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(54) Gas Mixing system

(57) In one aspect a mixing tube may be provided that may have mixing tube wall with a plurality of mixing tube ports. The mixing tube may have a gas inlet opening. A mixing assembly may include a mixing tube as described and a mixing body. The mixing body may include a first gas passage, a second gas passage and may include an opening that connects the first and the second gas passages. The mixing tube may mounted in the opening so that, in use, first gas that flows from the first gas passage to the second gas passage has to enter the gas inlet opening of the mixing tube and leave the mixing tube via the plurality of mixing tube ports. In yet another aspect, an exhaust gas recirculation system for an internal combustion engine may be provided that may include a mixing assembly as described.

EP 2 133 548 A1

Description

Technical Field

[0001] The disclosure relates to a gas mixing system, more particular to a gas mixing system for an exhaust gas recirculation system of an internal combustion engine.

Background

[0002] Mixing of two gases may be obtained by introducing a first gas flow into a second gas flow. Mixing of gases may, for example occur in an exhaust gas recirculation (EGR) system of an internal combustion engine. EGR is a technique commonly used for controlling the generation of undesirable pollutant gases and particulate matter in the operation of internal combustion engines, such as internal combustion engines provided with a turbocharger. It is known to remove exhaust gas to be recirculated upstream of an exhaust gas driven turbine associated with the turbocharger. In many EGR-applications, the exhaust gas is diverted directly from the exhaust manifold. Likewise, the recirculated exhaust gas may be reintroduced to the intake air stream downstream of a compressor of the turbocharger and an air-to-air aftercooler. For example, in many EGR-applications the recirculated exhaust gas is reintroduced to the intake manifold. EP-A-0 869 275 relates to such an EGR-system.

[0003] However, further improvement is desired. Especially the mixing of intake air and recirculated exhaust air may be improved. The length of the passage that forms the fluid connection between a meeting position where the intake air and the exhaust gas meet each other and the outlet ports and the length of the passage that forms the fluid connection between the meeting position and the inlet ports of the combustion chambers of the engine may be relevant for the pressure difference between intake air and the exhaust gas at the meeting position. Generally, a quick and good and quick mixing of two gas flows that are brought into contact with each other may be desired.

[0004] The present disclosure is directed, at least in part, to improving or overcoming one or more aspects of prior art gas mixing systems, more particular of the prior art EGR-systems.

Summary of the Invention

[0005] In one aspect, a mixing tube may be provided that may have a mixing tube wall with a plurality of mixing tube ports. The mixing tube may have a first and a second end. The first end of the mixing tube may define a gas inlet opening. The plurality of mixing tube ports may define gas outlet ports.

[0006] In another aspect, a mixing assembly may be provided. The mixing assembly may include a mixing tube as described and a mixing body. The mixing body may include a first gas passage, a second gas passage and may include an opening that connects the first and the second gas passages. The mixing tube may mounted in the opening so that, in use, first gas that flows from the first gas passage to the second gas passage has to enter the gas inlet opening of the mixing tube and leave the mixing tube via the plurality of mixing tube ports.

[0007] In yet another aspect, an exhaust gas recirculation system for an internal combustion engine may be provided. The engine may have an air intake system with an upstream part and a downstream part, the EGR-system may include a mixing assembly as described. The second gas passage of the mixing assembly may be an air intake channel that may have an air intake opening and a mixture outlet opening. The air intake opening may be connectable to the upstream part. The mixture outlet opening may be connectable to the downstream part. The first passage of the mixing assembly may have an exhaust gas intake opening.

[0008] In yet another aspect, a method for mixing a first gas flow with a second gas flow may be provided. The method may include providing a mixing assembly as described. The first gas may be supplied to the first gas passage. The second gas may be supplied to the second gas passage. The first gas may be introduced into the mixing tube. The first gas may be divided into multiple streams of first gas emanating from the mixing tube ports. The multiple streams of first gas may be supplied into the second gas to form a mixture of first and second gas. The mixture may be discharged from the mixing-assembly.

Brief Description of the Drawings

[0009] Fig. 1 is a perspective transverse cross section of an embodiment of a mixing assembly;

[0010] Fig. 2 is a perspective longitudinal cross section of the embodiment of the mixing assembly of Fig. 1;

[0011] Fig. 3 is a perspective transverse cross section of the embodiment of the mixing assembly of Fig. 1;

[0012] Fig. 4 is a schematic view of an internal combustion engine with an EGR-system;

[0013] Fig. 5 is a perspective view of a first exemplary embodiment of an EGR-module;

[0014] Fig. 6 is a perspective transverse cross section of the embodiment of Fig. 5;

[0015] Fig. 7 is a perspective longitudinal cross section of the embodiment of Fig. 5; and

[0016] Fig. 8 is a perspective view of a second exemplary embodiment.

Detailed Description

[0017] For mixing a first gas with a second gas, a mixing assembly tube and a mixing assembly may be provided. The mixing assembly may include the mixing tube.

[0018] An embodiment of a mixing assembly 80 is

shown in Figs. 1-3. The mixing assembly 80 may include a mixing tube 82.

[0019] The mixing tube 82 may have a mixing tube wall 84 that may have a plurality of mixing tube ports 86. The mixing tube 82 may have a first 88 and a second end 90. The first end 88 of the mixing tube 82 may define a gas inlet opening 92. The plurality of mixing tube ports 86 may define gas outlet ports. An end wall 94 may at least partly close off the second end 90 of the mixing tube 82. In an embodiment the end wall 94 may also include mixing tube ports. In another embodiment the end wall 94 may also completely close off the second end 90 of the mixing tube. The end wall 94 may also be omitted. The mixing tube 82 may include a mixing tube flange 96. The mixing tube flange 96 may be connected with the mixing tube wall 84 adjacent the first end 88. Alternatively, the mixing tube flange 96 may be connected with the mixing tube wall 84 adjacent the second end 90. Connecting positions of the mixing tube flange 96 and the mixing tube wall 84 between the first end 88 and the second end 90 may also be feasible. The mixing tube 82 may have a longitudinal axis that is parallel to the mixing tube wall. A cross section of the mixing tube wall perpendicular to the axis may have various configurations. For example, the cross section may be circular or square. Alternatively, the cross section may be elliptic or rectangular possibly with rounded corners. In the elliptic or rectangular embodiments, the mixing tube wall cross section may have two opposite long wall segments or sides and two opposite short wall segments or sides. In an embodiment, the plurality of mixing tube ports 86 may be provided predominantly provided in the long wall segments or sides of the mixing tube wall 84.

[0020] The mixing assembly 80 may include the mixing tube 82 and a mixing body 98. The mixing body 98 may include a first gas passage 100 and a second gas passage 102. An opening 104 may be present that connects the first and the second gas passages 100, 102. The mixing tube 82 may be mounted in the opening 104 so that, in use, first gas that flows from the first gas passage 100 to the second gas passage 102 has to enter the gas inlet opening 92 of the mixing tube 82 and leave the mixing tube 82 via the plurality of mixing tube ports 86. The mixing tube 82 may have a central axis that extends parallel to the mixing tube wall 84. The second gas passage 102 may have a central axis that extends parallel to a wall 106 bounding the second gas passage 102. The central axis of the mixing tube 82 may be perpendicular to the central axis of the second gas passage 102 adjacent the mixing tube 82 and the mixing tube ports 86 may be configured so that so that, in use, a second gas in the second gas passage 102 adjacent the mixing tube 82 has a flow direction that is substantially perpendicular to a flow direction of the first gas emanating from the mixing tube ports 86. The mixing body 98 may include a mixing tube mounting surface 108 for accommodating the mixing tube flange 96. The mixing body 98 may also include a circlip groove 110 adjacent the mixing tube mounting surface 108. The mixing tube 82 may be connected to the mixing body 98 by a circlip 112. The circlip 112 may be a flexible ring member with an interruption in the ring member, the interruption being bounded by two ends of the ring. The circumference of the ring member may be diminished by flexing the ends of the ring adjacent the interruption towards each other. Thus the circlip 112 may be snapped into the circlip groove 110.

[0021] The wall 106 bounding the second passage 102 may have a wall part 106' surrounding the opening 104. That wall part 106' may include the mixing tube mounting surface 108. The mixing tube mounting surface 108 may surround the opening 104. In such an embodiment, the mixing tube 82 may have the mixing tube flange 96 adjacent the first end 88.

[0022] In an alternative embodiment, the wall 106 bounding the second passage 102 may include a wall part 106" that is opposite to the opening 104. The mixing tube flange 96 may be adjacent the second end 90 of the mixing tube 82 that is closed by an end wall 94. The first end 88 of the mixing tube may connect to the opening 104 so that, in use, a first gas that flows from the first gas passage 100 to the second gas passage 102 has to enter the gas inlet opening 92 of the mixing tube 82. Such an embodiment is shown in Fig. 8. The wall part 106" may include a mixing tube opening through which the mixing tube 82 may extend when mounted in the mixing body 98. The wall part 106" may have an internal side and an external side. The internal side may be directed to the second gas passage 102 and the external side may be directed away from the second gas passage 102. The mixing tube mounting surface 108 may be provided in the external side.

[0023] A mounting of the mixing tube 82 in the mixing body 98 with other connecting means than a circlip 112 may be feasible. For example, a connection by means of screw, bayonet, clamp fitting or screw thread may be contemplated. The mixing assembly may have a first gas intake opening 118, a second gas intake opening 114 and a mixture outlet opening 116.

[0024] The mixing assembly 80 and/or the mixing tube 82 may also be part of an exhaust gas recirculation system for an internal combustion engine. The engine may have an air intake system with an upstream part and a downstream part. The second gas passage 102 of the mixing assembly may be an air intake channel. The first gas intake opening 118 may be an exhaust gas intake opening 118. An exhaust gas recirculation tube 120 may be connected to the first gas intake opening. The second gas intake opening 114 may be an air intake opening 114. The air intake opening 114 may be connectable to the upstream part of the air intake system. The mixture outlet opening 116 may be connectable to the downstream part of the air intake system.

[0025] The mixing assembly and/or the mixing tube may also be included in an EGR-module. Such a EGR-recirculation system will be described with reference to Figs. 4-8.

[0026] Fig. 4 schematically shows an internal combustion engine having an engine block 12. The internal combustion engine may have an air intake system and an exhaust system. The air intake system may include an air intake passage 14, 16, 18, 20. The air intake passage may include a compressor 22, a charged air cooler 24, an EGR-module 26 and an intake manifold 28. The exhaust system may include an exhaust passage 30, 32. The exhaust passage may include an exhaust manifold 34 and a turbine 36. The compressor 22 may be connected to the turbine 36 via a turbocharger shaft 38. In another embodiment the compressor 14 may also be driven by another element, for example, a shaft that is driven by an electric motor or by the internal combustion engine 12 via a transmission. In such a case the turbine 36 may not be present. The air intake system may include various additional components. On the other hand, the air intake system may also not include air cooler 24 or compressor 22. The exhaust system may also include various additional components, for example, an exhaust after-treatment system. The exhaust after-treatment system may, for example, include a diesel particulate filter and a diesel oxygen catalyst.

[0027] An exhaust recirculation passage 40 may be present. An inlet 42 of the exhaust recirculation passage 26 may emanate from the exhaust manifold 34. An outlet of the exhaust gas recirculation passage 40 may emanate in an exhaust gas intake opening 44 of the EGR-module 26. the exhaust recirculation passage 40 may include an EGR-cooler 46.

[0028] The EGR-module 26 may be mountable as a single unit in the air intake system between an upstream part 18 of the air intake passage and a downstream part 20 of the air intake passage of the air intake system. The EGR-module 26 may have an air intake channel 48. The air intake channel 48 may have an air intake opening 50 and a mixture outlet opening 52. The air intake opening 50 may be connectable to the upstream part 18 of the air intake passage of the air intake system. The mixture outlet opening 52 may be connectable to the downstream part 20 of the air intake passage of the air intake system. As stated before, the EGR-module 26 may also have an exhaust gas intake opening 44 that may be connected to an outlet of the exhaust recirculation passage 40. The EGR-module 26 may include an EGR-valve 54 that may control the amount of exhaust gas that may be recirculated. The EGR-module 26 may also include at least one non-return valve 56 that prevents that intake air present in air intake channel 48 flows into the EGR-passage 40. The non-return valves 40 may be of any type. Reed valves are particularly suitable because of the short response time and the low mass of the valve membranes of a reed valve. The EGR-valve 54 and the non-return valves 56 may be in an exhaust gas passage 64 in the EGR-module 26. The air intake channel 48 of the EGR-module 26 may include a throttle valve 58 for controlling the amount of intake air that is passing the air intake channel 48 and is delivered to the downstream part 20 of the air intake system. The EGR-module 26 may also include a mixing assembly 60 that may be configured for mixing exhaust gas introduced in the exhaust gas intake opening 44 and air introduced in the air intake channel 48 via the air intake opening 50. The mixing assembly 60 may be downstream of the non-return valves in the exhaust gas passage 64 of the EGR-module 26. The mixing assembly 60 may be accommodated in a mixing body 62 that may, for example, be a casting. The mixing assembly will be described in more detail with reference to the embodiments of EGR-modules shown in Figs. 5-8.

[0029] Figs. 5-7 show a first embodiment of an EGR-module 126. The EGR-module 126 may include a mixing body 162 that may at least partly define the air intake channel 148. The mixing body 162 may have a throttle valve body flange 166, an EGR-valve body flange 168 and an outlet flange 184 adjacent the mixture outlet opening 152. With the flange 184 a downstream part of the intake system may be connected. The EGR-module 126 may also include a throttle valve body 170 that may be connected to the throttle valve body flange 166 of the mixing body 162. The throttle valve body 170 may include a throttle valve motor 178. The throttle valve may include a valve flap 180 and a valve shaft 182 connected with the valve flap 180 for regulating the position of the valve flap 180 relative to the air intake channel 148. The valve shaft 182 may extend perpendicular to a central axis of the air intake channel 148 at that position. The valve shaft 182 may be driven by the throttle valve motor 178. This may be effected directly or via a transmission. Other types of throttle valves are feasible as well.

[0030] An EGR-valve body 172 may be connected to the EGR-valve body flange 168. The EGR-valve body 172 may have a motor flange 174. An EGR-valve motor 176 may be connected to the motor flange 174 of the EGR-valve body 172. The EGR-valve body 172 may include an EGR-valve member 186 for regulating the amount of exhaust gas that may pass the EGR-module 126. The EGR-valve body 172 may also include an exhaust gas intake opening 144 that may be surrounded by an EGR-passage connecting flange 145 and may be the upstream end of the exhaust gas passage 164 in the EGR-module 126.

[0031] In one embodiment, the non-return valve 140 may have the form of at least one reed valve 140. The at least one reed valve 140 may have a reed valve body 190 with a reed valve flange 192 that may be positioned between the EGR-valve body 172 and the mixing body 162. Thus, the non-return valve may be clamped in between the EGR-valve body 172 and the mixing body 162. This is clearly visible in Figs. 6 and 7. The reed valves 140 may include membranes 188 that are connected with one end to the reed valve body 190. Also other solutions to mount non-return valves 140 in the exhaust gas passage 164 are feasible.

[0032] The mixing assembly 140 may include at least one mixing tube 194 having a mixing tube wall with a plurality of mixing tube ports 196. The at least one mixing

tube 194 may have a central axis that extends parallel to the mixing tube wall. The air intake channel 148 that is at least partly bounded by the mixing body 162, may have a central axis that extends parallel to a wall bounding the air intake channel 148. The central axis of the mixing tube 194 may be perpendicular to the central axis of the air intake channel 148 adjacent the mixing tube 194 so that, in use, the flow of air in the air intake channel adjacent the mixing tube 194 is substantially perpendicular to the exhaust gas leaving the mixing tube ports 196. The valve shaft 182 of the throttle valve 150 has a longitudinal axis that may be parallel to the central axis of the at least one mixing tube 194. The mixing tube ports 196 may be orientated relative to the valve flap 180 of the throttle valve 150 so, that, when the valve flap 180 is in the entirely opened position (as shown in Fig. 7) exhaust gas leaving the mixing tube ports 196 may have a flow direction perpendicular to the main flow direction of the intake air adjacent the mixing tube 194.

[0033] The mixing tube 194 may have a mixing tube flange 198 and the mixing body 162 may have a mixing tube mounting surface 200 for accommodating the mixing tube flange 198. The mixing body 162 may have a circlip groove 202 adjacent the mixing tube mounting surface 200. Thus the mixing tube 192 may be connected to the mixing body 162 by a circlip 201. The circlip 201 1 may be a flexible ring member with an interruption in the ring member, the interruption being bounded by two ends of the ring. The circumference of the ring member may be diminished by flexing the ends of the ring adjacent the interruption towards each other. Other mixing assemblies are also feasible. Any elements that introduce turbulence in the area around the mixing assembly where the intake air and the recirculated exhaust gas are brought into contact with each other may be feasible for obtaining a good mixture between the intake air and the recirculated exhaust gas. Those elements may, for example, include baffles and fixed or moveable swirl elements that may change the direction of flow of the intake air and/or the exhaust gas adjacent the mixing assembly. The mixing tube 194 may have an exhaust gas inlet adjacent the mixing tube flange 198. The other end of the mixing tube may be closed off by an end wall 195. Such an embodiment is shown in Figs. 5-7. Alternatively, the mixing tube 194 may be closed off adjacent the end that is connected with the mixing tube flange 198. In such an embodiment, the end of the mixing tube 194 remote from the mixing tube flange 198 may be open and form an exhaust gas inlet.

[0034] The EGR-module 126 may include various sensors. For example a temperature sensor 204 and a pressure sensor 206. In the embodiment shown in Figs. 5-7 those sensors are positioned near the mixture outlet opening 152 of the EGR-module 126. Also more than one temperature sensor and more than one pressure sensor may be present. Also other sensors, for example, sensors for measuring the concentration of constituents of the mixture may be present.

[0035] Fig. 8 shows a second embodiment 226 that is mounted on an engine block 212. The EGR-module may have a mixing body 162, in which a mixing assembly 160 may be accommodated. The mixing assembly 160 may include a mixing tube 194. The mixing tube in Fig. 8 may be closed off adjacent the end that is connected with the mixing tube flange 198. The end of the mixing tube 194 remote from the mixing tube flange 198 may be open and form the inlet of the mixing tube 194.

[0036] The mixing body 162 may have a throttle valve body flange 166. On the throttle valve body flange 166 a throttle valve body 170 may be mounted. The throttle valve body 170 may define the air intake opening 150 of the EGR-module 226. The air intake opening 150 may be connected to an upstream part 218 of the air intake system. The mixing assembly 160 may be connected to an exhaust gas passage 264 of the EGR-module 226. Near an upstream end of that exhaust gas passage 264 an EGR-valve body flange 168 may be provided. An EGR-valve body 172 may be connected to the EGR-valve body flange 168. The exhaust gas passage 264 of the EGR-module 226 may include non-return valve 140. In the embodiment of Fig. 8 two sets reed valves 140 are accommodated in the EGR-module 226. However, it is contemplated that a different number of reed valves is accommodated in the EGR-module. The number may depend on the amount of exhaust gas that may be recirculated. An exhaust gas recircualtion passage connecting flange 145 that may be provided on the EGR-valve body 172 and may be connected to an exhaust gas recirculation passage 240. The EGR-valve body 172 may also include an EGR-valve member 186 that may be controlled by an EGR-valve motor 176.

Industrial Applicability

[0037] The mixing tube and the mixing assembly may be applied for mixing a first gas flow with a second gas flow. For example, the mixing tube and/or the mixing assembly may be applied in an exhaust gas recirculation system of an internal combustion engine.

[0038] A method may be provided that may include the provision of a mixing assembly 80 as described above. A first gas 122 may be supplied to the first gas passage 100. A second gas 124 may be supplied to the second gas passage 102. The first gas may be introduced into the mixing tube 82 and may be divided into multiple gas streams emanating from the mixing tube ports 86. The multiple streams of first gas 122 may be supplied into the second gas 124 to form a mixture 126 of first and second gas. The mixture 126 may be discharged from the mixing assembly 80.

[0039] The mixing of the first gas 122 and the second gas 124 may be performed by supplying the multiple streams of first gas 122 in the flow of second gas 124 with a first gas flow direction that is substantially perpendicular to the second gas flow direction adjacent the mixing tube 82. As already described, the mixing tube 82

may have a cross section that is elliptic or rectangular possibly with rounded corners. The plurality of mixing tube ports 86 may be provided predominantly in the long wall segments or sides of the mixing tube wall 84. The long wall segments or sides of the mixing tube may be substantially parallel to the flow direction of the second gas 124. Thus the major part of the plurality of mixing tube ports 86 may be oriented so that the multiple streams of first gas 122 are perpendicular to the second gas flow direction adjacent the mixing tube 82. The frontal surface of the mixing tube 82 viewed in the flow direction of the second gas 124 may be relatively small while at the same time a relatively large outflow surface is provided by the plurality of mixing tube ports 86 in the long wall segments or sides.

[0040] With such a mixing tube 82 and such a mixing assembly 80 a good and efficient mixing may be obtained. At a short distance downstream of the mixing tube 82 in the second gas passage 102 a good mixture 126 may be obtained. The mixing assembly 80 may relatively simple so that maintenance may be easy. When, for example, one or both of the first and second gases may foul the mixing tube 82, a relatively easy replacement of the mixing tube 82 may be feasible. This may be effected by removing the circlip 112 and the mixing tube 82. Next the mixing tube 82 may be replaced by another one and the circlip 112 may be mounted again.

[0041] An EGR-system including an EGR-module 26, 126, 226 with a mixing tube as described may be applied in any internal combustion engine. To that end a method for exhaust gas recirculation in an internal combustion engine having an air intake system with an upstream part and a downstream part, may be provided. The method may include providing an EGR-module 26, 126, 226 in the air intake system between the upstream part 18, 218 and the downstream part 20, 220. The method may also include supplying intake air 250 to an EGR-module 26, 126, 226 and supplying exhaust gas 252 to the EGR-module 26, 126, 226. This has been indicated in Figs. 5, 7 and 8 by the arrows 250, 252. In the EGR-module 26, 126, 226, the intake air 250 and the exhaust gas 252 may be mixed. The mixture 254 may be discharged form the EGR-module 26, 126, 226 into the downstream part 20, 220 of the air intake system.

[0042] For a more elaborate description of the manner in which the EGR-system may operate reference will be made to Fig. 4 in which the engine block 12 of an internal combustion engine is shown. Exhaust gas leaving the engine block 12 via the exhaust manifold 34 and exhaust passage 30 may drive a turbine 36 of a turbocharger. The exhaust gas may leave the turbine 36 via exhaust passage 32. The exhaust gas may be subjected to after-treatment in the exhaust system downstream of the turbine 36. The turbine 36 may drive a shaft 38 that may drive a compressor 22.

[0043] A part 252 of the exhaust gas may be recirculated via exhaust gas recirculation passage 40. That part 252 of the exhaust gas may be cooled in the EGR-cooler 46. The cooled exhaust gas may enter the EGR-module 26 via the exhaust gas intake opening 44. The amount of exhaust gas 252 taken in by the EGR-module 26 may be regulated by an EGR-valve 54 in the EGR-module 26. The exhaust gas taken in by EGR-module 26 may pass a non-return valve 56 and may then be supplied to the mixing assembly 60 that may be accommodated in the mixing body 62. The non-return valve 56 may prevent flowing back of exhaust gas 252 when the intake air pressure is higher than the exhaust gas pressure adjacent the non-return valve 56.

[0044] Intake air may enter the air intake system via air intake passage 14. Subsequently the intake air may be compressed by the compressor 22. The compressed air may flow via air intake passage 16 to air cooler 24. From the air cooler 24, the intake air may flow via intake air passage 18 to the EGR-module 26. The EGR-module 26 has an intake air opening 50 and an air intake channel 48. The amount of intake air 250 taken in by the EGR-module 26 may be regulated by the throttle valve 58 in the EGR-module 26. The intake air 250 may also be supplied to the mixing assembly 60. At the mixing assembly 60, the exhaust gas and the intake air may mix. The mixture 254 thus obtained may leave the EGR-module 26 via mixture outlet opening 52. The mixture 254 may be supplied via the downstream part 20 of the air intake system to the intake manifold 28 and may subsequently be supplied to the combustion chambers of the internal combustion engine.

[0045] As stated before, the non-return 56 valve may be embodied as a reed valve 140 as shown in the embodiments of Figs. 5-8. The reed valve membranes 188 of the reed valves 140 may flex when the pressure upstream from the reed valve 140 is higher then the pressure downstream of reed valve 140. Such a flexing opens the reed valve 140. Because the membranes 188 are light and flex easily, reed valves 140 have a very short response time and even small pressure differences are sufficient for opening and closing the reed valves 140. Thus, the amount of exhaust gas that may be recirculated may be optimal.

[0046] The mixing of intake air 250 and exhaust gas 252 may be performed with any suitable mixing assembly. A good mixing may be obtained by supplying multiple streams of exhaust gas in an intake air stream in the EGR-module with an exhaust gas flow direction that may be substantially perpendicular to the intake air flow direction in the EGR-module at that position. Such a flow pattern may be obtained with the mixing tube 194 as shown in the first and the second embodiment shown in Figs. 6-8. The mixing tube axis and the valve shaft axis may be parallel. Such an orientation may be beneficial for the flow rate of the intake air and may also be beneficial for the mixing performance.

[0047] The position of the throttle valve 58 that may be embodied as the valve flap 180 connected to a valve shaft 182, may be controlled by the throttle valve motor 178. The throttle valve motor 178 may receive a throttle

positioning signal outputted by a controller that may receive various input signals. One of the input signals for the controller may be the load to be driven by the internal combustion engine or a position of a fuel control lever that may be operated by a user.

[0048] The position of the EGR-valve 58 may be controlled by the EGR valve motor 176 and may be determined by a controller on the basis of various input signals of the controller. The input signals may also include signals obtained from the temperature sensor 204 and the pressure sensor 206 in the EGR-module 126. Also other sensors and signals available in the internal combustion engine, such as load sensors, speed sensors, injector steering signals, may be used for determining the position of the throttle valve 58, 180 and the EGR-valve 58, 186.

[0049] The EGR-system with the EGR-module as described may result in an improved mixing of intake air and recirculated exhaust air. Especially because the dimensions of the exhaust gas passages and the intake air passages in the EGR-module adjacent the mixing assembly are clearly defined, the mixing behavior of the EGR-system may be predictable and may be optimized. Because in one embodiment all components that regulate the exhaust gas supply and intake air supply may be integrated in a EGR-module configured as a unit, a single control connection may be feasible for controlling both the exhaust gas recirculation valve 58, 186 and the throttle valve 58, 180. A single control connection may be less vulnerable to malfunction. The EGR-module may be supplied by an external supplier as a unit. Consequently, the assembling effort for incorporating such an embodiment of the EGR-system in an internal combustion engine may be reduced. Because an embodiment of the EGR-module may be compact, packaging of the EGR-system in the limited space around the engine may be easier while maintaining or even improving the positioning of the various components relative to each other in the air intake system in view of optimal performance. An embodiment of the mixing assembly 60, 160 may be configured so that an optimal mixing result may be obtained in a limited space. The length of the passages that form the fluid connection between EGR-valve and the outlet ports and the inlet ports of the combustion chambers of the engine may be relevant for the pressure difference between intake air and the exhaust gas at the EGR-valve. For optimizing the pressure difference it may be desired to place the EGR-valve and the non-return valve close to the intake manifold. However, for optimizing mixing, a longer channel between the mixing position of the exhaust gas and the intake air on the one hand and the intake manifold on the other hand may be desired. By virtue of the mixing assembly 60, 160 in the shown embodiments of the EGR-module 26, 126, 226 and the optimized mixing circumstances that may be created in the EGR-module, the described EGR-module embodiments may be placed at a position near the intake manifold. Consequently, an optimal pressure difference between exhaust gas and intake air may be obtained while still keeping a good mixing performance. Thus, a higher degree of exhaust gas recirculation may be obtained.

[0050] Because in an embodiment all major components the EGR-system may now be integrated in the EGR-module that may be configured as a single unit, all these parts may be serviced simultaneously and may be kept in stock as a single unit. From a servicing point of view and from a logistic point of view that may be advantageous. When mounting such an embodiment of the EGR-module in the air intake system and the exhaust gas system, only three interfaces may be formed. Thus, the number of leakage sources may be reduced.

[0051] It will be apparent to those having ordinary skill in the art that various modifications and variations can be made to the EGR-system as disclosed herein. Other embodiments will be apparent to those having ordinary skill in the art from consideration of the specification. It is intended that the specification and examples are considered as exemplary only. Other aspects, features and advantages will be apparent upon an examination of the attached drawings and appended claims.

Claims

1. A mixing tube comprising a mixing tube wall with a plurality of mixing tube ports, the mixing tube having a first and a second end, the first end the mixing tube defining a gas inlet opening, the plurality of mixing tube ports defining gas outlet ports.

2. The mixing tube according to claim 1, including an end wall that at least partly closes off the second end of the mixing tube.

3. The mixing tube according to claim 1 or 2, including a mixing tube flange.

4. The mixing tube according to claim 3, wherein the mixing tube flange is connected with the mixing tube wall adjacent the first end.

5. The mixing tube according to claim 3, wherein the mixing tube flange is connected with the mixing tube wall adjacent the second end.

6. The mixing tube according to any of the preceding claims, wherein the mixing tube has a longitudinal axis parallel to the mixing tube wall wherein a cross section perpendicular to the longitudinal axis has a substantially circular or square configuration.

7. The mixing tube according to any of claim 1-5, wherein the mixing tube has a longitudinal axis parallel to the tube wall wherein a cross section perpendicular to the longitudinal axis has a substantially elliptic or rectangular configuration including two opposite

long wall segments and two opposite short wall segments.

8. The mixing tube according to claim 7, wherein the mixing tube ports are predominantly provided in the long wall segments.

9. A mixing assembly comprising:

- a mixing tube according to any one of claims 1-8;
- a mixing body, the mixing body including:
- a first gas passage
- a second gas passage;
- an opening that connects the first and the second gas passages

wherein the mixing tube is mounted in the opening so that, in use, first gas that flows from the first gas passage to the second gas passage has to enter the gas inlet opening of the mixing tube and leave the mixing tube via the plurality of mixing tube ports.

10. The mixing assembly according to claim 9, wherein the mixing tube has a central axis that extends parallel to the mixing tube wall and the second gas passage has a central axis that extends parallel to a wall bounding the second gas passage, wherein the central axis of the mixing tube is perpendicular to the central axis of the second gas passage adjacent the mixing tube and wherein the mixing tube ports are configured so that, in use, a second gas in the second gas passage adjacent the mixing tube has a flow direction that is substantially perpendicular to a flow direction of the first gas emanating from the mixing tube ports.

11. The mixing assembly of claim 8 or 9, wherein the mixing tube has a mixing tube flange, the mixing body including a mixing tube mounting surface for accommodating the mixing tube flange.

12. The mixing assembly according to claim 11, the mixing body including a circlip groove adjacent the mixing tube mounting surface, the mixing tube being connected to the mixing body by a circlip.

13. The mixing assembly according to claim 11 or 12, wherein the mixing body has a wall part surrounding the opening, the wall part including the mixing tube mounting surface, the mixing tube mounting surface surrounding the opening, the mixing tube having the mixing tube flange adjacent the first end.

14. The mixing assembly according to claim 11 or 12, wherein the mixing body has a wall bounding the second gas passage and including the opening, the wall including a wall part that is opposite to the opening, the wall part including the mixing tube mounting surface, the mixing tube flange being adjacent the second end of the mixing tube, the first end of the mixing tube connecting to the opening so that, in use, gas that flows from the first gas passage to the second gas passage has to enter the gas inlet opening of the mixing tube.

15. The mixing assembly according to claim 14, wherein the wall part includes a mixing tube opening through which the mixing tube extends when mounted in the mixing body.

16. The mixing assembly according to any one of claims 13-15 wherein the wall part has an internal side and an external side, the internal side being directed to the second gas passage and the external side being directed away from the second gas passage, mixing tube mounting surface being provided in the external side.

17. An exhaust gas recirculation system for an internal combustion engine, the engine having an air intake system with an upstream part and a downstream part, the EGR-system including:

- a mixing assembly according to any one of claims 9-16;
- the second gas passage being an air intake channel having an air intake opening and a mixture outlet opening;
- the air intake opening being connectable to the upstream part;
- the mixture outlet opening being connectable to the downstream part; and
- the first gas passage having an exhaust gas intake opening.

18. The exhaust gas recirculation system according to claim 17, the mixing assembly being included in an EGR-module, the EGR-module including at least one of:

- a throttle valve for regulating the amount of air passing the air intake channel;
- an exhaust gas recirculation valve for regulating the amount of exhaust gas introduced in the air intake channel; and
- a non-return valve arranged downstream of the exhaust gas intake opening and upstream of the mixing tube.

19. A method for mixing a first gas flow with a second gas flow the method including:

- providing a mixing assembly according to any one of claims 9-16;
- supplying the first gas to the first gas passage;

- supplying the second gas to the second gas passage;
- introducing the first gas into the mixing tube;
- dividing the first gas into multiple gas streams emanating from the mixing tube ports; and
- supplying the multiple streams of first gas into the second gas to form a mixture of first and second gas;
- discharging the mixture from the mixing assembly.

20. The method of claim 19, wherein the mixing of intake air and exhaust gas is performed by supplying the multiple streams of first gas in the flow of second gas with a first gas flow direction that is substantially perpendicular to the second gas flow direction adjacent the mixing tube.

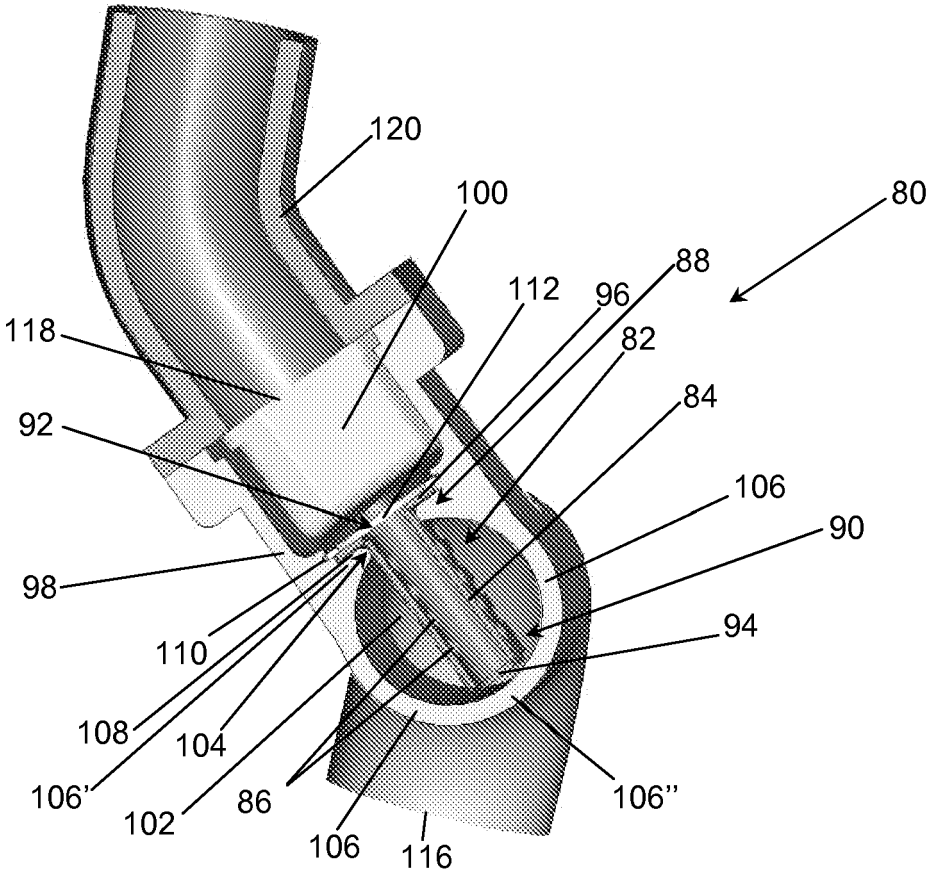
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Fig. 1

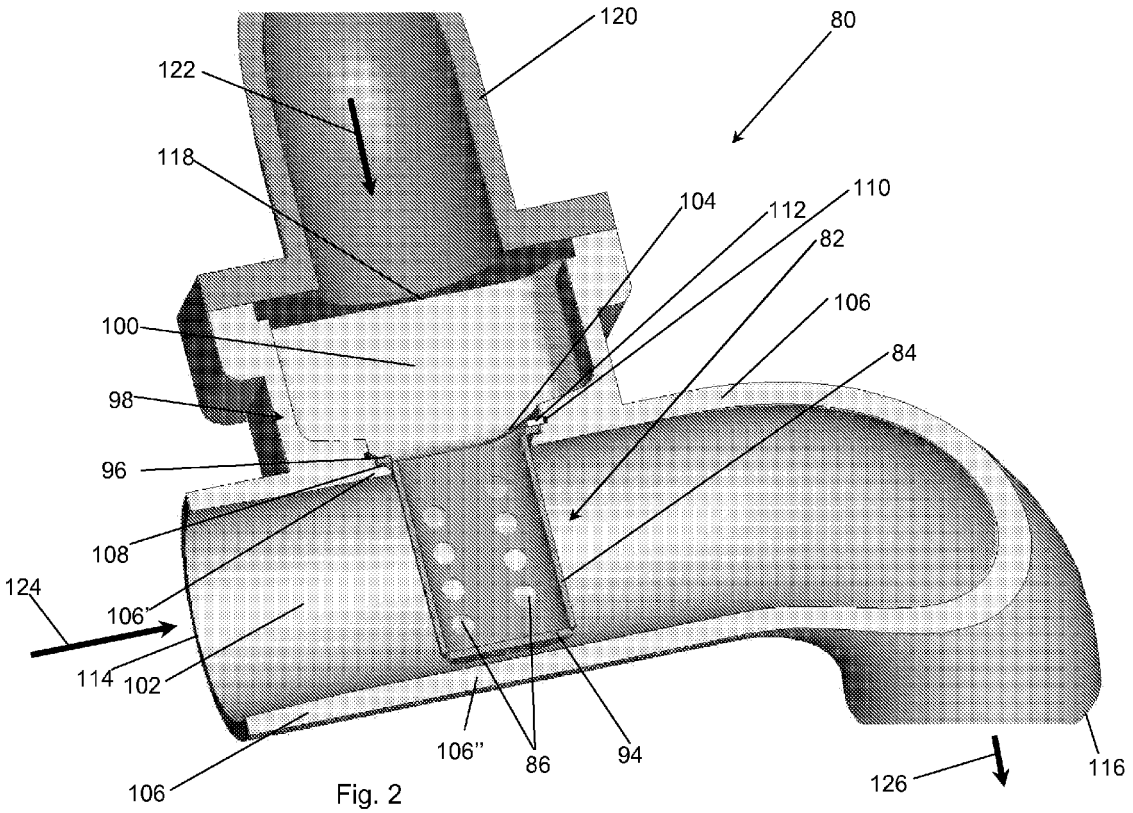
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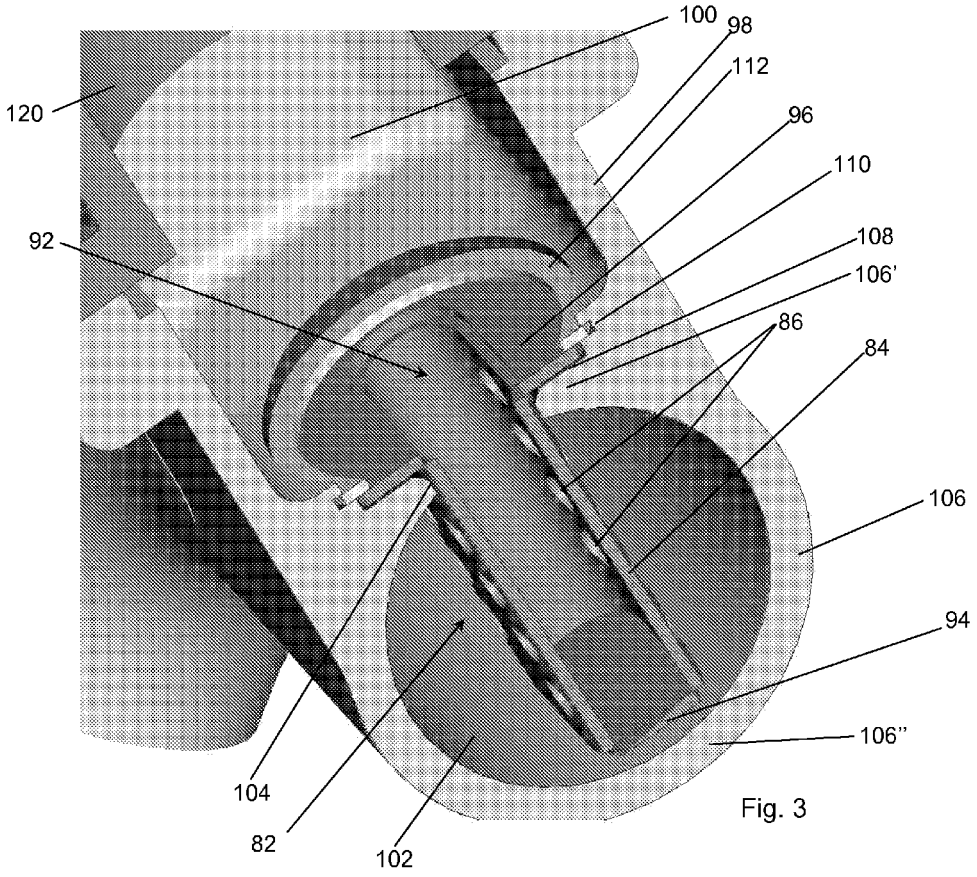
Fig. 2



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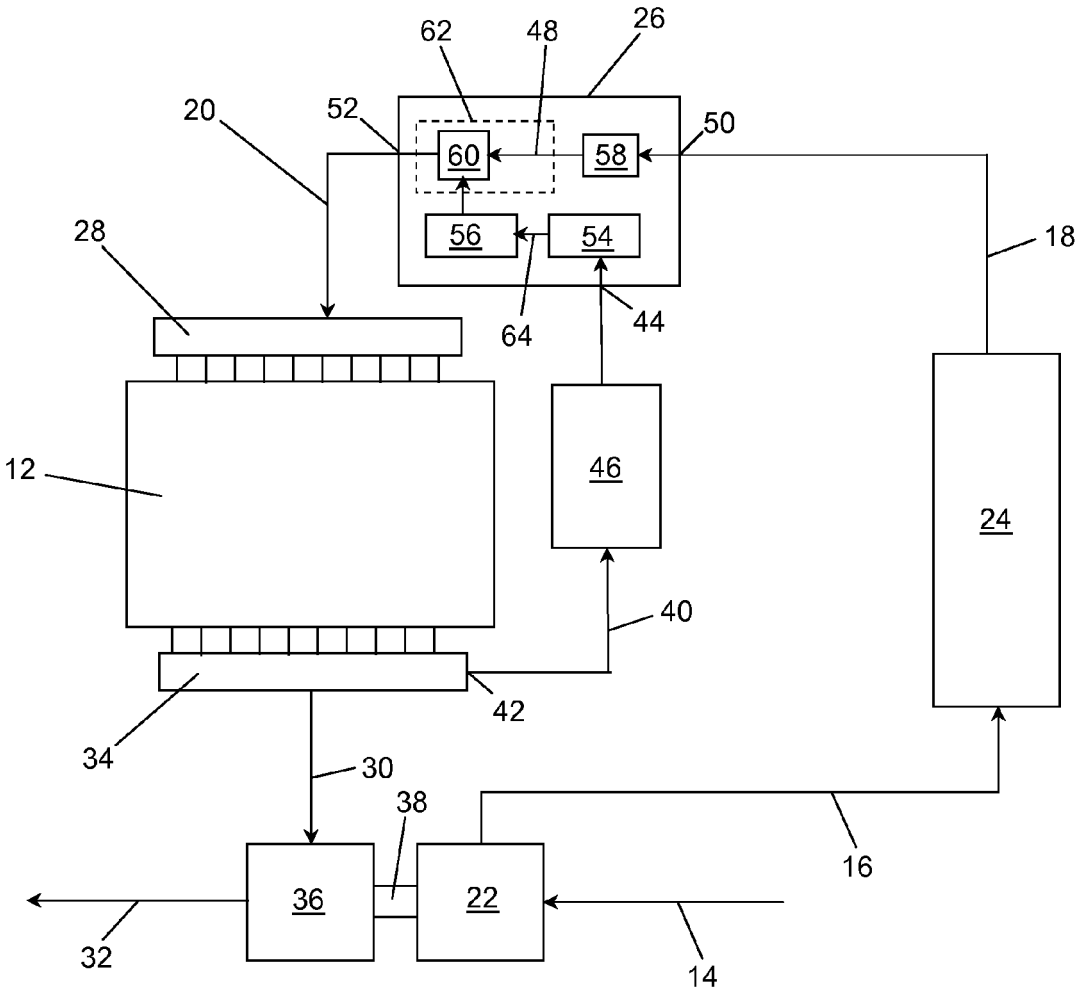
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Fig. 4

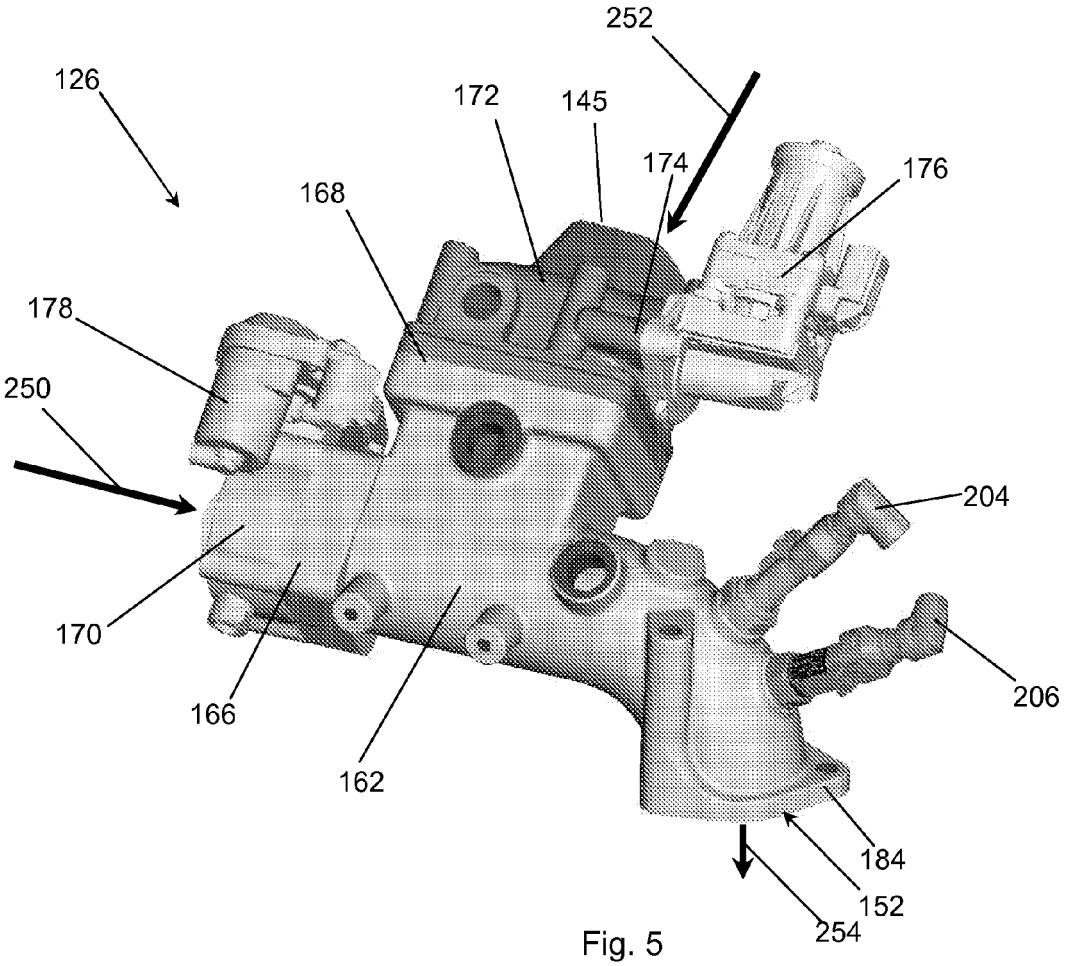
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Fig. 5

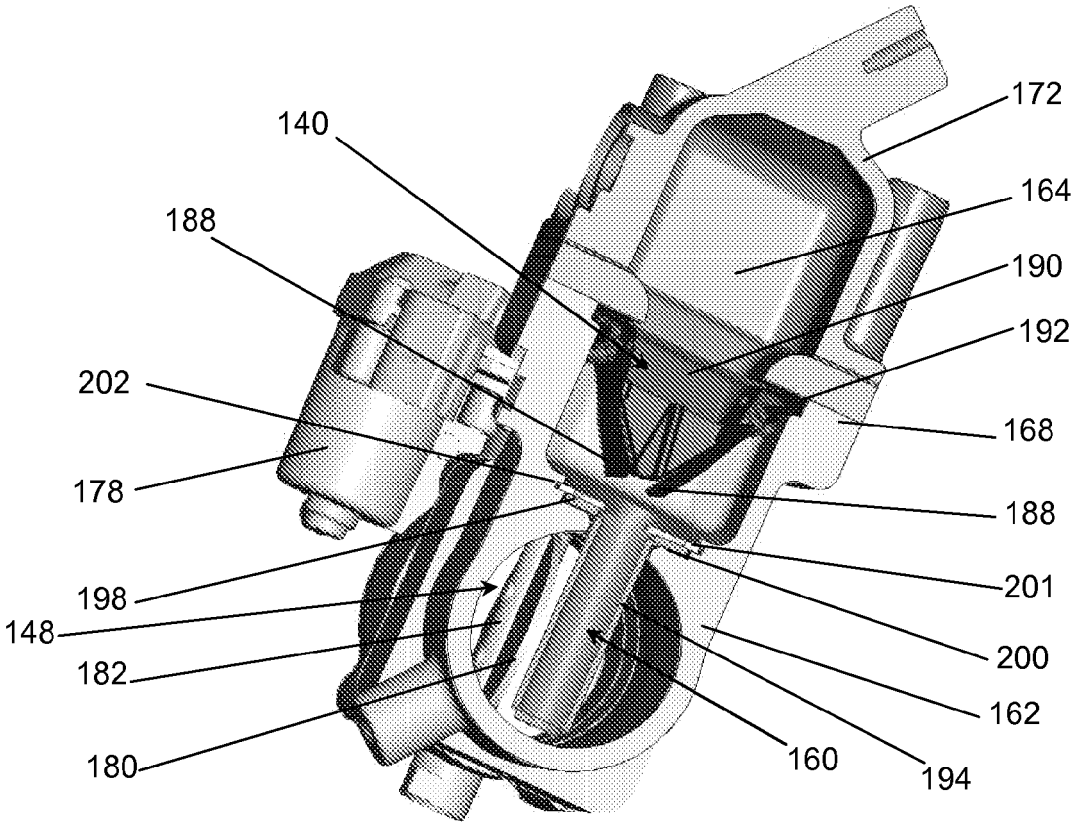
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Fig. 6

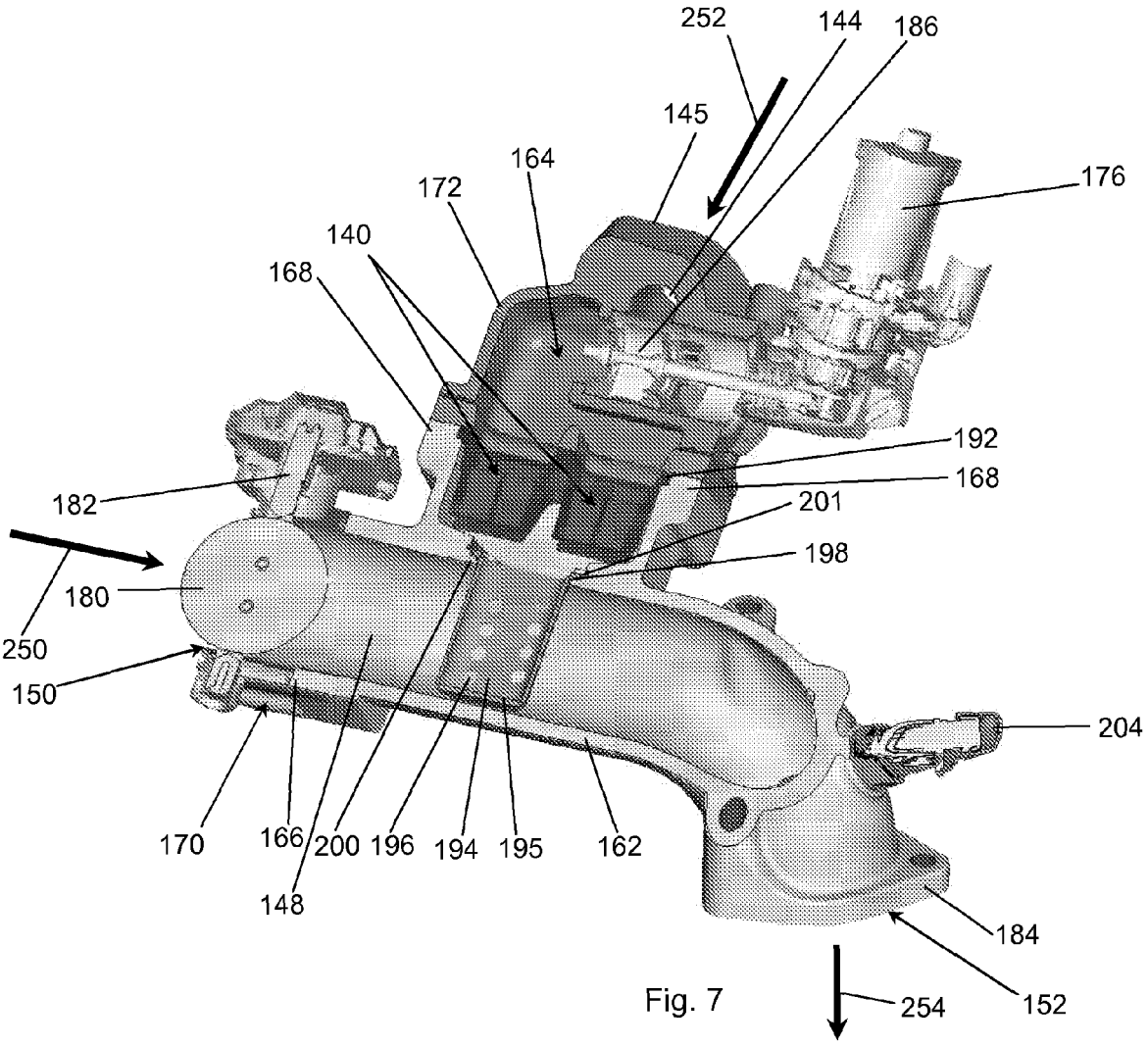
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Fig. 7

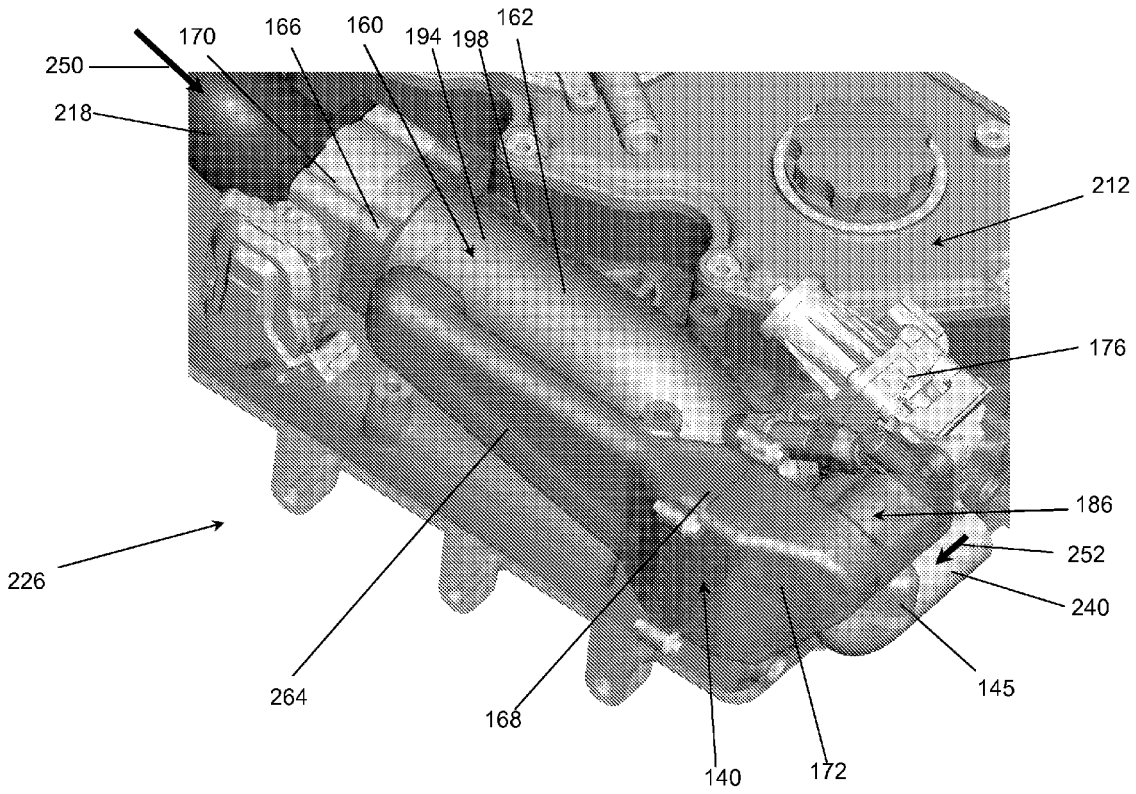
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Fig. 8

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EUROPEAN SEARCH REPORT

Application Number
EP 08 15 8172

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2006/060173 A1 (WEI PUNING [US] ET AL) 23 March 2006 (2006-03-23)	1,3-5, 9-17,19, 20	INV. F02M25/07
Y	* paragraph [0030] - paragraph [0043]; figures 1-4 *	18	

Y	DE 199 37 781 A1 (MANN & HUMMEL FILTER [DE]) 15 February 2001 (2001-02-15)	18	
A	* column 1, line 5 - column 2, line 18; figures 1-5 *	1-17,19, 20	

X	EP 1 533 512 A (MAHLE FILTERSYSTEME GMBH [DE]) 25 May 2005 (2005-05-25)	1-5, 7-17,19, 20	
	* paragraph [0015] - paragraph [0040]; figures 1-5 *		

X	DE 200 23 818 U1 (BOSCH GMBH ROBERT [DE]) 14 June 2006 (2006-06-14)	1-4,6, 11,12,17	
	* paragraph [0017] - paragraph [0033]; figures 1-3 *		
	-----		TECHNICAL FIELDS SEARCHED (IPC)
X	WO 02/070888 A (VOLVO LASTVAGNAR AB [SE]; BERTILSSON BERT-INGE [SE]; VULIN ROBERT [SE]) 12 September 2002 (2002-09-12)	1-4,6,9, 11-20	F02M
	* page 6 - page 11; figures 1-5 *		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	8 December 2008	Martinez Cebollada

CATEGORY OF CITED DOCUMENTS

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08-12-2008

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2006060173 A1	23-03-2006	NONE	
DE 19937781 A1	15-02-2001	AT 264993 T	15-05-2004
		WO 0111208 A1	15-02-2001
		EP 1203142 A1	08-05-2002
EP 1533512 A	25-05-2005	DE 10354129 A1	23-06-2005
DE 20023818 U1	14-06-2006	NONE	
WO 02070888 A	12-09-2002	AT 377147 T	15-11-2007
		BR 0207820 A	02-03-2004
		DE 60223229 T2	14-08-2008
		EP 1368565 A1	10-12-2003
		JP 2004519576 T	02-07-2004
		SE 522310 C2	03-02-2004
		SE 0100723 A	03-09-2002
		US 2004112345 A1	17-06-2004

EPO FORM P0459

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Patent documents cited in the description

- EP 0869275 A **[0002]**