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## (54) System for performing an engine braking procedure based on decompression events for a 4-stroke cycle engine

(57) System for performing an engine braking procedure based on decompression events for a 4-stroke cycle engine, the engine comprising at least a cylinder having an inlet pipe and an outlet pipe, cylinder inlet and outlet valves and control means for controlling a displacement of said cylinder valves. The system performs a first compression phase (B-II) followed by a first decompression event (B-II') and, in succession, a sucking phase (B-III) from the outlet pipe and a second compression phase (B-IV) followed by a second decompression event (B-IV').

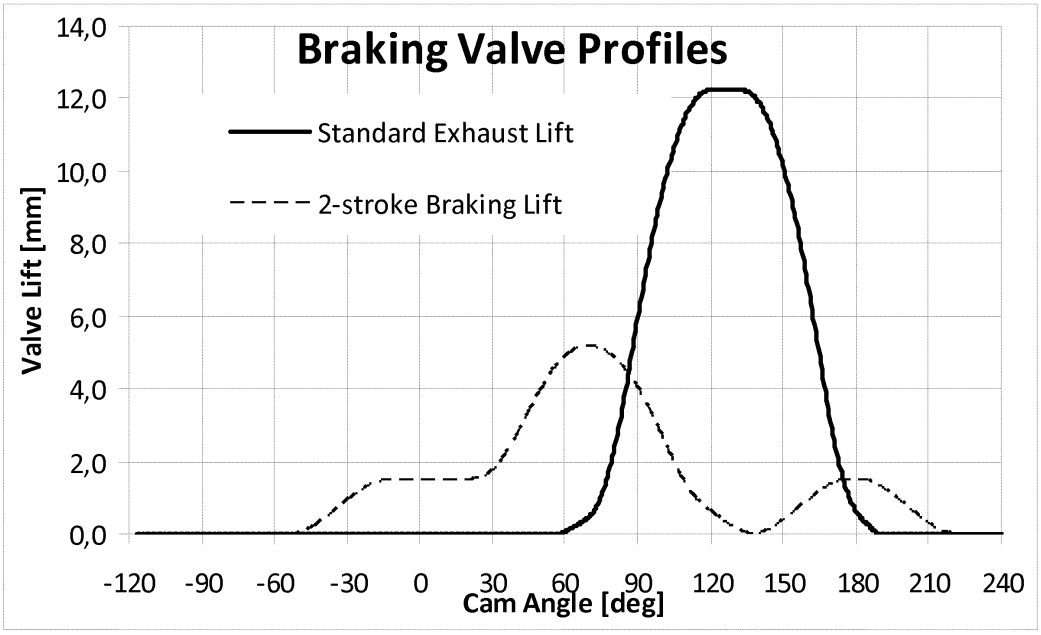


Fig. 2

EP 2 808 503 A1

## Description

### Field of the invention

**[0001]** The present invention relates to an engine braking system based on decompression events for a 4-stroke cycle engine.

### Description of the prior art

**[0002]** Engine braking systems for 4-stroke cycle engine are well known.

**[0003]** One of the braking system concept is based on a compression-decompression event. In practice, during a compression phase, where the fuel injection is inhibited, fresh air is compressed. When the piston reaches the top dead center (TDC), the exhaust valves are opened in order to release the compressed air, before such compressed air, acting as a spring, returns the energy received during the compression phase to the piston. Therefore, the engine compression energy is dissipated as braking force.

**[0004]** Several systems are known in order to enable the engine braking. In addition, some of them are not implemented due to the high complexity connected with the profiles of the cams. Usually, only one braking event is carried out for one complete cycle. In a 4-stroke engine, a complete cycle is intended when the crankshaft realizes two complete turns, namely 720 deg.

**[0005]** Two compression-decompression event strategies, for a complete cycle, are known to double the engine braking power. In this case the braking strategy enables a 2-stroke like engine behavior. Such strategies are currently not used due to their complexity in connection with the cam profiles.

### Summary of the invention

**[0006]** Therefore, it is the main object of the present invention to provide a system for easily implementing a 2-stroke braking strategy.

**[0007]** The present invention enables a 2-stroke-like engine braking in a simple and effective way.

**[0008]** A special exhaust lift profile in combination with a standard inlet profile is provided in order to realize a 2-stroke like engine braking in a 4-stroke engine.

**[0009]** In this context "standard" means that the cam profile commanding the inlet valves is completely unchanged with respect to the "fired" mode of the engine.

**[0010]** Therefore, thanks to the present invention, a compression-decompression event is carried out every crankshaft turn. In particular, a decompression event at each TDC.

**[0011]** According to a preferred embodiment of the present invention a braking strategy is carried out through the implementation of a cam shifting method, such as the "INA cam shifting method" Norbert Nitz, Harald Elendt, Arndt Ihlemann, Andreas Nendel, Schaeffler Symposium 2010.

**[0012]** The INA cam shifting method is based on a sleeve having at least two cam profiles. The sleeve is able to slide axially on a base shaft, while it is forced to rotate with the base shaft.

**[0013]** The cooperation of a control groove on the sleeve and an eccentric pin, supported by a rotating mandrel, which touches tangentially the control groove commands the axially sliding of the sleeve.

**[0014]** The method of the present invention comprises a step of providing the exhaust sleeve with two or more cam profiles on adjacent portions of the sleeve and a step of axially shifting said sleeve on said base shaft in order to enable a profile implementing two decompression events of a braking procedure.

**[0015]** The concept "adjacent portions" is clear in light of the abovementioned paper: several cam profiles are annularly defined on adjacent and consecutive portions of the sleeve along its longitudinal development.

**[0016]** According to another embodiment of the present invention the 2-stroke braking procedure is implemented by means of three-dimensional cams having different profiles according to an axial shifting of the cam itself on the base shaft. An example of such tridimensional cams is shown on EP0208663. Also the use of an axially shifting cam profile method in an engine braking procedure is part of the present invention. Preferably, such method is implemented in order to carry out an engine braking operation in heavy and commercial vehicles. These and further objects are achieved by means of the attached claims, which form an integral part of the present description.

### Brief description of the drawings

**[0017]** The invention will become fully clear from the following detailed description, given by way of a mere exemplifying and non limiting example, to be read with reference to the attached drawing figures, wherein:

- Fig. 1 shows a comparison between the four phases of a standard operating condition of a 4-stroke combustion engine and a braking condition according to the present invention;
- Fig. 2 shows a comparison between the same conditions of figure 1 according to the cam angle.

**[0018]** The same reference numerals and letters in the figures designate the same or functionally equivalent parts.

### Detailed description of the preferred embodiments

**[0019]** According to the present invention the control of the engine valves during a braking operation is carried out through at least one cam profile switched according to a cam shifting method, i.e., by axially shifting a sleeve on the base shaft in order to enable a different cam profile.

**[0020]** According to a preferred embodiment of the present invention for each complete cycle, i.e. for every 720 deg of the crankshaft, two decompression events are provided.

**[0021]** For a clear understanding of the invention, the first compression phase, during the braking procedure, coincides with the standard compression phase, i.e. when the engine is fired, even if during the braking procedure, the engine is obviously braked.

**[0022]** The first decompression event happens approximately at the TDC. It is preferable that the exhaust valves open slightly before the piston reaches the TDC, to release the pressure. According to the present invention the exhaust valves remain open - on the contrary with the respect to a standard (fired) valve behaviour - after said first decompression event in order to permit the same piston to suck air from the exhaust pipe.

**[0023]** During the second lifting phase of the piston, namely the fourth phase of a 4-stroke engine cycle, when the engine is fired, the exhaust valves are open in order to eject the exhaust gasses. On the contrary, according to the present invention, during the second lifting phase of an engine braking procedure, the exhaust valves are kept closed in order to carry out a second compression phase followed by a second decompression event.

**[0024]** It is clear that the cam lifting profile of the inlet valves is completely unchanged with respect to a standard cycle, i.e. a cycle in which the engine is fired.

**[0025]** Instead, according to the present invention, the exhaust valves are kept open during the second lowering phase of the piston, namely the third phase of a 4-stroke engine cycle, and closed during the second lifting phase (fourth phase of a 4-stroke engine cycle).

**[0026]** In other words, the first sucking phase is realized through the inlet valves, thus the inlet cam lifting profile is unchanged, while the second sucking phase is realized through the outlet valves, thus only the outlet cam lifting profile is varied.

**[0027]** Figure 1 shows a comparison, through the four phases of a 4-stroke engine, between a fired condition from F-I to F-IV, on the left of the figure, and a braking procedure from B-I to B-IV, on the right of the figure, according to the present invention.

**[0028]** F-I and B-I: first lowering of the piston for sucking fresh air from the inlet side. This phase is in common with both the conditions standard/braking, that is when the engine is fired and when it is in braking mode;

**[0029]** F-II and B-II: first lifting of the piston; during the braking procedure the fuel injection is inhibited and the second phase, B-II comprises the decompression event B-II'; F-III and B-III: second lowering of the piston: when the engine is fired both the inlet and outlet valves are closed; when the engine is in braking mode the exhaust valve is open, in order to carry out a second air sucking, but from the exhaust side;

**[0030]** F-IV and B-IV: when the engine is fired, during the fourth phase the exhaust gasses are ejected by the exhaust valves, instead during the braking procedure, the exhaust valves follow the same behaviour discussed during the second phase, that is a compression phase B-IV followed by decompression event B-IV'.

**[0031]** The decompression events are always commanded by the outlet cam/valve.

**[0032]** Also through this comparison it is clear that the behaviour of the inlet valves is completely unchanged through the four phases of both the cycles fired/braked.

**[0033]** Figure 2 shows a diagrammatic comparison of an exhaust cam profile between the two conditions standard (fired) and braked.

**[0034]** Such kind of diagrams is well known, therefore, its interpretation is immediately derivable by the figure 2 itself. The exhaust valves displacement, and thus the shape of the cam, can be varied according to the kind of combustion engine. Therefore, the lifting millimetres indicated on figure 2 should be considered as a non limitative example. The switching between the standard lifting profile and the braking profile, according to the present invention, is advantageously realised by an axially shifting cam profile. The adverb "axially" is well clear in this context, where it is clear that the shifting is operated on the base shaft of the cams.

**[0035]** With particular reference to figure 2, the dashed line refers to the braking profile, i.e. to the eccentricity of a portion of the sleeve defining the "braking profile".

**[0036]** These kinds of diagrams are clear and well known for the skilled person in the art.

**[0037]** During a braking procedure, the cam profile enabled is the dashed one on figure 2: it

- remains flat in the range -120 to -60 deg with a first value, substantially zero,
- increases its eccentricity in the range -60;-20 deg to a second value, substantially 1,8 mm, and
- remains flat in the range -20;30 with said second value, then
- increase its eccentricity until 70 deg, where a first peak is defined with a third value, substantially 5,2 mm, then
- decreases until 140 deg, returning to said first value, then
- increases its eccentricity in the range 140; 180 deg, where a second peak is defined, by reaching said second value, then
- decreases toward said first value at 220 deg. and
- assumes said first value until 240 deg, then the cycle restarts.

**[0038]** The continuous line of figure 2 shows a standard exhaust lift profile, adopted when the engine is fired. The just one peak is disposed substantially between said first and second peaks of the dashed curve.

**[0039]** By means of the present invention, it is possible to enable a 2-stroke braking strategy in a 4-stroke engine without changing the lifting control of the inlet valves.

**[0040]** Therefore, it is possible to double the engine braking power without implementing highly complex sys-

tems.

**[0041]** Many changes, modifications, variations and other uses and applications of the subject invention will become apparent to those skilled in the art after considering the specification and the accompanying drawings which disclose preferred embodiments thereof. All such changes, modifications, variations and other uses and applications which do not depart from the spirit and scope of the invention are deemed to be covered by this invention.

**[0042]** Further implementation details will not be described, as the man skilled in the art is able to carry out the invention starting from the teaching of the above description.

## Claims

1. Method for performing an engine braking procedure based on decompression events for a 4-stroke cycle engine, the engine comprising at least a cylinder having

   - an inlet pipe and an outlet pipe,
   - cylinder inlet and outlet valves and
   - control means for controlling said cylinder valves displacement;

   the method comprising a first compression phase (B-II) followed by a first decompression event (B-II') and, in succession,
   - a sucking phase (B-III) from the outlet pipe and
   - a second compression phase (B-IV) followed by a second decompression event (B-IV').

2. Method according to claim 1, further comprising a preliminary sucking phase (B-I) from the inlet pipe before said first compression phase (B-II).

3. Method according to one of the preceding claims, wherein the control means comprise a base shaft on which is fixed a sleeve with a cam profile, the method comprising a step of providing said sleeve with two or more cam profiles on adjacent portions of the sleeve and a step of axially shifting said sleeve on said base shaft in order to enable a profile implementing said decompression events (B-II', B-IV') of the braking procedure.

4. Method according to claims 1 or 2, wherein the control means comprise a base shaft on which is fixed a sleeve with a three-dimensional cam profile, the method comprising a step of axially shifting said sleeve on said base shaft in order to enable a profile implementing said decompression events (B-II', B-IV') of the braking procedure.

5. Device for performing an engine braking procedure based on decompression events for a 4-stroke cycle engine, the engine comprising at least a cylinder having

   - an inlet pipe and an outlet pipe,
   - cylinder inlet and outlet valves and
   - control means for controlling said cylinder valves displacement;

   the device control means configured to perform all the steps of any of the previous claims.

6. Device according to claim 5, wherein said means for controlling said cylinder valves by implementing said two decompression events (B-II', B-IV'), is according to the "2-stroke braking lift" curve of the diagram of figure 2.

7. Device according to claim 6, wherein said profile, implementing said at least one decompression events (B-II', B-IV') of a braking procedure

   - remains flat in the range -120 to -60 deg with a first value,
   - increases its eccentricity in the range -60;-20 deg,
   - remains flat in the range -20;30 with a second value,
   - increases its eccentricity until 70 deg, where a first peak is defined with a third value, then
   - decreases until 140 deg, returning to said first value,
   - increases its eccentricity in the range 140; 180 deg, where a second peak is defined with said second value, then
   - decreases toward said first value at 220 deg.

8. Device according to any of the preceding claims form 5 to 7, wherein a second exhaust lifting cam profile is suitable to operate the cylinder exhaust valve during a fired operating condition of the engine.

9. Device according to claim 8, wherein said second exhaust lifting cam profile has only one third peak disposed substantially between said first and second peaks.

10. 4-stroke cycle combustion engine comprising at least a cylinder having

    - an inlet pipe and an outlet pipe,
    - cylinder inlet and outlet valves and
    - control means for controlling said cylinder valves;

    and **characterized in** comprising the device for performing an engine braking procedure according to one of the claims 5 to 9.

11. Terrestrial Vehicle **characterised in** comprising a combustion engine according to claim 10.

**12.** Use of a cam shifting system for enabling a 2-stroke braking procedure.

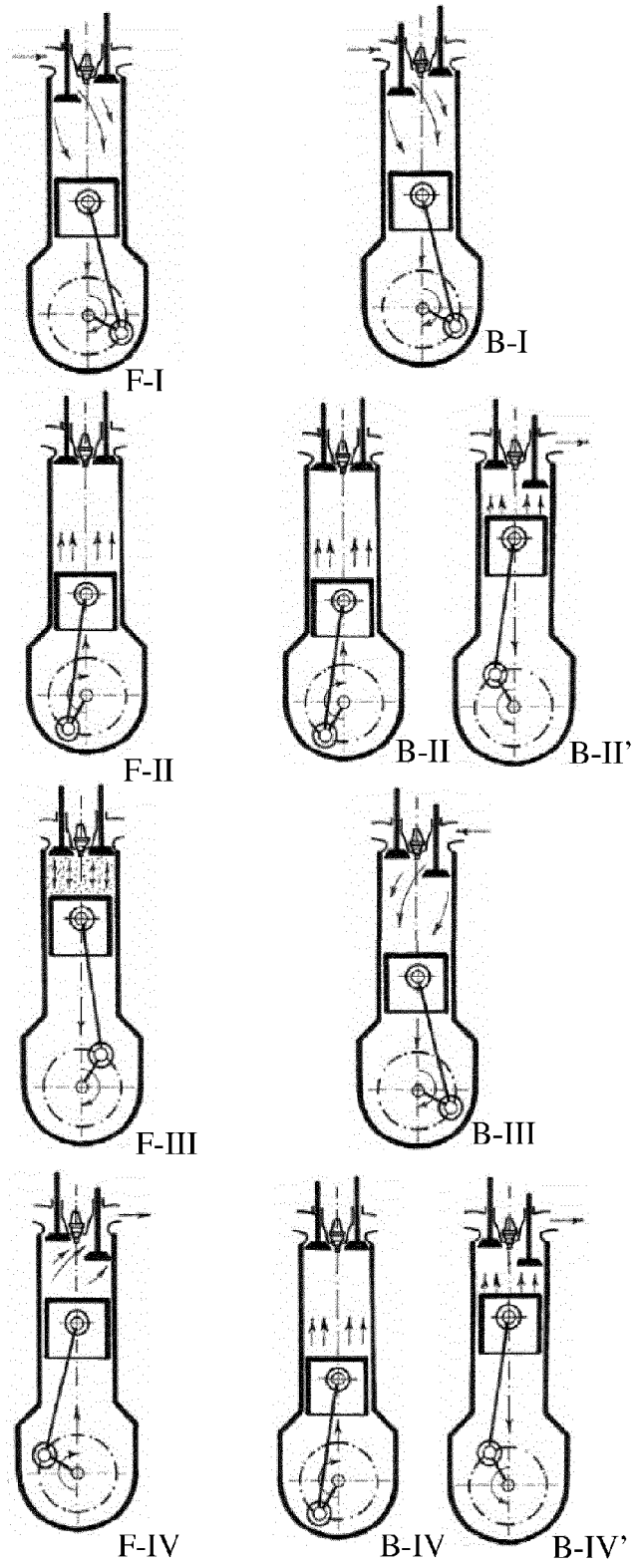


Fig. 1

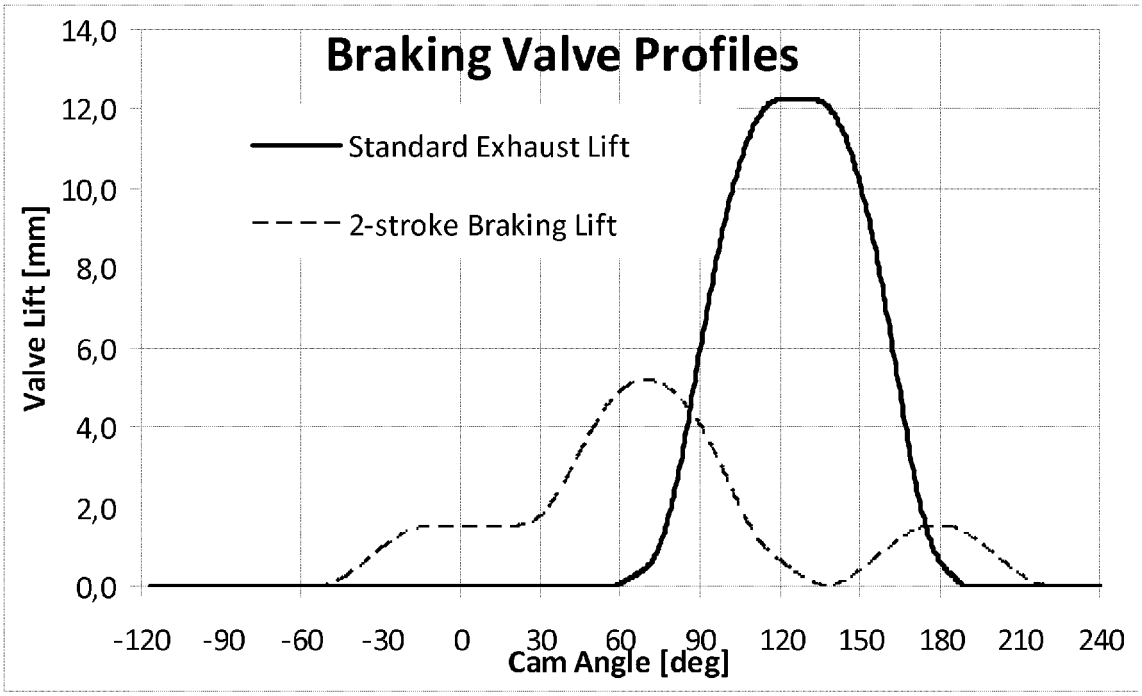
Braking Valve Profiles
Standard Exhaust Lift
2-stroke Braking Lift
Valve Lift [mm]
14,0
12,0
10,0
8,0
6,0
4,0
2,0
0,0
-120
-90
-60
-30
0
30
60
90
120
150
180
210
240
Cam Angle [deg]

Fig. 2

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Application Number
EP 13 16 9302

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The present search report has been drawn up for all claims

| Place of search | Date of completion of the search | Examiner |
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