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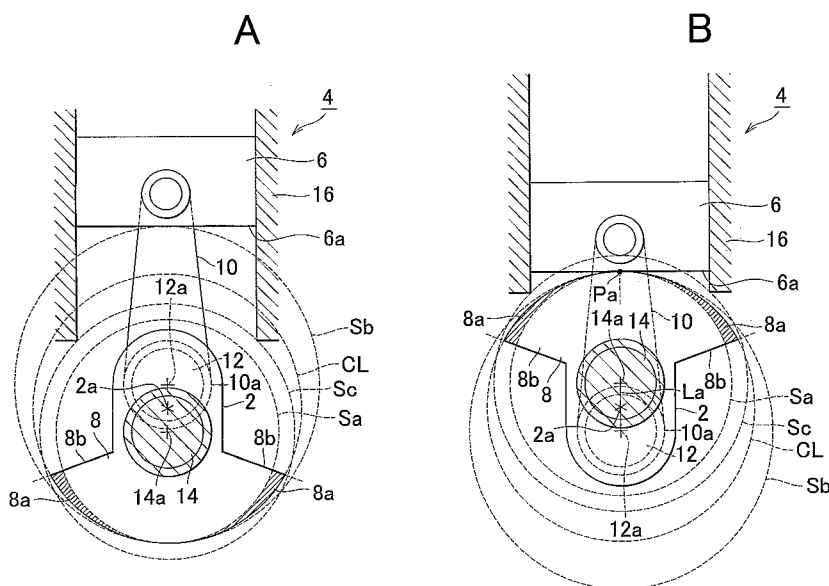
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(57) Abstract: In a counterweight (2) according to the invention, a weight portion (8) has an outer-radius extended portion (8a) that is formed in an overlapping region between a piston-lower-end non-interference region (Sb) and a cylinder-block non-interference region (Sc) that are located radially outwardly of a reference non-interference region (Sa). Thus, the weight portion (8) is expanded radially outward from the reference non-interference region (Sa) without interfering with a cylinder block (16) and the lower end face (6a) of a piston (6). It is thus possible to effectively increase the moment of inertia without incurring a significant increase in the weight of the counterweight (2).

COUNTERWEIGHT

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to counterweights mounted on a crankshaft of an internal combustion engine so as to prevent vibration of the engine.

2. Description of the Related Art

[0002] Counterweights, which are also called "balance weights", are provided on the crankshaft for preventing vibration of the internal combustion engine by balancing the motion of the crankshaft on the side of connecting rods with the motion of the crankshaft on the side of the counterweights. If the radius of the counterweight (i.e., distance from the axis of the crankshaft to the outer periphery of the counterweight) is large, the counterweight may interfere with the lower end face of the corresponding piston, or may interfere with a cylinder block including, for example, a crankcase, which is located around the crankshaft.

[0003] In view of the above situations, the profile of the counterweight is determined such that the outer periphery of the counterweight is limited to within the largest radius as measured from the axis of the crank journal, in which the counterweight does not interfere with the lower end face of the piston and the cylinder block, as disclosed on pages 4-5 and FIG. 1 in laid-open Publication No. H2-15044 of unexamined Japanese Utility Model Application.

[0004] With regard to the counterweight having the profile as described above, even if it is desired to increase the moment of inertia so as to further reduce or eliminate vibration, the outer periphery of the counterweight is limited as described above, and thus the radius of the counterweight cannot be simply increased to be larger than the above-indicated largest radius.

[0005] Under the circumstances as described above, it has been proposed to form weight expanded portions Ex on circumferentially opposite end faces of a

counterweight C_w , rather than on its radial end face, as shown in FIG. 7. If the weight expanded portions Ex are provided in this manner, however, the center of mass (or gravity) of the counterweight C_w gets closer to the center C_p of rotation of the crank journal C , which gives rise to a problem that the moment of inertia is not sufficiently increased by a degree commensurate with the increase of the mass due to the weight expanded portions Ex . In order to provide the required moment of inertia, it would be necessary to further increase the size or weight of the weight expanded portions Ex or increase the thickness of the counterweight C_w , resulting in an increased weight of the counterweight C_w and an accordingly increased weight of the engine.

SUMMARY OF THE INVENTION

[0006] It is therefore an object of the invention to provide a counterweight whose moment of inertia can be effectively increased without causing a significant increase in the weight of the counterweight, in an internal combustion engine in which a weight portion of the counterweight, when approaching a piston of the engine, is located closer to the lower end face of the piston placed at the bottom dead center than to a cylinder block when viewed in radial directions of the crankshaft.

[0007] A first aspect of the invention relates to a counterweight having a weight portion that extends radially from an axis of a crank journal in a direction opposite to a crank pin of a crankshaft. The counterweight is provided on the crankshaft in an internal combustion engine in which the counterweight is closer to a lower end face of a piston when placed at the bottom dead center than to a cylinder block when viewed in radial directions of the crankshaft. The weight portion has an outer-radius extended portion at least a part of which is located outside of a reference non-interference region having a center that lies on the axis of the crank journal and a radius that is set to the maximum length with which the reference non-interference region does not interfere with the lower end face of the

piston when placed at the bottom dead center. A portion of the outer-radius extended portion which is located outside of the reference non-interference region is located within an overlapping region between a cylinder-block non-interference region that is established around the crank journal so as not to interfere with the cylinder block, and a piston-lower-end non-interference region that is established around the crank pin so as not to interfere with the lower end face of the piston.

[0008] In the related art, the radial dimensions of the weight portion of the counterweight are limited by the outer periphery of the above-mentioned reference non-interference region. According to the first aspect of the invention, on the other hand, the weight portion is designed with reference to a piston-lower-end non-interference portion located outside of the reference non-interference region. The piston-lower-end non-interference region varies according to the phase of rotation of the crankshaft, i.e., the circumferential position of the crankshaft. While the outer periphery of the piston-lower-end non-interference region coincides with the outer periphery of the reference non-interference region at the circumferential position at which the outer periphery of the piston-lower-end non-interference region is located closest to the axis of the crank journal, the outer periphery of the piston-lower-end non-interference region is spaced radially outward from the reference non-interference region at the other circumferential positions. Accordingly, if the weight portion is expanded to be within the overlapping region between the piston-lower-end non-interference region and the cylinder-block non-interference region, the expanded weight portion does not interfere with the lower end face of the piston nor the cylinder block. Thus, the weight portion can be formed with the outer-radius extended portion such that at least a part of the extended portion is located outside of the reference non-interference region.

[0009] By forming the outer-radius extended portion in the manner as described above, it is possible to effectively increase the moment of inertia without incurring a significant increase in the weight of the counterweight.

[0010] In the counterweight according to the first aspect of the invention, the piston-lower-end non-interference region may be an elliptic region as viewed in an axial direction of the crankshaft, and the elliptic region may have a center that lies on an axis of the crank pin, a long radius that is set to the maximum length with which the piston-lower-end non-interference region does not interfere with the lower end face of the piston when placed at the bottom dead center or the top dead center, and a short radius that is set to the maximum length with which the piston-lower-end non-interference region does not interfere with the lower end face of the piston when placed at an intermediate point between the bottom dead center and the top dead center.

[0011] With the piston-lower-end non-interference region thus established to be within the range as described above, the weight portion of the counterweight can be designed making use of the overlapping region between the cylinder-block non-interference region and piston-lower-end non-interference region which are located outside of the reference non-interference region. It is thus possible to effectively increase the moment of inertia without incurring a significant increase in the weight of the counterweight.

[0012] In the counterweight according to the first aspect of the invention, the cylinder-block non-interference region may be a circular region as viewed in an axial direction of the crankshaft, and the circular region may have a center that lies on the axis of the crank journal, and a radius that is set to the maximum length with which the cylinder-block non-interference region does not interfere with the cylinder block.

[0013] With the cylinder-block non-interference region thus established to be within the range as described above, the outer-radius extended portion, at least a part of which is located outside of the reference non-interference region, can be formed in the overlapping region between the cylinder-block non-interference region and the piston-lower-end non-interference region. It is thus possible to effectively increase the moment of inertia without incurring a significant increase

in the weight of the counterweight.

[0014] In the counterweight according to the first aspect of the invention, a boundary line having a circular shape as viewed in the axial direction of the crankshaft and passing the overlapping region may be established around a center that lies on a straight line passing the axis of the crank journal and the axis of the crank pin, and at least a part of the outer periphery of the outer-radius extended portion may coincide with at least a part of the boundary line located within the overlapping region.

[0015] When the outer-radius extended portion is formed in the overlapping region, the circular boundary line may be established as described above, and a part or the whole of the boundary line present in the overlapping region may be specified or defined as a part or the whole of the outer periphery of the outer-radius extended portion.

[0016] In the counterweight according to the first aspect of the invention, a boundary line having a circular shape as viewed in the axial direction of the crankshaft and passing the overlapping region may be established around a center that lies on a point on a straight-line segment connecting the axis of the crank journal with the axis of the crank pin, which point is selected with exceptions of a point on the axis of the crank journal and a point on the axis of the crank pin. In this case, at least a part of the outer periphery of the outer-radius extended portion may coincide with at least a part of the boundary line located within the overlapping region.

[0017] The position of the center of the circular boundary line may be limited to between the axis of the crank journal and the axis of the crank pin, as described above, and the outer periphery of the outer-radius extended portion may be specified or determined with reference to the boundary line. If the outer periphery of the outer-radius extended portion is entirely defined or specified by the boundary line, the profile of the outer-radius extended portion consists solely of an arc (as a segment of a single circle) as viewed in the axial direction of the

crankshaft, and, therefore, the outer-radius extended portion can be easily formed by, for example, cutting.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The foregoing and further objects, features and advantages of the invention will become apparent from the following description of preferred embodiments with reference to the accompanying drawings, wherein like numerals are used to represent like elements and wherein:

FIG. 1A and FIG. 1B are explanatory views showing the shape and rotating conditions of a counterweight provided in an internal combustion engine according to a first embodiment of the invention;

FIG. 2 is an explanatory view showing a piston-lower-end non-interference region Sb, a cylinder-block non-interference region Sc and their overlapping region Sw of the counterweight of FIG. 1;

FIG. 3 is an explanatory view showing the shape of a counterweight provided in an internal combustion engine according to a second embodiment of the invention;

FIG. 4 is an explanatory view showing the shape of a counterweight provided in an internal combustion engine according to another embodiment of the invention;

FIG. 5A and 5B are explanatory views showing the shape of a counterweight provided in an internal combustion engine according to a further embodiment of the invention;

FIG. 6 is an explanatory view showing the shape of a counterweight according to a still another embodiment of the invention; and

FIG. 7 is an explanatory view showing the shape of a counterweight according to the related art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] FIG. 1A and FIG. 1B are vertical cross-sectional views of an internal combustion engine 4 using counterweights 2 according to a first embodiment of the invention. FIG. 1A shows a condition in which a piston 6 of the engine 4 is at the top dead center, and FIG. 1B shows a condition in which the piston 6 is at the bottom dead center.

[0020] A weight portion 8 of the counterweight 2 is formed on one side of a crank journal 14 opposite to a crank pin 12 to which a big end 10a of a connecting rod 10 is attached. The weight portion 8 is formed in the shape of a sector that extends radially from the axis 14a of the crank journal 14 in the opposite direction of the crank pin 12.

[0021] The weight portion 8 and various non-interference regions associated with formation of its outer-radius extended portion will be described in detail with reference to FIGS. 1A, 1B and 2. Referring first to FIG. 1A and FIG. 1B, a reference non-interference region Sa having a circular shape, a piston-lower-end non-interference region Sb in the shape of an ellipse, and a cylinder-block non-interference region Sc having a circular shape, as viewed in the axial direction of the crankshaft (i.e., the axial direction of the crank journal 14), are established.

[0022] The reference non-interference region Sa, when viewed in the axial direction of the crankshaft, is a circular region having a center that lies on the axis 14a of the crank journal 14. The radius of the reference non-interference region Sa is set to the maximum length with which the region Sa does not interfere with the lower end face 6a of the piston 6 when placed at the bottom dead center.

[0023] The piston-lower-end non-interference region Sb, when viewed in the axial direction of the crankshaft, is in the shape of an ellipse having a center that lies on the axis 12a of the crank pin 12. The long radius of the elliptic piston-lower-end non-interference region Sb, as measured from the axis 12a, is set to the maximum length with which the region Sb does not interfere with the lower end face 6a of the piston 6 when placed at the bottom dead center (or the top dead

center), and the short radius of this region Sb is set to the maximum length with which the region Sb does not interfere with the lower end face 6a of the piston 6 when placed at an intermediate point between the bottom dead center and the top dead center. In the crank-angle conditions as shown in FIG. 1A and FIG. 1B, the non-interference region Sb is vertically oriented such that its long radius extends in the vertical direction. The piston-lower-end non-interference region Sb contains the reference non-interference region Sa, and extends outward from the reference non-interference region Sa.

[0024] The cylinder-block non-interference region Sc, when viewed in the axial direction of the crankshaft, is a circular region having a center that lies on the axis 14a of the crank journal 14. The radius of this region Sc, as measured from the axis 14a, is set to the maximum length with which the region Sc does not interfere with a cylinder block 16 of the engine 4.

[0025] The internal combustion engine 4 is constructed so that the cylinder-block non-interference region Sc is larger than the reference non-interference region Sa. This means that the weight portion 8, when placed close to the piston 6, is located closer to the lower end face 6a of the piston 6 at the bottom dead center, than to the cylinder block 16, as viewed in radial directions of the crankshaft (i.e., radial directions of the crank journal 14). Namely, if the weight portion 8 is expanded in the radial directions of the crankshaft, the weight portion 8 would interfere with the lower end face 6a of the piston 6 at the bottom dead center before interfering with the cylinder block 16.

[0026] In FIG. 2, a region hatched with broken lines and located outside of the reference non-interference region Sa indicates an overlapping region Sw between the piston-lower-end non-interference region Sb and the cylinder-block non-interference region Sc. As shown in FIGS. 1A and 1B, the weight portion 8 is formed with an outer-radius extended portion 8a that extends outward from the reference non-interference region Sa, and the outer-radius extended portion 8a is entirely contained in the overlapping region Sw. In the present embodiment, a

midpoint 2a is established on a straight-line segment La that connects the axis 14a of the crank journal 14 with the axis 12a of the crank pin 12, and a circular boundary line CL that passes the overlapping region Sw is established such that the center of the boundary circle CL lies on the midpoint 2a. Furthermore, the boundary line CL used in this embodiment is set so as to pass a point Pa (FIG. 1B) at which an extension of the straight-line segment La which extends beyond the axis 14a of the crank journal 14 intersects with the outer periphery of the reference non-interference region Sa. The boundary line CL is also set to be within the cylinder-block non-interference region Sc in a circumferential region located radially outwardly of the weight portion 8. The circular boundary line CL set in this manner is sure to be within the overlapping region Sw insofar as it is in the circumferential region radially outside of the weight portion 8. The shape of the boundary line CL specifies or determines the shape of the entire outer periphery of the outer-radius extended portion 8a. Thus, the outer periphery of the outer-radius extended portion 8a is formed in the shape of an arc having a single radius, namely, an arc as a segment of a single circle.

[0027] With the weight portion 8 thus formed, the distance from the axis 14a of the crank journal 14 as the center of rotation of the counterweight 2 to the center of mass of the expanded portion (i.e., the outer-radius extended portion 8a) is made longer than that of the case where weight expanded portions Ex having the same mass as the outer-radius extended portion 8a are formed on circumferentially opposite end faces of the weight portion 8 as in the related art (FIG. 7). Accordingly, the moment of inertia is increased with substantially the same increase in the mass, as compared with the related art.

[0028] The first embodiment as explained above provides effects or advantages as follows. (I) In the related art, the size of the counterweight as measured in its radial directions is held within the reference non-interference region Sa. In the present embodiment, on the other hand, the counterweight 2 is designed with an attention paid to the piston-lower-end non-interference region Sb

that extends radially outward further than the reference non-interference portion Sa, and the outer-radius extended portion 8a is formed within the overlapping region Sw between the piston-lower-end non-interference region Sb and the cylinder-block non-interference region Sc. Thus, the weight portion 8 can be expanded radially outwardly of the reference non-interference region Sa, without interfering with the cylinder block 16 and the lower end face 6a of the piston 6. It is thus possible to effectively increase the moment of inertia without incurring a significant increase in the weight of the counterweight 2.

[0029] (II) In the present embodiment, the whole of the overlapping region Sw located at the outer radius of the weight portion 8 is not formed as the outer-radius extended portion 8a, but the outer-radius extended portion 8a is formed with its outer periphery defined by the boundary line CL set in the above manner. In this embodiment, a part of the boundary line CL present in the overlapping region Sw provides the entire length of the outer periphery of the outer-radius extended portion 8a. By adjusting the radius of the boundary line CL, or adjusting the width of the outer-radius extended portion 8a as measured in the circumferential direction, the entire length of the boundary line CL present in the overlapping region Sw may provide the entire length of the outer periphery of the outer-radius extended portion 8a. Thus, the profile of the outer-radius extended portion 8a is determined or specified by an arc having a single radius, namely, an arc as a segment of a single circle in the form of the boundary line CL. Therefore, the outer-radius extended portion can be easily formed.

[0030] Referring next to FIG. 3, a second embodiment of the invention will be described. In the second embodiment, a weight portion 38 of a counterweight 32 is designed without establishing any boundary line. Rather, an overlapping region located at the outer radius of the weight portion 38, which is contained in the overlapping region Sw established radially outside of the reference non-interference region Sa, is regarded as a shaped circumferential section Swa, and the whole of the shaped circumferential section Swa is formed as an

outer-radius extended portion 38a.

[0031] According to the second embodiment, it is possible to make full use of the overlapping region Sw, and increase the mass of the outer-radius extended portion 38a to be larger than that of the first embodiment. As a result, the distance from an axis 44a of a crank journal 44 as the center of rotation of the counterweight 32 to the center of mass of the outer-radius extended portion 38a is increased, whereby the moment of inertia can be further increased.

[0032] The second embodiment as explained above provides effects or advantages as follows. (I) It is possible to increase the moment of inertia of the counterweight 32 as required, by a larger degree than that of the first embodiment, without causing interference between the counterweight 32 and a cylinder block 46 and a lower end face 36a of a piston 36. It is thus possible to effectively increase the moment of inertia without incurring a significant increase in the weight of the counterweight 32.

[0033] (II) In the weight portion 38 of the counterweight 32, a part of the profile of the weight portion 38 extends along the outer periphery of the piston-lower-end non-interference region Sb, namely, extends along an arc as a segment of an ellipse that defines the non-interference region Sb, unlike the first embodiment. However, the arc as a segment of the ellipse may be approximated by an arc as a segment of a circle whose center lies on an axis 42a of a crank pin 42 such that the region defined by this arc is contained in the piston-lower-end non-interference region Sb. Thus, if the profile of the weight portion 38 consists of two different arcs as segments of two circles, the weight portion 38 may be relatively easily formed by circle cutting about the axis 44a of the crank journal 44 and circle cutting about the axis 42a of the crank pin 42.

[0034] In this connection, the mass of the outer-radius extended portion 38a can be easily adjusted by adjusting the radius of cutting of the outer-radius extended portion 38a, as measured from the axis 44a of the crank journal 44, to a reduced radius.

[0035] Other embodiments of the invention will be explained. (a) In the first embodiment, the boundary line CL that defines the profile of the outer-radius extended portion is in the form of a circle whose center lies on the straight-line segment between the axis of the crank journal and the axis of the crank pin. Instead, a center 62a of the boundary line CL may be placed at a position that falls outside the segment between an axis 74a of a crank journal 74 and an axis 72a of a crank pin 72, as in a counterweight 62 as shown in FIG. 4. In this case, the circular boundary line CL is established in the form of a circle having the center 62a, and an outer-radius extended portion 68a of a weight portion 68 of the counterweight 62 is formed with its outer periphery provided by a part or the whole of the boundary line CL located within the overlapping region Sw.

[0036] In FIG. 4, the center 62a is placed at a position below the axis 72a of the crank pin 72, on a straight line Lb that passes the axis 74a of the crank journal 74 and the axis 72a of the crank pin 72. The boundary line CL is established in the form of a circle having the center 62a thus positioned.

[0037] FIG. 5A shows another example of counterweight 92 in which a center 92a is placed at any position between an axis 104a of a crank journal 104 and an axis 102a of a crank pin 102, on a straight line Lb that passes the axis 104a and the axis 102a. In this example, a boundary line CL is established in the form of a circle having the center 92a thus positioned, and an outer-radius extended portion 98a of a weight portion 98 is formed with its outer periphery provided by a part or the whole of the boundary line CL located within the overlapping portion Sw.

[0038] FIG. 5B shows a further example of counterweight 122 in which a center 122a lies on a straight line Lb that passes an axis 134a of a crank journal 134 and an axis 132a of a crank pin 132, to be located above the axis 134a of the crank journal 134a. In this example, a boundary line CL is established in the form of a circle having the center 122a thus positioned, and an outer-radius extended portion 128a of a weight portion 128 is formed with its outer periphery

provided by a part or the whole of the boundary line CL located within the overlapping portion Sw.

[0039] The arrangements of FIG. 4 and FIG. 5 make it possible to effectively increase the moment of inertia without incurring a significant increase in the weight of the counterweight.

[0040] (b) In the illustrated embodiments, the outer periphery of the outer-radius extended portion consists solely of an arc as a segment of a single circle, or is a combination of two varieties of arcs (a segment of an ellipse and a segment of a circle or segments of two different circles), as viewed in the axial direction of the crankshaft. However, the outer periphery of the outer-radius extended portion may be a combination of three or more varieties of arcs including segments of circle(s) and/or ellipse(s). The outer periphery of the outer-radius extended portion may not necessarily consist of a segment(s) of a circle(s) and/or an ellipse(s), but may be in other forms or shapes. For example, the outer periphery may have a rectangular shape. In any case, it is possible to effectively increase the moment of inertia without incurring a significant increase in the weight of the counterweight.

[0041] (c) In the illustrated embodiments, the whole of the outer-radius extended portion is located outside of the reference non-interference region Sa, and is contained in the overlapping region Sw. However, as in a counterweight 152 as shown in FIG. 6, outer-radius extended portions 158a may protrude radially outward from the outer circumferential portions of a weight portion 158 located inside of the reference non-interference region Sa. In this case, a portion of the outer-radius extended portion 158 which is located outside of the reference non-interference region Sa is entirely contained in the overlapping region Sw.

[0042] With the above arrangement, too, it is possible to effectively increase the moment of inertia without incurring a significant increase in the weight of the counterweight.

[0043] (d) The weight portion may not necessarily be formed integrally

with the outer-diameter extended portion from the beginning of formation of the counterweight, but a separately prepared outer-radius extended portion may be joined to the weight portion after it is formed.

[0044] With the above arrangement, too, it is possible to effectively increase the moment of inertia without incurring a significant increase in the weight of the counterweight.

[0045] The embodiments as described above are preferred embodiments of the invention. It is, however, to be understood that the invention is not limited to these embodiments, but may be otherwise embodied with various modifications or improvements, without departing from the principle of the invention.

CLAIMS:

1. A counterweight provided on a crankshaft of an internal combustion engine, characterized by comprising

a weight portion that extends radially from an axis of a crank journal in a direction opposite to a crank pin of the crankshaft,

wherein the weight portion is positioned in the internal combustion engine so as to be closer to a lower end face of a piston when placed at the bottom dead center than to a cylinder block when viewed in radial directions of the crankshaft, and the weight portion has an outer-radius extended portion at least a part of which is located outside of a reference non-interference region having a center that lies on the axis of the crank journal and a radius that is set to the maximum length with which the reference non-interference region does not interfere with the lower end face of the piston when placed at the bottom dead center; and

a portion of the outer-radius extended portion which is located outside of the reference non-interference region is located within an overlapping region between a cylinder-block non-interference region that is established around the crank journal so as not to interfere with the cylinder block, and a piston-lower-end non-interference region that is established around the crank pin so as not to interfere with the lower end face of the piston.

2. A counterweight according to claim 1, wherein

the piston-lower-end non-interference region is an elliptic region as viewed in an axial direction of the crankshaft, said elliptic region having a center that lies on an axis of the crank pin, a long radius that is set to the maximum length with which the piston-lower-end non-interference region does not interfere with the lower end face of the piston when placed at the bottom dead center or the top dead center, and a short radius that is set to the maximum length with which the piston-lower-end non-interference region does not interfere with the lower end face

of the piston when placed at an intermediate point between the bottom dead center and the top dead center.

3. A counterweight according to claim 1 or 2, wherein

the cylinder-block non-interference region is a circular region as viewed in an axial direction of the crankshaft, said circular region having a center that lies on the axis of the crank journal, and a radius that is set to the maximum length with which the cylinder-block non-interference region does not interfere with the cylinder block.

4. A counterweight according to any one of claims 1 to 3, wherein:

a boundary line having a circular shape as viewed in an axial direction of the crankshaft and passing the overlapping region is established around a center that lies on a straight line passing the axis of the crank journal and the axis of the crank pin; and

at least a part of an outer periphery of the outer-radius extended portion coincides with at least a part of the boundary line located within the overlapping region.

5. A counterweight according to any one of claims 1 to 3, wherein:

a boundary line having a circular shape as viewed in an axial direction of the crankshaft and passing the overlapping region is established around a center that lies on a point on a straight-line segment connecting the axis of the crank journal with the axis of the crank pin, said point being selected with exceptions of a point on the axis of the crank journal and a point on the axis of the crank pin; and

at least a part of an outer periphery of the outer-radius extended portion coincides with at least a part of the boundary line located within the overlapping region.

6. A counterweight according to any one of claims 1 to 3, wherein

a boundary line having a circular shape as viewed in an axial direction of the crankshaft and passing the overlapping region is established around a center that lies on a midpoint between the axis of the crank journal and the axis of the crank pin, said midpoint lying on a straight-line segment connecting the axis of the crank journal with the axis of the crank pin; and

at least a part of an outer periphery of the outer-radius extended portion coincides with at least a part of the boundary line located within the overlapping region.

7. An internal combustion engine including a cylinder block and a piston, characterized by comprising

a crankshaft provided with a counterweight that is positioned so as to be closer to a lower end face of the piston when placed at the bottom dead center than to the cylinder block when viewed in radial directions of the crankshaft, wherein:

the counterweight has a weight portion that extends radially from an axis of a crank journal in a direction opposite to a crank pin of the crankshaft;

the weight portion has an outer-radius extended portion at least a part of which is located outside of a reference non-interference region having a center that lies on the axis of the crank journal and a radius that is set to the maximum length with which the reference non-interference region does not interfere with the lower end face of the piston when placed at the bottom dead center; and

a portion of the outer-radius extended portion which is located outside of the reference non-interference region is located within an overlapping region between a cylinder-block non-interference region that is established around the crank journal so as not to interfere with the cylinder block, and a piston-lower-end non-interference region that is established around the crank pin so as not to interfere with the lower end face of the piston.

FIG. 1B

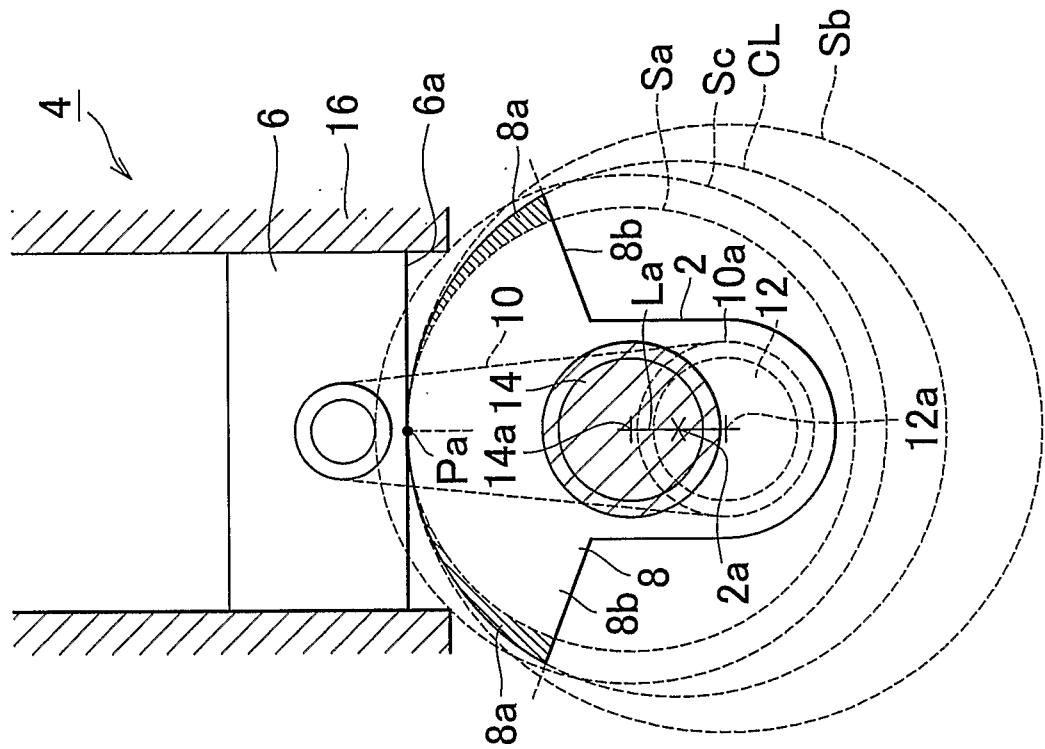


FIG. 1A

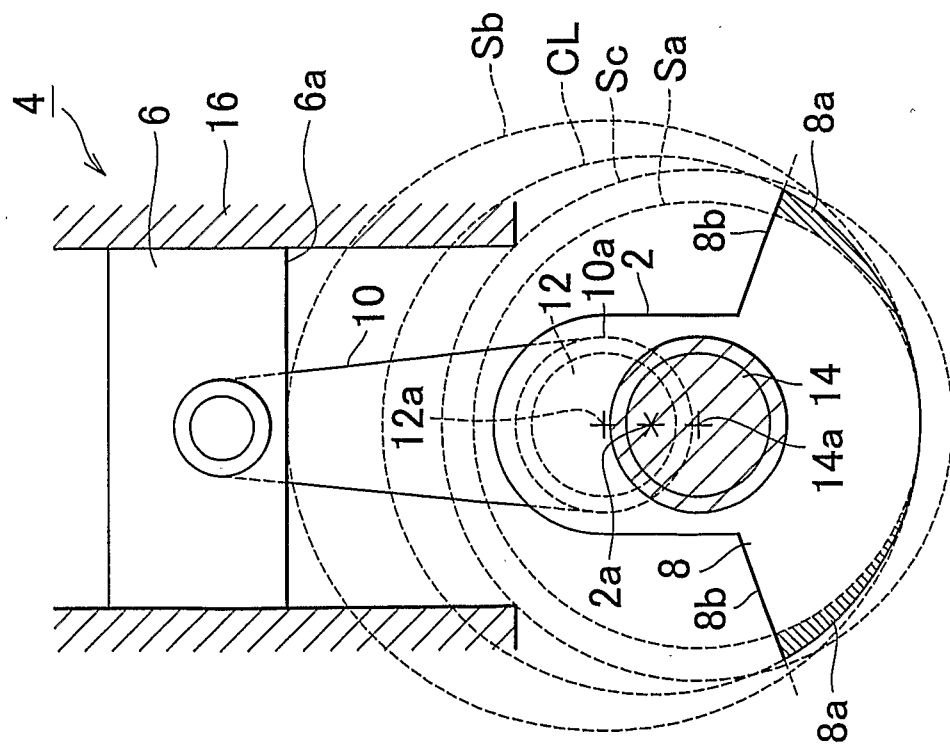


FIG. 2

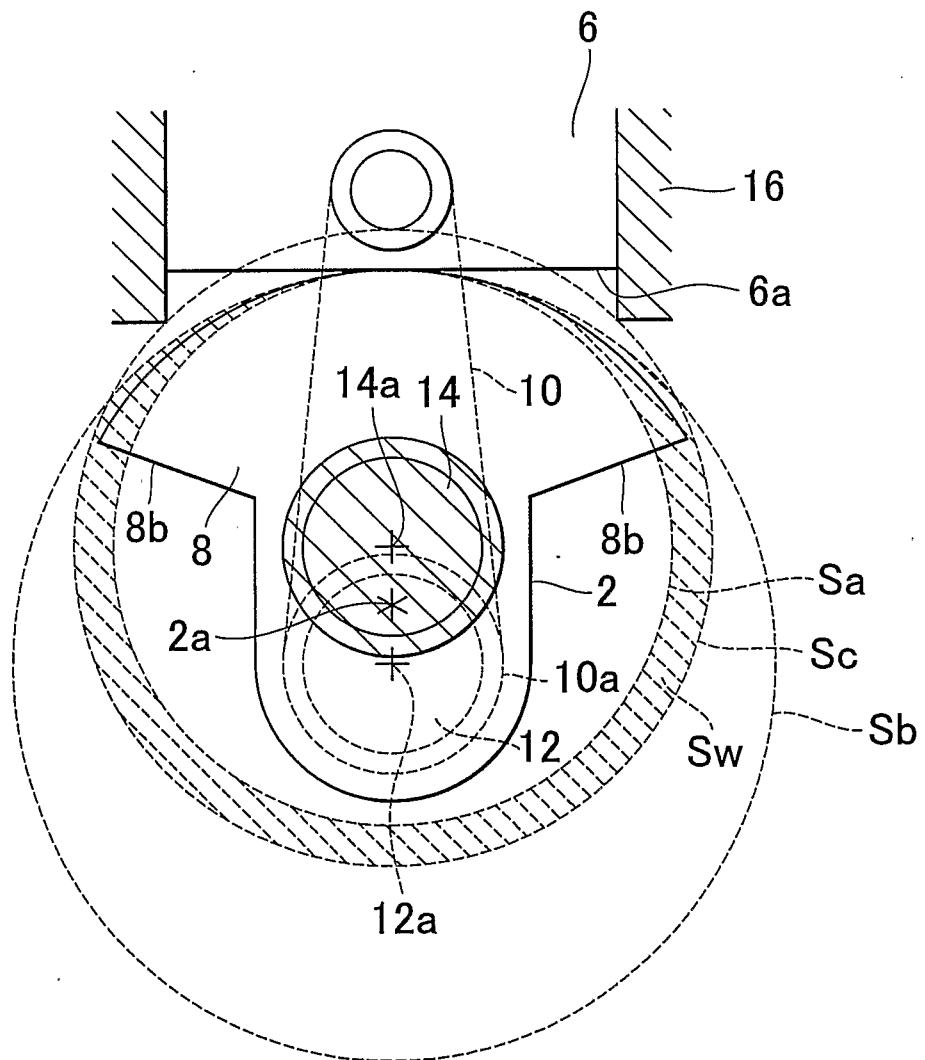


FIG. 4

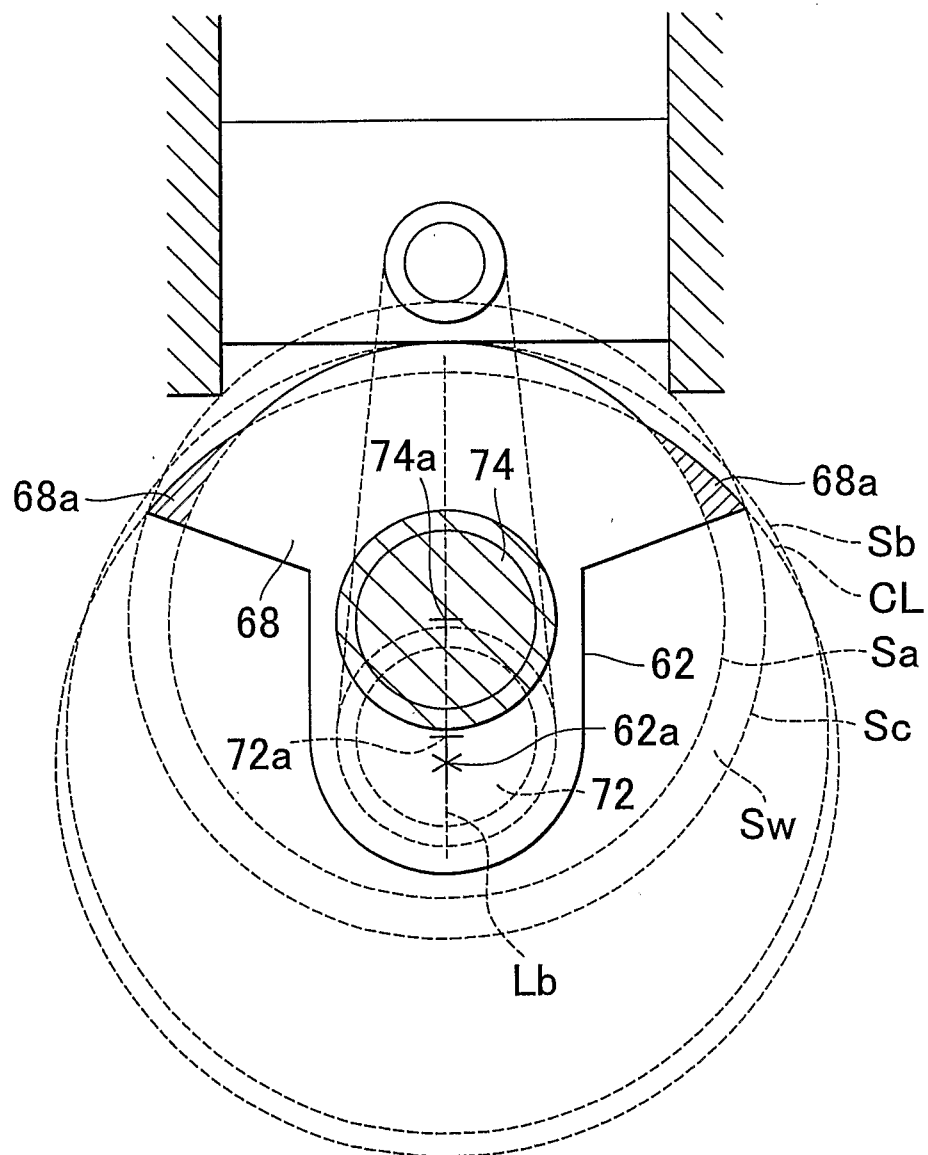


FIG. 5A

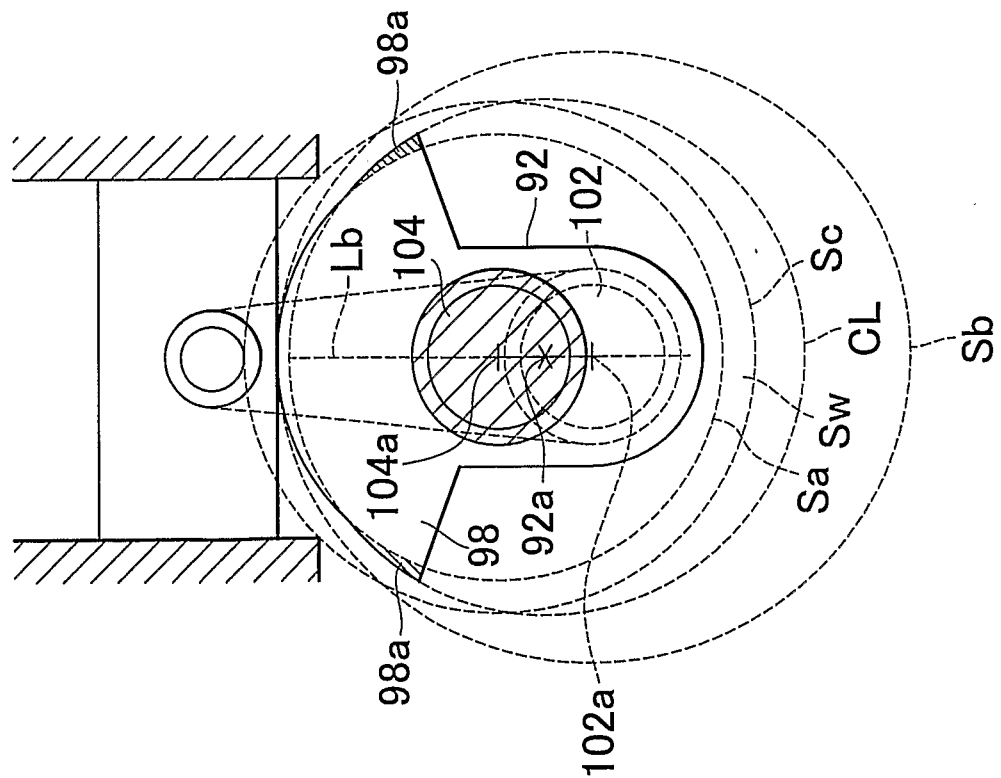


FIG. 5B

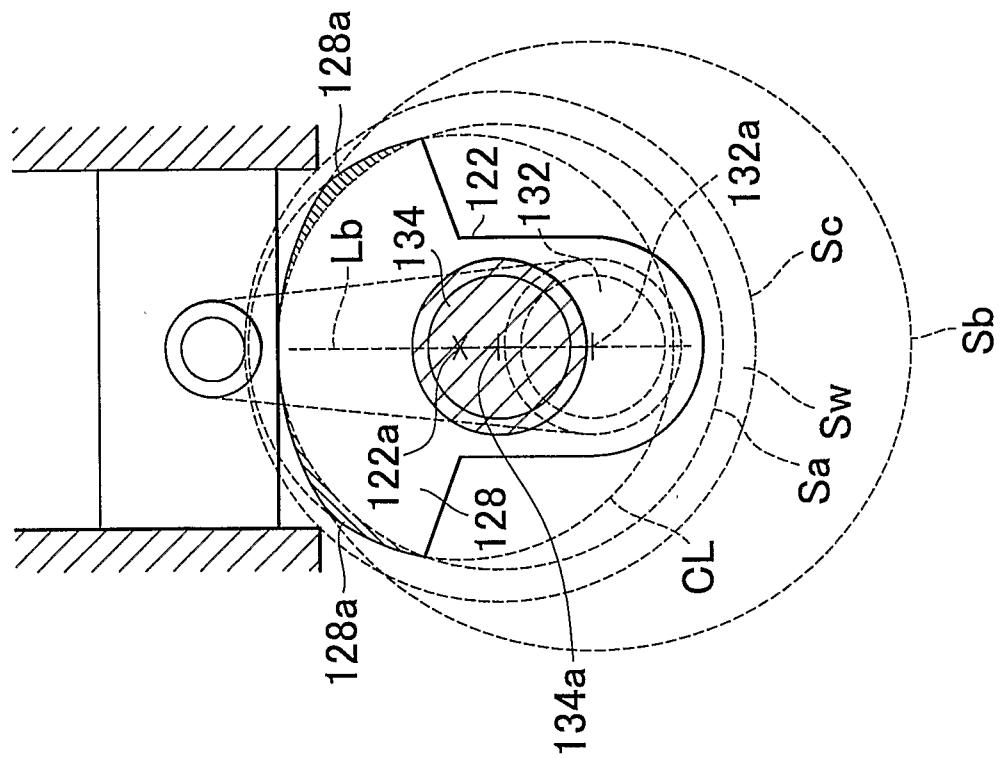


FIG. 6

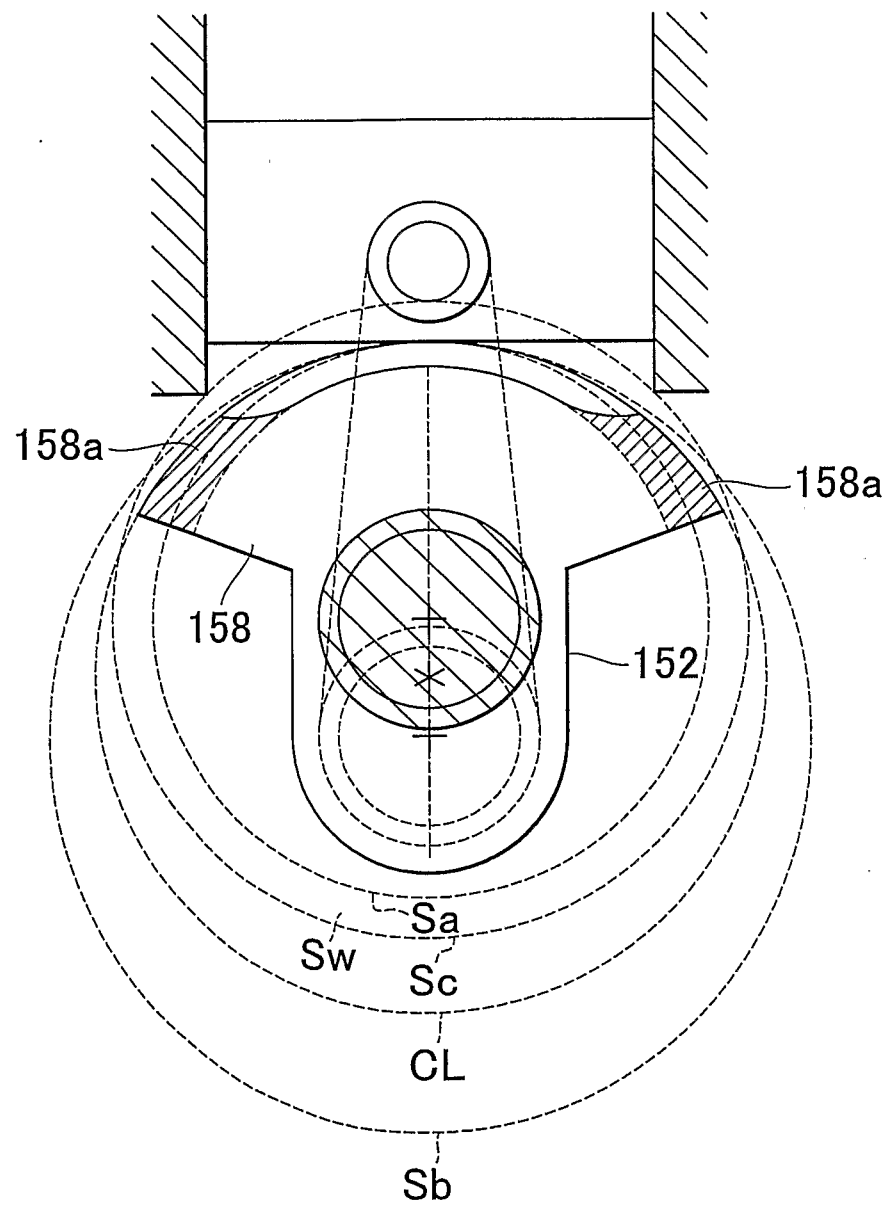


FIG. 7

