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(54) A reciprocating piston mechanism

(57) A reciprocating piston mechanism (1) comprises a crankcase (2), a crankshaft (3) which has at least a crankpin. The crankshaft (3) is supported by the crankcase (2). The mechanism (1) further comprises at least a connecting rod including a big end and a small end, a piston (12) being rotatably connected to the small end, a crank member (7) being rotatably mounted on the crankpin, and comprising at least a bearing portion (8) which is eccentrically disposed with respect to the crankpin, and having an outer circumferential wall which bears the big end of the connecting rod such that the connecting rod is rotatably mounted on the bearing portion (8) of the crank member (7) via the big end. The mechanism (1) further comprises a gear (13) which is fixed to the crank member (7), and an internal ring gear (14) which is disposed concentrically with respect to the crankshaft axis and which is fixed to and carried by an internal ring gear carrier (15). The gear (13) meshes with the internal ring gear (14) for rotating the crank member (7) with respect to the crankpin upon rotation of the crankshaft (3). The internal ring gear carrier (15) is connected to the crankcase (2) at an axial distance of the internal ring gear (14) and free from the crankshaft (3).

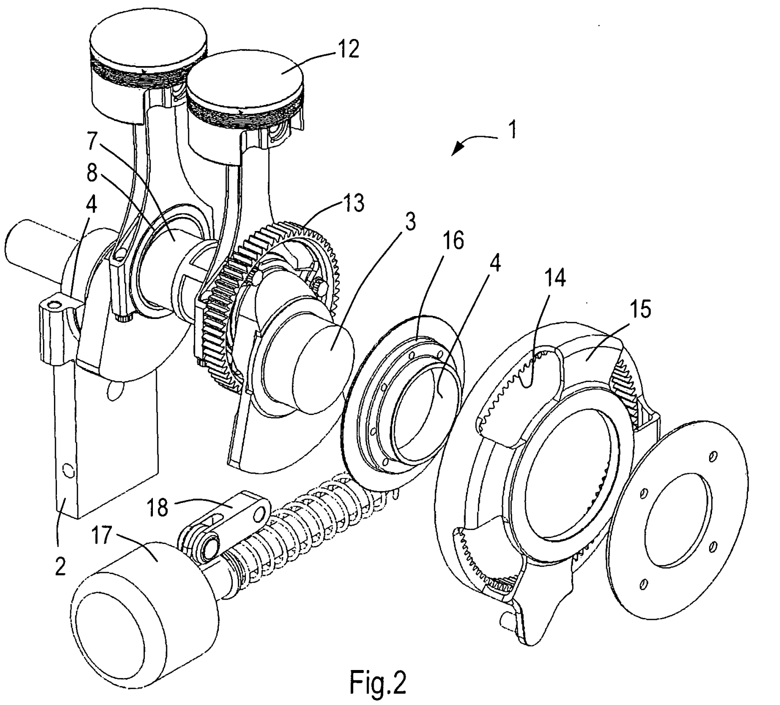

Fig.2

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Description

[0001] The present invention relates to a reciprocating piston mechanism comprising a crankcase; a crankshaft having at least a crankpin, said crankshaft being supported by the crankcase and rotatable with respect thereto about a crankshaft axis; at least a connecting rod including a big end and a small end; a piston being rotatably connected to the small end; a crank member being rotatably mounted on the crankpin, and comprising at least a bearing portion which is eccentrically disposed with respect to the crankpin, and having an outer circumferential wall which bears the big end of the connecting rod such that the connecting rod is rotatably mounted on the crank member via the big end; a gear which is fixed to the crank member; and an internal ring gear which is carried by a ring gear carrier and disposed concentrically with respect to the crankshaft axis with which the gear meshes for rotating the crank member with respect to the crankpin upon rotation of the crankshaft.

[0002] Such a reciprocating piston mechanism is known from WO 96/27079. The prior art piston mechanism has a crank-connecting rod mechanism which makes variable compression possible. The internal ring gear is rotatably connected to the crankshaft and its rotational position is adjustable by control means. A disadvantage of the prior art mechanism is its relatively high internal friction losses.

[0003] The present invention aims to improve the mechanical efficiency of the reciprocating piston mechanism.

[0004] For this purpose the ring gear carrier is connected to the crankcase at an axial distance of the internal ring gear and free from the crankshaft.

[0005] Due to these features the ring gear carrier is not continuously in contact with the rotating crankshaft during operation of the mechanism, which leads to minimized friction losses. Since the ring gear carrier is connected to the crankcase at an axial distance of the internal ring gear the mechanism provides the opportunity to avoid fitting of the carrier in the crankcase in radial direction of the internal ring gear; the latter would require accurate machining of the crankcase, which appears to be difficult in practice, certainly in case when this part of the crankcase is composed of two separate parts.

[0006] In a practical embodiment the internal ring gear carrier is connected to a side wall of the crankcase, which extends substantially perpendicularly to the crankshaft axis. This configuration is relatively easy to manufacture and to assemble. It is, for example, possible to prepare at least a portion of the side wall as a separate part before assembly.

[0007] The internal ring gear carrier may be connected to the crankcase at a supporting portion thereof which is located between the crankshaft and the internal ring gear as seen in radial direction of the crankshaft axis. This means that the supporting portion lies within the projected circumference of the internal ring gear which makes accurate manufacturing thereof more reliable, because of the relatively small dimensions of the supporting portion.

[0008] Preferably, the supporting portion is adjacent to a crankshaft bearing for supporting the crankshaft, because this results in efficient use of the space around the crankshaft bearing.

[0009] The internal ring gear carrier may be rotatably connected to the crankcase. This provides advantageous operating possibilities, such as variable compression ratio.

[0010] The internal ring gear carrier may be connected to a centring element on the crankcase having a circular outer circumferential wall which bears the internal ring gear carrier. Preferably, the centring element is made of one part. This embodiment has the advantage that the centring element can be made with high accuracy; it can be made by a turning operation, for example.

[0011] In an alternative embodiment the crankshaft comprises at least two crankpins which are angularly spaced with respect to each other about the crankshaft axis, and at least two respective crank members, gears and internal ring gears.

[0012] The internal ring gear carriers can be disposed between the crankpins as seen along the crankshaft axis. Preferably, the internal ring gear carriers are fixed to each other so as to operate both carriers at the same time.

[0013] The internal ring gear carriers may be disposed near end portions of the crank members facing in opposite directions as seen along the crankshaft axis. This has the advantage that the mechanism can be maintained compact between the crankpins in axial direction.

[0014] A driving means can be connected to the internal ring gear carrier, wherein the driving means may be adapted such that, under operating conditions, it rotates the internal ring gear carrier in a rotational direction similar to that of the crankshaft at a predetermined rotation frequency. This is an advantageous embodiment since it provides the opportunity to select the ratio of gear diameter and internal ring gear diameter and the rotation frequency and rotational direction of the internal ring gear such that the crank member rotates at half speed of the crankshaft speed. A lot of variations are possible, for example a combination wherein the crank member rotates about the crankpin in opposite direction of that of the crankshaft, but also a combination wherein the crank member rotates about the crankpin in the same direction of that of the crankshaft. In the latter case this means that the crank member has the same rotational speed with respect to the crankcase as above, but in opposite direction compared to those cases. Thus, the speed difference between the crank member and the crankpin as well as between the teeth of the gear and the internal ring gear is smaller due to driving the internal ring gear in the same direction as the crankshaft. As a consequence, the friction losses between the crank member and the crankpin is reduced, as well as the noise production due to the lower speed difference between the teeth of the gear and the internal ring gear.

[0015] Both conditions of the rotational direction of the crank member with respect to the crankpin and the relation to the dimensions of the gear and internal ring gear can be clarified by the following examples.

[0016] When driving the internal ring gear at 1/6 of the speed of the crankshaft and in the same direction thereof, and the ratio between the diameter of the internal ring gear and the diameter of the gear is 1.8, the rotation frequency of the crank member about its axis of rotation is a half of the crankshaft speed and in opposite direction thereof. This means, for example, that the diameter of the gear may be 2.5 times and the diameter of the internal ring gear 4.5 times the crank radius. Thus, in this case the speed difference between the crank member and the crankpin is similar to the case in which the internal ring gear does not rotate as described in the above-mentioned cases. The advantage of a combination of the selected speed of the internal ring gear, and the ratio between the diameter of the internal ring gear and the diameter of the gear such as chosen in this example is that the piston stroke of the mechanism can be increased without increasing the diameter of the internal ring gear. In other words, a longer piston stroke requires an increased crank length. Without increasing the diameter of the internal ring gear, the diameter of the gear must be reduced. This would mean that the gear rotates at a higher speed than a half of the crankshaft speed if the internal ring gear is not rotated. The desired gear speed is achieved by driving the internal ring gear in the same direction as the crankshaft. It is noted that the values mentioned hereinbefore are not limiting in respect of the scope of the invention. Numerous other combinations are conceivable.

[0017] When driving the internal ring gear at 7/10 of the speed of the crankshaft and in the same direction thereof, and the ratio between the diameter of the internal ring gear and the diameter of the gear is 1.66, the rotation frequency of the crank member about its axis of rotation is a half of the crankshaft speed, but in the same direction thereof. This means, for example, that the diameter of the gear may be 3 times and the diameter of the internal ring gear 5 times the crank radius. Thus, in this case the speed difference between the crank member and the crankpin is reduced by 2/3 with respect to the above-mentioned cases, resulting in lower friction losses. Similarly, the relative speeds of the gear and internal ring gear with respect to each other are 2/3 lower resulting in a lower noise level and friction. Since the internal ring gear carrier is driven in the same direction as the crankshaft, there is a relatively small speed difference between the internal ring gear carrier and the crankshaft. Therefore, it may be useful to support the internal ring gear carrier directly by the crankshaft. This will be dealt with hereinafter.

[0018] Preferably, the driving means is formed by the crankshaft which drives the internal ring gear carrier by a transmission, because this is efficient and provides a compact mechanism.

[0019] The invention also relates to a reciprocating piston mechanism comprising a crankcase; a crankshaft having at least a crankpin, said crankshaft being supported by the crankcase and rotatable with respect thereto about a crankshaft axis; at least a connecting rod including a big end and a small end; a piston being rotatably connected to the small end; a crank member being rotatably mounted on the crankpin, and comprising at least a bearing portion which is eccentrically disposed with respect to the crankpin, and having an outer circumferential wall which bears the big end of the connecting rod such that the connecting rod is rotatably mounted on the bearing portion of the crank member via the big end; a gear which is fixed to the crank member; and an internal ring gear which is disposed concentrically with respect to the crankshaft axis and which is rotatable with respect to the crankcase and the crankshaft, wherein the gear meshes with the internal ring gear for rotating the crank member with respect to the crankpin upon rotation of the crankshaft, wherein a driving means is connected to the internal ring gear for rotating the internal ring gear in similar rotational direction as the crankshaft, and the diameters of the gear and the internal ring gear and the rotation frequency of the internal ring gear are selected such that, under operating conditions, the crank member rotates about its axis of rotation at a rotation frequency which is substantially half of that of the crankshaft.

[0020] The diameters of the gear and the internal ring gear and the rotation frequency of the internal ring gear can be selected such that, under operating conditions, the crank member rotates about its axis of rotation in similar direction of the crankshaft. This reduces the friction losses between the crank member and the crankpin.

[0021] In a practical embodiment the ratio between the diameter of the internal ring gear and the diameter of the gear is substantially 1.66 and the rotation frequency of the internal ring gear is selected at substantially 7/10 of that of the crankshaft. This appears to be a good compromise between diameters of the gear and internal ring gear and the driving speed thereof. A smaller gear diameter leads to a higher required rotation frequency of the internal ring gear, if the crank member must rotate at half speed of the crankshaft speed and in similar direction thereof.

[0022] Alternatively, the diameters of the gear and the internal ring gear and the rotation frequency of the internal ring gear can be selected such that, under operating conditions, the crank member rotates about its axis of rotation in opposite direction of the crankshaft.

[0023] In a practical embodiment the ratio between the diameter of the internal ring gear and the diameter of the gear is substantially 1.8 and the rotation frequency of the internal ring gear is selected at substantially 1/6 of that of the crankshaft.

[0024] The internal ring gear may be rotationally connected to the crankshaft. In the case of a driven internal ring gear as described hereinbefore the friction losses between the internal ring gear and the crankshaft are relatively small because of the small speed difference between the internal ring gear and the crankshaft.

[0025] The crankshaft may comprise at least two crankpins which are angularly spaced with respect to each other about the crankshaft axis, and at least two respective crank members, wherein a first one of the crank members is provided with the gear which meshes with the internal ring gear, and a second one of the crank members is rotatably connected with the first one via a transmission which is adapted such that the second one rotates at the same rotation frequency as the first one. This embodiment is compact since the second one of the crank members is not provided with a combination of a gear and internal ring gear.

[0026] The transmission may comprise first transmission gears and second transmission gears, wherein each of the crank members is provided with at least one of the first transmission gears which is concentrically fixed to the crank member, wherein each first transmission gear meshes with one of the second transmission gears, wherein the second transmission gears are fixed to each other via a shaft which is rotatably connected to the crankshaft and rotatable about the crankshaft axis. This is a relatively simple configuration.

[0027] The invention also relates to a reciprocating piston mechanism comprising a crankcase, a crankshaft having at least a crankpin, said crankshaft being supported by the crankcase and rotatable with respect thereto about a crankshaft axis, at least a connecting rod including a big end and a small end, a piston being rotatably connected to the small end, a crank member being rotatably mounted on the crankpin, and comprising at least a bearing portion which is eccentrically disposed with respect to the crankpin, and having an outer circumferential wall which bears the big end of the connecting rod such that the connecting rod is rotatably mounted on the bearing portion of the crank member via the big end, a first transmission gear which is fixed to the crank member, and a second transmission gear which is disposed concentrically with respect to the crankshaft axis and which is rotatably mounted to the crankshaft, wherein the first transmission gear meshes with the second transmission gear for rotating the crank member with respect to the crankpin, wherein a driving means is connected to the second transmission gear for rotating the second transmission gear upon rotation of the crankshaft, wherein the diameters of the first and second transmission gears and the rotational speed of the second transmission gear are selected such that, under operating conditions, the crank member rotates about its axis of rotation at a rotation frequency which is substantially half of that of the crankshaft. The advantage of this mechanism is that an internal ring gear is not required, such that sufficient space is created in the crankcase for designing a mechanism having a long piston stroke.

[0028] The driving means may be formed by the crankshaft which drives the second transmission gear via a transmission for efficient use of the available space within the crankcase.

[0029] The invention will hereafter be elucidated with reference to the schematic drawings showing embodiments of the invention by way of example.

Fig. 1 is a perspective view of an embodiment of a reciprocating piston mechanism according to the invention.

Fig. 2 is a perspective and partly exploded view of the embodiment of Fig. 1 on a smaller scale.

Fig. 3 is a perspective view of the embodiment of Fig. 1 as seen from a different side.

Fig. 4 is a side view of the embodiment of Fig. 1.

Fig. 5 is a perspective and partly exploded view of an embodiment comparable to that of Fig. 1-4, but illustrating an alternative configuration of the internal ring gear carrier.

Fig. 6 is a perspective view of an alternative embodiment of a reciprocating piston mechanism according to the invention.

Fig. 7 is a perspective and exploded view of a part of the embodiment of Fig. 6.

Fig. 8 is a perspective and partly exploded view of the embodiment of Fig. 6 on a smaller scale.

Fig. 9 is a perspective view of another alternative embodiment of a reciprocating piston mechanism according to the invention.

Fig. 10 is a perspective view of the embodiment of Fig. 9 as seen from a different side.

Fig. 11 is a perspective view of still another alternative embodiment of a reciprocating piston mechanism according to the invention.

Fig. 12 is a side view of the embodiment of Fig. 11.

Fig. 13 is a perspective and exploded view of the crankshaft of the embodiment of Fig. 11.

Fig. 14 is a perspective view of a part of still another alternative embodiment of a reciprocating piston mechanism.

Fig. 15 is a perspective view of a part of the embodiment of Fig. 14 on enlarged scale.

Fig. 16 is a perspective view of still another alternative embodiment of a reciprocating piston mechanism.

[0030] Fig. 1 shows a two-cylinder internal combustion engine comprising an embodiment of a reciprocating piston mechanism 1 according to the invention. The reciprocating piston mechanism 1 comprises a crankcase 2, which supports a crankshaft 3 by crankshaft bearings 4. The crankshaft 3 in the embodiment has a crankpin 5 (invisible in Fig. 1) and is rotatable with respect to the crankcase 2 about a crankshaft axis 6.

[0031] Furthermore, the mechanism 1 comprises a crank member 7 which is rotatably mounted on the crankpin 5. The crank member 7 is provided with two bearing portions 8 which are disposed eccentrically with respect to the crankpin 5. Each of the bearing portions 8 has an outer circumferential wall which bears a big end 9 of a connecting rod 10. Thus, the connecting rod 10 is rotatably mounted on the crank member 7 via the big end 9. The connecting rod 10 also includes a small end 11 to which a piston 12 is rotatably connected.

[0032] The mechanism 1 is provided with a gear 13 which is fixed to the crank member 7 and meshes with an internal ring gear 14 which is disposed concentrically with respect to the crankshaft axis 6. As a consequence, when the crankshaft 3 is rotated the crank member 7 will be rotated through the gear 13 which rotates along the internal ring gear 14. The gear 13 is located at an axial end of the crankpin 5. This location has an advantage since the radial displacement of the crankshaft 3 is less than at a location of the crank member 7 between the connecting rods 10, because this location is closer to a crankshaft bearing. This means that less vibrations are transmitted to the internal ring gear 14 during engine running.

[0033] In this embodiment the ratio between the gear diameter and the internal ring gear diameter is 2:3, which means that the crank member 7 rotates once upon two revolutions of the crankshaft 3 and in opposite direction with respect to the crankshaft 3. More details about the advantages and the opportunities provided by the mechanism 1 are described in the European patent EP 1 080 320.

[0034] Fig. 2 shows the embodiment of the mechanism 1 when it is in partly disassembled condition. It can be seen that the internal ring gear 14 is fixed to and carried by an internal ring gear carrier 15. In this case the internal ring gear 14 and the internal ring gear carrier 15 are integrated as a single part. The internal ring gear carrier 15 is connected to the crankcase 2 at an axial distance of the internal ring gear 14. This has an advantage compared to a configuration in which the internal ring gear 14 is directly connected to the crankcase 2 in radial direction of the internal ring gear 14 since such a configuration would require accurate machining of the crankcase 2 at that location in order to position the internal ring gear 14 in the crankcase 2 concentrically with respect to the crankshaft axis 6. In Fig. 1 it is shown that the internal ring gear carrier 15 is connected to a side wall 2a of the crankcase 2. The side wall extends substantially perpendicularly to the crankshaft axis 6 in this case.

[0035] In Fig. 2 it can be seen that the internal ring gear carrier 15 is connected to a centring element or a supporting portion 16 which is fixed to the crankcase 2. In this case the centring element is made of one part, but this may be different in practice. In assembled condition the supporting portion 16 is located between the crankshaft 3 and the internal ring gear 14 as seen in radial direction of the crankshaft axis 6, see Fig. 3. More specifically, the supporting portion 16 is located close to the crankshaft bearing 4, which supports the crankshaft 3. The internal ring gear carrier 15 is supported by the supporting portion 16 having a circular outer circumferential wall which contacts a circular inner wall of the internal ring gear carrier 15. Due to this configuration the internal ring gear carrier 15 is free from the crankshaft 3, which means that there are no friction losses between the internal ring gear carrier 15 and the crankshaft 3. This appears to result in a relatively simple and a stable concentrical positioning of the internal ring gear 14 with respect to the crankshaft axis 6. Besides, this location and configuration of the supporting portion 16 provides the opportunity to rotatably connect the internal ring gear carrier 15 to the crankcase 2. The supporting portion 16 in combination with the crankshaft bearing 4 can be easily manufactured by a turning operation and integrated in the crankcase 2.

[0036] Fig. 1-4 further show an actuator 17 which is connected to the internal ring gear carrier 15 via a rod 18. Upon displacement of the actuator 17 the internal ring gear carrier 15 will be rotated within a certain angle about the crankshaft axis 6.

[0037] Fig. 5 shows an alternative embodiment of the internal ring gear carrier 15 having radial projections 19 facing the crankshaft axis 6 in assembled condition. The crankcase 2 is provided with radial counter projections 20 facing away from the crankshaft axis 6 in assembled condition. The angular position of the projections 19 and counter projections 20 determine the limits of the angle of rotation of the internal ring gear carrier 15 with respect to the crankcase 2. This part of the mechanism 1 may function in the same way as hydraulic cam phasers, known in internal combustion engines.

[0038] Fig. 6 shows an alternative embodiment of a reciprocating piston mechanism 1. In this embodiment the crankshaft 3 comprises two crankpins 5 which are angularly spaced with respect to each other about the crankshaft axis 6. Furthermore, it comprises two crank members 7 (not shown), gears 13 (not shown) and internal ring gears 14, each fixed to and carried by internal ring gear carriers 15.

[0039] In this case the internal ring gear carriers 15 are disposed between the crankpins 5 as seen along the crankshaft axis 6. Furthermore, the internal ring gear carriers 15 are fixed to each other.

[0040] Both internal ring gear carriers 15 are rotatably connected to the supporting portion 16 which is fixed to the crankcase 2 by bolts which, in practice, fix the cylinder head to the crankcase 2, as well. In assembled condition the bolts fit in the holes 21, see Fig. 6-8. The cylindrical through-hole in the supporting portion 16 functions as a crankshaft bearing 4. In this embodiment the crankshaft 3 is composed of two separate parts, such as illustrated in Fig. 8.

[0041] Alternatively, the internal ring gear carriers 15 can be disposed near end portions of the crank members 7 which face in opposite directions as seen along the crankshaft axis 6 (this embodiment is not shown).

[0042] Fig. 9 and 10 show perspective views from different sides of another alternative embodiment of a reciprocating piston mechanism 1 having one crank member 7 including two bearing portions 8, one gear 13 and one internal ring gear 14 and corresponding internal ring gear carrier 15. In this embodiment the internal ring gear 14 is rotatable with respect to the crankshaft 3 and is connected to the crankshaft 3 via a transmission 22 so as to drive the internal ring gear 14 in similar rotational direction as the crankshaft 3. Thus, the crankshaft 3 functions as a driving means for rotating the internal ring gear 14 in this case. The transmission 22 comprises chain wheels 23 and chains 24, and an auxiliary shaft 25 in this embodiment, but alternative transmissions are conceivable. It is noted that the auxiliary shaft 25 can be applied for driving other parts of an internal combustion engine, such as the oil pump.

[0043] In the embodiment shown in Fig. 9 the ratio between the diameter of the internal ring gear 14 and the diameter of the gear 13 is 1.5. In practice the rotation frequency of the internal ring gear 14 may be selected at 2/3 of that of the crankshaft 3. This means that under operating conditions the rotation frequency of the crank member 7 about its axis of rotation is a half of the rotation frequency of the crankshaft 3 and in similar direction thereof.

[0044] A similar rotation frequency and rotational direction of the crank member can be achieved with a different combination of the ratio between diameters of the gear 13 and internal ring gear 14 and rotation frequency of the internal ring gear 14.

[0045] In an embodiment of the mechanism 1 in which the internal ring gear 14 is driven in the same rotational direction as the crankshaft 3 it is not necessary that the internal ring gear 14 is rotationally connected to the crankcase 2, but it is also possible to connect it rotationally to the crankshaft 3, since the difference in rotational speed between the internal ring gear 14 or internal ring gear carrier 15 and the crankshaft 3 is relatively small in this case. This means that the friction losses between the crankshaft 3 and the internal ring gear 14 or internal ring gear carrier 15 are relatively low.

[0046] Fig. 11 and 12 show an embodiment of mechanism 1 which comprises four crankpins 5. Each crankpin 5 supports a crank member 7 which in turn supports the big end 9 of a connecting rod 10. The embodiment further comprises two pairs of drivable internal ring gear carriers 15. The internal ring gear carriers 15 of each pair are fixed to each other. Between each pair of internal ring gears 15 a chain wheel 23 is fixed to the carriers 15 for driving the internal ring gear 14 via the chains 24, the auxiliary shaft 25 and other chain wheels 23. In this embodiment the crankshaft 3 can be composed of three separate parts, wherein separations are located where the internal ring gear carriers 15 are supported by the supporting portion 16 of the crankcase 2 or by the crankshaft 3, see Fig. 13. If the internal ring gear carriers 15 are supported by the crankshaft 3 there is more space for the chain wheel 23 and chain 24 between the pair of internal ring gear carriers 15 when maintaining the cylinder distance.

[0047] It is also possible to have a four-cylinder mechanism which includes two crankpins 5 which are angularly spaced with respect to each other about the crankshaft axis 6, and wherein a pair of internal ring gear carriers 15 are supported at a location between the crankpins 5 in axial direction of the crankshaft 3. In that case, the crankshaft 3 can be composed of two parts, whereas the separation is located between the crankpins 5 in axial direction of the crankshaft 3. This embodiment is not shown.

[0048] Fig. 14 shows a part of a mechanism including an alternative transmission 22. In this case the mechanism includes two adjacent crankpins 5 as seen along the crankshaft axis 6 which are angularly spaced with respect to each other about the crankshaft axis 6. In Fig. 14 a first crank member 7' disposed at an end portion of the crankshaft 3 is provided with one bearing portion 8, one first transmission gear 26 and the gear 13 which meshes with the internal ring gear 14, which may be drivable. A second crank member 7", which is adjacent to the first crank member 7' as seen along the crankshaft axis 6 is provided with one bearing portion 8 and two first transmission gears 26. The transmission gears 26 are each concentrically fixed to the crank members 7', 7". Furthermore, the embodiment of Fig. 14 is also provided with second transmission gears 27. The second transmission gears 27 are fixed to each other via a shaft which is rotatably connected to the crankshaft 3 and rotatable about the crankshaft axis 6. When the first crank member 7' is rotated upon rotation of the crankshaft 3 the rotation of the first crank member 7' will be transmitted to the second crank member 7" and to the other crank members of the mechanism 1 through the first and second transmission gears 26, 27. In this case only one gear 14 and internal ring gear 14 is required, which saves space. The internal ring gear 14 may be disposed at a location nearby the flywheel of the engine.

[0049] Fig. 15 shows an enlarged perspective view of the first and second transmission gears 26, 27 mounted on the crankshaft 3.

[0050] Fig. 16 shows an embodiment of a two-cylinder engine including one crankpin 5, wherein the crank member 7 is provided with a first transmission gear 26 which meshes with a second transmission gear 27. In this embodiment the crank member 7 is not driven by a rotatably driven internal ring gear, but via an alternative transmission 22. A first chain wheel 28 is fixed to the crankshaft 3 and drivably connected to a second chain wheel 29, which is mounted to a first auxiliary shaft 30. On the auxiliary shaft 30 a third chain wheel 31 is fixed. The third chain wheel 31 is drivably connected to a fourth chain wheel 32 which is mounted to a second auxiliary shaft 33. The second auxiliary shaft 33 is rotatably connected to the crankshaft 3 and is rotatable about the crankshaft axis 6. The second transmission gear 27 is fixed to the second auxiliary shaft 33.

[0051] Under operating conditions the crankshaft 3 drives the crank member 7 via the transmission 22. Preferably, the transmission 22 and the diameter of the first transmission gear 26 are adapted such that the crank member 7 rotates at a rotational speed which is a half of the rotational speed of the crankshaft 3 and in similar direction thereof. This is for example possible when the transmission 22 is designed such that the second auxiliary shaft 33 rotates at a rotational speed which is 1.7 times the crankshaft speed and the diameter of the first transmission gear 26 is 1.5 times that of the second transmission gear 27.

[0052] The fourth chain wheel 32 includes an adjusting member, for example a cam phaser-like mechanism to enable the crank member to be rotatable with respect to the first auxiliary shaft 30 such that its rotational position may be varied with respect to a certain rotational position of the crankshaft 3.

[0053] It is noted that the transmission as shown in Fig. 16 may be different in order to achieve the same conditions for the crank member 7, for example by planetary gearing. Furthermore, the first auxiliary shaft 30 may be used for driving other auxiliary parts of the engine. The embodiment of Fig. 16 is typically suitable for long-stroke engines, since the mechanism is not limited by a maximum allowable diameter of an internal ring gear.

[0054] From the foregoing, it will be clear that the invention provides a reciprocating piston mechanism with a high mechanical efficiency.

[0055] The invention is not limited to the embodiments shown in the drawings and described hereinbefore, which may be varied in different manners within the scope of the claims and their technical equivalents. For example, the reciprocating piston mechanism may be used for other piston engines such as a piston compressor. Furthermore, the features of the different embodiments may be combined.

Claims

1. A reciprocating piston mechanism (1) comprising

a crankcase (2);
a crankshaft (3) having at least a crankpin (5), said crankshaft (3) being supported by the crankcase (2) and rotatable with respect thereto about a crankshaft axis (6);
at least a connecting rod (10) including a big end (9) and a small end (11);
a piston (12) being rotatably connected to the small end (11);
a crank member (7) being rotatably mounted on the crankpin (5), and comprising at least a bearing portion (8) which is eccentrically disposed with respect to the crankpin (5), and having an outer circumferential wall which bears the big end (9) of the connecting rod (10) such that the connecting rod (10) is rotatably mounted on the bearing portion (8) of the crank member (7) via the big end (9);
a gear (13) which is fixed to the crank member (7); and
an internal ring gear (14) which is disposed concentrically with respect to the crankshaft axis (6) and which is fixed to and carried by an internal ring gear carrier (15) and, wherein the gear (13) meshes with the internal ring gear (14) for rotating the crank member (7) with respect to the crankpin (5) upon rotation of the crankshaft (3),
characterized in that the internal ring gear carrier (15) is connected to the crankcase (2) at an axial distance of the internal ring gear (14) and free from the crankshaft (3).

2. A reciprocating piston mechanism according to claim 1, wherein the internal ring gear carrier (15) is connected to a side wall (2a) of the crankcase (2) extending substantially perpendicularly to the crankshaft axis (6).

3. A reciprocating piston mechanism according to claim 1 or 2, wherein the internal ring gear carrier (15) is connected to the crankcase (2) at a supporting portion (16) thereof which is located between the crankshaft (3) and the internal ring gear (14) as seen in radial direction of the crankshaft axis (6).

4. A reciprocating piston mechanism according to claim 3, wherein the supporting portion (16) is adjacent to a crankshaft bearing for supporting the crankshaft (3).

5. A reciprocating piston mechanism according to one of the preceding claims, wherein the internal ring gear carrier (15) is rotatably connected to the crankcase (2).

6. A reciprocating piston mechanism according to one of the preceding claims, wherein the internal ring gear carrier (15) is connected to a centring element on the crankcase (2) having a circular outer circumferential wall which bears the internal ring gear carrier, wherein the centring element is preferably made of one part.

7. A reciprocating piston mechanism according to one of the preceding claims, wherein the crankshaft (3) comprises at least two crankpins (5) which are angularly spaced with respect to each other about the crankshaft axis (6), and at least two respective crank members (7), gears (13) and internal ring gears (14).

8. A reciprocating piston mechanism according to claim 7, wherein the internal ring gear carriers (15) are disposed between the crankpins (5) as seen along the crankshaft axis (6).

9. A reciprocating piston mechanism according to claim

8, wherein the internal ring gear carriers (15) are fixed to each other.

10. A reciprocating piston mechanism according to claim 7, wherein the internal ring gear carriers (15) are disposed near end portions of the crank members (7) facing in opposite directions as seen along the crankshaft axis (6).

11. A reciprocating piston mechanism according to one of the preceding claims, wherein a driving means is connected to the internal ring gear carrier (15), which driving means is adapted such that, under operating conditions, it rotates the internal ring gear carrier (15) in a rotational direction at a predetermined rotation frequency, preferably similar to that of the crankshaft (3).

12. A reciprocating piston mechanism according to claim 11, wherein the driving means is formed by the crankshaft (3) which drives the internal ring gear carrier (15) by a transmission.

13. A reciprocating piston mechanism comprising

a crankcase (2);
a crankshaft (3) having at least a crankpin (5), said crankshaft (3) being supported by the crankcase (2) and rotatable with respect thereto about a crankshaft axis (6);
at least a connecting rod (10) including a big end (9) and a small end (11);
a piston (12) being rotatably connected to the small end (11);
a crank member (7) being rotatably mounted on the crankpin (5), and comprising at least a bearing portion (8) which is eccentrically disposed with respect to the crankpin (5), and having an outer circumferential wall which bears the big end (9) of the connecting rod (10) such that the connecting rod (10) is rotatably mounted on the bearing portion (8) of the crank member (7) via the big end (9);
a gear (13) which is fixed to the crank member (7); and
an internal ring gear (14) which is disposed concentrically with respect to the crankshaft axis (6) and which is rotatable with respect to the crankcase (2) and the crankshaft (3), wherein the gear (13) meshes with the internal ring gear (14) for rotating the crank member (7) with respect to the crankpin (5) upon rotation of the crankshaft (3),
wherein a driving means is connected to the internal ring gear (14) for rotating the internal ring gear (14), and the diameters of the gear (13) and the internal ring gear (14) and the rotation frequency of the internal ring gear (14) are selected such that, under operating conditions, the crank member (7) rotates about its axis of rotation at a rotation frequency which is substantially half of that of the crankshaft (3), preferably in similar rotational direction as the crankshaft (3).

14. A reciprocating piston mechanism according to claim 13, wherein the diameters of the gear (13) and the internal ring gear (14) and the rotation frequency of the internal ring gear (14) are selected such that, under operating conditions, the crank member (7) rotates about its axis of rotation in similar direction of the crankshaft (3).

15. A reciprocating piston mechanism according to claim 14, wherein the ratio between the diameter of the internal ring gear (14) and the diameter of the gear (13) is substantially 1.66 and the rotation frequency of the internal ring gear (14) is selected at substantially 7/10 of that of the crankshaft (3).

16. A reciprocating piston mechanism according to claim 13, wherein the diameters of the gear (13) and the internal ring gear (14) and the rotation frequency of the internal ring gear (14) are selected such that, under operating conditions, the crank member (7) rotates about its axis of rotation in opposite direction of the crankshaft (3).

17. A reciprocating piston mechanism according to claim 16, wherein the ratio between the diameter of the internal ring gear (14) and the diameter of the gear (13) is substantially 1.8 and the rotation frequency of the internal ring gear (14) is selected at substantially 1/6 of that of the crankshaft (3).

18. A reciprocating piston mechanism according to one of the claims 13 -17, wherein the internal ring gear (14) is rotationally connected to the crankshaft (3).

19. A reciprocating piston mechanism according to one of the claims 13-18, wherein the crankshaft (3) comprises at least two crankpins (5) which are angularly spaced with respect to each other about the crankshaft axis (6), and at least two respective crank members (7), wherein a first one of the crank members (7) is provided with the gear (13) which meshes with the internal ring gear (14), and a second one of the crank members (7) is rotatably connected with the first one via a transmission (22) which is adapted such that the second one rotates at the same rotation frequency as the first one.

20. A reciprocating piston mechanism according to claim 19, wherein the transmission comprises first transmission gears (26) and second transmission gears (27), wherein each of the crank members (7) is provided with at least one of the first transmission gears

(26) which is concentrically fixed to the crank member (7), wherein each first transmission gear (26) meshes with one of the second transmission gears (27), wherein the second transmission gears (27) are fixed to each other via a shaft which is rotatably connected to the crankshaft (3) and rotatable about the crankshaft axis (6).

21. A reciprocating piston mechanism comprising

a crankcase (2);
a crankshaft (3) having at least a crankpin (5), said crankshaft (3) being supported by the crankcase (2) and rotatable with respect thereto about a crankshaft axis (6);
at least a connecting rod (10) including a big end (9) and a small end (11);
a piston (12) being rotatably connected to the small end (11);
a crank member (7) being rotatably mounted on the crankpin (5), and comprising at least a bearing portion (8) which is eccentrically disposed with respect to the crankpin (5), and having an outer circumferential wall which bears the big end (9) of the connecting rod (10) such that the connecting rod (10) is rotatably mounted on the bearing portion (8) of the crank member (7) via the big end (9);
a first transmission gear (26) which is fixed to the crank member (7); and
a second transmission gear (27) which is disposed concentrically with respect to the crankshaft axis (6) and which is rotatably mounted to the crankshaft (3), wherein the first transmission gear (26) meshes with the second transmission gear (27) for rotating the crank member (7) with respect to the crankpin (5),
wherein a driving means is connected to the second transmission gear (27) for rotating the second transmission gear (27) upon rotation of the crankshaft (3), wherein the diameters of the first and second transmission gears (26, 27) and the rotational speed of the second transmission gear (27) are selected such that, under operating conditions, the crank member (7) rotates about its axis of rotation at a rotation frequency which is substantially half of that of the crankshaft (3).

22. A reciprocating piston mechanism according to claim 21, wherein the driving means is formed by the crankshaft (3) which drives the second transmission gear (27) via a transmission (22).

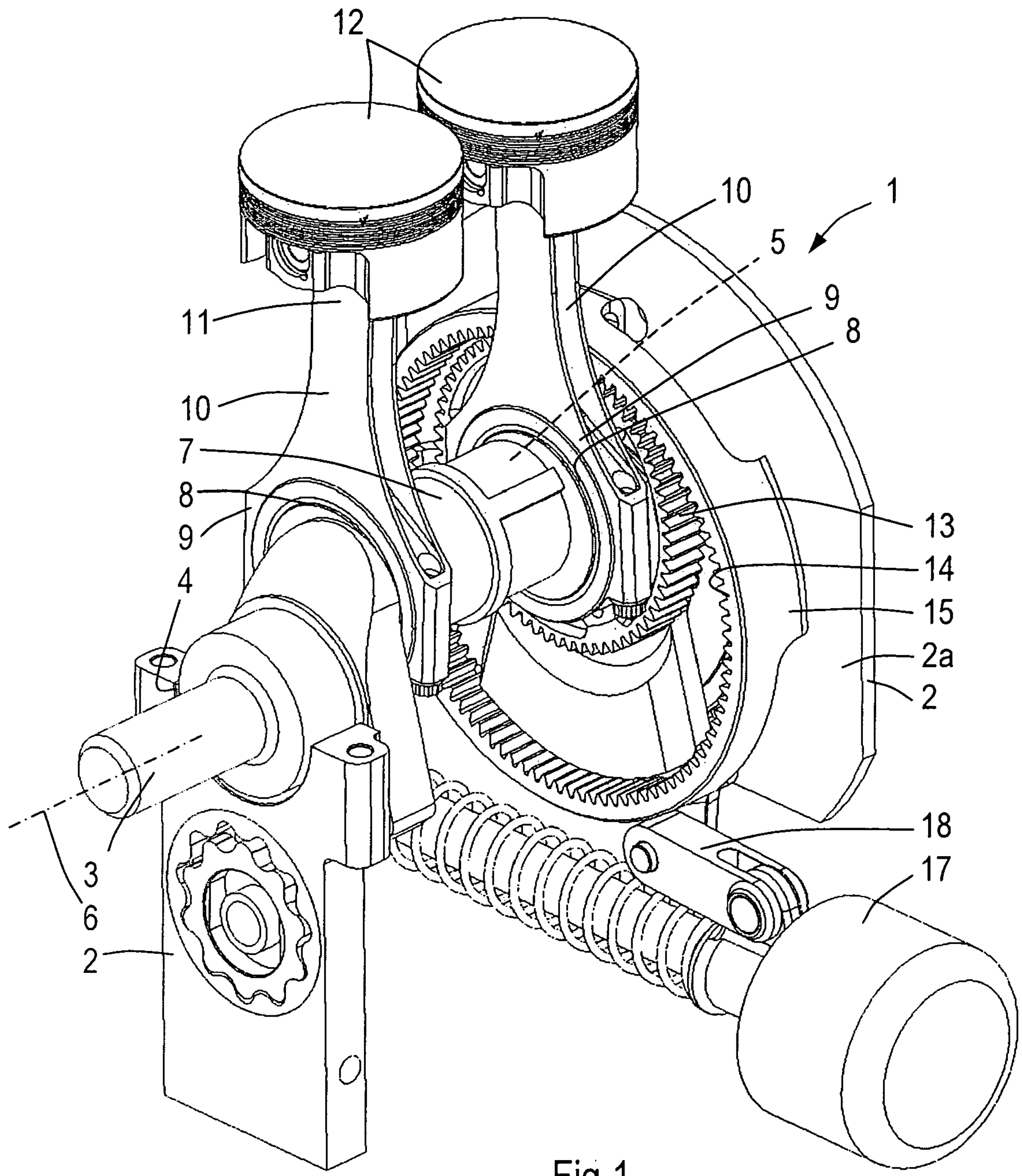

Fig.1

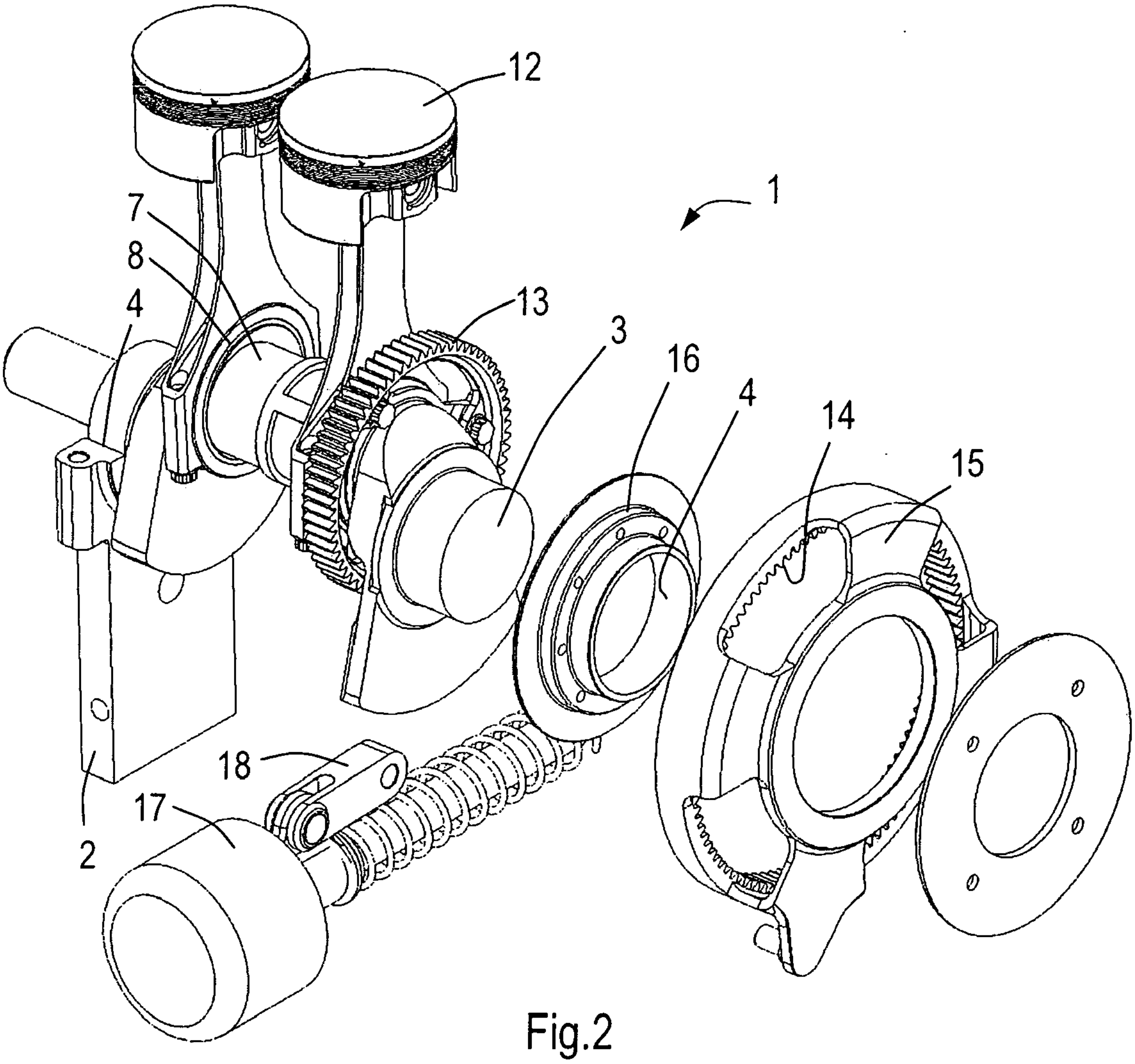

Fig.2

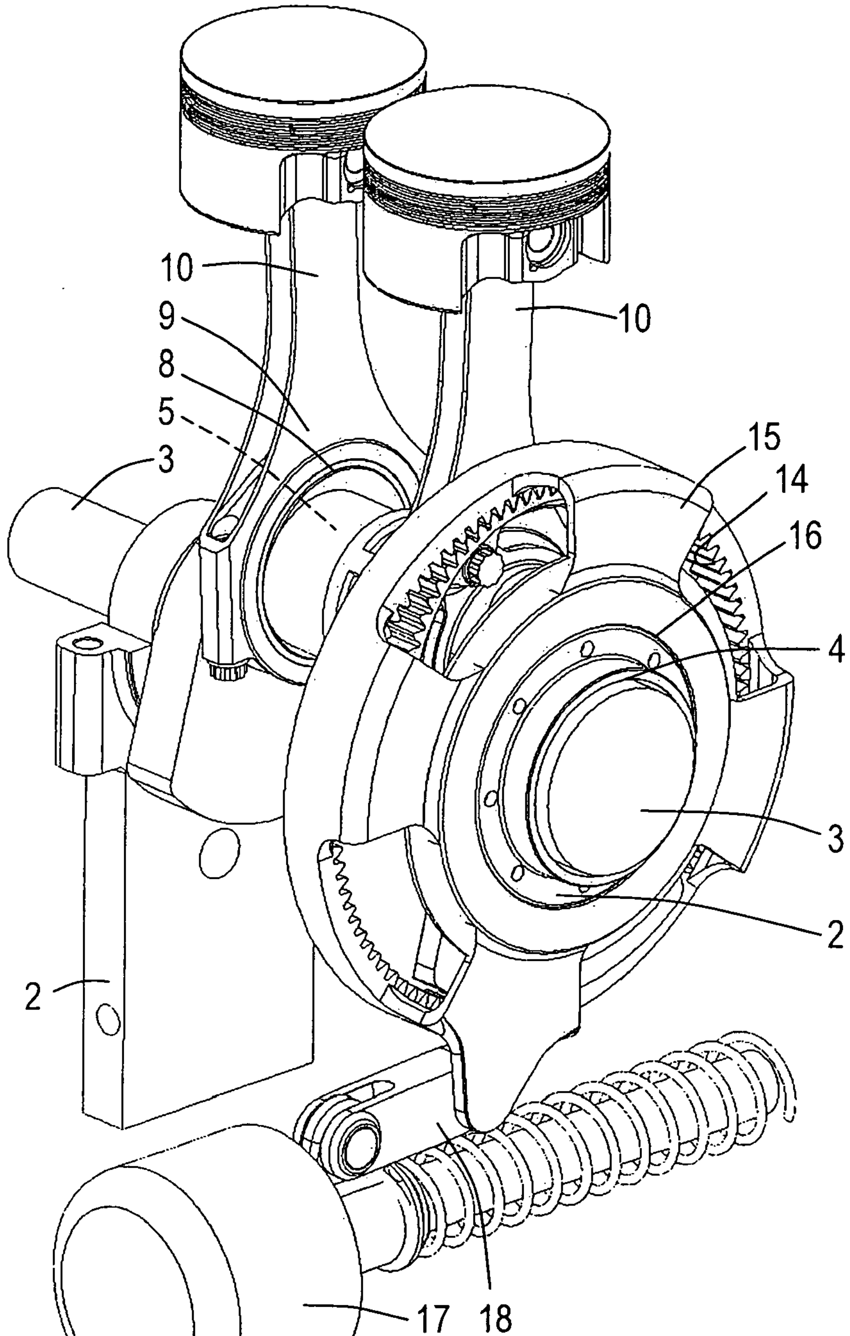

Fig.3

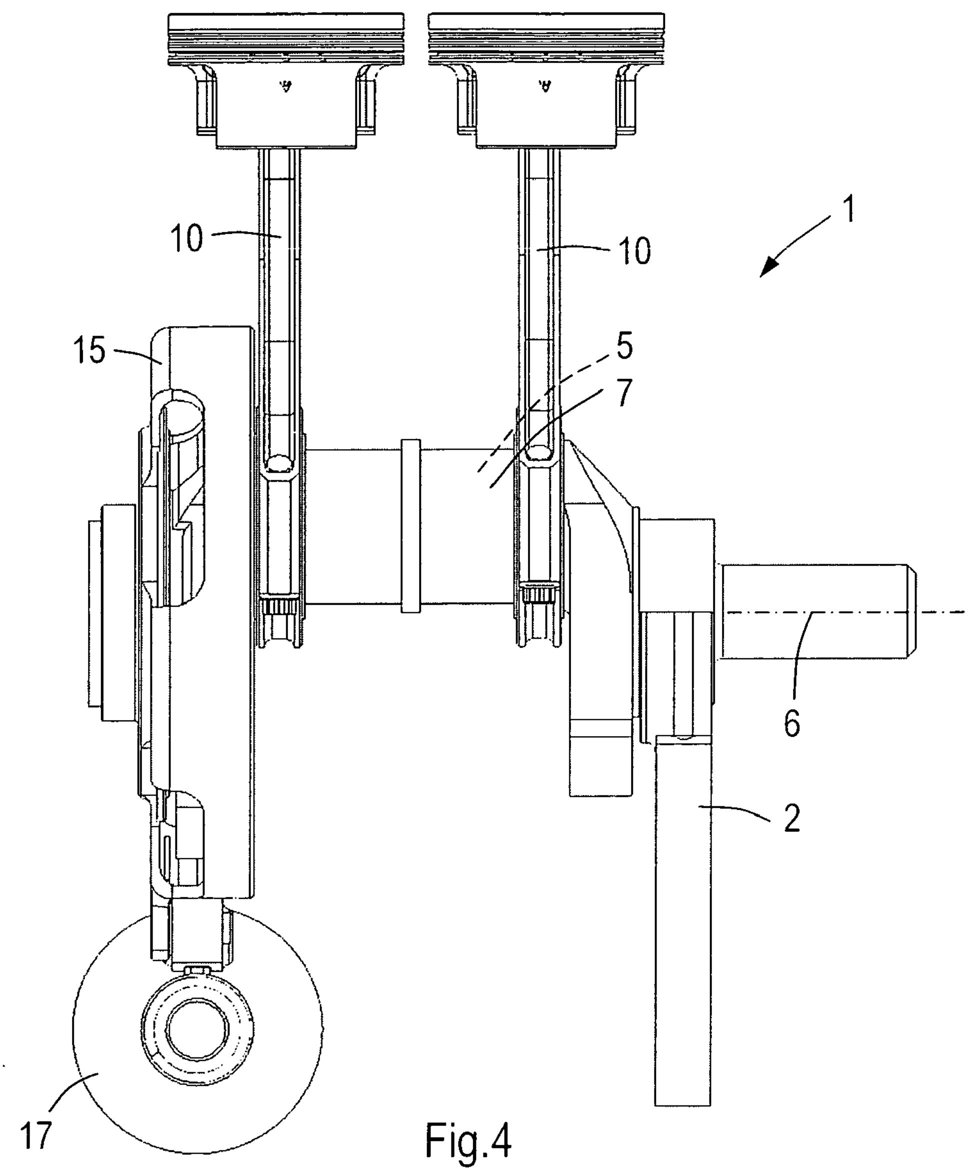

Fig.4

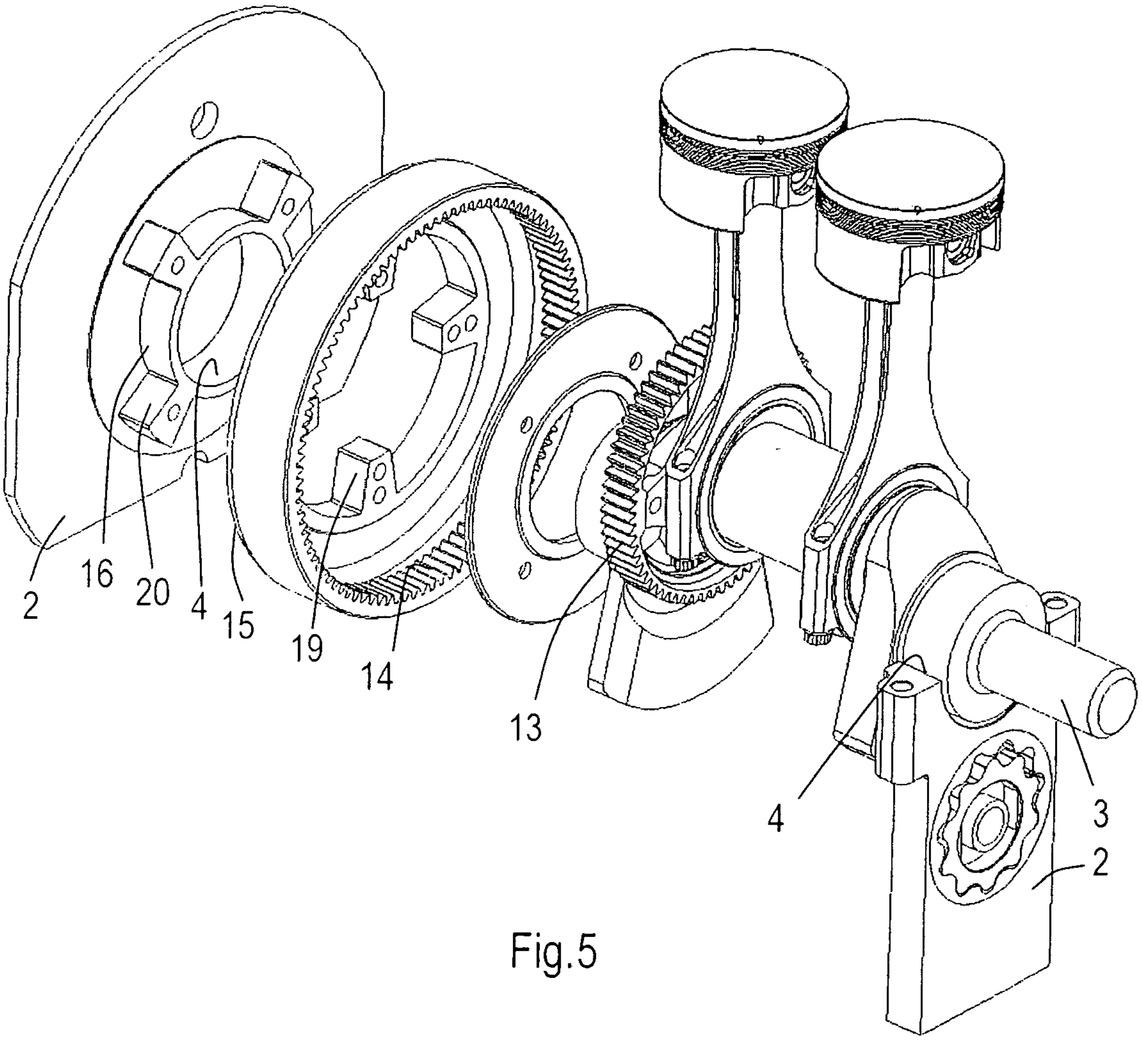

Fig.5

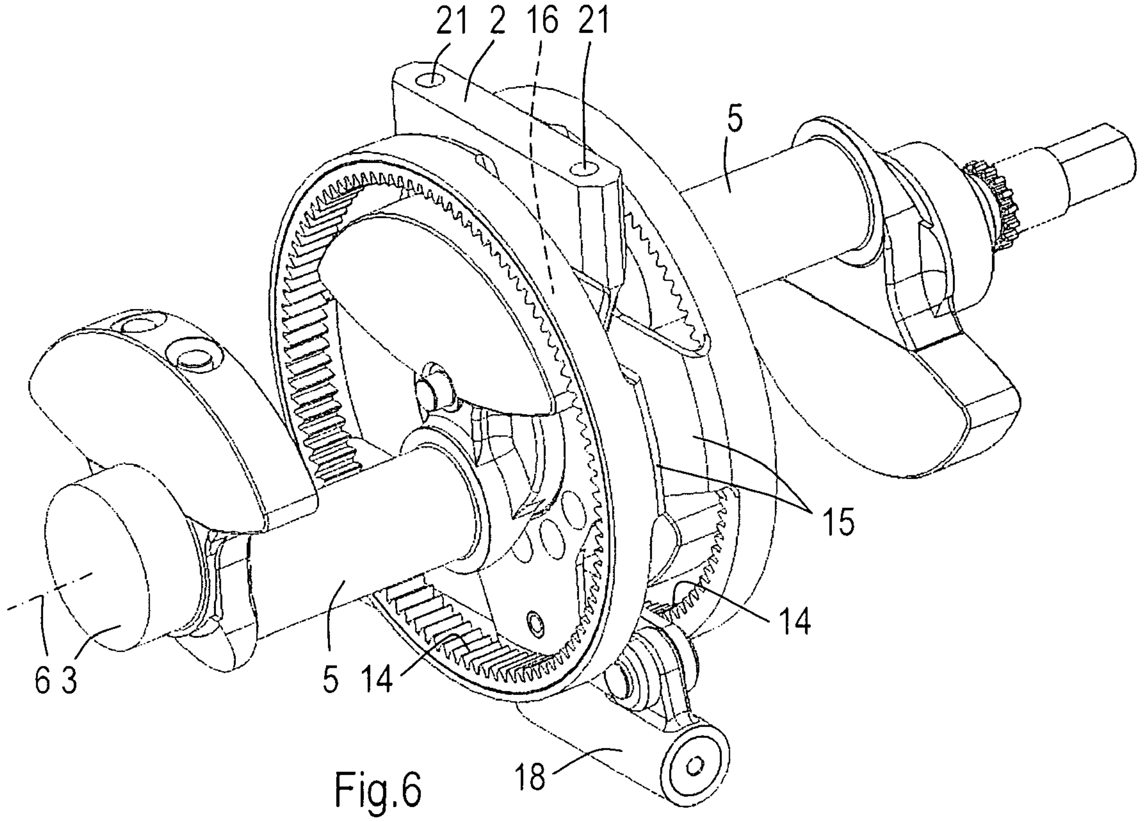

Fig.6

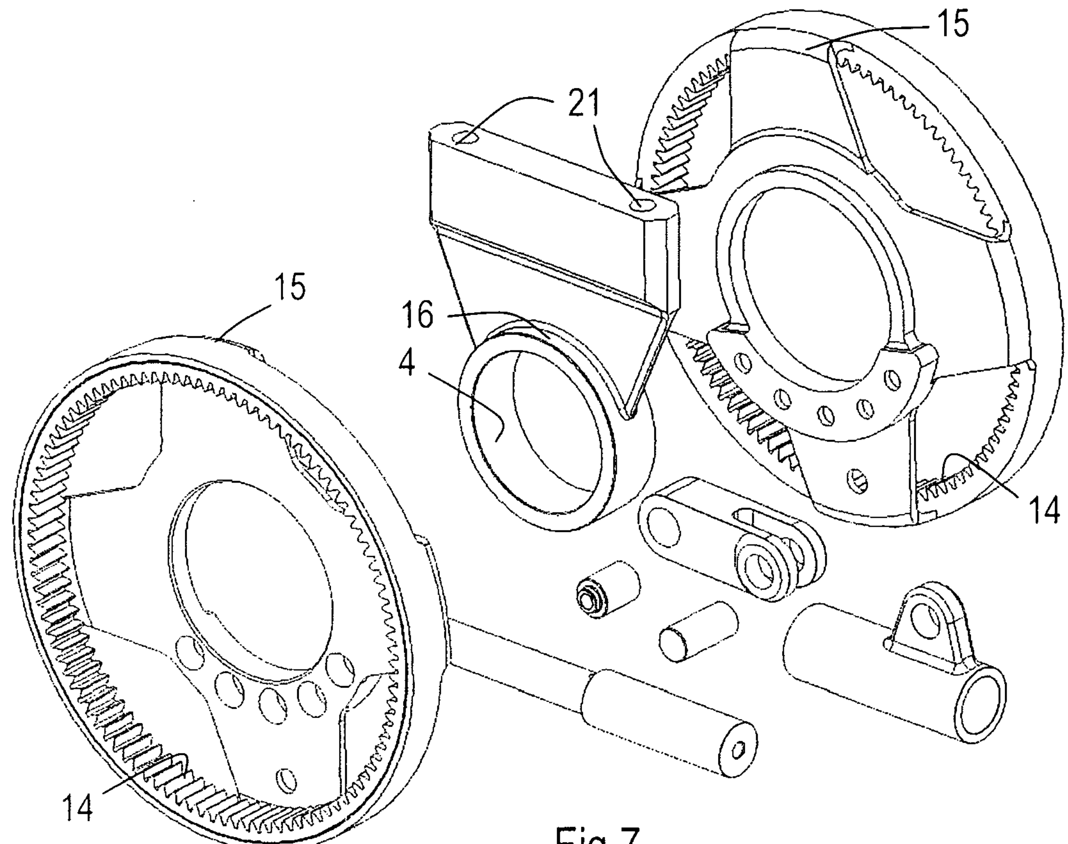

Fig.7

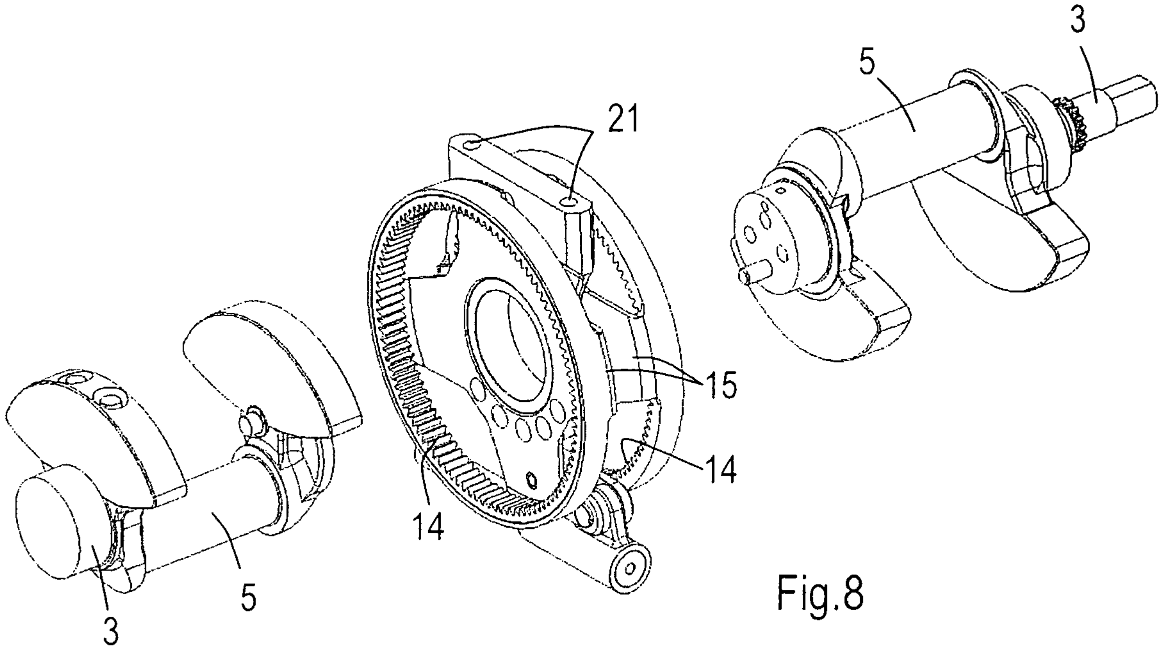

Fig.8

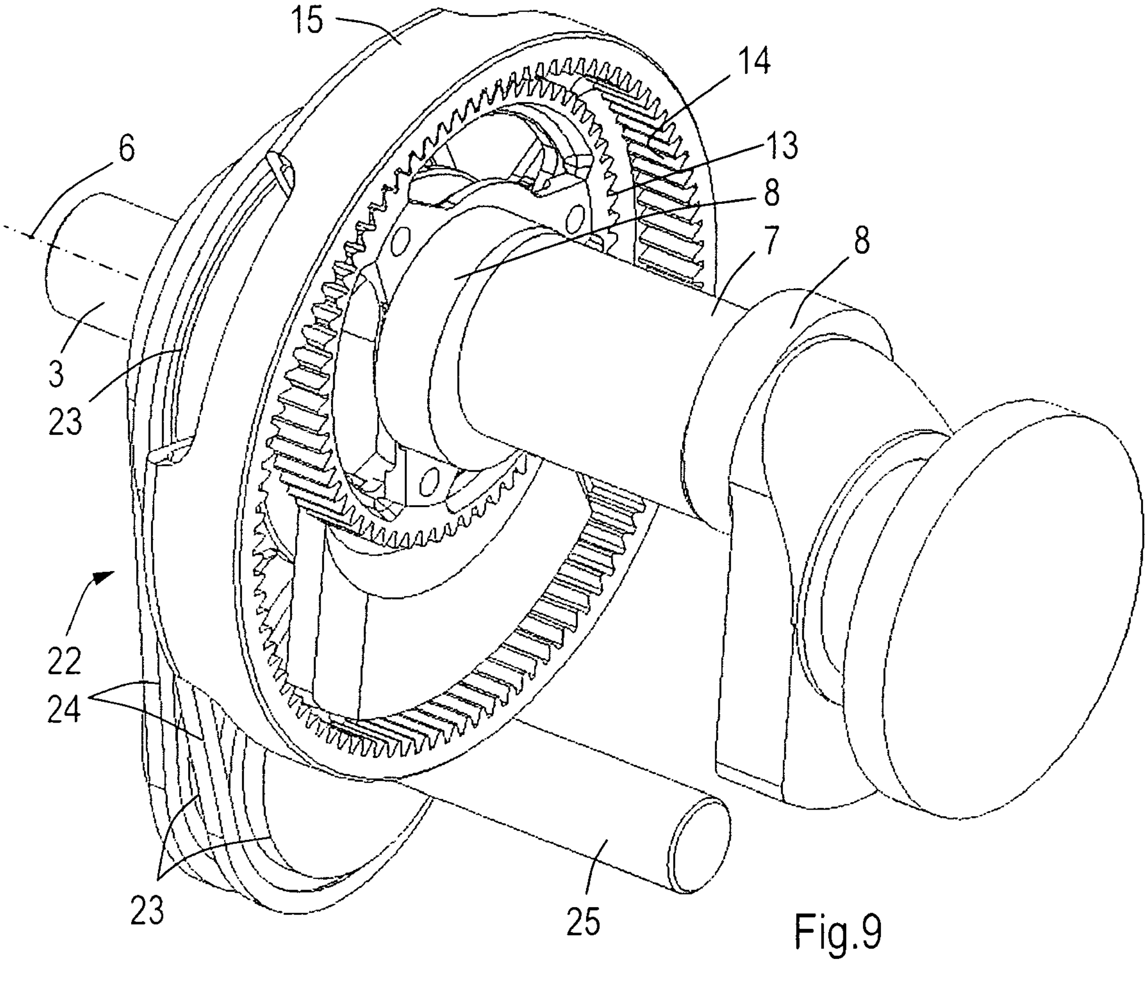

Fig.9

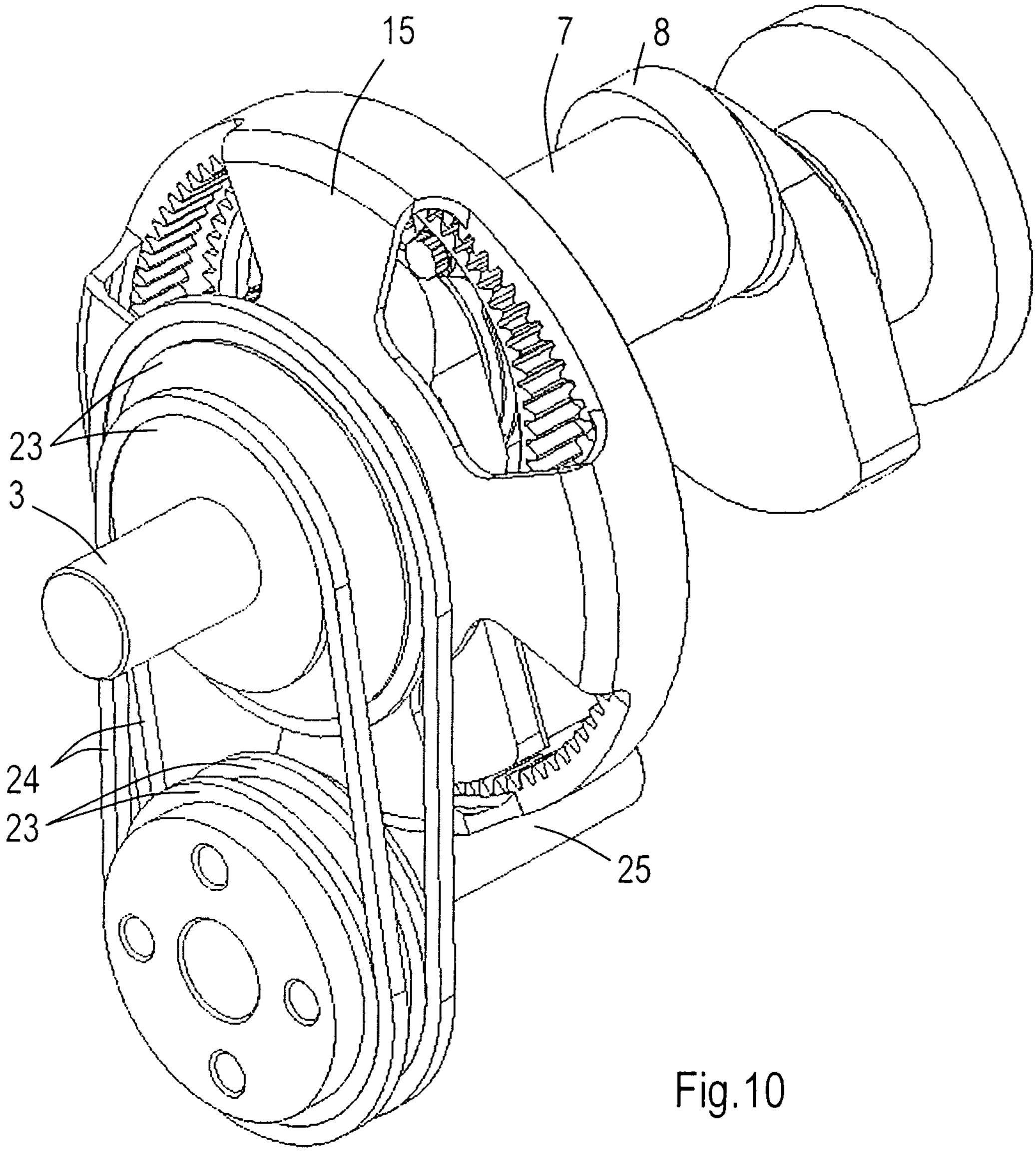

Fig.10

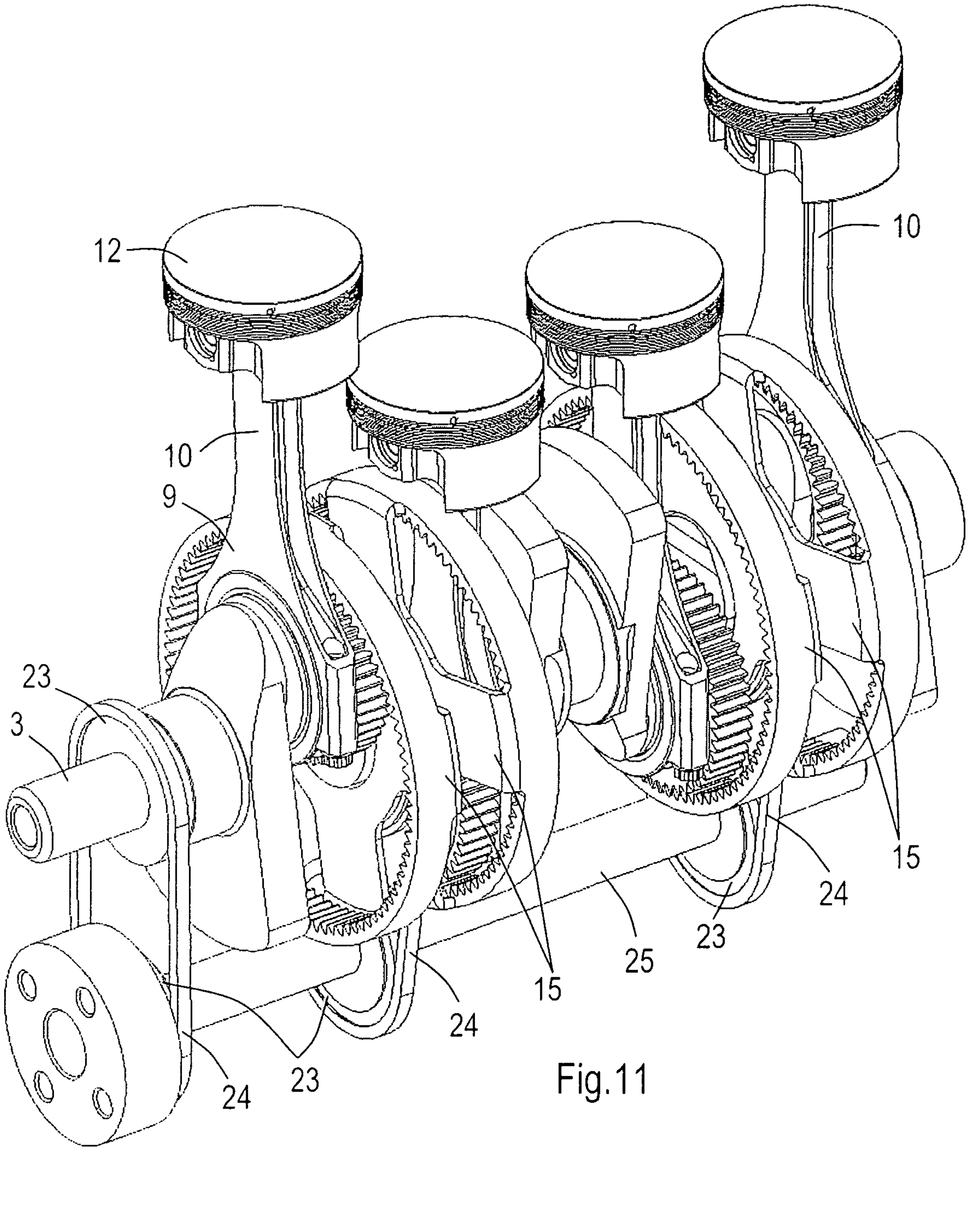

Fig.11

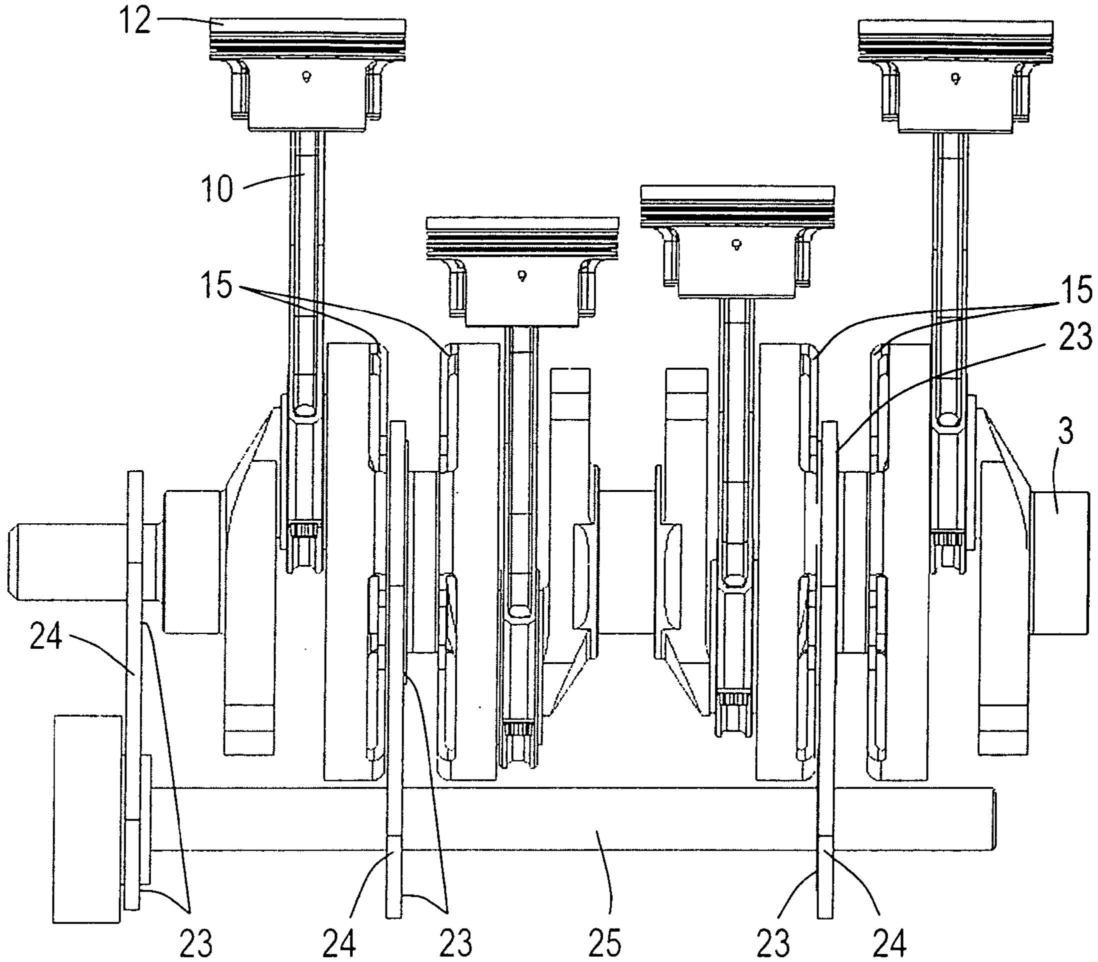

Fig.12

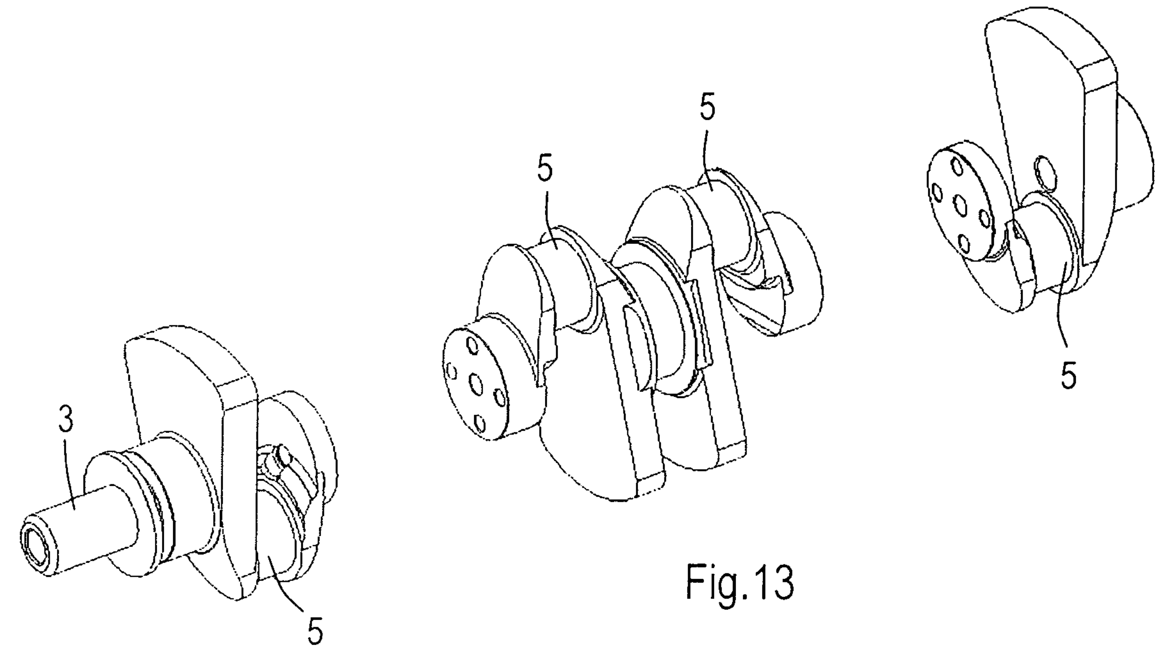

Fig.13

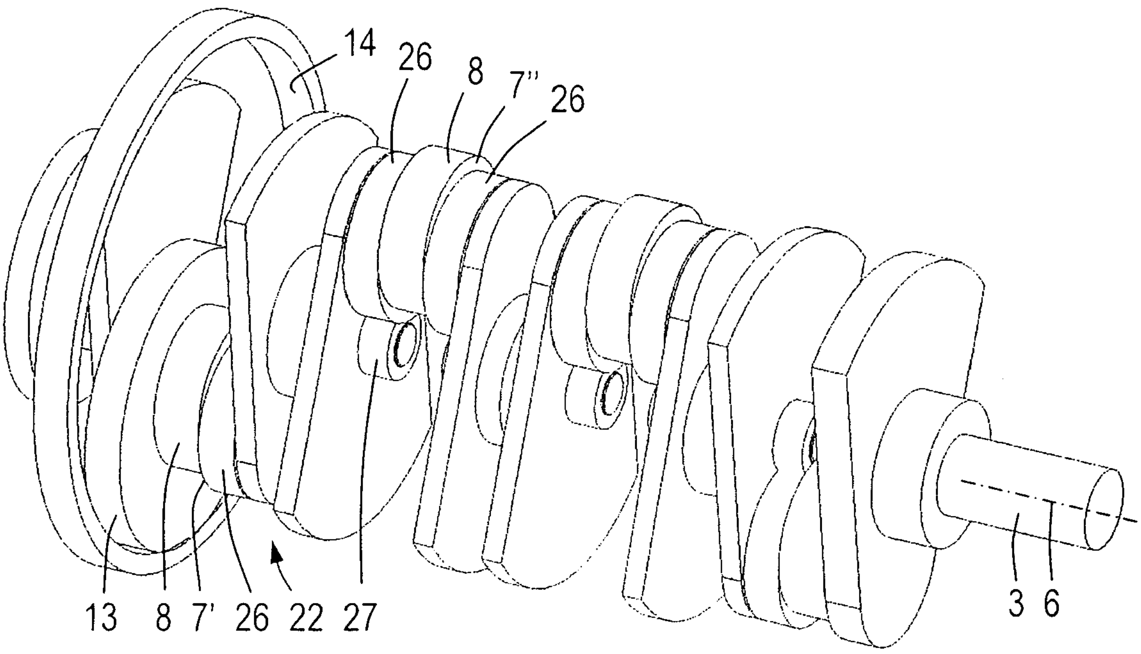

Fig.14

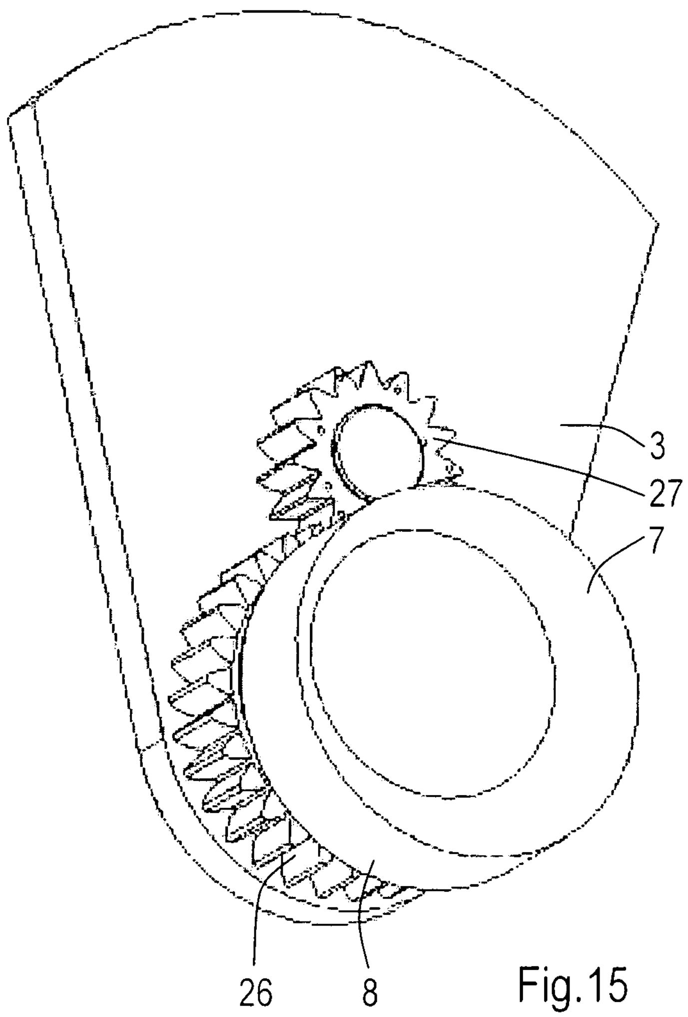

Fig.15

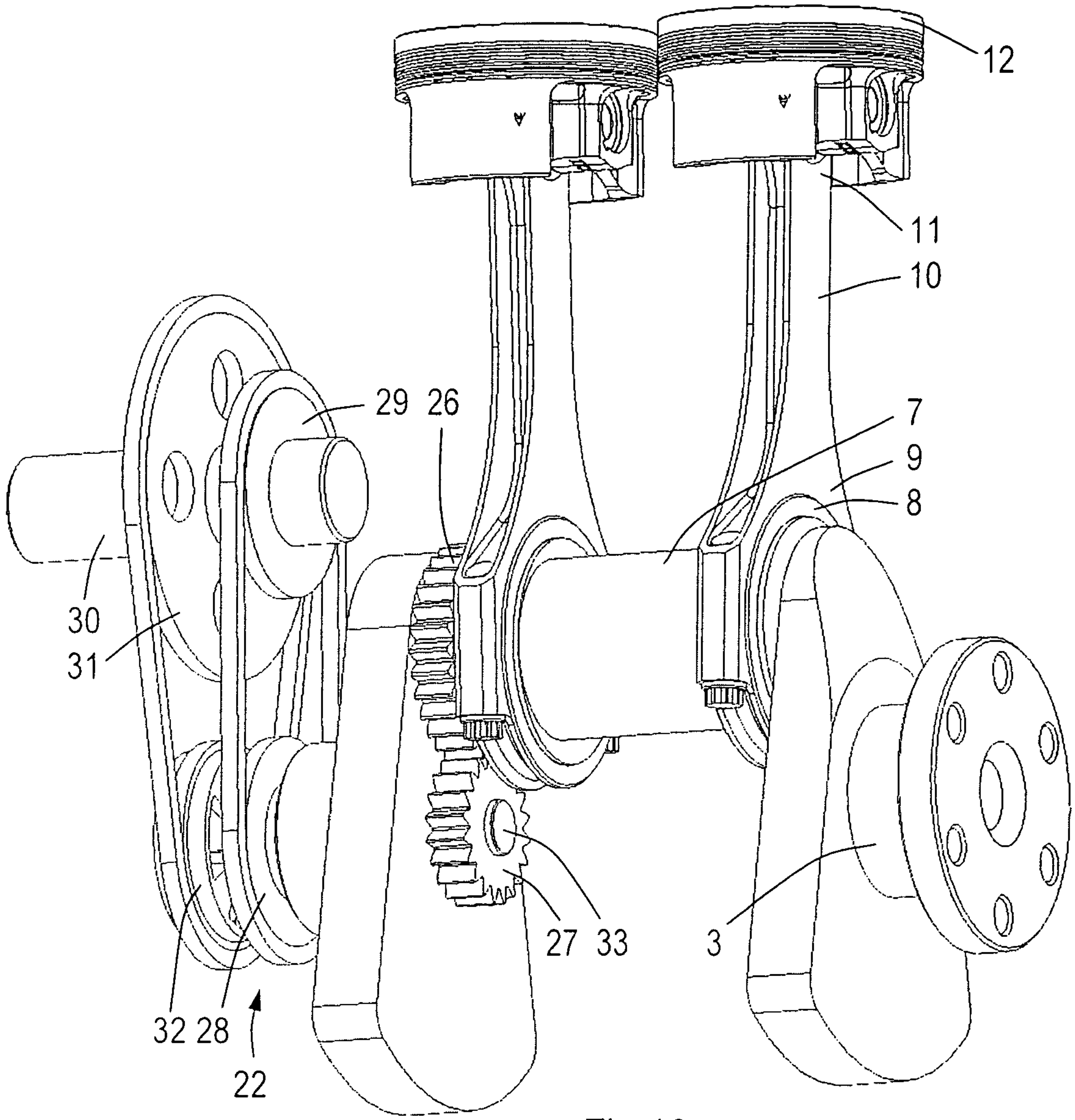

Fig.16

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 07 11 4078

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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~~The present search report has been drawn up for all claims~~

Place of search	Date of completion of the search	Examiner
Munich	17 January 2008	Yates, John

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CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
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& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

European Patent Office

Application Number

EP 07 11 4078

CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

☐ Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid, namely claim(s):

☐ No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

☐ All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

☐ As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

☐ Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

☒ None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

1-12

☐ The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

European Patent Office

LACK OF UNITY OF INVENTION SHEET B

Application Number

EP 07 11 4078

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-12

   Piston mechanism having a sleeve between the conrod and crankshaft intermeshing with a ring gear, particularly in relation to the fixing of the ring gear.

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2. claims: 13-20

   Piston mechanism having a sleeve between the conrod and crankshaft intermeshing with a ring gear, particularly in relation to the relative speed of the sleeve and crankshaft

   ---

3. claims: 21,22

   Piston mechanism having a sleeve between the conrod and crankshaft intermeshing with a transmission mechanism no longer requiring a ring gear.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 07 11 4078

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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17-01-2008

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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