United States Patent

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[33] **Japan**
[31] **43/49657 and 43/49658**

[54] **PERFECTLY BALANCED VIBRATIONLESS ROTATION-RECIPROCATION DEVICES OF CRANKSHAFT ROTARY MOTION SYSTEM**
4 Claims, 8 Drawing Figs.

[52] **U.S. Cl.** **123/192,** 74/49, 74/603, 123/197
[51] **Int. Cl.** **F02b 75/06,** F02b 75/32
[50] **Field of Search** ..... 74/49, 50, 603, 604; 123/192, 192 (B), 197, 197 (AA), 197 (AB), 197 (AC)

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ABSTRACT: A perfectly balanced rotation-reciprocation device providing a rod rotatably supported by a crank pin of a crankshaft through an eccentric collar and cooperating means to produce linear reciprocating motion of the rod, the device further providing balance weight means to theoretically balance the caused unbalance forces irrespective to the fact that the balance weights are secured asymmetrically to the longitudinal axis of the rod.

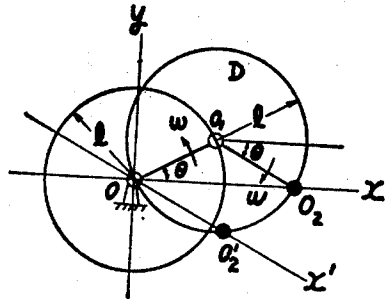


Fig 1

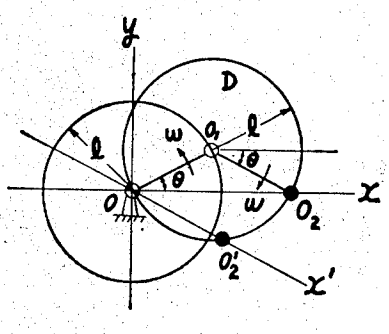

y
D
ω
a
l
l
θ
θ
O
x
ω
O2
O'2
x'

Fig 2

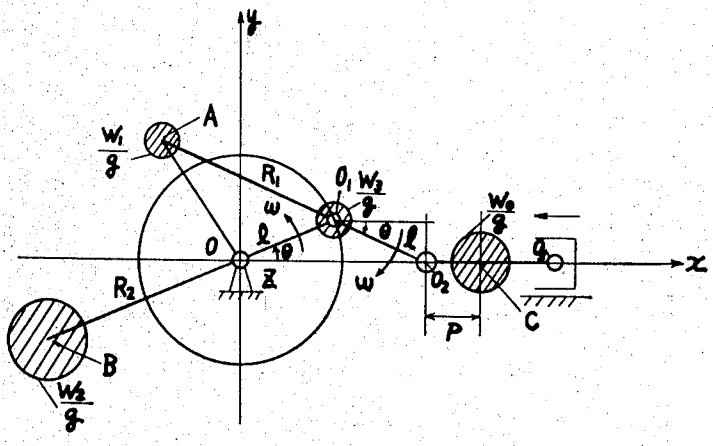

y
A
W1/g
R1
O1 W2/g
ω
θ
l
l
O
θ
R2
ω
O2
W0/g
Q0
x
P
C
B
W2/g

Fig 3

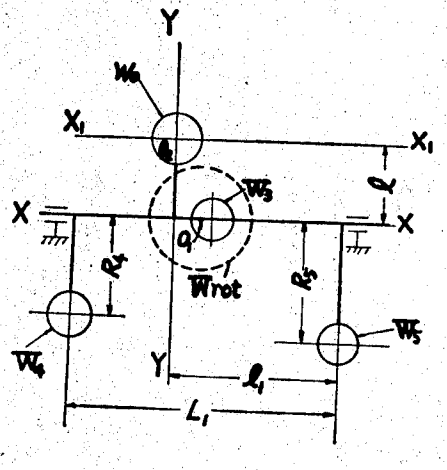

Y
W6
X1
X1
W5
X
X
R4
R5
Wrot
W4
W5
Y
l1
L1

Fig 4

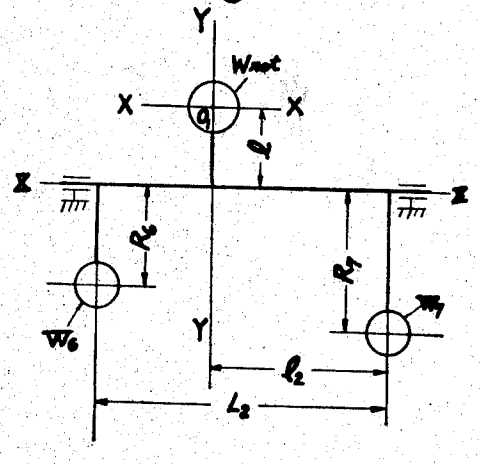

Y
Wrot
X
X
l2
R6
R7
W6
W7
Y
l2
L2

Fig 5

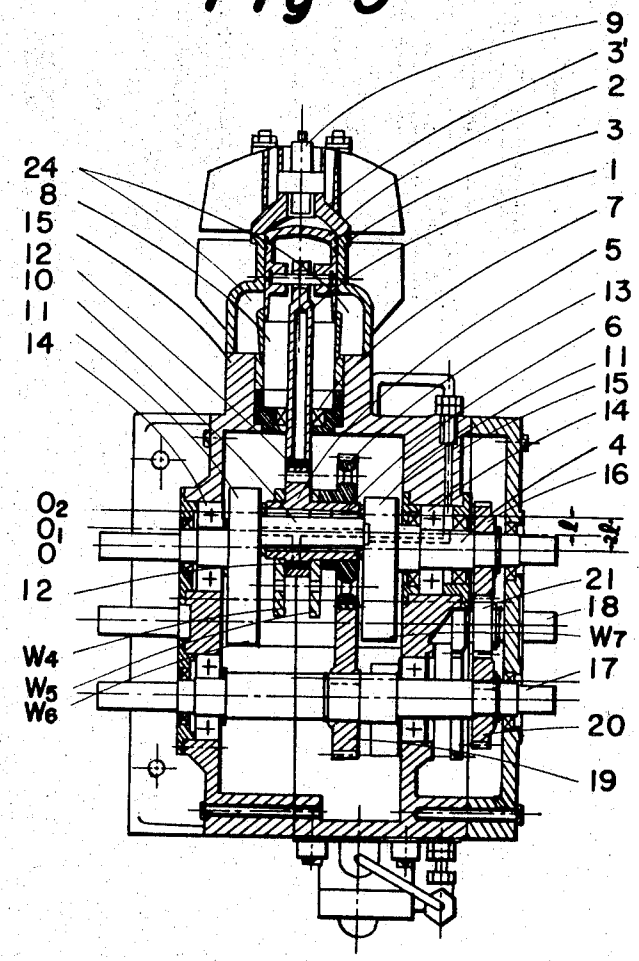

9
3'
2
3
1
7
5
13
6
11
15
14
4
16
24
8
15
12
10
11
14
O2
O1
O
12
W4
W5
W6
21
18
W7
17
20
19

Fig 6

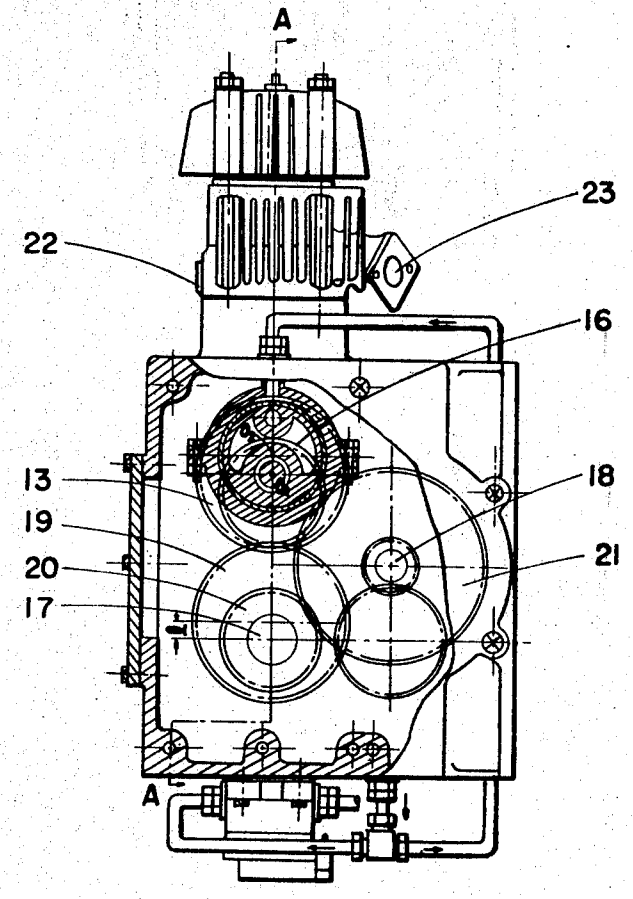


Fig 7

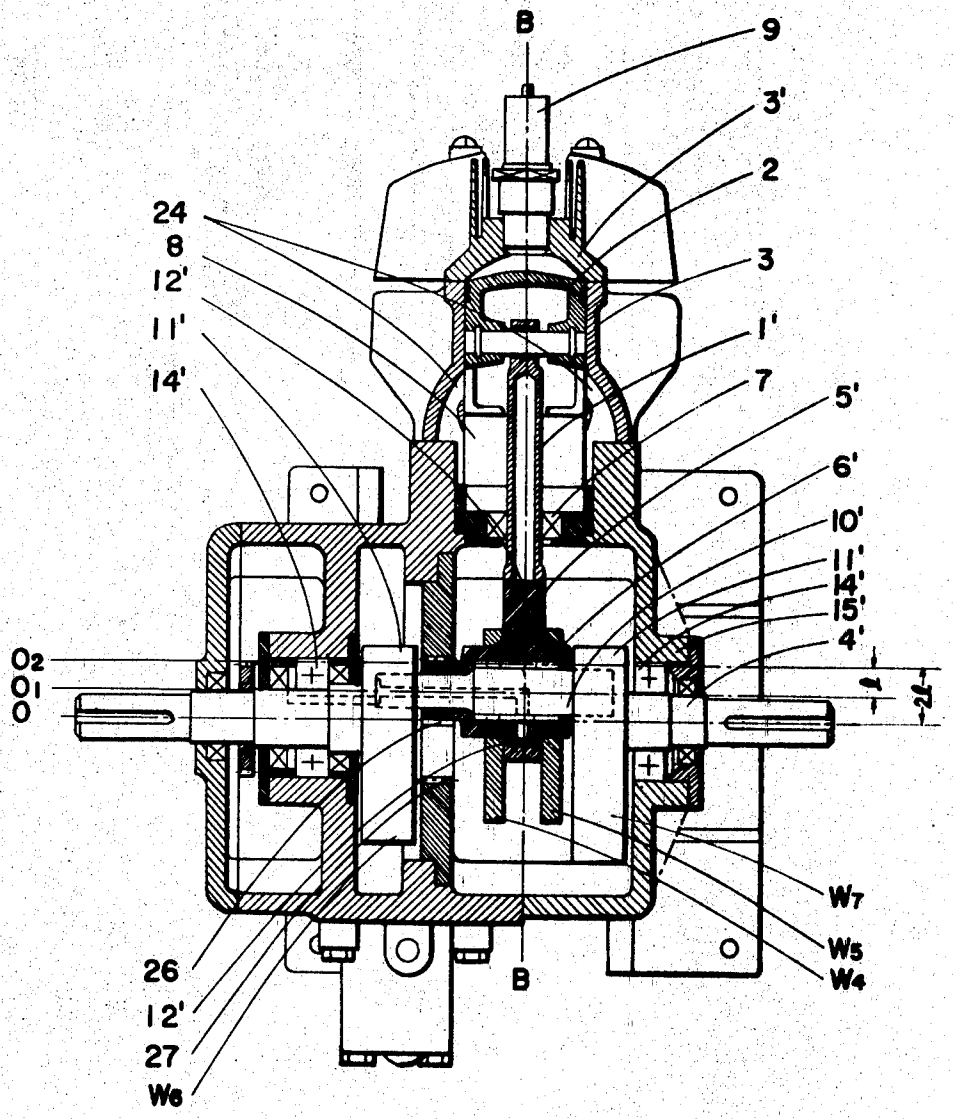
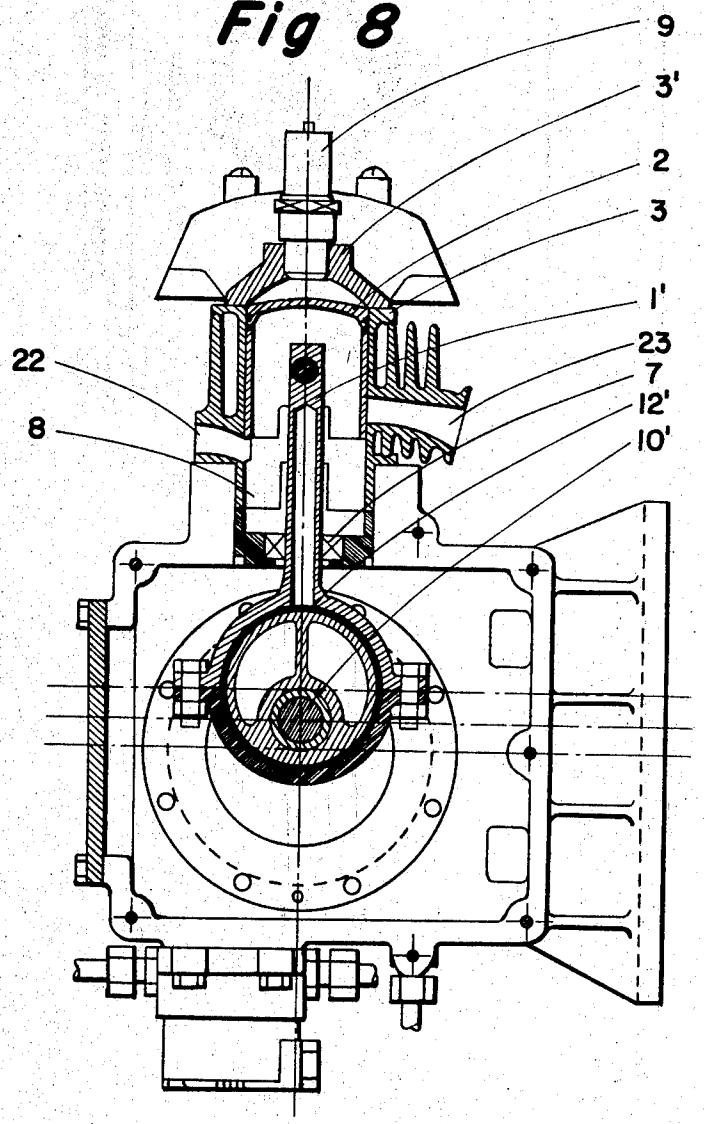

B
9
3'
2
24
8
12'
3
11'
1'
14'
7
5'
6'
10'
11'
14'
15'
4'
O2
O1
O
t
2t
W7
W5
W4
26
12'
27
W6
B

Fig 8



PERFECTLY BALANCED VIBRATIONLESS ROTATION-RECIPROCATION DEVICES OF CRANKSHAFT ROTARY MOTION SYSTEM

The present invention relates to a rotation-reciprocation device and more particularly to a perfectly balanced reciprocating machine or machine part combined by reciprocating motion and uniform speed circular motion.

Known piston-crank device or rotation-reciprocation device such as internal combustion engine inevitably accompanies vibration as the unbalanced forces caused by inertia of reciprocating mass such as piston and connecting rod cannot be balanced theoretically. The vibration causes known hazards, according to an increase of the number of revolution or the torque.

The primary object of the present invention is to eliminate such disadvantages and to provide a perfectly balanced vibrationless rotation-reciprocation device which theoretically eliminates unbalance force of the reciprocating mass which has been assumed inevitable to such kind of devices heretofore.

In order to attain above-mentioned object, the perfectly balanced vibrationless rotation-reciprocation device, according to the present invention, has its feature to comprise a casing, a rod having working means at one end, an eccentric collar means rotatably supporting the other end portion of said rod and having an opening at eccentricity l from the center of the collar, a crankshaft rotatably supported by the casing and rotatably supporting the opening of the collar means by a crankpin having eccentricity l, means to cooperate said eccentric collar means and said crankshaft to rotate said crankshaft and collar means at the same angular velocity and in the reverse direction each other and to effect linear reciprocating motion of the rod, balance weight means having weights W_4 and W_5 respectively secured to the eccentric collar in the opposite side of the center of the eccentric collar at distances R_4 and R_5 to the axis of the crankpin and at distances (L_1-l_1) and l_1 from longitudinal axis of the rod respectively, another balance weight means having weights W_6 and W_7 respectively secured to each crank arms of the crankshaft in the opposite side of the crankpin at distances R_6 and R_7 from the axis of the crankshaft and at distances (L_2-l_2) and l_2 from the longitudinal axis of the rod respectively, and said both balance weight means being determined to satisfy formulae

$$W0l = W_4R_4 + W_5R_5$$

$$L_1W_4R_4 = l_1W0l$$

$$(W_0 + W_3 + W_4 + W_5)l = W_6R_6 + W_7R_7$$

$$L_2W_6R_6 = l_2(W_0 + W_3 + W_4 + W_5)l$$

wherein,

W_0 : reciprocating weight

W_3 : rotating weight

L_1 : distance between centers of gravity of W_4 and W_5

L_2 : distance between centers of gravity of W_6 and W_7

so that unbalanced forces caused by reciprocating mass are balanced.

As mentioned above, the rotation-reciprocation device according to the present invention provides a linearly reciprocating rod, a rotating crankshaft, an eccentric collar supporting the rod and rotating and revolving on the crankpin, and cooperating means to produce linear reciprocation of the rod. The device further provides balance weight means according to the present invention, as will be explained more fully hereinafter, which theoretically balances all unbalance forces. The construction is very simple and need not to add much parts to the conventional crank and rod mechanism. The vibration amplitude characteristic of the device according to the present invention is in the order of 3 to 4μ at 5,000 r.p.m. of the crankshaft, the value is about one-eightieth to conventional crank and rod device.

The balance weight can be determined very easily and need not secure symmetrically to the longitudinal axis of the rod, so that the versatility of utilization of the device is furthermore increased.

Further as the rod to connect piston or working means performs linear reciprocating motion, the rod receives only compression load and no bending moment acts to the rod, also no side pressure is applied to the cylinder.

The above-mentioned features of the perfectly balanced vibrationless rotation-reciprocation device according to the present invention can be utilized in many applications as prime movers, such as internal combustion engines or hot gas engines and also as working machines or mechanisms driven by other input power source. Some of the applications will be mentioned below.

At first the vibrationless feature can advantageously be utilized as machines which are not to be mounted on rigid foundation. Such applications include portable gasoline engines for many uses such as chain saw, mower, branch cutter or sprayer; and also soft foundation engines for vehicles such as boats, motorcycles, automobiles, airplanes or lawn mowers.

The feature of the vibrationless linearly reciprocating rod can be advantageously utilized as prime movers and working machines. As prime movers, both sides of the piston can be utilized as double acting engine or underside of the piston can be utilized as precompression space for intake of gas mixture or air especially for two-cycle engine. As compressors, double-acting or two-stage compressor can easily be attained. Further, the connecting rod can be divided to insert spring means for accommodating torque variation or to insert adjustable means to vary compression ratio.

The linear reciprocating feature also can be utilized as working machines or mechanisms driven by other input source. Such applications include needle bar mechanism for sewing machine, reciprocating mechanism for spinning and weaving machine, spring expansion mechanism for spring testing machine, reciprocating mechanism for machine tools, riveters, chisels, or hammers.

Principles, mechanisms, features and advantages of the present invention will become apparent in the following detailed description referring to the accompanying drawings, in which:

FIG. 1 shows a locus diagram of a point on a periphery of a disc D which rotates on its axis at a constant angular velocity and revolves at the same constant angular velocity in the reverse direction;

FIG. 2 shows a diagram illustrating each moving mass projected on X–Y plane;

FIG. 3 shows a diagram illustrating rotating masses shown in FIG. 2 projected on X–Y plane;

FIG. 4 shows a diagram illustrating revolving masses shown in FIG. 2 projected on X–Y plane;

FIG. 5 shows a longitudinal sectional view along line A–A of FIG. 6 showing a crankshaft rotating eccentric geared perfectly balanced two-cycle reciprocating engine embodying the present invention;

FIG. 6 shows a partially broken away side view of the engine shown in FIG. 5;

FIG. 7 shows a longitudinal sectional view of a crankshaft rotating internal geared perfectly balanced two-cycle reciprocating engine embodying the present invention; and

FIG. 8 shows a sectional view along line B–B of FIG. 7.

At first, theoretical analysis of basic principle about generation of linear reciprocating motion by combining two uniform speed circular motions will be explained.

As shown in FIG. 1, a disc D rotates on its axis O_1 at constant angular velocity ω, and at the same time the point O_1 revolves on a center O at distance l at the constant angular velocity ω in the reverse direction with the disc, then every points on the periphery of the disc D at radius l perform linear reciprocating motion through the point O. That is, when a crank OO_1 rotates on the axis O at constant angular velocity ω, and a link O_1O_2 rotates on the crankpin O_1 at constant angular velocity ω in the reverse direction of the crank, the point O_2 performs linear reciprocating motion along line O–X at stroke $4l$ by rotation and revolution of the link O_1O_2.

Theoretical principle of the perfect balancing of the above-mentioned mechanism is as follows:

In the description, it is assumed that, rotation members rotate at constant angular velocity, and that frictional forces between members and effects of play between shafts and bearings are neglected.

As shown in FIG. 2, when,

A : center of gravity of rotation balance weight
B : center of gravity of revolution balance weight
C : center of gravity of reciprocating mass
O : revolution center
O_1 : rotation center
O_2 : center of big end of connecting rod
W_0 : reciprocating weights (sum of mass as piston, connecting rod, and reciprocating parts of crank O_1O_2)
W_1 : weight of rotation balance weight
W_2 : weight of revolution balance weight
W_3 : rotation weight except W_0 and W_1
g : acceleration of gravity
R_1 : vector showing position of point A from center O_1
R_2 : vector showing position of point B from center O
l : distance between centers O and O_1
P : vector showing position of point C from center O_2

Inertia force F acting to the reciprocating mass

$$m=\frac{W_0}{g}$$

is obtained as follows:

Position vector of point C is

$$OC=OO_1+O_1O_2+O_2C=l\epsilon^{j\theta}+l\epsilon^{-j\theta}+P=2l\cos\theta+P \quad (1)$$

Inertia force F acting at point C is

$$F=\frac{W_0}{g}\ddot{\vec{OC}}=\frac{W_0}{g}\,l\omega^2(\epsilon^{j\theta}+\epsilon^{-j\theta})=2\frac{W_0}{g}\,l\omega^2\cos\theta \quad (2)$$

Inertia force F_1 acting to the rotation balance mass

$$m_1=\frac{W_1}{g}$$

is obtained as follows:

Position vector of point A is

$$OA=OO_1+O_1A=l\epsilon^{j\theta}+R_1\epsilon^{j(\pi-\theta)}=l\epsilon^{j\theta}-R_1\epsilon^{-j\theta} \quad (3)$$

Inertia force F_1 acting to point A is

$$F_1=-\frac{W_1}{g}\,OA=\frac{W_1}{g}\,\omega^2(l\epsilon^{j\theta}-R_1\epsilon^{-j\theta}) \quad (4)$$

Inertia force F_2 acting to revolution balance mass

$$m_2=\frac{W_2}{g}$$

is obtained as follows:

Position vector of point B is

$$OB=R_2\epsilon^{j(\pi+\theta)}=-R_2\epsilon^{j\theta}$$

Inertia force F_2 acting to point B is

$$F_2=-\frac{W_2}{g}\,R_2\omega^2\epsilon^{j\theta} \quad (5)$$

Inertia force F_3 acting to rotation mass

$$m_3=\frac{W_3}{g}$$

is obtained as follows:

Position vector of point O_1 is

$$OO_1=l\epsilon^{j\theta} \quad (6)$$

Inertia force F_3 acting to point O_1 is

$$F_3=-\frac{W_3}{g}\ddot{\vec{OO_1}}=\frac{W_3}{g}\,l\omega^2\epsilon^{j\theta} \quad (7)$$

Sum of the forces must be zero at balanced condition, thus,

$$F+F_1+F_2+F_3$$

$$=\frac{W_0}{g}\,l\omega^2(\epsilon^{j\theta}+\epsilon^{-j\theta})+\frac{W_1}{g}\,\omega^2(l\epsilon^{j\theta}-R_1\epsilon^{-j\theta})-\frac{W_2}{g}\,R_2\omega^2\epsilon^{j\theta}+\frac{W_3}{g}\,l\omega^2\epsilon^{j\theta}$$

$$=0$$

$$\therefore (W_0l+W_1l-W_2R_2+W_3l)\epsilon^{j\theta}+(W_0l-W_1R_1)\epsilon^{-j\theta}=0 \quad (8)$$

thus,

$$W_0l=W_1R_1 \quad (9)$$

$$(W_0+W_1+W_3)l=W_2R_2 \quad (10)$$

Other condition to obtain perfect balance is balancing of moment of inertia force. Moment of inertia force M_{01} about rotational center O_1 is

$$M_{01}O_1O_2\times F+O_1A\times F_1$$

$$=l\epsilon^{-j\theta}\times\frac{W_0}{g}\,l\omega^2(\epsilon^{j\theta}+\epsilon^{-j\theta})-R_1\epsilon^{-j\theta}\times\frac{W_1}{g}\,\omega^2(l\epsilon^{j\theta}-R_1\epsilon^{-j\theta})$$

$$=\frac{l\omega^2}{g}(W_0l-W_1R_1)\,\epsilon^{-j\theta}\times\epsilon^{j\theta}$$

as formula (9),

$$W_0l=W_1R_1$$

$$M_{01}=O \quad (11)$$

In this mechanism, extension lines of inertia forces F_1, F_2 and F_3 are all pass through the point O, moment of inertia forces about point O are all zero. Moment M_0 of inertia forces F_1 about revolution center O is

$$M_0=(l\epsilon^{j\theta}-R_1\epsilon^{-j\theta})\times\frac{W_1}{g}\,\omega^2(l\epsilon^{j\theta}-R_1\epsilon^{-j\theta})=0 \quad (12)$$

Thus, extension of the inertia force F_1 acting to the rotation balance mass passes through point O. Consequently, moment of inertia forces about axis Z are perfectly balanced.

As stated above, when balancing condition shown in formulas (9) and (10) are satisfied by suitably selecting values l, W_0, W_1, W_2, W_3, R_1 and R_2, perfect balancing on X–Y plane will be obtained.

However, in actual mechanism, masses are distributed in the direction of Z axis, balancing condition of inertia forces in the direction of Z axis is necessary. The balancing condition of rotation and revolution masses in the direction of Z axis will be described. As shown in FIG. 3,

W_0: reciprocating weight
W_3: rotation weight
W_4: rotation balance weight on left side
W_5: rotation balance weight on right side
W_{rot} : total rotation weight
XX : axis of rotation shaft
X_1X_1 : axis of big end of connecting rod
YY : longitudinal axis of cylinder
O_1 : center of gravity of W_{rot}
O_2: center of big end of connecting rod
R_4 : distance between center of gravity of W and rotation axis
R_5 : distance between center of gravity of W and rotation axis
l : distance between axis of big end of connecting rod and rotation axis
l_1 : distance between axis of cylinder and center of gravity of W_5
L_1: distance between centers of gravity of W_4 and W_5

As it can be assumed that center of gravity of reciprocating weight W_0, is at point O_2, balancing condition of rotation is

$$L_1W_4R_4=l_1W_0l$$

Formula (9) is rewritten by W_4, W_5, R_4 and R_5

$$W_0l=W_1R_1=W_4R_4+W_5R_5 \quad (14)$$

Total rotation weight W_{rot} is

$$W_{rot}=W_0+W_1+W_3=W_0+W_3+W_4+W_5 \quad (15)$$

Balancing condition of revolution will be described.

In FIG. 4,

W_6: revolution balance weight on left side
W_7: revolution balance weight on right side
ZZ : axis of revolution shaft
XX : axis of rotation shaft
YY : axis of center of gravity of W_{rot}
O_1 : position of center of gravity of W_{rot}
R_6 : distance between center of revolution and center of gravity of W_6
R_7 : distance between center of revolution and center of gravity of W_7
l : distance between center of rotation and center of revolution
l_2 : distance between axis of center of gravity of W_{rot} and center of gravity of W_7
L_2: distance between centers of gravity of W_6 and W_7

As it can be assumed that center of gravity of total rotation weight W_{rot} is at point O_1, balancing condition of revolution is

$$L_2W_6R_6=l_2W_{rot}l \quad (16)$$

Formula (10), is rewritten by W_6, W_7, R_6 and R_7,

$$W_{rot}l=W_2R_2=W_6R_6+W_7R_7 \quad (17)$$

Thus, perfect balance in the direction of Z axis will be obtained by suitably selecting W_0, W_3, W_4, W_5, W_6, W_7, l, l_1, l_2, L_1, L_2, R_4, R_5, R_6 and R_7 to satisfy balancing condition of inertia forces in the direction of Z axis shown by formulas (13) through (17).

As basic principles of linear reciprocating motion obtained by combination of circular motions and perfect balancing of the mechanism according to the invention are described, two embodiments of perfectly balanced vibrationless rotation-reciprocation device according to the invention will be described.

FIGS. 5 and 6 show a two-cycle reciprocating engine providing eccentric gear mechanism. While this is used as an example to describe the invention, it will be understood that the invention has applications to almost all reciprocating machines or mechanisms to attain reciprocating motion by rotating motive power such as compressors, riveters, chisels, reciprocating cutters, spring testing machines, high speed fatigue testing machines, or beating motion mechanism of weaving machines, and to attain rotating motion by reciprocating motive power such as two-cycle or four-cycle gasoline or diesel engine.

As shown in FIG. 5, big end of a linear reciprocating rod **1** providing a piston **2** which is slidably engaged in a cylinder **3**, is rotatably supported through a plane bearing means **12** by an eccentric collar **5** which is rotatably supported through needle bearing means **6** by a crankpin **10** of a crankshaft **4**.

A seal **7** is secured to a casing **15** to slidably engage the linearly reciprocating rod **1** to define an enclosed chamber **8** in the cylinder **3** between the seal **7** and the piston **2**. The cylinder **3** provides a spark plug **9** to the cylinder head portion **3'**.

The eccentric collar **5** is supported by a crankpin **10** which is secured by crank arms **11** of the crankshaft **4**. To one end of the eccentric collar **5** a rotation spur gear **13** is secured to rotate with the collar **5** about the axis of the crankpin **10**. The crankshaft **4** is rotatably supported by ball bearings **14** which are supported by the casing **15**. A revolution spur gear **16** is secured to one end portion of the crankshaft **4**. An eccentric gear shaft **17** and a reduction gear shaft **18** are rotatably supported by the casing **15** respectively. An eccentric gear **19** is secured to the eccentric gear shaft **17** and meshes with the rotation spur gear **13**. A spur gear **20** is secured to the eccentric gear shaft **17** and meshes with a reduction gear **21** which is secured to the reduction gear shaft **18** and in turn meshes with the revolution spur gear **16** secured to the crankshaft **4**. Thus, rotation of the crankshaft **4** can be transmitted to the eccentric collar **5**.

As shown in FIGS. **5** and **6**, in the lower portion of the cylinder **3** an inlet port **22** is provided to introduce gas mixture to the lower chamber **8**, an exhaust port **23** is provided to exhaust spent gas and scavenge passage **24** are provided to supply compressed gas mixture to combustion space.

Operation of the two-cycle reciprocating engine shown in FIGS. **5** and **6** is as follows:

As the piston **2** moves upwards, the inlet port is opened to introduce gas mixture to the chamber **8**, and at the same time gas mixture which has supplied to the combustion chamber is compressed by the piston **2**. By combustion of the gas mixture ignited by the spark plug **9**, the piston **2** is forced downwards, and spent gas is exhausted from the exhaust port **23**. The downward movement of the piston **2** compresses the gas mixture in the chamber **8** and the precompressed gas mixture is supplied to the combustion chamber through scavenger passages **24**. Thus, as to the operation, the two-cycle reciprocating engine according to the invention is similar to known crankcase compression two-cycle engine.

The thermal energy produced in the combustion chamber is transmitted through the piston **2** and the linearly reciprocating rod **1** to rotation of the eccentric collar **5** having angular velocity ω; the rotation is transmitted through the rotation spur gear **13** which is secured to the eccentric collar **5** to the eccentric gear **19** which is secured to the eccentric gear shaft **17** with eccentricity l and having the same number of teeth with the rotation spur gear **13**. Rotation of the eccentric gear **19** is transmitted through the secured eccentric gear shaft **17** and the gear **20** which is also secured to the shaft **17** to the reduction gear **21** which is secured to the reduction gear shaft **18**. The reduction gear **21** in turn transmits the rotation to the crankshaft **4** through the gear **16** which is secured to the crankshaft **4** and having the same number of teeth with the gear **20**. Thus, the crankshaft **4** rotates at angular velocity ω in the reverse direction of the rotation spur gear **13** which is supported by the crankpin **10** having center axis O_1 at eccentricity l from the crankshaft center axis O. Consequently, the spur gear **13** rotates on the axis O_1 and revolves on the axis O in the reverse direction and at the same angular velocity. As shown previously, as center O_2 of the rotation eccentric collar **5** is on the longitudinal axis of the rod **1** and is at the distance $2l$ from the axis O, the center O_2 performs linear reciprocating motion having stroke $4l$; the linear reciprocating motion is transmitted through the gears **13**, **19**, **20**, **21** and **16** to the crankshaft **4** as rotation.

Balancing of the reciprocating engine shown in FIGS. **5** and **6** is described. As shown in FIG. **5**, the rotation eccentric collar **5** provides to both sides of the roll **1** left and right rotation balance weights W_4 and W_5 in the reverse side of the eccentricity of the collar **5** about the axis O_1. The crank arms **11** of the crankshaft **4** respectively provide revolution balance weights W_6 and W_7 in the reverse side of the crankpin **10** about the axis O. The balance weights W_4, W_5, W_6 and W_7 are determined, according to the invention, to satisfy above-mentioned formulas (9), (10) and (13) through (17), i.e.,

$$W_0l=W_1R_1;$$
$$(W_0+W_1+W_3)l=W_2R_2;$$
$$L_1W_4R_4=l_1W0l;$$
$$W_0l=W_1R_1=W_4R_4+W_5R_5;$$
$$W_{rot}=W_0+W_1+W_3=W_0+W_3+W_4+W_5;$$
$$L_2W_6R_6=l_2W_{rot}l;$$
$$W_{rot}l=W_2R_2=W_6R_6+W_7R_7.$$

The balance weights are secured to the eccentric collar **5** and the crank arms **11** as weights W_1 and W_2 at distances R_1 and R_2 between the center of gravity and the axis, or as weights W_4, W_5, W_6 and W_7 at distances R_4, R_5, R_6 and R_7. Thus, as described before the reciprocating engine is perfectly balanced. In the formulas W_0 is the reciprocating weight, W_3 is rotating weight,

$W_1=W_4+W_5$, $W_2=W_6W_7$,

l is an amount of eccentricity, l_1 is a distance between center of gravity of W_5 and axis of cylinder, l_2 is distance between axis of center of gravity of W_{rot} and center of gravity of W_7, L_1 is distance between centers of gravity of W_4 and W_5, and L_2 is distance between centers of gravity of W_6 and W_7.

As a two-cycle engine, the reciprocating machine shown in FIGS. **5** and **6** has advantages that, the engine is perfectly balanced, and the vibration amplitude characteristic is in an order of 3—4μ at 5,000 r.p.m. of the crankshaft, which is about one-eightieth of ordinary engine, so that the engine is especially suitable for engines without rigid foundation, such as portable engines. Further, as the connecting rod **1** reciprocates linearly, lower space of the cylinder **3** can be sealed from crankcase space by the seal **7**, so that the defined chamber **8** can be utilized as other compression chamber. The compression ratio of the chamber **8** can very easily be accommodated to any desired value, so that effective scavenging can be attained.

FIGS. **7** and **8** show another embodiment of the present invention utilizing internal geared transmitting mechanism. FIGS. **7** and **8** also show two-cycle reciprocating engine for the sake of clarity and to simplify description. The same reference numerals are used to represent similar parts or portions. Big end of a linearly reciprocating rod **1'** is supported

through a bearing means **12'** by an eccentric collar **5'** which in turn is supported through needle bearing means **6'** by a crankpin **10'** of a crankshaft **4'**. A planet gear **26** is secured to one end of the eccentric collar **5'**. The crankshaft **4'** is rotatably supported through ball bearings **14'** by a portion of a casing **15'**. The planet gear **26** meshes with an internal gear **27** having twice number of teeth to the gear **26** and secured to the casing **15'**. The axis of the internal gear **27** coincides with the axis of the crankshaft **4'**, and the axis of the planet gear **26** coincides with the axis of the crankpin **10'**. As before, the eccentric collar **5'** provides to both sides of the rod **1'** left and right rotation balance weights W_4 and W_5 in the reverse side of the eccentricity of the collar **5'** about the axis O_1. The crank arms **11'** of the crankshaft **4'** respectively provide revolution balance weights W_6 and W_7 in the reverse side of the crankpin **10'** about the axis O. Balance weights W_4, W_5, W_6 and W_7 are determined to satisfy above-mentioned formulas (9), (10) and (13) through (17).

Operation of the two-cycle internal combustion engine shown in FIGS. **7** and **8** is utterly similar to the engine shown in FIGS. **5** and **6**.

As the piston **2** moves upwards, the inlet port **22** is opened to introduce gas mixture to the chamber **8** and at the same time gas mixture which has supplied to the combustion chamber is compressed. By combustion of the gas mixture, the piston **2** is forced downwards and thermal energy produced in the combustion chamber is transmitted through the piston **2** and the linearly reciprocating rod **1'** to rotation of the eccentric collar **5'**. As the axis of the planet gear **26** having pitch circle diameter $2l$ and secured to or integral with the eccentric collar **5'** coincides with the axis of the crankpin **10'** and as the planet gear **26** meshes with the internal gear **27** which is secured to the casing **15'** and having twice number of teeth with that of the planet gear **26**, axis O_2 of the eccentric collar **5'** aligns to a point on the periphery of the pitch circle of the internal gear **27** having pitch circle diameter $4l$ and reciprocates linearly. The crankshaft **4'** acts as planet carrier of the planet gear **26** and rotates on the axis of the internal gear **27**.

Thus, as above-mentioned mechanism, linear reciprocating motion of the connecting rod **1'** is performed, and the reciprocating motion is transmitted to the rotation of the planet gear **26** meshing with the internal gear **27** about the axis O_1 of the crankpin **10'** to effect rotation of the eccentric collar **5'** of angular velocity ω on the center axis O_2. At the same time, the crankpin **10'** revolves on the crankshaft axis O at the same angular velocity ω and in the reverse direction to the eccentric collar **5'**. Consequently, the eccentric collar **5'** rotates on the axis O_1 and revolves on the axis O at the same angular velocity and in the reverse direction each other. Balancing of this device is the same in the case of reciprocating engine providing eccentric gear mechanism (as shown in FIGS. **5** and **6**). Thus, a simpler mechanism compared to the mechanism shown in FIGS. **5** and **6** is obtained to attain perfectly balanced rotation-reciprocation machine according to the invention.

Also in this case, the application of the device and the balancing theory is not limited to the shown two-cycle reciprocating engine or other engines to drive the output shaft. The same device can be used to be driven by input shaft, such as compressors, riveters, high speed fatigue testing machines, or other machines or mechanisms to attain reciprocating motion without vibration from rotating motive power source.

I claim:

1. A perfectly balanced rotation-reciprocation device comprising a casing, a rod having working means at one end; an eccentric collar means rotatably supporting the other end portion of said rod and having an opening at an amount of eccentricity $-l$ from the center of the collar, a crankshaft rotatably supported by the casing and rotatably supporting the opening of the collar means by a crankpin having the amount of eccentricity $-l$, means to cooperate said eccentric collar means and said crankshaft to rotate said crankshaft and collar means at the same constant angular velocity and in the reverse direction each other and to effect linear reciprocating motion of the rod, balance weight means having weights W_4 and W_5 respectively secured to the eccentric collar in the opposite side of the center of the eccentric collar at distances R_4 and R_5 to the axis of the crankpin and at distances (L_1-l_1) and l_1 from longitudinal axis of the rod respectively, another balance weight means having weights W_6 and W_7 respectively secured to each crank arms of the crankshaft in the opposite side of the crankpin at distances R_6 and R_7 from the axis of the crankshaft and at distances (L_2-l_2) and l_2 from longitudinal axis of the rod respectively, and said both balance weight means being determined to satisfy formulae

$$W_0 l = W_4 R_4 + W_5 R_5,$$

$$L_2 W_6 R_6 = l_2 (W_0 + W_3 + W_4 + W_5) l, \text{ and}$$

$$L_2 W_6 R_6 = l_2 (W_0 + W_3 + W_4 + W_5),$$

wherein W_0 being reciprocating weight, W_3 being rotating weight, L_1 being distance between centers of gravity of W_4 and W_5, L_2 being distance between centers of gravity of W_6 and W_7, so that unbalanced forces caused by reciprocating mass are balanced.

2. A rotation-reciprocation device claimed in claim **1**, wherein said means to cooperate the eccentric collar and the crankshaft comprising a first gear secured to the eccentric collar, a first and a second shafts rotatably supported by the casing and being parallel to the axis of the crankshaft, an eccentric gear having the same number of teeth with that in the first gear and the amount of eccentricity $-l$ and being secured to the first shaft and meshing with the first gear, a second gear secured to the first shaft, a third gear supported by the second shaft and meshing with the second gear, a fourth gear secured to the crankshaft and meshing with the third gear and having the same number of teeth with that in the second gear.

3. A rotation-reciprocation device claimed in claim **1**, wherein said means to cooperate the eccentric collar and the crankshaft comprising planet gear means having pitch circle diameter $2l$ and being secured to the eccentric collar to rotate on the crankpin, and internal gear means secured to the casing to be concentric to the crankshaft axis and meshing with the planet gear means and having pitch circle diameter $4l$.

4. A rotation-reciprocation device claimed in any of preceding claims in which said working means connected to one end of the rod being piston means, and the device further comprising cylinder means accommodating said piston means and defining combustion chamber between the piston means, said piston means having inlet, outlet and scavenging passage means and being connected to the casing, spark plug means mounted to the cylinder means, seal means secured to the casing and slidably engaging said rod to define a further space in the cylinder means between said piston and said casing, and said inlet means and one end of the scavenging passage means being communicated to said further space whereby the device is formed as two-cycle internal combustion engine and the further space is formed as precompression chamber of the engine.