(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 136 688 A2

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
26.09.2001 Bulletin 2001/39

(51) Int Cl.7: **F02M 25/07**

(21) Application number: **01104948.3**

(22) Date of filing: **28.02.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **22.03.2000 LU 90551**

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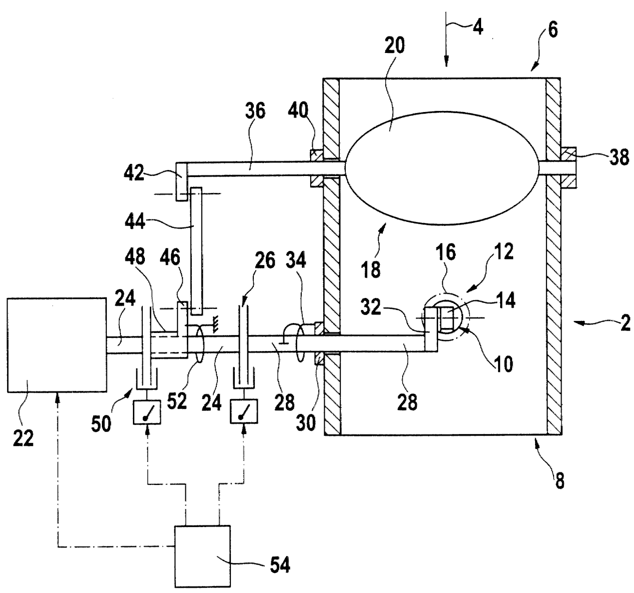
(54) Exhaust gas re-circulation device for an internal combustion engine

(57) An exhaust gas re-circulation device for an internal combustion engine comprises an intake air channel (2), an intake air control valve (18), an exhaust gas re-circulation valve (12) and an actuator (22), a first motion transmission mechanism between the actuator (22) and the exhaust gas re-circulation valve (12) and a second motion transmission mechanism between the actuator (22) and the intake air control valve (18). A first uncoupling means (26) is included in the first motion transmission mechanism and a first pull-back spring (34) biases the exhaust gas re-circulation valve (12) in a closed position. The device enables to control exhaust gas re-circulation rates by simultaneously driving the two valves in opposite senses and to obtain a smooth engine shut-off, by simultaneously closing the two valves. In a preferred embodiment, with a second uncoupling means (50) in the second motion transmission mechanism and a second pull-back spring (52) biasing the intake air control valve (18) in an open position, low exhaust gas re-circulation rates can be controlled with the intake air control valve (18) fully open.



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Description

Field of the invention

[0001] The present invention relates to an exhaust gas re-circulation device for an internal combustion engine.

Background of the invention

[0002] In order to reduce NOx emission of internal combustion engines, it is known to re-circulate oxygen depleted exhaust gases from the engine exhaust in the engine intake air. A device for exhaust gas re-circulation generally includes an intake air tube, an intake air control valve and an exhaust gas re-circulation valve. The intake air control valve allows to throttle the intake air flow in the intake air tube. The exhaust gas re-circulation valve meters the flow of exhaust gases re-circulated into the intake air tube.

[0003] Stringent exhaust emission requirements make it necessary to carefully control the proportion of re-circulated exhaust gas into the intake air. Thus, the proportion of re-circulated exhaust gas must at all load levels be sufficient to respect NOx emission limits. However, if the proportion of re-circulated exhaust gas becomes too high, the engine may — due to a lack of oxygen — stop at low load levels or cause undesirable emissions at high load levels. There is consequently a need for an efficient control of the exhaust gas re-circulation device at all load levels.

[0004] It is known to equip the exhaust gas re-circulation valve and the intake air control valve with rotational electric actuators or with linear actuators, such as pneumatic actuators or solenoids, controlled by an engine control module. In such a device low/medium exhaust gas re-circulation rates are controlled by commanding the actuator of the exhaust gas re-circulation valve only; whereas higher exhaust gas re-circulation rates are controlled by commanding the actuator of the exhaust gas re-circulation valve and the actuator of the intake air control valve simultaneously. Fully closing the intake air control valve and exhaust gas re-circulation valve further enables to achieve a smooth engine shut-off. Thus, an efficient control of exhaust gas re-circulation should be possible at all load levels. In practice however, such an exhaust gas re-circulation device still has serious deficiencies. For example, as both valves, i.e. the exhaust gas re-circulation valve and the intake air control valve, influence the intake air flow, it is necessary to detect which valve is responsible for a measured deviation of a control parameter. Furthermore, the actuators of the two valves are generally of different types, having inter alia different hysteresis errors, which can result in accuracy problems if both valves are to be operated synchronously.

[0005] Some of these deficiencies could — at least partially — be compensated by more complex control systems, using for example two sensors, i.e. one for the intake air and one for the re-circulated exhaust gases. It will however be appreciated that component costs are important considerations in automotive vehicle applications. Furthermore, an exhaust gas re-circulation device that is more compact in size can be of advantage, because of limitations on available space in a vehicle engine compartment. Weight reductions of components of course help to reduce fuel consumption of the vehicle. Thus it would be desirable to produce compact and cost-effective exhaust gas re-circulation devices.

[0006] EP 0900930 discloses a compact and cost-effective exhaust gas re-circulation device with an exhaust gas re-circulation valve and a flap valve or strangler that fulfils the function of an intake air control valve. This device comprises one single actuator, which is connected to the actuation shaft of the exhaust gas re-circulation valve. An eccentric on the action shaft drives (i. e. closes) the intake air control valve when the exhaust gas re-circulation valve overruns a certain opening position. This mechanism allows to control low/medium exhaust gas re-circulation rates by driving the exhaust gas re-circulation valve only, the intake air control valve being fully open, and high rate exhaust gas re-circulation rates by driving both the exhaust gas re-circulation valve and the intake air control valve synchronously (the intake air control valve closes when the exhaust gas re-circulation-valve further opens). This rather simple and compact device does of course not provide the same flexibility than a device with two separate actuators separately controlled. Thus it is for example not possible to fully close the intake air control valve and exhaust gas re-circulation valve to achieve a smooth engine shut-off.

Object of the invention

[0007] The technical problem underlying the present invention is to provide a compact exhaust gas re-circulation device for an internal combustion engine, which allows an efficient and simple control of exhaust gas re-circulation rates and a smooth engine shut-off. This problem is solved by a device as claimed in claim 1.

Summary of the invention

[0008] An exhaust gas re-circulation device in accordance with the invention comprises an intake air channel, an intake air control valve, which is associated with the intake air channel, an exhaust gas re-circulation valve, for re-circulating a controlled amount of engine exhaust gases into the intake air channel, and an actuator. A first motion transmission mechanism is connected between the actuator and the exhaust gas re-circulation valve. A second motion transmission mechanism is connected between the same actuator and the intake air control valve. In accordance with an important aspect of the present invention, the first motion transmission mechanism includes a first uncoupling means, and a first pull-back spring biases the exhaust gas re-circulation valve in a closed position. It will be appreciated that this device, which has only one single actuator, enables:

(1) to open the exhaust gas re-circulation valve and simultaneously close the intake air control valve to progressively increase exhaust gas re-circulation rates, wherein the exhaust gas re-circulation valve is coupled to the first motion transmission mechanism and the actuator is driven in a first sense;
(2) to close the exhaust gas re-circulation valve and simultaneously open the intake air control valve to progressively decrease exhaust gas re-circulation rates, wherein the exhaust gas re-circulation valve is coupled to the first motion transmission mechanism and the actuator is driven in the opposite sense;
(3) to simultaneously close the two valves, in order to obtain a smooth engine shut-off, wherein the exhaust gas re-circulation valve is now uncoupled from the first motion transmission mechanism and it is closed by the first pull-back spring; and
(4) to achieve intake air control with the 0% exhaust gas re-circulation, wherein the exhaust gas re-circulation valve is uncoupled from the first motion transmission mechanism and is maintained in its closed position by the first pull-back spring.

[0009] It will be appreciated that all these functions can be achieved with a single actuator. Due to the absence of a second actuator, the device has a reduced weight and size and can be manufactured at lower costs. Furthermore, as the two valves are — during exhaust gas re-circulation control — simultaneously operated by a common actuator, the synchronous control of the two valves is simpler.

[0010] In a preferred embodiment, a second uncoupling means is included in the second motion transmission mechanism and a second pull-back spring biases the intake air control valve in an open position. With this preferred embodiment it becomes possible to control low exhaust gas re-circulation rates exclusively with the exhaust gas re-circulation valve, wherein the intake air control valve is uncoupled from the second motion transmission mechanism and is maintained in its open position by the second pull-back spring.

[0011] The above embodiment is typical for a Diesel engine. In case of a gasoline engine, a second pull-back spring will normally be used to bias the intake air control valve in a closed position.

[0012] Normally the actuator includes a drive shaft, the first motion transmission mechanism includes a first actuating shaft connected to the exhaust gas re-circulation valve, and the second motion transmission mechanism includes a second actuating shaft connected to the intake air control valve.

[0013] In accordance with a first embodiment, the first uncoupling means connects the drive shaft of the actuator directly to the first actuating shaft, whereas the second motion transmission mechanism includes an actuating lever on the second actuating shaft, a free running sleeve with a crank arm mounted on the drive shaft and a connecting rod connecting this actuating lever to this crank arm. In this first embodiment, the second uncoupling means is used to connect the drive shaft to the free running sleeve. The first pull-back spring is then associated with the first actuating shaft; and the second pull-back spring is associated with the free running sleeve.

[0014] In accordance with an alternative embodiment, the second uncoupling means connects the drive shaft of the actuator directly to the second actuating shaft, whereas the first motion transmission mechanism includes an actuating lever on the first actuating shaft, a free running sleeve with a crank arm mounted on the drive shaft and a connecting rod connecting this actuating lever to this crank arm. In this alternative embodiment, the first uncoupling means is used to connect the drive shaft to the free running sleeve. The second pull-back spring is then associated with the second actuating shaft; and the first pull-back spring is associated with the free running sleeve.

[0015] A suitable air control valve normally includes a flap mounted on the second actuating shaft, which is pivotably mounted in the intake air channel. A suitable exhaust gas re-circulation valve normally includes an obturating body and an axially guided actuating stem. The first actuating shaft then includes a crank arm connected to the actuating stem.

[0016] The first and/or second uncoupling means preferably include an electrically switchable clutch, which can be easily controlled by means of an electronic control system. Hence, the control of the exhaust gas re-circulation device becomes much more flexible, in comparison with a device with a mechanically controlled uncoupling means, using for example a cam means to set the uncoupling point.

[0017] The common actuator is advantageously an electrical torque motor. Such a motor has a small packaging size for a high output torque and is rather insensitive to orientation. It is capable of producing a constant torque over a wide angular range, wherein this output torque can be increased by simply increasing the current.

[0018] The first and/or second pull back spring are advantageously torsion springs, which have a small packaging size when associated e.g. with the actuating shafts of the two valves.

Brief description of the drawings

[0019] The present invention will now be described, by way of example, with reference to the accompanying drawing, in which:

Fig. 1: is a diagrammatic view of a preferred embodiment of an exhaust gas re-circulation

device in accordance with the invention.

Detailed description of a preferred embodiment

[0020] In Fig.1 reference number 2 globally identifies a portion of an intake air tube of an internal combustion engine (not shown). The direction of air flow is shown by arrow 4. The upstream-end 6 of the tube 2 is connected, for example via an air cleaner (not shown), to the atmosphere or, in case of an engine with a turbocharger, to a compressor (not shown). The downstream-end 8 of the tube 2 is connected to an intake air manifold of the engine (not shown).

[0021] Via an intermediate opening 10, the intake air tube 2 communicates with an exhaust gas duct (not shown) of the engine. Associated with this opening 10 is an exhaust gas re-circulation valve 12, which allows to meter exhaust gas flow through the opening 10. This valve 12 comprises an actuating stem 14, which is guided in the opening 10 by a valve guide (not shown), and an obturating disk 16 (shown by a dotted line), which is associated with a valve seat located in the exhaust gas duct upstream of the opening 10. The obturating disk 16 can be pulled by means of its actuating stem 14 against its seat, so as to close the opening 10 gastightly, and be pushed from its seat, so that exhaust gases can flow through the opening 10 into the intake air tube 2.

[0022] Upstream of the opening 10 is arranged a flap valve, the so called intake air control valve 18, which allows to meter intake air flow. When intake air control valve 18 is in an entirely open position, a flap 20 is substantially parallel to the central axis of the intake air tube 2, thus offering a minimum resistance to air flow. This flap 20 is designed to provide, in the closed position of the intake air control valve 18, a substantially airtight sealing of the inlet section of the tube 2.

[0023] The actuation mechanism of the exhaust gas re-circulation valve 12 and the intake air control valve 18 will now be described in detail. This actuation mechanism comprises one single reversible actuator 22 which drives a main drive shaft 24. The actuator 22 is advantageously an electric rotary motor, as for example a torque motor. If a linear motor is preferred as actuator, it will for example be possible to use a solenoid or a pneumatic actuator. A beam-and-crank mechanism or a rack-and-pinion gear may then be used for transforming the linear movement of the actuator into a rotational movement of the main drive shaft 24.

[0024] A first motion transmission mechanism is connected between the main drive shaft 24 and the exhaust gas re-circulation valve 12. This first motion transmission mechanism includes a first uncoupling means 26 that connects the main drive shaft 24 to an actuating shaft 28, which penetrates into the tube 2 through a gastight bearing 30. Inside of the tube 2, the actuating shaft 28 has a crank arm 32, which is connected by means of an articulation to the actuating stem 14 of the exhaust gas re-circulation valve 12. Outside of the tube 2, a torsion spring 34 is associated as a pull-back spring with the actuating shaft 28, so as to bias the exhaust gas re-circulation valve 12 in a closed position. In other words, the spring 34 urges the obturating disk 16 of the exhaust gas re-circulation valve 12 in the direction of its seat, so as to close the exhaust gas re-circulation valve 12 if the actuating shaft 28 is uncoupled from the main drive shaft 24 by means of the uncoupling device 26.

[0025] A second motion transmission mechanism is connected between the main drive shaft 24 and the intake air control valve 18. The latter has an actuating shaft 36 which is pivotably supported by two gastight bearings 38, 40. Outside of the tube 2, the actuating shaft 36 has a lever arm 42, which is connected by means of an articulated connecting rod 44 to a crank arm 46, which is integral with a free running sleeve 48 mounted on the drive shaft 24. A second uncoupling means 50 connects this free running sleeve 48 to the drive shaft 24. A torsion spring 52 is associated as a pull-back spring with the free running sleeve 48. This spring 52 urges the second motion transmission mechanism in a position defined by an end-stop, in which the flap 20 is substantially parallel to the central axis of the air intake channel. In other words, the spring 52 opens the intake air control valve 18 if the free running sleeve 48 is uncoupled from the main drive shaft 24 by means of the uncoupling device 50.

[0026] It will be noted that the uncoupling means 26 and 50 are advantageously electrically switchable clutches. Engagement and disengagement of such electrically switchable clutches can be easily controlled by an electronic controller 54, which is also responsible for starting, stopping and reversing the sense of rotation of the actuator 22.

[0027] It will further be noted that a damper (not shown), can be associated with each of the springs 34, 52, so as to be capable of obtaining a damped closing movement of the valves 12, 18.

[0028] The operation possibilities of the above described gas re-circulation device can be summarised as follows.

[0029] In the idle position, the exhaust gas re-circulation valve 12 is entirely closed, i.e. the obturating disk 16 sits on its seat and closes the opening 10 gastightly. The intake air control valve 18 is entirely open, i.e. the flap 20 is substantially parallel to the central axis of the intake air tube 2, thus offering a minimum resistance to air flow. It will be appreciated that this idle position can be obtained with both clutches 26, 50 being disengaged.

[0030] Low exhaust gas re-circulation rates are preferably controlled with the intake air control valve 18 fully open. The clutch 50 remains therefore disengaged, but the clutch 26 is engaged. The exhaust gas re-circulation valve 12 may now be progressively opened by rotating the actuator 22 in a first sense. If the exhaust gas re-circulation rate has to be reduced again, the sense of rotation of the actuator 22 is simply reversed. In conclusion, low exhaust gas re-circulation rates are exclusively controlled by metering the flow of exhaust gases through the opening 18.

[0031] In order to obtain and control high exhaust gas re-circulation rates, the intake air control valve 18 has to be progressively closed. This is achieved by engaging the clutch 50. Rotating the actuator 22 in a first sense now closes the intake air control valve 18 and continues to open the exhaust gas re-circulation valve 12, so as to progressively increase exhaust gas re-circulation rates. In order to progressively decrease exhaust gas re-circulation rates, the sense of rotation of the actuator 22 is simply reversed, whereby the intake air control valve 18 progressively opens and the exhaust gas re-circulation valve 12 progressively closes again.

[0032] If a smooth engine shut-off has to be obtained, the clutch 26 is disengaged, so that the spring 34 closes the exhaust gas re-circulation valve 12. The clutch 50 is engaged, so that the actuator 22 can progressively close the intake air control valve 18.

[0033] It will be appreciated that a return to the idle position can be obtained by simply disengaging both clutches 26 and 50. In other words, the actuator 22 must not be operated in order to return to the idle position, when the engine is shut-off.

[0034] It will further be appreciated that air control with 0% exhaust gas re-circulation can be obtained by disengaging the clutch 26, whereas the clutch 50 is engaged.

[0035] In the embodiment described above, the idle position is characterised in that the exhaust gas re-circulation valve is in the fully closed position and the intake air control valve is in the fully open position. This is typical for a Diesel engine. For a gasoline engine however, the idle position will generally be characterised in that the exhaust gas re-circulation valve and the air intake control valve are both in the closed position. In such a gasoline engine the air intake control valve must then be opened in advance of the exhaust gas re-circulation valve, using the actuator 22 with the clutch 50 engaged and the clutch 26 disengaged.

[0036] In the embodiment described above, the actuator 22 is aligned with the actuating shaft 28 of the exhaust gas re-circulation valve 12. Alternatively, the actuator 22 could also be aligned with the actuating shaft 36 of the intake air control valve 18. In this case, a clutch should be used to connect the main drive shaft 24 directly to the actuating shaft 36. The first motion transmission mechanism would then include an actuating lever on the actuating shaft 28, a free running sleeve with a crank arm mounted on the drive shaft 24 and a connecting rod connecting said actuating lever to said crank arm, and a further clutch would be used to connect the drive shaft 24 to the free running sleeve.

Claims

1. Exhaust gas re-circulation device for an internal combustion engine comprising:

an intake air channel (2);

an intake air control valve (18) associated with said intake air channel (2); and

an exhaust gas re-circulation valve (12) for re-circulating a controlled amount of engine exhaust gases into said intake air channel (2);

an actuator (22);

a first motion transmission mechanism connected between said actuator (22) and said exhaust gas re-circulation valve (12);

a second motion transmission mechanism connected between said actuator (22) and said intake air control valve (18);

characterised by

a first uncoupling means (26) included in said first motion transmission mechanism; and

a first pull-back spring (34) biasing said exhaust gas re-circulation valve (12) in a closed position.

2. Exhaust gas re-circulation device as claimed in claim 1, **characterised by**

a second uncoupling means (50) included in said second motion transmission mechanism; and

a second pull-back spring (52) biasing said intake air control valve (18) in an open position.

3. Exhaust gas re-circulation device as claimed in claim 1, **characterised by**
a second pull-back spring (52) biasing said intake air control valve (18) in a closed position.

4. Exhaust gas re-circulation device as claimed in claim 2 or 3, **characterised in that**:

said actuator (22) includes a drive shaft (24);

said first motion transmission mechanism includes a first actuating shaft (28) connected to the exhaust gas re-circulation valve (12); and

said second motion transmission mechanism includes a second actuating shaft (36) connected to said intake air control valve (18).

5. Exhaust gas re-circulation device as claimed in claim 4, characterised:

in that said first uncoupling means (26) connects said drive shaft (24) directly to said first actuating shaft (28); and

in that said second motion transmission mechanism includes:

an actuating lever (42) on said second actuating shaft (36);

a free running sleeve (48) with a crank arm (46) mounted on said drive shaft (24);

a connecting rod (44) connecting said actuating lever (42) to said crank

arm (46); and

in that said second uncoupling means (50) connects said drive shaft (24) to said free running sleeve (48).

6. Exhaust gas re-circulation device as claimed in claim 5, **characterised in that**:

said first pull-back spring (34) is associated with said first actuating shaft
(28); and
said second pull-back spring (52) is associated with said free running sleeve (48).

7. Exhaust gas re-circulation device as claimed in claim 4, characterised:

in that said second uncoupling means (50) connects said drive shaft (24) directly to said second actuating shaft (36); and

in that said first motion transmission mechanism includes:

an actuating lever on said first actuating shaft (28);

a free running sleeve with a crank arm mounted on said drive shaft (24);

a connecting rod connecting said actuating lever to said crank arm; and in that said first uncoupling means (26) connects said drive shaft (24) to said free running sleeve.

8. Exhaust gas re-circulation device as claimed in claim 7, **characterised in that**:

said second pull-back spring is associated with said second actuating shaft (36); and

said first pull-back spring is associated with said free running sleeve.

9. Exhaust gas re-circulation device as claimed in any one of claims 4 to 8,
characterised in that said air control valve (18) includes a flap (20) mounted on said second actuating shaft (36), which is pivotably mounted in said intake air channel (2).

10. Exhaust gas re-circulation device as claimed in any one of claims 4 to 9,
characterised in that

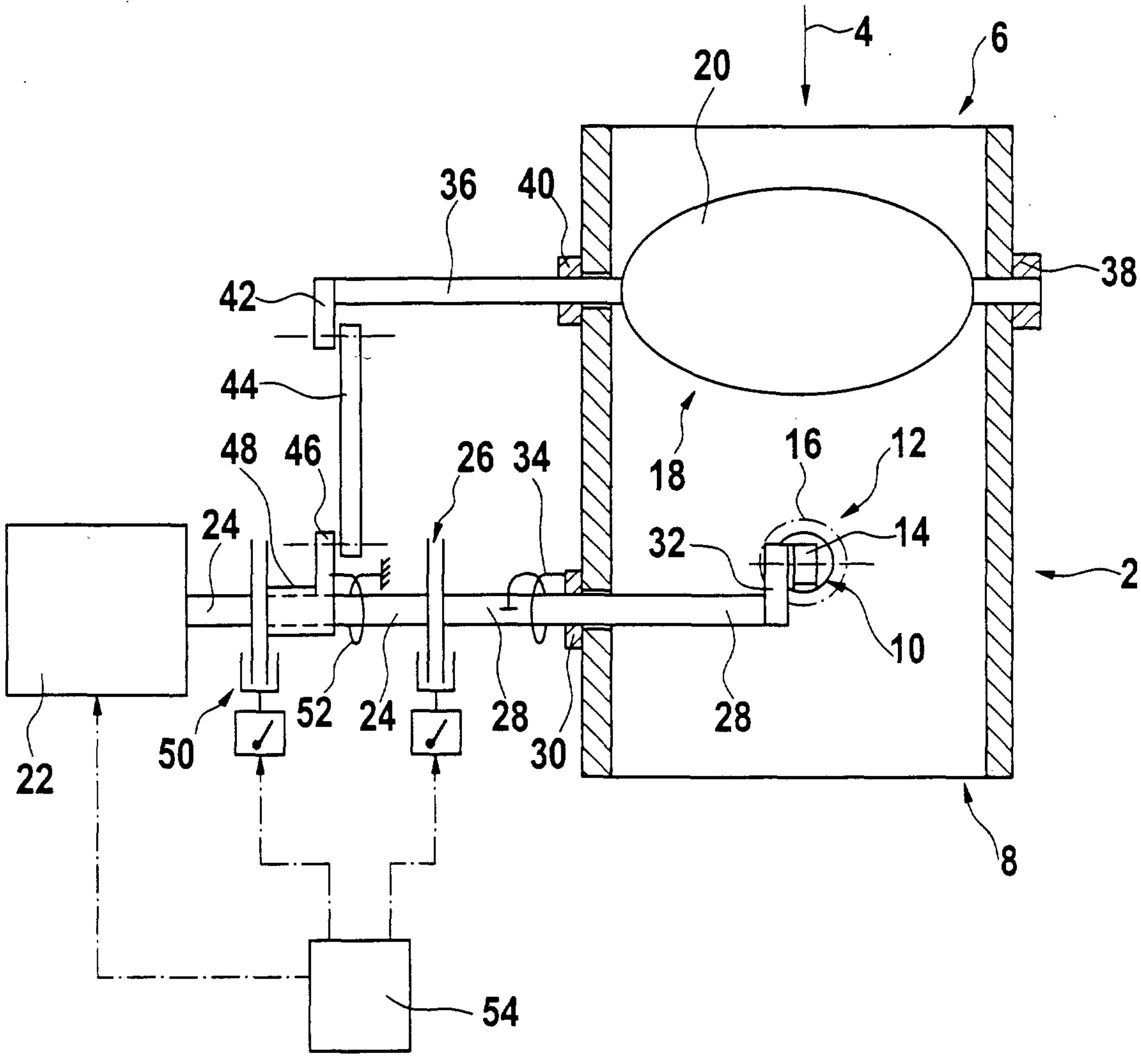
said exhaust gas re-circulation valve (12) includes an obturating body (16) and an axially guided actuating stem (14); and

said first actuating shaft (28) includes a crank arm (32) connected to said actuating stem (14).

11. Exhaust gas re-circulation device as claimed in any one of claims 1 to 10,
characterised in that said first and/or second uncoupling means (26, 50) comprises an electrically switchable clutch.

12. Exhaust gas re-circulation device as claimed in any one of claims 1 to 11,
characterised in that said actuator (22) is an electrical torque motor.

13. Exhaust gas re-circulation device as claimed in any one of claims 1 to 12,
characterised in that said first and/or second pull back spring (34, 52) are torsion springs.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