cross-sectional view along line VI-VI of FIG. **4**.

FIG. **7** is a drawing showing movements of a slider housing applied to a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention.

FIG. **8** and FIG. **9** are drawings showing mechanical motions of cams of a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention.

FIG. **10** is a graph of a valve profile of a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention.

It should be understood that the appended drawings are not necessarily to scale, presenting a somewhat simplified representation of various features illustrative of the basic principles of the invention. The specific design features of the present invention as disclosed herein, including, for example, specific dimensions, orientations, locations, and shapes will be determined in part by the particular intended application and use environment.

In the figures, reference numbers refer to the same or equivalent parts of the present invention throughout the several figures of the drawing.

DETAILED DESCRIPTION

Reference will now be made in detail to various embodiments of the present invention(s), examples of which are illustrated in the accompanying drawings and described below. While the invention(s) will be described in conjunction with exemplary embodiments, it will be understood that the present description is not intended to limit the invention (s) to those exemplary embodiments. On the contrary, the invention(s) is/are intended to cover not only the exemplary embodiments, but also various alternatives, modifications, equivalents and other embodiments, which may be included within the spirit and scope of the invention as defined by the appended claims.

In the following detailed description, only certain exemplary embodiments of the present invention have been shown and described, simply by way of illustration.

As those skilled in the art would realize, the described embodiments may be modified in various different ways, all without departing from the spirit or scope of the present invention

A part irrelevant to the description will be omitted to clearly describe the present invention, and the same or similar elements will be designated by the same reference numerals throughout the specification.

In the drawings, the thickness of layers, films, panels, regions, etc., are exaggerated for clarity.

Throughout the specification and the claims, unless explicitly described to the contrary, the word "comprise" and variations such as "comprises" or "comprising", will be understood to imply the inclusion of stated elements but not the exclusion of any other elements.

An exemplary embodiment of the present invention will hereinafter be described in detail with reference to the accompanying drawings.

FIG. **1** is a perspective view of an engine provided with a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention, FIG. **2** is a partial exploded perspective view of an engine provided with a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention and FIG. **3** is a cross-sectional view along line III-III of FIG. **1**.

FIG. **4** is a partial perspective view of a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention, FIG. **5** is a partial exploded perspective view of a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention and FIG. **6** is a partial cross-sectional view along line VI-VI of FIG. **4**.

Referring to FIG. **1** to FIG. **6**, an engine according to an exemplary embodiment of the present invention includes an engine block **1**, a cylinder head **10** mounted on the engine block **1** and a continuous variable valve duration apparatus mounted to the cylinder head **10**.

In the drawings, the engine includes 4 cylinders **211**, **212**, **213** and **214**, but is not limited thereto.

The continuously variable valve duration apparatus includes a camshaft **30**, a plurality of first cams **71** and second cams **73** of which a cam key **72** and **74** is formed respectively thereto, and of which relative phase angles with respect to the camshaft **30** are variable, a plurality of rotation rings **60** mounted to the camshaft **30** and of which a ring key **62** is formed thereto respectively, a plurality of inner brackets **80** transmitting rotation of the camshaft **30** to the cam keys **72** and **74** of the first cams **71** and the seconds **73** respectively, a plurality of slider housings **90** of which each inner bracket **80** is rotatable inserted therein, a support bracket **96** connecting the slider housings **90** and a control portion **100** selectively moving the support bracket **96** and moving positions of the slider housings **90** so as to change rotation centers of the inner brackets **80**.

The camshaft **30** may be an intake camshaft or an exhaust camshaft.

In the drawings, the first and second cam **71** and **73** is disposed to open valves **200** as a pair, but is not limited thereto.

The continuous variable valve duration apparatus further includes first pins **82** of which a ring key slot **81**, the each ring key **62** is slidably inserted thereto, is formed thereto respectively and second pins **84** of which a cam key slot **83**, the each the cam key **72** and **74** is slidably inserted thereto, is formed thereto respectively. And a first sliding pin hole **86** and a second sliding pin hole **88**, of which the first pin **82** and the second pin **84** are inserted thereto respectively are formed to the inner bracket **80**.

A camshaft hole **32** and a rotation ring hole **64** is formed to the camshaft **30** and the rotation ring **62** respectively and a connecting pin **66** is inserted into the camshaft hole **32** and the rotation ring hole **64** for connecting the camshaft **30** and the rotation rings **62**.

The first pin **82** and the second pin **84** are formed as a circular cylinder shape and the first sliding pin hole **86** and the second sliding pin hole **88** are formed for the first pin **82** and the second pin **84** to be rotated within thereto. Since the first pin **82**, the second pin **84**, the first sliding pin hole **86** and the second sliding pin hole **88** are formed as a circular cylinder, thus wear resistance may be enhanced.

Also, productivity may be increased due to simple shapes of the first pin **82**, the second pin **84**, the first sliding pin hole **86** and the second sliding pin hole **88**.

Parts of the first sliding pin hole **86** and the second sliding pin hole **88** are opened for movements of the ring key **62** and the cam keys **72** and **74** not to be interrupted.

A bearing **92** is inserted between the slider housing **90** and the inner bracket **80**. Thus, rotation of the inner bracket **80** may be easily performed. In the drawings, the bearing **92** is depicted as a needle bearing, however it is not limited thereto. On the contrary, various bearings such as a ball bearing, a roller bearing and so on may be applied thereto.

The continuous variable valve duration apparatus further includes a guider **94** mounted to the cylinder head **10** and of which a guide hole **95** is formed thereto, a guide protrusion **91** is formed to the slider housing **90**, the guide protrusion **91** is inserted into the guide hole **95** and the guide hole **95** guides movements of the guide protrusion **91**. Thus, the slider housing **90** may move stably.

The control portion **100** include a ball screw **104** engaged with the support bracket **96** and a control motor **106** selectively rotating the ball screw **104**. A screw bearing **98** is mounted to the support bracket **96** for rotatably supporting the ball screw **104**.

A spacer **108** is disposed to the camshaft **30** for maintaining distances between one cylinder and neighboring cylinder. The spacer **108** may fix positions of the cams **71** and **73** so as to prevent the cams **71** and **73** from being separated from the inner bracket **80**.

According to rotation of the control motor **106**, positions of the slider housings **90** and the inner brackets **80** are changed and relative positions of rotation centers of the inner bracket **80** with respect to a position of a rotation center of the camshaft **30** are changed.

In an exemplary embodiment of the present invention, since rotation of one rotation ring **60** may be transmitted to the first and the second cam **71** and **73** simultaneously, thus numbers of elements may be reduced and durability may be improved.

As shown FIG. **3** and in FIG. **5**, for example, an engine with the first, second, third and fourth cylinders **211**, **212**, **213** and **214** may vary durations of each cam **71** and **73** with four rotation rings **60**, four inner brackets **80**, four slider housings **90** and one control motor **106**. Thus numbers of elements may be reduced, durability may be improved and operation stability may be secured.

FIG. **7** is a drawing showing movements of a slider housing applied to a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention, and FIG. **8** and FIG. **9** are drawings showing mechanical motions of cams of a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention.

According to engine operation states, the ECU transmits control signals to the motor **106** of the control portion **100** to change the relative position of the slider housing **90**.

In the exemplary embodiment of the present invention, the positions of the slider housing **90** with respect to the camshaft **30** are changed up and down directions.

When the slider housing **90** moves upward for example, as shown in FIG. **8** the rotation speed of the cams **71** and **73** is relatively faster than rotation speed of the camshaft **30** from phase a to phase b and from phase b to phase c, then the rotation speed of the cams **71** and **73** is relatively slower than rotation speed of the camshaft **30** from phase c to phase d and from phase d to phase a. That is, the valve duration is changed.

When the slider housing **90** moves downward for example, as shown in FIG. **9**, the rotation speed of the cams **71** and **73** is relatively slower than rotation speed of the camshaft **30** from phase a to phase b and from phase b to phase c, then the rotation speed of the cams **71** and **73** is relatively faster than rotation speed of the camshaft **30** from phase c to phase d and from phase d to phase a. That is, the valve duration is changed.

While the rotation ring **60** is rotated together with the camshaft **30**, the ring key **62** is slidable within the ring key slot **81**, the first pin **82** and the second pin **84** are rotatable within the first sliding pin hole **86** and the second sliding pin

hole **88** respectively and the cam keys **72** and **74** are slidable within the cam key slot **83**. Thus, when the relative rotation centers of the inner brackets **80** and the camshaft **30** are changed, the relative rotation speed of the cams **71** and **73** with respect to the rotation speed of the camshaft **30** is changed.

FIG. **10** is a graph of a valve profile of a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention.

As shown in FIG. **10**, although maximum lift of the valve **200** is constant, however rotation speed of the cam **71** and **73** with respect to the rotation speed of the camshaft **30** is changed according to relative positions of the slider housings **90** so that closing and opening time of the valve **200** is changed. That is, duration of the valve **200** is changed.

While opening time of the valve **200** is constant, closing time of the valve **200** is changed in FIG. **9**, it is not limited thereto. According to various mounting angle of the cams **71** and **73** and the valve **200**, various contacting angles between cam lobe of the cams **71** and **73** and the valve **200** and so on, various valve duration may be performed. That is, according to contacting positions of the valve **200** and the cams **71** and **73**, closing timing of the valve **200** may be constant, opening timing and closing timing of the valve **200** may be changed simultaneously, or the continuous variable valve duration apparatus may be operated as a continuously variable valve timing apparatus.

As described above, a continuous variable valve duration apparatus according to an exemplary embodiment of the present invention may vary an opening duration of a valve according to operation conditions of an engine, with a simple construction.

The continuous variable valve duration apparatus according to an exemplary embodiment of the present invention may be reduced in size and thus the entire height of a valve train may be reduced.

Since the continuous variable valve duration apparatus may be applied to an existing engine without excessive modification, thus productivity may be enhance and production cost may be reduced.

For convenience in explanation and accurate definition in the appended claims, the terms "upper", "lower", "inner" and "outer" are used to describe features of the exemplary embodiments with reference to the positions of such features as displayed in the figures.

The foregoing descriptions of specific exemplary embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teachings. The exemplary embodiments were chosen and described in order to explain certain principles of the invention and their practical application, to thereby enable others skilled in the art to make and utilize various exemplary embodiments of the present invention, as well as various alternatives and modifications thereof. It is intended that the scope of the invention be defined by the Claims appended hereto and their equivalents.

What is claimed is:

1. A valve duration control apparatus comprising:
- a camshaft;
- a plurality of first cams and a plurality of second cams of which a cam key is formed respectively thereto, and of which relative phase angles with respect to the camshaft are variable;
- a plurality of rotation rings mounted to the camshaft and of which a ring key is formed thereto respectively,
- a plurality of inner brackets transmitting rotation of the camshaft to the cam keys of the first cams and the second cams, respectively;
- a plurality of slider housings of which each inner bracket is rotatable inserted therein;
- a support bracket connecting the plurality of slider housings; and
- a control portion moving the support bracket and moving positions of the plurality of slider housings to change rotation centers of the plurality of inner brackets.

2. The valve duration control apparatus of claim **1**, further comprising:
- a first pin of which a ring key slot where the ring key is slidably inserted thereto is formed thereto; and
- a second pin of which a cam key slot where the cam key is slidably inserted thereto is formed thereto; and
- wherein a first sliding pin hole and a second sliding pin hole where the first pin and the second pin are inserted thereto respectively are formed to the plurality of inner brackets respectively.

3. The valve duration control apparatus of claim **2**, wherein
- the first pin and the second pin are formed as a circular cylinder shape; and
- the first sliding pin hole and the second sliding pin hole are formed for the first pin and the second pin to be rotated within thereto.

4. The valve duration control apparatus of claim **3**, wherein parts of the first sliding pin hole and the second sliding pin hole are open so that the ring key and the cam key are movable through the open parts of the first sliding pin hole and the second sliding pin hole, respectively.

5. The valve duration control apparatus of claim **1**, further comprising a bearing inserted between each slider housing and each inner bracket.

6. The valve duration control apparatus of claim **1**, further comprising a guider including a guide hole,
- wherein a guide protrusion is formed to each slider housing, the guide protrusion is inserted into the guide hole, and the guide hole guides movements of the guide protrusion.

7. The valve duration control apparatus of claim **1**, wherein the control portion comprises:
- a ball screw engaged with the support bracket; and
- a control motor rotating the ball screw.

8. The a valve duration control apparatus of claim **7**, further comprising a screw bearing mounted to the support bracket for rotatably supporting the ball screw.

9. The valve duration control apparatus of claim **1**, wherein the camshaft and the rotation ring are connected through a connecting pin.

10. The valve duration control apparatus of claim **1**, further comprising a spacer disposed to the camshaft and configured for maintaining distances between one cylinder and a neighboring cylinder.

11. An engine comprising:
- a camshaft;
- a plurality of first cams and a plurality of second cams of which a cam key is formed respectively thereto, of which relative phase angles with respect to the camshaft are variable, and disposed on a corresponding cylinder of the engine, respectively;
- a plurality of rotation rings mounted to the camshaft, of which a ring key is formed thereto respectively, and disposed on the corresponding cylinder respectively,

a plurality of inner brackets transmitting rotation of the camshaft to the cam keys of the first cams and the second cams, respectively,

a plurality of slider housings of which each inner bracket is rotatable inserted therein;

a support bracket connecting the plurality of slider housings; and

a control portion moving the support bracket and moving positions of the plurality of slider housings to change rotation centers of the plurality of inner brackets.

12. The engine of claim **11**, further comprising:

a first pin of which a ring key slot where the ring key is slidably inserted thereto is formed thereto; and

a second pin of which a cam key slot where the cam key is slidably inserted thereto is formed thereto; and

wherein a first sliding pin hole and a second sliding pin hole where the first pin and the second pin are inserted thereto respectively are formed to the plurality of inner brackets respectively.

13. The engine of claim **12**, wherein

the first pin and the second pin are formed as a circular cylinder shape; and

the first sliding pin hole and the second sliding pin hole are formed for the first pin and the second pin to be rotated within thereto.

14. The engine of claim **13**, wherein parts of the first sliding pin hole and the second sliding pin hole are open so that the ring key and the cam key are movable through the open parts of the first sliding pin hole and the second sliding pin hole, respectively.

15. The engine of claim **11**, further comprising a bearing inserted between each slider housing and each inner bracket.

16. The engine of claim **11**, further comprising a guider including a guide hole,

wherein a guide protrusion is formed to each slider housing, the guide protrusion is inserted into the guide hole, and the guide hole guides movements of the guide protrusion.

17. The engine of claim **11**, wherein the control portion comprises:

a ball screw engaged with the support bracket; and

a control motor rotating the ball screw.

18. The engine of claim **17**, further comprising a screw bearing mounted to the support bracket for rotatably supporting the ball screw.

19. The engine of claim **11**, wherein the camshaft and the rotation ring are connected through a connecting pin.

20. The engine of claim **11**, further comprising a spacer disposed to the camshaft and configured for maintaining distances between one cylinder and a neighboring cylinder of the engine.

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