Abstract:
One embodiment of the invention includes a product including at least one module integrating multiple engine breathing system components including at least one of an exhaust air cooler, a low-pressure EGR valve, an exhaust throttle valve, a low-pressure EGR mixer, and a particulate separator into a common housing. The module may be including in a low pressure exhaust gas recirculation (EGR) path and/or a high pressure EGR path.
as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(Ui))

of inventorship (Rule 4.17(iv))

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TECHNICAL FIELD

The field to which the disclosure generally relates includes components for engine breathing systems, breathing system, and methods of making and using the same.

BACKGROUND

Current and future emissions requirements for diesel and gasoline engines in Europe, US and most foreign markets will require engine concepts capable of achieving low NOx and low particulate matter emissions while at the same time meeting requirements for low-cost systems and packaging needs.

FIG. 1 is the schematic illustration of a prior art diesel engine breathing system 64 using a single-stage turbo charger. Such a system includes a high-pressure loop 68 including a first EGR path 15, first EGR valve 16, and first EGR cooler 17. The system 64 includes a low pressure exhaust gas recirculation (EGR) loop 66, including a second EGR path 7, second EGR valve 8, a second cooler 9. Exhaust gas is generated by an engine 1 and exits through an exhaust gas manifold 2. The exhaust gas from the exhaust gas manifold 2 can be directed in two directions. In the first direction, the gas may flow through
the high pressure loop 68 including the first EGR path 15, the first EGR valve 16 and the first EGR cooler 17 into the intake manifold 14. To create enough EGR flow through the first EGR path 15 and first EGR cooler 17, the first EGR valve 16 can be adjusted accordingly. If the first EGR valve is fully opened and more flow through the first EGR path 15, and first EGR cooler 17 is required, the intake first throttle valve 13, which is commonly a flapper-type valve, can be closed gradually. Alternatively, in the second direction, the exhaust may pass through the variable turbine 3 and introduced into an emission control device such as a diesel particulate filter 4, catalyst or combination filter/catalyst (or no device) where the gas is cleaned of various constituents that may include soot, carbon monoxide or hydrocarbons. After flowing through the emission device 4 and the exhaust throttle 5 the exhaust gas then exits through the exhaust pipe 6. The second EGR valve 8 can be opened to allow flow through a second EGR cooler 9 and through the second EGR path 7 back to the intake duct 10. The exhaust throttle 5 can be adjusted accordingly to support the flow through the second EGR path 7, second EGR valve 8 and second EGR cooler 9 as desired.

[0005] In the embodiment shown in FIG. 2, fresh air is introduced through the intake duct 10 and mixes with the EGR gas coming from the low-pressure second EGR path 7 which may include the second EGR valve 8, second EGR cooler 9, is boosted by the compressor 11, is cooled by the air charge cooler 12, flows through the throttle valve 13, before it mixes with EGR gas from the high-pressure first EGR path 15 including the first EGR valve 16 and first EGR cooler 17 before flowing into the intake manifold 14. Other engine layouts may include
only one EGR loop or multiple turbo chargers. With multiple turbocharges, EGR paths may be placed between turbochargers to provide a mid pressure EGR path.

[0006] The low-pressure first EGR cooler 7 is typically located and bolted into the conduit of the low-pressure first EGR path 7. Similarly, the second EGR valve 8 may be bolted into conduit of the second EGR path 7. The exhaust throttle valve 5 likewise may be bolted into the exhaust pipe 6.

[0007] Similarly, the high-pressure first EGR cooler 17 may be bolted into the conduit of the first EGR path 15. The high-pressure first EGR valve 16 may be bolted into conduit making up the first EGR path 15. The air intake throttle valve 13 is typically bolted into the air intake duct 10 in a location upstream of the high-pressure first EGR path 15.

SUMMARY OF EXEMPLARY EMBODIMENTS OF THE INVENTION

[0008] One embodiment of the invention includes a product including at least one module integrating multiple engine breathing system components including at least one of an exhaust cooler, a low-pressure EGR valve, an exhaust or air intake throttle valve, an EGR mixer, or a particulate separator into a common housing. The module may be included in a low EGR path, a high pressure EGR path or a mid pressure EGR path.

[0009] Other exemplary embodiments of the invention will become apparent from the detailed description provided hereinafter. It should be understood that the detailed description and specific examples, while disclosing
exemplary embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention.

**BRIEF DESCRIPTION OF THE DRAWINGS**

[0010] Exemplary embodiments of the invention will become more fully understood from the detailed description and the accompanying drawings, wherein:

[0011] FIG. 1 is a schematic illustration of a prior art engine breathing system.

[0012] FIG 2 is a schematic illustration of an engine breathing system according to one embodiment of the invention.

[0013] FIG. 3 is a perspective view of a module including an EGR valve and exhaust throttle valve combination, EGR cooler and EGR mixer according to one of embodiment of the invention.

[0014] FIG. 4 is a schematic illustration of an engine breathing system including a module according to one embodiment of the invention.

[0015] FIG. 5 is a partially exploded perspective view of a first and second module according to one embodiment of the invention.

[0016] FIG. 6 is a partially sectioned view of the first and second modules of FIG. 5, in assembled form, according to one embodiment of the invention.

**DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS**
The following description of the embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

One embodiment of the invention includes a product including at least one module integrating multiple engine breathing system components including at least one of an exhaust cooler, an EGR valve, an exhaust or air intake throttle valve, an EGR mixer, or a particulate separator into a common housing. The module may be included in a low EGR path, a high pressure EGR path or mid pressure EGR path.

Referring now to FIG. 2, one embodiment of the invention may include a product 100 including a module 20a that may be utilized to form at least a portion of a low-pressure second EGR path 7 extending from the exhaust side 70 of the engine breathing system 64 toward the air intake side 72. Such a module 20a may include a second EGR gas cooler 9 and at least one of a second throttle valve 5, second EGR valve 8, mixer 32 (FIG. 6) and an emission device 4 such as a particulate filter, catalyst, filter/catalyst combination. The module 20a may include a combined EGR valve and throttle valve 31 (FIG. 3), or a single actuator 40 (FIG. 5) and a single valve 38 that functions as both an EGR valve 8 and a throttle valve 5 or the module may include a separate EGR valve 8 and throttle valve 5 which may be actuated either by one or two actuators. In another embodiment an EGR valve 8 and at least one of a throttle valve 5 and exhaust gas cooler 7 may be combined in a single housing module 20b which forms a part of the exhaust pipe 6, air intake duct 10 and extends therebetween.
An engine may burn any of a variety of fuels, including but not limited to diesel or gasoline.

[0020] FIG. 3 illustrates another embodiment of the invention which may include an EGR mixer constructed and arranged to mix relatively hot EGR gas and relatively cool intake air prior to flowing into the compressor. The mixing of hot and cold gases prevents potential damage of the compressor associated with relatively hot and cold gases hitting the compressor at different locations. The EGR gas and air intake gas are mixed so that the mixed gas hits that compressor at any one time is within a relatively narrow temperature range. Details of illustrative embodiments of the EGR mixer are set forth hereafter. In the embodiment illustrated in FIG. 3, the EGR valve and exhaust throttle valve 9 are contained in a first module and the EGR cooler and EGR mixer are combined in a second module that are connected together for example by bolting together flanges of the first and second modules.

[0021] Referring now to FIG. 4, in another embodiment of the invention an EGR valve 8 and at least one of a throttle valve 5 or a gas cooler 9 are combined in a common housing to form a first module. In this embodiment, the throttle valve 5 is constructed and arranged to function as an air intake throttle valve and the module forms a portion of the air intake duct. In another embodiment, an EGR valve 8 and at least one of an air intake throttle 5' and exhaust cooler 9
are provided in a common housing to form a module 2Od which forms a portion of the air intake duct 10 and extends therefrom to the exhaust pipe 6.

Referring now to FIG. 5, one embodiment of the invention includes a first module 22 connected to a second module 24. In one embodiment, the first module 22 includes a first housing 26 including a first conduit portion 74 and associated first opening 28, second conduit portion 76 and associated second opening 30, and third conduit portion 78 and associated third opening 32 to facilitate the flow of gas through the housing 26. The first housing 26 may also include a central bore 34 constructed and arranged to receive a shaft 36 which may be connected to a valve plate 38 at one end and an actuator 40 at the other end for 36 and the valve plate 38. In one embodiment, the valve plate 38 may have a half-moon configuration constructed and arranged to selectively open and close each of the first opening 28 and second opening 30. In other embodiments, the valve plate 38 may be a cylindrical disc having openings or windows formed therein constructed and arranged to control the flow of gas through the first opening 28, second opening 30 and third opening 32 in an independent or dependent manner as desired. The actuator 40 may be any type of actuator including electric, pneumatic or hydraulic. The first housing 26 may also include a cooling fluid passage 52 (FIG. 6) communicating with at least a first cooling fluid port 42 constructed and arranged to allow the flow of cooling fluid in or out of the housing 26. The first housing 26 may include a flange 44 constructed and arranged to allow the housing 26 to be bolted to the second module 24.
The second module 24 may include a second housing 44 constructed and arranged to form a portion of the air intake duct 10. The second module 24 may also include an exhaust gas cooling device 46 which may include an exhaust gas conduit portion 46a which in one embodiment may include one or a plurality of bundled tubes through which the exhaust gas flows a portion of the housing 44 may form a shell 46b through which cooling fluid may flow to cool the exhaust gas flowing through the exhaust gas conduit portion 46a. The housing 44 may also include a second liquid coolant port 50 to allow the flow of coolant in or out of the housing 44. In one embodiment, the cooling channel 52 formed in the housing 26, the shell 46b form a continuous liquid cooling flow path for cooling fluid to flow through both the first module 22 to cool the valve components including the valve plate 38, shaft 36 and actuator 40 and to cool the exhaust gas flowing through the exhaust gas conduit portion 46a of the second module 24. The second module 24 may include an EGR mixer 32 which will be described in greater detail hereafter which is positioned in the housing and constructed and arranged to mix the EGR gas and intake air prior to reaching the compressor 11. The second housing 44 may include a second flange 45 which may be bolted to the first flange 43 of the first housing 26. The second housing 44 may also include a fourth conduit portion 80 and a fifth conduit portion 82 to facilitate the flow of gases through the second housing 44. The first housing 26 and second housing 44 may each be a casting or metal fabrication.

FIG. 6 illustrates the product 100 of FIG. 5 in assembled form with a section removed. As previously stated, the first housing 26 may include a
liquid coolant channel 52 formed therein in a variety of designs constructed and arranged to cool the valve plate 38, shaft 36, actuator 40 and/or housing 26. In one embodiment, the first housing 26 includes a second cooling fluid port 54 to allow the flow of coolant in or out of the first housing 26.

[0025] The second module 24 may include an EGR mixer 32 for mixing EGR gas and air intake gas flowing through the second module 24 and into the compressor 11. In one embodiment, the EGR mixer 32 includes a generally tubular portion 60 having a plurality of slots 62 therein to define baffles 90. Exhaust gas flows around the baffles 90, through the slots 62 and into the inner portion of the tubular portion 60. In one embodiment the tubular portion 60 may be a portion of the fourth conduit portion 80 or fifth conduit portion 82. Intake air also flows through the tubular portion 60. In one embodiment, exhaust gas flows through the exhaust gas conduit 46a into a mixing chamber 56 concentrically positioned with respect to the tubular portion 60 and so that exhaust gas can flow from the mixing chamber 56 and is evenly distributed through the slots 62, into the tubular portion 60 to be mixed with air and then into the compressor 11.

[0026] The second module 24 may include a filter means 84, for example a particulate separator such as a metal or high temperature screen, filter mesh or material to prevent particles or debris from damaging the compressor wheel 92 of the compressor 11. A third liquid coolant passage 88 may be provided about the mixer 32 and mixing chamber 56 to further cool the exhaust gas. The filter means 84 may also be a centrifugal type separator located in the interface between the housing and the mixer 32. The coolant passages 86, 52, 88 may
provide one continuous connected coolant passage or the first, second and third coolant passage 86, 52, 88 may be separate from each other and have separate heat exchangers to remove heat from the coolant.

[0027] In another embodiment the EGR valve 8, EGR gas cooler 9, exhaust or air intake throttle valve 5, mixer 32 and particulate separator may be contained in a single, contiguous housing. In other embodiments, various combinations of these components may be combined in a module and used in either or both of the low pressure path 7 or high pressure path 15.

[0028] In another embodiment of the invention, the EGR gas cooler may be formed by casting a heat exchanger device in the first housing 26 or second housing 44 to provide a plurality of exhaust gas flow channels and cooling fluid flow channels. In one embodiment, an exhaust gas channel and an adjacent liquid cooling channel may be separated by a cast-in-place wall. Exhaust gas headers and liquid coolant headers may be also cast into either of the housings 26, 44.

[0029] In another embodiment, the housings 22, 44 may be cast to provide a plurality of fins so that the EGR valve plate 38, shaft 36 and actuator 40 may be air cooled or the exhaust gas may be air cooled by blowing air over the finned portions of the housings 26, 44.

[0030] In another embodiment, the modules 22 and 24 may be connected together for easy de-coupling using quick connections known to those skilled in the art.
Another embodiment of the invention includes a method of cooling the EGR valve 38, shaft 36 and actuator 40 and an exhaust gas cooler 7 comprising flowing cooling fluid through the housing of the EGR valve and then through a heat exchanger having exhaust gas flowing therethrough.

In another embodiment, the direction of the flow of cooling fluid is reversed so that the cooling fluid flows first through a heat exchanger having exhaust gas flowing therethrough and then the cooling fluid flows through the housing 26 of the EGR valve 8.

In yet another embodiment, the EGR valve 8 and the exhaust gas cooler 9 are cooled by separate liquid coolant fluid systems.

The above description of embodiments of the invention is merely exemplary in nature and, thus, variations thereof are not to be regarded as a departure from the spirit and scope of the invention.
CLAIMS

What is claimed is:

1. A product comprising:

an exhaust gas recirculation device comprising a first module or a second module;

the first housing having first, second and third conduit portions, a heat exchanger portion, the first conduit portion configured to receive exhaust gases produced by an internal combustion engine, the second and third conduit portions in communication with the first conduit and configured to receive at least a portion of the exhaust gases from the first conduit portion, the heat exchanger portion in communication with the third conduit portion, the heat exchanger portion configured to receive the exhaust gases from the third conduit portion and decrease a temperature of the exhaust gases therein;

a first valve coupled to the first housing, the first valve configured to move between at least first and second positions, the first valve operably coupled to the heat exchanger to flow exhaust gas therethrough; and

an actuator coupled to the first valve, the actuator configured to move the first valve to the first position such that at least a portion of the exhaust gases is routed through at least one of the second or third conduit.

2. The product as recited in claim 1, wherein the first housing is made of a one-piece casting or fabrication.
3. The product as recited in claim 1, wherein the housing has first, second and third openings, the first opening in communication with an end portion of the first conduit portion opposite the second and third conduit portions, the first opening configured to receive the exhaust gases from the internal combustion engine, the second opening in communication with an end portion of the second conduit portion opposite the first conduit portion, the third opening in communication with an end portion of the third conduit portion opposite the first conduit portion.

4. The product as recited in claim 1, further comprising a second valve coupled to the second conduit portion, the second valve configured to move between third and fourth positions, such that at least a portion of the exhaust gases are routed through the second conduit in response to the second valve being move toward the third position, and the second valve prevents exhaust gases from being routed through the second conduit in response to the second valve being moved toward the fourth position.

5. The product as recited in claim 4, wherein the actuator is coupled to the second valve, the actuator being configured to move the second valve between the third and fourth positions.
6. The product as recited in claim 5, wherein the actuator is further configured to move the second valve between the third and fourth positions in response to the actuator moving the first valve between the second and first positions, respectively.

7. The product as recited in claim 1, wherein the heat exchanger portion has a shell and at least one tube, the shell has a first liquid coolant passage with the at least one tube disposed therein, the at least one tube in communication with the third conduit portion and configured to receive the exhaust gases therefrom, and the first coolant passage configured to route a coolant therethrough such that the coolant decreases a temperature of the exhaust gases in the at least one tube.

8. The product as recited in claim 7, wherein the housing defines a second coolant passage disposed adjacent to the first conduit portion, the second coolant passage configured to route the coolant therethrough and decrease a temperature of at least the first valve or housing, and wherein the first coolant passage of the shell in communication with the second coolant passage and configured to receive the coolant therefrom.

9. The product as recited in claim 7, wherein the housing defines a second coolant passage adjacent to the third conduit portion, the second coolant passage configured to route the coolant therethrough and
decrease a temperature of the exhaust gases in the third conduit portion, the first coolant passage of the shell in communication with the second coolant passage and configured to receive the coolant therefrom.

10. The product as recited in claim 7, wherein the housing further includes a mixing chamber portion and fourth and fifth conduit portions, the mixing chamber portion in communication with the heat exchanger portion and configured to receive the cooled exhaust gases therefrom, the mixing chamber in communication with the fourth conduit portion and configured to receive ambient air therefrom, and the fifth conduit portion in communication with the mixing chamber portion and configured to route an ambient air and exhaust gas mixture to the internal combustion engine.

11. The product as recited in claim 10, wherein the housing is made of a one-piece casting or fabrication.

12. The product as recited in claim 10, wherein the product is made of the first module and the second module coupled to the first module, each of the first and second modules made of one-piece casting or fabrication, the first module defining the first, second and third conduit portions, and the second module defining the mixing chamber portion and the fourth and fifth conduit portions.
13. The product as recited in claim 10, wherein the housing defines a third coolant passage adjacent to the mixing chamber portion, the third coolant passage configured to route the coolant therethrough and decrease a temperature of the exhaust gases in the mixing chamber portion, the third coolant passage in communication with the shell and configure to receive the coolant therefrom.

14. The product as recited in claim 10, wherein the housing defines a third coolant passage adjacent to the fifth conduit portion, the third coolant passage configured to route the coolant therethrough and decrease a temperature of the exhaust gases in the housing, the third coolant passage in communication with the shell and configure to receive the coolant therefrom.

15. The product as recited in claim 10, wherein the housing has a series of baffle members extending into the mixing chamber.

16. The product as recited in claim 1, further comprising a screen member or filter mesh disposed in the housing, the screen member or filter mesh configured to collect particulates or debris from the exhaust gases.

17. A method of cooling engine breathing system components and exhaust gases from an internal combustion engine, the method comprising:

   routing exhaust gases through a first conduit portion of a housing;
actuating a first valve to move between first and second positions such that the first valve routes at least a portion of the exhaust gases from the first conduit portion to at least one of a second conduit portion or a third conduit portion of the housing, respectively, the second and third conduit portions in communication with the first conduit portion;

routing exhaust gases from the third conduit portion into a heat exchanger, the heat exchanger in communication with the third conduit portion;

decreasing a temperature of the exhaust gases in the heat exchanger;

routing liquid coolant about the first valve, such that the coolant decreases a temperature of the first valve; and

routing liquid coolant through the heat exchanger.

18. The method as recited in claim 17 wherein the routing of the coolant is through a continuous coolant channel path about the valve and through the heat exchanger.

19. The method as recited in claim 17 wherein the routing coolant is through separate coolant channels comprising a first channel about the valve and a second channel through the heat exchanger.

20. The method as recited in claim 18 wherein the continuous coolant channel further comprises a portion about a mixing chamber portion of
the housing constructed and arranged to at least mix the exhaust gases exiting the heat exchanger.

21. A product comprising:
    at least one module integrating multiple engine breathing system components including at least one of an exhaust gas cooler,
    an exhaust or air intake throttle valve,
    an EGR mixer or a particulate separator in a common housing.

22. A product comprising:
    an exhaust gas recirculation device comprising a housing,
    a heat exchanger portion received in the housing,
    a combination exhaust gas recirculation valve and throttle valve having a single valve plate construction and arranged to control the flow of gas through a first opening in the housing to at least one of a second opening or third opening in the housing.

23. A product as set forth in claim 22 wherein the housing comprises a first coolant passage associated with the heat exchanger portion and a second coolant passage constructed and arranged to cool at least one of the valve plate or housing.
24. A product as set forth in claim 23 wherein the first coolant passage and second coolant passage are connected together to provide a continuous coolant flow path about the valve and heat exchanger portion.

25. A product as set forth in claim 23 wherein the first coolant passage and the second coolant passage are separated from each other.

26. A product comprising:
   a housing,
   a heat exchanger at least a portion of which is received in the housing and constructed and arranged to exchange heat between exhaust gas flowing through the heat exchanger and a liquid coolant flowing through the heat exchanger,
   an exhaust gas mixer received in the housing constructed and arranged to evenly distribute exhaust gas into an air intake conduit.

27. A product as set forth in claim 26 wherein the housing comprises a first coolant passage associated with the heat exchanger and an other coolant passage constructed and arranged to cool exhaust gas in the exhaust gas mixer.

28. A product as set forth in claim 27 wherein the first coolant passage and the other coolant passage are connected together to provide a continuous coolant flow path through the housing.
29. A product as set forth in claim 27 wherein the first coolant passage and the other coolant passage are separate and not connected together.

30. A product as set forth in claim 26 wherein the housing is made of a one-piece casting or fabrication.