**Abstract:**

An engine braking method includes the steps of engaging a cam roller (235) of an internal combustion engine with an engine power cam (230) for an engine power operation; disengaging the cam roller (235) from the engine power cam (230); losing a motion from the engine power cam (230); and generating an engine valve motion for the engine braking operation. An engine braking system includes an engine power cam (230) of an internal combustion engine; an engine braking cam (2302) of the internal combustion engine; and a cam roller (235) that is designed to engage with the engine power cam (230) for an engine power operation and to engage with the engine braking cam (2302) for an engine braking operation.

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**Figure 1:**

[Image of the diagram showing the engine brake system and related components]
before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

— with international search report (Art. 21(3))
ENGINE BRAKING METHOD AND SYSTEM

FIELD OF THE INVENTION

[0001] The present application relates to engine braking, particularly to an engine braking method and system.

BACKGROUND OF THE INVENTION

[0002] In the prior art, conventional valve actuation for a vehicle engine is well known and its application has more than one hundred years of history. It uses a conventional valve actuator to control engine valve motion, including the normal exhaust valve motion and normal intake valve motion, for engine power operation. However, due to the additional requirements on engine emission and engine braking, more and more engines need to produce an auxiliary engine valve event, such as an exhaust gas recirculation event or an engine braking event, in addition to the normal engine valve event. The engine brake has gradually become the must-have device for the heavy-duty commercial vehicle engines.

[0003] The engine braking technology is also well known. During engine braking, the engine is temporarily converted to an air compressor, and in the conversion process, fuel supply is cut off, and the exhaust valve is opened near the end of the compression stroke of the engine piston, thereby allowing the compressed gases (being air during braking) to be released. The energy absorbed by the compressed gases during the compression stroke cannot be returned to the engine piston at the subsequent expansion stroke, but is dissipated by the engine exhaust and cooling systems, which results in an effective engine braking and the slow-down of the vehicle.

[0004] An example of engine brake devices in the prior art is disclosed by Cummins in U.S. Patent No. 3220392. The invention utilizes a hydraulic linkage to transfer the motion from the nearby injection cam or exhaust cam to an engine valve, creating a compression release braking valve event in addition to the conventional engine valve event. The invention produces only a compression-release braking in each four-stroke engine cycle.

[0005] U.S. Patent No. 4,572,114 (1986) discloses two-stroke engine braking devices and methods in a four-stroke engine. Thus, for each two-stroke or each crankshaft rotation of the engine, one engine braking is generated. Theoretically, the braking power from two compression releases of the two-stroke braking in each engine four-stroke cycle would be twice that of conventional four-stroke
braking power. However, since the invention uses two hydraulic actuation systems with great structural complexity, there is no practical application.

[0006] U.S. Patent No. 5,537,976 (1996) discloses another two-stroke engine braking apparatus and method using a cam drive, hydraulic linkage, high-speed solenoid valve and electronic control means, to achieve the valve motion. Because within each cycle, the solenoid valve is required to open at least once, the solenoid valve has a particularly high reliability and durability requirements. Plus other issues with the hydraulically actuation, such as valve seating velocity control, engine cold start, etc., the invention has no real application.

[0007] U.S. Patent No. 6,293,248 (2001) discloses yet another two-stroke engine braking apparatus and method. In order to achieve the two-stroke engine braking on a four-stroke engine, in addition to the four cams, four rocker arms must be used: two exhaust rocker arms (one for firing and the other for braking) and two intake rocker arms (one for firing and the other for braking). The structure and the control are complex. Also, hydraulic actuation is used to open the engine valves.

SUMMARY OF THE INVENTION

[0008] An object of the present invention is to provide an engine braking method and system to solve the technical problems in the prior art, such as complex structure and control, poor reliability and durability of hydraulic valve actuation, and limited applications. The mechanical loading (through solid contact) of the present invention also eliminates the failure modes of hydraulic loading (through liquid volume), such as high oil pressure, high leakage and high compliance.

[0009] According to one aspect of the present invention, a new engine braking method comprises the following steps:

1. engaging a cam roller of an internal combustion engine with an engine power cam for an engine power operation;
2. disengaging the cam roller from the engine power cam;
3. losing a motion from the engine power cam and a motion of an engine valve associated with the motion from the engine power cam;
4. engaging the cam roller with an engine braking cam for an engine braking operation;
5. transmitting a motion from the engine braking cam to the engine valve; and generating an engine valve motion for the engine braking operation.
[0010] Further, the step of engaging the cam roller with the engine power cam includes using an axial cam roller driver to move the cam roller axially on a roller shaft of the engine to a first axial position on the roller shaft, and wherein the step of engaging the cam roller with the engine braking cam includes using the axial cam roller driver to move the cam roller axially on the roller shaft of the engine to a second axial position on the roller shaft.

[0011] Further, the axial cam roller driver is integrated into a valve actuator of the engine.

[0012] Further, the axial cam roller driver comprises a piston-spring mechanism in the valve actuator, said piston-spring mechanism being engaged with one end of a linkage or a sliding fork, the other end of the linkage or the sliding fork being engaged with the cam roller.

[0013] Further, the axial cam roller driver is placed outside of a valve actuator of the engine, said axial cam roller driver moving the cam roller axially on the roller shaft through a linkage or a sliding fork.

[0014] Further, the cam roller is designed to have a tendency to separate radially from the cam shaft to enhance the axial motion of the cam roller on the roller shaft.

[0015] Further, the engine power cam and the engine braking cam are located on a common cam shaft, are adjacent to each other, and have the same or substantially the same inner base circle.

[0016] Further, the engine braking method comprises a transition mechanism that assists the cam roller to move between the engine power cam and the engine braking cam.

[0017] Further, the engine braking method comprises a transition mechanism, wherein the transition mechanism includes an inclined line or surface transition between a first height on the engine power cam and a second height on the engine braking cam.

[0018] Further, the step of engaging the cam roller with the engine power cam includes using an axial cam driver to move both the engine power cam and the engine braking cam axially on the camshaft to a first axial position on the camshaft, and wherein the step of engaging the cam roller with the engine braking cam includes using the axial cam driver to move both the engine power cam and the engine braking cam axially on the camshaft of the engine to a second axial position on the camshaft.

[0019] Further, the cam roller is placed on a rocker arm of the engine, and the step of engaging the cam roller with the engine power cam includes using an axial rocker arm driver to move the rocker
arm axially on a rocker shaft of the engine to a first axial position on the rocker shaft, and wherein the step of engaging the cam roller with the engine braking cam includes using the axial rocker arm driver to move the rocker arm axially on the rocker shaft of the engine to a second axial position on the rocker shaft.

[0020] Further, the cam roller comprises an exhaust cam roller, said engine power cam comprises a normal exhaust cam, and said engine braking cam comprises a braking exhaust cam.

[0021] Further, the engine braking method comprises the following steps:

1. engaging the exhaust cam roller with the normal exhaust cam for the engine power operation;
2. disengaging the exhaust cam roller with the normal exhaust cam;
3. losing a motion from the normal exhaust cam and a motion of an engine exhaust valve associated with the motion from the normal exhaust cam;
4. engaging the exhaust cam roller with the braking exhaust cam for the engine braking operation;
5. transmitting a motion from the braking exhaust cam to the engine exhaust valve; and
6. generating an engine exhaust valve motion for the engine braking operation.

[0022] Further, the braking exhaust cam comprises three braking exhaust cam lobes, the first braking exhaust cam lobe being the first compression release cam lobe and associated with a location near the engine compression top dead center, the second braking exhaust cam lobe being the second compression release cam lobe and associated with a location near the engine exhaust top dead center, the third braking exhaust cam lobe being the exhaust gas recirculation cam lobe and associated with a location mainly in the engine expansion stroke, immediately following the first compression release cam lobe or directly connecting to the first compression release cam lobe.

[0023] Further, the cam roller comprises an exhaust cam roller and an intake cam roller, said engine power cam comprises a normal exhaust cam and a normal intake cam, and said engine braking cam comprises a braking exhaust cam and a braking intake cam.

[0024] Further, the engine braking method comprises the following steps:

1. engaging the exhaust cam roller with the normal exhaust cam for the engine power operation, and engaging the intake cam roller with the normal intake cam
for the engine power operation;
2. disengaging the exhaust cam roller with the normal exhaust cam, and disengaging the intake cam roller with the normal intake cam;
3. losing a motion from the normal exhaust cam and a motion of an engine exhaust valve associated with the motion from the normal exhaust cam, and losing a motion from the normal intake cam and a motion of an engine intake valve associated with the motion from the normal intake cam;
4. engaging the exhaust cam roller with the braking exhaust cam for the engine braking operation, and engaging the intake cam roller with the braking intake cam for the engine braking operation;
5. transmitting a motion from the braking exhaust cam to the engine exhaust valve, and transmitting a motion from the braking intake cam to the engine intake valve; and
6. generating an engine exhaust valve motion for the engine braking operation, and generating an engine intake valve motion for the engine braking operation.

Further, the braking exhaust cam comprises at least two braking exhaust cam lobes, the first braking exhaust cam lobe being the first compression release cam lobe and associated with a location near the engine compression top dead center, the second braking exhaust cam lobe being the second compression release cam lobe and associated with a location near the engine exhaust top dead center.

Further, the braking intake cam comprises at least two braking intake cam lobes, the first braking intake cam lobe being associated with a location mainly in the engine's intake stroke, and the second braking intake cam lobe being associated with a location mainly in the engine's expansion stroke.

Further, the engine has a valve actuator, said valve actuator comprising a rocker arm and a valve bridge, one end of the rocker arm being engaged with the engine power cam or the engine braking cam through the cam roller, the other end of the rocker arm being over the valve bridge, the two ends of the valve bridge being engaged respectively with an inner valve that is close to the cams and with an outer valve that is away from the cams, wherein said engine braking method further comprises the following steps:

1. disengaging the rocker arm from the center of the valve bridge while the engagement of
the cam roller to the engine power cam is being switched to the engine braking cam,
2. opening the inner valve by the rocker arm while the outer valve being kept closed,
3. transmitting the motion of the engine braking cam to the inner valve, and generating the
engine braking operation.

[0028] Further, a lost motion mechanism is provided to disengage the rocker arm from the center of
the valve bridge, said lost motion mechanism being integrated into the valve actuator.

[0029] Further, the lost motion mechanism comprises a hydraulic piston mechanism integrated with
the rocker arm, said hydraulic piston mechanism including an auto lash adjusting system.

[0030] Further, the lost motion mechanism comprises a mechanical linkage mechanism integrated
with the rocker arm, said rocker arm comprising a full rocker arm for actuating the inner valve and
a half rocker arm for actuating both the inner valve and the outer valve, one end of the full rocker
arm being engaged with one of the two cams through the cam roller, the other end of the full rocker
arm being engaged with the inner valve, the half rocker arm and the full rocker arm being
rotationally placed on a common rocker shaft, the end of the half rocker arm being over the center
of the valve bridge, and the two rocker arms being linked through the mechanical linkage
mechanism.

[0031] The present invention is also a new engine braking system, which comprises an engine
power cam on a camshaft of an international combustion engine; an engine braking cam on the
camshaft of the internal combustion engine; and a cam roller that is designed to engage with the
engine power cam for an engine power operation and to engage with the engine braking cam for an
engine braking operation.

[0032] Further, the new engine braking system comprises an axial cam roller driver, and a roller
shaft, wherein the cam roller is rotationally placed on the roller shaft, wherein the cam roller is also
axially slidable along the roller shaft between a first axial position and a second axial position, in
said first axial position, the cam roller being engaged with the engine power cam for the engine
power operation, and in said second axial position, the cam roller being engaged with the engine
braking cam for the engine braking operation.

[0033] Further, the axial cam roller driver comprises a piston-spring mechanism integrated into a
valve actuator of the engine, said piston-spring mechanism being engaged with one end of a linkage
or a sliding fork, the other end of the linkage or the sliding fork being engaged with the cam roller.
Further, the axial cam roller driver is placed outside of a valve actuator of the engine, and wherein said axial cam roller driver moves the cam roller axially on the roller shaft through a linkage or a sliding fork.

Further, the cam roller is designed to have a tendency to separate radially from the cam shaft to enhance the axial motion of the cam roller on the roller shaft.

Further, the engine power cam and the engine braking cam are located on a common cam shaft, are adjacent to each other and have the same or substantially the same inner base circle.

Further, the new engine brake system comprises a transition mechanism that assists the cam roller to move between the engine power cam and the engine braking cam.

Further, the new engine brake system comprises a transition mechanism, wherein the transition mechanism includes an inclined surface transition between a first height on the engine power cam and a second height on the engine braking cam.

Further, the new engine brake system comprises an axial cam driver, wherein both the engine power cam and the engine braking cam are axially slidable along the camshaft between a first axial position and a second axial position, in said first axial position, the cam roller being engaged with the engine power cam for the engine power operation, and in said second axial position, the cam roller being engaged with the engine braking cam for the engine braking operation.

Further, the new engine brake system comprises an axial rocker arm driver, wherein the cam roller is placed on a rocker arm of the engine, and said rocker arm is axially slidable along a rocker shaft of the engine between a first axial position and a second axial position, in said first axial position, the cam roller on the rocker arm being engaged with the engine power cam for the engine power operation, and in said second axial position, the cam roller on the rocker arm being engaged with the engine braking cam for the engine braking operation.

Further, the engine power cam comprises a normal exhaust cam, and said engine braking cam comprises a braking exhaust cam.

Further, the braking exhaust cam comprises three braking exhaust cam lobes, the first braking exhaust cam lobe being the first compression release cam lobe and associated with a location near the engine compression top dead center, the second braking exhaust cam lobe being
the second compression release cam lobe and associated with a location near the engine exhaust top
dead center, the third braking exhaust cam lobe being the exhaust gas recirculation cam lobe and
associated with a location mainly in the engine expansion stroke, immediately following the first
compression release cam lobe or directly engaging with the first compression release cam lobe.

[0043] Further, the engine power cam comprises a normal exhaust cam and a normal intake cam,
and said engine braking cam comprises a braking exhaust cam and a braking intake cam.

[0044] Further, the braking exhaust cam comprises at least two braking exhaust cam lobes, the first
braking exhaust cam lobe being the first compression release cam lobe and associated with a
location near the engine compression top dead center, the second braking exhaust cam lobe being
the second compression release cam lobe and associated with a location near the engine exhaust top
dead center.

[0045] Further, the braking intake cam comprises at least two braking intake cam lobes, the first
braking intake cam lobe being associated with a location mainly in the engine's intake stroke, and
the second braking intake cam lobe being associated with a location mainly in the engine's
expansion stroke.

[0046] Further, the engine braking system comprises a lost motion mechanism, wherein said lost
motion mechanism is integrated into the engine's valve actuator, wherein when said lost motion
mechanism is actuated, the engine's rocker arm is disconnected to the center of the engine's valve
bridge, said valve bridge having two ends being engaged respectively with the inner valve that is
close to the cams and with an outer valve that is away from the cams, and there being also a single
valve linkage mechanism between the rocker arm and the inner valve.

[0047] Further, lost motion mechanism comprises a hydraulic piston mechanism integrated with the
rocker arm, said hydraulic piston mechanism being also an auto lash adjusting system.

[0048] Further, the lost motion mechanism comprises a mechanical linkage mechanism integrated
with the rocker arm, said rocker arm comprises a full rocker arm for actuating the inner valve and a
half rocker arm for actuating both the inner valve and the outer valve, one end of the full rocker
arm being engaged with one of the two cams through the cam roller, the other end of the full rocker
arm being engaged with the inner valve, the half rocker arm and the full rocker arm are rotationally
placed on a common rocker shaft, the end of the half rocker arm being over the center of the valve
bridge, and the two rocker arms being linked through the mechanical linkage mechanism.
Further, the engine braking system comprises an anti-no-follow mechanism, wherein said anti-no-follow mechanism comprises an elastic part.

A working principle of the present invention is summarized as follows. When an engine power operation needs to be converted to an engine braking operation, an engagement of a cam roller with an engine power cam is switched to an engine braking cam. The switching is accomplished in one or more of three different ways: (1) using an axial cam roller driver to move the cam roller axially on a roller shaft from a first axial position on the roller shaft where the cam roller is engaged with the engine power cam to a second axial position on the roller shaft where the cam roller is engaged with the engine braking cam; (2) using an axial rocker arm driver to move a rocker arm axially on a rocker arm shaft from a first axial position on the rocker shaft where a cam roller on the rocker arm is engaged with the engine power cam to a second axial position on the rocker shaft where the cam roller on the rocker arm is engaged with the engine braking cam; and (3) using an axial cam driver to move both engine power cam and engine braking cam axially on a camshaft from a first axial position on the camshaft where a cam roller is engaged with the engine power cam to a second axial position on the camshaft where the cam roller is engaged with the engine braking cam. After the switching, the motion from the engine power cam and the motion of an engine valve associated with the motion from the engine power cam are lost, while the motion from the engine braking cam is transmitted to the engine valve for the engine braking operation.

The present application has positive and significant advantages over the prior art. By changing the engagement of the cam roller from the engine power cam to the engine braking cam, the present invention achieves the conversion between the engine power (firing) operation and the engine braking operation. The simple and compact structure is easy to assemble and manufacture with a wide range of applications and other advantages. Since the engine braking cam and the engine power cam are independent from each other, engine braking performance can be optimized. The present invention uses a solid chain (mechanical linkage) to transfer loads, eliminating the high oil pressure, high compliance and high leakage as well as hydraulic jacking and other disadvantages or failure modes linked to the hydraulic loading of conventional engine brakes.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is an engine braking control diagram used in the first embodiment of the engine braking method of the present invention.
[0053] Figure 2 is a schematic view showing an engine braking device (side view) according to the first embodiment of the engine braking method of the present invention.

[0054] Figure 3 is a schematic diagram showing an axial cam roller driver (partial top view) when the cam roller is in the first axial position according to the first embodiment of the engine braking method of the present invention.

[0055] Figure 4 is a schematic diagram showing an axial cam roller driver (partial top view) when the cam roller is at the second axial position according to the first embodiment of the engine braking method of the present invention.

[0056] Figure 5 is a schematic diagram showing the normal cam (or valve) lift profiles.

[0057] Figure 6 is a schematic diagram showing a braking exhaust cam (or valve) lift profile during the engine braking operation according to the first embodiment of the engine braking method of the present invention.

[0058] Figure 7 is a schematic diagram showing braking exhaust and braking intake cam (or valve) lift profiles during the engine braking operation according to the second embodiment of the engine braking method of the present invention.

[0059] Figure 8 is a schematic view showing an engine braking system according to the third embodiment of the engine braking method of the present invention.

[0060] Figure 9 is a schematic view showing a liquid flow control valve according to the third embodiment of the engine braking method of the present invention.

[0061] Figure 10 is a schematic view showing an engine braking system according to the fourth embodiment of the engine braking method of the present invention.

[0062] Figure 11 is a schematic view showing an engine braking system (side view) according to the fifth embodiment of the engine braking method of the present invention.

[0063] Figure 12 is a top view of the fifth embodiment when the full rocker arm is in the first axial position on the rocker shaft and the cam roller is engaged with the engine power cam.

[0064] Figure 13 is a top view of the fifth embodiment when the full rocker arm is in the second axial position on the rocker shaft and the cam roller is engaged with the engine braking cam.

[0065] Figure 14 is a schematic view showing an engine braking system (side view) according to
the sixth embodiment of the engine braking method of the present invention.

[0066] Figure 15 is an engine braking control diagram used in the seventh embodiment of the engine braking method of the present invention.

5 DETAILED DESCRIPTION OF THE EMBODIMENTS

First Embodiment

[0067] Figures 1 to 6 are used to describe the first embodiment of the engine braking method of the present invention. Figure 1 is an engine braking control diagram of the invention. The engine power operation 10 follows the solid line arrows on the left in Figure 1. The engine brake controller 50 is turned off (not energized). The axial cam roller driver 100 biases the cam roller 235 to a first axial position. The cam roller 235 is engaged with an engine power cam 230, and the motion from the engine power cam 230 is transmitted to an engine valve for the engine power operation 10. When the engine power operation 10 needs to be converted to an engine braking operation 20, the engine braking control is switched to the right in Figure 1 and follow the dashed line arrows. The engine brake controller 50 is now turned on (energized). The axial cam roller driver 100 moves the cam roller 235 from the first axial position to the second axial position. The cam roller 235 is disengaged from the engine power cam 230 and switched to an engagement with an engine braking cam 2302. The motion from the engine power cam 230 is completely lost, while the motion from the engine braking cam 2302 is transmitted to the engine valve for the engine braking operation 20. As can be seen from Figure 1, the engine power operation 10 and the engine braking operation 20 are independent of each other.

[0068] Figure 2 is a schematic diagram (side view) of an engine brake device of the present invention. The engine's valve actuator 200, for both intake valve actuator and exhaust valve actuator, includes two cams (an engine power cam 230 and an engine braking cam 2302), a cam roller 235 and a roller shaft 231. The cam roller 235 can rotate on the roller shaft 231. It can also slide axially along the roller shaft between a first axial position (Figure 3) and a second axial position (Figure 4). The engine power cam (cam lobe 220) and the engine braking cam (cam lobes 232 and 233) have different lift and timing. Note that the engine braking cam lobes 232 and 233 have much lower lifts than the engine power cam lobe 220. The two cams are located on a common camshaft 225, adjacent to each other and have the same or substantially the same inner base circle. The valve actuator 200 further includes a rocker arm 210 rotationally mounted on a rocker shaft
205. There is a flow passage 211 in the rocker shaft 205. Through a valve lash adjusting mechanism, the rocker arm 210 actuates the engine valve 301 (shown here is a single valve, but the present invention is equally applicable to dual-valve engine, but a valve bridge is needed for actuating two engine valves). The valve 301 is biased by a valve spring 311 on valve seat 320 in the engine block 500 to prevent gases from flowing between the engine cylinder and gas duct 600. The valve lash adjustment mechanism includes a valve lash adjusting screw 110, a locking nut 105, and an elephant foot 114.

[0069] Figures 3 and 4 (partial top views) illustrate the axial cam roller driver 100 used in the first embodiment of the engine braking method of the present invention with the cam roller 235 being movable between a first axial position and a second axial position. Near the cam side, there is a gap or open slot in the end of the rocker arm 210 (rocker arm 210 shown here can also be a cam follower of a push-tube engine). A roller shaft 231 is provided across the gap, and on the roller shaft 231 provided with the cam roller 235. The cam roller 235 can not only rotate on the roller shaft 231, but also move axially along the roller shaft 231. The length of the roller shaft 231 in the gap is larger than the width of the cam roller 235. The cam roller 235 has a first axial position (Figure 3) and a second axial position (Figure 4) on the roller shaft 231. The axial cam roller driver 100 is integrated in the rocker arm 210, which moves the cam roller 235 between the first axial position and the second axial position through a linkage or a sliding fork 236.

[0070] One end of the sliding fork 236 includes two spaced prongs, and each of the two prongs has a hole or slot 238 and 239. The roller shaft 231 passes through the holes or slots 238 and 239 in the two prongs, and the cam roller 235 is placed between the two prongs. The other end 237 of the sliding fork 236 is engaged with the axial cam roller driver 100 (the way of the engagement may vary). The axial cam roller driver 100 shown here is a piston-spring mechanism integrated in the valve actuator (the rocker arm 210). The piston-spring mechanism includes a piston 164 disposed within a piston bore 260, with its axial direction being parallel to the axis of the roller shaft 231. There is a fluid passage 214 on one side of the piston 164, and a spring 156 on the other side. Piston 164 is pushed separately by the spring force near the spring side (left side in the Figures) and by a fluid (e.g. engine oil) force near the fluid passage side (right side in the Figures). The two forces have opposite directions and make the piston 164 move axially. The piston-spring mechanism is engaged with one end 237 of the sliding fork 236 (the connection here is that the end 237 of the sliding fork 236 is located in annular groove 126 of the piston 164, and the connecting
end 237 having a guide groove 270 in the rocker arm 210). The motion of the piston 164 is transmitted to the cam roller 235 through the sliding fork 136, and the cam roller 235 being moved between the first axial position (Figure 3) and the second axial position (Figure 4) on the roller shaft 231.

[0071] When the cam roller 235 is in the first axial position, it is engaged with the engine power cam 230 on the camshaft 225 (Figure 3). When the cam roller 235 is in the second axial position, it is engaged with the engine braking cam 2302 on the camshaft 225 (Figure 4). Preferably the engine power cam 230 and the engine braking cam 2302 are designed to have the same or substantially the same inner base circle, and to have an axial transition mechanism that assists the cam roller to move between them, such as an inclined surface transition between a first height on the engine power cam 230 to a second height on the engine braking cam 2302, so that the cam roller 235 could have a smooth and stable transition when the engagement of the cam roller 235 is switched between the two cams. Alternatively, the transition mechanism could include any other suitable mechanism. For example, the transition may be accomplished by switching between the two cams only when the height difference between the engine power cam 230 and the engine braking cam 2302 is below a certain value to reduce any impact during the switch. Also it is better for the cam roller 235 to have a tendency to separate radially from the camshaft 225 to enhance the axial motion of the cam roller 235 on the roller shaft 231.

[0072] The operation of this embodiment is as follows. Spring 156 biases piston 164 to the bottom surface of piston bore 260 near the side with fluid passage 214 (the right side). The piston 164, through the sliding fork 236, pushes the cam roller 235 to the first axial position (the right side in Figure 3), and the cam roller 235 is engaged with the engine power cam 230. The motion of the engine power cam 230 is transmitted to the engine valve 301 (Figure 2), generating the valve motion for engine power operation (see Figure 5 for the valve profile 220 (exhaust) or 321 (intake)). When it is desired to convert the engine power operation 20 to the engine braking operation 20, the engine brake controller 50 is turned on to provide a driving force to the axial cam roller driver 100. Fluid, such as engine oil through the fluid passages, for example, 211 and 214 in the rocker shaft and rocker arm, flows into piston bore 260. The oil pressure overcomes the force of spring 156 and moves piston 164 in piston bore 260 to the side with spring 156 (left side), and piston 164 pushes the sliding fork 236 with the cam roller 235 to the second axial position (left side in Figure 4). The cam roller 235 is disengaged from the engine power cam 230 and engaged with
the engine braking cam 2302. The motion of the engine power cam 230 is lost, while the motion of the engine braking cam 2302 is transmitted to the engine valve 301 for the engine braking operation.

[0073] Note that the above description applies to both the exhaust valve actuation and the intake valve actuation. However, in this embodiment, the engine braking operation 20 simply switches the power operation of the exhaust valve to the engine braking operation, the engine power operation of the intake valve is maintained without any change. The intake valve motion for engine power operation is shown in Figure 5 (the intake lift curve 321) and the engine braking exhaust valve motion which is from the braking exhaust cam 2302, as shown in Figure 6 as an example, is generated by three braking exhaust cam lobes. The first braking exhaust cam lobe is the first compression release cam lobe 232, located near the engine’s compression top dead center (0° crank angle); the second braking exhaust cam lobe is the second compression release cam lobe 233, located near the engine’s exhaust top dead center (360° crank angle); and the third braking exhaust cam lobe is the exhaust gas recirculation cam lobe 231, mainly located in the expansion stroke of the engine and immediately following the first compression-release cam lobe 232 or directly connecting to the first compression release cam lobe 232 to form a combined cam lobe.

Second Embodiment:

[0074] In this embodiment of the present invention, the intake valve engine braking operation is added to the above-described embodiment. The exhaust valve actuator and the intake valve actuator are both provided with the axial cam roller driver 100, which has the same working principle and procedure as described in the first embodiment, and is not repeated here.

[0075] The engine power cams in the present embodiment are the same as embodiment one, including both the normal exhaust cam and the normal intake cam, whose lift curves are shown in Figure 5 (220 for exhaust and 312 for intake). The braking cams include the braking exhaust cam and a braking intake cam, whose lift curves are shown in Figure 7 (232 and 233 for exhaust, and 322 and 323 for intake). Therefore, the present embodiment has one more braking intake cam than the first embodiment. When the engine power operation is needed, the axial cam roller driver 100 biases the cam roller 235 to the first axial position, both the intake and exhaust cam rollers are engaged with the normal intake and exhaust cams respectively, whose motions are passed to the engine’s intake and exhaust valves to produce the intake and exhaust valve motions for the engine power operation (see Figure 5 for the intake and exhaust lift curves 321 and 220).
When it is desired to convert the engine power operation 10 to the engine braking operation 20, the engine brake controller 50 is turned on to provide a driving force to the axial cam roller driver 100, which moves the exhaust cam roller 235 from the first axial position to the second axial position, switching the connection of the exhaust cam roller 235 from the normal exhaust cam 230 to the braking exhaust cam 2302, losing the normal exhaust cam motion and the corresponding normal exhaust valve motion, generating the engine braking exhaust valve motion. At the same time, the intake cam roller is also moved from the first axial position to the second axial position, switching the connection of the intake cam roller from the normal intake cam to the braking intake cam, losing the normal intake cam motion and the corresponding normal intake valve motion, generating the engine braking intake valve motion.

As shown in Figure 7, the braking exhaust cam has two braking exhaust cam lobes, one being the first compression-release cam lobe 232 located near the engine's compression top dead center (0° crank angle), and the other being the second compression release cam lobe 233 located near the engine's exhaust top dead center (360° crank angle). Figure 7 also shows two braking intake cam lobes for the braking intake cam, one being the first braking intake cam lobe 322, mainly located in the intake stroke of the engine, and the other being the second braking intake cam lobe 323, mainly located in the expansion stroke of the engine. The first braking intake cam lobe 322 is to charge the engine cylinder prior to the first compression release event, and the first compression release cam lobe 232 to achieve the first stroke braking. The second braking intake cam lobe 323 is to charge the engine cylinder prior to the second compression release event, and the second compression release cam lobe 233 to achieve the second stroke braking. Thus, the four-stroke engine is able to achieve two-stroke braking in one cycle, greatly improving the braking power. Note that the two braking exhaust cam lobes (the first and second compression-release cam lobes 232 and 233) are much smaller (lower lift and short duration) than the two braking intake cam lobes.

Third Embodiment:

Figures 8 and 9 are used to illustrate the third embodiment of the present invention. The present embodiment has two valves 301 and 302 that are biased against the valve seat 320 in the engine block 500 by the two valve springs 311 and 312. The valve actuator 200 also includes a rocker arm 210 and a valve bridge 400 placed on the two valves. The rocker arm 210 actuates a single engine valve (the first valve or the inner valve close to the cams) through a lash adjusting
mechanism (a lash adjusting screw 1102), an e-foot 1142, and a braking bar 116 in the valve bridge 400. The lash adjusting screw 1102 is fixed on the rocker arm 210 by a lock nut 1052. The rocker arm 210 contains also a lost motion mechanism that is a hydraulic piston mechanism including a hydraulic piston 160 and a liquid flow control valve 75 (see Figure 9 for details of the valve), which happens also to be an auto lash adjusting mechanism. The hydraulic piston 160 is slidably placed in a piston bore 190. A hydraulic linkage with a liquid column is formed between piston 160 and rocker arm 210 through the liquid flow control valve 75. The height 234 of the liquid column is automatically adjusted according to the gap between the cam 230 and the bridge 400 or the two valves. The hydraulic piston 160 is engaged with the center of the valve bridge 400 though an e-foot 114.

[0079] The liquid flow control valve 75 (Figure 9 for cross section view) integrated into the rocker arm 210 includes a one-way ball valve 165, biased upwards by spring 177. The top of the ball valve 165 is actuated by a funnel shaped piston 58 that is biased downwards by spring 256. When pressured liquid (for example, engine lube oil) is provided though flow passage 218, oil pressure overcomes the force of the spring 256 and moves the piston 58 upward. At the same time, oil pressure overcomes the force of the spring 177 and moves the ball valve 165 downwards. Oil is fed into the hydraulic passage 216 as well as all the hydraulic passages and chambers including the piston bore 190 underneath the ball valve 165 to form a hydraulic lock.

[0080] The operation of this embodiment is as follows. The axial motion of the cam roller 235 on the roller shaft 231 is the same as the first embodiment. The axial cam roller driver 100 shown in Figures 3 and 4 has a spring 156 or oil pressure that biases the piston 164 to the bottom surface of piston bore 260 near the side with the fluid passage 214 (the right side). The piston 164, through the sliding fork 236, pushes the cam roller 235 to the first axial position (the right side in Figure 3), and the cam roller 235 is engaged with the engine power cam 230. Through the roller shaft 231, the rocker arm 210, the lost motion mechanism that forms a hydraulic linkage and the valve bridge 400, the motion of the engine power cam 230 is transmitted to both of the two engine valve 301 and 302 (Figure 8), generating the valve motion for engine power operation (see Figure 5 for the valve lift profile 220 (exhaust) or 321 (intake)). Since the rocker ratio at the e-foot 1142 that opens the inner valve is smaller than the rocker ration at the e-foot 114 that actuates the valve bridge 400 and both of the two valves 301 (inner valve) and 302 (outer valve), the e-foot 1142 will not be loaded or transmit any motion to the inner valve 301.
[0081] When it is desired to convert the engine power operation 10 to the engine braking operation 20, the engine brake controller 50 is turned on to provide a driving force to the axial cam roller driver 100. Fluid, such as engine oil through the fluid passages 211 and 214 in the rocker shaft and rocker arm, flows into piston bore 260 (Figures 3 and 4). The oil pressure overcomes the force of spring 156 and moves piston 164 in piston bore 260 to the side with spring 156 (left side), and piston 164 pushes the sliding fork 236 with the cam roller 235 to the second axial position (left side in Figure 4). The cam roller 235 is disengaged from the engine power cam 230 and engaged with the engine braking cam 2302. The motion of the engine power cam 230 is lost.

[0082] At the same time, oil to the liquid flow control valve 75 is discharged through fluid passage 218. Piston 58 moves downwards under the action of spring 256 (see Figure 9) and pushes the one-way ball valve 165 off its seat. Oil is discharged from the piston bore 190 through the hydraulic passage 216. The liquid column 234 is now like an air gap and the hydraulic linkage is lost. The motion from the engine braking cam (cam lobes 232 and 233) is lost at the e-foot 114 and cannot be transmitted to the two engine valves 301 and 302 through the center of the valve bridge 400. However, due to the engagement of the rocker arm 210 with the inner valve 301 through the e-foot 1142 and the braking bar 116 in the valve bridge 400, the motion of the engine braking cam 2302 engaged with the cam roller is transmitted to the inner valve 301 for the engine braking operation with a single valve actuation, which has much lower engine braking load.

[0083] In summary, the present embodiment uses an axial cam roller driver to move the cam roller axially on the roller shaft to switch its connection from the engine power cam to the engine braking cam. The motion of the engine power cam is lost. At the same time, the connection between the rocker arm and the center of the valve bridge is also cut off by a lost motion mechanism, which converts the valve actuator 200 from opening two valves to opening one valve. The motion of the engine braking cam 2302 is transmitted by the rocker arm to one of the two valves, i.e., the inner valve 301 for the engine braking operation with a single valve actuation.

[0084] The clip ring 176 (or other stopping mechanism) inside the piston bore 190 is used to limit the stroke of piston 160 as well as to keep the piston 160 from falling out of the bore (good for shipping and assembly). An anti-no-follow mechanism is added to prevent no-follow of the moving parts due to the gap 234 formed by the lost motion mechanism 250. The anti-no-follow mechanism includes a spring or an elastic part, such as 117, 118 and 198 in Figure 8. The shape, type, installation and location of the springs or elastic parts can be changed to serve the purpose of
keeping the moving parts, such as the valve bridge 400, from having no-follow. The height of the gap 234 is determined by the braking cam lobes to escape (or lose) the motion of the braking cam lobes so that it won't be transmitted to the valves through the valve bridge 400.

**Fourth Embodiment:**

[0085] Figure 10 is used to illustrate the fourth embodiment of the present invention. Instead of a single rocker arm in the third embodiment, the present embodiment has two rocker arms: a full rocker arm 210 for opening one valve (the inner valve) 301 and a half rocker arm 212 for opening both of the two valves (the inner and outer valves) 301 and 302. The lost motion mechanism 250 is now a mechanical linkage mechanism that connects the full rocker arm 210 and the half rocker arm 212. The full rocker arm 210 is similar to that of the first embodiment and has the cam roller 235 on the roller shaft 231 on its end close to the cams 230 and 2302. The other end of the full rocker arm 210 is linked to the first valve (the inner valve) 301 through a braking lash adjusting mechanism, an e-foot 1142 and a braking bar 116. The half rocker arm 212 and the full rocker arm 210 are placed rotationally on the common rocker shaft 205. For example, the full rocker arm 210 could be placed in the middle while the half rocker arm 212 have a fork shape and be placed on both sides of the full rocker arm 210. Note that the half rocker arm 212 is not engaged with cam 230 or 2302. The end of the half rocker arm 212 is engaged with the center of the valve bridge 400 through a valve lash adjusting screw 110 and an e-foot 114. The valve bridge 400 is engaged with the two valves 301 and 302. The adjusting screw 110 is fixed on the half rocker arm 212 by a lock nut 105. The half rocker arm 212 is also engaged with the full rocker arm 210 though the lost motion mechanism (the mechanical linkage mechanism) 250. The mechanical linkage mechanism 250 includes two links 184 and 186 that are linked through a middle pin 125. The other (left) end of link 184 is engaged with the full rocker arm 210 through a left pin 122. The other (right) end of link 186 is engaged with the half rocker arm 212 through a right pin 128. One end of a returning spring 198 is placed on the extension part of the right end of link 186. Another end of the returning spring 198 is located on the half rocker arm 212.

[0086] When it is desired to convert the engine power operation 10 to the engine braking operation 20, the engine brake controller 50 is turned on to provide driving force to the axial cam roller driver 100. Fluid, such as engine oil through the fluid passage 214, flows into piston bore 260 (Figures 3 and 4). The oil pressure overcomes the force of spring 156 and moves piston 164 in piston bore 260 to the side with spring 156 (left side), and piston 164 pushes the sliding fork 236 with the cam...
roller 235 to the second axial position (left side in Figure 4). The cam roller 235 is disengaged from
the engine power cam 230 and engaged with the engine braking cam 2302. The motion of the
engine power cam 230 is lost.

[0087] At the same time, the engine brake controller 50 supplies oil to the activation piston 162 in
Figure 10. Oil pressure overcomes the action of spring 198 and pushes upwards the activation
piston 162 as well as the center of the mechanical linkage mechanism 250 near the middle pin 125.
The half rocker arm 212 rotates anticlockwise and the e-foot 114 is disconnected from the valve
bridge 400 and the two valves. The motion from the engine braking cam (cam lobes 232 and 233)
is lost at the e-foot 114 and cannot be transmitted to the two valves 301 and 302 through the center
of the valve bridge 400. However, due to the connection of the full rocker arm 210 to the inner
valve 301 through the e-foot 1142 and the braking bar 116 in the valve bridge 400, the motion of
the engine braking cam 2302 being engaged with the cam roller 235 is transmitted to the inner
valve 301 for the engine braking operation with a single valve actuation.

Fifth Embodiment

[0088] Figures 11 to 13 are used to describe the fifth embodiment of the engine braking method of
the present invention. Similar to embodiment four, the present embodiment has also two rocker
arms: a full rocker arm 210 and a half rocker arm 212. However, the full rocker arm 210 of the
present embodiment can be moved axially on the rocker shaft 205 between a first axial position
(Figure 12) and a second axial position (Figure 13). When the full rocker arm 210 is in the first
axial position on the rocker shaft 205, the cam roller 235 on one end of the full rocker arm 210 is
engaged with the engine power cam 230 on the camshaft 225 as shown in Figure 11. When the full
rocker arm 210 is in the second axial position, the cam roller 235 is engaged with the engine
braking cam 2302 as shown in Figure 12. Note that the cam roller 235 on the full rocker arm 210 is
not axially movable in the present embodiment. The other end of the full rocker arm 210 is engaged
with the half rocker arm 212.

[0089] An axial rocker arm driver (not shown here) 100 is used to move the full rocker arm 210
axially on the rocker shaft 205 through a linkage, such as a hydraulic piston 162 in the full rocker
arm 210. The axial rocker arm driver 100 is placed outside of the valve actuator of the engine and it
can be a hydraulic, pneumatic, electromagnetic, and mechanical mechanism or a combination of the
above mechanisms. The motion of the axial rocker arm driver 100 can be synchronized with the
motion of the camshaft 225.
Sixth Embodiment

[0090] Figure 14 is used to describe the sixth embodiment of the engine braking method of the present invention. The present embodiment is similar to the fifth embodiment except that the lost motion mechanism 250 in the third embodiment (Figure 8) is used here in the half rocker arm 212. The half rocker arm 212 is also engaged with the inner valve 301 through a braking bar 116. The operation of the present embodiment is a combination of the fifth embodiment (to move the full rocker arm 212 axially on the rocker shaft 205 between a first axial position and a second axial position so that the cam roller 235 on the full rocker arm 210 will be engaged with the engine power cam 230 or the engine braking cam 2302) and the third embodiment (to disengage the half rocker arm 212 from the center of the valve bridge 400 by a lost motion mechanism 250 so that the motion from the engine braking cam 2302 can only be transmitted to the inner valve 301, not to the outer valve 302).

Seventh Embodiment

[0091] Figure 15 is used to describe the seventh embodiment of the engine braking method of the present invention. Figure 15 is similar to Figure 1 and the present embodiment is an extension of the previous embodiments. The engine power cam 230 and the engine braking cam 2302 are placed on the same camshaft 225 and are axially movable between a first axial position and a second axial position on the camshaft 225. However, the cam roller 235 of the engine is no longer axially movable. The step of engaging the cam roller 235 with the engine power cam 230 includes using an axial cam driver 100 to move both the engine power cam 230 and the engine braking cam 2302 axially on the camshaft 225 to the first axial position on the camshaft 225, and the step of engaging the cam roller 235 with the engine braking cam 2302 includes using the axial cam driver 100 to move both the engine power cam 230 and the engine braking cam 2302 axially on the camshaft 225 of the engine to the second axial position on the camshaft 225.

[0092] While the above description contains many specific embodiments, these embodiments should not be regarded as limitations on the scope of the present invention, but rather as specific exemplifications. Many other variations are likely to be derived from the specific embodiments. For example, the engine braking method or device described herein can be used not only for overhead cam engines, but also for push tube engines; not only for actuating one engine valve, but also for two engine valves. Also, the present invention involves different cams, such as the intake cam, the exhaust cam, and the braking cam, which include cam lobes that could have different
number, size, shape, timing, lift and so on.

[0093] In addition, the axial cam roller driver, the axial rocker arm driver and the axial cam driver described herein can not only be the piston-spring mechanism, but also other mechanism, such as a hydraulic, a pneumatic, a electromagnetic, and mechanical mechanism or a combination of the above mechanisms; it can not only be integrated in the valve actuator (such as with the rocker arm), but also be placed outside of the valve actuator (such as on the engine) to move the cam roller, the rocker arm or the cams axially on the roller shaft, the rocker shaft or the camshaft through a linkage.

[0094] In addition, the lost motion mechanism integrated into the valve actuator could have different type, shape, size and location (such as integrated into a valve bridge), etc.

[0095] Therefore, the scope of the present invention should not be defined by the above-mentioned specific examples, but by the appended claims and their legal equivalents.
What is claimed is:

1. An engine braking method comprising:
   engaging a cam roller of an internal combustion engine with an engine power cam for an engine power operation;
   disengaging the cam roller from the engine power cam;
   losing a motion from the engine power cam and a motion of an engine valve associated with the motion from the engine power cam;
   engaging the cam roller with an engine braking cam for an engine braking operation;
   transmitting a motion from the engine braking cam to the engine valve; and
   generating an engine valve motion for the engine braking operation.

2. The engine braking method according to claim 1, wherein the step of engaging the cam roller with the engine power cam includes using an axial cam roller driver to move the cam roller axially on a roller shaft of the engine to a first axial position on the roller shaft, and wherein the step of engaging the cam roller with the engine braking cam includes using the axial cam roller driver to move the cam roller axially on the roller shaft of the engine to a second axial position on the roller shaft.

3. The engine braking method according to claim 2, wherein said axial cam roller driver is integrated into a valve actuator of the engine.

4. The engine braking method according to claim 3, wherein said axial cam roller driver comprises a piston-spring mechanism in the valve actuator, said piston-spring mechanism being engaged with one end of a linkage or a sliding fork, the other end of the linkage or the sliding fork being engaged with the cam roller.

5. The engine braking method according to claim 2, wherein said axial cam roller driver is placed outside of a valve actuator of the engine, said axial cam roller driver moving the cam roller axially on the roller shaft through a linkage or a sliding fork.

6. The engine braking method according to claim 2, wherein said cam roller is designed to have a tendency to separate radially from the cam shaft to enhance the axial motion of the cam roller on the roller shaft.

7. The engine braking method according to claim 1, wherein the engine power cam and the engine braking cam are located on a common cam shaft, are adjacent to each other, and have
the same or substantially the same inner base circle.

8. The engine braking method according to claim 1, further comprising a transition mechanism that assists the cam roller to move between the engine power cam and the engine braking cam.

9. The engine braking method according to claim 1, further comprising a transition mechanism, wherein the transition mechanism includes an inclined line or surface transition between a first height on the engine power cam and a second height on the engine braking cam.

10. The engine braking method according to claim 1, wherein the step of engaging the cam roller with the engine power cam includes moving both the engine power cam and the engine braking cam to a first axial position on a camshaft, and wherein the step of engaging the cam roller with the engine braking cam includes moving both the engine power cam and the engine braking cam to a second axial position on the camshaft.

11. The engine braking method according to claim 1, wherein the cam roller is placed on a rocker arm of the engine, and the step of engaging the cam roller with the engine power cam includes moving the rocker arm to a first axial position on a rocker shaft, and wherein the step of engaging the cam roller with the engine braking cam includes moving the rocker arm to a second axial position on the rocker shaft.

12. The engine braking method according to claim 1, wherein said cam roller comprises an exhaust cam roller, said engine power cam comprises a normal exhaust cam, and said engine braking cam comprises a braking exhaust cam.

13. The engine braking method according to claim 12, comprising, engaging the exhaust cam roller with the normal exhaust cam for the engine power operation; disengaging the exhaust cam roller with the normal exhaust cam; losing a motion from the normal exhaust cam and a motion of an engine exhaust valve associated with the motion from the normal exhaust cam; engaging the exhaust cam roller with the braking exhaust cam for the engine braking operation; transmitting a motion from the braking exhaust cam to the engine exhaust valve; and generating an engine exhaust valve motion for the engine braking operation.

14. The engine braking method according to claim 12, wherein said braking exhaust cam comprises three braking exhaust cam lobes, the first braking exhaust cam lobe being the first compression release cam lobe and associated with a location near the engine compression top.
dead center, the second braking exhaust cam lobe being the second compression release cam lobe and associated with a location near the engine exhaust top dead center, the third braking exhaust cam lobe being the exhaust gas recirculation cam lobe and associated with a location mainly in the engine expansion stroke, immediately following the first compression release cam lobe or directly engaging with the first compression release cam lobe.

15. The engine braking method according to claim 1, wherein said cam roller comprises an exhaust cam roller and an intake cam roller, said engine power cam comprises a normal exhaust cam and a normal intake cam, and said engine braking cam comprises a braking exhaust cam and a braking intake cam.

16. The engine braking method according to claim 15, comprising

engaging the exhaust cam roller with the normal exhaust cam for the engine power operation, and

engaging the intake cam roller with the normal intake cam for the engine power operation;

disengaging the exhaust cam roller with the normal exhaust cam, and disengaging the intake cam roller with the normal intake cam;

losing a motion from the normal exhaust cam and a motion of an engine exhaust valve associated with the motion from the normal exhaust cam, and losing a motion from the normal intake cam and a motion of an engine intake valve associated with the motion from the normal intake cam;

engaging the exhaust cam roller with the braking exhaust cam for the engine braking operation, and

engaging the intake cam roller with the braking intake cam for the engine braking operation;

transmitting a motion from the braking exhaust cam to the engine exhaust valve, and transmitting a motion from the braking intake cam to the engine intake valve; and

generating an engine exhaust valve motion for the engine braking operation, and generating an engine intake valve motion for the engine braking operation.

17. The engine braking method according to claim 15, wherein said braking exhaust cam comprises at least two braking exhaust cam lobes, the first braking exhaust cam lobe being the first compression release cam lobe and associated with a location near the engine compression top dead center, the second braking exhaust cam lobe being the second compression release cam lobe and associated with a location near the engine exhaust top dead center.

18. The engine braking method according to claim 15, wherein said braking intake cam comprises
at least two braking intake cam lobes, the first braking intake cam lobe being associated with a location mainly in the engine's intake stroke, and the second braking intake cam lobe being associated with a location mainly in the engine's expansion stroke.

19. The engine braking method according to claim 1, wherein the engine has a valve actuator, said valve actuator comprising a rocker arm and a valve bridge, one end of the rocker arm being engaged with the engine power cam or the engine braking cam through the cam roller, the other end of the rocker arm being over the valve bridge, the two ends of the valve bridge being engaged respectively with an inner valve that is close to the cams and with an outer valve that is away from the cams, wherein said engine braking method further comprises the following steps:

- disengaging the rocker arm from the center of the valve bridge while the connection of the cam roller to the engine power cam is being switched to the engine braking cam,
- opening the inner valve by the rocker arm while the outer valve being kept closed, and
- transmitting the motion of the engine braking cam to the inner valve, and generating the engine braking operation.

20. The engine braking method according to claim 19, wherein a lost motion mechanism is provided to disengage the rocker arm from the center of the valve bridge, said lost motion mechanism being integrated into the valve actuator.

21. The engine braking method according to claim 20, wherein said lost motion mechanism comprises a hydraulic piston mechanism integrated with the rocker arm, said hydraulic piston mechanism including an auto lash adjusting system.

22. The engine braking method according to claim 20, wherein said lost motion mechanism comprises a mechanical linkage mechanism integrated with the rocker arm, said rocker arm comprising a full rocker arm for actuating the inner valve and a half rocker arm for actuating both the inner valve and the outer valve, one end of the full rocker arm being engaged with one of the two cams through the cam roller, the other end of the full rocker arm being engaged with the inner valve, the half rocker arm and the full rocker arm being rotationally placed on a common rocker shaft, the end of the half rocker arm being over the center of the valve bridge, and the two rocker arms being linked through the mechanical linkage mechanism.

23. An engine braking system comprising:
an engine power cam of an international combustion engine;
an engine braking cam of the internal combustion engine; and
a cam roller that is designed to engage with the engine power cam for an engine power operation
and to engage with the engine braking cam for an engine braking operation.

24. The engine braking system according to claim 23, further comprising an axial cam roller driver,
and a roller shaft, wherein the cam roller is rotationally placed on the roller shaft, wherein the
cam roller is also axially slidable along the roller shaft between a first axial position and a
second axial position, in said first axial position, the cam roller being engaged with the engine
power cam for the engine power operation, and in said second axial position, the cam roller
being engaged with the engine braking cam for the engine braking operation.

25. The engine braking system according to claim 24, wherein said axial cam roller driver
comprises a piston-spring mechanism integrated into a valve actuator of the engine, said
piston-spring mechanism being engaged with one end of a linkage or a sliding fork, the other
end of the linkage or the sliding fork being engaged with the cam roller.

26. The engine braking system according to claim 24, wherein said axial cam roller driver is
placed outside of a valve actuator of the engine, and wherein said axial cam roller driver
moves the cam roller axially on the roller shaft through a linkage or a sliding fork.

27. The engine braking system according to claim 23, wherein said cam roller is designed to have
a tendency to separate radially from the cam shaft to enhance the axial motion of the cam roller
on the roller shaft.

28. The engine braking system according to claim 23, wherein the engine power cam and the
engine braking cam are located on a common cam shaft, are adjacent to each other and have
the same or substantially the same inner base circle.

29. The engine braking system according to claim 23, further comprising a transition mechanism
that assists the cam roller to move between the engine power cam and the engine braking cam.

30. The engine braking system according to claim 23, further comprising a transition mechanism,
wherein the transition mechanism includes an inclined surface transition between a first height
on the engine power cam and a second height on the engine braking cam.

31. The engine braking system according to claim 23, further comprising an axial cam driver,
wherein both the engine power cam and the engine braking cam are axially slidable along a
camshaft between a first axial position and a second axial position, in said first axial position,
the cam roller being engaged with the engine power cam for the engine power operation, and
in said second axial position, the cam roller being engaged with the engine braking cam for the
engine braking operation.

32. The engine braking system according to claim 23, further comprising an axial rocker arm
driver, wherein the cam roller is placed on a rocker arm of the engine, and said rocker arm is
axially slidable along a rocker shaft of the engine between a first axial position and a second
axial position, in said first axial position, the cam roller on the rocker arm being engaged with
the engine power cam for the engine power operation, and in said second axial position, the
cam roller on the rocker arm being engaged with the engine braking cam for the engine
braking operation.

33. The engine braking system according to claim 23, wherein said engine power cam comprises a
normal exhaust cam, and said engine braking cam comprises a braking exhaust cam.

34. The engine braking system according to claim 33, wherein said braking exhaust cam
comprises three braking exhaust cam lobes, the first braking exhaust cam lobe being the first
compression release cam lobe and associated with a location near the engine compression top
dead center, the second braking exhaust cam lobe being the second compression release cam
lobe and associated with a location near the engine exhaust top dead center, the third braking
exhaust cam lobe being the exhaust gas recirculation cam lobe and associated with a location
mainly in the engine expansion stroke, immediately following the first compression release
cam lobe or directly engaging with first compression release cam lobe.

35. The engine braking system according to claim 23, wherein said engine power cam comprises a
normal exhaust cam and a normal intake cam, and said engine braking cam comprises a
braking exhaust cam and a braking intake cam.

36. The engine braking system according to claim 35, wherein braking exhaust cam comprises at
least two braking exhaust cam lobes, the first braking exhaust cam lobe being the first
compression release cam lobe and associated with a location near the engine compression top
dead center, the second braking exhaust cam lobe being the second compression release cam
lobe and associated with a location near the engine exhaust top dead center.

37. The engine braking system according to claim 35, wherein said braking intake cam comprises
at least two braking intake cam lobes, the first braking intake cam lobe being associated with a
location mainly in the engine's intake stroke, and the second braking intake cam lobe being
associated with a location mainly in the engine's expansion stroke.

38. The engine braking system according to claim 23, further comprising a lost motion mechanism, wherein said lost motion mechanism is integrated into the engine's valve actuator, wherein when said lost motion mechanism is actuated, the engine's rocker arm is disconnected to the center of the engine's valve bridge, said valve bridge having two ends being engaged respectively with the inner valve that is close to the cams and with an outer valve that is away from the cams, and there being also a single valve linkage mechanism between the rocker arm and the inner valve.

39. The engine braking system according to claim 38, wherein said lost motion mechanism comprises a hydraulic piston mechanism integrated with the rocker arm, said hydraulic piston mechanism being also an auto lash adjusting system.

40. The engine braking system according to claim 38, wherein said lost motion mechanism comprises a mechanical linkage mechanism integrated with the rocker arm, said rocker arm comprises a full rocker arm for actuating the inner valve and a half rocker arm for actuating both the inner valve and the outer valve, one end of the full rocker arm being engaged with one of the two cams through the cam roller, the other end of the full rocker arm being engaged with the inner valve, the half rocker arm and the full rocker arm are rotationally placed on a common rocker shaft, the end of the half rocker arm being over the center of the valve bridge, and the two rocker arms being linked through the mechanical linkage mechanism.

41. The engine braking system according to claim 23, further comprising an anti-no-follow mechanism, wherein said anti-no-follow mechanism comprises an elastic part.
Fig. 14

Fig. 15
INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2015/001625

A. CLASSIFICATION OF SUBJECT MATTER

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)

FOIL F02D

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT,CNKI,WPI,EPODOC:engine,brake,cam,roller,power cam,exhaust,engine valve,axial,position

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Relevant to claim No.</th>
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<td>CN 101994539 A (SHANGHAI UNIVERSOON AUTOPARTS CO., LTD.) 30 March 2011 (201 1-03-30) description, paragraphs [0023]-[0032] and figures 1-4</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

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Date of the actual completion of the international search

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Date of mailing of the international search report

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Form PCT/ISA/210 (second sheet) (July 2009)
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