



(51) International Patent Classification:

F02D 13/02 (2006.01) FOIL 1/34 (2006.01)
F02D 13/06 (2006.01) FOIL 13/00 (2006.01)
F02D 17/00 (2006.01)

(21) International Application Number:

PCT/US20 12/032701

(22) International Filing Date:

9 April 2012 (09.04.2012)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

61/474,950 13 April 2011 (13.04.2011) US
61/545,297 10 October 2011 (10.10.2011) US

(71) Applicant (for all designated States except US):

BORGWARNER INC. [US/US]; Patent Department,
3850 Hamlin Road, Auburn Hills, Michigan 48326 (US).

(72) Inventor; and

(75) Inventor/Applicant (for US only): ROTH, David B.
[US/US]; 64 Walden Lane, Groton, New York 13073
(US).

(74) Agents: BROOKS, Cary W. et al; Brooks Group, 48685

Hayes, Shelby Township, Michigan 48315 (US).

(81) Designated States (unless otherwise indicated, for every

kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every

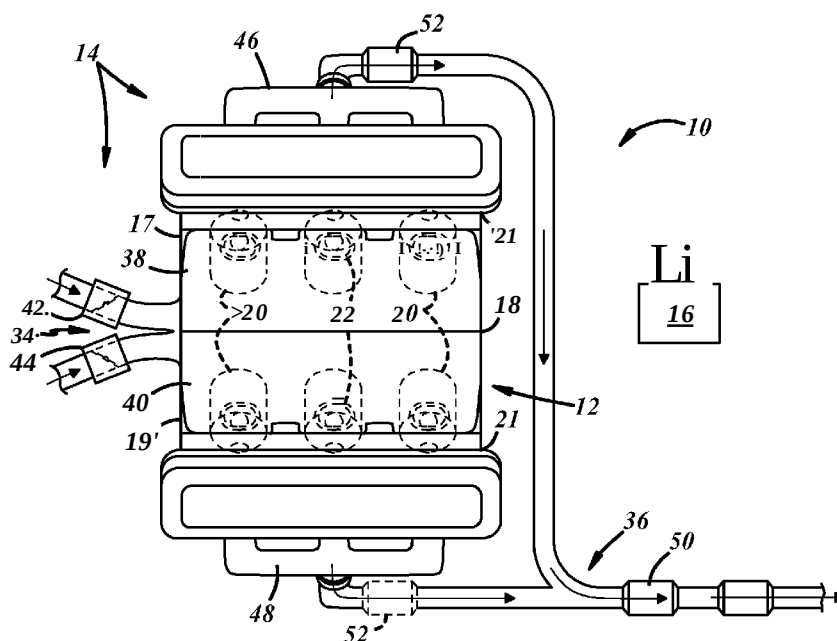
kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- as to applicant's entitlement to apply for and be granted a patent (Rule 4.1 7(H))
- as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.1 7(in))

[Continued on nextpage]

(54) Title: CYLINDER DEACTIVATION BY NEGATIVE VALVE OVERLAP



(57) Abstract: Intake and exhaust valve timing is adjusted to a negative valve overlap condition to deactivate an engine cylinder.

Published:

- *without international search report and to be republished
upon receipt of that report (Rule 48.2(g))*

CYLINDER DEACTIVATIONBY NEGATIVE VALVE OVERLAP**CROSS REFERENCE TO RELATED APPLICATIONS**

[0001] This application claims the benefit of United States Provisional Application serial number 61/474,950 filed April 13, 2011 (Attorney Docket No. DKT1 1063 (0309.4155.901)); and United States Provisional Application serial number 61/545,297 filed October 10, 2011 (Attorney Docket No. DKT1 1064 (0309.4156.901)).

TECHNICAL FIELD

[0002] The field to which the disclosure generally relates to includes operation of internal combustion engines and, more particularly, variable valve timing of internal combustion engines.

BACKGROUND

[0003] Many types of internal combustion engines typically may include engine blocks having two cylinder banks each with a corresponding close-coupled catalyst, one or more cylinders in each of the cylinder banks, and pistons in the cylinders to establish combustion chambers. These engines also usually may include intake valves to control intake of gases and/or fuel into the combustion chambers, exhaust valves to control exhaust of combustion gases out of the combustion chambers, intake and exhaust camshafts to open and close the intake and exhaust valves, and variable valve timing devices to adjust timing of the opening and closing of the intake and exhaust valves.

[0004] In certain situations it may be desirable to deactivate engine cylinders. Cylinder deactivation may be accomplished by cutting off fuel and spark to one or more cylinders. However, if this method is used without deactivating cylinder valves to seal off the cylinder, the pressure within the cylinder drops so low that oil is drawn around seals on the pistons and escapes into the cylinder. To prevent such as oil loss problem most engines uses a mechanism to deactivate the valves. Valve deactivation is typically accomplished by deactivating a link (rocker arm) that is normally between

the cam and the valve. Such an expensive system is illustrated in United States Patent No. 6,532,920.

SUMMARY OF ILLUSTRATIVE EMBODIMENTS

[0005] An embodiment of a method of operating an internal combustion engine includes activating an engine cylinder by supplying fuel and combustion gas to the engine cylinder and controlling opening and closing of intake and exhaust valves associated with the engine cylinder in accordance with base timing. The method also includes deactivating the engine cylinder by not supplying fuel to the engine cylinder and adjusting timing of the intake and exhaust valves to a negative valve overlap (NVO) condition.

[0006] An embodiment of a method of operating an internal combustion engine having a first cylinder bank and a second cylinder bank includes activating the first and second cylinder banks by supplying fuel and combustion gas to the engine cylinders of the first and second cylinder banks and controlling opening and closing of intake and exhaust valves associated with the engine cylinders of the first and second cylinder banks in accordance with base timing. The method also includes deactivating the second cylinder bank by not supplying fuel to the engine cylinders of the second cylinder bank and adjusting timing of the intake and exhaust valves associated with the engine cylinders of the second cylinder bank to an NVO condition.

[0007] An embodiment of a method of starting an internal combustion engine having two cylinder banks includes not supplying fuel to engine cylinders of at least one of the two cylinder banks, and ensuring that timing of both intake valves and exhaust valves associated with the engine cylinders of the at least one of the two cylinder banks is set to an NVO condition.

[0008] An embodiment of a method of deactivating an engine cylinder of an internal combustion engine includes not supplying fuel to the engine cylinder, and adjusting timing of intake and exhaust valves to an NVO condition.

[0009] An embodiment of an exhaust system for an engine having a first cylinder bank and a second cylinder bank, wherein the exhaust system includes a common exhaust gas treatment device in downstream fluid communication with the first and second cylinder banks, a close-coupled exhaust gas treatment device

corresponding to the first cylinder bank and in upstream fluid communication with the common exhaust gas treatment device, and no close-coupled exhaust gas treatment device corresponding to the second cylinder bank.

[0010] Other illustrative embodiments of the invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while disclosing illustrative embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] Select examples of embodiments of the invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0012] FIG. 1 illustrates a schematic top view of an embodiment of an engine system;

[0013] FIG. 2 illustrates a schematic end view of an embodiment of an internal combustion engine of the engine system of FIG. 1;

[0014] FIG. 3 illustrates a graphical plot of an embodiment of engine valve lift and timing;

[0015] FIG. 4 illustrates a graphical plot of an engine cylinder pumping loop with base timing of engine valves and a closed throttle;

[0016] FIG. 5 illustrates a graphical plot of an engine cylinder pumping loop with base timing of engine valves and an open throttle;

[0017] FIG. 6 illustrates a graphical plot of an engine cylinder pumping loop with engine valves deactivated;

[0018] FIG. 7 illustrates graphical plots of an embodiment of engine cylinder pumping loops with an open and a closed throttle and 95 degrees of negative valve overlap between exhaust and intake engine valves;

[0019] FIG. 8 illustrates a graphical plot of brake mean effective pressure (BMEP) versus engine valve timing for an embodiment of 90 degrees of negative valve overlap for cylinder deactivation in a closed throttle condition;

- [0020] FIG. 9 illustrates a table including BMEP values obtained with valve deactivation compared with BMEP values obtained with the embodiment of cylinder deactivation via negative valve overlap of FIG. 8;
- [0021] FIG. 10 illustrates a graphical plot of engine cylinder mass flow versus engine crankshaft angle for a closed throttle condition according to the embodiment of FIG. 8; and
- [0022] FIG. 11 illustrates a graphical plot of engine cylinder mass flow versus engine crankshaft angle for an open throttle condition according to the embodiment of FIG. 8.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

- [0023] The following description of the embodiments is merely illustrative in nature and is in no way intended to limit the invention, its application, or uses.
- [0024] According to an embodiment of a method, intake and exhaust valve timing is adjusted to a negative valve overlap condition to deactivate an engine cylinder.
- [0025] An illustrative operating environment is illustrated in FIG. 1, and may be used to implement one or more presently disclosed methods of deactivating an engine cylinder, operating an engine, and/or starting an engine. The methods may be carried out using any suitable system and, more specifically, may be carried out in conjunction with an engine system such as system 10. The following system description simply provides a brief overview of one example engine system, but other systems and components not shown here could also support the presently disclosed methods.
- [0026] In general, the system 10 may include an internal combustion engine 12 that may combust a mixture of fuel and induction gases for conversion into mechanical rotational energy and exhaust gases, an engine breathing system 14 that may deliver induction gases to the engine 12 and carry exhaust gases away from the engine 12, a fuel system (not separately shown), which may include fuel injectors or the like, to provide any suitable liquid and/or gaseous fuel to the engine 12 for combustion therein with the induction gases, and an ignition system (not separately shown), which may include spark plugs, glow plugs, or the like, to ignite combustion gases. Any of a variety of fuels may be used including, but not limited to, gasoline,

diesel, biofuel, propane, hydrogen, and/or the like. The system 10 also may include a control system 16 to control operation of the engine system 10.

[0027] Referring to FIGS. 1 and 2, the internal combustion engine 12 may be any suitable type of engine, such as a spark-ignition engine like a gasoline engine, an autoignition or compression-ignition engine like a diesel engine, or the like. The engine 12 may include a block 18 having first and second cylinder banks 17, 19 with cylinders 20 and pistons 22 therein, which, along with cylinder heads 21, may define combustion chambers for internal combustion of a mixture of fuel and induction gases. The engine 12 may also include any suitable quantities of intake valves 24 and exhaust valves 26 (FIG. 2). The pistons 22 may be pivotally connected to the crankshaft by piston rods.

[0028] The engine 12 may include any quantity of cylinders, and may be of any size and configuration. For example, the engine 12 may be a V-6 engine, as illustrated, but instead may include 2, 3, 4, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, or any other suitable quantity of cylinders. In another example, the engine 12 may instead be configured as an inline or straight engine, a horizontally opposed engine, a rotary engine, a "W" engine, or as any other suitable configuration. In a further example, the engine 12 may be a 90 degree "V" configuration as illustrated, a 60 degree "V" configuration, or of any other suitable angled configuration between the cylinder banks 17, 19. As used herein, the phrase "cylinder bank" may include a cylinder bank laterally or angularly offset from another cylinder bank as in a "V" or "W" engine configuration, or a cylinder bank axially or longitudinally offset as in an inline engine configuration. In the latter example, one or more camshafts may correspond to a first plurality of cylinders, and one or more other camshafts may correspond to a second plurality of cylinders offset from the first.

[0029] The engine 12 may operate according to any suitable speeds and loads. Example idle speeds may be on the order of about 500 to about 800 RPM, and typical maximum engine speed may be on the order of about 5500-6500 RPM but may even exceed that range. As used herein, the term low speeds and loads may include about 0% to 33% of maximum engine speeds and loads, intermediate speeds and loads may include about 25% to 75% of maximum engine speeds and loads, and high speeds and loads may include about 66% to 100% of maximum engine speeds and loads. As used herein, moderate speeds and loads may include about 0% to 50% of maximum

engine speeds and loads, and heavier speeds and loads may include about 50% to 100% of maximum engine speeds and loads.

[0030] Referring to FIG. 2, the engine 12 may include variable valve timing (VVT) devices 28 to actuate the valves 24, 26. For example, the VVT devices may include dual overhead camshaft and valvetrain arrangements as illustrated wherein the intake valves on a given bank are operated by cams on a given camshaft and the exhaust valves are operated by cams on a separate camshaft. In another example, the VVT devices 28 may include single overhead camshaft and valvetrain arrangements with dual acting concentric cam shaft devices that may be used to actuate intake and exhaust valves separately. In another example, the devices 28 may include cam torque actuated (CTA) brand timing devices available from the assignee hereof and having mid-position or intermediate position locks. Example CTA devices may include those disclosed in U.S. Patents and Publications 7,255,077, 6,374,787, 6,263,846, and 2008/230027.

[0031] The timing of the valves 24, 26 may be controlled by adjusting the phase or angle between cam shafts 30, 31 and an engine crankshaft 32, for example, using camshaft phasers of the devices 28.

[0032] Accordingly, valve timing may be regulated via camshafts and cam phasers or, in other embodiments, via valve solenoids or the like to open and close the valves. In a typical engine cycle (e.g., a four stroke engine cycle), an exhaust valve opens just before a piston reaches a bottom dead center (BDC) position and soon thereafter about half of all combusted induction gases exit the combustion chambers under relatively high pressure. This is commonly referred to as a blowdown phase of the exhaust portion of the engine cycle. The piston sweeps back upward toward a top dead center position (TDC) and displaces most if not all of the remaining combusted induction gases out of the combustion chambers under relatively lower pressure. This is commonly referred to as a scavenging phase of the exhaust portion of the engine cycle.

[0033] Referring to FIG. 1, the engine breathing system 14 may include an induction system 34 in upstream fluid communication with the engine 12 that may convey induction gases to the engine 12 and an exhaust system 36 in downstream fluid communication with the engine 12 that may carry exhaust gases away from the engine 12. The engine breathing system 14 may also include an exhaust gas

recirculation (EGR) system (not shown) in communication across the exhaust and induction systems 34, 36 to recirculate exhaust gases for mixture with fresh air to reduce emissions and pumping losses from the engine system 10. The engine breathing system 14 may further include a turbocharging system (not shown) between the induction and exhaust systems 34, 36 to compress intake air and thereby improve combustion to increase engine power output. As used herein, the phrase "induction gases" may include fresh air, compressed air, and/or recirculated exhaust gases.

[0034] The induction system 34 may include, in addition to suitable conduit, connectors, and the like, a first induction or intake manifold 38 in fluid communication with the first cylinder bank 17, a second intake manifold 40 in fluid communication with the second cylinder bank 19, a first throttle 42 in fluid communication with the first intake manifold 38, and a second throttle 44 in fluid communication with the second intake manifold 40. In another embodiment, the induction system 34 may include only one intake manifold common to both cylinder banks 17, 19 and/or only one throttle common to both cylinder banks 17, 19.

[0035] The exhaust system 36 may include a first manifold 46 in downstream fluid communication with the first cylinder bank 17, a second manifold 48 in downstream fluid communication with the second cylinder bank 19, and a common exhaust treatment device 50 in downstream fluid communication with the first and second manifolds 46, 48. As used herein, "exhaust treatment device" may include a catalytic converter, diesel particulate filter, or any other suitable device that may be used to reduce or otherwise treat engine exhaust emissions. The exhaust system 36 also may include a close-coupled exhaust gas treatment device 52 corresponding to the first manifold 46 and in upstream fluid communication with the common exhaust treatment device 50. In one embodiment, the exhaust system 36 further may include another close-coupled exhaust gas treatment device 52, corresponding to the second manifold 48 and in upstream fluid communication with the common exhaust treatment device 50. In another embodiment, the exhaust system 36 does not include the other close-coupled exhaust gas treatment device 52 corresponding to the second manifold 48.

[0036] Accordingly, at least in one embodiment, the intake manifolds 38, 40 and/or the exhaust manifolds 46, 48 may be segregated between the cylinder banks 17, 19 of the engine 12. However, other embodiments may include a common intake

manifold for engine cylinder banks or a common exhaust manifold for engine cylinder banks.

[0037] The control system 16 may include any suitable hardware, software, and/or firmware to carry out at least some portions of the methods disclosed herein below. For example, the control system 16 may include various engine system actuators and sensors (not shown). The engine system sensors are not individually shown in the drawings but may include any suitable devices to monitor engine system parameters. For example, an engine speed sensor may measure the rotational speed of an engine crankshaft (not shown), pressure sensors in communication with the engine combustion chambers may measure engine cylinder pressure, intake and exhaust manifold pressure sensors may measure pressure of gases flowing into and away from the combustion chambers, an inlet air mass flow sensor may measure incoming airflow in the induction system, and an intake manifold mass flow sensor may measure flow of induction gases to the engine. In another example, temperature sensors may measure the temperature of induction gases flowing to the engine. A throttle position sensor, such as an integrated angular position sensor, may measure the position of the throttle. A tailpipe temperature sensor may be placed just upstream of a tailpipe outlet to measure the temperature of the exhaust gases exiting the exhaust system. Also, temperature sensors may be placed at, upstream, and/or downstream of the emissions device(s) to measure the temperature of exhaust gases thereof. Similarly, one or more pressure sensors may be placed across the emissions device(s) to measure the pressure drop thereacross. An oxygen sensor may be placed in the exhaust and/or induction systems to measure oxygen in the exhaust gases and/or induction gases.

[0038] In addition to the sensors discussed herein, any other suitable sensors and their associated parameters may be encompassed by the presently disclosed system and methods. For example, the sensors may also include accelerator sensors, vehicle speed sensors, powertrain speed sensors, filter sensors, other flow sensors, vibration sensors, knock sensors, intake and exhaust pressure sensors, and/or the like. In other words, any sensors may be used to sense any suitable physical parameters including electrical, mechanical, and chemical parameters. As used herein, the term sensor may include any suitable hardware and/or software used to sense any engine system parameter and/or various combinations of such parameters.

[0039] The control system 16 further may include one or more controllers (not separately shown) in communication with the actuators and sensors for receiving and processing sensor input and transmitting actuator output signals. The controller(s) may include one or more suitable processors and memory devices (not separately shown). The memory may be configured to provide storage of data and instructions that provide at least some of the functionality of the engine system 10 and that may be executed by the processor(s). At least portions of the method may be enabled by one or more computer programs and various engine system data or instructions stored in memory as look-up tables, formulas, algorithms, maps, models, or the like. In any case, the control system 16 may control engine system parameters by receiving input signals from the sensors, executing instructions or algorithms in light of sensor input signals, and transmitting suitable output signals to the various actuators. As used herein, the term "model" may include any construct that represents something using variables, such as a look up table, map, formula, algorithm and/or the like. Models may be application specific and particular to the exact design and performance specifications of any given engine system.

[0040] Embodiments of the methods may be carried out as one or more computer programs within the operating environment of the engine system 10 described above. The embodiments are similar in many respects to one another, and the descriptions of the embodiments are incorporated by reference into one another and the common subject matter generally may not be repeated. Those skilled in the art will also recognize that methods according to any number of embodiments may be carried out using other engine systems within other operating environments. As the description of the methods progress, reference will be made to the engine system 10 of FIG. 1, the engine 12 of FIG. 2, and the diagrams of FIGS. 3 through 11.

[0041] According to a first method embodiment, the internal combustion engine 12 may be operated by activating at least one engine cylinder 20 by supplying fuel and combustion gas to the engine cylinder 20 and controlling opening and closing of intake and exhaust valves 24, 26 associated with the engine cylinder 20 in accordance with base timing, and deactivating the engine cylinder 20 by not supplying fuel to the engine cylinder 20 and adjusting timing of the intake and exhaust valves 24, 26 to a negative valve overlap (NVO) condition.

[0042] For example, the intake and exhaust valve timing may be adjusted by about 90 crankshaft degrees to the NVO condition. More specifically, the timing of the exhaust valve 26 may be advanced about 90 crankshaft degrees and timing of the intake valve 24 may be retarded about 90 crankshaft degrees. Also, fuel is not supplied, for example, by not supplying fuel at engine startup, by ceasing a supply of fuel during engine operation, or the like.

[0043] In addition, combustion gas and/or spark may not be supplied to the engine cylinder during the deactivating step. For example, one or both of the throttles 42, 44 may be closed to cut off supply of combustion gas. In another example, the engine ignition system may not supply power to a spark plug associated with the engine cylinder.

[0044] In any event, the intake and exhaust valves 24, 26 are not deactivated during the deactivating step. Accordingly, there is no need for complex and costly valve deactivation hardware and controls.

[0045] As shown in FIG. 3, exhaust and intake valve timing may be adjusted from a base timing condition to a negative valve overlap condition. As used herein, the phrase "base timing condition" may include any condition other than the negative valve overlap condition. For example, base timing condition may include whatever cam phase is optimal for a particular firing cylinder condition. Typically, the base timing condition would be the timing at which the engine is being run just prior to or after cylinder deactivation. Those of ordinary skill in the art will recognize that the base timing condition is engine design dependent and may vary significantly from one engine type to another.

[0046] In one embodiment of the base timing condition, exhaust valve opening (line 71) may be centered at about 270 degrees of crankshaft angle. Over 75%, and as shown approximately 96%, of the exhaust valve lift may occur during the exhaust stroke of the engine with small percentages of the exhaust lift occurring during the power stroke and intake stroke. Intake valve opening (line 73) may be centered at about 450 degrees of crankshaft angle. For example, the maximum exhaust valve lift may be at about 270 degrees of crankshaft angle, and the maximum intake valve lift may be at about 450 degrees of crankshaft angle. Over 75%, and as shown approximately 96%, of the intake valve lift occurs during the intake stroke of the engine with small percentages of the intake lift occurring during the exhaust

stroke and compression stroke. Also in the base timing condition, there may be overlap 74 in exhaust valve and intake valve opening. More specifically, the overlap may include about 60 degrees of crankshaft angle centered just before top dead center.

[0047] During the valve deactivation mode, phase authority for the devices 28 may be on the order of about 90 degrees (for example, 80-110 degrees) of crankshaft angle at moderate speeds and loads. As used herein, the term about when used with reference to crankshaft angle, includes plus or minus 15 degrees of crankshaft angle.

[0048] Accordingly, in the negative valve overlap condition, exhaust valve opening may be centered between 160 (77A) and 200 (77B) degrees of crankshaft angle. At least 30% of the exhaust lift may occur during the power stroke of the engine. Intake valve opening may be centered between 520 (79A) and 560 (79B) degrees of crankshaft angle. At least 30% of the intake valve lift may occur during the compression stroke of the engine. In one embodiment, exhaust valve opening may be centered at about 180 degrees of crankshaft angle, and intake valve opening may be centered at about 540 degrees of crankshaft angle. For example, in one embodiment the maximum exhaust valve lift may be at about 180 degrees of crankshaft angle, and the maximum intake valve lift may be at about 540 degrees of crankshaft angle. In another embodiment, the negative valve overlap between the intake and exhaust valves may be symmetric, wherein the valve timing is adjusted the same but in opposite directions.

[0049] The VVT device 28 may include a cam phaser to adjust the timing of the valves 24, 26 relatively quickly. For example, a 300 degree/second cam phaser may adjust the timing of the valves 24, 26 between base timing and the NVO timing within three to four engine cycles at 1500 RPM and within six to seven engine cycles at 2500 RPM. In another example, a 600 degree/second cam phaser may adjust the timing of the valves 24, 26 between base timing and the NVO timing within one to two engine cycles at 1500 RPM and within three to four engine cycles at 2500 RPM. In one embodiment, the cam phasers may be open loop controlled to move to maximum limits of travel corresponding to the negative valve overlap condition. In another embodiment, the cam phasers may be closed loop controlled to move to positions corresponding to the negative valve overlap condition.

[0050] When transitioning to and from cylinder deactivation mode, the opening of the engine intake throttle(s) 42, 44 and spark advance setting may be adjusted to minimize engine torque disturbances.

[0051] FIGS. 4 through 7 generally illustrate the effect of the cylinder deactivation according to the presently disclosed method. FIGS. 4 through 6 illustrate logarithmic plots of pumping work in an engine cylinder. More specifically, FIG. 4 illustrates a plot of pumping work with base timing of exhaust and intake valves and with a closed throttle. FIG. 5 illustrates a plot of pumping work with base timing of exhaust and intake valves and with an open throttle. FIG. 6 illustrates that the pumping work is basically zero when the exhaust and intake valves are deactivated by valve deactivation devices.

[0052] FIG. 7 illustrates that pumping work for NVO cylinder deactivation is somewhat greater than with valve deactivation but significantly less than that with base timing with an open throttle. Accordingly, cylinder deactivation via NVO may result in nearly complete elimination of the pumping loop and, thus, PMEP, of an engine cylinder. Therefore, relatively little fluid will be pumped through the engine cylinder wherein PMEP and motored brake mean effective pressure (BMEP) may be minimized. Thus, premature or otherwise undesirable cooling of a downstream exhaust catalyst may be reduced or avoided during NVO cylinder deactivation.

[0053] FIGS. 8 and 9 more specifically illustrate the effect of the cylinder deactivation according to the presently disclosed method. FIG. 8 illustrates a plot of BMEP versus a negative valve overlap in crankshaft angle degrees for a closed throttle condition. In FIG. 8, three plots of BMEP are compared to an average BMEP of about -0.2 Bar according to valve deactivation. The average BMEP for valve deactivation is represented by a box with three BMEP values corresponding to 1500, 2000, and 2500 engine revolutions per minute (RPM). Likewise, the three plots for NVO cylinder deactivation include a first plot at 1500 RPM, a second plot at 2000 RPM, and a third plot at 2500 RPM. In each of the three plots, BMEP is minimized at 90 degrees of negative valve overlap of exhaust and intake valve timing.

[0054] FIG. 9 is a table to compare example reductions in BMEP between valve deactivation and the presently disclosed negative valve overlap (NVO) cylinder deactivation. The first column represents engine RPM and includes 1500, 2000, and 2500 RPM data sets. The second column represents base BMEP for each of the

engine speeds. The third column represents BMEP achieved with valve deactivation, which data corresponds to that shown in the box in FIG. 8. The fourth column represents example BMEP results achieved with the presently disclosed NVO cylinder deactivation, which data corresponds to the peak data points in each of the three plots shown in FIG. 8. The fifth column represents the reduction in BMEP from base BMEP achieved by the valve deactivation. The sixth column represents example reduction in BMEP from base BMEP that may be achieved by the presently disclosed NVO cylinder deactivation. The seventh column represents one non-limiting example of a benefit of NVO cylinder deactivation compared to valve deactivation. For example, use of NVO cylinder deactivation may result in BMEP reduction that may be about 70 to 90 percent of valve deactivation. In other words, NVO cylinder deactivation may be nearly as effective as valve deactivation, but without costly valve deactivation hardware and controls.

[0055] FIGS. 10 and 11 further illustrate the effect of the cylinder deactivation according to the presently disclosed method. FIG. 10 illustrates that a peak mass flow rate through the cylinder is negligible at 0.000044 kg/s when using NVO cylinder deactivation with a closed throttle at 1500 RPM. FIG. 11 illustrates that a peak mass flow rate through a cylinder with an open throttle condition at 1500 RPM may be only about 0.0006 kg/s when using NVO cylinder deactivation in contrast to about 0.035 kg/s for baseline timing. The example flow rates are for a 2.0 liter displacement engine. Such a low peak mass flow rate may represent less than 2% of a baseline mass flow rate. Also, the average mass flow rate may be less than 1% of the baseline mass flow rate. Finally, a throttle-open minimum mass flow at 1500 RPM in NVO cylinder deactivation mode may be about 0.7 kg/h in contrast to 89 kg/h for baseline valve timing for a 2.0 liter four cylinder engine.

[0056] In a first variation of the first method embodiment, the activation and deactivation of the engine cylinder 20 may be adjusted to maintain a temperature of an exhaust gas treatment device above a minimum threshold. For example, the temperature of one or more of the exhaust gas treatment devices 50, 52 may be sensed or modeled in any suitable manner. For instance, the temperature may be sensed by any suitable exhaust system sensors, or the temperature may be modeled based on a sensed ambient temperature and based on time since the deactivating step was carried out. Then, if it is determined that the temperature is below the minimum threshold for

the device(s) 50, 52, then the deactivated engine cylinder 20 may be activated by adjusting timing of the intake and exhaust valves 24, 26 to a base timing condition and supplying fuel and combustion gas to the cylinder 20.

[0057] In a second variation of the first method embodiment, the deactivating step may be carried out during a vehicle coasting condition to reduce powertrain drag. For example, a vehicle coasting condition may be determined in any suitable manner, for instance, via throttle position sensing, vehicle speed sensing, and/or the like. Then, in response to such a determination, the cylinder deactivation via NVO may be carried out.

[0058] According to a second method embodiment, the internal combustion engine of the engine system 10 may be operated such that one of the cylinder banks 17, 19 is deactivated. First, both of the first and second cylinder banks 17, 19 may be activated by supplying fuel and combustion gas to the engine cylinders 20 of the first and second cylinder banks 17, 19 and controlling opening and closing of the intake and exhaust valves 24, 26 associated with the engine cylinders 20 of the first and second cylinder banks 17, 19 in accordance with base timing. Second, the second cylinder bank 19 may be deactivated by not supplying fuel to the engine cylinders 20 of the second cylinder bank 19 and adjusting timing of the intake and exhaust valves 24, 26 associated with the engine cylinders 20 of the second cylinder bank 19 to a negative valve overlap condition.

[0059] For example, the intake and exhaust valve timing may be adjusted by about 90 crankshaft degrees to the NVO condition. More specifically, the timing of the exhaust valve 26 may be advanced about 90 crankshaft degrees and timing of the intake valve 24 may be retarded about 90 crankshaft degrees.

[0060] In a variation on the second embodiment, the activation and deactivation of the cylinder banks 17, 19 may be adjusted to maintain a temperature of one or more of the exhaust gas treatment devices 50, 52. For example, it may be determined that a temperature of the closely-coupled exhaust gas treatment device 52 corresponding to the second cylinder bank 19 has fallen below a threshold. Then, in response to the determining step, the second cylinder bank 19 may be activated. For instance, fuel and combustion gas may be supplied to the engine cylinders 20 of the second cylinder bank 19 and opening and closing of the intake and exhaust valves 24, 26 associated with the engine cylinders 20 of the second cylinder bank 19 may be

controlled in accordance with base timing. Also, in response to the determining step, the first cylinder bank 17 may be deactivated by not supplying fuel to the engine cylinders 20 of the first cylinder bank 17 and adjusting timing of the intake and exhaust valves 24, 26 associated with the engine cylinders 20 of the first cylinder bank 17 to the negative valve overlap condition. In other words, activation and deactivation of the cylinder banks 17, 19 may be switched back and forth between the cylinder banks 17, 19 to maintain a temperature of one or more of the exhaust gas treatment devices 50, 52.

[0061] According to a third method embodiment, the internal combustion engine 12 may be started by initially not supplying fuel to engine cylinders 20 of at least one of the two cylinder banks 17, 19, and ensuring that timing of the intake and exhaust valves 24, 26 associated with the engine cylinders 20 of the at least one of the two cylinder banks 17, 19 is set to a negative valve overlap condition to deactivate the at least one of the two cylinder banks 17, 19.

[0062] In a first variation on the third method embodiment, the first cylinder bank 17 may be activated by supplying fuel and combustion gas to the engine cylinders 20 of the first cylinder bank 17 and by controlling opening and closing of the intake and exhaust valves 24, 26 associated with the engine cylinders 20 of the first cylinder bank 17 in accordance with base timing. Also, the second cylinder bank 19 may be activated when a temperature of the common exhaust gas treatment device 50 reaches an activation level. The activation level may be the "light off" temperature or the minimal operating temperature of the device 50. Accordingly, engine emissions may be reduced because the close-coupled exhaust gas treatment device 50 associated with the first cylinder bank 17 reaches its activation temperature level faster than if both cylinder banks 17, 19 had been initially activated at engine startup. Also, a close-coupled exhaust gas treatment device is not required for association with the second cylinder bank 19 when the common exhaust gas treatment device 50 is in fluid communication with both cylinder banks 17, 19.

[0063] In a second variation on the third method embodiment, after or during deactivation of the at least one of the two cylinder banks 17, 19, the engine 12 may be cranked by rotating the crankshaft 32, for example, via a starter motor (not shown) or in any other suitable manner. Also, it may be determined whether the engine has fired, and/or that the crankshaft 32 has rotated more than a minimum amount. For

instance, any suitable crankshaft rotation sensor or the like may be used for the determination(s). The crankshaft rotation speed may be 350 to 450 RPM, 400 RPM, or any other suitable threshold value to indicate that the engine has fired, and the minimum amount of rotation may be one to four revolutions or any amount corresponding to a peak initial load.

[0064] Thereafter, in response to the crankshaft rotation determination or engine firing determination, at least one of the two cylinder banks 17, 19 may be activated by supplying fuel and combustion gas to the engine cylinders 20 of the at least one of the two cylinder banks 17, 19 and by controlling opening and closing of the intake and exhaust valves 24, 26 associated with the engine cylinders 20 of the at least one of the two cylinder banks 17, 19 in accordance with base timing. Accordingly, a peak torque to crank the engine 12 may be lower than it otherwise would be without use of the NVO cylinder deactivation.

[0065] One or more of the disclosed methods may enable, at moderate speeds and loads, reduction of BMEP on one cylinder bank of an engine such that the cylinders of the bank are virtually deactivated, i.e. without deactivating the valves corresponding to those cylinders. Also, cylinder pressure and airflow may be relatively unaffected by throttle position. Furthermore, providing a closed throttle on a deactivated cylinder bank may enable effectively no mass flow of fluid through a downstream exhaust gas treatment device close-coupled with the deactivated cylinder bank. One or more of the presently disclosed methods may be applied to any suitable number of cylinders of any suitable engine configuration.

[0066] The methods or parts thereof may be implemented in a computer program product including instructions carried on a computer readable medium for use by one or more processors of one or more computers to implement one or more of the method steps. The computer program product may include one or more software programs comprised of program instructions in source code, object code, executable code or other formats; one or more firmware programs; or hardware description language (HDL) files; and any program related data. The data may include data structures, look-up tables, or data in any other suitable format. The program instructions may include program modules, routines, programs, objects, components, and/or the like. The computer program product may be executed on one computer or on multiple computers in communication with one another.

[0067] The program(s) may be embodied on non-transitory computer readable media, which may include one or more storage devices, articles of manufacture, or the like. Example non-transitory computer readable media include computer system memory, e.g. RAM (random access memory), ROM (read only memory); semiconductor memory, e.g. EPROM (erasable, programmable ROM), EEPROM (electrically erasable, programmable ROM), flash memory; magnetic or optical disks or tapes; and/or the like. The non-transitory computer readable medium may also include computer to computer connections, for example, via a network or another communications connection (either wired, wireless, or a combination thereof). Non-transitory computer readable media include all computer readable media, with the sole exception of transitory propagating signals. Any combination(s) of the above examples is also included within the scope of the computer-readable media. It is therefore to be understood that the method(s) may be at least partially performed by any electronic articles and/or devices capable of executing instructions corresponding to one or more steps of the disclosed method(s).

[0068] The following is a description of select illustrative embodiments within the scope of the invention. The invention is not, however, limited to this description; and each embodiment and components, elements, and steps within each embodiment may be used alone or in combination with any of the other embodiments and components, elements, and steps within the other embodiments.

[0069] In select embodiments an engine may be operated by opening at least one exhaust valve early on the power stroke and opening up the intake valve late during the intake stroke so that enough air is trapped in the cylinder to prevent oil from leaking around seals. The operation of the engine may also be performed so that the amount of air, if any, that is pumped by the cylinders from the intake manifold to the exhaust manifold is not enough air to cool the catalyst of the catalytic converter of the exhaust system below the catalyst light-off temperature or effective operating temperature of the catalyst.

[0070] Again, the negative valve overlap strategy may be used in a variety of applications through a variety of embodiments. In select embodiments the negative valve overlap strategy may be applied to any number of cylinders of an engine by cam phasers. The negative valve overlap strategy may be applied a V-type engine wherein the deactivation of cylinder banks may be repeatedly switched back and forth between

banks (or between cylinders) to keep one of more close-coupled catalyst hot, or at or above the catalyst light-off or effective operating temperature of the catalyst. The negative valve overlap strategy may be applied to reduce the crank load during engine start-up. The negative valve overlap strategy may be applied to an engine with a concentric camshaft. The negative valve overlap strategy may also be applied to an engine during cold-start to minimize exhaust emissions.

[0071] Embodiment 1 of the invention may include a method of operating an internal combustion engine, including activating an engine cylinder by supplying fuel and combustion gas to the engine cylinder and controlling opening and closing of intake and exhaust valves associated with the engine cylinder in accordance with base timing, and deactivating the engine cylinder by not supplying fuel to the engine cylinder and adjusting timing of the intake and exhaust valves to a negative valve overlap condition.

[0072] Embodiment 2 of the invention may include a method as set forth in embodiment 1 wherein the timing of the intake and exhaust valves are adjusted by about 90 crankshaft degrees to the negative valve overlap condition.

[0073] Embodiment 3 of the invention may include a method as set forth in any one of embodiments 1 or 2 wherein the timing of the intake and exhaust valves are adjusted by 80 to 100 crankshaft degrees to the negative valve overlap condition.

[0074] Embodiment 4 of the invention may include a method as set forth in any one of embodiments 1 through 3 wherein timing of the exhaust valves is advanced about 90 crankshaft degrees and timing of the intake valves is retarded about 90 crankshaft degrees.

[0075] Embodiment 5 of the invention may include a method as set forth in any one of embodiments 1 through 4 wherein activation and deactivation of the engine cylinder is adjusted to maintain a temperature of an exhaust gas treatment device above a minimum threshold.

[0076] Embodiment 6 of the invention may include a method as set forth in any one of embodiments 1 through 5 wherein the deactivating step is carried out during a vehicle coasting condition to reduce powertrain drag.

[0077] Embodiment 7 of the invention may include a method as set forth in any one of embodiments 1 through 6, further comprising not supplying combustion gas and spark to the engine cylinder during the deactivating step.

- [0078]** Embodiment 8 of the invention may include a method as set forth in any one of embodiments 1 through 7 wherein the valves are not deactivated during the deactivating step.
- [0079]** Embodiment 9 of the invention may include a computer program product stored on a computer usable medium and including instructions executable by a computer-controlled engine system including an engine, an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine system to implement steps according to any one of embodiments 1 through 8.
- [0080]** Embodiment 10 of the invention may include a method of operating an internal combustion engine having a first cylinder bank and a second cylinder bank. The method may include activating the first and second cylinder banks by supplying fuel and combustion gas to the engine cylinders of the first and second cylinder banks and controlling opening and closing of intake and exhaust valves associated with the engine cylinders of the first and second cylinder banks in accordance with base timing, and deactivating the second cylinder bank by not supplying fuel to the engine cylinders of the second cylinder bank and adjusting timing of the intake and exhaust valves associated with the engine cylinders of the second cylinder bank to a negative valve overlap condition.
- [0081]** Embodiment 11 of the invention may include a method as set forth in embodiment 10 wherein the timing of the intake and exhaust valves are adjusted by about 90 crankshaft degrees to the negative valve overlap condition.
- [0082]** Embodiment 12 of the invention may include a method as set forth in any one of embodiments 10 through 11 wherein the timing of the intake and exhaust valves are adjusted by 80 to 100 crankshaft degrees to the negative valve overlap condition.
- [0083]** Embodiment 13 of the invention may include a method as set forth in any one of embodiments 10 through 12 wherein activation and deactivation of the cylinder banks is adjusted to maintain a temperature of an exhaust gas treatment device above a minimum threshold.
- [0084]** Embodiment 14 of the invention may include a method as set forth in any one of embodiments 10 through 13, further comprising determining that a temperature of an exhaust gas treatment device corresponding to the second cylinder

bank has fallen below a minimum threshold, and in response to the determining step, activating the second cylinder bank by supplying fuel and combustion gas to the engine cylinders of the second cylinder bank and controlling opening and closing of intake and exhaust valves associated with the engine cylinders of the second cylinder bank in accordance with base timing, and deactivating the first cylinder bank by not supplying fuel to the engine cylinders of the first cylinder bank and adjusting timing of the intake and exhaust valves associated with the engine cylinders of the first cylinder bank to a negative valve overlap condition.

[0085] Embodiment 15 of the invention may include a method as set forth in any one of embodiments 10 through 14 wherein the determining step is carried out by at least one of sensing temperature of the exhaust gas treatment device or modeling temperature of the exhaust gas treatment device based on an ambient temperature and time since the deactivating step was carried out.

[0086] Embodiment 16 of the invention may include a method as set forth in any one of embodiments 10 through 15, further comprising not supplying combustion gas and spark to the engine cylinder during the deactivating step.

[0087] Embodiment 17 of the invention may include a method as set forth in any one of embodiments 10 through 16 wherein the valves are not deactivated during the deactivating step.

[0088] Embodiment 18 of the invention may include a computer program product stored on a computer usable medium and including instructions executable by a computer-controlled engine system including an engine, an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine system to implement steps according to any one of embodiments 10 through 17.

[0089] Embodiment 19 of the invention may include a method of starting an internal combustion engine having two cylinder banks, the method including not supplying fuel to engine cylinders of at least one of the two cylinder banks, and ensuring that timing of intake valves and of exhaust valves associated with the engine cylinders of the at least one of the two cylinder banks is set to a negative valve overlap condition.

- [0090]** Embodiment 20 of the invention may include a method as set forth in embodiment 19 wherein the timing of the intake and exhaust valves is adjusted by about 90 crankshaft degrees to the negative valve overlap condition.
- [0091]** Embodiment 21 of the invention may include a method as set forth in any one of embodiments 19 through 20 wherein the timing of the intake and exhaust valves is adjusted by 80 to 100 crankshaft degrees to the negative valve overlap condition.
- [0092]** Embodiment 22 of the invention may include a method as set forth in any one of embodiments 19 through 21, further comprising activating a first cylinder bank of the two cylinder banks by supplying fuel and combustion gas to the engine cylinders of the first cylinder bank and controlling opening and closing of intake and exhaust valves associated with the engine cylinders of the first cylinder bank in accordance with base timing.
- [0093]** Embodiment 23 of the invention may include a method as set forth in any one of embodiments 19 through 22 wherein the at least one of the two cylinder banks also includes a second cylinder bank that is activated when a temperature of an exhaust gas treatment device common to both cylinder banks reaches an activation level.
- [0094]** Embodiment 24 of the invention may include a method as set forth in any one of embodiments 19 through 23 wherein engine emissions are reduced because a close-coupled exhaust gas treatment device associated with the first cylinder bank reaches an activation temperature level faster than if both cylinder banks were activated at engine startup, and no close-coupled exhaust gas treatment device is required for association with the second cylinder bank when a common exhaust gas treatment device is in fluid communication with both cylinder banks.
- [0095]** Embodiment 25 of the invention may include a method as set forth in any one of embodiments 19 through 24, further comprising cranking the engine by rotating a crankshaft of the engine, determining that the crankshaft has rotated more than a minimum amount, and in response to the determining step, activating at least one of the two cylinder banks by supplying fuel and combustion gas to the engine cylinders of the at least one of the two cylinder banks and controlling opening and closing of intake and exhaust valves associated with the engine cylinders of the at least one of the two cylinder banks in accordance with base timing.

- [0096]** Embodiment 26 of the invention may include a method as set forth in any one of embodiments 19 through 25 wherein a peak torque in cranking the engine is lower than it otherwise would be without use of the negative valve overlap condition.
- [0097]** Embodiment 27 of the invention may include a method of deactivating an engine cylinder of an internal combustion engine, the method including not supplying fuel to the engine cylinder, and adjusting timing of intake and exhaust valves to a negative valve overlap condition.
- [0098]** Embodiment 28 of the invention may include a method as set forth in embodiment 27 wherein the timing of the intake and exhaust valves are adjusted by about 90 crankshaft degrees to the negative valve overlap condition.
- [0099]** Embodiment 29 of the invention may include a method as set forth in any one of embodiments 27 through 28 wherein the timing of the intake and exhaust valves are adjusted by 80 to 100 crankshaft degrees to the negative valve overlap condition.
- [00100]** Embodiment 30 of the invention may include a method as set forth in any one of embodiments 27 through 29 wherein the adjusting timing step is carried out by controlling intake and exhaust cam phasers operatively coupled to the intake and exhaust valves.
- [00101]** Embodiment 31 of the invention may include a method as set forth in any one of embodiments 27 through 30 wherein the cam phasers are open loop controlled to move to maximum limits of travel corresponding to the negative valve overlap condition.
- [00102]** Embodiment 32 of the invention may include a method as set forth in any one of embodiments 27 through 31 wherein the cam phasers are closed loop controlled to move to positions corresponding to the negative valve overlap condition.
- [00103]** Embodiment 33 of the invention may include a method as set forth in any one of embodiments 27 through 32, further comprising not supplying combustion gas and spark to the engine cylinder.
- [00104]** Embodiment 34 of the invention may include a method as set forth in any one of embodiments 27 through 33 wherein the valves are not deactivated.
- [00105]** Embodiment 35 of the invention may include a computer program product stored on a computer usable medium and including instructions executable by

a computer-controlled engine system including an engine, an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine system to implement steps according to any one of embodiments 27 through 34.

[00106] Embodiment 36 of the invention may include an exhaust system for an engine having a first cylinder bank and a second cylinder bank, wherein the exhaust system includes a common exhaust gas treatment device in downstream fluid communication with the first and second cylinder banks, a close-coupled exhaust gas treatment device corresponding to the first cylinder bank and in upstream fluid communication with the common exhaust gas treatment device, and no close-coupled exhaust gas treatment device corresponding to the second cylinder bank.

[00107] Embodiment 37 of the invention may include an engine system including the exhaust system as set forth in embodiment 36 and also including an induction system in upstream fluid communication with the first and second cylinder banks. The induction system includes a first intake manifold in fluid communication with the first cylinder bank, a second intake manifold in fluid communication with the second cylinder bank, a first throttle in fluid communication with the first intake manifold, and a second throttle in fluid communication with the second intake manifold.

[00108] Embodiment 38 of the invention may include the engine system of embodiment 37 wherein the exhaust system also includes a first manifold in fluid communication with the first cylinder bank, and a second manifold in fluid communication with the second cylinder bank.

[00109] Embodiment 39 may include a reciprocating piston four stroke internal combustion engine comprising an engine block with at least two cylinders each having a piston, mounted therein, the piston being pivotally connected with a crankshaft; at least one selectively deactivatable cylinder having a variable phased intake valve having base timing of at least 75% of lift during an intake stroke of said engine and having deactivated timing of at least 30% lift during a compression stroke of said engine, and said deactivatable cylinder having a variable phased exhaust valve having base timing of at least 75% of lift during an exhaust stroke of said engine and having deactivated timing of at least 30% lift during a power stroke of said engine.

[001 10] Embodiment 40 may include an engine as described in embodiment 39 having at least first and second cylinder banks wherein at least the second cylinder bank cylinders are selectively deactivatable.

[001 11] Embodiment 41 may include a computer program product stored on a computer usable medium and including instructions executable by a computer-controlled engine including an engine, an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine to implement a method as set forth in embodiment 1, and wherein the engine is connected to an exhaust gas treatment device and wherein activating and deactivating of the engine cylinder is adjusted to maintain a temperature of the exhaust gas treatment device above a minimum temperature.

[001 12] Embodiment 42 may include a computer program product stored on a computer usable medium and including instructions executable by a computer-controlled engine, the engine including an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine to implement steps according to embodiment 14.

[001 13] The above description of select examples of embodiments of the invention is merely illustrative in nature and, thus, variations or variants thereof are not to be regarded as a departure from the spirit and scope of the invention.

CLAIMS

What is claimed is:

1. A method of operating an internal combustion engine, the method comprising:

activating an engine cylinder by supplying fuel and combustion gas to the engine cylinder and controlling opening and closing of intake and exhaust valves associated with the engine cylinder in accordance with base timing; and

deactivating the engine cylinder by not supplying fuel to the engine cylinder and adjusting timing of the intake and exhaust valves to a negative valve overlap condition.

2. The method of claim 1 wherein the timing of the intake and exhaust valves are adjusted by about 90 crankshaft degrees to the negative valve overlap condition.

3. The method of claim 1 wherein the timing of the intake and exhaust valves are adjusted by 80 to 100 crankshaft degrees to the negative valve overlap condition.

4. The method as set forth in claim 1 wherein timing of the exhaust valves is advanced about 90 crankshaft degrees and timing of the intake valves is retarded about 90 crankshaft degrees.

5. The method as set forth in claim 1 wherein activation and deactivation of the engine cylinder is adjusted to maintain a temperature of an exhaust gas treatment device above a minimum threshold.

6. The method as set forth in claim 1 wherein the deactivating step is carried out during a vehicle coasting condition to reduce powertrain drag.

7. The method of claim 1 further comprising not supplying combustion gas and spark to the engine cylinder during the deactivating step.

8. The method of claim 1 wherein the valves are not deactivated during the deactivating step.

9. A computer program product stored on a computer usable medium and including instructions executable by a computer-controlled engine system including an engine, an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine system to implement steps according to claim 1.

10. A method of operating an internal combustion engine having a first cylinder bank and a second cylinder bank, the method comprising:

activating the first and second cylinder banks by supplying fuel and combustion gas to the engine cylinders of the first and second cylinder banks and controlling opening and closing of intake and exhaust valves associated with the engine cylinders of the first and second cylinder banks in accordance with base timing; and

deactivating the second cylinder bank by not supplying fuel to the engine cylinders of the second cylinder bank and adjusting timing of the intake and exhaust valves associated with the engine cylinders of the second cylinder bank to a negative valve overlap condition.

11. The method of claim 10 wherein the timing of the intake and exhaust valves are adjusted by about 90 crankshaft degrees to the negative valve overlap condition.

12. The method of claim 10 wherein the timing of the intake and exhaust valves are adjusted by 80 to 100 crankshaft degrees to the negative valve overlap condition.

13. The method as set forth in claim 10 wherein activation and deactivation of the cylinder banks is adjusted to maintain a temperature of an exhaust gas treatment device above a minimum threshold.

14. The method as set forth in claim 10, further comprising:

determining that a temperature of an exhaust gas treatment device corresponding to the second cylinder bank has fallen below a minimum threshold; and

in response to the determining step, activating the second cylinder bank by supplying fuel and combustion gas to the engine cylinders of the second cylinder bank and controlling opening and closing of intake and exhaust valves associated with the engine cylinders of the second cylinder bank in accordance with base timing, and deactivating the first cylinder bank by not supplying fuel to the engine cylinders of the first cylinder bank and adjusting timing of the intake and exhaust valves associated with the engine cylinders of the first cylinder bank to a negative valve overlap condition.

15. The method set forth in claim 14 wherein the determining step is carried out by at least one of sensing temperature of the exhaust gas treatment device or modeling temperature of the exhaust gas treatment device based on an ambient temperature and time since the deactivating step was carried out.

16. The method of claim 10 further comprising not supplying combustion gas and spark to the engine cylinder during the deactivating step.

17. The method of claim 10 wherein the valves are not deactivated during the deactivating step.

18. A computer program product stored on a computer usable medium and including instructions executable by a computer-controlled engine system including an engine, an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine system to implement steps according to claim 10.

19. A method of starting an internal combustion engine having two cylinder banks, the method comprising:

not supplying fuel to engine cylinders of at least one of the two cylinder banks; and

ensuring that timing of intake valves and of exhaust valves associated with the engine cylinders of the at least one of the two cylinder banks is set to a negative valve overlap condition.

20. The method of claim 19 wherein the timing of the intake and exhaust valves is adjusted by about 90 crankshaft degrees to the negative valve overlap condition.

21. The method of claim 19 wherein the timing of the intake and exhaust valves is adjusted by 80 to 100 crankshaft degrees to the negative valve overlap condition.

22. The method as set forth in claim 19, further comprising:

activating a first cylinder bank of the two cylinder banks by supplying fuel and combustion gas to the engine cylinders of the first cylinder bank and controlling opening and closing of intake and exhaust valves associated with the engine cylinders of the first cylinder bank in accordance with base timing.

23. The method as set forth in claim 19 wherein the at least one of the two cylinder banks also includes a second cylinder bank that is activated when a temperature of an exhaust gas treatment device common to both cylinder banks reaches an activation level.

24. The method as set forth in claim 23, wherein engine emissions are reduced because a close-coupled exhaust gas treatment device associated with the first cylinder bank reaches an activation temperature level faster than if both cylinder banks were activated at engine startup, and no close-coupled exhaust gas treatment device is required for association with the second cylinder bank when a common exhaust gas treatment device is in fluid communication with both cylinder banks.

25. The method as set forth in claim 19, further comprising:
cranking the engine by rotating a crankshaft of the engine;
determining that the crankshaft has rotated more than a minimum amount; and
in response to the determining step, activating at least one of the two cylinder banks by supplying fuel and combustion gas to the engine cylinders of the at least one of the two cylinder banks and controlling opening and closing of intake and exhaust valves associated with the engine cylinders of the at least one of the two cylinder banks in accordance with base timing.
26. The method as set forth in claim 25 wherein a peak torque in cranking the engine is lower than it otherwise would be without use of the negative valve overlap condition.
27. A method of deactivating an engine cylinder of an internal combustion engine, the method comprising:
not supplying fuel to the engine cylinder; and
adjusting timing of intake and exhaust valves to a negative valve overlap condition.
28. The method of claim 27 wherein the timing of the intake and exhaust valves are adjusted by about 90 crankshaft degrees to the negative valve overlap condition.
29. The method of claim 27 wherein the timing of the intake and exhaust valves are adjusted by 80 to 100 crankshaft degrees to the negative valve overlap condition.
30. The method of claim 27 wherein the adjusting timing step is carried out by controlling intake and exhaust cam phasers operatively coupled to the intake and exhaust valves.

31. The method of claim 30 wherein the cam phasers are open loop controlled to move to maximum limits of travel corresponding to the negative valve overlap condition.

32. The method of claim 30 wherein the cam phasers are closed loop controlled to move to positions corresponding to the negative valve overlap condition.

33. The method of claim 27 further comprising not supplying combustion gas and spark to the engine cylinder.

34. The method of claim 27 wherein the valves are not deactivated.

35. A computer program product stored on a computer usable medium and including instructions executable by a computer-controlled engine system including an engine, an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine system to implement steps according to claim 27.

36. An exhaust system for an engine having a first cylinder bank and a second cylinder bank, wherein the exhaust system comprises:

a common exhaust gas treatment device in downstream fluid communication with the first and second cylinder banks;

a close-coupled exhaust gas treatment device corresponding to the first cylinder bank and in upstream fluid communication with the common exhaust gas treatment device; and

no close-coupled exhaust gas treatment device corresponding to the second cylinder bank.

37. An engine system including the exhaust system as set forth in claim 36 and also including an induction system in upstream fluid communication with the first and second cylinder banks, wherein the induction system includes:

a first intake manifold in fluid communication with the first cylinder bank;

a second intake manifold in fluid communication with the second cylinder bank;

a first throttle in fluid communication with the first intake manifold; and

a second throttle in fluid communication with the second intake manifold.

38. The engine system as set forth in claim 37 wherein the exhaust system also includes:

a first manifold in fluid communication with the first cylinder bank; and

a second manifold in fluid communication with the second cylinder bank.

39. A reciprocating piston four stroke internal combustion engine comprising:

an engine block with at least two cylinders each having a piston, mounted therein, the piston being pivotally connected with a crankshaft;

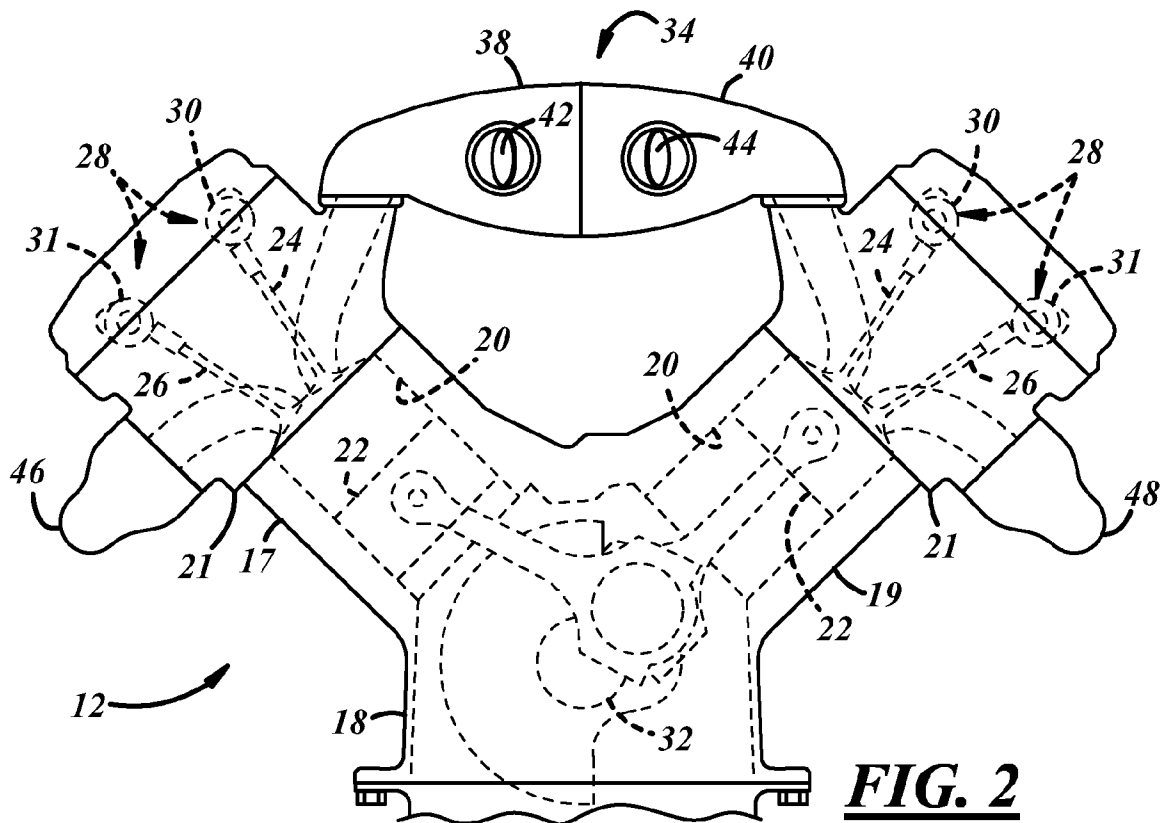
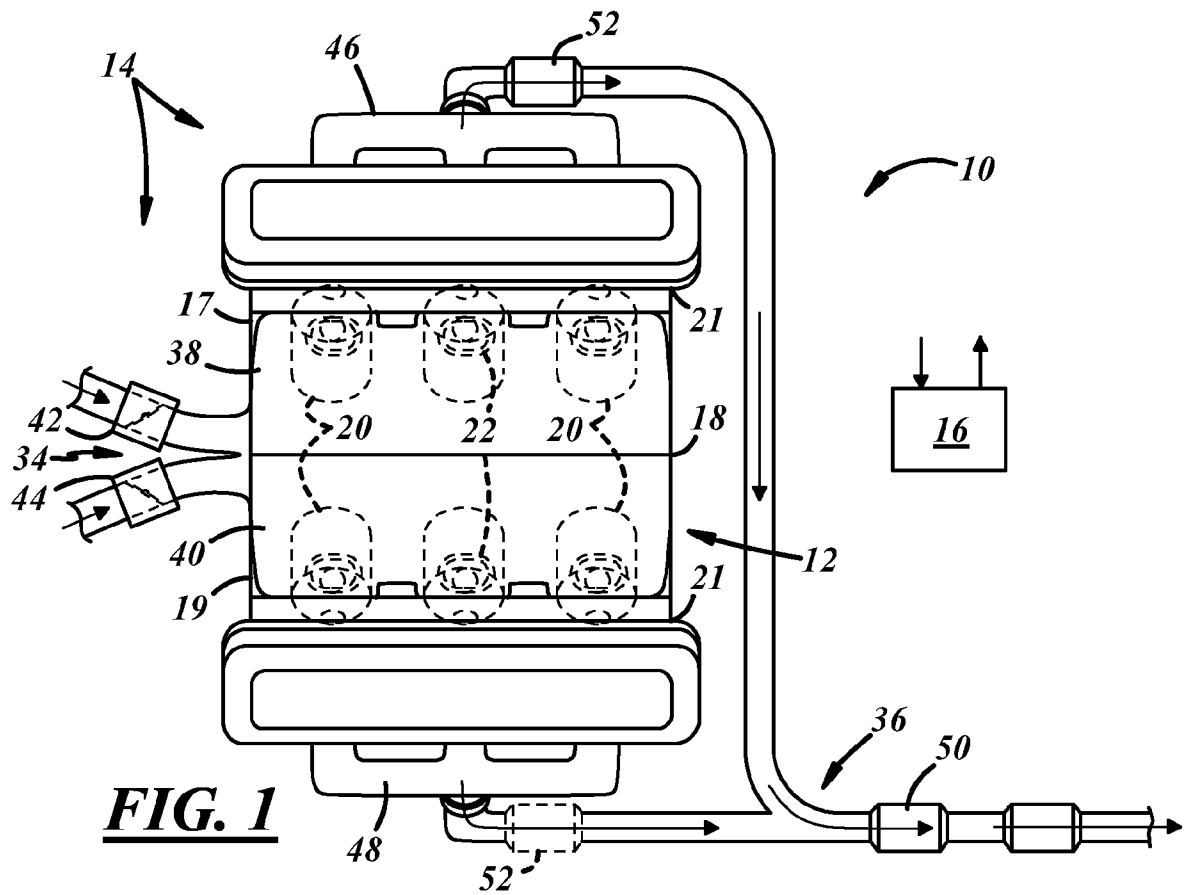
at least one selectively deactivatable cylinder having a variable phased intake valve having base timing of at least 75% of lift during an intake stroke of said engine and having deactivated timing of at least 30% lift during a compression stroke of said engine, and said deactivatable cylinder having a variable phased exhaust valve having base timing of at least 75% of lift during an exhaust stroke of said engine and having deactivated timing of at least 30% lift during a power stroke of said engine.

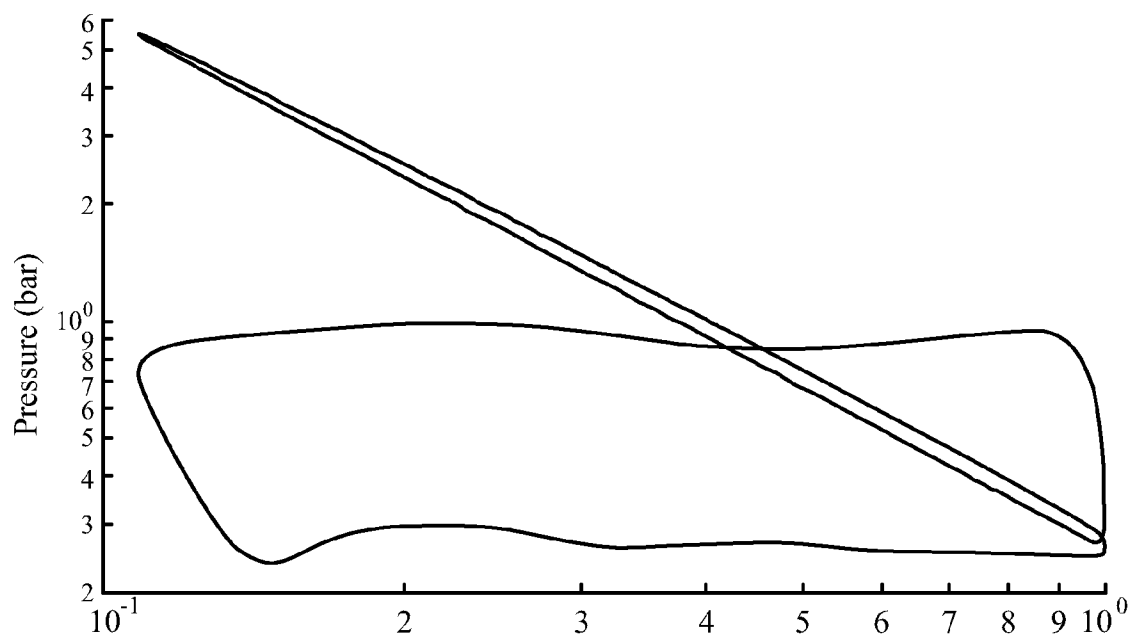
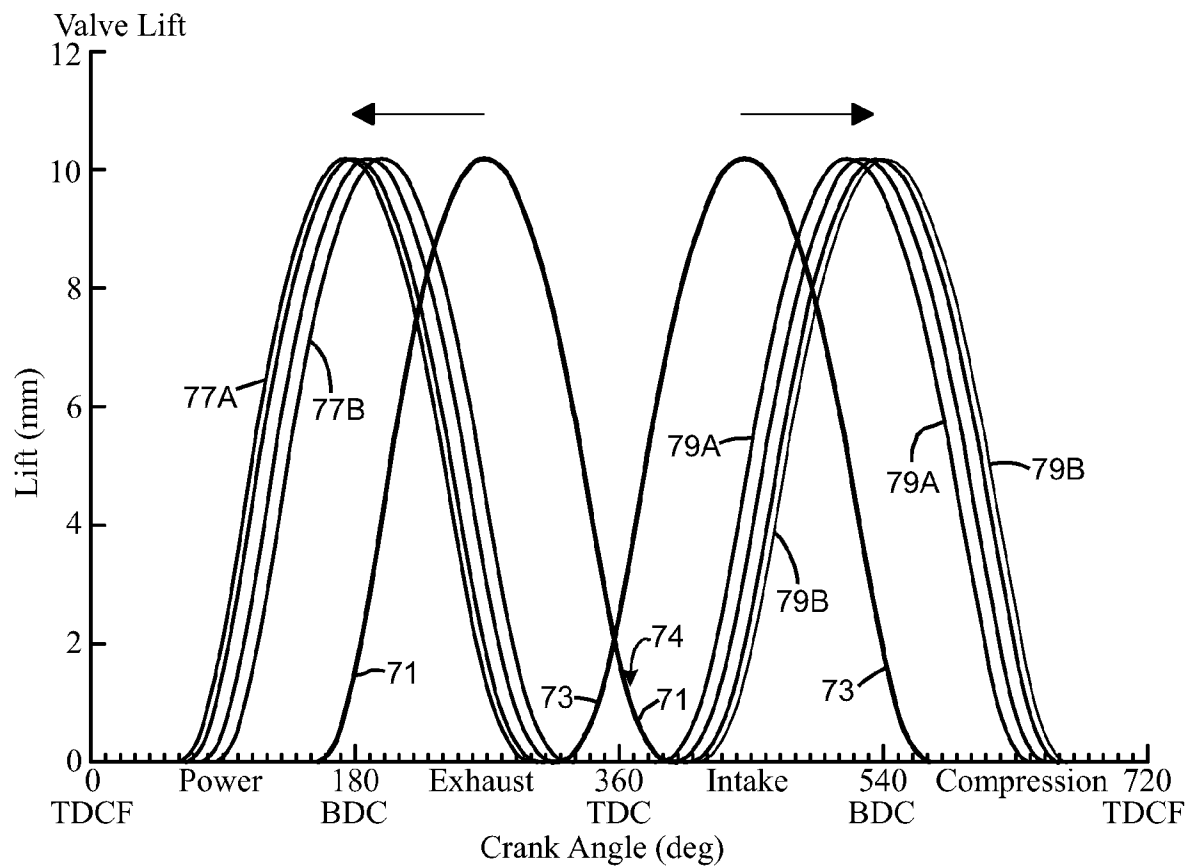
40. An engine as described in claim 39 having at least first and second cylinder banks wherein at least the second cylinder bank cylinders are selectively deactivatable .

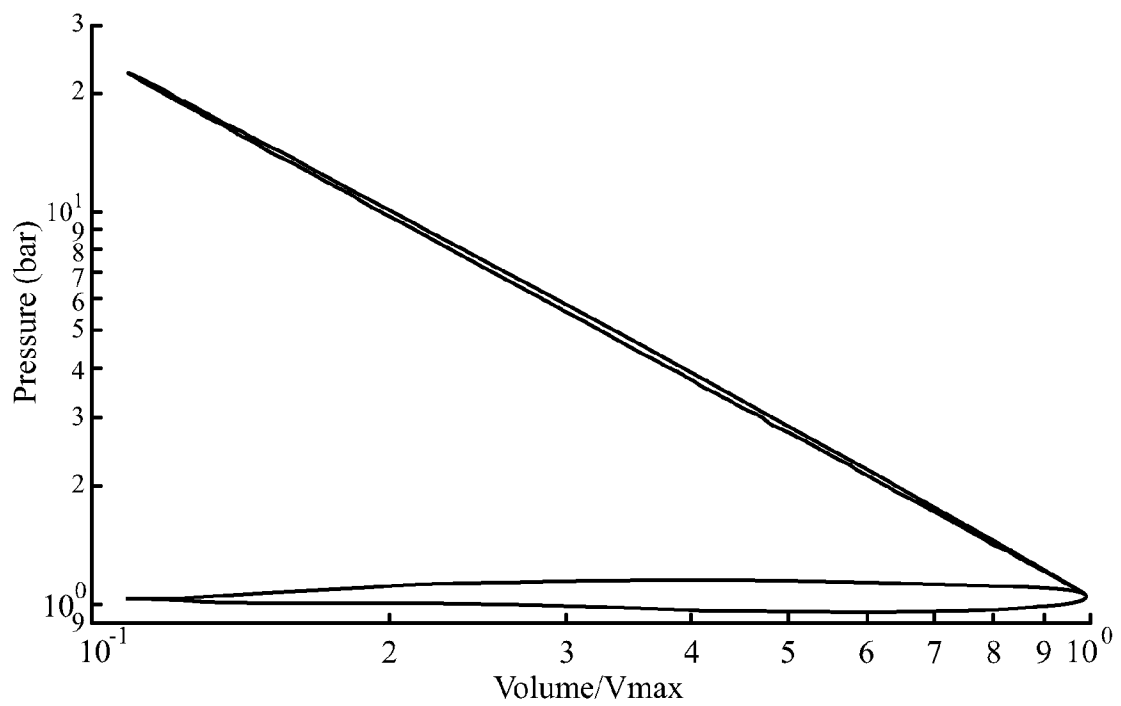
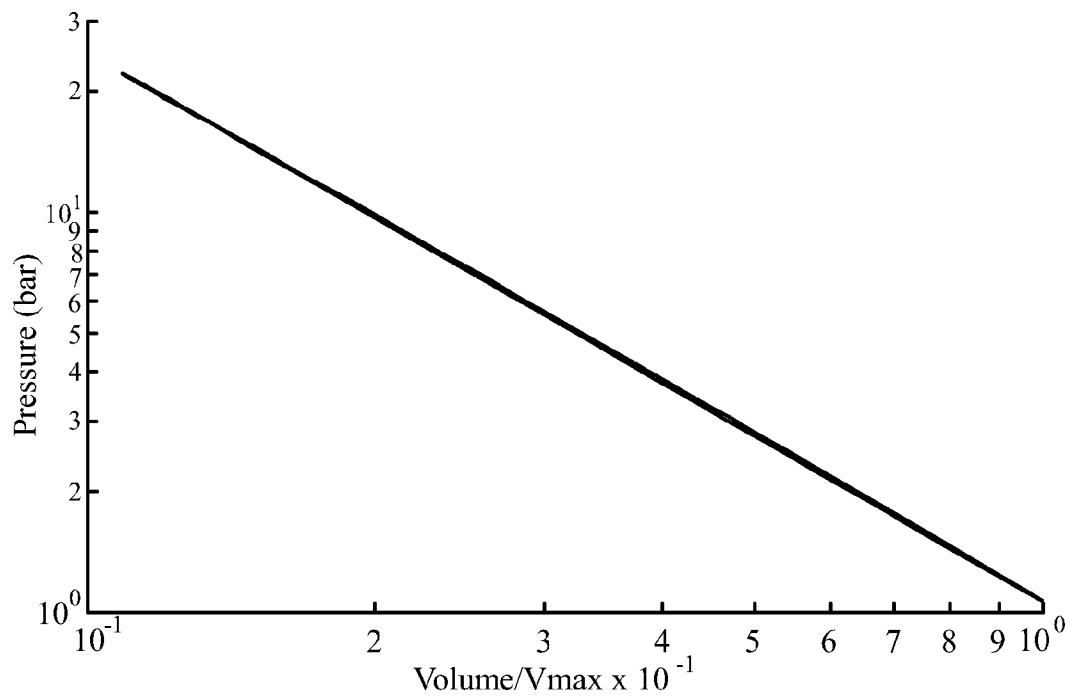
41. A computer program product stored on a computer usable medium and including instructions executable by a computer-controlled engine including an engine, an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine to implement a method as set forth in claim 1, and

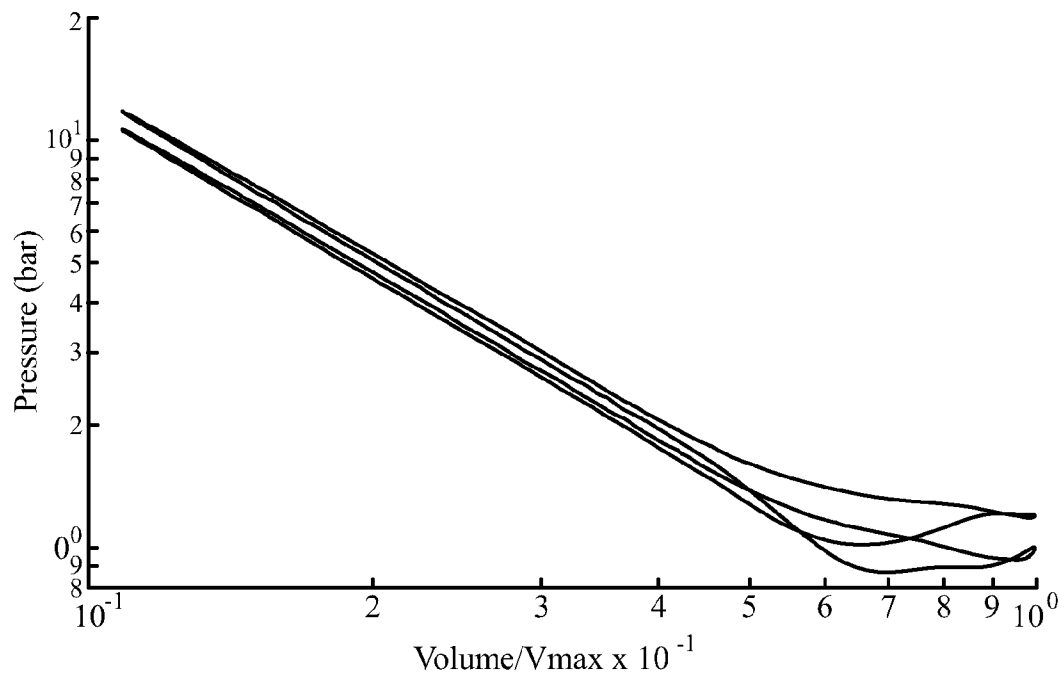
wherein the engine is connected to an exhaust gas treatment device and wherein activating and deactivating of the engine cylinder is adjusted to maintain a temperature of the exhaust gas treatment device above a minimum temperature.

42. A computer program product stored on a computer usable medium and including instructions executable by a computer-controlled engine, the engine including an induction system in upstream communication with the engine, and an exhaust system in downstream communication with the engine, wherein the instructions cause the engine to implement steps according to claim 14.





**FIG. 5****FIG. 6**

**FIG. 7**

Throttle Closed BMEP Reduction Potential (Bar, %)						
RPM	Base BMEP	Valve Deact BMEP	NVO BMEP	% Deact BMEP Reduction	% NVO BMEP Reduction	NVO % of Valve Deact Benefit
1500	-0.733	-0.215	-0.270	70.7	63.1	89.3
2000	-0.780	-0.203	-0.305	73.9	60.8	82.3
2500	-0.778	-0.197	-0.375	74.7	51.8	69.4

FIG. 9

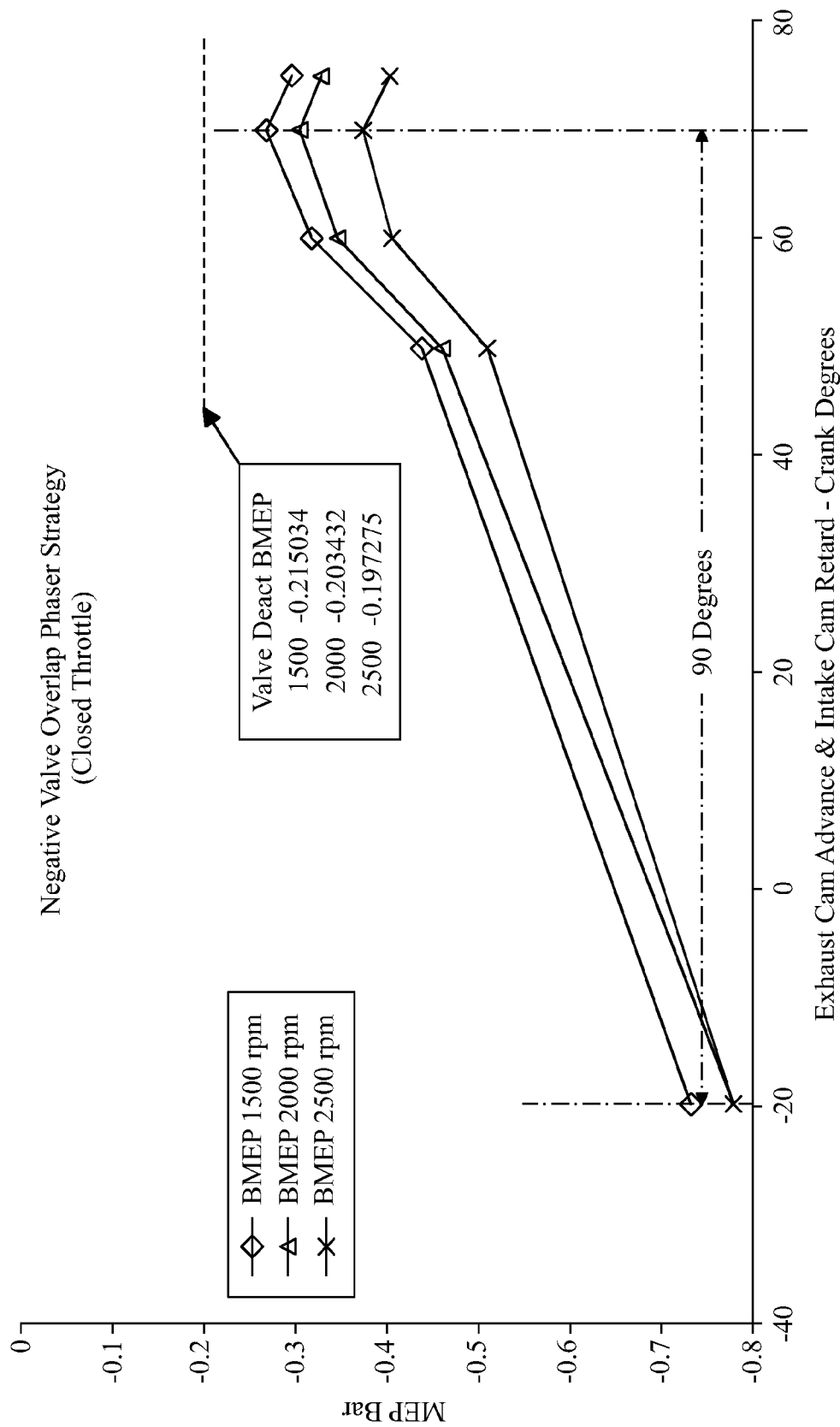


FIG. 8

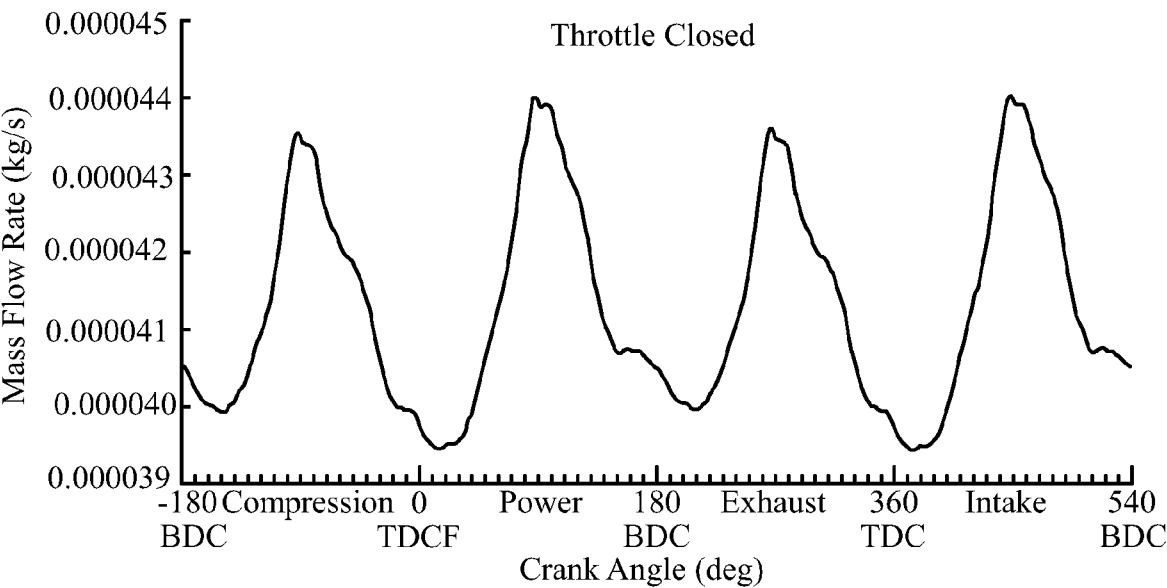


FIG. 10

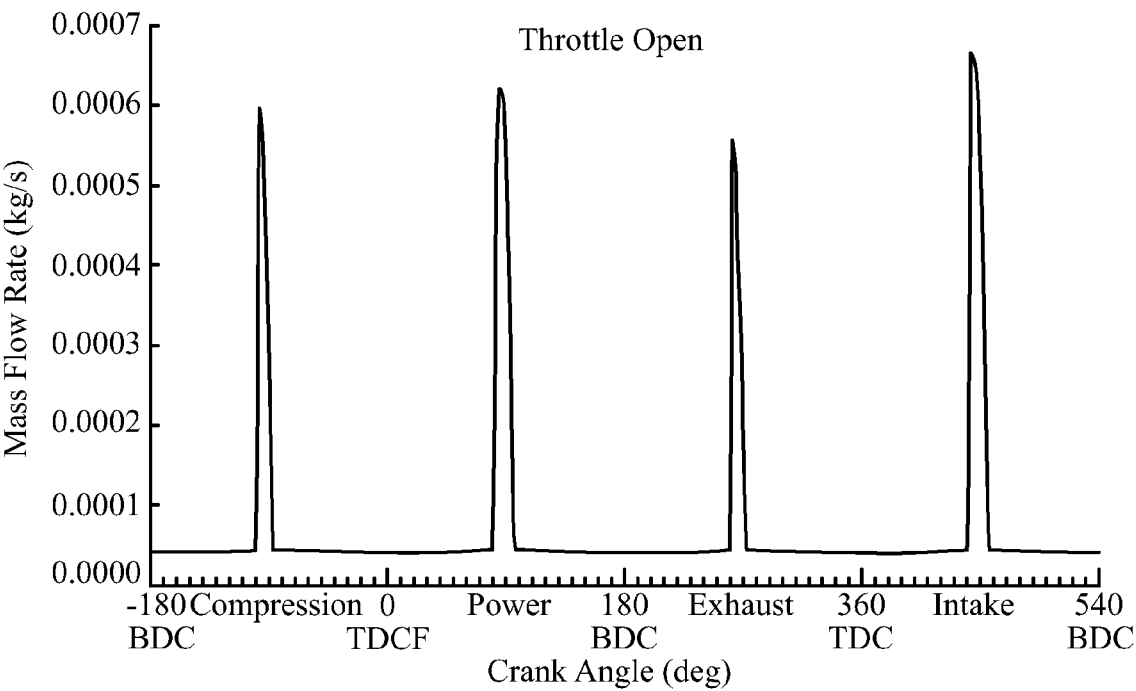


FIG. 11