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DESCRIPTION

"APPARATUS FOR MUTUAL CONVERSION BETWEEN
CIRCULAR MOTION AND RECIPROCAL MOTION"

5 Technical Field

The present invention relates to an apparatus for mutual conversion between circular motion and reciprocal motion which is used for converting reciprocal motion of, e.g., the piston of a four-cycle reciprocating engine into rotary motion of a crankshaft.

Background Art

FIG. 47 shows a schematic sectional view of a cylinder part of a conventional four-cycle reciprocating engine having a cylinder 341 in which a piston 342 moves up and down reciprocally. The piston 342 is connected with a crankshaft 343 via a connecting rod 344 so that the reciprocal motion of the piston 342 is converted into rotary motion. In FIG. 47, a reference numeral 345 denotes a heat radiation plate.

20 As one of the factors that hinder an increase in output efficiency of such a four-cycle reciprocating engine, the unavoidable side thrust of the piston 342 is known. This side thrust cannot be avoided since the piston 342 and the crankshaft 343 are coupled to each other by using the connecting rod 344. More specifically, since the reciprocal motion of the piston 342 is not smoothly transmitted to the crankshaft 343,

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the side thrust is increased, thus causing an energy loss.

In this manner, conventionally, the connecting rod intervenes to convert the reciprocal motion or linear motion into rotary motion. With this connecting rod, however, since the piston oscillates as the crank moves, in, e.g., a four-cycle reciprocating engine, a side thrust is generated between the piston and the cylinder. Therefore, the engine idling speed must be increased to about 1,000 rpm, causing a problem in fuel consumption as well.

The side thrust causes an energy loss. Moreover, the piston must be made of a heavy, strong metal in order to prevent damage to the piston, e.g., cracking, partial breaking, and the like of the piston caused by collision of the piston against the inner wall of the cylinder due to the side thrust. Then, the weight of piston cannot be decreased by making the piston with, e.g., a ceramic.

FIG. 28 shows a relationship between a piston position in a cylinder of a conventional four-cycle reciprocal engine and a rotation angle of the engine. In FIG. 28, the solid line shows a graph denoting an ideal piston position, while the broken line shows a graph denoting a piston position of a conventional four-cycle reciprocating engine. As seen from the figure, in the compression stroke from zero to 180 degrees of the

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conventional engine, the piston position or the compression rate of the fuel gas with respect to the rotation angle is lower than that of the ideal piston position.

In the expansion stroke of 180-360 degrees, the expansion speed of the combustion gas is faster than that of the ideal speed. For example, when the ignition point is at 160-degree, the pressure of the fuel gas in the conventional engine is lower than that of the ideal engine due to a so-called late raise of the piston. As a result, the expansion pressure applied to the piston face will be small compared with that of the ideal engine. In the expansion stroke, the pressure of the combustion gas applied to the piston face decreases faster than that in the ideal engine due to a so-called early fall of the piston. As a result, it is not possible to convert the pressure generated by the gas combustion into mechanical energy with high efficiency.

FIG. 29 shows a graph showing a relationship between gas volume (V) in the cylinder and the gas pressure (mega-Pascal:MPa) as conversion efficiency, when the gas combustion energy is converted into mechanical energy. In this figure, the dashed line denotes the conversion efficiency of the conventional reciprocal engine.

The so-called late raise of the piston and so-called early fall of the piston are called as a subtraction operation of the piston. In order to decrease the

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subtraction operation in a marine engine, the connecting rod should be made as long as possible. For example, a connecting rod of 15 meters in height is used.

FIG. 30 is a graph for showing operations of the piston 342, connecting rod 344 and crankshaft 343 shown in FIG. 47, where s denotes the stroke of the piston 342, L denotes the length of the connecting rod 344, r denotes the radius of the rotational locus of the crankshaft 343, α denotes an angle between a line connecting the piston 342 and the center of the crankshaft 343 and the connecting rod 344, and θ denotes the rotational angle of the crankshaft 343.

The piston stroke s in the conventional engine is shown by the following equations.

$$s = r(1 - \cos\theta) + L(1 - \cos\alpha)$$

$$L \cdot \sin\alpha = r \cdot \sin\theta$$

From these equations the following equation (1) can be obtained.

$$s = r(1 - \cos\theta) + L(1 - (1 - r^2 \sin^2\theta / L^2)^{0.5})$$

$$\dots (1)$$

where $**2$ denotes power of 2 and $**0.5$ denotes power of $1/2$.

As can be seen from the equation (1), the piston stroke s is defined by a term including the power of $1/2$ denoting the rotational angle θ of the crankshaft 343. Therefore, the curve showing the piston stroke s or the piston position does not represent an ideal sine

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curve as shown by the dashed line in FIG. 28.

Further, the conventional engine is provided with a flywheel and a counter weight for the crankshaft so as to smoothen the engine rotation. These flywheel and the counter weight, however, absorb the mechanical energy generated from the engine in the acceleration period. This absorbed energy is wasted as heat energy during the braking or deceleration period.

Disclosure of the Invention

It is, therefore, an object of the present invention to provide an apparatus for mutual conversion between circular motion and reciprocal motion that can decrease an energy loss caused when converting the reciprocal motion of the piston of, e.g., a two- or four-cycle reciprocating engine into the rotary motion of the crankshaft and can decrease the weight of the engine by forming the piston with a ceramic, for example.

According to an aspect of the present invention, there is provided an apparatus for mutual conversion between circular motion and reciprocal motion, comprising: a rotary body; a lever member having a fulcrum as well as an action point and a force point one of which is rotatably mounted at a point on a line connecting a rotational center and a circumference of the rotary body, one of the action point and the force point being provided with a first regulator and the fulcrum

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being provided with a second regulator for functioning the fulcrum as a movable fulcrum; and a reciprocating body to which one of the action point and the force point provided with the first regulator is coupled;

5 wherein the first and second regulators include support members for supporting one of the force and action points and the fulcrum to be movable in a longitudinal direction of the lever member.

According to another aspect of the present

10 invention, there is provided an apparatus for mutual conversion between circular motion and reciprocal motion, comprising: a rotary body; a lever member having a fulcrum as well as a force point and an action point which is rotatably mounted at a point on a line connect-

15 ing a rotational center and a circumference of a rotary body, the force point being provided with a first regulator and the fulcrum being provided with a second regulator for functioning the fulcrum as a movable fulcrum; and a reciprocating motor to which the force

20 point provided with the first regulator is coupled; wherein the first and second regulators include support members for supporting the force point and the fulcrum to be movable in a longitudinal direction of the lever member.

25 According to further aspect of the present invention, there is provided an apparatus for mutual conversion between circular motion and reciprocal

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motion, comprising: a rotary motor; and a lever member having a fulcrum as well as a force point and an action point which is rotatably mounted at a point on a line connecting a rotational center and a circumference of a rotary motor, the action point being provided with a first regulator and the fulcrum being provided with a second regulator for functioning the fulcrum as a movable fulcrum, and the action point provided with the first regulator being coupled to a reciprocating body of a reciprocated machine; wherein the first and second regulators include support members for supporting action point and the fulcrum to be movable in a longitudinal direction of the lever member.

According to still another aspect of the present invention, there is provided an apparatus for mutual conversion between circular motion and reciprocal motion, comprising: a rotary body; and a lever member having a fulcrum as well as a force point and an action point connected to the rotary body to be driven, the force point being provided with a first regulator and the fulcrum being provided with a second regulator for functioning the fulcrum as a movable fulcrum; wherein the force point provided with the first regulator is coupled to a piston of a reciprocating body of a motor, the piston is movably mounted in a cylinder of the motor, the cylinder has inlet and exhaust units of a power gas at each of two ends thereof, and the first and

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second regulators have support members for supporting the force point and the fulcrum to be movable in a longitudinal direction of the lever member.

According to still another aspect of the present invention, there is provided an apparatus for mutual conversion between circular motion and reciprocal motion, comprising: a rotary body; and a lever member having a fulcrum as well as a force point and an action point which is rotatably mounted at a point on a line connecting a rotational center and a circumference of the rotary body, the force point being provided with a first regulator and the fulcrum being provided with a second regulator for functioning the fulcrum as a movable fulcrum; wherein the force point provided with the first regulator is coupled to a piston of a reciprocating motor, the piston is movably mounted in a cylinder, the cylinder has inlet and exhaust units of a fuel gas and an ignition unit at each of two ends thereof, and the first and second regulators have support members for supporting the force point and the fulcrum to be movable in a longitudinal direction of the lever member.

According to still further aspect of the present invention, there is provided an apparatus for mutual conversion between circular motion and reciprocal motion comprising a lever member having a first regulator provided at an end of the lever member for functioning

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as a force point or an action point, and a second
regulator provided at another end of the lever member
for functioning as an oscillation support point, a point
between both of the ends functioning as an action point
5 or a force point rotatably and axially secured on a line
connecting a rotation center of a rotary member and a
circumference with each other, wherein a reciprocal
motion member is connected with the first regulator and
that the first and second members have a support member
10 for movably supporting the force or action points and
the oscillation support point such that the force or
action points and the oscillation support point are
movable in a lengthwise direction of the lever member.

According to still another aspect of the present
15 invention, there is provided an apparatus for mutual
conversion between circular motion and reciprocal motion
comprising, a rotary member; and a lever member having a
first regulator provided at an end of the lever member
for functioning as a force point or an action point, and
20 a second regulator provided at another end of the lever
member for functioning as an oscillation support point,
a point between both of the ends functioning as an
action point or a force point rotatably and axially
secured on a line connecting a rotation center of the
25 rotary member and a circumference with each other,
wherein the first and second members have a support
member for movably supporting the force or action points

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and the oscillation support point such that the force or action points and the oscillation support point are movable in a lengthwise direction of the lever member.

According to still further aspect of the present invention, there is provided an apparatus for mutual conversion between circular motion and reciprocal motion comprising: a rotary member; a lever member having a first regulator provided at an end of the lever member for functioning as a force point or an action point, a second regulator provided at another end of the lever member for functioning as an oscillation support point, a point between both of the ends functioning as an action point or a force point rotatably and axially secured on a line connecting a rotation center of the rotary member and a circumference with each other; and a reciprocal motor connected with the first regulator, wherein the first and second members have a support member for movably supporting the force or action points and the oscillation support point such that the force or action points and the oscillation support point are movable in a lengthwise direction of the lever member.

According to still further aspect of the present invention, there is provided an apparatus for mutual conversion between circular motion and reciprocal motion comprising: a lever member having a first regulator provided at an end of the lever member for functioning as an action point and a second regulator provided at

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another end of the lever member for functioning as an oscillation support point, a point between both of the ends functioning as a force point rotatably and axially secured on a line connecting a rotation center of a rotary member and a circumference with each other; and a rotary motor having an output shaft connected with the force point, wherein the first regulator is connected with a reciprocal motion member as a reciprocal motion member and that the first and second members have a support member for movably supporting the force or action points and the oscillation support point such that the force or action points and the oscillation support point are movable in a lengthwise direction of the lever member.

According to still another aspect of the present invention, there is provided an apparatus for mutual conversion between circular motion and reciprocal motion comprising a rotary member and a lever member having a first regulator provided at an end of the lever member for functioning as a force point, and a second regulator provided at another end of the lever member for functioning as an oscillation support point, a middle point between both of the ends functioning as an action point rotatably and axially secured on a line connecting a rotation center of the rotary member and a circumference with each other, wherein the first regulator is connected with a piston of a reciprocal motion motor, that

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the piston is movably included in a cylinder, that the cylinder have ends both respectively provided with an intake/exhaust device for taking in/exhausting a power gas, and that the first and second members have a support member for movably supporting the force or action points and the oscillation support point such that the force or action points and the oscillation support point are movable in a lengthwise direction of the lever member.

10 Brief Description of the Invention

FIG. 1 is a perspective view showing an embodiment of the present invention;

FIG. 2 is a view showing an example of the loci of rotating and reciprocating portions shown in FIG. 1;

15 FIG. 3 is a view showing another example of the loci of the rotating and reciprocating portions shown in FIG. 1;

FIG. 4 is a schematic sectional view showing another embodiment of the present invention;

20 FIG. 5 is a perspective view showing still another embodiment of the present invention;

FIG. 6 shows views representing the operation processes of the embodiment shown in FIG. 5;

25 FIG. 7 is a front view showing a concrete embodiment corresponding to the embodiment shown in FIG. 5;

FIG. 8 is a plan view of the apparatus of the embodiment shown in FIG. 7;

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FIG. 9 is a sectional side view of the apparatus of the embodiment shown in FIG. 7;

FIG. 10 is a front view of the apparatus of the embodiment shown in FIG. 7;

5 FIG. 11 is a schematic sectional view showing still another embodiment of the present invention;

FIG. 12 is a schematic sectional view showing a modification of the embodiment shown in FIG. 11;

10 FIG. 13 is a schematic side view showing still another embodiment of the present invention;

FIG. 14 shows schematic views showing still another embodiment of the present invention;

FIG. 15 is a schematic side view showing still another embodiment of the present invention;

15 FIG. 16 is a schematic side view showing still another embodiment of the present invention;

FIG. 17 is a schematic side view showing still another embodiment of the present invention;

20 FIG. 18 is a schematic side view showing still another embodiment of the present invention;

FIG. 19 is a schematic side view showing still another embodiment of the present invention;

FIG. 20 shows schematic views showing still another embodiment of the present invention;

25 FIG. 21 is a perspective view showing a still further embodiment of the present invention;

FIG. 22 is a front view showing a still another

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embodiment of the present invention;

FIG. 23 is a front view showing a still further embodiment of the present invention;

FIG. 24 is a side view showing a partial cross-
5 section of a structure according to a still further embodiment of the present invention;

FIG. 25 is a view for showing loci explaining an operation of respective sections of the embodiment shown in FIG. 24;

10 FIG. 26 is a view for showing loci explaining an operation of respective sections of a modification of the embodiment shown in FIG. 24;

FIG. 27 is a view for showing loci explaining an operation of respective sections of a modification of
15 the embodiment shown in FIG. 24;

FIG. 28 is a graph showing a relationship of a piston position and a rotation angle according to the embodiment of FIG. 24, compared with a conventional engine;

20 FIG. 29 is a graph showing a relationship between a gas volume and a pressure in a cylinder according to the embodiment of FIG. 24;

FIG. 30 is a diagram showing a relationship between a piston, a connecting rod, and a crankshaft in a conventional reciprocating engine;
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FIG. 31 is a diagram showing a piston, a moving fulcrum type lever device, and a crankshaft in the

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embodiment of FIG. 24;

FIG. 32 is a table comparing characteristics of a conventional reciprocating engine, those of an inner moving fulcrum type Z-mechanism engine, and those of an outer moving fulcrum type Z-mechanism engine of the present invention with each other;

FIG. 33 is a front view showing a cross-section of an outer moving fulcrum type Z-mechanism engine according to still another embodiment of the present invention;

FIG. 34 is a top view showing a cross-section of the outer moving fulcrum type Z-mechanism engine according to the embodiment of FIG. 33;

FIG. 35 is a side view showing a cross-section of the outer moving fulcrum type Z-mechanism engine according to the embodiment of FIG. 33;

FIG. 36 is a front view showing a across section of an outer moving fulcrum type Z-mechanism engine according to a still another embodiment of the present invention;

FIG. 37 is a top view showing a cross-section of the outer moving fulcrum type Z-mechanism engine according to the embodiment of FIG. 36;

FIG. 38 is a side view showing a cross-section of the outer moving fulcrum type Z-mechanism engine according to the embodiment of FIG. 36;

FIG. 39 is a front view showing a cross-section of

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an outer moving fulcrum type Z-mechanism engine according to a still further embodiment of the present invention;

FIG. 40 is a front view showing a cross-section of
5 a practical form of the embodiment of FIG. 33;

FIG. 41 is a front view showing a cross-section of an outer moving fulcrum type Z-mechanism engine according to still another embodiment of the present invention;

10 FIG. 42 is a side view showing a cross-section of the outer moving fulcrum type Z-mechanism engine according to the embodiment of FIG. 41;

FIG. 43 is a perspective view showing an outer moving fulcrum type Z-mechanism engine according to a
15 still further embodiment of the present invention;

FIG. 44 is a view schematically showing a structure of an outer moving fulcrum type Z-mechanism engine according to a still another embodiment of the present invention;

20 FIG. 45 is a view schematically showing a structure of an outer moving fulcrum type Z-mechanism engine according to still further embodiment of the present invention;

FIG. 46 is a view schematically showing a structure
25 of a flying member constituted with use of an apparatus for mutual conversion between circular motion and reciprocal motion; and

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FIG. 47 is a view schematically showing a conventional reciprocating engine.

Best Mode of Carrying Out the Invention

The preferred embodiments of the present invention will be described in detail with reference to the accompanying drawings.

FIG. 1 is a perspective view showing the overall arrangement of an embodiment of the present invention. This embodiment has a lever member 5 whose one end serving as a force point is rotatably mounted, through a pin 4, to a position close to the circumference of a disk 3 mounted to a rotating shaft 2 of a motor 1.

The fulcrum 6a of the lever member 5 is rotatably supported by a fulcrum regulator 6 so that the fulcrum is movable in its longitudinal direction. The fulcrum 6a is a pin and is mounted on the lever member 5 so as to support a roller 6b rotatably to the lever member 5 through the pin 6a. The fulcrum regulator 6 is composed of the roller 6b and guide plates 6c and 6d for guiding the roller 6b as well as the lever member 5 to be movable in the longitudinal direction of the lever member 5.

An action point regulator 7 is provided to the action point 7a at the other end of the lever member 5. The action point regulator 7 has a roller 7b rotatably mounted to the other end of the lever member 5 through a pin 7a, and guide plates 7c and 7d for guiding the

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roller 7b so that the roller 7b as well as the action point 7a are movable in the longitudinal direction of the lever member 5.

5 The action point regulator 7 is fixed to substantially the central portion of a cylindrical piston 8, and the piston 8 is inserted in a cylinder 9. Piston rings (not shown) are mounted at the peripheral portions near to the both end portions of the piston 8 so as to seal a gap between the piston 8 and the inner wall of
10 the cylinder 9.

Pairs of inlet and exhaust pipes 10a and 10b, and 10c and 10d are mounted to the two end faces of the cylinder 9, and opening/closing valves 11a, 11b, 11c, and 11d are provided to the respective pipes.

15 In this arrangement, when the motor 1 is connected to a power supply and driven, the disk 3 is rotated in, e.g., the direction of an arrow A shown in FIG. 1, and the lever member 5 repeats pivot motion in the counterclockwise and clockwise directions every half
20 turn of the disk 3. Accordingly, the action point 7a of the lever member 5 repeats a reciprocal motion in the direction normal to its longitudinal direction along with rotation of the disk 3.

25 The reciprocal motion of the action point of the lever member 5 is transmitted to the action point regulator 7, and accordingly the piston 8 performs linear reciprocal motion in the cylinder 9. At this time, the

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roller 7b is guided to be movable in the longitudinal direction of the lever member 5 along the guide plates 7c and 7d of the regulator 7.

In this case, when the valves 11a to 11d are opened and closed at predetermined timings as the piston 8 moves in response to the vertical movement of the lever member 5, a liquid can be taken from the pipes 10a and 10c into the cylinder 9 and exhausted from the pipes 10b and 10d, respectively.

At this time, since the side thrust of the piston 8 toward the inner wall of the cylinder 9 does not appear due to the regulators 6 and 7, and the side thrust of the lever member 5 toward the guide plates 6c, 6d, 7c, and 7d, which is caused at the movable fulcrum 6a and the action point 7a of the lever member 5, is absorbed as rotation of the rollers 6b and 7b, mechanical losses at these portions are very small.

The apparatus of the embodiment shown in FIG. 1 is a reversible apparatus. For example, when a high-pressure liquid or air is alternately supplied from the pipes 10a and 10c to vertically move the piston 8 with the high-pressure liquid or air, and the reciprocal motion of the piston 8 is transmitted to the disk 3 through the lever member 5 to rotate the disk 3, the motor 1 can be driven as a power generator.

In this case as well, since the side thrust of the piston 8 toward the inner wall of the cylinder 9 and

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that of the lever member 5 toward the guide plates 6c, 6d, 7c, and 7d, which is caused at the movable fulcrum 6a and the force point 7a of the lever member 5 by the reciprocal motion of the piston 8, is absorbed as
5 rotation of the rollers 6b and 7b of the regulators 6 and 7, mechanical losses at these portions are very small.

FIGS. 2 and 3 are views showing the loci of the pins 4, 6a, and 7a in motion which respectively serve as
10 the force point, the fulcrum, and the action point of the lever member 5 in the embodiment shown in FIG. 1. More specifically, the pin 4 performs a complete circular motion, the fulcrum pin 6a linearly moves between the guide plates 6c and 6d in the longitudinal direction
15 of the lever member 5, and the pin 7a moves between the guide plates 7c and 7d in response to the reciprocal motion of the piston 8 to form a locus as shown in FIG. 2 or 3. The difference in locus of the pin 7a between FIGS. 2 and 3 is caused by the difference in
20 position of the movable fulcrum pin 6a.

FIG. 4 is a view showing the schematic arrangement of an embodiment in which the present invention is applied to a four-cycle engine. An inlet pipe 21, an exhaust pipe 22, an inlet valve 23, and an exhaust valve
25 24 are provided at the upper portion of a cylinder 20 of the four-cycle engine.

A piston 25 is provided in the cylinder 20 to move

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vertically along the inner wall of the cylinder 20.

Although not shown, a piston ring is mounted on the outer circumferential surface of the piston 25 to seal the piston 25 with respect to the inner wall of the

5 cylinder 20. In the piston 25, a guide groove 25c is formed between a pair of guide plates 25a and 25b separated from each other by a predetermined distance in a direction perpendicular to the moving direction of the piston 25.

10 A roller 26 having an outer diameter of almost the same size as the width of the guide groove 25c is inserted in the guide groove 25c. The roller 26 is rotatably mounted to one end or force point of a lever member 28 through a pin 27. The plates 25a, 25b and the
15 roller 26 function as a force point regulator.

The lever member 28 is supported through a movable fulcrum regulator 29 which has an arrangement identical to that of the embodiment shown in FIG. 1. The other end of the lever member 28 is rotatably coupled to the
20 crankshaft arm 30 of a crankshaft 32 or the peripheral portion of a rotary disk through a pin. The movable fulcrum regulator 29 is constituted by a pin 28a, a roller 28b, and guide plates 28c and 28d. The guide plates 28c and 28d are provided along the direction of
25 the reciprocal motion of the piston 25, and the roller 28b is also supported to be movable in the direction of the reciprocal motion of the piston 25.

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In this embodiment, when the fuel-air mixture is ignited by an ignition plug 33 near the upper dead point in the compression stroke of the piston 25, the piston 25 is pushed down by explosion of the fuel-air mixture. This pressure is transmitted to the lever member 28 through the roller 26 and the pin 27, is then transmitted from the crankshaft arm 30 to the center rod of the crankshaft 32.

In the embodiment of FIG. 4, the piston 25 is urged against the inner wall of the cylinder 20 by the pressure of the explosion. Since the piston 25 and the lever member 28 are coupled to each other through the regulator composed of the plates 25a and 25b and the roller 26 serving as a force point regulator and through the regulator 29 serving as the movable fulcrum regulator, the force urging the piston 25 is fully transmitted to the crankshaft arm 30 and does not receive any counteraction from the lever member 28, so that the side thrust is greatly decreased as compared to a conventional reciprocal engine. Similarly, the fulcrum 28a of the lever member 28 is supported by the movable fulcrum regulator 29, and accordingly the reciprocal motion of the piston 25 is converted into a rotary motion with a small mechanical loss.

In this case, since the piston 25 is not urged against the inner wall of the cylinder 20 by a large force, the major portion of the piston 25 can be formed

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of, e.g., a ceramic. Since the side thrust is decreased, the energy loss is decreased, and the idling speed can be decreased to, e.g., 50 rpm or less, leading to a great advantage in fuel consumption as well.

5 In the embodiment of FIG. 5, two cylinders and two pistons each identical to that of the embodiment in FIG. 4 are coaxially coupled to have a simplified arrangement, thereby further improving the efficiency. Accordingly, in FIG. 5, portions corresponding to those
10 in the arrangement of FIG. 4 are denoted by the same reference numerals, and a detailed description thereof will be omitted or simplified.

Referring to FIG. 5, pairs of inlet pipes 21a and 21b, exhaust pipes 22a and 22b, and ignition plugs 33a
15 and 33b are mounted to the two end faces of a cylinder 20. A piston 25 is inserted in the cylinder 20, and a pin 27 acting as a force point and a roller 26 and guide plates 25a and 25b serving as a force point regulator are provided in the piston 25. The pin 27 is mounted to
20 one end of a lever member 28, and the lever member 28 is rotatably coupled to a crankshaft arm or a power receiving portion 30a of a crankshaft 32 through a fulcrum regulator 29. The power receiving portion 30a corresponds to the crankshaft arm 30 of the crankshaft 32 in
25 the embodiment of FIG. 4.

In the embodiment of FIG. 5, the inlet pipes 21a and 21b, and the exhaust pipes 22a and 22b are opened

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and closed by valves (not shown) at predetermined timings. These portions may have the same arrangement as that of a conventional four-cycle engine and the detailed explanations thereof are thus omitted.

5 Assume that the crankshaft 32 is rotated by a starter motor (not shown), that, e.g., the piston 25 is moved in the cylinder 20 to come close to the left end in FIG. 5, and that the fuel-air mixture is compressed at this time. When the fuel-air mixture is ignited by
10 the ignition plug 33a, the piston 25 is pushed to the right in FIG. 5, and the lever member 28 is rotated in the clockwise direction through the pin 27 as well as the force point regulator. When the lever member 28 is rotated about the fulcrum pin 28a clockwise, the
15 crankshaft 32 is rotated in the counterclockwise direction. As a result, the piston 25 is moved in the cylinder 20 to come close to the right end in FIG. 5, and then the exhaust gas is exhausted from the pipe 22b. If it is designed that an explosion takes place in a
20 second cylinder (not shown), the crankshaft 32 is continuously rotated.

 When an explosion takes place in the second cylinder, the piston 25 in FIG. 5 is moved to the left to exhaust the exhaust gas through the pipe 22a, and
25 simultaneously the fuel-air mixture is taken from the inlet pipe 21b. When an explosion takes place in another third cylinder as the piston 25 comes to the

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left end in FIG. 5, the piston 25 is moved to the right to compress the fuel-air mixture taken in the inlet pipe 21b. The piston 25 is moved in the cylinder 20 to come close to the right end in FIG. 5. When the ignition
5 plug 33b ignites the compressed fuel-air mixture at this time, the piston 25 is pushed to the left. In this manner, the crankshaft 32 is continuously rotated in the direction shown by an arrow A.

FIG. 6(a) shows the process of a four-cycle engine in which two cylinders having the arrangement as shown in
10 FIG. 5 are coupled to the crankshaft 32, and FIG. 6(b) shows operation steps of another two cylinders of the four-cycle engine in which a total of four cylinders identical to that employed in FIG. 5 are arranged to
15 continuously cause four-cycle operation. In this case, if the four cylinders are arranged such that an explosion always takes place in a push-pull manner at the two sides of the lever member 28 of FIG. 5, the operation efficiency is increased, thereby realizing a quiet
20 engine having a small vibration.

In this embodiment, the piston 25 arranged with a good balance on the two sides of the pin 27, and the piston 25 only linearly contacts the guide plates 25a and 25b of the lever member 28 corresponding to the
25 conventional connecting rod through the roller 26. Therefore, during each explosion, the piston 25 does not cause a large side thrust to act on the inner wall of

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the cylinder 20. Accordingly, the energy loss caused by the side thrust becomes small, so that a high-efficiency reciprocating engine can be constituted. Since a very large force does not act on the piston 25 due to the side thrust, the piston 25 can be formed of a ceramic.

When the reciprocating engine can be formed by using a ceramic, the internal temperature of the cylinder 20 can be increased to twice to three times that of a conventional engine. It is known that the heat efficiency of the conventional reciprocating engine is 20%. In this embodiment, the mechanical loss can also be largely decreased. For example, if a 10% mechanical loss can be recovered, assuming that a 70% remaining heat loss can be decreased to 1/3, a high efficiency of $(10 + 70/3 + 20)\%$, i.e., more than 50% can be obtained.

Since the total coefficient of friction from the piston 25 to the crankshaft 32 becomes very small, a smooth movement as a whole can be obtained, and the idling speed can be reduced to, e.g., 50 rpm or less.

FIGS. 7 to 10 show an embodiment of a horizontal coaxial four-cycle engine in which a cylinder having the arrangement of the embodiment of FIG. 5 is placed horizontally. Referring to FIG. 7, a roller 43a is fitted in a guide groove 42a formed between guide plates 42b and 42c formed in a piston 41a inserted in a cylinder 40a and is mounted to one end of a lever member

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45a through a pin 44a.

The roller 43a, two guide plates 42b and 42c form a force point regulator and the pin 44a acts as a force point of the lever member 45a.

5 The lever member 45a is supported by a pin 48a acting as a movable fulcrum which is provided with a fulcrum regulator formed by a roller 47a inserted in a guide groove 46a. The other end or action point of the lever member 45a is coupled to a crankshaft arm 49a of a
10 crankshaft. The crankshaft arm 49a is coupled to cam shafts 50a and 50b through a belt 61 and rollers 62a, 62b, 62c, 62d, and 62e as shown in FIG. 10 and serving as a coupling member, and drives cams 51a and 51b mounted to the cam shafts 50a and 50b. The cams 51a and
15 51b drive valves 54a and 54b through lever members 53a and 53b having movable fulcrum regulators 52a and 52b, respectively.

As shown in FIG. 8, in addition to the valve 54a, another valve 55a is provided to one side of the
20 cylinder 40a. The valve 55a is driven by a lever member 56a in a similar manner. As shown in FIG. 8, in addition to the valve 54b, another valve 55b is provided to the other side of the cylinder 40a. The valve 55b is driven by a lever member 56b in a similar manner.
25 Referring to FIG. 8, pairs of ignition plugs 57a and 57b, and 58a and 58b are respectively provided to the two sides of the cylinder 40a.

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FIG. 9 is a sectional side view taken along the portion of the lever member 45a shown in FIG. 7. The crankshaft arm 49a coupled to the lower end of the lever member 45a is rotatably supported by bearings 60a and 60b.

The engine shown in FIGS. 7 to 10 is basically the same as that shown in FIG. 5 and a description of the operation thereof will be omitted. In this engine, a lever member identical to the lever member 28 used between the piston 25 and the crankshaft 32 in FIG. 5 is employed in the driving mechanism of the valves 54a to 55b, so that the engine can be rotated at a higher speed.

Examples of a valve opening/closing mechanism will be described with reference to FIGS. 11 and 12. In FIG. 11, the valve opening/closing mechanism is applied to a tappet valve. A guide groove 71 of a force point regulator is formed in the distal end of a tappet 70 in a direction perpendicular to the moving direction of the tappet 70, and a roller 72 is inserted in the guide groove 71. The roller 72 is mounted to force point of a lever member 74 through a pin 73, and a valve shaft 75 is rotatably mounted to the action point or the other end of the lever member 74. The movable fulcrum of the lever member 74 is supported by a roller 77 through a pin 76, and the roller 77 is held on an engine body 79 through a guide groove 78 of a fulcrum regulator so that

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it can freely move in the longitudinal direction of the lever member 74.

A valve 80 is formed on the distal end of the valve shaft 75. A washer 81 is fixed to the valve shaft 75.

5 The valve 80 formed on the distal end of the valve shaft 75 constantly closes, e.g., an exhaust hole 83 by the operation of a coil spring 82 inserted between the washer 81 and the engine body 79. The tappet 70 is regulated by the engine body 79 acting as an input
10 movable force point regulator and the valve shaft 75 is regulated by the engine body 79 acting as an output action point regulator.

When the valve opening/closing mechanism is formed in this manner, the vertical movement of the tappet 70
15 regulated by the input force point regulator is smoothly transmitted to the valve shaft 75, and the movement of the valve shaft 75 is regulated by the output action point regulator as well as by a wall 71a on the upper side of the guide groove 71 formed in the distal end of
20 the tappet 70. Thus, even if the engine speed increases, the valve 80 always follows the vertical movement of the tappet 70 precisely so as not to cause so-called crush. Therefore, the engine speed can remarkably increases as compared to the conventional
25 engine.

FIG. 12 shows an example in which the valve opening/closing mechanism is applied to an OHC (overhead

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cam) valve. FIG. 12 is different from FIG. 11 only in that the valve opening/closing mechanism is driven by an overhead cam 85 in place of the tappet 70 and that a guide groove 78 is formed between a guide plate 78a and an engine body 79. The operation of this mechanism is basically the same as that of FIG. 11.

All of the above embodiments are related to apparatuses for conversion between rotary motion and linear reciprocal motion. The following embodiments are related to apparatuses for directly converting rotary motion into reciprocal pivot motion of a lever member.

FIG. 13 shows a basic actuator arrangement 111 of such an apparatus. Referring to FIG. 13, a rotor arm 101A is coupled to a motor 100 through a rotating shaft 101 and is driven by it. A lever member 103 is coupled to the other end of the rotor arm 101A through a pin 102, and a movable fulcrum 104 of the lever member 103 is rotatably supported between a pair of parallel guide plates 106 and 107 of a fulcrum regulator through a roller 105. All these constituent elements are housed in a rectangular case 109, and especially the portion of the motor 100 is sealed in a shock absorber filler 110.

In this arrangement 111, when power is supplied to the motor 100 to rotate the shaft 101, as the motor 100 rotates, the free end of the rotor arm 101A or the pin 102 performs a circular motion to form a trace having almost the same size as that of the length of the arm

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101A. Accordingly, the roller 105 is linearly moved between the guide plates 106 and 107, and the lever member 103 reciprocally rotates about the movable fulcrum 104 as the center. By this arrangement, rotation of the rotary arm 101A is smoothly converted into the reciprocal motion of the lever member 103. Note that the angle of reciprocal swing motion of the lever member 103 can be changed by changing the ratio of the distances among the fulcrum 104, the force point 102, and the action point 112.

In FIG. 14, the blades 125a, 125b, 126a, 126b of a flying object are constituted by using two sets of the basic arrangements 111 each identical to that shown in FIG. 13. FIG. 14(a) is a front view, and FIG. 14(b) is a plan view. Referring to FIG. 14, rotary disks 121 and 122 are coupled to the rotary shafts of the motors (not shown) and driven by them. Rotary motions of the disk 121 is transmitted to blades 125a, 125b and those of the disk 122 to blades 126a, 126b, respectively. Gears are formed at the periphery of the disks 121 and 122 so that the disks 121 and 122 are meshed with each other to drive the blades 125a, 125b in synchronism with the blades 126a, 126b. These blades are serving as lever members through movable fulcrum regulators 123 and 124, and converted into flapping. The disks 121 and 122 may be driven other than the motors such as a rubber string. In such a case, one

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end of the rubber string may be hooked to the hook
127.

FIG. 15 shows a structure in which one end of a
lever member 133 is coupled to the peripheral portion of
5 a rotary body 131 through a pin 132. In this case, the
lever member 133 is used as the arm of a crane using a
movable fulcrum 135. A balance weight 134 is provided
at the rear end of the lever member 133 so that the
lever member 133 can smoothly move as the crane.

10 In an embodiment of FIGS. 16 and 17, a support
shaft 143 is inclinedly mounted to the rotating shaft of
a motor 141 through a mounting member 142, a rotatable
roller 145 acting as a moving fulcrum is mounted midway
along the support shaft 143, and the roller 145 is
15 sandwiched by two parallel guide plates 146 and 147
functioning as a moving fulcrum regulator. With this
arrangement, the support shaft 143 forms a rotational
trace forming a circular cone having the roller 145 as
the vertex. Hence, when a triangular plate 148 is
20 mounted to this support shaft 143, the plate 148 can be
operated as the propeller of a boat.

FIG. 18 shows an example in which a humanoid foot
is constituted by using three sets of the basic arrange-
ments 111A, 111B and 111C each identical to that shown in
25 FIG. 13. More specifically, the distal end of a lever
member 103A of the basic arrangement 111A is fixed to a
case 109B of the basic arrangement 111B, and the distal

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end of a lever member 103B of the basic arrangement 111B is fixed to a case 109C of the basic arrangement 111C. When disks 100A to 100C of the basic arrangements 111A to 111C are driven by motors (not shown), the respective
5 lever members 103A to 103C are swung to perform the movement of the humanoid foot in which the lever member 103A acts as a femoral region, the lever member 103B as a leg and the lever member 103C as a foot.

FIG. 19 shows an example in which a humanoid arm is
10 constituted by using three sets of the basic arrangements 111a, 111B and 11C each identical to that shown in FIG. 13. More specifically, the distal end of a lever member 103A of the basic arrangement 111A is fixed to a case 109B of a basic arrangement 111B, and the distal
15 end of a lever member 103B of the basic arrangement 111B is fixed to a case 109C of a basic arrangement 111C. When disks 100A to 100C of the basic arrangements 111A to 111C are driven by motors 100a, 100B and 100C, the respective lever members 103A to 103C are swung to
20 perform the movement of the humanoid arm in which the lever member 103A acts as an upper arm, the lever member 103B as an arm and the lever member 103C as a hand.

FIG. 20 shows still another embodiment of the present invention which is constituted as, e.g., the
25 balancer of a robot. FIG. 20(a) is a side view, and FIG. 20(b) is a plan view. In this embodiment as well, two sets of the basic arrangements 111A and 11B each

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identical to that shown in FIG. 13 are used. The distal
end of a lever member 103A of the first basic arrange-
ment 111A is fixed to the distal end of a fixed arm
151, projecting from the rear portion of a case 109B of
5 the second basic arrangement 111B, at an angle of 90°. A
columnar weight 152 is mounted to the distal end of a
lever member 103B of a second basic arrangement 111B.
Accordingly, the pivot direction of the lever member
103A of the first basic arrangement 111A and that of the
10 lever member 103B of the second basic arrangement 111B
form an angle of 90°. As a result, if this balancer is
mounted to, e.g., a robot which walks with two feet and
the lever members 103A and 103B of the basic arrange-
ments 111A and 111B are pivoted in accordance with the
15 output from the attitude sensor of the robot by driving
the lever members 103A and 103B by means of the motors
100A and 100B, respectively, a very fine attitude
control operation can be performed.

The embodiment of FIG. 5 shows a case wherein the
20 reciprocal motion of the piston 25 is output from the
crankshaft 32 as the rotational motion by means of the
lever member 28. However, according to the gist of the
present invention, it is possible to convert the
reciprocal motion of the piston 25 into a plurality of
25 rotational motions and output from a plurality of crank-
shafts simultaneously by means of a plurality of lever
members.

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FIG. 21 shows an embodiment for outputting a plurality of rotational motions from one reciprocal piston movement. In the figure, a circularly cut portion 25AA is formed at a substantial middle portion of a piston 25A. At each one end of four lever members 28A, 28B, 28C and 28D acting as a force point is provided with rollers 26A, 26B, 26C and 26D are mounted rotatably by means of pins and the rollers 26A-26D are engaged between the end faces 25Aa and 25Ab of the circular cut portion 25AA.

Rollers 28Aa, 28Ba, 28Ca and 28Da are mounted rotatably at inner fulcrum portions of the lever members 28A, 28B, 28C and 28D. These rollers 28Aa-28Da are rotatably supported between pairs of guide plates 28ca, 28da; 28cb, 28db; 28cc, 28dc; and 28cd, 28dd acting as fulcrum regulators.

The end portions of the lever members 28A-28D acting as action points are rotatably engaged to crank arms 30A, 30B, 30C and 30D.

Accordingly, when the piston 25A is reciprocally driven in the cylinder 20, four synchronously rotational outputs can be obtained simultaneously.

FIG. 22 shows a four-cylindere radial engine according to still another embodiment of the present invention. In the figure, first and second common cylindrical cylinders 161 and 162 are so arranged that the axis of the cylinders 161 and 162 are parallel with

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each other. Both ends of the cylinders 161 and 162 are closed by head covers 163, 164, 165 and 166. Two valves 167a, 167b are mounted through the head cover 163. In the similar manner, valves 168a, 168b, 169a, 169b, 170a and 170b are mounted through the head covers 164, 165 and 166.

First and second piston members 171 and 172 are provided in the cylinder 161 and are connected with each other by a connecting member 173. Two guide plates 174 and 175 are provided between the piston members 171 and 172 so that a roller 176 can be moved freely between the guide plates 174 and 175 in the direction normal to the axial direction of the cylinder 161. Recesses 171a and 172a are formed in the piston members 171 and 172 to decrease the weight thereof, and the open ends of the recesses 171 and 172 are closed by piston plates 177 and 178 so that combustion chambers 179 and 180 are formed between head covers 163, 164 and piston plates 174, 175. Sealing members or piston rings 181 are provided for sealing the combustion chambers 179, 180 at the gaps between the piston members 171, 172 and the cylinder 161.

In the similar manner, first and second piston members 185 and 186 are provided in the cylinder 162 and are connected with each other by a connecting member 187. Two guide plates 188 and 189 are provided between the piston members 185 and 186 so that a roller 190 can

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be moved freely between the guide plates 188 and 189 in the direction normal to the axial direction of the cylinder 162. Recesses 191a and 192a are formed in the piston members 185 and 186 to decrease the weight thereof, and the open ends of the recesses 185 and 186 are closed by piston plates 192 and 193 so that combustion chambers 194 and 195 are formed between head covers 165, 166 and piston plates 192, 193. Sealing members 196 are provided for sealing the combustion chambers 194, 195 in the similar manner as in the cylinder 161.

Cylinders 161 and 162 are fixed to a frame 200 so that the cylinders 161 and 162 are parallel with each other to have a center rod 201 of a crankshaft 202 being in a direction normal to the axes of the cylinders 161 and 162.

The roller 176 is rotatably mounted to one end of a lever member 203 through a pin 204. The lever member 203 is supported by a movable fulcrum 204 constituted by a supporting roller 204a through a pin 204b between guide plates 204c, 204d functioning as a moving fulcrum regulator for movably supporting the lever member 203 in the longitudinal direction thereof. The other end of the lever member 203 is coupled to a power receiving portion of the crankshaft 202 rotatably. In the similar manner, the roller 190 is rotatably mounted to one end of a lever member 205 through a pin 206. The lever member 205 is supported by a movable fulcrum 207

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constituted by a supporting roller 207a through a pin 207b between guide plates 207c, 207d of a moving fulcrum regulator for movably supporting the lever member 205 in the longitudinal direction thereof. The other end of
5 the lever member 205 is coupled to a power receiving portion of the crankshaft 202 rotatably.

When a spark or ignition plug (not shown) is energized in the combustion chamber 179, the fuel-air mixture or the combustion gas introduced into the
10 chamber 179 through the valve 167a, for example, is fired to push the piston members 171 and 172 toward the head cover 164 so as to compress the combustion gas introduced into the chamber 180 through the inlet valve 168a, for example. At the same time, combustion gas is
15 introduced into the chamber 194 and the combust gas is exhausted from the chamber 195 through the exhaust valve 170b, for example.

When the piston member 171 is pushed toward the chamber 180, the roller 176 guided between the plates
20 174 and 175 is also moved in the same direction and the lever member 203 is swung in the counterclockwise direction around the pin 204b of the roller 204a while the roller 204a is guided between the plate 204c and 204d in the longitudinal direction of the lever member 203,
25 thereby rotating the crankshaft 202 in the clockwise direction about the center rod 201.

As a result of this operation, the piston member

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171 goes to its lower dead point and the piston member 172 goes to its upper dead point where the introduced combustion gas is compressed in the chamber 180. When the compressed combustion gas is fired in the chamber 5 180 by an ignition plug (not shown), the piston member 172 is pushed toward the head cover 163 to rotate the lever member 203 in the clockwise direction about the movable fulcrum 204 to further rotate the crankshaft 202 in the clockwise direction as shown by an arrow A.

10 Thus, so-called explosion steps occur in the chambers 179, 180, 194 and 195 in the order mentioned and so-called four-cycle steps, i.e., inlet, compression, explosion and exhaust steps are performed at each of the chambers 179, 180, 194 and 195 to rotate the 15 crankshaft 202 continuously.

According to the embodiment of FIG. 22, it is possible to form a four-cylinder engine using two cylinders 161 and 162, thereby enabling to reduce the size, weight and volume of the reciprocating engine.

20 Further, since the piston motion is transmitted to the crankshaft using the movable fulcrum type lever member 203, no side thrust of the piston members 171, 172, 185 and 186 with respect to the inner wall of the cylinders 161 and 162 occur, thereby transmitting the 25 motion of the piston members very smoothly to decrease the energy loss. Accordingly, it is possible to decrease the idling speed from 1000 rpm to 50 rpm, for

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example. Further, since the lever members 203 and 205 can be formed to have the same length with each other, it is possible to design the distance from the axis of the cylinder 161 to the center of the crankshaft rod 201 to be equal to that between the axis of the cylinder 162 and the center of the rod 201 so as to minimize the vibration of the four-cycle reciprocating engine.

Further, since no side thrust occurs at the piston members 171, 172, 185 and 186 with respect to the inner wall of the cylinders 161 and 162, it is possible to form the piston members as ceramic pistons, thereby reducing the weight of the piston members as well as the total weight of the engine.

FIG. 23 shows a radial engine with 8 cylinders embodied in accordance with the present invention wherein two sets of the four-cylindere engine as shown in FIG. 22 are combined to form the 8-cylindere reciprocating engine. The 8-cylindere engine of FIG. 23 can be formed using four cylinders 161, 162, 261 and 262. The cylinders 161 and 162 have the same structure as those shown in FIG. 22. Therefore, explanations of the structure with respect to the cylinders 161 and 162, as well as those of the cylinders 361 and 362 can be omitted here except for the fact that the lever members 203 and 205 are connected to one crankshaft arm 202a and the lever members 403 and 405 are connected to another crankshaft arm 202b apart from the arm 202a by

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180 degrees with respect to the center of the crankshaft rod 201.

Now, operations of the 8-cylindereed reciprocating engine will be described. In FIG. 23, the piston member 5 171 is positioned at its lower dead point as a result of the explosion step in the combustion chamber 179 in the cylinder 161. In the same time, the piston member 185 is also positioned at its lower dead point as a result of the explosion step in the combustion chamber 194 in 10 the cylinder 162. At this time, the chambers 180 and 195 are in the last stage of the compression stroke, while, piston members 371, 372, 385 and 386 are at the mid position in the cylinders 361 and 362, respectively.

When the compressed fuel gas in the chambers 180 and 15 195 is ignited by ignition plugs (not shown), the lever members 203 and 205 are swung in the clockwise and counterclockwise directions, respectively, to rotate the crankshaft rod 201 in the direction shown by the arrow A. Accordingly, the lever members 403 and 405 rotate in 20 the clockwise and counterclockwise directions, respectively, thereby compressing the fuel gas in the chambers 380 and 395 and the fuel gas is inlet into the chambers 379 and 394, respectively.

According to the present embodiment of FIG. 23, all 25 the lever members 203, 205, 403 and 405 can be made identically so that whole structure of the 8-cylindereed engine can be formed symmetrically with respect to the

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crankshaft center rod 201, thereby further canceling the vibration in the engine.

As has been described above in detail, according to the embodiments using inner movable fulcrum type lever members, an apparatus for mutual conversion between circular motion and reciprocal motion can be provided, which can decrease an energy loss when converting the reciprocal motion of, e.g., the piston of a four-cycle reciprocating engine into rotary motion of the crankshaft, and which can be reduced in weight by using a ceramic as the material to form the apparatus.

The present invention can also be embodied using an outer movable fulcrum type lever member. The following embodiments are those using the outer movable fulcrum type lever member.

FIG. 24 is a cross-section showing the entire structure of still another embodiment of the present invention. This embodiment is a four-cycle engine having a structure in which a columnar piston 212 is provided in a cylinder 211 placed in a horizontally position, and vertically opposing wall surfaces 213 and 214 are formed in a notch portion in a central position of the piston 212. Cylinder heads 211A and 211B are respectively provided at both ends of the cylinder 211, and the cylinder 211 is equipped with an ignition plug and intake and exhaust valves which are not shown in the figure. Piston rings not shown are provided at both

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peripheral ends of the piston 212, thereby to ensure sealing between the inner wall of the cylinder and the piston.

5 A rotation roller 217 is inserted between the vertically opposite wall surfaces 213 and 214 and the roller 217 has a diameter substantially equal to the distance between the wall surfaces 213 and 214. The roller 217 is rotatably supported by an upper end of a lever member 218 which functions as a force point of
10 this member projecting downwardly from between the wall surfaces. The wall surfaces 213 and 214 function as a force point regulator for retaining the force point of the lever member 218 by the roller 217 such that the force point can freely oscillate in the clockwise and
15 counterclockwise directions.

The cylinder 211 is supported at its lower portion by a pair of support frames 215 and 216. Guide plates 219 and 220 are mounted on internally opposing wall surfaces 215 and 216 of these support frames 215 and 216
20 with spacers 215a and 216a inserted therebetween. A rotation roller 221 rotatably supported at a lower end of the lever member 218 is inserted between the guide plates 219 and 220. The lower end of the lever member 218 functions as a fulcrum and is supported between the
25 guide plates 219 and 220 such that the fulcrum can freely moves in the lengthwise direction of the lever member 218. Therefore, this fulcrum is referred to as

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a movable fulcrum and the guide plates 219 and 220 are referred to as movable fulcrum regulators.

A mid-point of the lever member 218 is rotatably connected as an action point with a crankshaft 222.

5 Therefore, when the upper end of the lever member 218 is driven in the right and the left, the lever member 218 is rotated around the center of the roller 221 as an outer fulcrum in the clockwise and counterclockwise directions. In this state, the rollers 217 and 221
10 respectively guide the lever member 218 in the length-wise direction thereof between the surfaces 213 and 214 and between the guide plates 219 and 220 as the crankshaft 222 rotates. As a result of this, the upper end of the lever member 218 is oscillated by reciprocal
15 linear motion of the piston 212 through the roller 217, and this reciprocal motion is converted by the crankshaft 222 into rotation motion with excellent smoothness.

Specifically, a side thrust to be generated between
20 the piston 212 and the inner wall of the cylinder 211 by the reciprocal motion of the piston 212 in the right and left is absorbed by rotation of each of the roller 217 and 221, and mechanical losses are extremely low.

In an engine according to this embodiment, it is
25 possible to maintain stable rotation at a lower speed of 100rpm or lower, while the crankshaft 222 need not be equipped with a counter balance or a flywheel.

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Therefore, energy losses are not involved during acceleration or deceleration if the engine is mounted on a car, and the axial output efficiency is thus remarkably improved.

5 FIGS. 25, 26, and 27 respectively show loci of the rotation center 217c of the rotation roller 217 as a force point of the lever member 218, the rotation center 221c of the rotation roller 221 as a fulcrum, and a connection point 222c of the crankshaft 222 as an action
10 point, in the embodiment of FIG. 24. FIGS. 25 and 27 show examples in which the ratio of the distance between the fulcrum 221c and the force point 217c to the distance between the fulcrum 221c and the action point 222c is 2:1. FIG. 26 shows an example in which the ratio of
15 the distance between the fulcrum 221c and the force point 217c to the distance between the fulcrum 221c and the action point 222c is 4:1. As seen from these views, the action point 222c moves tracing an absolute circle in accordance with an oblate circular movement of the
20 force point 217c, while the movable fulcrum 221c achieves linear reciprocal motion along the lengthwise direction of the lever member 218.

FIG. 28 is a graph in which a solid line shows a relationship between the piston displacement and the
25 engine rotation angle, in the embodiment shown in FIG. 24. This relationship forms an absolute or ideal sine curve. Therefore, the piston is in an ideal piston

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position at an ignition point during the combustion process from 0 to 180°, so that ignition is obtained with a combustion gas being sufficiently compressed, thereby generating a maximum combustion pressure. On the other hand, a rapid displacement of the piston 212 is prevented during the expansion process from 180°, so that the combustion pressure is transmitted to the piston 212 with the highest efficiency and is efficiently converted into a mechanical energy. This state is indicated by a continuous line in FIG. 29. This figure apparently shows that the maximum combustion pressure is generated since ignition is obtained with a combustion gas being sufficiently compressed in the present invention.

Next, specific explanation will be made to phases in which the piston 212 of the embodiment shown in FIG. 24 moves with displacements forming an absolute sine curve, with reference to FIG. 31.

FIG. 31 helps analyzation of operations of the piston 212, lever member 218, and the crankshaft 222 shown in FIG. 24. In FIG. 31, x denotes a displacement in the lengthwise direction of the lever member, y denotes a displacement within the cylinder 211 of the piston 212, $L1$ denotes distance between the action point 222c and the rotation center 221c of the rotation roller 21 as an movable fulcrum of the lever member 218, $L2$ denotes a distance between the force point 217c and the the action

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point 222c connected with the crankshaft 222, r denotes
 a rotation radius of the crankshaft 222, α denotes an
 angle between the lever member 218 and the crankshaft
 222, and θ denotes a rotation angle of the crankshaft
 5 222.

More specifically, the displacement y of the piston
 212 of the embodiment shown in FIG. 24 is expressed by
 the following equation:

$$y = L_1 \sin \alpha \quad \dots (2)$$

10 Here, the following equation exists:

$$r \sin \theta = (L_1 - L_2) \sin \alpha$$

Therefore, the following is obtained.

$$\sin \alpha = r(L_1 - L_2) \sin \theta \quad \dots (3)$$

The equation (2) is substituted into the equation (3) as
 15 follows:

$$y = L_1 \{r / (L_1 - L_2)\} \sin \theta$$

The displacement of the piston 212 is accordingly
 expressed as follows:

$$y = \{L_1 / (L_1 - L_2)\} r \sin \theta \quad \dots (4)$$

20 As is apparent from the equation (4), this equation
 is expressed only by linear terms of θ , and therefore,
 forms an absolute sine curve as indicated by the solid
 line in FIG. 28. Thus, the displacement of the piston
 212 is an ideal one so that a heat energy generated
 25 within the cylinder 211 is efficiently extracted there-
 from in form of a mechanical energy. Furthermore, if
 another engine which have the same structure as shows in

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FIG. 24 is connected to the crankshaft 222 with a phase difference of 180° , and two pistons are driven and displaced with the phase difference of 180° , maintained, both the vibrations generated by the pistons cancel each other and the engines can thus constitute a noiseless engine unit.

FIG. 32 is a table comparing the engine characteristics of 2000 CC of four-cylinder engines in each of which a lever member having an outer movable fulcrums constituted by application of the present invention is used as a power transmission mechanism from the piston to the crankshaft, with the engine characteristics of an engine using a conventional connecting rod and those of an engine using, as a power transmission mechanism, a lever member having an internal movable fulcrum according to the present invention. Note that data in the table are characteristics under condition where each engine has a stroke of 86 mm and a bore diameter of 86 mm and is operated at 3000 rpm. To simplify the following explanation, the engines with the above lever mechanisms members will be referred to as an internal movable fulcrum Z-mechanism engine and outer movable fulcrum Z-mechanism engines.

As is apparent from FIG. 32, an output loss due to side thrusts of pistons in a conventional engine reaches about 19% of the output power shown in the figure, while that of the internal movable fulcrum Z-engine is about

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8.6% which is reduced to about half of the output loss of the conventional engine. In the outer movable fulcrum Z-engine according to the present invention, the output loss is remarkably low, i.e., 2.7%. The

5 "indicated power output" means a workload decided by subtracting an exhaust loss and a heat loss from a combustion output. In the inner and outer movable fulcrum Z-engines of the present invention, since the displacement of the force point by which the piston is

10 driven to move is small while the piston is moving, the moment by which the piston is rotated is small and the friction coefficient is small so that the side thrust is reduced to be extremely small.

As is also apparent from the top column of FIG. 32,

15 the indicated power output of the conventional engine is smaller than those of the internal and outer movable fulcrum Z-mechanical engines, because of "a late raise and an early fall" of the piston which has been explained beforehand.

20 A side thrust workload means a balance between respective pistons, and is obtained by firstly a side thrust force by integration from 0 to 720°, and by then multiplying the side thrust force by a friction coefficient. Conditions are determined as follows:

25 Friction coefficients:

conventional engine	0.366
internal movable fulcrum Z-engine ...	0.340

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outer movable fulcrum Z-engine 0.166

The friction coefficients are determined on the basis of a mechanical engineering handbook. Although these friction coefficients vary depending on surface pressures of pistons, the above coefficients are determined since a piston normally presses a cylinder with an average pressure of about 30.2 kg/cm² in a conventional engine, with an average pressure of about 18.9 kg/cm² in an internal movable fulcrum Z-engine, and with an average pressure of about 7.1 kg/cm² in an outer movable fulcrum Z-engine.

Also, a conventional engine causes a loss of total 2% or so due to use of a flywheel and a counter-weight as has been explained beforehand, while an engine using a movable fulcrum lever member as a moving power transmission mechanism involves no loss.

In a conventional engine, an indicated workload is normally said to be about 38% of the total heat generation workload of a fuel. This is evaluated as 80.17PS from calculation. An effective workload (i.e., an axial workload) is obtained by subtracting a mechanical loss from the indicated workload. Where the workload due to a side thrust is estimated to be 85% of a mechanical loss, the mechanical loss is 17.25PS. This mechanical loss is subtracted from the indicated workload, thereby obtaining an effective workload of 62.7PS from calculation. Calculation is made supposing that the

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mechanical loss of an outer movable fulcrum Z-mechanism engine excluding a side thrust workload is equal to that of a conventional engine.

A side thrust loss output (J) is especially remarkable in FIG. 32. This output is 66.0 in the present invention which is apparently reduced by 15% in comparison with a conventional engine. In comparison with an internal movable fulcrum Z-mechanism engine according to the preceding invention, the side thrust output loss is reduced to about 1/3. Although various attempts have been made to reduce side thrusts in the history of developments of engines, none of those attempts reaches a remarkable reduction as in the present invention.

As a result, output increasing ratios of effective outputs are 1.17 in the internal movable fulcrum Z-mechanism engine using a lever member according to the preceding invention and 1.23 in the outer movable fulcrum Z-mechanism engine using a lever member having an outer movable fulcrum of the present invention, with respect to the effective output of a conventional engine as a reference of 1.00. Thus, the embodiment using the outer movable fulcrum achieves an increase of 23% compared with a conventional engine.

Further, the weight of an outer movable fulcrum Z-mechanism engine according to the present invention is estimated as 111.8 kgf, where this engine is a 2000 cc

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four-cylinder engine. On the other hand, a conventional engine has a weight of 149.0 kgf. Therefore, the weight is reduced by 33.0%. The engine of the present invention has a schematic size of 685.0 mm × 610.0 mm × 615.0 mm which is much more compact than that of the conventional engine of 450 mm × 550.0 mm × 420.0 mm.

The outer movable fulcrum Z-mechanism engine according to the present invention attains an output (per weight) of 1.47 PS/kgf at a rotation speed of 6500 rpm, while the conventional engine attains an output (per weight) of only 0.97 PS/kgf at a rotation speed of 6500 rpm.

In addition, the apparatus according to the embodiment shown in FIG. 24 is a reversible engine, and can be used as a pump for compressing and feeding a liquid or a gas if an electric motor not shown is connected with the crankshaft 222 so as to rotate and drive this crankshaft thereby reciprocally moving the piston 212 within the cylinder 211.

In this case, a side thrust generated in accordance with reciprocal motion of the piston 212 is absorbed as rotations of rollers 217 and 221, and these components cause extremely low mechanical losses.

FIGS. 33, 34, and 35 are views schematically showing the structure of an embodiment in which the present invention is adopted to a two-cycle engine, and are cross-sections in a front view, a top view, and

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a side view, respectively. In FIGS. 33 to 35, an inlet port 231 and an outlet port 232 are provided at an upper portion of a cylinder 230 of a two-cycle engine. A cylinder head 233 is provided at a top end of the cylinder 230. The inlet port 230 is connected to a carburetor 231a secured to an engine block 241 through a crank chamber 241A formed in the engine block 241. Lubrication oil is supplied to a piston 234 and a lever member 238 together with petrol, by injecting a mixed gas of petrol and lubrication oil from the carburetor 231a.

A piston 234 is inserted in the cylinder 230. This piston 234 is provided with a notch portion 236 in which guide walls 235a and 235b are formed so as to extend in a direction perpendicular to the center axis of the piston 234. A rotation roller 237 is inserted between the guide walls 235a and 235b in a direction perpendicular to the center axis of the piston 234 such that the rotation roller 237 is rotatable, and this rotation roller 237 is rotatably secured to a force point 239 of the lever member 238. These guide walls 235a and 235b together with the rotation roller 237 function as a movable force point regulator.

Another end of the lever member 238 is a movable fulcrum 240 to which a rotation shaft of a rotation roller 243 is secured, and the rotation roller 243 is rotatably inserted between guide plates 242a and 242b

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fixed to the engine block 241. These guide plates 242a and 242b together with the rotation roller 243 function as a movable fulcrum regulator.

5 A pin 244 used as an action point is fixed between the force point 239 and the support point 240 of the lever member 238. The pin 244 is engaged with an eccentric disc 246 which has a crank hole formed to be deviated from a rotation main shaft 245.

10 The piston 234 is provided in a cylinder 230 and moves up and down along the inner wall of the cylinder 230. A ring is provided on a circumference of the piston 234, thereby to ensure sealing with respect to fuel gas and oil.

15 In the embodiment shown in FIGS. 33 to 35, the lever member 238 is supported by an outer movable fulcrum regulator having the same structure as in the embodiment shown in FIG. 24, and the action point of the lever member 238 is rotatably connected to the crank hole of the eccentric disc 246 by the pin 244.

20 More specifically, in the two-cycle engine of this embodiment, when a mixed gas taken in and compressed by the carburetor 231a is ignited by an ignition plug not shown in the vicinity of a top dead point in the intake and compression process, the fired mixed gas expands
25 thereby pressing down the piston 234. This motion of the piston 234 is transmitted through the roller 237 to a lever member 238 having an outer movable fulcrum, and

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is then transmitted through the pin 244 to the eccentric disc 246 which converts the reciprocal motion into rotary motion and transmits the motion to the rotation main shaft 245.

5 In the embodiment of FIGS. 33 to 35, when the piston 234 is pressed against the inner wall of the cylinder 230 by an expansion pressure, the piston 234 does not generate a thrust force to the cylinder 230, which will otherwise be caused by a reaction from the
10 lever member 238, since the piston 234 and the lever member 238 are connected with each other by the movable force point regulator consisting of the guide walls 235a and 235b and the rotation roller 237. As a result, an energy loss caused by a side thrust is greatly reduced
15 in comparison with a conventional engine. In the same way, the movable fulcrum of the lever member 238 is supported by the guide plates 242a and 242b and the rotation roller 243 which are combined together to operate as a movable fulcrum regulator. Therefore,
20 reciprocal motion of the piston 234 is converted into rotary motion with less losses.

 In this case, since the piston 234 is not pressed against the cylinder 230 with a strong pressure, the main part of the piston 234 may be formed of ceramics.
25 Further, since the side thrust is small, energy losses are reduced so that the idling speed can be set to 50 rpm or less which leads to advantages in view of fuel

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consumption.

If a reciprocating engine can thus be formed of ceramics, the cylinder 230 can be set to a value two or three times higher than a conventional engine. Although it is known that a conventional reciprocating engine attains only a heat efficiency of 20%, this embodiment can lead to a great reduction in mechanical loss. For example, supposing that a mechanical loss is recovered by 10%, a high heat efficiency of 50% or more can be attained if the remaining heat loss of 70% is reduced to one third, i.e., 10% plus 70/3% plus 20%.

FIGS. 36, 37, and 38 show an embodiment which uses a cylinder 230 and a piston 234 common to the embodiment of FIGS. 33 to 35 and is provided with lever members 238A and 238B with the piston 234 being inserted therebetween. Therefore, those components of FIGS. 36 to 38 which correspond to the components of embodiment shown in FIGS. 33 to 35 are referred to by common reference numerals, and explanation of those components will be omitted or only briefly made in the following.

In the embodiment shown in FIGS. 36 to 38, one or both of the rotation main shafts 245A and 245B are rotated so that, for example, the piston 234 moves in the cylinder 230 to the vicinity of the top end shown in the figure whereby a mixed gas is compressed. In this state, when the mixed gas is ignited by an ignition plug not shown, the piston is pressed in the downward

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direction in the figures and the lever members 238A and 238B are respectively rotated in the clockwise and counter clockwise directions by the rotation rollers 237A and 237B of force point regulators, with components 242aA, 242bA, and 243A as well as components 242aB, 242bB, and 243B being positioned as movable fulcrums. The components 242aA, 242bA and 243A constitute a movable fulcrum regulator while the components 242aB, 242bB and 243B also constitute another movable fulcrum regulator. As the lever members 238A and 238B are rotated in the directions as stated above, the rotation main shafts 245A and 245B are respectively rotated in the counterclockwise and clockwise directions by pins 244A and 244B. As a result, the piston 234 moves in the cylinder 230 to the vicinity of the bottom end in the figures, whereby exhausting process is completed and a primary compression of an intake gas is simultaneously carried out in the crank chamber 241A. While this process is repeatedly performed, the two-cycle engine comes to maintain continuous rotation by itself without help of a starter motor. Consequently, two outputs in form of rotation in opposite directions can be obtained simultaneously through two rotation main shafts 245A and 245B, from one single cylinder 230 and one single piston 234.

FIG. 39 shows an embodiment of a four-cycle engine of a horizontal coaxial type in which cylinder heads

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251A and 251B are respectively provided at both ends of one cylinder 250 placed in a horizontal position such that the heads 251A and 251B face each other, and in which one single piston 252 is driven to reciprocate
5 between the cylinder heads 251A and 251B. In FIG. 39, two rotation rollers 254A and 254B are inserted between a pair of guide plates 253A and 253B provided in the piston 252 which is inserted in the cylinder 250. These rollers 254A and 254B are respectively secured to the
10 ends of lever members 256A and 256B which function as force points.

The lever member 256A has another end which is supported by a movable fulcrum regulator consisting of a rotation roller 258A inserted between a pair of guide
15 members 257A and of a pin 259A connecting the lever member and the roller. The lever member 256A is connected at its mid-point with a crankshaft 261A by a pin 260A.

The lever member 256B has another end which is supported by a movable fulcrum regulator consisting of a
20 rotation roller 258B inserted between a pair of guide members 257B and of a pin 260B connecting the lever member and the roller. The lever member 256B is connected at its mid-point with a crankshaft 261B by a pin
25 260B.

The crankshafts 261A and 261b connected to the lever members 256A and 256b contained in the crank

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chamber 269 are connected with a camshaft, for example, through a belt and a roller not shown, thereby to drive a cam installed on the camshaft. This cam drives intake valves 262A and 262B as well as exhaust valves 263A and 263B provided on the cylinder heads 251A and 251B, respectively, at predetermined timings, thereby to achieve four processes of a four-cycle engine, i.e., expansion, exhausting, intake, and compression. As a result, horizontal synchronized reverse rotation twin outputs are obtained from the crankshafts 261A and 261B, as indicated by arrows in FIG. 39.

The engine shown in FIG. 39 is basically the same as that shown in FIG. 33, and therefore, explanation to operation of the engine of FIG. 39 will be omitted here. However, the engine of FIG. 39 can be rotated at a higher speed if a structure similar to the lever members 256A and 256B respectively provided between the piston 252 and the crankshafts 261A and 261B is used as drive mechanisms for intake valves 262A and 262B as well as the exhaust valves 263A and 263B.

FIG. 40 shows an embodiment having a structure which is substantially the same as that of the embodiment shown in FIG. 39. However, the embodiment of FIG. 40 adopts a lay-out which is much more suitable for practical production and is also more compact than that of FIG. 39. Further, the embodiment of FIG. 40 differs from that of FIG. 39 in that FIG. 40 reveals ignition

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plugs 264A and 264B (not shown in FIG. 39), that cams
265A, 266A, 265B and 266B for driving valves are
included, and that exhaust ports 267A and 267B as well
as intake ports 268A and 268B are specifically
5 illustrated. The other components of FIG. 40 will be
referred to by the same references as those in FIG. 39,
and explanation thereof will be omitted here.

FIGS. 41 and 42 show an embodiment in which the
basic structure of the embodiment shown in FIG. 24 is
10 used in two sets thereby to extract outputs from two
pistons combined by one single crankshaft. Those
components of FIGS. 41 and 42 which correspond to the
components of FIG. 24 are referred to by the same or
similar reference numerals.

15 In FIG. 41, two cylinders 211A and 211B having an
equal inner diameter and extending in the horizontal
direction are formed in a cylinder block 272 surrounded
by heat radiating fins 271. FIG. 42 is a view cut along
line 42-42 of FIG. 41 showing an engine including a
20 cylinder 211A having a structure corresponding to that
of FIG. 24. The other cylinder 211B also has the same
structure.

A piston 212A is inserted in the cylinder 211A, and
a pair of roller guide plates 213A and 214A are provided
25 in an opening portion 273 open in a center portion of
the piston 212A toward a downward direction, such that
the plates 213A and 214A are fixed to the body of the

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piston 212A by, screws with a predetermined distance maintained between the plates. A rotation roller 217A is inserted between the roller guide plates 213A and 214A, and the roller 217A is rotatably installed on a
5 force point of a lever member by a pin 217CA. A roller 221A is installed on a pin 221CA which serves as a fulcrum for the lever member 218A. The roller 221A is retained between a pair of guide plates 219A and 220A installed on the cylinder block 272 such that the plates
10 project into the crank chamber 274 formed in a lower portion of the cylinder block 272. The roller 221A and the pair of guide plates 219A and 220A constitute a movable fulcrum regulator.

A round hole 222CA which functions as an action
15 point is formed in a mid-point of the lever member 218A, and a crank pin 275A of a crankshaft 275 is engaged in the action point hole 222CA. Another crank pin 275B is also formed on the crankshaft 275, and is engaged in an action point hole 222CB formed in a lever member 218B
20 provided in conjunction with another cylinder 211B.

The crankshaft 275 penetrates through walls of the cylinder block 272 which are facing each other and forming the crank chamber 274 and is thereby supported. A projecting shaft of the crankshaft is used as a rotation
25 main shaft 277 for extracting an output and another projecting shaft thereof is connected to a camshaft not shown and a drive gear 282 of a starter motor through

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a belt 279 and a pulley 280 as connecting components, thereby to drive a cam installed on the camshaft. This cam drives intake and exhaust valves provided on the cylinder head at predetermined timings, thereby to prosecute four processes of a four-cycle engine, i.e., expansion, exhausting, intake, and compression.

FIG. 43 is a perspective view schematically showing an embodiment which uses two basic structures each corresponding to the basic structure shown in FIG. 40 to obtain three rotation outputs. Therefore, those components which are common to those of FIG. 40 are referred to by the same reference numerals and detailed explanation of those components will be omitted in the following.

In this figure, a twin coaxial piston 252A is inserted in a first cylinder 250A, and the output of the piston 252A is extracted from lever members 256B1 and 256A1 through two movable force point rollers 254B1 and 254A1. A fulcrum at another end of the lever member 256B1 is supported by a pair of guide plates 257B1 and a roller 258B1 which constitute a movable fulcrum regulator, such that this fulcrum can freely move between the guide plates 258B1. Therefore, the rotation torque of the lever member 256B1 is converted into rotation of a crankshaft 260B1, and is extracted as a first rotation output indicated by an arrow.

A fulcrum at another end of the lever member 256A1

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is supported by a pair of guide plates 257A1 and a roller 258A1 which constitute a movable fulcrum regulator, such that this fulcrum can freely move between the guide plates 257A1. Therefore, the rotation torque of the lever member 256A1 is converted into
5 rotation of a crankshaft 260A1, and is extracted as a second rotation output in the direction opposite to the first rotation, indicated by another arrow.

Another twin coaxial piston 252B is inserted in a
10 second cylinder 250A, and the output of the piston 252B is extracted from lever members 256B2 and 256A2 through two movable force point rollers 254B2 and 254A2. Note that the twin coaxial pistons 252A and 252B have driving phases opposite to each other and are driven such that,
15 fore example, when the piston 252A is at a top dead point, the piston 252B is at a bottom dead point. A support point at another end of the lever member 256B2 is supported by a pair of guide plates 257B2 and a roller 258B2 which constitute a movable fulcrum
20 regulator, such that this fulcrum can freely move. Therefore, the rotation torque of the lever member 256B2 is converted into rotation of a crankshaft 260B2. Since this crankshaft 260B2 is formed to be integral with the crankshaft 260A1 such that these two crankshaft main-
25 tains a phase difference of 180°, outputs from these two crankshafts are extracted and united together as the second rotation output indicated by the arrow.

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A fulcrum at another end of the lever member 256A2 is supported by a pair of guide plates 257A2 and a roller 258A2 which constitute a movable fulcrum regulator, such that this fulcrum can freely oscillate.

5 Therefore, the rotation torque of the lever member 256A2 is converted into rotation of a crankshaft 260A2, and is extracted as a third rotation output indicated by another arrow of the same direction as the arrow of the first rotation output.

10 The above embodiments are examples in which reciprocal motion of a piston is transmitted to a crank device through a lever device of a movable outer fulcrum type and is then extracted as a rotary motion from an action point at a mid-point of the lever member. If the
15 lever member of this lever device is extended from the position of the movable outer fulcrum and a movable action point regulator consisting of a pair of guide plates and a roller is formed on the top end of the extended lever member such that, for example, a piston
20 of a pump is reciprocated by the action point regulator, mechanical outputs of two different types can be extracted from one engine.

FIG. 44 is a view schematically showing the structure of an example of such an engine as stated
25 above. Reciprocal motion of a piston 291 inserted in a cylinder 290 having the same structure as in FIG. 24 is transmitted to a lever member 293 through a force point

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regulator consisting of guide plates 291A and 291B and a roller 292, and is then converted into rotary motion of a crankshaft 295 connected to an action point 294.

Another end of the lever member 293 is supported by a movable fulcrum regulator consisting of a pair of guide plates 296A and 296B and a roller 297. This end of the lever member 293 is further extended, and a roller 298 is rotatably secured to the extended end of the lever member 293. This roller 298 is inserted between a guide plates 299A and 299B, thereby functioning as an action point regulator. The pair of guide plates 299A and 299B are formed to be integral with each other and are used as a piston which reciprocates within a cylinder 300. This structure therefore can be used as a pump, for example.

In this structure, reciprocal motion of the piston 291 is transmitted to a crank device 295 through the lever device 293 of a movable outer fulcrum type and is then extracted as rotary motion from the support point 294 at a mid-point of the lever member 293. Further, a movable action point regulator consisting of a pair of guide plates and a roller is formed on the extended top end of the lever member such that a piston of a pump is reciprocated by the action point regulator. Therefore, mechanical outputs of two different types can be extracted from one engine.

In the embodiment of FIG. 41, reciprocal motion of

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two pistons respectively inserted in two cylinders arranged in parallel with each other is transmitted through lever devices of a movable outer fulcrum type to crank pins which have different rotation phases and are connected with one single crankshaft, thereby to extract one single output. However, two cylinders may be arranged apart from each other and one single output may be extracted from between the cylinders in a manner different from the embodiment of FIG. 41.

FIG. 45 shows an example of such a different manner. Piston 303 and 304 inserted in two cylinders 301 and 302 have a pair of guide plates 305 and 305 and a pair of guide plates 306A and 306B, respectively. A roller 307 is inserted between the guide plates 305A and 305B, and this roller 307 is rotatably secured to a force point of a first lever member 308. A roller 309 is inserted between the guide plates 306A and 306B, and this roller 309 is rotatably secured to a force point of a second lever member 310.

Rollers 311 and 312 are respectively secured to support points of other ends of the lever members 308 and 310. These rollers 311 and 312 are respectively inserted between a pair of guide plates 313A and 313B and between a pair of guide plates 314A and 314B, and are thereby supported.

In FIG. 45, when the pistons 303 and 304 are pressed downwardly in the cylinders 301 and 302 by

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expansion of a combustion gas, the motion of these pistons are transmitted to the lever members through movable force point regulators consisting of guide plates 305A, 305B, 306A, and 306B and rollers 307 and 309. Since support points of the lever members 308 and 310 are respectively supported by movable outer fulcrum regulators consisting of the roller 311 and the pair of guide plates 313A and 313B as well as the pair of guide plates 314A and 314B, linear motion of the pistons 303 and 304 are smoothly converted into rotary motion of a crank pin 316 of a crankshaft 315.

All of the above embodiments relate to an apparatus for conversion between rotary motion and linear reciprocal motion. The present invention, however, may apply to an apparatus for directly converting rotary motion into a reciprocal motion of a lever member, as explained in the following embodiment.

FIG. 46 shows an example of the apparatus. In this figure, rotation shafts 320 and 321 are respectively connected to an electric motor through power transmission mechanisms not shown and are thereby driven to rotate. The rotation shafts 320 and 321 have ends rotatably connected by arms 322 and 323 to lever members 324 and 325 at positions apart by a predetermined distance from ends of these lever members. Other ends of the rotation shafts 320 and 321 are rotatably connected through arms to lever members 326 and 327 at positions

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apart by a predetermined distance from ends of these lever members.

Rollers 328 and 329 are rotatably secured at ends of the lever members 324 and 325, thereby to constitute movable fulcrums. The roller 328 is rotatably and movably supported between two parallel guide plates 330A and 330B, while the roller 329 is rotatably and movably supported between two parallel guide plates 331A and 331B. All of these components are contained in a casing 332 of a rectangular parallelepiped except for lever members 324 and 325. Components relevant to the other lever members 326 and 327 are also contained in the casing 332. In addition, the lever members 324, 325, 326, and 327 are formed like a flying object, e.g., wings of a dragonfly.

In this structure, when rotation shafts 320 and 321 are rotated by supplying a power to an electric motor not shown, the lever members 324 and 325 are reciprocally rotated around the axes of the rollers 328 and 329 shafts as centers of rotations. Since the rollers 328 and 329 are rotatably and movably supported between the guide plates 330A and 330B as well as 331A and 331B, rotations of the rotation shafts 320 and 321 are smoothly converted into reciprocal motion of the lever members 324 and 325. The angle of the reciprocal rotation of the lever members can be changed in accordance with a distance between from the force points to the

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movable fulcrum rollers 328 and 329 as well as the sizes of arms 322 and 323, so that the angle of flapping motion of wings 324 and 325 as the lever members can be changed. The other pair of wings 326 and 27 can be
5 driven in the same manner.

As has been described above, according to the present invention, it is possible to provide an apparatus for conversion between rotary motion and reciprocal motion which enables reduction in energy losses when
10 reciprocal motion of a piston of a two- or four-cycle engine, for example, is converted into rotary motion, reduction in size and/or weight of the engine, and further reduction in weight by forming the engine with ceramics.



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1. An apparatus for mutual conversion between circular motion and reciprocal motion, comprising:

5 a lever member having a fulcrum as well as an action point and a force point one of which is rotatably mounted at a point on a line connecting a rotational center and a circumference of a rotary body, the action point or force point being provided with a first regulator and the fulcrum being provided with a second
10 regulator for functioning the fulcrum as a movable fulcrum,

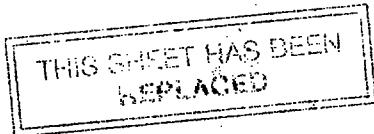
wherein the first regulator is coupled to a reciprocating body, and the first and second regulators include support members for supporting one of the force
15 point or action point and the fulcrum to be movable in a longitudinal direction of the lever member.

2. An apparatus for mutual conversion between circular motion and reciprocal motion, comprising:

a rotary body;
20 a lever member having a fulcrum as well as an action point and a force point one of which is rotatably mounted at a point on a line connecting a rotational center and a circumference of the rotary body, one of the action point and the force point being provided with
25 a first regulator and the fulcrum being provided with a second regulator for functioning the fulcrum as a movable fulcrum; and

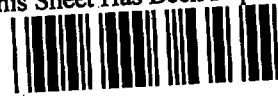


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a reciprocating body to which one of the action point and the force point provided with the first regulator is coupled;

5 wherein the first and second regulators include support members for supporting one of the force and action points and the fulcrum to be movable in a longitudinal direction of the lever member.

3. An apparatus for mutual conversion between circular motion and reciprocal motion, comprising:

10 a rotary body;

a lever member having a fulcrum as well as a force point and an action point which is rotatably mounted at a point on a line connecting a rotational center and a circumference of a rotary body, the force point being provided with a first regulator and the fulcrum being
15 provided with a second regulator for functioning the fulcrum as a movable fulcrum; and

a reciprocating motor to which the force point provided with the first regulator is coupled;

20 wherein the first and second regulators include support members for supporting the force point and the fulcrum to be movable in a longitudinal direction of the lever member.

4. An apparatus for mutual conversion between
25 circular motion and reciprocal motion, comprising:

a rotary motor; and

a lever member having a fulcrum as well as a force



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point and an action point which is rotatably mounted at
a point on a line connecting a rotational center and a
circumference of a rotary motor, the action point being
provided with a first regulator and the fulcrum being
5 provided with a second regulator for functioning the
fulcrum as a movable fulcrum, and the action point
provided with the first regulator being coupled to a
reciprocating body of a reciprocated machine;

wherein the first and second regulators include
10 support members for supporting action point and the
fulcrum to be movable in a longitudinal direction of the
lever member.

5. An apparatus for mutual conversion between
circular motion and reciprocal motion, comprising:

15 a rotary body; and

a lever member having a fulcrum as well as a force
point and an action point which is rotatably mounted at
a point on a line connecting a rotational center and a
circumference of the rotary body, the force point being
20 provided with a first regulator and the fulcrum being
provided with a second regulator for functioning the
fulcrum as a movable fulcrum;

wherein the force point provided with the first
regulator is coupled to a piston of a reciprocating
25 motor, the piston is movably mounted in a cylinder, the
cylinder has inlet and exhaust units of a power gas at
each of two ends thereof, and the first and second



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regulators have support members for supporting the force point and the fulcrum to be movable in a longitudinal direction of the lever member.

6. An apparatus for mutual conversion between
5 circular motion and reciprocal motion, comprising:

a rotary body; and

a lever member having a fulcrum as well as a force point and an action point which is rotatably mounted at a point on a line connecting a rotational center and a
10 circumference of the rotary body, the force point being provided with a first regulator and the fulcrum being provided with a second regulator for functioning the fulcrum as a movable fulcrum;

wherein the force point provided with the first
15 regulator is coupled to a piston of a reciprocating motor, the piston is movably mounted in a cylinder, the cylinder has inlet and exhaust units of a fuel gas and an ignition unit at each of two ends thereof, and the first and second regulators have support members for
20 supporting the force point and the fulcrum to be movable in a longitudinal direction of the lever member.

7. An apparatus according to claim 6, wherein said inlet and exhaust units have valves for opening/closing inlet and exhaust holes of said cylinder, operating arms
25 coupled to said valves, and driving units for driving said vales through said operating arms, said operating arms have force point regulators coupled to said driving



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units, action point regulators coupled to said valves,
and movable fulcrum regulators, and said force point and
movable fulcrum regulators have support members for
supporting the force point and the movable fulcrum to be
5 movable in a longitudinal direction of said operating
arms.

8. A radial engine including a plurality of basic
engine units radially arranged around an output axle,
each of the units being provided for mutual conversion
10 between circular motion and reciprocal motion, each of
said basic engine units comprising:

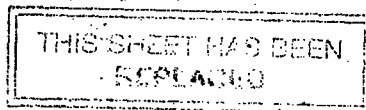
a rotary body connected to the output axle;

a reciprocating motor including a cylinder having
first and second end portions each of which has inlet
15 and exhaust units of a fuel gas and an ignition unit,
and a piston body having two piston members inserted in
the cylinder to face with the first and second end
portions; and

a lever member having a fulcrum as well as a force
20 point and an action point which is rotatably mounted at
a point on a line connecting a rotational center and a
circumference of the rotary body, the force point being
provided with a first regulator and the fulcrum being
provided with a second regulator for functioning the
25 fulcrum as a movable fulcrum;

wherein the force point provided with the first
regulator is coupled to said piston body of the





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reciprocating motor, the piston body is movably mounted in said cylinder, and the first and second regulators have support members for supporting the force point and the fulcrum to be movable in a longitudinal direction of the lever member.

9. An apparatus for mutual conversion between circular motion and reciprocal motion comprising a lever member having a first regulator provided at an end of the lever member for functioning as a force point or an action point, a second regulator provided at another end of the lever member for functioning as a movable fulcrum, and a portion between both of the ends functioning as an action point or a force point rotatably and axially secured at a point on a line connecting a rotation center of a rotary member and a circumference of the rotary member, wherein

a reciprocal motion member is connected with the first regulator, and the first and second regulators have a support member for movably supporting the force or action points and the movable fulcrum such that the force or action points and the movable fulcrum are movable in a lengthwise direction of the lever member.

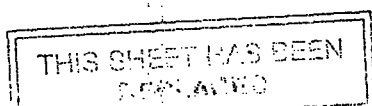
10. An apparatus for mutual conversion between circular motion and reciprocal motion comprising:

a rotary member; and

a lever member having a first regulator provided at an end of the lever member for functioning as a force

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point or an action point, a second regulator provided at another end of the lever member for functioning as a movable fulcrum, and a portion between both of the ends functioning as an action point or a force point rotatably and axially secured at a point on a line connecting a rotation center of the rotary member and a circumference of the rotary member, wherein

the first and second regulators have support members for movably supporting the force or action points and the movable fulcrum such that the force or action points and the movable fulcrum are movable in a lengthwise direction of the lever member.

11. An apparatus for mutual conversion between circular motion and reciprocal motion comprising:

15 a rotary member;

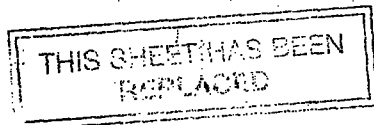
a lever member having a first regulator provided at an end of the lever member for functioning as a force point or an action point, a second regulator provided at another end of the lever member for functioning as a movable fulcrum, and a portion between both of the ends functioning as an action point or a force point rotatably and axially secured at a point on a line connecting a rotation center of the rotary member and a circumference of the rotary member; and

25 a reciprocal motor connected with the first regulator, wherein

the first and second regulators have support

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members for movably supporting the force or action points and the movable fulcrum such that the force or action points and the movable fulcrum are movable in a lengthwise direction of the lever member.

- 5 12. An apparatus for mutual conversion between circular motion and reciprocal motion comprising:

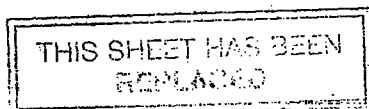
 a lever member having a first regulator provided at an end of the lever member for functioning as an action point, a second regulator provided at another end of the lever member for functioning as a movable fulcrum, and a
10 portion between both of the ends functioning as a force point rotatably and axially secured at a point on a line connecting a rotation center of a rotary member and a circumference of the rotary member; and

- 15 a rotary motor having an output shaft connected with the force point, wherein

 the first regulator is connected with a reciprocal motion member, and the first and second regulators have support members for movably supporting the force or
20 action points and the movable fulcrum such that the force or action points and the movable fulcrum are movable in a lengthwise direction of the lever member.

13. An apparatus for mutual conversion between circular motion and reciprocal motion comprising a
25 rotary member and a lever member having a first regulator provided at an end of the lever member for functioning as a force point, a second regulator provided at





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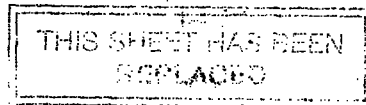
another end of the lever member for functioning as a movable fulcrum, and a middle point between both of the ends functioning as an action point rotatably and axially secured on a line connecting a rotation center of the rotary member and a circumference of the rotary member, wherein

the first regulator is connected with a piston of a reciprocal motion motor, the piston is movably mounted in a cylinder, the cylinder has ends respectively provided with an intake/exhaust device for taking in/exhausting a power gas, and the first and second regulators have support members for movably supporting the force point and the movable fulcrum such that the force point and the movable fulcrum are movable in a lengthwise direction of the lever member.

14. An apparatus for mutual conversion between circular motion and reciprocal motion comprising a rotary member and a lever member having a middle point for functioning as an action point rotatably and axially secured on a line connecting a rotation center of the rotary member and a circumference of the rotary member, a first regulator provided at an end of the lever member for functioning as an action point, and a second regulator provided at another end of the lever member for functioning as a movable fulcrum, wherein

the first regulator is connected with a piston of a reciprocal motion member, the piston is movably mounted





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in a cylinder, the cylinder have ends respectively provided with an intake/exhaust device for taking in/exhausting a fuel gas and an ignition device, and the first and second regulators have support members for movably supporting the action point and the movable fulcrum such that the action point and the movable fulcrum are movable in a lengthwise direction of the lever member.

15. An apparatus for mutual conversion between circular motion and reciprocal motion, according to claim 14, wherein the intake/exhaust device comprises valves for opening/closing inlet and outlet ports of a cylinder, an action arm connected to the valves, and a drive device for driving the valves through the action arm, the action arm has a force point regulator connected to the driving device, an action point regulator and a movable fulcrum regulator both connected to the valves, and the force point regulator and the movable fulcrum regulator have support members for movably supporting the force point and the movable fulcrum in a lengthwise direction of the lever member.

16. An apparatus for mutual conversion between circular motion and reciprocal motion comprising:
a reciprocal motion motor having a cylinder, a piston movably inserted in the cylinder, intake and exhaust devices for taking in and exhausting a fuel gas provided at both ends of the cylinder, and an ignition

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device;

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a plurality of rotary members; and

a plurality of lever members each having a mid-point functioning as an action point rotatably secured on a line connecting a rotation center and a circumference of each of the rotary members with each other, a first regulator provided at an end of the lever member for functioning as a force point, and a second regulator provided at another end of the lever member for functioning as a movable fulcrum, wherein

the first regulators are connected to the piston of the reciprocal motion motor such that the first regulators are arranged symmetrical to each other.

17. An apparatus for mutual conversion between circular motion and reciprocal motion comprising:

first and second reciprocal motion motors each having a cylinder, a piston movably inserted in the cylinder, intake and exhaust devices for taking in and exhausting a fuel gas provided at both ends of the cylinder, and an ignition device;

first, second, and third rotary members;

first lever member having a mid-point functioning as an action point rotatably secured on a line connecting a rotation center and a circumference of the first rotary member, a first regulator provided at an end of the lever member for functioning as a force point, and a second regulator provided at another end of the lever

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member for functioning as a movable fulcrum;

second lever member having a mid-point functioning
as an action point rotatably secured on a line connect-
ing a rotation center and a circumference of the second
5 rotary member, a first regulator provided at an end of
the lever member for functioning as a force point, and a
second regulator provided at another end of the lever
member for functioning as a movable fulcrum; and

third and fourth lever members each having a
10 mid-point functioning as an action point rotatably
secured on a line connecting a rotation center and a
circumference of the third rotary member, a first
regulator provided at an end of the lever member for
functioning as a force point, and a second regulator
15 provided at another end of the lever member for func-
tioning as a movable fulcrum, wherein

the first regulators of the third and fourth lever
members are respectively connected to the pistons of the
first and second reciprocal motion motors such that the
20 first regulators are arranged symmetrical to each other,
that the first regulators of the first and second lever
members are respectively connected to the pistons of the
first and second reciprocal motion motors, and that the
first and second rotary members are rotated in a reverse
25 direction in synchronization with the third rotary
member.

18. An apparatus for mutual conversion between

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circular motion and reciprocal motion comprising:

a rotary member; and

a lever member having a first regulator provided at
an end of the lever member for functioning as a force
point, a second regulator provided at another end of the
5 lever member for functioning as a movable fulcrum, and a
middle point between both of the ends functioning as an
action point rotatably and axially secured on a line
connecting a rotation center of the rotary member and a
10 circumference, wherein

the first regulator is connected with a piston of a
reciprocal motion motor, the piston is movably mounted
in a cylinder, the cylinder has ends respectively
provided with an intake/exhaust device for taking
15 in/exhausting a power gas, the first and second regula-
tors have a support member for movably supporting the
force point and the movable fulcrum such that the force
point and the movable fulcrum are movable in a length-
wise direction of the lever member, and the lever member
20 has a third regulator functioning as an action point on
a line extended from the end functioning as the movable
fulcrum, said third regulator being connected to a
reciprocal motion member of a reciprocal motion motor.

19. An apparatus for mutual conversion between
25 circular motion and reciprocal motion comprising a
rotary member and a lever member having a first
regulator provided at an end of the lever member for

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functioning as a force point, a second regulator provided at another end of the lever member for functioning as a movable fulcrum, and a middle point between both of the ends functioning as an action point rotatably and
5 axially secured on a line connecting a rotation center of the rotary member and a circumference, wherein

the first regulator is connected with pistons of first and second reciprocal motion motors, each of the pistons are movably inserted in a cylinder, the cylinder
10 has ends both respectively provided with intake/exhaust devices for taking in/exhausting a power gas, and that the first and second regulators have support members for movably supporting the force point and the movable fulcrum such that the force point and the movable
15 fulcrum are movable in a lengthwise direction of the lever member.

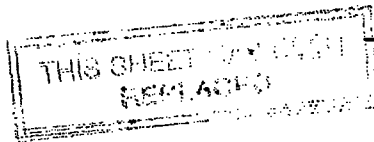
20. A flying member comprising:

a plurality of lever members, each including portions acting as wings of a flying member, each having a first regulator provided at an end of the lever member
20 for functioning as a movable fulcrum, and each having a point between the end and another end of the lever member, for functioning as a force point rotatably secured on a line connecting a rotation center of a
25 rotary member and a circumference, said lever members are arranged symmetrical with each other;

a plurality of rotary members having output shafts

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respectively connected to the force points; and

means for driving the plurality of rotary member in
synchronization with each other, wherein

the first and second regulators have support
5 members for movably supporting the movable fulcrums such
that the lever members are movably supported in a
lengthwise direction of the lever members.



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