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(54) VARIABLE COMPRESSION RATIO V-TYPE INTERNAL COMBUSTION ENGINE

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F02B 75/22 (2006.01)
F02D 15/02 (2006.01)

(52) **U.S. Cl.**
CPC ***F02B 75/22*** (2013.01); ***F02B 75/041*** (2013.01); *F02D 15/02* (2013.01); *F02B 75/045* (2013.01); *F02B 75/048* (2013.01)
USPC .... **123/48 B**

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USPC .... 123/48 B
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(56) **References Cited**

U.S. PATENT DOCUMENTS

7,036,468	B2 *	5/2006	Kamiyama	123/78 R
7,917,279	B2 *	3/2011	Akihisa et al.	701/103
2008/0178857	A1 *	7/2008	Kamiyama	123/78 C
2009/0241910	A1 *	10/2009	Shin et al.	123/48 B
2011/0048383	A1 *	3/2011	Pattakos et al.	123/48 B

FOREIGN PATENT DOCUMENTS

JP	2002-250241	A	9/2002
JP	2004-324464	A	11/2004
JP	2005-113743	A	4/2005
JP	2008-175135	A	7/2008
JP	2009-052455	A	3/2009
JP	2009-097449	A	5/2009

* cited by examiner

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(57) **ABSTRACT**

The present variable compression ratio V-type internal combustion engine is a variable compression ratio V-type internal combustion engine which joins cylinder blocks of two cylinder groups and makes the joined cylinder block move relatively to a crankcase, wherein the engine is provided with a first relative movement mechanism which is fastened to a first cylinder group side of the joined cylinder block through a plurality of supports and a second relative movement mechanism which is fastened to a second cylinder group side of the joined cylinder block through a plurality of supports. The number of the supports in each of the first relative movement mechanism and the second relative movement mechanism is made at least a number greater by exactly one than the number of cylinders of the first cylinder group and the second cylinder group, respectively.

4 Claims, 6 Drawing Sheets

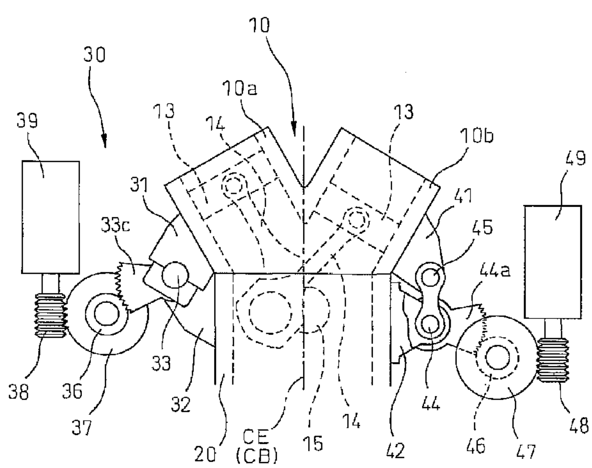


Fig.1

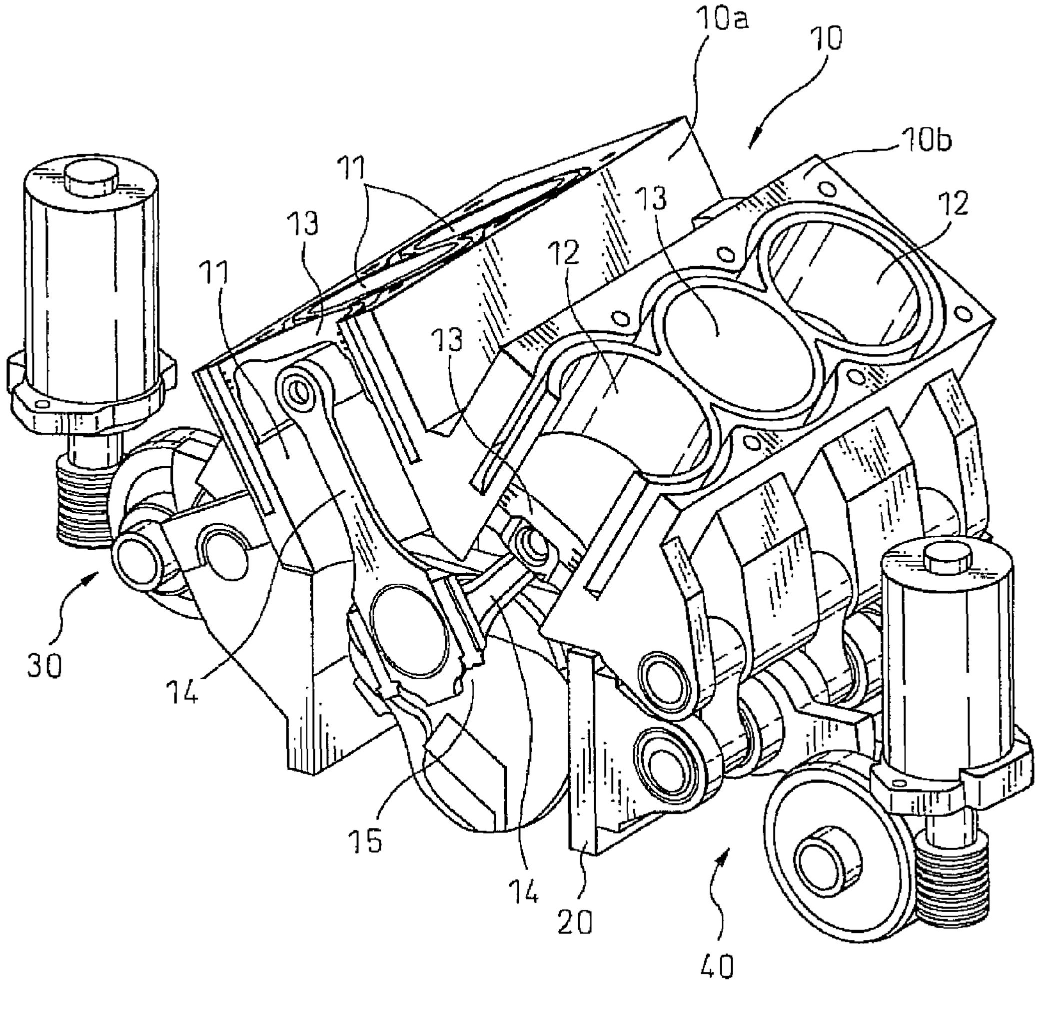
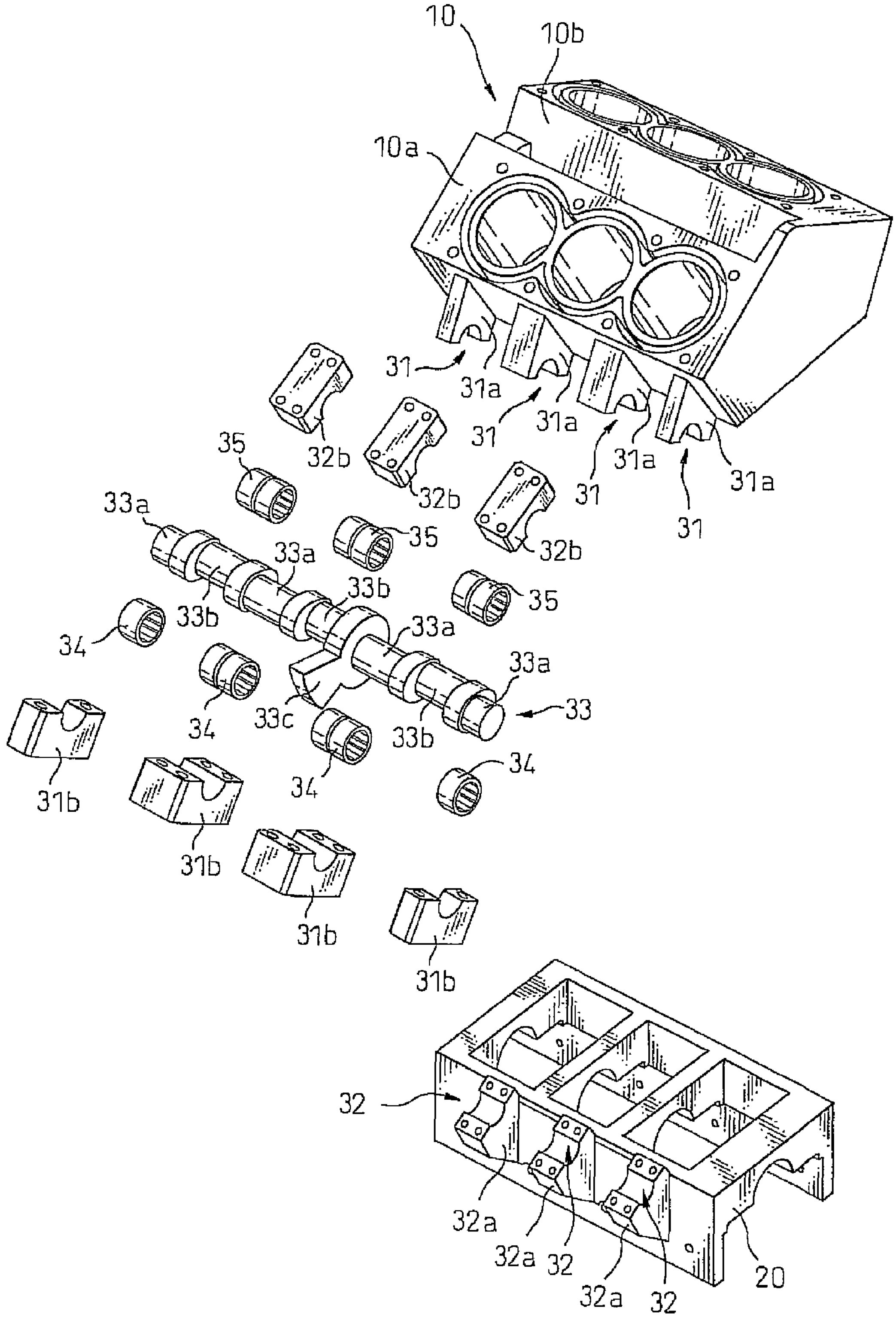


Fig.2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33a
33b
33b
33a
33a
34
34
33c
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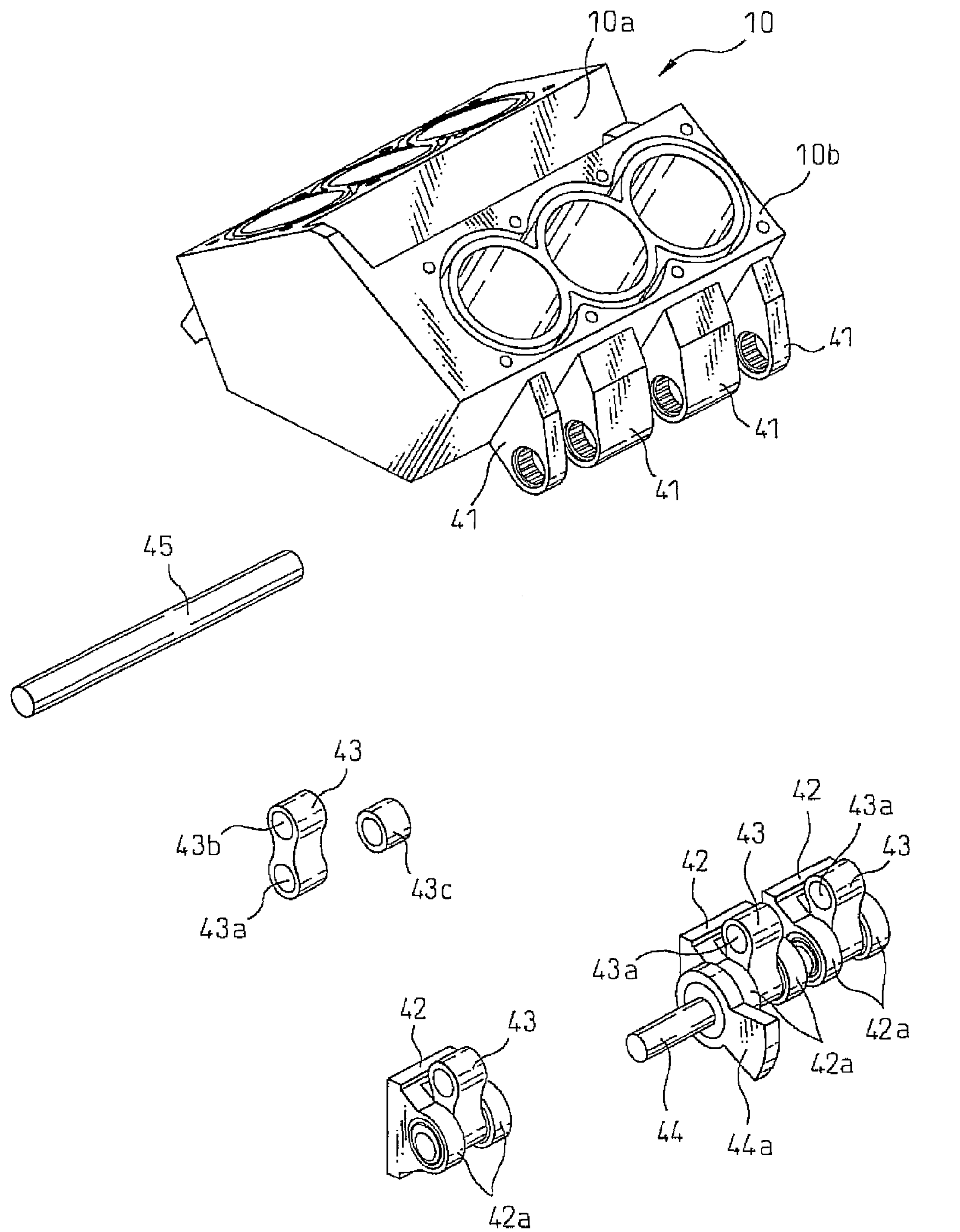
32a
32
20

Fig.3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43
43b
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43c
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43a
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42
43
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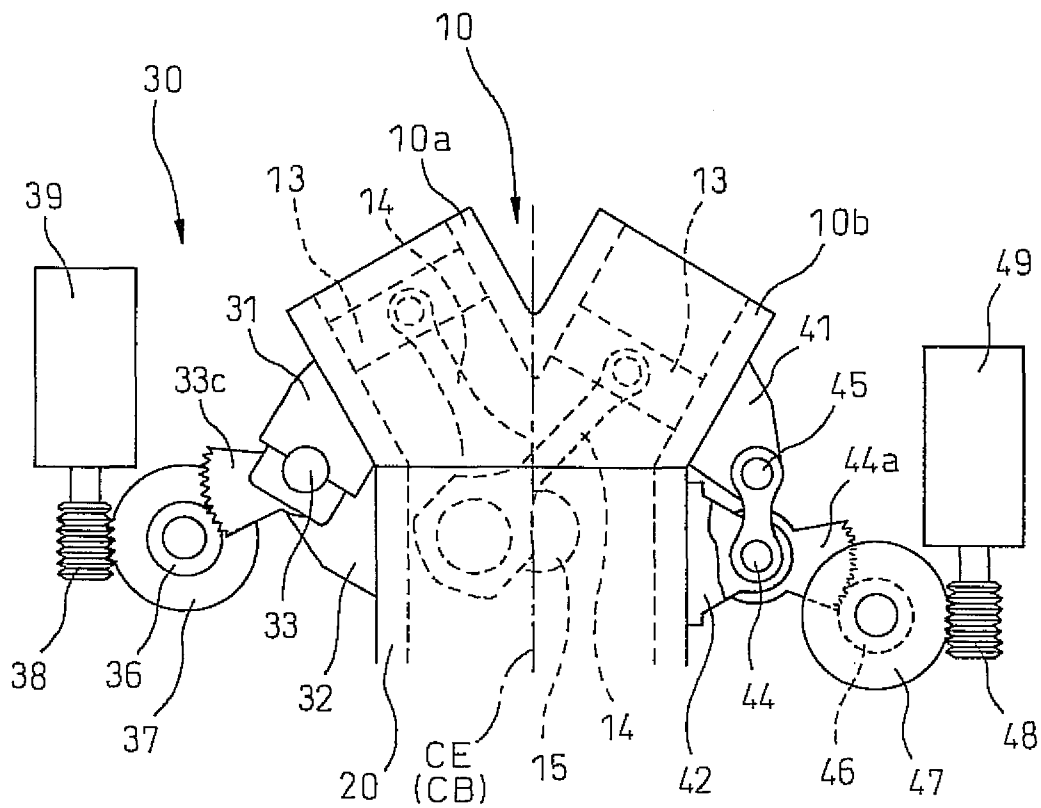
42
43
42a

Fig.4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30
10a
13
14
13
10b
39
31
41
49
33c
45
44a
38
36
33
32
37
20
CE
(CB)
15
14
42
44
46
47
48

Fig.5

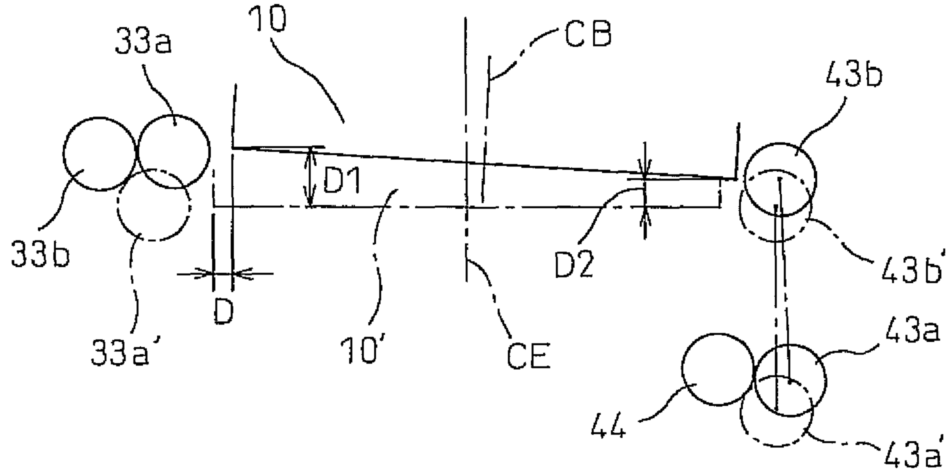
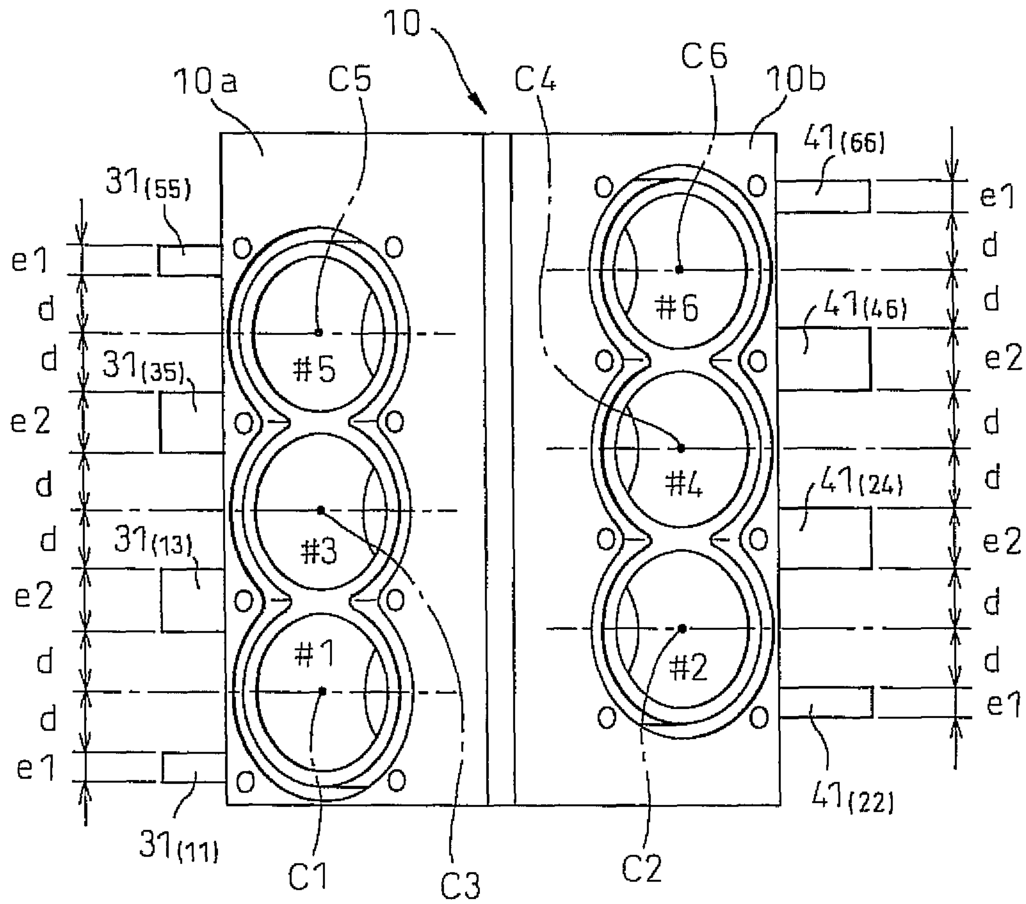

10
33a
CB
43b
33b
D1
D2
43b'
D
33a'
10'
CE
43a
44
43a'

Fig.6


10
C6
10a
C5
C4
10b
41(66)
31(55)
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#5
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#3
#1
#2
41(22)
31(11)
C1
C3
C2

Fig.7

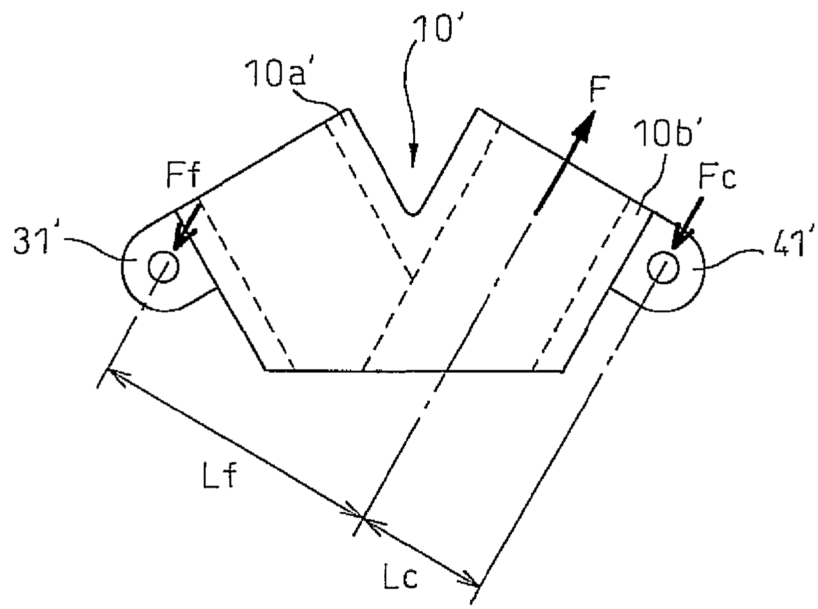
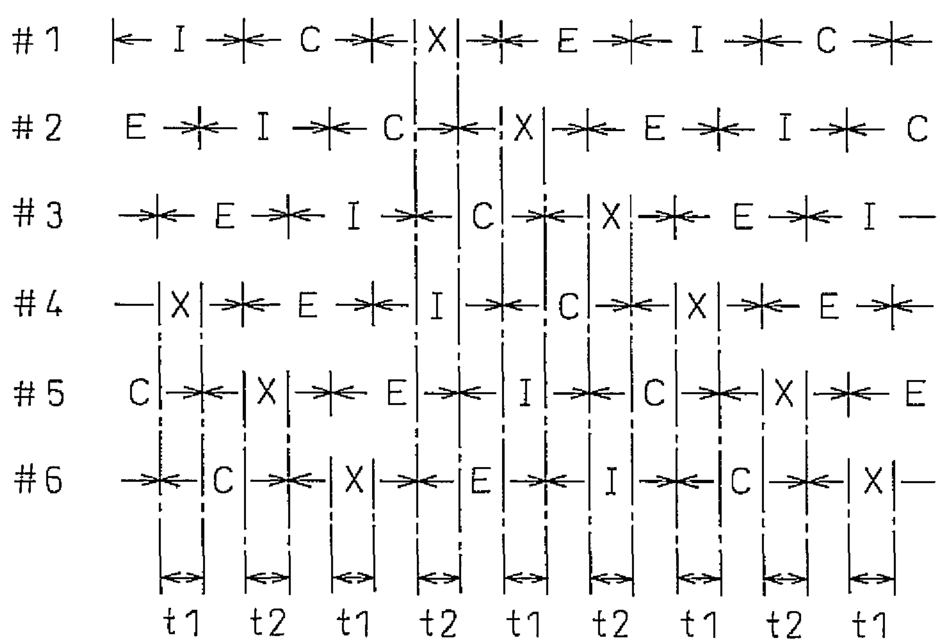


Fig.8



VARIABLE COMPRESSION RATIO V-TYPE INTERNAL COMBUSTION ENGINE

TECHNICAL FIELD

The present invention relates to a variable compression ratio V-type internal combustion engine.

BACKGROUND ART

In general, the lower the engine load, the worse the heat efficiency, so at the time of engine low load operation, the mechanical compression ratio ((top dead center cylinder volume stroke volume)/top dead center cylinder volume) is preferably raised to raise the expansion ratio and thereby improve the heat efficiency. For this, it has been known to make the cylinder block and crankcase move relative to each other to change the distance between the cylinder block and the crankshaft and thereby make the mechanical compression ratio variable.

In a V-type internal combustion engine, it has been proposed to make the cylinder block parts of the two cylinder groups move relatively to the crankcase separately along the cylinder centerlines of the cylinder groups, but it is difficult to make different cylinder block parts move relatively to the crankcase by a single link mechanism (or cam mechanism). A pair of link mechanisms (or cam mechanisms) becomes necessary for each cylinder block part, so overall two pairs of link mechanisms end up becoming necessary.

To reduce the number of link mechanisms, a variable compression ratio V-type internal combustion engine has been proposed which joins the cylinder blocks of two cylinder groups and makes the joined cylinder block move relatively to the crankcase by a pair of relative movement mechanisms (for example, a pair of link mechanisms) (refer to Japanese Patent Unexamined Publication (A) No. 2005-113743, Japanese Patent Unexamined Publication (A) No. 2002-250241, Japanese Patent Unexamined Publication (A) No. 2008-175135, and Japanese Patent Unexamined Publication (A) No. 2009-097449).

The relative movement mechanism at one cylinder group side and the relative movement mechanism at the other cylinder group side respectively have pluralities of supports for fastening to the cylinder block and pluralities of supports for fastening to the crankcase.

In general, the plurality of supports at the cylinder block side in the relative movement mechanism at one cylinder group side and the plurality of supports at the cylinder block side at the relative movement mechanism at the other cylinder group side are arranged symmetrically about a median plane between the two cylinder groups.

DISCLOSURE OF THE INVENTION

Incidently, in the above-mentioned variable compression ratio V-type internal combustion engine, the cylinder block and the crankcase are coupled by just one pair of relative movement mechanisms. The force which tries to push up the cylinder block in the cylinder axial line direction at the time of firing at each cylinder acts on the pair of relative movement mechanisms.

If the supports of the cylinder block sides of the pair of relative movement mechanism are arranged symmetrically as explained above, the force which is generated at the time of firing at each cylinder will act mainly on one or two supports thereby making it necessary to make the supports thicker or otherwise in order to increase the strength of the supports.

Therefore, an object of the present invention is to provide a variable compression ratio V-type internal combustion engine which joins the cylinder blocks of two cylinder groups and makes the joined block move relatively to the crankcase wherein it is not necessary to increase the strength of the plurality of supports at the cylinder block sides of the pair of relative movement mechanisms that much.

A variable compression ratio V-type internal combustion engine as set forth in claim **1** of the present invention is provided, characterized in that the variable compression ratio V-type internal combustion engine joins cylinder blocks of two cylinder groups and makes the joined cylinder block move relatively to a crankcase, and is provided with a first relative movement mechanism which is fastened to a first cylinder group side of the joined cylinder block through a plurality of supports and a second relative movement mechanism which is fastened to a second cylinder group side of the joined cylinder block through a plurality of supports, the number of the supports of the first relative movement mechanism is made at least a number greater by exactly "1" than the number of cylinders of the first cylinder group so that one of the supports of the first relative movement mechanism is positioned at the two sides of the center axial lines of the cylinders in the first cylinder group when viewing the first cylinder group side by the side view, the number of the supports of the second relative movement mechanism is made at least a number greater by exactly "1" than the number of cylinders of the second cylinder group so that one of the supports of the second relative movement mechanism is positioned at the two sides of the center axial lines of the cylinders in the second cylinder group when viewing the second cylinder group side by the side view, and, due to an offset between the cylinders of the first cylinder group and the cylinders of the second cylinder group in the crankshaft direction, one of the supports of the first relative movement mechanism is positioned on the center axial line of each cylinder in the second cylinder group when viewing the first cylinder group side by the side view and one of the supports of the second relative movement mechanism is positioned on the center axial line of each cylinder in the first cylinder group when viewing the second cylinder group side by the side view.

A variable compression ratio V-type internal combustion engine as set forth in claim **2** of the present invention is provided as the variable compression ratio V-type internal combustion engine as set forth in claim **1** characterized in that the supports of the first relative movement mechanism are comprised of first supports which are positioned between center axial lines of two cylinders adjoining each other in the first cylinder group when viewing the first cylinder group side by the side view and second supports which are not positioned between center axial lines of two cylinders adjoining each other in the first cylinder group when viewing the first cylinder group side by the side view, a thickness of the first supports is two times a thickness of the second supports, the supports of the second relative movement mechanism are comprised of third supports which are positioned between center axial lines of two cylinders adjoining each other in the second cylinder group when viewing the second cylinder group side by the side view and fourth supports which are not positioned between center axial lines of two cylinders adjoining each other in the second cylinder group when viewing the second cylinder group side by the side view, and a thickness of the third supports is two times a thickness of the fourth supports.

A variable compression ratio V-type internal combustion engine as set forth in claim **3** of the present invention is provided as the variable compression ratio V-type internal combustion engine as set forth in claim **1** or **2** characterized in that the first relative movement mechanism and the second relative movement mechanism are made independently controllable, a first relative movement distance in a front view engine centerline direction which passes through a center of a crankshaft which is caused by the first relative movement mechanism at the first cylinder group side of the joined cylinder block and a second relative movement distance in the engine centerline direction which is caused by the second relative movement mechanism at the second cylinder group side of the joined cylinder block can be made different, the first relative movement mechanism changes the first relative movement distance when none of the cylinders of the first cylinder group is in an expansion stroke, and the second relative movement mechanism changes the second relative movement distance when none of the cylinders of the second cylinder group is in an expansion stroke.

According to the variable compression ratio V-type internal combustion engine as set forth in claim **1** of the present invention, the number of the supports to fasten the first relative movement mechanism to the first cylinder group side of the joined cylinder block is made at least a number greater by exactly "1" than the number of cylinders of the first cylinder group so that one of the supports of the first relative movement mechanism is positioned at the two sides of the center axial lines of the cylinders in the first cylinder group when viewing the first cylinder group side by the side view, the number of the supports to fasten the second relative movement mechanism to the second cylinder group side of the joined cylinder block is made at least a number greater by exactly "1" than the number of cylinders of the second cylinder group so that one of the supports of the second relative movement mechanism is positioned at the two sides of the center axial lines of the cylinders in the second cylinder group when viewing the second cylinder group side by the side view, and, due to an offset between the cylinders of the first cylinder group and the cylinders of the second cylinder group in the crankshaft direction, one of the supports of the first relative movement mechanism is positioned on the center axial line of each cylinder in the second cylinder group when viewing the first cylinder group side by the side view and one of the supports of the second relative movement mechanism is positioned on the center axial line of each cylinder in the first cylinder group when viewing the second cylinder group side by the side view. Due to this, the force which tries to push up the cylinder block in the cylinder axial line direction at the time of firing of each cylinder acts on the two supports adjoining the firing cylinder when viewing the cylinder group side corresponding to the firing cylinder by the side view and the one support which is positioned on the center axial line of the firing cylinder when viewing the other cylinder group side by the side view, so it is not necessary to increase the strength of the supports of the first relative movement mechanism and second relative movement mechanism that much compared with the case where the force acts on mainly one or two supports.

According to the variable compression ratio V-type internal combustion engine as set forth in claim **2** of the present invention, in the variable compression ratio V-type internal combustion engine as set forth in claim **1**, the supports of the first relative movement mechanism are comprised of first supports which are positioned between center axial lines of two cylinders adjoining each other in the first cylinder group when viewing the first cylinder group side by the side view and second supports which are not positioned between center axial lines of two cylinders adjoining each other in the first cylinder group when viewing the first cylinder group side by the side view, the first supports are close in common to two cylinders adjoining each other, so the force at the time of firing of the two cylinders acts on them and therefore the farce at the time of firing acts on them a number of times two times greater than the second supports which are close to just one cylinder, so a thickness of the first supports is made two times a thickness of the second supports to make the strength two times as well, further the supports of the second relative movement mechanism are comprised of third supports which are positioned between center axial lines of two cylinders adjoining each other in the second cylinder group when viewing the second cylinder group side by the side view and fourth supports which are not positioned between center axial lines of two cylinders adjoining each other in the second cylinder group when viewing the second cylinder group side by the side view, the third supports are close in common to two cylinders adjoining each other, so the force at the time of firing of the two cylinders act on them and therefore the force at the time of firing act on them a number of times two times greater than the fourth supports which are close to just one cylinder, so a thickness of the third supports is made two times a thickness of the fourth supports to make the strength two times as well.

According to the variable compression ratio V-type internal combustion engine as set forth in claim **3** of the present invention, in the variable compression ratio V-type internal combustion engine as set forth in claim **1** or **2**, the first relative movement mechanism and the second relative movement mechanism are made independently controllable, a first relative movement distance in a front view engine centerline direction which passes through a center of a crankshaft which is caused by the first relative movement mechanism at the first cylinder group side of the joined cylinder block and a second relative movement distance in the engine centerline direction which is caused by the second relative movement mechanism at the second cylinder group side of the joined cylinder block can be made different, when none of the cylinders of the first cylinder group is in an expansion stroke, one of the cylinders of the second cylinder group is in the expansion stroke and the force of that firing cylinder does not act that much on the first relative movement mechanism where the moment length becomes longer compared with the second relative movement mechanism, so the first relative movement mechanism can easily change the first relative movement distance, while when none of the cylinders of the second cylinder group is in an expansion stroke, one of the cylinders of the first cylinder group is in the expansion stroke and the force of that firing cylinder does not act that much on the second relative movement mechanism where the moment length becomes longer compared with the first relative movement mechanism, so the second relative movement mechanism can easily change the second relative movement distance.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is a perspective view showing part of a variable compression ratio V-type internal combustion engine according to the present invention.

FIG. **2** is a disassembled perspective view of a first relative movement mechanism which is provided at the variable compression ratio V-type internal combustion engine of FIG. **1**.

FIG. **3** is a disassembled perspective view of a second relative movement mechanism which is provided at the variable compression ratio V-type internal combustion engine of FIG. **1**.

FIG. **4** is a front view showing part of a variable compression ratio V-type internal combustion engine according to the present invention.

FIG. **5** is a view explaining the operations of the first relative movement mechanism and the second relative movement mechanism.

FIG. **6** is a plan view of a cylinder block of the variable compression ratio V-type internal combustion engine according to the present invention.

FIG. **7** is a front view of a cylinder block which shows still another embodiment of the variable compression ratio V-type internal combustion engine according to the present invention.

FIG. **8** is a time chart which shows the relationship between the strokes of the cylinders.

DESCRIPTION OF EMBODIMENTS

FIG. **1** is a perspective view showing part of a variable compression ratio V-type internal combustion engine according to the present invention. In FIG. **1**, **10** indicates a cylinder block, **20** a crankcase, **30** a first relative movement mechanism of a first cylinder group side, and **40** a second relative movement mechanism of a second cylinder group side. The cylinder block **10** is comprised of a first cylinder group side part **10***a* and a second cylinder group side part **10***b* formed integrally. Inside first cylinder group side cylinder bores **11** and second cylinder group side cylinder bores **12**, pistons **13** are arranged. The pistons **13** are connected by a connecting rod **14** to a crank shaft **15**.

This V-type internal combustion engine is a spark ignition type. The first cylinder group side part **10***a* and the second cylinder group side part **10***b* of the cylinder block **10** are mounted with cylinder heads (not shown). At the cylinder heads, spark plugs are provided for the cylinder bores. At each cylinder head, intake ports and exhaust ports are formed. Each intake port is communicated through an intake valve to a corresponding cylinder bore, while each exhaust port is communicated through an exhaust valve to a corresponding cylinder bore **11**. For each cylinder head, an intake manifold and exhaust manifold are connected. The intake manifolds open to the atmosphere either independently of each other or by merging via an air cleaner, while the exhaust manifolds are also open to the atmosphere either independently of each other or by merging via a catalyst device. Further, the V-type internal combustion engine may be a diesel engine as well.

In general, the lower the engine load is, the worse the heat efficiency becomes, so at the time of engine low load operation, if raising the mechanical compression ratio to raise the expansion ratio, it is possible to improve the heat efficiency due to the work time of the pistons in the expansion stroke becoming longer. The mechanical compression ratio becomes the ratio (V**1**+V**2**)/V**1** of the sum of the cylinder volume V**1** at the top dead center crank angle and the stroke volume V**2** with respect to the cylinder volume V**1** at the top dead center crank angle, and is equal to the expansion ratio of the expansion stroke. Due to this, the V-type internal combustion engine uses the first relative movement mechanism **30** and the second relative movement mechanism **40** to make the cylinder block **10** move relatively to the crankcase **20**. By changing the distance between the cylinder block **10** and the crank shaft **15**, the mechanical compression ratios of the first cylinder group and the second cylinder group are made variable. For example, the mechanical compression ratios are controlled so that the lower the engine load is, the higher the mechanical compression ratio is made.

The first relative movement mechanism **30**, as shown in FIG. **2**, has a plurality of cylinder block side supports **31** which are fastened to the bottom part of the side surface of the first cylinder group side part **10***a* of the cylinder block **10** and a plurality of crankcase side supports **32** which are fastened to the top part of the side surface of the first cylinder group side of the crankcase **20**. The cylinder block side supports **31** and crankcase side supports **32** are alternately positioned and support a single first shaft **33**. In this way, the first cylinder group side part **10***a* of the cylinder block **10** and the first cylinder group side of the crankcase **20** are connected through the first relative movement mechanism **30**.

The cylinder block side supports **31** and the crankcase side supports **32** are split into the two pieces **31***a* and **31***b* and **32***a* and **32***b* to enable support of the first shaft **33**. The first shaft **33** has a plurality of cylinder block side support parts **33***a* which are supported by the cylinder block side supports **31** and a plurality of crankcase side support parts **33***b* which are supported by the crankcase side supports **32**. The cylinder block side support parts **33***a* are concentric with each other, while the crankcase side support parts **33***b* are concentric with each other. However, the cylinder block side support parts **33***a* and the crankcase side support parts **33***b* are eccentric. Reference numeral **34** shows bearing elements which are fit at the cylinder block side support parts **33***a*, while **35** shows bearing elements which are fit at the crankcase side support parts **33***b*. These are split into two to enable fitting at the cylinder block side support parts **33***a* and crankcase side support parts **33***b*. Reference numeral **33***c* shows a fan-shaped gear which is concentric with the crankcase side support part **33***b* of the first shaft **33**.

As shown in FIG. **4**, the fan-shaped gear **33***c* engages with the small diameter gear **36**, while a large diameter gear **37** concentric with the small diameter gear **36** engages with a worm gear **38** of a first motor **39**. By operating the first motor **39** and making the worm gear **38** rotate in this way, it is possible to make the first shaft **33** rotate about the crankcase side support part **33***b* through the large diameter gear **37**, small diameter gear **36**, and the fan-shaped gear **33***c*.

On the other hand, the second relative movement mechanism **40**, as shown in FIG. **3**, has a plurality of cylinder block side supports **41** which are fastened to the bottom part of the side surface of the second cylinder group side part **10***b* of the cylinder block **10** and a plurality of crankcase side supports **42** which are fastened to the top part of the side surface of the second cylinder group side of the crankcase **20**. Each crankcase side support **42** has two bearings **42***a*. Between the two bearings **42***a*, an arm **43** is inserted. The arm **43** has at its ends a first through hole **43***a* and a second through hole **43***b*. Inside the first through hole **43***a*, an eccentric boss **43***c* is inserted. A second shaft **44** passes through the two bearings **42***a* of the crankcase side supports **42** and passes through the eccentric holes of the eccentric bosses **43***c* which are inserted into the first through holes **43***a* of the arms **43**. Further, a third shaft **45** passes through the cylinder block side supports **41** and second through holes **43***b* of the arms **43** positioned between two cylinder block side supports **41**. In this way, the second cylinder group side part **10***b* of the cylinder block **10** and the second cylinder group side of the crankcase **20** are connected through the second relative movement mechanism **40**.

The bearings **42***a* of the cylinder block side supports **41** and the crankcase side supports **42** are provided with bearing elements. Reference numeral **44***a* shows a fan-shaped gear which is concentric with the second shaft **44**. As shown in FIG. **4**, the fan-shaped gear **44***a* engages with the small diameter gear **46**, while a large diameter gear **47** which is concentric with the small diameter gear **46** engages with a worm gear

48 of the second motor **49**. In this way, the second motor **49** is operated to make the worm gear **48** rotate, whereby the second shaft **44** is made to rotate through the large diameter gear **47**, the small diameter gear **46**, and the fan-shaped gear **44***a*. The eccentric bosses **43***c*, which are joined with the second shaft **44** by insertion into the eccentric holes, can be made to rotate about the second shaft **44** at the first through holes **43***a* of the arms **43**.

In FIG. **4**, CE is the engine centerline which passes through the center of the crankshaft **15** in the front view and in general is a vertical line passing through the center of the crankshaft. In the present embodiment, at the lowest position of the cylinder block **10** which is shown in FIG. **5** where the cylinder block **10** and the crankcase **20** abut against each other, in the front view, the cylinder block centerline CB between the cylinder centerline of the first cylinder group and the cylinder centerline of the second cylinder group and the engine centerline CE match. Further, in the front view, the intersecting point of the cylinder centerline of the first cylinder group and the cylinder centerline of the second cylinder group, that is, the front view intersecting point, and the crankshaft center match.

As shown in FIG. **5**, in the variable compression ratio V-type internal combustion engine of the present embodiment, to change the mechanical compression ratio, the first motor **39** of the first relative movement mechanism **30** is made to operate to make the first shaft **33** turn about the crankcase side support part **33***b*. Due to this, the first relative movement mechanism **30** acts as a link mechanism with a single degree of freedom to make the first cylinder group side of the cylinder block **10** move with respect to the crankcase **20** in the engine centerline CE direction by exactly the first set distance D**1** through the cylinder block side support part **33***a* which is eccentric with respect to the crankcase side support part **33***b*. Simultaneously with this, the second motor **49** of the second relative movement mechanism **40** is made to operate to make the second shaft **44** turn. Due to this, the second relative movement mechanism **40** acts as a link mechanism with two degrees of freedom to make the second cylinder group side of the cylinder block **10** move with respect to the crankcase **20** in the engine centerline CE direction by exactly the second set distance D**2** smaller than the first set distance D**1** by the arm **43** through the eccentric boss **43***c* which is eccentric with respect to the second shaft **44**.

In this way, the cylinder block **10'** at the lowest position which is shown by the one-dot chain line moves like the cylinder block **10** which is shown by the solid line. The cylinder block side support part **33***a*' of the first shaft **33** and the first through hole **43***a*' and second through hole **43***b*' of the arm **43** at the lowest position which are shown by the one-dot chain lines also respectively move like the cylinder block side support part **33***a*, first through hole **43***a*, and second through hole **43***b* which are shown by the solid lines.

Since the first relative movement mechanism **30** is made a simple link mechanism with one degree of freedom, the cylinder block **10** is made to move with respect to the crankcase **20** upward (direction of centerline of engine CE) and simultaneously move to the second cylinder group side. With that, both the mechanical compression ratio of the first cylinder group and the mechanical compression ratio of the second cylinder group can be made smaller, but the mechanical compression ratio of the second cylinder group ends up becoming smaller than the mechanical compression ratio of the first cylinder group. Due to this, using the second relative movement mechanism **40**, the cylinder block **10** is moved a bit upward at the second cylinder group side compared with the first cylinder group side. In the front view, the cylinder block centerline CB is made to slant with respect to the engine centerline CE. Due to this, even if the cylinder block **10** moves to the second cylinder group side by exactly D, the mechanical compression ratio of the first cylinder group and the mechanical compression ratio of the second cylinder group side can be equally made the desired mechanical compression ratios.

FIG. **6** is a plan view of a cylinder block **10** of a variable compression ratio V-type internal combustion engine according to the present invention. In the present embodiment, the number of cylinder block side supports **31** for fastening the first relative movement mechanism **30** to the first cylinder group side part **10***a* of the cylinder block **10** is made at least a number greater by exactly "1" than the number of cylinders of the first cylinder group so that one of the cylinder block side supports **31** is positioned at the two sides of the center axial lines C**1**, C**3**, and C**5** at the cylinders of the first cylinder group when viewing the first cylinder group side part **10***a* by the side view, that is, in the present embodiment, since there are three cylinders in the first cylinder group, the number of cylinder block side supports **31** is made four.

Further, the number of cylinder block side supports **41** for fastening the second relative movement mechanism **40** to the second cylinder group side part **10***b* of the cylinder block **10** is made at least a number greater by exactly "1" than the number of cylinders of the second cylinder group so that one of the cylinder block side supports **41** is positioned at the two sides of the center axial lines C**2**, C**4**, and C**6** at the cylinders of the second cylinder group when viewing the second cylinder group side part **10***b* by the side view, that is, in the present embodiment, since there are three cylinders in the second cylinder group, the number of cylinder block side supports **41** is made four.

Further, due to an offset between the cylinders of the first cylinder group and the cylinders of the second cylinder group in the crankshaft direction, one of the supports **31** of the first relative movement mechanism is positioned on each of the center axial lines C**2**, C**4**, and C**6** of the cylinders in the second cylinder group when viewing the first cylinder group side part **10***a* by the side view (it is preferable to make centerlines of supports **31** and center axial lines of the center axial line C**2**, C**4**, and C**6** of the cylinders match) and one of the supports **41** of the second relative movement mechanism is positioned on each of the center axial lines C**1**, C**3**, C**5** of the cylinders in the first cylinder group when viewing the second cylinder group side part **10***a* by the side view (it is preferable to make centerlines of supports **41** and center axial lines of the center axial lines C**1**, C**3**, and C**5** of the cylinders match).

FIG. **7** is a front view of a cylinder block **10'** which shows another embodiment of a variable compression ratio V-type internal combustion engine according to the present invention. The difference from the embodiment shown in FIGS. **4** and **6** is that the cylinder block side supports **31'** of the first relative movement mechanism are arranged at the highest part of the side surface of the first cylinder group side part **10***a*' of the cylinder block **10'**, while the cylinder block side supports **41'** of the second relative movement mechanism are arranged at the highest part of the side surface of the second cylinder group side part **10***b*' of the cylinder block **10'**.

In each embodiment, at the time of firing of a cylinder, as shown in FIG. **7**, a force F is produced which tries to push up the cylinder block in the center axial line direction of the firing cylinder. This force F mainly acts at the cylinder block side supports of the first relative movement mechanism and second relative movement mechanism near the firing cylinder. In the arrangement of cylinder block side supports which is shown in FIG. **6**, the two cylinder block side supports which adjoin the firing cylinder when viewing the cylinder group side corresponding to the firing cylinder by the side view and the single cylinder block side support which is positioned on the center axial line of the firing cylinder when viewing the other cylinder group side by the side view are acted on. In this way, it is possible to make the force which is produced at the time of firing of each cylinder act dispersed to three cylinder block side supports, so there is no need to increase the strength of the cylinder block side supports **31** and **41** of the first relative movement mechanism and second relative movement mechanism that much. As opposed to this, in general, cylinder block side supports of the first relative movement mechanism and the second relative movement mechanism are arranged symmetrically with respect to a Median plane between the two cylinder groups, so the above-mentioned force F acts mainly against just one or two supports and it is necessary to make the strength of the cylinder block side supports very high.

For example, in FIG. **6**, when the #4 cylinder of the second cylinder group which has the center axial line C**4** fires, the above-mentioned force F acts against the two cylinder block side supports $\mathbf{41}_{(24)}$ and $\mathbf{41}_{(46)}$ of the second relative movement mechanism which are positioned at the two sides of the center axial line C**4** of the #4 cylinder when viewing the second cylinder group side part **10***b* by the side view and against the single cylinder block side support $\mathbf{31}_{(35)}$ of the first relative movement mechanism which is positioned on the center axial line C**4** of the #4 cylinder when viewing the first cylinder group side part **10***a* by the side view. Further, when the #5 cylinder of the first cylinder group which has the center axial line C**5** fires, the above-mentioned force F acts against the two cylinder block side supports $\mathbf{31}_{(35)}$ and $\mathbf{31}_{(55)}$ of the first relative movement mechanism which are positioned at the two sides of the center axial line C**5** of the #5 cylinder when viewing the first cylinder group side part **10***a* by the side view and against the single cylinder block side support $\mathbf{41}_{(46)}$ of the second relative movement mechanism which is positioned on the center axial line C**5** of the #5 cylinder when viewing the second cylinder group side part **10***b* by the side view.

Further, the cylinder block side supports **31** of the first relative movement mechanism **30** are comprised of first supports $\mathbf{31}_{(13)}$ and $\mathbf{31}_{(35)}$ which are positioned between the center axial lines of two cylinders which adjoin each other in the first cylinder group when viewing the first cylinder group side part **10***a* by the side view and second supports $\mathbf{31}_{(11)}$ and $\mathbf{31}_{(55)}$ which are not positioned between the center axial lines of two cylinders which adjoin each other in the first cylinder group when viewing the first cylinder group side part **10***a* by the side view. The first supports $\mathbf{31}_{(13)}$ and $\mathbf{31}_{(35)}$ are close in common to two cylinders, so the force at the time of firing of the two cylinders acts on them. The force acts on them at the time of firing by a number of times two times that of the second supports $\mathbf{31}_{(11)}$ and $\mathbf{31}_{(55)}$ which are close to just single cylinders, so the thickness e**2** of the first supports $\mathbf{31}_{(13)}$ and $\mathbf{31}_{(35)}$ is made two times the thickness e**1** of the second supports $\mathbf{31}_{(11)}$ and $\mathbf{21}_{(55)}$ and the strength is made two times that as well.

Further, the cylinder block side supports **41** of the second relative movement mechanism **40** are comprised of third supports $\mathbf{41}_{(24)}$ and $\mathbf{41}_{(46)}$ which are positioned between the center axial lines of two cylinders which adjoin each other in the second cylinder group when viewing the second cylinder group side part **10***b* by the side view and fourth supports $\mathbf{41}_{(22)}$ and $\mathbf{41}_{(66)}$ which are not positioned between the center axial lines of two cylinders which adjoin each other in the second cylinder group when viewing the second cylinder group side part **10***b* by the side view. The third supports $\mathbf{41}_{(24)}$ and $\mathbf{41}_{(46)}$ are close in common to two cylinders, so the force at the time of firing of the two cylinders acts on them. The force acts on them at the time of firing by a number of times two times that of the fourth supports $\mathbf{41}_{(22)}$ and $\mathbf{41}_{(66)}$ which are close to just single cylinders, so the thickness e**2** of the third supports $\mathbf{41}_{(24)}$ and $\mathbf{41}_{(46)}$ is made two times the thickness e**1** of the fourth supports $\mathbf{41}_{(22)}$ and $\mathbf{41}_{(66)}$ and the strength is made two times that as well.

Further, the first supports $\mathbf{31}_{(12)}$ and $\mathbf{31}_{(35)}$, the second supports $\mathbf{31}_{(11)}$ and $\mathbf{31}_{(55)}$, the third supports $\mathbf{41}_{(24)}$ and $\mathbf{41}_{(46)}$, and the fourth supports $\mathbf{41}_{(22)}$ and $\mathbf{41}_{(66)}$ all are made separated by the equal distances "d" from the center axial lines C**1**, C**2**, C**3**, C**4**, C**5**, and C**6** of the cylinders adjoining each other in the side view.

Incidentally, in the embodiment which is shown in FIG. **7**, the cylinder block side supports **31'** of the first relative movement mechanism are arranged at the highest part of the side surface of the first cylinder group side part **10***a*' of the cylinder block **10'**, while the cylinder block side supports **41'** of the second relative movement mechanism are arranged at the highest part of the side surface of the second cylinder group side part **10***b*' of the cylinder block **10'**, so when the force F which is produced at the time of firing is divided into the force Fc which acts on the two cylinder block side supports (in FIG. **7**, **41'**) at the cylinder group side of the firing cylinder and the force Ff which acts on the single cylinder block side support (in FIG. **7**, **31'**) of the cylinder group side opposite to the firing cylinder, the moment length Lf up to the working point (center of axial bore) of the single cylinder block side support at the cylinder group side opposite to the firing cylinder can be made relatively longer than the moment length Lc up to the working points (centers of axial bores) of the two cylinder block side supports at the cylinder group side of the firing cylinder.

In this way, from the relationships of F=Fc+Ff and Fc*Lc=Ff*Lf, it is possible to make the force Ff which acts on the single cylinder block side support of the cylinder group opposite to the firing cylinder smaller.

FIG. **8** is a time chart which shows the relationship of the strokes of the cylinders. "I" shows an intake stroke, "C" a compression stroke, "X an expansion stroke, and "E" an exhaust stroke. As shown in FIG. **6**, the #1 cylinder, #3 cylinder, and #5 cylinder form the first cylinder group, the #2 cylinder, #4 cylinder, and #6 cylinder form the second cylinder group, and the firing sequence becomes the #1 cylinder-#2 cylinder-#3 cylinder-#4 cylinder-#5 cylinder-#6 cylinder.

As shown in FIG. **8**, the cylinders of the first cylinder group and the cylinders of the second cylinder group alternately enter the expansion stroke every 120 degrees crank angle. Due to this, in the 60 degree crank angle range which is shown by t**1**, none of the cylinders of the first cylinder group are in the expansion stroke, while one of the cylinders of the second cylinder group is in the expansion stroke. The force of a firing cylinder of the second cylinder group acts divided to the corresponding single cylinder block side support of the first relative movement mechanism and the corresponding two cylinder block side supports of the second relative movement mechanism. At this time, the force which acts on the cylinder block side supports of the first relative movement mechanism where the moment length becomes longer than that of the cylinder block side supports of the second relative movement mechanism will not become that large. Due to this, at this time, if using the first relative movement mechanism **30** to make the first cylinder group side of the cylinder block move with respect to the crankcase in the engine centerline CE direction by exactly the first set distance, it is possible to make the first relative movement mechanism operate by a small working force.

Further, in the range of 60 degrees crank angle which is shown by t**2**, none of the cylinders of the second cylinder group is in the expansion stroke, while one of the cylinders of the first cylinder group is in the expansion stroke, so the force of a firing cylinder of the first cylinder group acts divided to the corresponding single cylinder block side support of the second relative movement mechanism and the corresponding two cylinder block side supports of the first relative movement mechanism. At this time, the force which acts on the cylinder block side support of the second relative movement mechanism where the moment length becomes longer than that of the cylinder block side supports of the first relative movement mechanism will not become that large. Due to this, at this time, if using the second relative movement mechanism **40** to make the second cylinder group side of the cylinder block move with respect to the crankcase in the engine centerline CE direction by exactly the second set distance, it is possible to make the second relative movement mechanism operate by a small working force.

Of course, it is also possible to make the first relative movement mechanism operate slightly in the crank angle range which is shown by t**1**, make the second relative movement mechanism operate slightly in the crank angle range which is shown by t**2**, and repeat these so as to finally make the first cylinder group side of the cylinder block move by exactly the first set distance, make the second cylinder group side of the cylinder block move by exactly the second set distance, and thereby make mechanical compression ratios of the first cylinder group and the second cylinder group the desired mechanical compression ratios.

In the embodiments which were explained up to here, the first relative movement mechanism and the second relative movement mechanism were made separately controllable and the first relative movement distance in the engine centerline direction of the first cylinder group side of the cylinder block and the second relative movement distance in the engine centerline direction of the second cylinder group side of the cylinder block were able to be made different, but when the cylinder block centerline CB and the engine centerline CE always match and the cylinder block moves relatively to the crankcase, the first relative movement mechanism and the second relative movement mechanism may also be made to simultaneously operate by a single actuator. In this case as well, the arrangement of the cylinder block side supports of the first relative movement mechanism and second relative movement mechanism which is shown in FIG. **6** is effective.

LIST OF REFERENCE NUMERALS

10: cylinder block

20: crankcase

30: first relative movement mechanism

31: cylinder block side support of first relative movement mechanism

40: second relative movement mechanism

41: cylinder block side support of second relative movement mechanism

The invention claimed is:

1. A variable compression ratio V-type internal combustion engine which joins cylinder blocks of two cylinder groups and makes the joined cylinder block move relatively to a crankcase, the engine comprising:

a first relative movement mechanism which is fastened to a first cylinder group side of said joined cylinder block through a plurality of supports, which are fastened to the cylinder block; and

a second relative movement mechanism which is fastened to a second cylinder group side of said joined cylinder block through a plurality of supports, which are fastened to the cylinder block,

wherein the number of said supports of said first relative movement mechanism is made at least a number greater by exactly one than the number of cylinders of said first cylinder group so that one of said supports of said first relative movement mechanism is positioned at the two sides of center axial lines of the cylinders in said first cylinder group when viewing said first cylinder group side by the side view, the number of said supports of said second relative movement mechanism is made at least a number greater by exactly one than the number of cylinders of said second cylinder group so that one of said supports of said second relative movement mechanism is positioned at the two sides of center axial lines of the cylinders in said second cylinder group when viewing said second cylinder group side by the side view,

wherein due to an offset between the cylinders of said first cylinder group and the cylinders of said second cylinder group in a crankshaft direction, one of said supports of said first relative movement mechanism is positioned on the center axial line of each cylinder in said second cylinder group when viewing said first cylinder group side by the side view and one of said supports of said second relative movement mechanism is positioned on the center axial line of each cylinder in said first cylinder group when viewing said second cylinder group side by the side view,

wherein a force acting to push up the cylinder block, in the cylinder axial line direction, at a time of firing of each cylinder, is dispersed to the two supports of the cylinder group side corresponding to the firing cylinder and the one support of the cylinder group side opposing the firing cylinder, and

wherein said first relative movement mechanism and said second relative movement mechanism are made independently controllable, a first relative movement distance in a front view engine centerline direction which passes through a center of a crankshaft which is caused by said first relative movement mechanism at said first cylinder group side of said joined cylinder block and a second relative movement distance which is caused by said second relative movement mechanism at said second cylinder group side of said joined cylinder block can be made different.

2. The variable compression ratio V-type internal combustion engine according to claim **1**, wherein said supports of said first relative movement mechanism are comprised of first supports which are positioned between center axial lines of two cylinders adjoining each other in said first cylinder group when viewing said first cylinder group side by the side view and second supports which are not positioned between center axial lines of two cylinders adjoining each other in said first cylinder group when viewing said first cylinder group side by the side view, a thickness of said first supports is two times a thickness of said second supports, said supports of said second relative movement mechanism are comprised of third supports which are positioned between center axial lines of two cylinders adjoining each other in said second cylinder group when viewing said second cylinder group side by the side view and fourth supports which are not positioned between center axial lines of two cylinders adjoining each other in said second cylinder group when viewing said second cylinder group side by the side view, and a thickness of said third supports is two times a thickness of said fourth supports.

3. The variable compression ratio V-type internal combustion engine according to claim **1**, wherein said first relative movement mechanism changes said first relative movement distance when none of the cylinders of said first cylinder group is in an expansion stroke, and said second relative movement mechanism changes said second relative movement distance when none of the cylinders of said second cylinder group is in an expansion stroke.

4. The variable compression ratio V-type internal combustion engine according to claim **2**, wherein said first relative movement mechanism changes said first relative movement distance when none of the cylinders of said first cylinder group is in an expansion stroke, and said second relative movement mechanism changes said second relative movement distance when none of the cylinders of said second cylinder group is in an expansion stroke.

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