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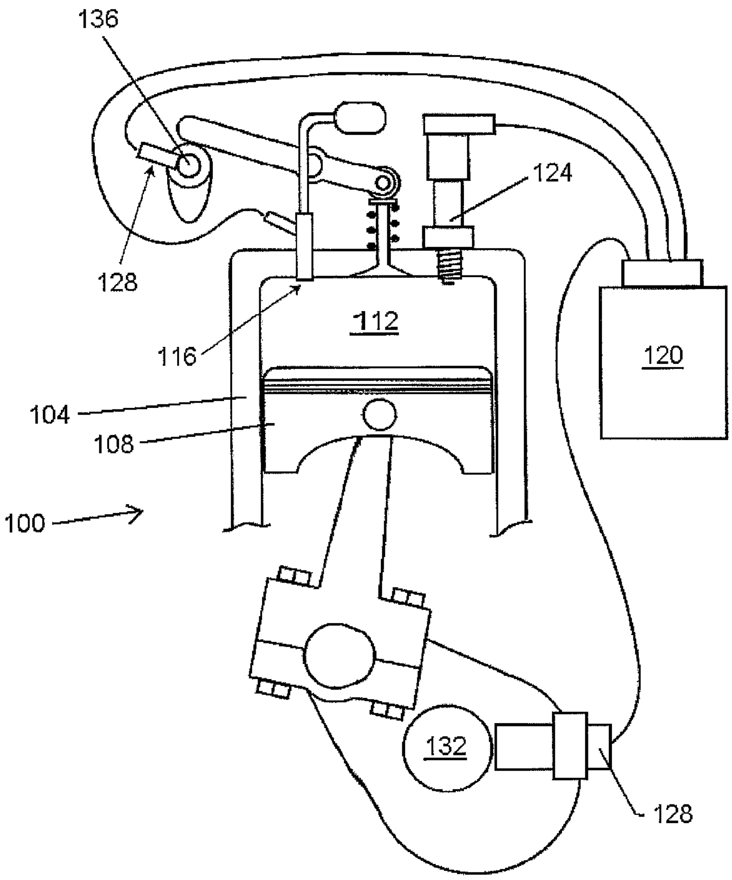
(54) **Title:** METHOD AND SYSTEM FOR STARTING OR RESTARTING AN INTERNAL COMBUSTION ENGINE VIA SELECTIVE COMBUSTION




(57) **Abstract:** A selective combustion starting system and method selectively provides a proper amount of fuel to one or more combustion chambers in an internal combustion engine. The particular combustion chambers selected depend upon the state of the piston of the combustion chamber and the volume of the combustion chamber, which is dependent upon the position of the piston. Once proper amounts of fuel have been provided to the one or more combustion chambers, the resulting fuel air mixture in the combustion chambers is ignited and combusts to rotate the crankshaft of the engine to commence normal operation of the engine.

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# Method and System for Starting or Restarting An Internal Combustion Engine Via Selective Combustion

## FIELD OF THE INVENTION

[0001] The present invention relates to a method and system for starting or restarting an internal combustion engine. More specifically, the present invention relates to a method and system of starting or re-starting an internal combustion engine either solely, or in conjunction with another starter system, by combusting a fuel-air mixture in one or more cylinders of the engine.

## BACKGROUND OF THE INVENTION

[0002] Internal combustion engines are conventionally started by rotating the crankshaft of the engine via an electric starter motor, or electric starter/generator or starter/alternator, to operate the valves, fuel and ignition and other systems of the engine. Fuel and spark are then provided to the cylinders of the engine in the attempt to initiate normal operation of the engine.

[0003] Such starter systems typically include a DC electric motor with a relatively small pinion gear which drives a relatively large ring gear on the flywheel of the engine. The gear ratio achieved between the pinion gear and the ring gear allow the starter motor to develop the necessary torque to rotate the internal combustion engine up to a starting speed.

[0004] While such starter systems are generally reliable when used as intended, they do suffer from numerous disadvantages. The electric starter motor must be cable of producing sufficient torque to rotate the internal combustion engine and the starter is thus typically quite large/heavy. The electric power required for the electric starter motor to rotate the internal combustion engine at a sufficient speed to permit starting of the engine is also very large, typically over a hundred amps at twelve volts, requiring large power storage systems (conventionally lead acid batteries) with the corresponding heavy power cables, the use of solenoids to operate the starter, etc.

[0005] Further, such electric starter systems are typically over-designed for normal operating conditions as they must provide reliable starting during extreme starting conditions, such as sub-zero temperatures. This over-design includes over-sizing the starter motor, over-sizing the storage battery, etc.

[0006] Accordingly, conventional electric starter systems increase the expense of the vehicle while decreasing its fuel efficiency due to the weight of the starter motor, power storage batteries, etc.

[0007] Further, such pinion and ring gear systems produce relatively high levels of noise when operated and such noise levels are now generally unacceptable, or at least undesirable by automotive manufacturers and automobile owners.

[0008] Some recent vehicle designs employ stop-start drive strategies wherein the internal combustion engine may be stopped and re-started, as needed, during operation of the vehicle. For example, when the vehicle is stopped at a traffic light, etc., the internal combustion engine is stopped to enhance fuel economy and reduce emissions. When the light changes and the vehicle driver presses on the accelerator, the internal combustion engine is re-started and the vehicle moves from the traffic light.

[0009] In conventional internal combustion drive vehicles, a typical design criteria is that the starter system should be able to reliably operate to start the internal combustion engine about forty thousand times over the typical lifetime of the vehicle. With vehicles employing stop-start drive strategies, a typical design criteria is that the starter system should be able to reliably operate to start the internal combustion engine four hundred thousand times, or more, over the lifetime of the vehicle – at a minimum ten-fold increase in the required expected operating lifetime.

[0010] Accordingly, the electric starter motor system in such stop-start drive vehicles must be much more robust than in conventional systems, at best adding to the weight and expense disadvantages experienced with conventional electric starter systems and at worst failing to meet the reliability criteria.

[0011] Present attempts to provide suitable starting systems for stop-start drive vehicles have focused on alternator-starters or generator-starters. These systems are typically belt-drive systems wherein torque from the starter motor is applied to the engine via a belt drive, although some inline systems, wherein the generator-starter is inline in the drive train, have also been manufactured. However, such alternator-starter or generator-starter systems are expensive to manufacture, add weight to the vehicle and also require ancillary components such as heavy duty belts or complicated control circuitry, to be included on the vehicle. Further, such systems generally require more volume in the vehicle engine compartment which may not be readily available.

## SUMMARY OF THE INVENTION

[0012] It is an object of the present invention to provide a novel system and method for starting or re-starting an internal combustion engine which obviates or mitigates at least one disadvantage of the prior art.

[0013] According to a first aspect of the present invention, there is provided a system for starting or restarting an internal combustion engine via selective combustion, comprising: at least one sensor for determining the angular position of a rotatable member in the engine; a fuel injection system operable to provide determined amounts of fuel to combustion chambers in the engine; an ignition system operable to ignite the fuel air mixture resulting from the injection of the determined amounts of fuel into respective combustion chambers; an engine control unit operable to determine, from the at least one sensor, the state and position of the pistons in the engine and the volume of the respective combustion chambers formed by the pistons and to select at least one combustion chamber for selective combustion, the engine control unit operable to determine the amount of fuel to be provided to each selected combustion chamber and to have the injection system inject the determined amounts of fuel into each selected combustion chamber and to have the ignition system ignite the resulting fuel air mixture in each selected combustion chamber, the combustion of the fuel air mixture in the at least one selected combustion chamber rotating the crankshaft of the engine to start normal operation of the engine.

[0014] According to another aspect of the present invention, there is provided a method for starting or re-starting an internal combustion engine via selective combustion, comprising the steps of: (i) determining the position and state of the pistons in the engine; (ii)selecting a piston for selective combustion based upon criteria including at least the state of the piston and the position of the piston within its respective cylinder; (iii) determining an appropriate amount of fuel to be provided to the selected piston; (iv) providing the determined amount of fuel to the selected cylinder; (v) igniting the fuel provided to the selected cylinder to combust the fuel, moving the piston in the cylinder to commence rotation of the engine; and (vi) commencing normal operation of the now rotating engine by supplying fuel and ignition to each piston in the engine, in turn.

[0015] The present invention provides a selective combustion starting system and method which selectively provides a proper amount of fuel to one or more combustion chambers in an internal combustion engine. The particular combustion chambers selected depend upon the state of the piston of the combustion chamber and the volume of the combustion chamber, which is dependent upon the position of the piston. Once proper amounts of fuel have been provided to the one or more combustion chambers, the resulting fuel air mixture in the combustion chambers is ignited and combusts to rotate the crankshaft of the engine to commence normal operation of the engine.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0016] Preferred embodiments of the present invention will now be described, by way of example only, with reference to the attached Figures, wherein Figure 1 shows a schematic view of a portion of an internal combustion engine employing a selective combustion starting system in accordance with the present invention.

## DETAILED DESCRIPTION OF THE INVENTION

[0017] The assignee of the present invention has developed novel sensor systems and methods for measuring the angular position and/or speed of a rotating member. Aspects of these systems and methods are described in detail in co-pending U.S. provisional patent applications: “Rotational Position Sensor Based Engine Controller System”, serial no. 60/621,767, filed October 25, 2004, “Vehicle Control System And Method”, serial no. 60/631,756, filed November 29, 2004, “Engine Controller System and Method Employing High Speed Angular Position Sensor”, serial no. 60/652,722, filed February 14, 2005, “System and Method For Measuring Torsional Vibrations In An Engine and Managing Operation of the Engine To Reduce Those Vibrations”, serial number 60/697,879, filed July 8, 2005 and co-pending U.S. patent application, “Rotational Position Sensor Based Engine Controller System”, serial no 11/146,727, filed June 7, 2005, the contents of each of which are incorporated herein by reference.

[0018] As described in these incorporated references, the novel sensor systems include a digital processor, an A/D converter (which can be integral with the processor or separate) and one or more sensors, each sensor preferably employing two pairs of oppositely orientated magnetic sensors, each pair arranged at right angles to one another, such as is available in the model 2SA-10 sensor manufactured by Sentron AG, Baarerstrasse 73, 6300 Zug, Switzerland.

[0019] The sensor is located adjacent at least one dipole magnet which rotates with the rotating member and, as the magnetic field from the dipole magnet rotates with the rotating member, the output from each sensor pair measuring the dipole's field is a sinusoid voltage signal, with the output of one sensor pair being ninety degrees out of phase with the output signal of the other sensor pair. The sinusoid voltages are converted to digital values by the A/D converter and, in one embodiment, are provided to the processor which calculates the arctan ($\tan^{-1}$) of the sinusoid voltages to determine the angular position of the rotating member.

[0020] Specifically, if the angular position of the rotating member is $\alpha$, and the output voltage from the first sensor pair is $V_1$ and the output voltage from the second sensor pair is $V_2$, then in this embodiment $\alpha$ can be determined from:

$$V_1 = \cos(\alpha)$$
$$V_2 = \sin(\alpha)$$
$$\frac{V_2}{V_1} = \frac{\sin(\alpha)}{\cos(\alpha)} = \tan(\alpha)$$
$$\alpha = \arctan(\frac{V_2}{V_1})$$

where

For ($V_1>0$, $V_2>0$), $\alpha=\arctan(V_2/V_1)$;

For ($V_1=0$, $V_2>0$), $\alpha=90°$;

For ($V_1<0$), $\alpha=180°+\arctan(V_2/V_1)$;

For ($V_1=0$, $V_2<0$), $\alpha=270°$; and

For ($V_1>0$, $V_2<0$), $\alpha=360°+\arctan(V_2/V_1)$.

[0021] Unlike conventional engine sensor systems which typically comprise toothed gears with inductive or magnetic sensors, the angular position sensor systems described in the above-mentioned co-pending patent applications and preferably employed with the present invention provide relatively precise information (typically better than one degree) with respect to the angular position of a rotating member in an internal combustion engine. Further, unlike conventional sensor systems, the angular position sensor systems preferably employed with the present invention can provide position information with respect to the angular position of the rotating member when stopped and/or rotating at slow speeds. In contrast, the above-mentioned conventional sensor systems typically do not provide meaningful angular positional information for an engine until the engine is rotating at at least three hundred RPM.

[0022] Another advantage of the sensor system preferably employed with the present invention is that it is not-contacting (requiring no physical contact between the sensor and the rotating member) and thus can be utilized with a wide variety of rotating members including the engine crankshaft, camshaft(s), jackshaft or rotating members of engine subsystems such as an oil pump drive shaft or water pump drive shaft. Further, the preferred sensor system is, relative to other sensor systems commonly employed, very tolerant to variations in installation, including alignment with the dipole magnets and/or rotating member and movement of the rotating members, over time, due to wear and/or normal operations, etc.

[0023] While the present invention preferably employs the angular position sensor systems and methods described in the above-mentioned pending patent applications, the present invention is not so limited and, as will be apparent from the following description, any suitable sensor system or method which is capable of providing information indicating the angular position of a rotatable member of an engine, when that engine is stopped and when operating at start up speeds (typically below three hundred RPM), can be utilized.

[0024] In particular, the present invention can instead employ the method and system of processing the output of sensors taught in the above-mentioned U.S. Provisional Patent Application ,"Engine Controller System and Method Employing High Speed Angular Position Sensor", serial no. 60/652,722, filed February 14, 2005.

[0025] Figure 1 shows a schematic representation of a portion of an engine 100 which includes a selective combustion starting system in accordance with the present invention. While just one is illustrated in Figure 1, engine 100 includes a series of cylinders 104 and pistons 108 which form combustion chambers 112. Engine 100 is equipped with a fuel injection system which permits individual injectors 116 for each respective combustion chamber 112 to be triggered as needed by an engine control unit (ECU) 120. Similarly, the engine is equipped with an ignition system which permits individual spark plugs 124 to be fired, for each respective combustion chamber 112, as needed by ECU 120.

[0026] As is also illustrated, the engine is equipped with one or more sensors 128 which can provide information indicating the absolute angular position of a rotatable member of engine 100, such as a crankshaft 132 or camshaft 136. If sensors 128 are the particular sensors described above, then the processor to process the output signals of the sensors can be integral with ECU 120 or can be a separate processor, not shown.

[0027] From the determined position of the rotatable member, ECU120 knows, or can determine, the position of each piston 108 in each respective cylinder 104 of the engine, and thus the present volume of each combustion chamber 112.

[0028] However, as will be apparent, it is not sufficient to determine the volume of combustion chambers 112 as the state of each cylinder 104/piston 108 pair must also be determined as a piston 108 can be moving toward or away from Top Dead Center (TDC) and, when moving towards TDC, can be in a compression stroke or an exhaust stroke, or, when moving away from TDC, can be in a power stroke or inlet stroke.

[0029] Accordingly, one method to identify the actual state of each cylinder 104/piston 108 pair is to determine the general position of camshaft 136, which can be measured directly, or derived from other information. If sensor 128 is determining the position of crankshaft 132 or another (non-camshaft) rotating member, a second sensor 128 or any other suitable means can be used to determine the general position of camshaft 136 to determine the state of cylinder 104/piston 108 pairs.

[0030] It will be understood that, if the position of pistons 108 are known relatively accurately, the position of camshaft 136 need not be determined with a high degree of accuracy as this information is only used to determine the state of pistons 108. Thus it is sufficient to determine the angular position of camshaft 136 with an accuracy in the range of tens of degrees.

[0031] However, as will also be apparent, the rotatable member that sensor 128 measures can be camshaft 136 and, if sensor 128 employs the above-described sensor, with the accuracy with which the position of camshaft 136 can be determined with sensor 128, ECU 120 can determine the position and state of the pistons 108 from this single measurement.

[0032] To start engine 100, ECU 120 determines the position and state of each piston 108 in the engine using one or more sensors 128. Depending upon the number of pistons 108 in the engine, ECU 120 selects at least one piston 108 which is past TDC and whose state is such that the piston is on the combustion stroke (i.e. – the inlet and exhaust valves for the piston are both closed).

[0033] The selection of a piston 108 can involve the consideration of several factors including, but not limited to: the volume of the combustion chamber 112 formed by the respective piston 108 and cylinder 104 with the respective piston 108 in its determined position; and the angle of the connecting rod extending between the respective piston 108 and the crankshaft 132, which angle changes the mechanical advantage between the piston 108 and the crankshaft 132.

[0034] As will be apparent to those of skill in the art, the preferred values of these factors used in the selection process will vary from engine design to engine design, as characteristics such as the total engine starting inertia, the diameter of the cylinder bores, the length of the piston stroke, etc. will vary between engine designs. An appropriate set of selection factors are determined and provided to ECU 120 by the manufacturer of engine 100.

[0035] Employing the provided factors, ECU 120 selects one or more pistons 108 for the selective combustion starting of engine 100. ECU 120 determines the volume of each respective combustion chamber 112 formed by each respective selected piston 108 and cylinder 104 pair with the respective piston 108 in its determined position. This volume can be determined by accessing a pre-calculated look up table of data for engine 100, can be calculated as needed or can be determined in any appropriate manner as will occur to those of skill in the art.

[0036] If a selected piston 108 is near (just past) TDC, the volume of combustion chamber 112 will be relatively low, while the mechanical advantage between the connecting rod and crankshaft 132 will be relatively high. Conversely, if the selected piston 108 is well past TDC the volume of combustion chamber 112 will be relatively large while the mechanical advantage between the connecting rod and crankshaft 132 will be relatively low. When a selective combustion starting system in accordance with the present invention is configured for engine 100, a determination will be made by the designers of engine 100 of an optimal range of positions for pistons 108.

[0037] Generally, a position of a piston 108 which results in the angle of the connecting rod to crankshaft 132 being in the range of from about sixty degrees (with zero degrees corresponding to the TDC position and one hundred and eighty degrees corresponding to BDC position) to about one hundred and twenty degrees is preferred, but specific engine designs will result in different preferred positions. As will be apparent to those of skill in the art, the preferred ranges of piston positions can be calculated from specific engine designs, or can be determined empirically or otherwise.

[0038] When a piston 108 is selected, ECU 120 calculates an appropriate amount of fuel, preferably stoichiometric, to provide for the volume of the selected combustion chamber 112 which is formed by the selected piston 108 in its determined position. ECU 120 can accept inputs from other sensors, such as sensors which measure ambient air temperature and density, engine temperature, etc. when calculating the appropriate amount of fuel. By accurately determining the volume of the combustion chamber 112 for each respective selected combustion chamber 112, as well as the other sensor inputs such as engine temperature, ambient air temperature, air pressure, etc., ECU 120 can determine the appropriate amounts of fuel to be provided to each respective combustion chamber 112 to obtain reliable starting and fuel and emission efficient combustion in the combustion chambers 112.

[0039] As will be apparent now to those of skill in the art, during the starting operations ECU 120 determines an appropriate amount of fuel in view of the fact that the selected combustion chamber 112 is at ambient pressure (as pistons 108 are stationary, the air in the respective combustion chamber 112 is not compressed), rather than the over-ambient conditions which exist during normal operation of engine 100.

[0040] When the appropriate amount of fuel is determined, ECU 120 triggers the injector 116 for the selected combustion chamber 112 to inject the fuel and then fires the spark plug 124 for the selected combustion chamber 112 to ignite the fuel. The fuel in the selected combustion chamber 112 combusts and forces piston 108 down cylinder 104, rotating crankshaft 132.

[0041] As crankshaft 132 is rotating, ECU 120 then provides appropriate amounts of fuel and spark to each other combustion chamber 112, in turn, in the appropriate firing sequence, to continue rotating crankshaft 132 and to bring the rotational speed of crankshaft 132 up to a normal minimal operating speed (e.g. – about three hundred and fifty or more RPM).

[0042] It is contemplated that, after the selected combustion chamber 112 has been fired, the next combustion chamber 112 to be fired in the normal firing sequence will not produce its normal amount of compression of the air it contains and/or will not contain it's normal volume of air, due to the fact that, when the selected combustion chamber 112 was fired, the piston 108 of the next cylinder 104 to be fired would have been at a position above bottom dead center and would thus not move through a complete stroke length to compress the air in the next combustion chamber 112.

[0043] Accordingly, ECU 120 will be able to determine the position of piston 108 of the next combustion chamber 112, and thus the expected volume of air in the next combustion chamber 112, from the position of the selected piston 108 and ECU 120 can use fuel/air mixtures, injection timings and ignition timings which are appropriate for the reduced amount of compression for the firing of this next combustion chamber 112.

[0044] Depending upon the number of cylinders in engine 100, the next (third) combustion chamber to be fired in the firing sequence may have achieved full compression of the air in it, or ECU 120 may again determine the expected volume of air in this next combustion chamber 112 and use fuel/air mixtures, injection timings and ignition timings which are appropriate for the reduced amount of compression for the firing of this next combustion chamber 112. In most circumstances, it is contemplated that by the time the fourth combustion chamber in the firing sequence is to be fired, ECU 120 will be able to assume that a normal volume of air will be present in the fourth combustion chamber 112, although the above-described process of determining appropriate fuel/air mixtures, injection timings and ignition timings which are appropriate for a reduced amount of compression can be continued, if needed.

[0045] While ECU 120 brings the operating speed of engine 100 up to a normal operating speed from a stopped speed, ECU 120 can use fuel/air mixtures, injection timings and ignition timings which are appropriate for these slow operating speeds, which mixtures and timings may be different than those used when engine 100 is operating at normal operating conditions and speeds. It is contemplated that in many circumstances these mixtures and/or timings will be conventional (as used during regular operation of the engine) but they can be altered, if desired, to reduce emissions or otherwise enhance the process of starting, or re-starting, the engine.

[0046] Another contemplated advantage of using the above-described sensor system with the present invention is that the sensor system can also provide accurate and reliable information to ECU 120 to determine the rotational speed of engine 100 as engine 100 accelerates to normal operating speeds. ECU 120 can use this rotational speed information to determine the amount of compression produced in each combustion chamber 112 (which may be significantly less than the normal compression produced at the higher, normal engine operating speeds) when determining the appropriate amount of fuel to provide to each combustion chamber 112 to meet performance and emissions requirements. If the present invention is employed with a different sensor system which is not able to provide accurate data with respect to the rotational speed of engine 100 during this start up, it may be desirable to provide engine 100 with additional sensors operable to provide an indication of the pressure/compression obtained in combustion chambers 112 as engine 100 is being started.

[0047] In the example described above, if engine 100 has eight or more cylinders, it may not be sufficient to supply fuel and spark to a single combustion chamber 112 to start rotation of crankshaft 132 due to the friction and inertia of the larger number of engine components. In such a case ECU 120 can select two or more pistons 108 which are positioned after TDC and which are in the combustion stroke state. In such as case, ECU 120 will determine an appropriate amount of fuel for the volume of the combustion chamber 112 formed by each piston 108, which amount will be different for each combustion chamber 112 as each combustion chamber 112 will have a different volume.

[0048] ECU 120 will then trigger the respective injector 116 to inject the respective determined amount of fuel into each respective combustion chamber 112 and will fire the respective spark plug 124 for each combustion chamber 112. By firing two, or more, combustion chambers 112 simultaneously, rotation of crankshaft 132 can be initiated despite relatively high levels of friction an/or inertia.

[0049] In the examples above, the engine is started solely by selective combustion of fuel supplied to one or more combustion chambers 112. However, it is contemplated that in adverse operating conditions, such as extreme cold conditions, or for engines with very high starting loads, such a system may not be sufficient to provide an assured ability to start the engine. In such a case, it is contemplated that the selective combustion can be combined with an electric starter motor, such as a conventional pinion/ring gear starter, or with a belt drive alternator starter. In this case, the selective combustion system described above can be used to overcome the relatively high levels of starting friction and inertia to assist the starter motor so that the starter motor need only produce a much lower amount of torque to complete the starting of engine 100. Thus, the size and weight of the electric starter motor can be reduced, as can the associated batteries and cabling systems.

[0050] As should now be apparent to those of skill in the art, selective combustion of the present invention can be utilized instead of, or in combination with, electric starting systems such as pinion/ring-gear starter motors or alternator-starters to start engine 100.

[0051] It is further contemplated that the combustion start system described herein can be combined with a belt-drive alternator/starter, or a pinion/ring gear electric motor, which is used to incrementally move crankshaft 132 to “jog” a piston 108 to an optimal position with its cylinder 104 for selective combustion to start engine 100.

[0052] For example, in a four cylinder engine, it may be that no piston 108 is both in the combustion state and in an position wherein the volume of its respective combustion chamber 112 and the angle of the connecting rod to the crankshaft are close to optimal for providing enough force to start the engine. In such a case ECU 120 can control an alternator/starter or electric motor to move crankshaft 132 such that a piston 108 in the correct state will be located at, or near, an optimal position wherein a desired volume of its respective combustion chamber and the desired angle of the connecting rod and crankshaft will be obtained.

[0053] As this movement of crankshaft 132 can be performed much less quickly than would be required for starting engine 100 conventionally with a starter motor, the electric motor employed for this purpose can be much smaller than conventional electric starter motors and can require much lower electric currents to operate. Accordingly, the above-described weight and/or other disadvantages of conventional electric starter motors can be avoided or mitigated.

[0054] It should be noted that the electric motor employed to moved crankshaft 132 can operate to rotate crankshaft 132 in either direction, to move a piston 108 back towards or away from TDC as necessary.

[0055] Recent advances in engines have included electronically controlled valve trains. In such systems, inlet and exhaust valves are opened and closed via solenoids, hydraulic actuators, or other electronically controlled systems. If engine 100 employs such an electronically controlled valve train, ECU 120 can selectively combust all, or a subset of, the combustion chambers 112 of cylinders 104 which are past TDC, as the state of the pistons 108 can effectively be set, as needed, by appropriate operation of the electronic valve trains. Thus, for example, in an eight cylinder engine as many as four cylinders can be selectively combusted at one time to provide an initial force to rotate crankshaft 132.

[0056] As will be apparent to those of skill in the art, engines with such electronically controlled valve trains do not include a camshaft. One method to implement such an engine is to employ a sensor 128, such as the above described sensor, to determine the position of crankshaft 132 and to have ECU 120 initially decide the desired state of the pistons 108 and then to dynamically update that state corresponding with the measured rotation of crankshaft 132. In such a case, ECU 120 will know and/or be able to establish, the position and state of all pistons 108 in the engine without the presence of a camshaft.

[0057] The present inventors believe that the selective combustion system and method described herein is particularly useful with vehicles employing stop-start drive techniques wherein the gasoline engine is stopped when the vehicle is stopped at traffic lights, or stopped in traffic, etc. To date, such stop-start drive systems have required electric starter systems with pinion/ring gear starter motors which are much more robust than conventional electric starter systems as the starter system will is required to operate much more often than those of conventional internal combustion engines and/or which require belt-drive alternator/starters to augment, or replace, the electric starter motor. Thus, the starter systems employed with stop-start drive systems are typically heavier and more expensive than conventional electric starters.

[0058] By instead employing the above-described selective combustion system and method for restarting the engine in a stop-start drive, the weight, expense and/or reliability issues with electric starter systems can be avoided.

[0059] Further, as stop-start strategies involve restarting an engine which was recently stopped, the engine will typically be at, or near, its normal operating temperature thus reducing the initial starting load which would result from cold engine oil, etc. which enhances the ability of the above-described selective combustion starting system and method to efficiently restart the engine.

[0060] It is contemplated that it may be desirable in some circumstances to employ a combination of selective combustion starting with an electric starting motor or alternator/starter, as described above, for stop-start drive vehicles and such a combination is also within the scope of the present invention.

[0061] The selective combustion starting system and method described herein provides an efficient method for starting and/or restarting internal combustion engines by selectively providing a proper amount of fuel to one or more combustion chambers in the engine. The particular combustion chambers selected depend upon the state of the piston of the combustion chamber and the volume of the combustion chamber, which is dependent upon the position of the piston. Once the proper amounts of fuel have been provided to the one or more combustion chambers, the resulting fuel air mixture in the combustion chambers is ignited and combusts to rotate the crankshaft of the engine to commence normal operation of the engine.

[0062] The described selective combustion starting can be employed instead of, or in combination with, an electric starter motor and/or alternator/starter. The starting system and method is reliable, inexpensive to implement and is quieter in operation than conventional pinion and ring gear electric starter systems.

[0063] The above-described embodiments of the invention are intended to be examples of the present invention and alterations and modifications may be effected thereto, by those of skill in the art, without departing from the scope of the invention which is defined solely by the claims appended hereto.

We claim:

1. A system for starting or restarting an internal combustion engine via selective combustion, comprising:

at least one sensor for determining the angular position of a rotatable member in the engine;

a fuel injection system operable to provide determined amounts of fuel to combustion chambers in the engine;

an ignition system operable to ignite the fuel air mixture resulting from the injection of the determined amounts of fuel into respective combustion chambers;

an engine control unit operable to determine, from the at least one sensor, the state and position of the pistons in the engine and the volume of the respective combustion chambers formed by the pistons and to select at least one combustion chamber for selective combustion, the engine control unit operable to determine the amount of fuel to be provided to each selected combustion chamber and to have the injection system inject the determined amounts of fuel into each selected combustion chamber and to have the ignition system ignite the resulting fuel air mixture in each selected combustion chamber, the combustion of the fuel air mixture in the at least one selected combustion chamber rotating the crankshaft of the engine to start normal operation of the engine.

2. The system of claim 1 wherein the engine control unit selects at least two combustion chambers.

3. The system of claim 1 wherein the engine further includes an electric starter motor, the electric starter motor cooperating with the rotation of the crankshaft by the combustion of the fuel air mixture to start normal operation of the engine.

4. The system of claim 3 wherein combustion of the fuel air mixture

overcomes the initial inertia of the engine and the electric starter motor then rotates the engine to complete the starting of normal operation of the engine.

5. The system of claim 1 wherein the engine further includes an electric motor operable by the engine control unit to rotate the engine to position at least one piston in the engine to obtain at least one combustion chamber of a desired volume for selection by the engine control unit.

6. The system of claim 5 wherein the electric motor is operable to rotate the engine in forward and reverse directions to position the at least one piston.

7. The system of any preceding claim wherein the system is employed in a stop-start drive vehicle.

8. A method for starting or re-starting an internal combustion engine via selective combustion, comprising the steps of:

(i) determining the position and state of the pistons in the engine;

(ii) selecting a piston for selective combustion based upon criteria including at least the state of the piston and the position of the piston within its respective cylinder;

(iii) determining an appropriate amount of fuel to be provided to the selected piston;

(iv) providing the determined amount of fuel to the selected cylinder;

(v) igniting the fuel provided to the selected cylinder to combust the fuel, moving the piston in the cylinder to commence rotation of the engine; and

(vi) commencing normal operation of the engine.

9. The method of claim 8 wherein the engine has an electrically controllable valvetrain and step (i) comprises determining the position of the pistons in the engine and selecting a state for said pistons and further

comprising the step of, between steps (iv) and (v), operating the valvetrain to obtain the selected state for the pistons.

10. The method of claim 9 wherein steps (ii) to (v) are simultaneously carried out on at least two pistons.

11. The method of claim 8 wherein step (ii) includes rotating the engine to position the piston in an optimal position.

12. The method of claims 8, 9, 10 or 11 wherein said appropriate amount of fuel is a stoichiometric amount.

13. The method of claims 8, 9, 10 or 11 wherein step (i) includes determining a position of each piston relative to top dead center.

14. The method of claim 13 wherein step (i) includes determining whether a piston is in a combustion stroke.

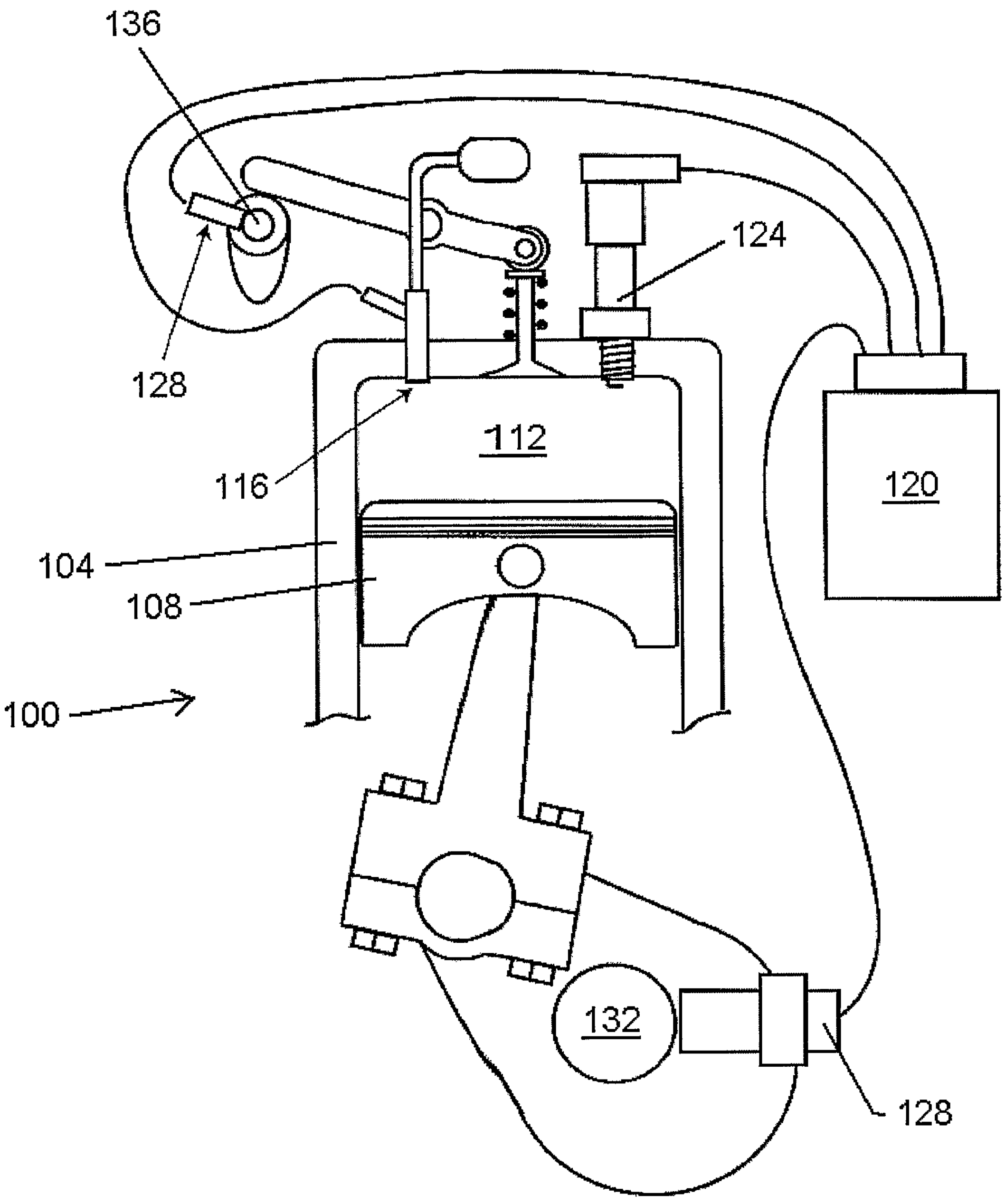


Fig. 1

# INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2005/001628

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***F02D 41/06*** (2006.01) , ***F02N 11/00*** (2006.01)
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC: F02D 41/06 (2006.01) , F02N 11/00 (2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
DELPHION; USPTO; Espacenet; IEEE Xplore; Canadian database: selective, combustion, starting, stop-start, angular position, re-starting, selected cylinder, de-activat$, selective combustion starting

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | US 5 710 703 (KIRN ET AL) 20 January 1998 (20-01-1998) Entire document | 1-14 |

[ ] Further documents are listed in the continuation of Box C. [X] See patent family annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| 3 February 2006 (03-02-2006) | 15 February 2006 (15-02-2006) |

| Name and mailing address of the ISA/CA | Authorized officer |
|---|---|
| Canadian Intellectual Property Office<br>Place du Portage I, C114 - 1st Floor, Box PCT<br>50 Victoria Street<br>Gatineau, Quebec K1A 0C9<br>Facsimile No.: 001(819)953-2476 | Arvo Taagepera (819) 997-3089 |

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/CA2005/001628

| tent Document ed in Search Report | Publication Date | Patent Family Member(s) | Publication Date |
|---|---|---|---|
| 35710703 | 20-01-1998 | NONE | |