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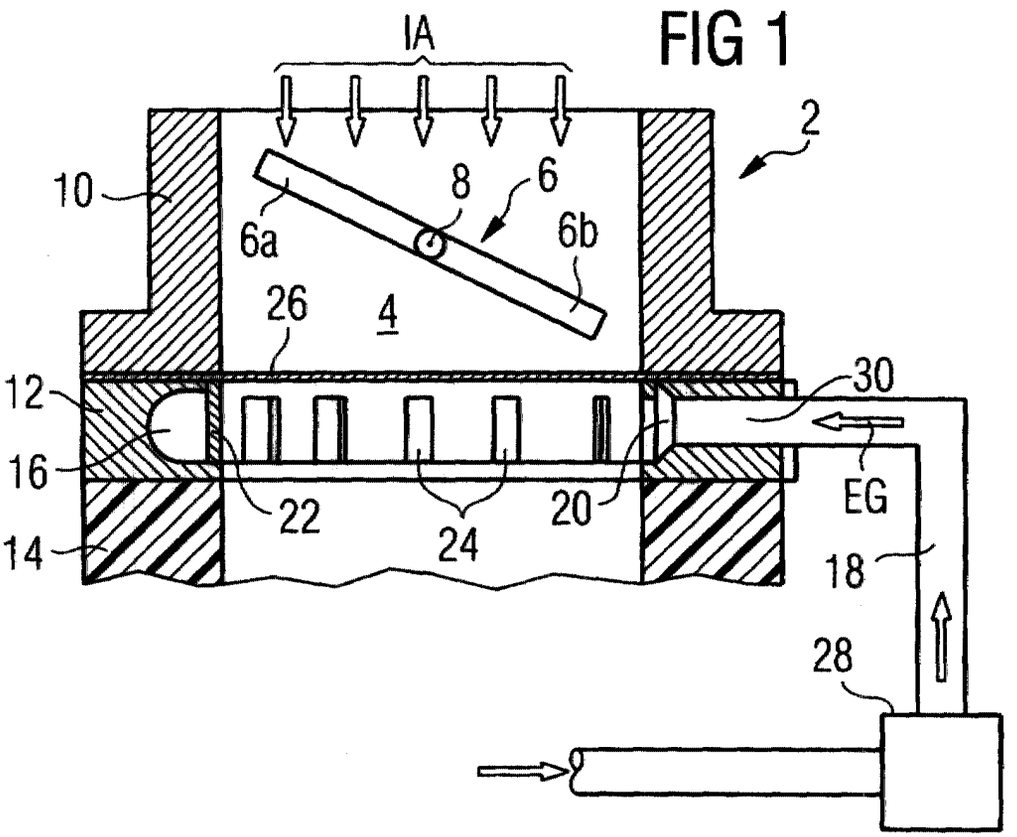
(54) Method and apparatus for recirculating exhaust gas into an inlet air stream

(57) A method and an apparatus for recirculating exhaust gas into an intake passage (4) of an internal combustion engine. More exhaust gas is introduced into the intake passage (4) on its one side than on its opposite side in order to enable to introduce the exhaust gas as close as possible to the throttle blade (6) without being entrained in any air recirculation zone downstream of the throttle blade (6).

FIG 1



EP 1 152 141 A1

Description

Field of the Invention

[0001] This invention relates to a method and an apparatus for recirculating exhaust gas into inlet air flowing through an intake passage of an internal combustion engine.

Background of the Invention

[0002] A conventional air intake and exhaust gas recirculation assembly comprises a housing including an intake passage for inlet air, a throttle valve including a throttle blade arranged in the intake passage so as to be rotatable about a pivot axis between opening and closing positions, and an exhaust gas recirculation conduit communicating with said intake passage downstream of the throttle valve so as to introduce exhaust gas into the inlet air flowing through the intake passage.

[0003] There are a number of problems related to such an air intake and exhaust gas recirculation assembly:

The exhaust gas should be introduced into the inlet airstream so as to be evenly distributed to every engine cylinder. When using a single entry point in the inlet system between the throttle body and the inlet ports at the cylinder head it is very important to provide good mixing of the exhaust gas with the inlet air.

The exhaust gas contains many products of the combustion process and residual substances carried away from the combustion chamber during the exhaust process. Such components of the exhaust gas are known to cause deposit build-up on the throttle body surfaces with which they come in contact. Deposits on the throttle body represent a serious concern in that they may cause the throttle blade to stick. For electronically controlled throttle valves deposits cause a serious problem also in that they may block the airflow past the throttle blade in the limp home mode. For engine safety concepts this is a serious problem.

[0004] During cold ambient operation of the internal combustion engine it is possible that ice can form on the throttle body. Ice forms where there is sufficient moisture in the inlet air to condensate on cold surfaces and then to change to ice. Ice formation influences the airflow through the intake passage in a similar way to deposits and therefore affects the operation of the engine severely. Icing of the throttle body occurs when the throttle body surfaces are cold and sufficient moisture is present in the inlet air. Inside the inlet manifold moisture comes from both the exhaust gas and blow-by gas from the crank case.

[0005] When the inlet manifold downstream of the throttle body is made of plastic material, it is necessary to manage the thermal inputs so as to avoid damage of the plastic material. The introduction of exhaust gas into the inlet airstream poses a difficult problem in that gases may be introduced at a temperature above the temperature allowable for the plastic material. In order to avoid deposit build-up in the exhaust gas recirculation circuit it is necessary to maintain a gas temperature above 350°C. Most plastic manifolds have an operating limit of about 170°C. So the exhaust gas should be introduced in such a way that it does not cause any damage to the plastic inlet manifold.

[0006] The following patent publications which attempt to solve at least certain of the above described problems have become known:

[0007] EP 0 881 378 A3 describes a method of introducing exhaust gas in such a way that it is drawn into the inlet manifold downstream of the throttle body through tangential openings. The tangential introduction results in a spiral motion of the entering gas which is said to facilitate good mixing with the inlet air.

[0008] US-A-4 697 569 describes a method of introducing exhaust gas at the throttle body through semicircular annular openings to facilitate good mixing with the inlet air.

[0009] US-A-4 461 150 describes a method of introducing exhaust gas into the inlet manifold downstream of the throttle body through a number of symmetrically arranged angled inlets so as to produce a spiral gas flow into the inlet manifold. Similar as in the above mentioned EP 0 881 378 such spiral gas flow is said to provide for good mixing of the inlet air and the exhaust gas. Furthermore, such spiral gas flow is intended to prevent the exhaust gas from contacting the throttle body. To this end the exhaust gas is fed into a region downstream of the throttle blade so as not to get entrained into the backflow air region formed in the wake of the throttle blade.

[0010] DE 4 420 247 A1 describes a method of introducing exhaust gas into the inlet manifold downstream of the throttle body through a plurality of openings arranged in a circular symmetrical pattern about the axis of the intake passage. This patent discloses also another embodiment wherein the plurality of openings is replaced by a single annular opening. The intake passage includes a venturi section at the area into which the exhaust gas is introduced by the openings. Such a venturi section will create higher inlet air velocity which may improve the mixing of inlet air and recirculated exhaust gas. Furthermore, this patent talks about a thermal insulation between the throttle body and the plastic inlet manifold to prevent damage to the plastic manifold.

Summary of the Invention

[0011] It is a primary object of this invention to provide for good mixing of the inlet air and the recirculated exhaust gas while minimizing deposit build-up and ice for-

mation on the surfaces of the intake passage and throttle valve.

[0012] The invention solving this problem has been defined in patent claims 1 and 5.

[0013] According to the method and apparatus of the present invention more exhaust gas is introduced into the intake passage on its side adjacent the upstream opening blade section of the throttle blade than on its side adjacent the downstream opening blade section.

[0014] The inventor has recognized that air recirculation zones resulting from air flow around the throttle blade are not symmetrical with respect to the axis of the intake passage due to the angular positions of the throttle blade. Actually, more of the air recirculation zone extends on the side adjacent the downstream opening blade section of the throttle blade than on the other side. Directing more exhaust gas towards the upstream opening blade section side rather than towards the other side allows to introduce the exhaust gas into the intake passage very close to the throttle blade without the exhaust gas being entrained into the air recirculation zone.

[0015] Preferably, the exhaust gas is introduced into the intake passage close to the throttle blade at a location where the inlet air is free flowing and has been accelerated due to the cross-sectional area of the intake passage being restricted by the throttle blade. Furthermore, it is preferred that the exhaust gas is introduced into the intake passage so as to flow substantially only in radial and axial directions, i.e. not in a circumferential direction to avoid spiral flow thereof.

[0016] The present invention provides for good mixing of the inlet air and the recirculated exhaust gas because the entry point for the exhaust gas can be disposed very close to the throttle valve so that the gases have the longest possible time to mix. A further benefit of the exhaust gas entry point being close to the throttle valve is the heating of the housing at an area close to the throttle valve. This should help to prevent ice formation on the surfaces of the intake passage and the throttle valve. Furthermore, as a result of the mixing time being maximized, the heat of the exhaust gas is diluted well before it reaches the interior surfaces of an inlet manifold downstream of the throttle valve. So the manifold even if it is made of plastic material will not be damaged by the hot exhaust gas.

[0017] Due to the asymmetrical distribution of the exhaust gas flow pattern in the intake passage the exhaust gas can be prevented from being entrained into the air recirculation zone even though the exhaust gas is introduced into the intake passage very close to the throttle blade. As a result thereof the exhaust gas is prevented from contacting the interior surfaces of the intake passage and the throttle blade so that deposit formation in these areas is minimized. Another advantage thereof is that no moisture contained in the exhaust gas is recirculated within the intake passage and to the throttle blade to prevent ice formation on the surfaces of the intake passage and the throttle blade.

[0018] To summarize, the present invention allows to prevent deposit and ice formation and at the same time to provide for good mixing.

[0019] Further developments and modifications of the invention are defined in the dependent patent claims.

Brief Description of the Drawings

[0020] These and other objects, features and advantages of this invention will be apparent from the following detailed description of the preferred embodiment and best mode, appended claims and accompanying drawings, in which:

Fig. 1 is a schematic sectional view of an air intake and exhaust gas recirculation assembly;

Fig. 2 is a plan view of an annular member in the assembly of Fig. 1;

Fig. 3 is an end view of the annular member in Fig. 2;

Fig. 4 is a schematic sketch to illustrate the flow pattern in the assembly of Fig. 1 during different operating conditions;

Fig. 5 is a schematic sketch to illustrate the asymmetrical distribution of exhaust gas introduced into the intake passage.

Detailed Description of the Preferred Embodiment

[0021] Referring to Fig. 1, the air intake and exhaust gas recirculation assembly shown therein comprises a housing 2 including an intake passage 4 for feeding inlet air IA towards a plurality of cylinders of an internal combustion engine (not shown). A throttle valve has a throttle blade 6 which is disposed within the intake passage 4 so as to be rotatable about a pivot axis 8 between opening and closing positions. The throttle blade 6 has blade sections 6a and 6b on opposite sides of the pivot axis 8, with the blade section 6a moving in an upstream direction and the blade section 6b moving in a downstream direction when the blade 6 is moved towards an opening position.

[0022] The housing 2 comprises a throttle body 10, an annular member 12, and an inlet manifold 14, with the annular member 12 being positioned between the throttle body 10 and the inlet manifold 14. The intake passage 4 extending through the throttle body 10, the annular member 12 and the inlet manifold 14 is of cylindrical shape, i.e. of uniform cross-section.

[0023] The annular member 12 includes an annular flow passage 16 extending about the intake passage 4. The annular passage 16 communicates with an exhaust gas recirculation conduit 18 so as to receive exhaust gas from an exhaust gas system of the internal combustion engine. The exhaust gas recirculation conduit 18 is con-

nected to the annular flow passage 16 by a single port 20 of oblong cross-section, see Figs. 2 and 3.

[0024] The annular passage 16 is formed by a circumferential channel in the annular member 12, which channel is internally confined by a band-shaped annular ring 22. The ring 22 is provided with an annular array of circumferentially spaced openings 24 in the shape of slots so as to enable the exhaust gas to flow from the annular passage into the intake passage 4 as will be explained in more detail below.

[0025] During operation inlet air flows through intake passage 4 around throttle blade 6, which will result in air recirculation zones downstream of throttle blade 6. As schematically shown in Fig. 4 the extent of the air recirculating zone depends on the angular position of the throttle blade 6. Fig. 4 shows by full lines an air recirculation zone AR1 during part or low load conditions and by dotted lines an air recirculation zone AR2 during full load conditions. As will be noted the air recirculation zones AR1 and AR2 are somewhat asymmetrical to the longitudinal axis of the intake passage 4, i.e. they are somewhat displaced towards the right side in Fig. 4 due to the angular positions of the throttle blade 6.

[0026] This asymmetrical flow pattern of the air recirculation zones allows to introduce the recirculated exhaust gas from the annular passage 16 into the intake passage 4 in a similar asymmetrical flow pattern very close to the throttle blade 6, while the exhaust gas is prevented from being entrained into the air recirculation zones under all operating conditions. To this end more exhaust gas is introduced into the intake passage 4 on its left side than on its right side in Fig. 4. More particularly and as schematically indicated in Fig. 5 a greater amount such as 70 to 80% of the exhaust gas received from the exhaust gas recirculation conduit 18 is introduced into the intake passage 4 over an arc C of about 160 to 180°.

[0027] To provide for this asymmetrical distribution of the exhaust gas when entering the intake passage 4, the openings 24 are of cross-sectional areas which increase from one side to the other, as schematically indicated in Fig. 1. Alternatively or additionally, the number of the openings 24 on one side may exceed the number of openings 24 on the other side. Furthermore, the cross-sectional area of the annular flow passage 16 may be increased from one side to the other. Further additional or alternative measures to ensure the desired asymmetrical distribution of the recirculated exhaust gas introduced into the intake passage 4 are readily available to the skilled person.

[0028] As shown in particular in Figs. 1 and 4 the slot-shaped openings 24 are disposed in a common plane extending perpendicularly with respect to the longitudinal axis of the intake passage 4. The distance D between such common plane and a radial plane extending through the pivot axis 8 (see Fig. 4) is chosen such that the exhaust gas introduced into the intake passage 4 just avoids the air recirculation zone AR1, i.e. to introduce the exhaust gas as close as possible to the throttle blade 6 without being entrained into the air recirculation zone. It is important to note that the exhaust gas is introduced at a location where the inlet air is free flowing past the throttle blade 6 around the air recirculation zone. At this location the inlet air flows at increased velocities due to the flow restriction which results from the throttle blade 6 being in an angular position.

[0029] The openings 24 are arranged such that the exhaust gas when being introduced into the intake passage 4 flows substantially only in radial and axial directions. This is in contrast to some prior art solutions where circumferential flow components provide for a spiral flow of the exhaust gas.

[0030] The throttle body 10 and the annular member 12 are made of a metal of low thermal inertia, preferably of die cast aluminium. While in the embodiment shown the throttle body 10 and the annular member 12 are separate structural parts, it is to be understood that they could be integrally formed as a single part. The ring 22 is preferably made of stainless steel.

[0031] Introducing the hot exhaust gas close to the throttle valve and making the throttle body 10 and the annular member 12 of materials of low thermal inertia will cause the surfaces thereof to be rapidly heated as required to prevent ice formation. In order to improve heat transfer from the annular member 12 to the throttle body 10 a thermally conductive sealing means 26 comprising a gasket is disposed between the annular member 12 and the throttle body 10. A further advantage of this structure is that during a hot soak condition the throttle body can cool at the fastest possible rate dependent on the ambient temperature surrounding it.

[0032] The inlet manifold 14 is preferably, but not exclusively, made of plastic material. Introducing the exhaust gas into the intake passage 4 in the manner as described above allows to reduce the temperature of the exhaust gas sufficiently so that it cannot damage the plastic inlet manifold.

[0033] As mentioned above the exhaust gas recirculation conduit 18 is a single pipe feeding the recirculated exhaust gas into the annular passage 16. A bore 30 of a hydraulic diamter equivalent to that of the exhaust gas recirculation conduit 18 is used to connect the conduit opening to the port 20 of the annular flow passage 16. An exhaust gas recirculation valve 28 is disposed in the exhaust gas recirculation conduit 18 so as to be remote from the housing 2, even though it could also be integrated into the housing 2.

Claims

1. A method of recirculating exhaust gas into inlet air flowing through an intake passage (4) of an internal combustion engine, said intake passage (4) including a throttle blade (6) rotatable about a pivot axis (8) between opening and closing positions and hav-

ing upstream and downstream opening blade sections (6a, 6b) on opposite sides of said pivot axis (8), in which method more exhaust gas is introduced into said intake passage (4) on its side adjacent said upstream opening blade section (6a) than on its side adjacent said downstream opening blade section (6b).

2. The method of claim 1 wherein exhaust gas is introduced into said intake passage (4) as close as possible to said throttle blade (6) without being entrained into any air recirculation zone (AR) resulting from air flow around said throttle blade (6).

3. The method of claim 1 or claim 2 wherein the exhaust gas is introduced into said intake passage (4) so as to flow substantially only in radial and axial directions.

4. The method of any of claims 1 to 3 wherein the exhaust gas is introduced into said intake passage (4) at a location where the inlet air is free flowing and has been accelerated due to the cross-sectional area of the intake passage (4) being restricted by the throttle blade (6).

5. Apparatus for recirculating exhaust gas into inlet air flowing through an intake passage (4) of an internal combustion engine, comprising

a housing (2) including said intake passage (4) to communicate the inlet air to at least one cylinder of the internal combustion engine,

a throttle valve including a throttle blade (6) arranged in said intake passage (4) so as to be rotatable about a pivot axis (8) between opening and closing positions, said throttle blade (6) having upstream and downstream opening blade sections (6a, 6b), and

an annular flow passage (16) disposed in said housing (2) and extending about said intake passage (4), said annular flow passage (16) receiving exhaust gas from an exhaust gas recirculation conduit (18) of an exhaust gas system of the internal combustion engine and introducing the exhaust gas into said intake passage (4) downstream of said throttle valve via an annular array of circumferentially spaced openings (24) such that more exhaust gas is introduced into the intake passage (4) on its side adjacent said upstream opening blade section (6a) than on its side adjacent said downstream opening blade section (6b).

6. The apparatus of claim 5 wherein said circumferentially spaced openings (24) are arranged such that exhaust gas is introduced into said intake passage (4) as close as possible to said throttle blade (6) without being entrained into any air recirculation zone (AR) resulting from air flow around said throttle blade (6).

7. The apparatus of claim 5 or claim 6, wherein said circumferentially spaced openings (24) are arranged such that the exhaust gas when being introduced into said intake passage (4) flows substantially only in radial and axial directions.

8. The apparatus of any of claims 5 to 7, wherein said circumferentially spaced openings (24) are arranged such that exhaust gas is introduced into said intake passage (4) at a location where the inlet air is free flowing and has been accelerated due to the cross-sectional area of the intake passage (4) being restricted by the throttle blade (6).

9. The apparatus of any of claims 5 to 8, wherein approximately 70 to 80% of the exhaust gas received in said annular flow passage (16) from said exhaust recirculation conduit (18) is introduced into said intake passage (4) on its side adjacent said upstream opening blade section (6a).

10. The apparatus of any of claims 5 to 9, wherein said annular flow passage (16) is of a cross-sectional area increasing from the side of the intake passage (4) adjacent said upstream opening blade section (6a) to the side of the intake passage (4) adjacent said downstream opening blade section (6b).

11. The apparatus of any of claims 5 to 10, wherein said circumferentially spaced openings (24) are of cross-sectional areas increasing from the side of the intake passage (4) adjacent said upstream opening blade section (6a) to the side of the intake passage (4) adjacent said downstream opening blade section (6b).

12. The apparatus of any of claims 5 to 11, wherein more of said circumferentially spaced openings (24) are disposed on the side of the intake passage (4) adjacent said upstream opening blade section (6a) than on the side of the intake passage (4) adjacent said downstream opening blade section (6b).

13. The apparatus of any of claims 5 to 12, wherein said exhaust gas recirculation conduit (18) opens into said annular flow passage (16) via a single port (20) on the side of the intake passage (4) adjacent said downstream opening blade section (6b) and in a direction perpendicular to said pivot axis (8).

14. The apparatus of any of claims 5 to 13, wherein said intake passage (4) is of uniform cross-section in a

region containing said throttle blade (6) and said circumferentially spaced openings (24).

15. The apparatus of any of claims 5 to 14, wherein said housing (2) comprises:

a throttle body (10) including said throttle blade (6),

an annular member (12) including said annular flow passage (16), and

an inlet manifold (14),

said annular member (12) being disposed between said throttle body (10) and said inlet manifold (14).

16. The apparatus of claim 15, wherein said annular member (12) has a circumferentially extending channel forming said annular flow passage (16) and internally confined by a ring (22), with said circumferentially spaced openings (24) being provided in said ring (22).

17. The apparatus of claim 15 or claim 16, wherein said annular member (12) and said throttle body (10) are made of a metal of low thermal inertia.

18. The apparatus of any of claims 15 to 17, wherein said throttle body and said annular member are of integral structure.

19. The apparatus of any of claims 15 to 17, wherein said throttle body (10) and said annular member (12) are separate parts and a heat conductive sealing means (26) is disposed between said throttle body (10) and said annular member (12).

20. The apparatus of any of claims 15 to 19, wherein said inlet manifold (14) is made of plastic material.

21. The apparatus of any of claims 5 to 20, wherein said exhaust gas recirculation conduit (18) includes an exhaust gas recirculation valve (28) remote from or integrated into said housing (2).

FIG 1

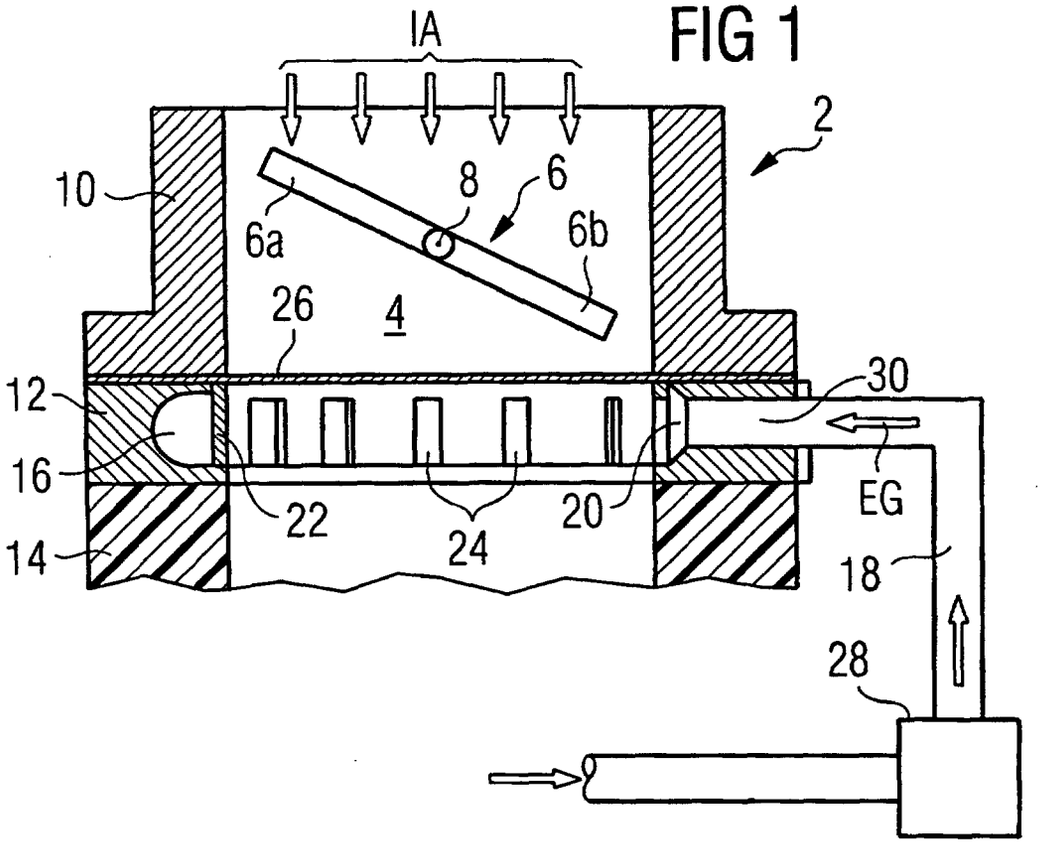


FIG 2

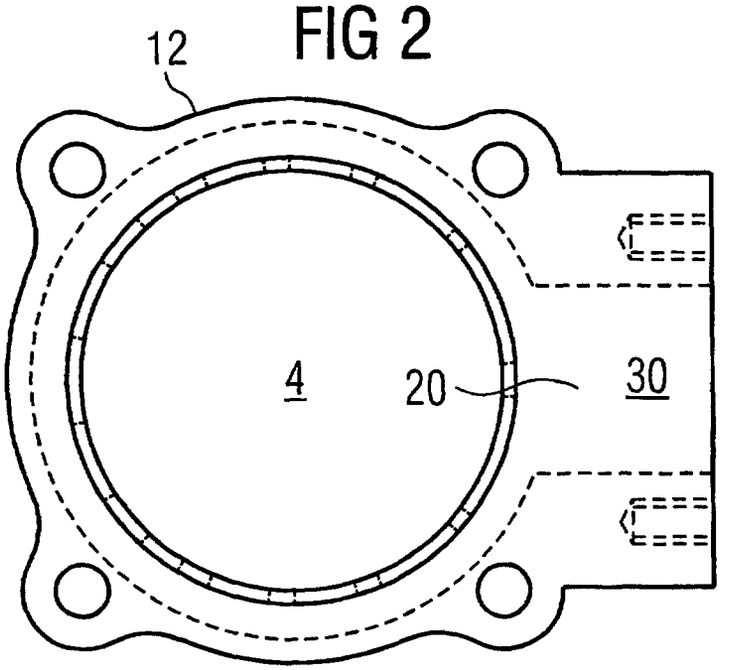


FIG 3

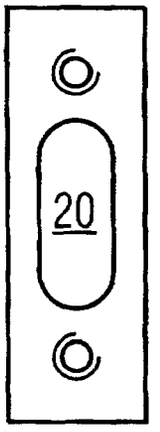


FIG 4

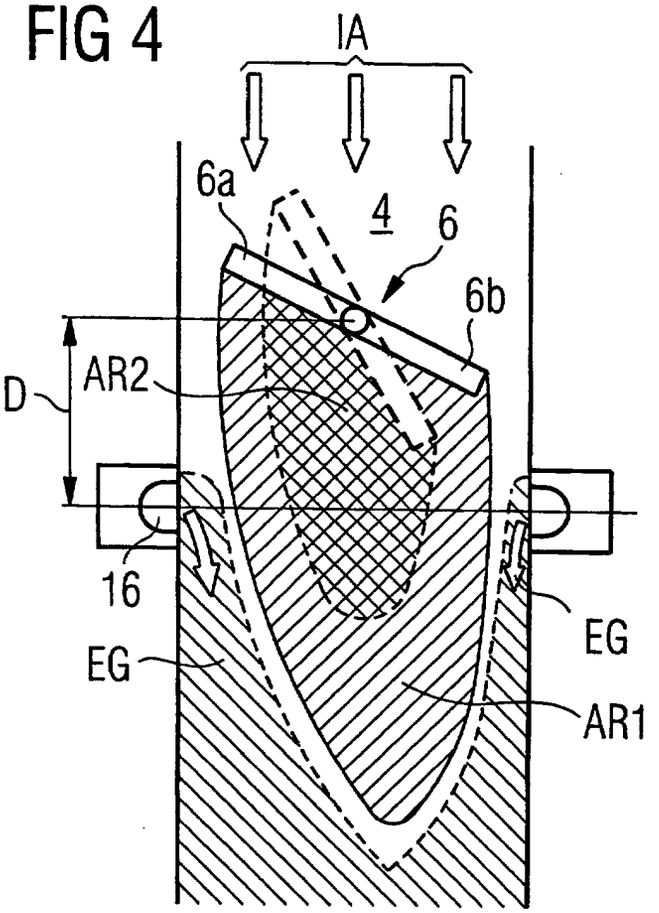
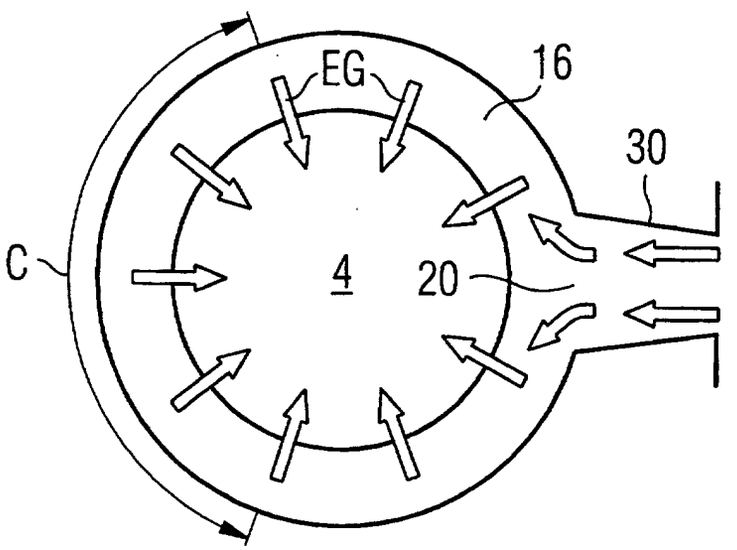


FIG 5



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EUROPEAN SEARCH REPORT

Application Number
EP 00 10 9646

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
D,X	EP 0 881 378 A (NISSAN) 2 December 1998 (1998-12-02) * column 5, line 22 - line 36 * * column 7, line 56 - column 8, line 10 *	1,2,4	F02M25/07
Y	* column 8, line 16 - line 25; figure 25 *	5-8, 14-16,18	
Y	DE 198 09 862 A (FILTERWERK MANN & HUMMEL) 9 September 1999 (1999-09-09) * column 3, line 2 - line 16; figures 3-6 *	5-8, 14-16,18	
X	EP 0 809 012 A (NIPPON SOKEN) 26 November 1997 (1997-11-26) * column 1, line 43 - line 53 * * column 3, line 8 - line 12 * * column 3, line 24 - line 36 * * column 7, line 15 - line 34 * * column 7, line 47 - line 59 * * column 8, line 44 - column 9, line 8; figure 3 *	1-4	
			TECHNICAL FIELDS SEARCHED (Int.Cl.7)
X	DE 21 28 646 A (GM) 9 December 1971 (1971-12-09) * page 4, line 11 - line 23; figures 1,2 *	1	F02M
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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
THE HAGUE	3 October 2000	Joris, J

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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