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(54) **SELECTABLE 2 STROKE / 4 STROKE CAMSHAFT DRIVE SYSTEM**

SELEKTIERBARER ZWEITAKT ODER VIERTAKT NOCKENWELLENANTRIEB

SYSTEME D'ENTRAINEMENT D'ARBRE A CAMES, A DEUX OU QUATRE TEMPS AU CHOIX

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- **PATENT ABSTRACTS OF JAPAN vol. 016, no. 585 (M-1347), 25 December 1992 (1992-12-25) & JP 04 234508 A (ISUZU SERAMITSUKUSU KENKIYUUSHIYO:KK), 24 August 1992 (1992-08-24)**

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Description

Field of the invention

[0001] The present invention relates to a camshaft drive system for operating an internal combustion engine according to the two-stroke cycle or the four-stroke cycle.

Background of the invention

[0002] Conventional internal combustion engines operate according to thermodynamic principles following either the two-stroke cycle or the four-stroke cycle and are commonly classified as two-stroke engines or four-stroke engines (see DE-A-3 842 267) respectively. Both type of engines can operate using a range of fuels including gasoline, diesel, alcohol and gaseous fuels; the fuel can be introduced into the engine by a range of devices including carburettors and fuel injectors into the air intake system and fuel injectors aimed directly into the engine cylinder; and the fuel-air mixture can be ignited by a range of methods including spark ignition and compression ignition. Each engine cycle type has different merits and shortcomings making it a subject of continuous debate as to which is more suitable for automotive application taking into account various parameters such as power density, fuel consumption, exhaust emissions, noise, vibration, engine size, weight and cost etc. Currently, the automotive manufacturer must first decide on the engine cycle type, then design the engine accordingly.

Summary of the invention

[0003] With a view of combining the merits of both engine cycle types, there is provided a camshaft drive system for a selectable two-stroke/four-stroke internal combustion engine with exhaust and intake poppet valves opened and closed by at least one camshaft, wherein the camshaft is connected permanently to a planetary gear set which is driven continuously by the engine crankshaft, and wherein means are provided for setting the planetary gear set in one of two selectable stable modes to function either as a gear box or as a rigid coupling.

[0004] In the invention, the camshaft is driven by the planetary gear set according to the selectable mode at either the same speed as the engine crankshaft or half the speed of the engine crankshaft, and the phasing of the camshaft in relation with the crank angle position of the piston is adjustable using the planetary gear set to position the exhaust and intake gas exchange events appropriately for either the two-stroke or the four-stroke engine cycle respectively.

[0005] Preferably, the planetary gear set is mounted concentrically to the camshaft. Alternatively, it may be mounted concentrically to the engine crankshaft or it may be mounted separately next to the camshaft and the crankshaft.

[0006] Various configuration are possible in using the planetary gear set to drive the camshaft according to the present invention. The input from the engine may be connected to any one of the three members of the planetary gear set which may be the ring gear, the sun gear or the planetary gear carrier, the output to the camshaft may be connected to any one of the remaining two members, and the mode setting means may be provided in the remaining last member which is the reaction member between the input and output members.

[0007] In the case where the planetary gear carrier is the reaction member, idler gears coupled with the planetary gears may be additionally provided on the planetary gear carrier such that the ring gear and the sun gear rotate in the same direction.

[0008] In the invention, the means for setting the planetary gear set to function as a gear box is a device for holding the reaction member of the gear set stationary relative to a fixed datum so that the gears rotate relative to one another within the gear set, whereas the means for setting the planetary gear set to function as a rigid coupling is a device for holding the reaction member of the gear set stationary relative to either the rotating input member or the rotating output member so that the gears are locked relative to one another within the gear set and the whole assembly rotate together.

[0009] In a preferred example, the ring gear is the input member driven by the engine at half crankshaft speed, the sun gear is the output member connected to the camshaft, and the planetary gear carrier is the reaction member of the gear set. The speed ratio between the ring gear and the sun gear is 1:2.

[0010] In this example, means are provided for setting the planetary gear carrier in one of two selectable stable modes such that in the two-stroke mode the carrier is held stationary relative to the engine frame so that the gear set acts as a gear box, and in the four-stroke mode the carrier is held stationary relative to the rotating ring gear so that the entire gear set acts as a rigid coupling. Additionally, means are provided for allowing the carrier to slip and rotate relative to the engine frame or relative to the rotating ring gear in order to adjust the phasing and the speed of the camshaft during a mode change.

[0011] In operation, when the two-stroke mode is selected, the carrier, which has been held stationary relative to the rotating ring gear in the four-stroke mode, is first allowed to slip and rotate relative to the rotating ring gear in order to adjust the phasing and the speed of the camshaft progressively towards the two-stroke mode, at which point the carrier is then held stationary relative to the engine frame thereafter. In this case, the planetary gear set acts as a gear box in which the camshaft is driven at twice the speed of the ring gear and each engine valve along the camshaft is opened and closed at a predetermined two-stroke valve timing once during every engine revolution consistent with the two-stroke cycle.

[0012] In addition to the above, a combination of various operating parameters in the engine necessary for

executing the two-stroke cycle is implemented, and this would be obvious to a person familiar with the state-of-the-art. For example, an air blower would be necessary to supply pressurised air for the two-stroke scavenging process and the frequency and timing of the fuel injection and/or spark ignition would be scheduled appropriately.

[0013] When the four-stroke mode is selected, the carrier, which has been held stationary relative to the engine frame in the two-stroke mode, is first allowed to slip and rotate relative to the engine frame in order to adjust the phasing and the speed of the camshaft progressively towards the four-stroke mode, at which point the carrier is then held stationary relative to the rotating ring gear thereafter. In this case, the planetary gear set acts as a rigid coupling in which the camshaft is driven at the same speed as the ring gear and each engine valve along the camshaft is opened and closed at a predetermined four-stroke valve timing once during every two engine revolutions consistent with the four-stroke cycle.

[0014] In addition to the above, a combination of various operating parameters in the engine necessary for executing the four-stroke cycle is implemented, and this would be obvious to a person familiar with the state-of-the-art. The air blower for two-stroke operation may in this case be used to supply boosted air for four-stroke operation.

[0015] The above example is only one of many possible configurations for the camshaft to be driven by a mode selectable planetary gear set of the present invention. In another example, the planetary gear carrier is the input member driven at half crankshaft speed, the sun gear is the output member connected to the camshaft, and the ring gear is the reaction member of the gear set. The speed ratio between the carrier and the sun gear is 1:2.

[0016] In this case, the ring gear may be set in one of two selectable modes such that in the two-stroke mode the ring gear is held stationary relative to the engine frame so that the planetary gear set acts as a gear box and the camshaft is driven at crankshaft speed, and in the four-stroke mode the ring gear is held stationary relative to the carrier so that the entire gear set acts as a rigid coupling and the camshaft is driven at half crankshaft speed.

[0017] In a further example, the sun gear is the input member driven at crankshaft speed, the planetary gear carrier is the output member connected to the camshaft, and the ring gear is the reaction member of the gear set. The speed ratio between the sun gear and the carrier is 2:1.

[0018] In this case, the ring gear may be set in one of two selectable modes such that in the two-stroke mode the ring gear is held stationary relative to the carrier so that the entire gear set acts as a rigid coupling and the camshaft is driven at crankshaft speed, and in the four-stroke mode the ring gear is held stationary relative to the engine frame so that the epicycle gear set acts as a gear box and the camshaft is driven at half crankshaft speed.

[0019] The principle of operating a planetary gear set in several selectable modes is well known and is commonly used in automotive automatic transmission systems for driving a vehicle. The present invention proposes to apply the same principle for driving a camshaft in order to enable the engine to be operated in either the two-stroke or the four-stroke mode with smooth and rapid transition and with the minimum risk of misfire during a mode change even at high speed. This provides a camshaft drive which is permanently in mesh and avoids the abruptness and uncertainty caused by temporarily de-coupling and then re-coupling the camshaft and the crankshaft as proposed in the previously known systems such as US Patent 4,907,544 and US Patent 2,178,152 which are unacceptable for automotive application.

[0020] The technology for controlling the planetary gear set to operate in the selectable modes and to change mode smoothly and imperceptibly using brakes, clutches, and sensors is well advanced in the automatic transmission field and may be transferred readily to the camshaft drive system of the present invention.

Brief description of the drawing

[0021] The invention will now be described further, by way of example, with reference to a single drawing of a schematic view of a preferred embodiment of the invention in which two planetary gear sets are used to drive separately the intake and exhaust camshafts of an internal combustion engine.

Detailed description of the preferred embodiment

[0022] Figure 1 shows two planetary gear sets each comprising a ring gear 10, a sun gear 12, and three planetary gears 14 with additional idler gears 15 mounted on a carrier 16. The speed ratio between the ring gear 10 and the sun gear 12 is 1:2. The ring gear 10 is the input member driven at half crankshaft speed by a timing belt or chain 22 from the crankshaft 20 of the engine, the sun gear 12 is the output member connected directly to one camshaft of the engine, and the carrier 16 is the reaction member.

[0023] Respective braking or clutching means (not shown) are provided for engaging the carrier 16 to either the engine frame or the rotating ring gear 10, enabling the carrier 16 to be held stationary relative to either the engine frame or the rotating ring gear 10, and to slip and rotate when desired relative to either the engine frame or the rotating ring gear 10. The use of such braking and clutching means is common practice in the automatic transmission field for selecting between different speed ratios and direct drive, and would be obvious to a person familiar with the state-of-the-art.

[0024] Sensors (not shown) are also provided in a closed-loop control system for sensing the angular positions of the camshaft and the crankshaft, thereby ena-

bling accurate control of the phasing and the speed of the camshaft progressively during a mode change. Electro-magnetic or electro-hydraulic controlled latches (not shown) may also be provided and energised when the gear set is approaching the desired camshaft position in order to engage the appropriate members of the gear set precisely at the required position relative to one another. Once again the use of such control system in operating the braking, clutching and latching means would be obvious to a person familiar with the state-of-the-art.

[0025] In operation, when the two-stroke mode is selected, the carrier 16 in each planetary gear set, which has been held stationary relative to the rotating ring gear 10 in the four-stroke mode, is first allowed to slip and rotate relative to the rotating ring gear 10 in order to adjust the phasing and the speed of each camshaft progressively towards the two-stroke mode, at which point the carrier 16 is then held stationary relative to the engine frame thereafter. In this case each planetary gear set acts as a gear box in which each camshaft is driven at twice the speed of the ring gear 10 and each engine valve along the camshaft is opened and closed according to a predetermined two-stroke valve timing once during every engine revolution.

[0026] When the four-stroke mode is selected, the carrier 16 in each planetary gear set, which has been held stationary relative to the engine frame in the two-stroke mode, is first allowed to slip and rotate relative to the engine frame in order to adjust the phasing and the speed of each camshaft progressively towards the four-stroke mode, at which point the carrier 16 is then held stationary relative to the rotating ring gear 10 thereafter. In this case, each planetary gear set acts as a rigid coupling in which each camshaft is driven at the same speed as the ring gear 10 and each engine valve along the camshaft is opened and closed according to a predetermined four-stroke valve timing once during every two engine revolutions.

[0027] It would be clear in the invention that the same cam profile carried on the camshaft driven at one or the other selectable mode would automatically give the appropriate duration of valve opening to suit each engine cycle mode respectively, namely, the two-stroke valve opening duration would be half the four-stroke valve opening duration.

[0028] It would also be clear in the invention that the phasing of the camshaft in relation with the crankshaft may at any time be re-positioned using the planetary gear set by briefly allowing the reaction member to slip while operating in either the two-stroke or the four-stroke mode.

[0029] The invention enables a selectable two-stroke/four stroke internal combustion engine to be used in a road vehicle to suit different operating conditions resulting in a better combination of engine performance, fuel economy, exhaust emissions, noise, vibrations, and drive quality while the mode transitions could be controlled and refined to be imperceptible to the driver.

Claims

1. A camshaft drive system for a selectable two-stroke/four-stroke internal combustion engine with exhaust and intake poppet valves opened and closed by at least one camshaft, wherein the camshaft is connected permanently to a planetary gear set (10, 12, 14, 15, 16) which is driven continuously by the engine crankshaft (20), and wherein means are provided for setting the planetary gear set in one of two selectable stable modes to function either as a gear box or as a rigid coupling.

2. A camshaft drive system as claimed in claim 1, wherein the camshaft is driven by the planetary gear set according to the selectable mode at either the same speed as the engine crankshaft or half the speed of the engine crankshaft, and wherein the phasing of the camshaft in relation with the crank angle position of the piston is adjustable using the planetary gear set to position the exhaust and intake gas exchange events appropriately for either the two-stroke or the four-stroke engine cycle respectively.

3. A camshaft drive system as claimed in claim 1 or 2, wherein the input from the engine is connected to any one of the three members of the planetary gear set which may be the ring gear (10), the sun gear (12) or the planetary gear carrier (16), the output to the camshaft is connected to any one of the remaining two members, and the mode setting means is provided in the remaining last member which is the reaction member between the input and output members.

4. A camshaft drive system as claimed in claim 3, wherein idler gears (15) coupled with the planetary gears (14) are additionally provided on the planetary gear carrier (16) such that the ring gear (10) and the sun gear (12) rotate in the same direction.

5. A camshaft drive system as claimed in claim 3 or 4, wherein means are provided for setting the reaction member of the planetary gear set in one of two selectable stable modes such that in one mode the reaction member is held stationary relative to the engine frame so that the gear set acts as a gear box, and in the other mode the reaction member is held stationary relative to the rotating input or output members so that the entire gear set acts as a rigid coupling.

6. A camshaft drive system as claimed in claim 3 or 4, wherein additional means are provided for allowing the reaction member of the planetary gear set to slip and rotate relative to the engine frame or relative to the rotating input and output members in order to

adjust the phasing and the speed of the camshaft during a mode change.

7. A camshaft drive system as claimed in claim 5 or 6, wherein respective braking and clutching means are provided for holding the reaction member of the planetary gear set in the respective selectable modes, and for allowing the reaction member to slip and rotate relative to the engine frame or relative to the rotating input and output members.

8. A camshaft drive system as claimed in claim 6 or 7, wherein sensors are provided in a closed-loop control system for sensing the angular positions of the camshaft and the crankshaft, thereby enabling accurate control of the phasing and the speed of the camshaft progressively during a mode change.

Revendications

1. Système d'entraînement d'arbre à cames pour moteur à combustion interne à deux temps ou à quatre temps, au choix, dont les soupapes d'échappement et d'admission s'ouvrent et se ferment au moyen d'au moins un arbre à cames, dans lequel l'arbre à cames est relié en permanence à un train d'engrenages planétaires (10, 12, 14, 15, 16) qui est entraîné continuellement par le vilebrequin du moteur (20), et dans lequel des moyens sont fournis pour régler le train d'engrenages planétaires selon un mode parmi deux modes stables sélectionnables afin de fonctionner soit comme une boîte de vitesse, soit comme un accouplement rigide.

2. Entraînement d'arbre à cames selon la revendication 1 dans lequel l'arbre à cames est entraîné par le train d'engrenages planétaires selon le mode sélectionnable, soit à la même vitesse que le vilebrequin du moteur, soit à une vitesse égale à la moitié de celle du vilebrequin du moteur, et dans lequel le calage de l'arbre à cames par rapport à la position angulaire du vilebrequin est réglable à l'aide du train d'engrenages planétaires pour positionner les événements d'échanges gazeux d'échappement et d'admission respectivement pour le cycle moteur à deux temps ou le cycle moteur à quatre temps.

3. Entraînement d'arbre à cames selon la revendication 1 ou 2 dans lequel l'entrée du moteur est reliée à l'un des trois organes du train d'engrenages planétaires qui peut être la couronne (10), le planétaire (12) ou le porte-satellite (16), la sortie vers l'arbre à cames est reliée à l'un des deux organes restants et le moyen de réglage de mode réside dans le dernier organe restant qui est l'organe de réaction entre les organes d'entrée et de sortie.

4. Entraînement d'arbre à cames selon la revendication 3 dans lequel des pignons intermédiaires (15) couplés aux pignons planétaires (14) sont en outre présents sur le porte-satellite (16) de telle sorte que la couronne (10) et le planétaire (12) tournent dans le même sens.

5. Entraînement d'arbre à cames selon la revendication 3 ou 4 dans lequel des moyens sont fournis pour régler l'organe de réaction du train d'engrenages planétaires selon un mode parmi deux modes stables sélectionnables de telle sorte que dans un mode, l'organe de réaction est maintenu fixe par rapport au bâti du moteur, le train d'engrenages fonctionnant comme une boîte de vitesse, et dans l'autre mode, l'organe de réaction est maintenu fixe par rapport aux organes tournants d'entrée ou de sortie, de telle sorte que l'ensemble du train d'engrenages joue le rôle d'un accouplement rigide.

6. Entraînement d'arbre à cames selon la revendication 3 ou 4 dans lequel des moyens supplémentaires sont fournis pour permettre le glissement et la rotation de l'organe de réaction du train d'engrenages planétaires par rapport au bâti du moteur ou par rapport aux organes tournants d'entrée et de sortie afin de régler le calage et la vitesse de l'arbre à cames pendant un changement de mode.

7. Entraînement d'arbre à cames selon la revendication 5 ou 6 dans lequel des moyens de freinage et d'embrayage sont respectivement fournis pour maintenir l'organe de réaction du train d'engrenages planétaires dans les modes sélectionnables respectifs, et pour permettre le glissement et la rotation de l'organe de réaction par rapport au bâti du moteur ou par rapport aux organes tournants d'entrée et de sortie.

8. Entraînement d'arbre à cames selon la revendication 6 ou 7 dans lequel des capteurs sont fournis dans un circuit de commande en boucle fermée pour détecter les positions angulaires de l'arbre à cames et du vilebrequin, en autorisant ainsi une commande précise du calage et de la vitesse de l'arbre à cames progressivement pendant un changement de mode.

Patentansprüche

1. Nockenwellenantriebssystem für eine wahlweise im Zweitakt-/ Viertakt-Betrieb betreibbare Brennkraftmaschine mit Auslaß- und Einlaß-Tellerventilen, welche von wenigstens einer Nockenwelle geöffnet und geschlossen werden, worin die Nockenwelle permanent mit einem Planetengetriebezug (10, 12, 14, 15, 16) verbunden ist, welcher kontinuierlich von einer Motorkurbelwelle (20) angetrieben wird, und

worin Mittel vorgesehen sind, den Planetengetriebezug in eine von zwei wählbaren stabilen Betriebsarten umzuschalten, so daß er entweder als Getriebe oder als starre Kupplung wirkt.

2. Nockenwellenantriebssystem nach Anspruch 1, worin die Nockenwelle durch den Planetengetriebezug je nach der wählbaren Betriebsart entweder mit derselben Drehzahl wie die Motorkurbelwelle oder mit halber Motorkurbelwellendrehzahl angetrieben wird, und worin die Phaseneinstellung der Nockenwelle in bezug auf die Kurbelwellenwinkelstellung unter Einsatz des Planetengetriebezuges derart einstellbar ist, daß die Auslaß- und Einlaß-Gaswechselereignisse jeweils passend für entweder den Zweitakt- oder den Viertakt-Motorzyklus positioniert werden.

3. Nockenwellenantriebssystem nach Anspruch 1 oder 2, worin der Eingang vom Motor mit einem beliebigen der drei Glieder des Planetengetriebezuges verbunden ist, welches der Zahnkranz (10) sein kann, das Sonnenrad (12) oder der Planetenradträger (16), der Ausgang zur Nockenwelle mit einem beliebigen der beiden verbleibenden Glieder verbunden ist, und die Mittel zur Einstellung der Betriebsart durch das letzte verbleibende Glied gestellt werden, das dann das Abstützglied zwischen dem Eingangs- und dem Ausgangsglied bildet.

4. Nockenwellenantriebssystem nach Anspruch 3, worin zusätzlich mit den Planetenrädem (14) gekoppelte Zwischenräder (15) an dem Planetenradträger (16) vorgesehen sind, so daß sich der Zahnkranz (10) und das Sonnenrad (12) in derselben Richtung drehen.

5. Nockenwellenantriebssystem nach Anspruch 3 oder 4, worin Mittel vorgesehen sind, mit welchen das Abstützglied des Planetengetriebezuges auf eine von zwei wählbaren stabilen Betriebsarten eingestellt werden kann, so daß in einer der Betriebsarten das Abstützglied stationär in bezug auf den Motorrahmen gehalten wird, so daß der Getriebezug als Getriebe wirkt, und daß in der anderen Betriebsart das Abstützglied stationär in bezug auf das sich drehende Eingangs- oder Ausgangsglied gehalten wird, so daß der gesamte Getriebezug wie eine starre Kupplung wirkt.

6. Nockenwellenantriebssystem nach Anspruch 3 oder 4, worin zusätzliche Mittel vorgesehen sind, mittels welcher es möglich ist, das Abstützglied des Planetengetriebezuges rutschen zu lassen und sich relativ zum Motorrahmen oder relativ zu dem sich drehenden Eingangs- oder Ausgangsglied derart verdrehen zu lassen, daß die Phaseneinstellung und die Drehgeschwindigkeit der Nockenwelle im Verlauf eines Betriebsartenwechsels verstellt wird.

7. Nockenwellenantriebssystem nach Anspruch 5 oder 6, worin entsprechende Brems-oder Kupplungsmittel vorgesehen sind, um das Abstützglied des Planetengetriebezuges in den jeweiligen wählbaren Betriebsarten zu halten, und um ein Rutschen und Verdrehen des Abstützgliedes relativ zum Motorrahmen oder relativ zu den sich drehenden Eingangs- oder Ausgangsgliedem zu ermöglichen.

8. Nockenwellenantriebssystem nach Anspruch 6 oder 7, worin Sensoren in einem geschlossenen Regelkreissystem vorgesehen sind, um die Winkelstellungen der Nockenwelle und der Kurbelwelle zu erfassen, so daß eine genaue und allmähliche Steuerung der Phaseneinstellung und der Drehgeschwindigkeit der Nockenwelle während eines Betriebsartenwechsels ermöglicht wird.

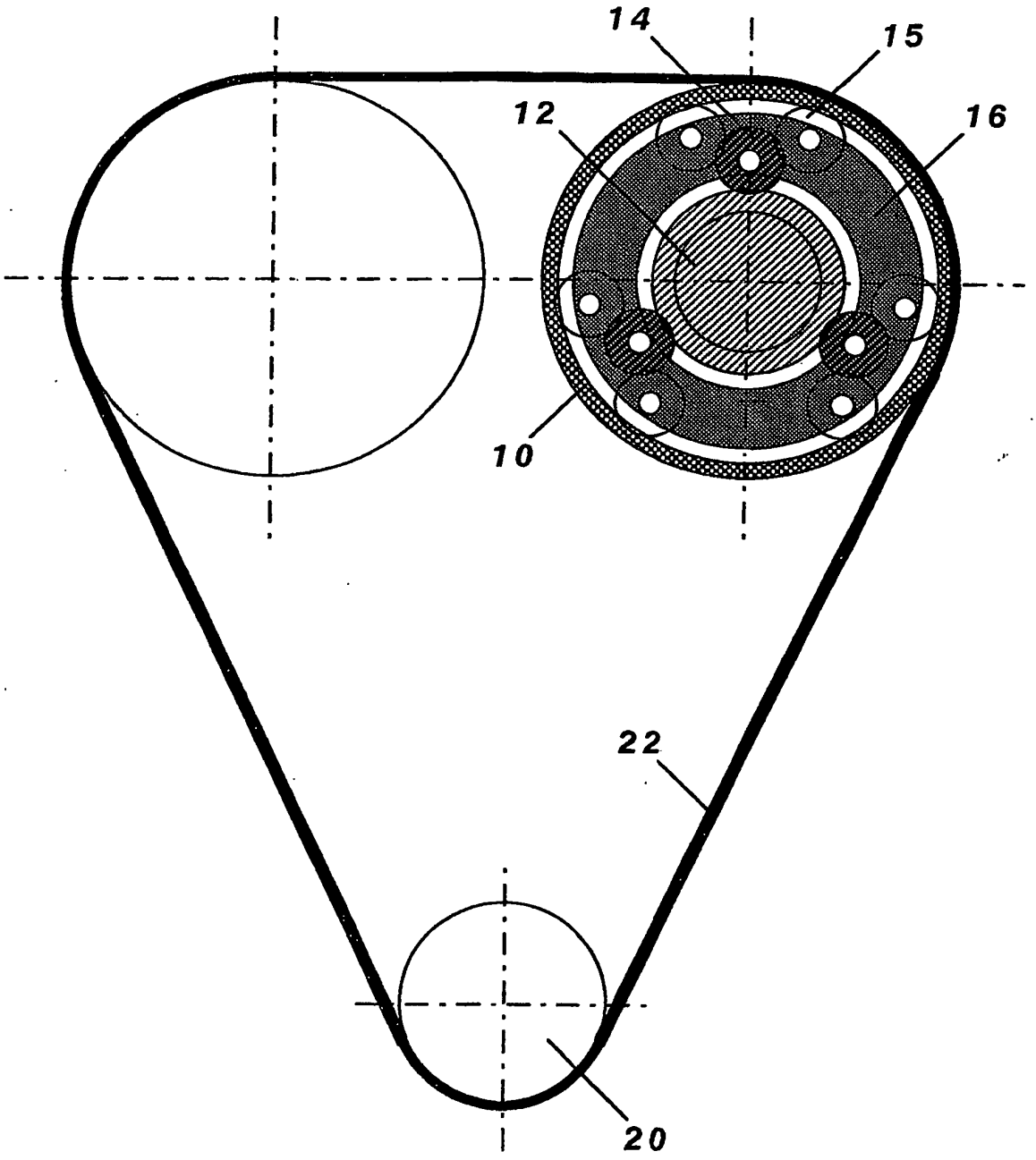

Fig.1