(12) UK Patent (19) GB (11) 2564689 (13) B

(45) Date of B Publication 14.08.2019

(54) Title of the Invention: An EGR apparatus with a turbocharger and an EGR compressor

(51) INT CL: ***F02M 26/34*** (2016.01) ***F02B 37/007*** (2006.01) ***F02B 37/12*** (2006.01) ***F02B 37/16*** (2006.01) ***F02B 37/18*** (2006.01) ***F02M 26/07*** (2016.01) ***F02M 26/08*** (2016.01) ***F02M 26/09*** (2016.01)

(21) Application No: **1711652.6**

(22) Date of Filing: **20.07.2017**

(43) Date of A Publication **23.01.2019**

(56) Documents Cited:
US 5937651 A
JP 3627470

(58) Field of Search:
As for published application 2564689 A viz:
INT CL **F02B, F02M**
Other: **WPI, EPODOC**
updated as appropriate

Additional Fields
INT CL **F02C, F04D**
Other: **None**

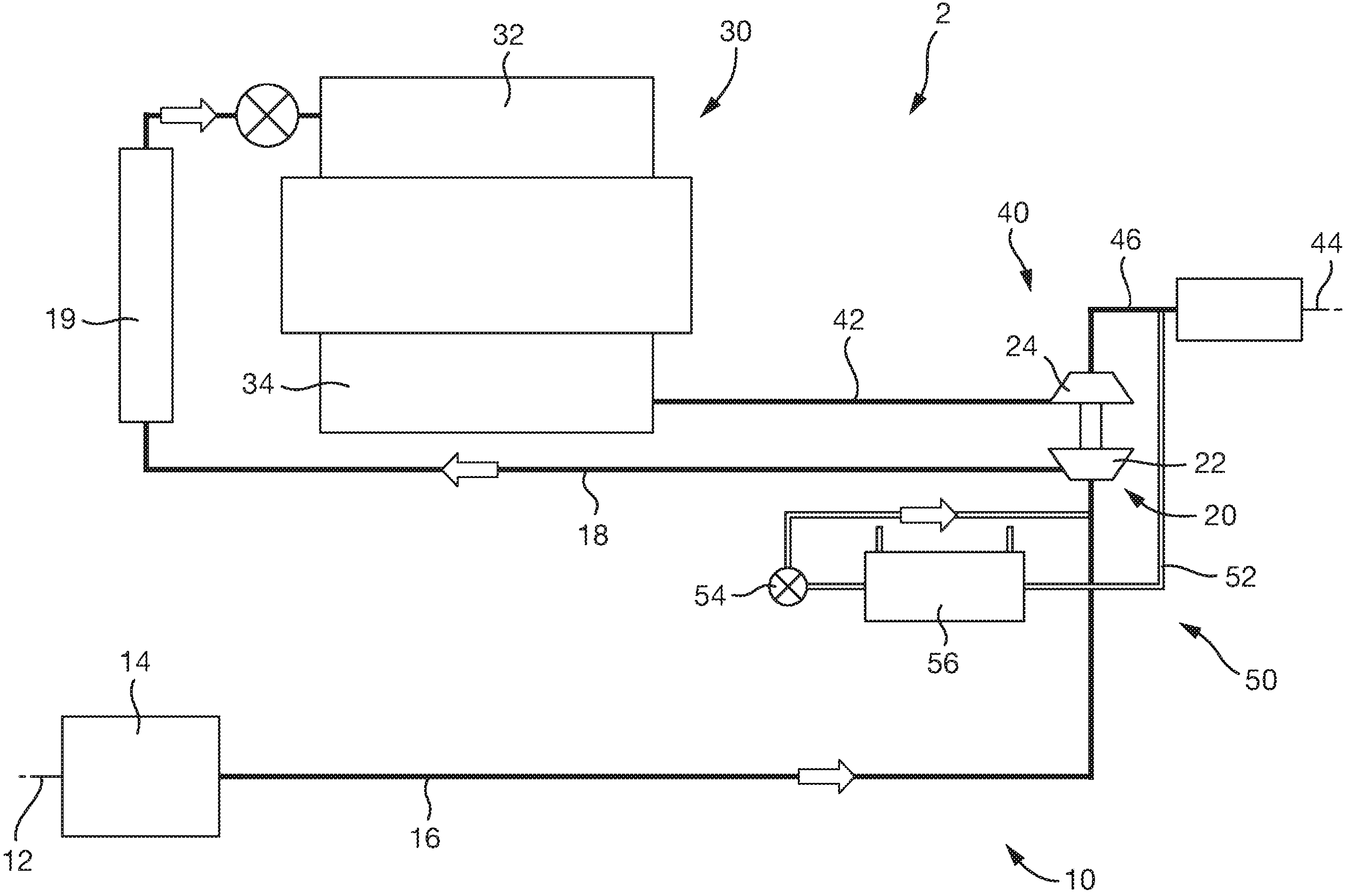
(72) Inventor(s):
Jonathan Edward Caine
Sam Penzato
Steve Johnson
Paul Nigel Turner

(73) Proprietor(s):
Ford Global Technologies, LLC
(Incorporated in USA - Delaware)
Fairlane Plaza South Suite 800,
330 Town Center Drive, Dearborn 48126, Michigan, United States of America

(74) Agent and/or Address for Service:
Haseltine Lake Kempner LLP
5th Floor Lincoln House, 300 High Holborn, London, WC1V 7JH, United Kingdom

GB 2564689 B

Fig. 1



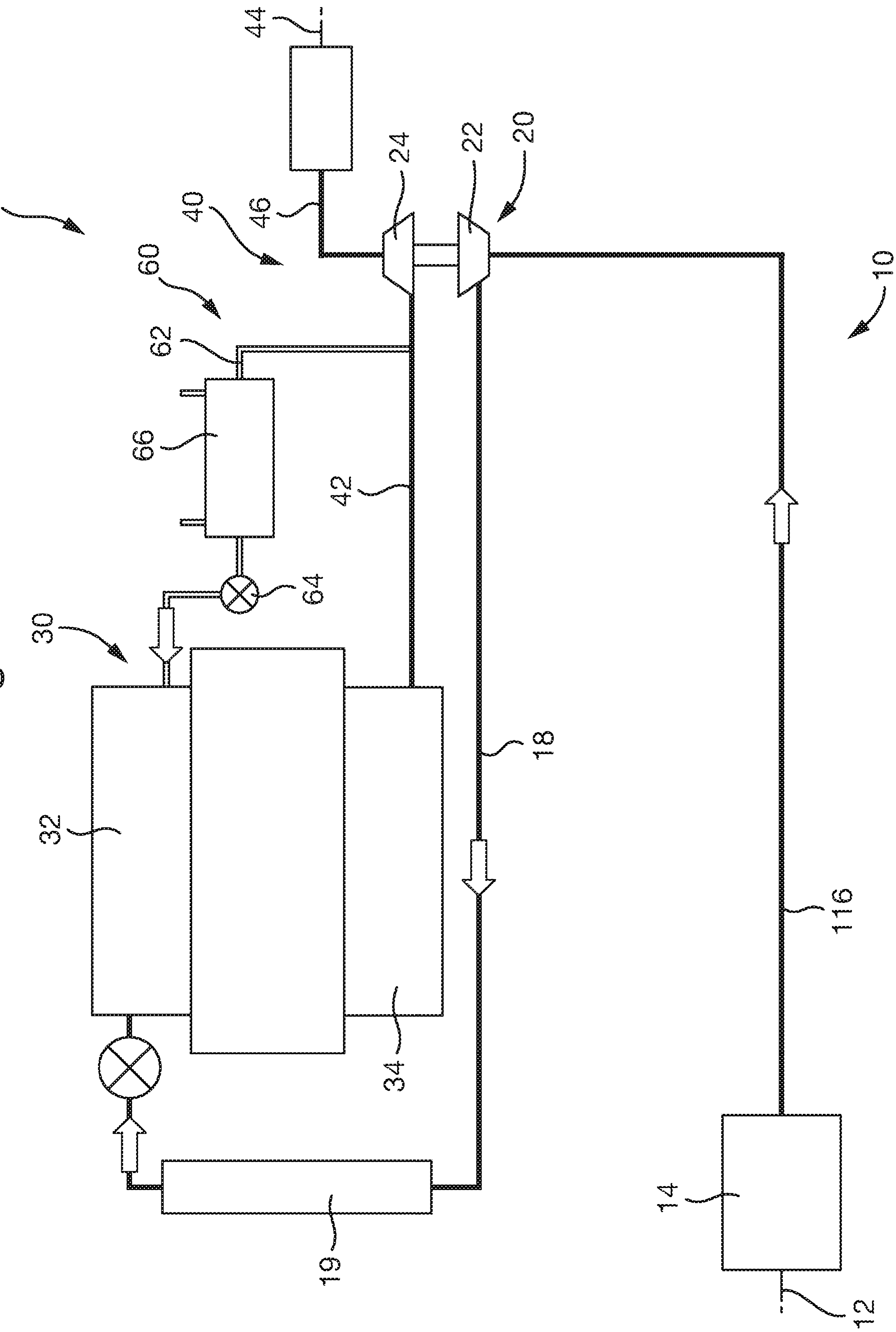
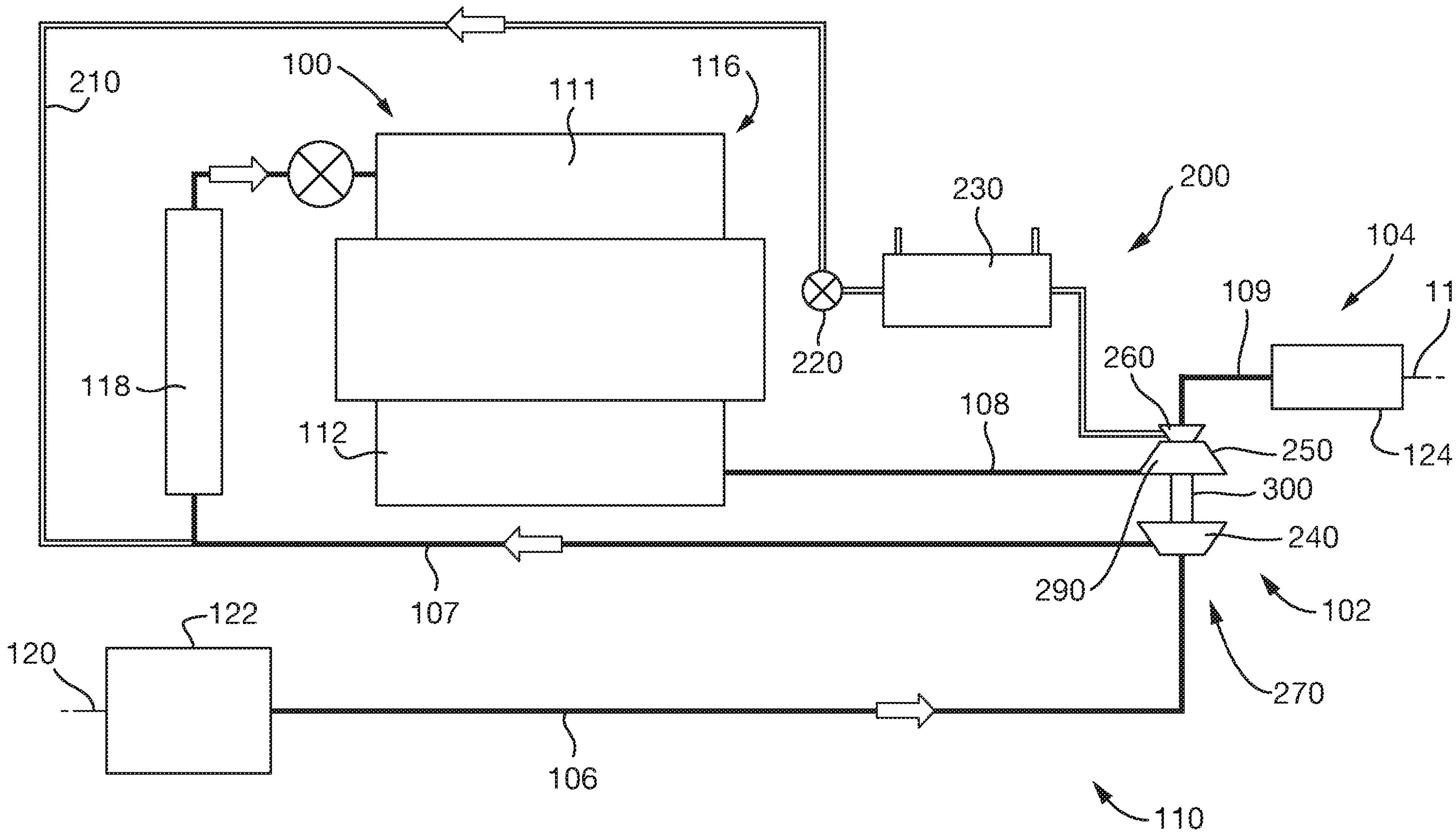


Fig. 2

Fig. 3



100
111
116
210
118
112
220
230
200
104
109
114
260
108
250
300
240
124
290
102
107
122
120
270
106
110

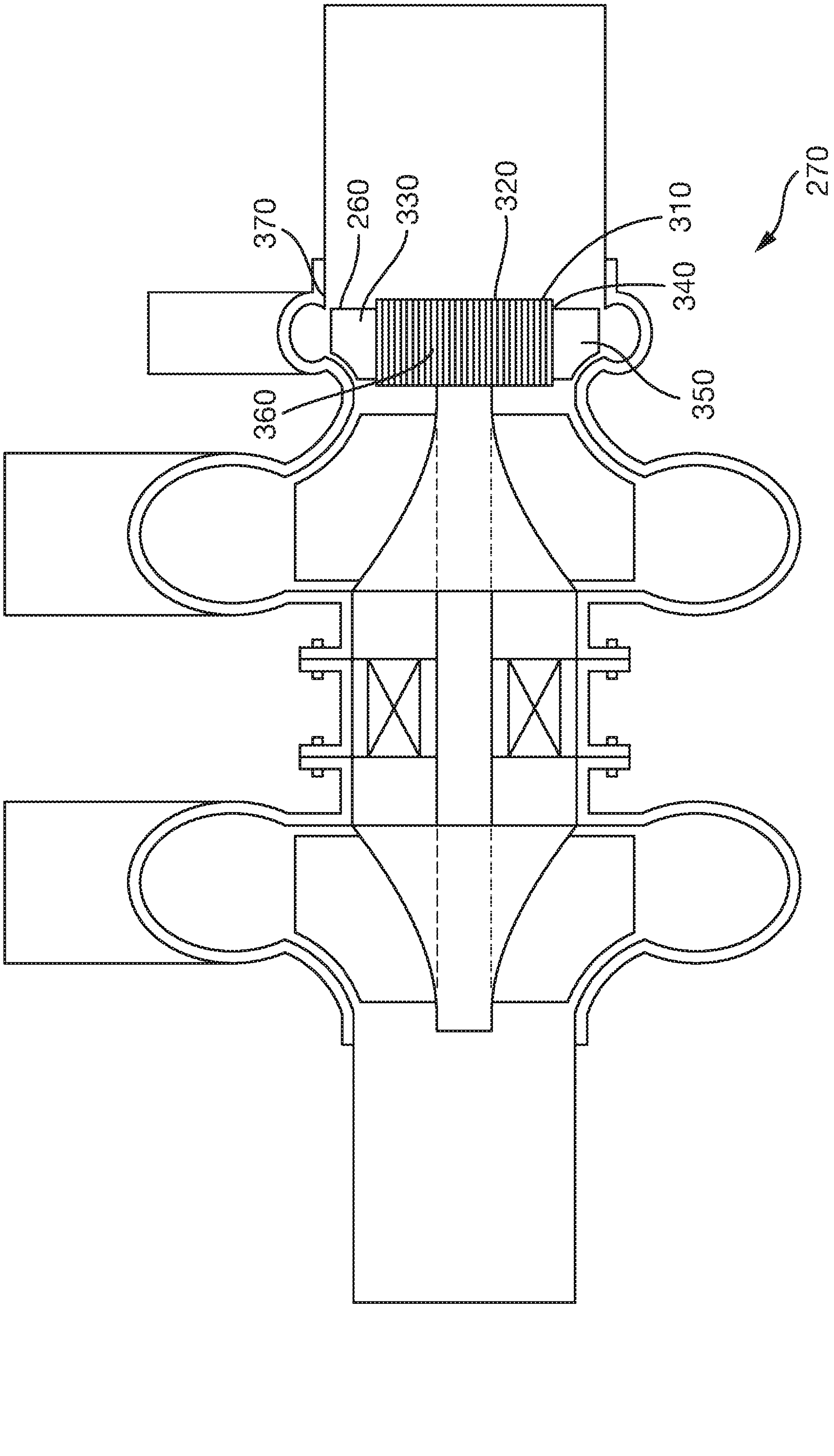


Fig. 4

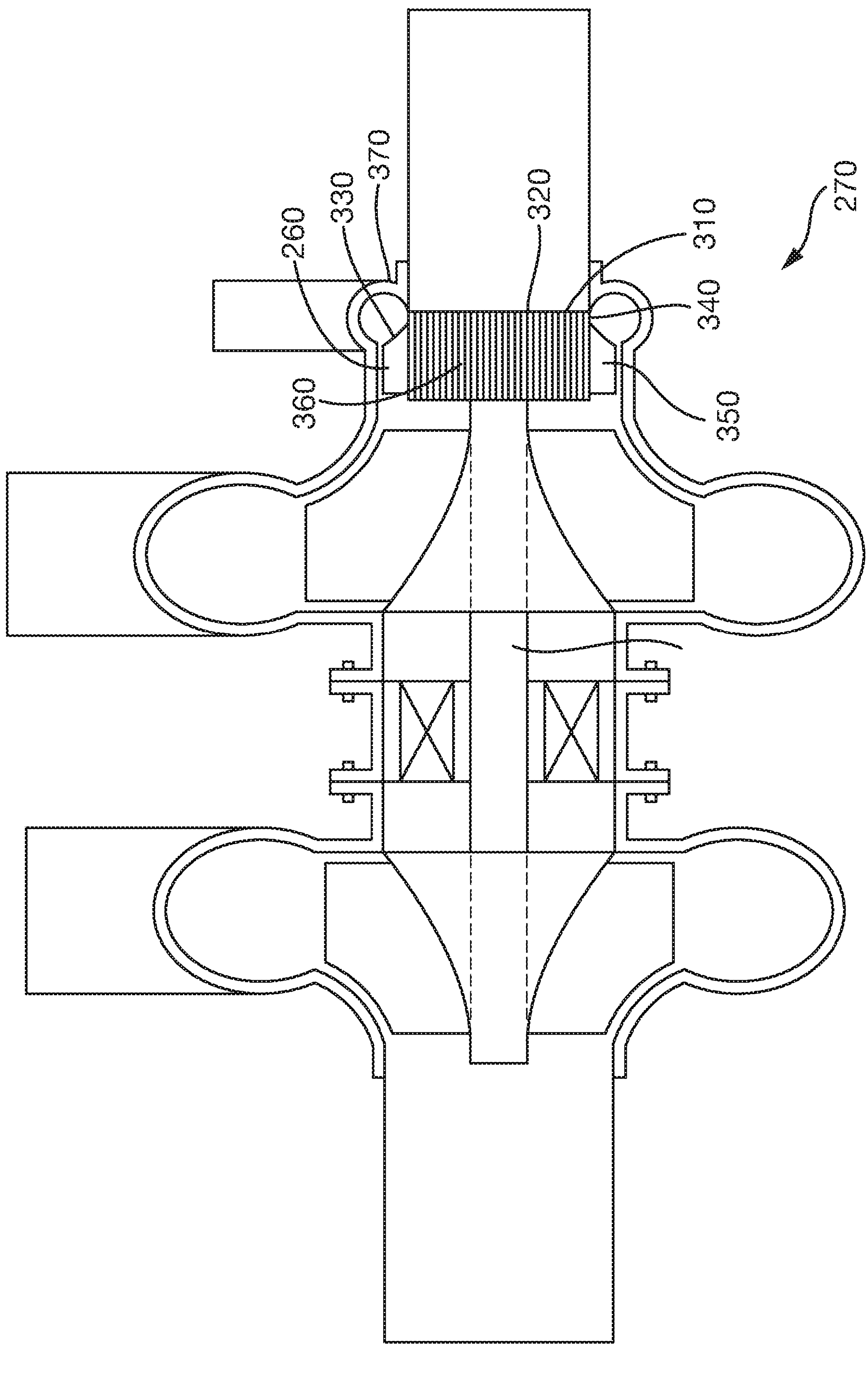


Fig. 5

An EGR apparatus with a turbocharger and an EGR compressor

Technical Field

The present disclosure relates to an Exhaust Gas Recirculation (EGR) system with improved performance, and is particularly, although not exclusively, concerned with an exhaust gas recirculation system for a motor vehicle

Background

With reference to Figure 1, an engine assembly 2 for a motor vehicle comprises an intake system 10, a turbocharger 20, an engine 30, and an exhaust system 40.

The intake system 10 comprises an air inlet 12. Air enters the intake system 10 via the inlet 12 and passes through an air filter 14 into a cold inlet duct 16. The inlet air is carried by the cold inlet duct 16 to a compressor 22 of the turbocharger 20. The turbocharger compressor 22 is configured to increase the pressure of inlet gases in order to provide enhanced induction to the engine 30. A hot inlet duct 18 is arranged to carry the compressed inlet gases from the turbocharger compressor 22 to an inlet manifold 32 of the engine 30.

19 06 18

When the inlet gases are compressed by the turbocharger compressor 22, the temperature of the inlet gases also increases. It is desirable for the inlet gases within the engine manifold 32 to be cold and dense, to allow a greater quantity, e.g. mass, of inlet gases to be drawn into the engine 30. The intake system 10 therefore comprises a charge air cooler 19 provided on the hot inlet duct 18 and configured to cool the compressed inlet gases before they are delivered to the inlet manifold 32.

The inlet gases are drawn from the inlet manifold 32 into cylinders (not shown) of the engine 30. The inlet gases are mixed with fuel within cylinders and the mixture of inlet gases and fuel is combusted. The gases produced through the combustion are exhausted from the engine 30 via an exhaust manifold 34 to the exhaust system 40.

The exhaust system 40 comprises a hot exhaust duct 42 configured to carry the exhaust gases from the exhaust manifold 34 to a turbine 24 of the turbocharger 20. The exhaust gases pass through the turbocharger turbine 24 and are expanded and cooled by the turbocharger turbine 24, which extracts energy from the exhaust gases to drive the turbocharger compressor 22.

The expanded and cooled exhaust gases are carried from the turbocharger turbine 24 to an exhaust outlet 44 of the exhaust system via a cold exhaust duct 46.

Engine assemblies often comprise an Exhaust Gas Recirculation (EGR) system, such as a Low Pressure (LP) EGR system and/or a High Pressure (HP) EGR system, configured to recirculate a portion of the exhaust gases back to the intake system of the engine assembly. By replacing a portion of the oxygen rich inlet air with burnt exhaust gases, the peak temperature of combustion within the engine cylinders is reduced limiting the formation of NO_X within the engine 30. Furthermore, by controlling the amount of exhaust gases that are recirculated, the power produced by the engine 30 may be controlled without a throttle being provided within the inlet system, allowing the efficiency of the engine assembly 2 to be increased, particularly at low power levels.

The engine assembly 2 depicted in Figure 1 comprises an LP-EGR system 50 including an LP-EGR duct 52 configured to recirculate a portion of the exhaust gases from a position on the cold exhaust duct 46, e.g. between the turbocharger turbine 24 and the exhaust outlet 44, to a position upstream of the turbocharger compressor 22.

19 06 18

The LP-EGR system 50 comprises an LP-EGR valve 54 configured to control the flow of recirculated exhaust gases within the LP-EGR Duct 52.

Exhaust gases that flow from the cold exhaust duct into the LP-EGR Duct 52 may be at a higher temperature than the inlet air within the cold intake duct 16 upstream of the compressor. It may therefore be desirable for the recirculated exhaust gases to be cooled prior to being introduced into the cold inlet duct 16. The LP-EGR system therefore comprises an EGR cooler 56 provided on the EGR duct 52 and configured to cool the exhaust gases passing through the LP-EGR duct. Cooling the recirculated exhaust gases reduces the temperature of the mixture of EGR gases and inlet air within the turbocharger compressor 22, which improves the efficiency of the compressor.

With reference to Figure 2, the engine assembly 2 may comprise a HP-EGR system 60. The HP-EGR system 60 may be provided in addition or as an alternative to the LP-EGR system 50 shown in Figure 1. The HP-EGR system 60 comprises an HP-EGR duct 62 configured recirculate a portion of the exhaust gases leaving the engine back to the inlet of the engine 30. As depicted in Figure 2, the HP-EGR duct may recirculate exhaust gases from the hot exhaust duct 42, e.g. from a position between the exhaust manifold 34 and the turbo charger turbine 24 to the inlet manifold 32. Alternatively, the HP-EGR duct may recirculate the exhaust gases back to a position on the hot inlet duct 18, e.g. between the turbocharger compressor 22 and the inlet manifold 32.

The HP-EGR system 60 comprises an HP-EGR valve 64 configured to control the flow of recirculated exhaust gases through the HP-EGR duct 62.

The exhaust gases within the hot exhaust duct 42 may be at a higher temperature than the exhaust gases within the hot inlet duct 18 and the inlet manifold 32. Hence, it may be desirable for the recirculated exhaust gases to be cooled before they are mixed with the inlet gases within the hot inlet duct 18 or the inlet manifold 32, in order to increase the density of the mixture of inlet air and recirculated exhaust gases within the inlet manifold 32. The HP-EGR system 60 therefore comprises an HP-EGR cooler 66 provided on the HP-EGR duct 62 and configured to cool the recirculated exhaust gases.

In some engine operating conditions, e.g. at high engine power when the turbocharger is operating to increase the pressure of inlet gases within the inlet manifold 32, the pressure of inlet gases within the inlet manifold 32 and hot inlet duct 18 may be greater than the pressure of exhaust gases within the hot exhaust duct 42. In such engine operating conditions, recirculation of exhaust gases using the HP-EGR system 60 may not be possible.

19 06 18

In contrast to this, since the LP-EGR system recirculates exhausts gases to a position upstream of the turbocharger compressor, the LP-EGR system may be capable of recirculating exhaust gases at substantially all operating conditions of the engine assembly 2.

Recirculating exhaust gases using the LP-EGR system may however lead to deterioration of the turbocharger compressor 22 due to condensing water droplets within the recirculated exhaust gases impacting the blades of the compressor as the recirculated exhaust gases pass though the compressor.

Furthermore, HP-EGR systems can be easier to control, as the recirculated exhaust gases can be introduced directly into the inlet manifold 32 of the engine, providing an immediate engine response.

It is desirable to provide an EGR system that overcomes the disadvantages of both LP-EGR and HP-EGR systems.

Statements of Invention

According to arrangements of the present disclosure, there is provided, an Exhaust Gas Recirculation (EGR) apparatus for an engine assembly, wherein the engine assembly comprises: an exhaust gas duct configured to direct exhaust gases flowing from the engine to an exhaust outlet; and an EGR duct configured to recirculate exhaust gases to an air inlet of the engine by means of the EGR apparatus comprising: a turbocharger turbine arranged in the exhaust gas duct, wherein the turbocharger turbine is configured to expand the exhaust gases flowing through the exhaust gas duct; an EGR compressor arranged between the turbocharger turbine and the EGR duct, e.g. relative to the flow of exhaust gases, wherein a rotor of the EGR compressor defines a bypass channel which provides a passage for a flow of expanded exhaust gasses to pass to the exhaust outlet thereby bypassing the EGR compressor.

19 06 18

The EGR apparatus may further comprise a flow divider for dividing the expanded exhaust gases from the turbocharger turbine into: a bypass flow, which bypasses the EGR compressor and passes to the exhaust outlet through the bypass channel; and an EGR compressor flow which is compressed by the EGR compressor and is directed into the EGR duct.

The bypass channel may be substantially circular in cross section.

A radius of the bypass channel may be less than a radius of a turbocharger turbine outlet.

The EGR compressor may be coupled to the turbocharger turbine such that the EGR compressor is driven by the turbocharger turbine.

The EGR compressor may further comprise a plurality of EGR compressor blades, a housing, e.g. a turbine housing or a separate EGR compressor housing, configured to house the plurality of EGR compressor blades and a turbine side of the housing facing the turbocharger turbine. The turbine side of the housing may be configured to expose the plurality of EGR compressor blades and the bypass channel to exhaust gases that are exhausted from the turbocharger turbine such that these exhaust gases flow through the plurality of EGR compressor blades and the bypass channel.

The flow divider may be configured to provide a barrier between the plurality of EGR compressor blades and the bypass channel such that the EGR compressor flow passes through the plurality of EGR compressor blades into the EGR channel and the bypass flow passes through the bypass channel into the exhaust outlet.

The flow divider may be coupled to the plurality of EGR compressor blades, e.g. such that the flow divider rotates with the plurality of EGR blades.

The flow divider may be coupled to the housing of the EGR compressor blades, e.g. such that the exhaust gas divider is stationary relative to the plurality of rotating EGR compressor blades.

The turbocharger turbine may further comprise a plurality of turbocharger turbine blades. The plurality of EGR compressor blades may be connected to the plurality of turbocharger turbine blades such that the plurality of EGR compressor blades are driven by the plurality of turbocharger turbine blades.

19 06 18

The EGR compressor may be a radial outflow compressor. Furthermore, the plurality of EGR compressor blades may be impeller blades.

The EGR compressor may be an axial flow compressor.

According to another arrangement of the present disclosure, there is provided an EGR system comprising: an air inlet duct configured to direct inlet air to an air inlet of the engine via a turbocharger compressor; an exhaust gas duct configured to direct exhaust gas flowing from the engine to an exhaust outlet; an EGR duct configured to recirculate exhaust gases to the air inlet of the engine by means of the EGR apparatus; a turbocharger turbine arranged in the exhaust gas duct, wherein the turbocharger turbine is configured to expand the exhaust gases flowing through the exhaust gas duct; and an EGR compressor arranged between the turbocharger turbine and the EGR duct, e.g. relative to the flow of exhaust gases, wherein a rotor of the EGR compressor defines a bypass channel which provides a passage for a flow of expanded exhaust gasses to pass to the exhaust outlet thereby bypassing the EGR compressor.

The EGR compressor flow may be recirculated through the EGR duct and reintroduced to the air inlet duct at a point between the turbocharger compressor and the engine.

The EGR system may further comprise a turbocharger shaft configured to connect together the turbocharger compressor, the turbocharger turbine and the EGR compressor. The EGR system may further comprise one or more EGR compressor connectors, e.g. radial connectors or spokes. The one or more EGR compressor connectors may be configured to connect the turbocharger shaft to the plurality of EGR compressor blades such that the plurality of EGR compressor blades are driven by the turbocharger shaft.

According to another aspect of the present disclosure, there is provided a method of operating an engine assembly, wherein the engine assembly comprises: an exhaust gas duct configured to direct exhaust gases flowing from the engine to an exhaust outlet; and an EGR duct configured to recirculate exhaust gases to an air inlet of the engine by means of an EGR apparatus comprising: a turbocharger turbine arranged in the exhaust gas duct, wherein the turbocharger turbine is configured to expand the exhaust gases flowing through the exhaust gas duct; an EGR compressor arranged between the turbocharger turbine and the EGR duct; wherein a rotor of the EGR compressor defines a bypass channel which provides a passage for a flow of expanded exhaust gasses to pass to the exhaust outlet thereby bypassing the EGR compressor, wherein the method comprises: channelling a bypass flow of expanded exhaust gasses into the bypass channel thereby bypassing the EGR compressor.

19 06 18

To avoid unnecessary duplication of effort and repetition of text in the specification, certain features are described in relation to only one or several aspects or arrangements of the invention. However, it is to be understood that, where it is technically possible, features described in relation to any aspect or arrangement of the invention may also be used with any other aspect or arrangement of the invention.

Brief Description of the Drawings

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a schematic view of an engine assembly comprising a low pressure exhaust gas recirculation system;

Figure 2 is a schematic view of an engine assembly comprising a high pressure exhaust gas recirculation system;

Figure 3 is a schematic view of an engine assembly comprising a turbine pumped exhaust gas recirculation system, according to arrangements of the present disclosure; and

Figure 4 is a schematic view of an exhaust gas recirculation apparatus, according to arrangements of the present disclosure.

Figure 5 is a schematic view of an exhaust gas recirculation apparatus, according to an alternative arrangement of the present invention.

Detailed Description

With reference to Figure 3, an engine assembly 100, according to arrangements of the present disclosure, comprises an intake system 110, a turbocharger 102, an engine 116, and an exhaust system 104.

The intake system 110, the turbocharger 102, the engine 116 and the exhaust system 104 are similar to the intake system 10, turbocharger 20, engine 30 and the exhaust system 40 of the engine assembly 2 described above with reference to Figure 1 and 2. The features of the engine assembly 2 described above may apply equally to the engine assembly 100.

The engine assembly 100 differs from the engine assembly 2 in that the engine assembly 100 comprises a turbine pumped EGR system 200 according to arrangements of the present disclosure.

The intake system 110 comprises an air inlet 120, an air filter 122, a cold inlet duct 106, a turbocharger compressor 240 of the turbocharger 102, a hot inlet duct 107 and an inlet manifold 111 of the engine 116.

The exhaust system 104 comprises a hot exhaust duct 108, an exhaust manifold 112, a plurality of turbocharger turbine blades 290, a turbocharger shaft 300, an exhaust outlet 114 and a cold exhaust duct 109.

The exhaust system 104 further comprises an exhaust catalyst 124 through which the exhaust gases flow before being exhausted into the ambient environment.

19 06 18

The turbine pumped EGR system 200 comprises an EGR duct 210, an EGR apparatus 270 and a turbocharger turbine 250 of the turbocharger 102.

With reference to Figure 4, the EGR apparatus 270 comprises an EGR compressor 260, a bypass channel 320, an EGR channel 330, a flow divider 340, a housing 370 and one or more EGR compressor connectors 360.

Also with reference to Figure 4, the EGR compressor 260 comprises a rotor 310 and a plurality of EGR compressor blades 350 attached to a hub (not shown) of the rotor 310.

In use of the engine assembly 100, as shown in Figures 3 and 4, inlet air enters the intake system 110 via the air inlet 120 and passes through the air filter 122 into the cold inlet duct 106. The inlet air is conveyed by the cold inlet duct 106 to the turbocharger compressor 240. The turbocharger compressor 240 is configured to increase the pressure of inlet gases in order to provide enhanced induction to the engine 116. The hot inlet duct 107 is arranged to convey the compressed inlet gases from the turbocharger compressor 240 to the inlet manifold 111 of the engine 30.

19 06 18

The exhaust gases from the engine 116 are conveyed from the exhaust manifold 112 to the turbocharger turbine 250. The exhaust gases pass through the turbocharger turbine 250 and are expanded and cooled by the turbocharger turbine 250, which extracts energy from the exhaust gases to drive the turbocharger compressor 240. The expanded and cooled exhaust gases are conveyed from the turbocharger turbine 250 to an exhaust outlet 114 of the exhaust system 104 via a cold exhaust duct 109. The turbocharger turbine 250 is connected to the turbocharger compressor 240 by the turbocharger shaft 300. The energy extracted from the exhaust gases by the turbocharger turbine 250 is used to generate torque on the turbocharger shaft 300 and thus drive the turbocharger compressor 240.

The EGR compressor 260 is arranged between the turbocharger turbine 250 and the EGR duct 210. The rotor 310 of the EGR apparatus 270 is arranged within the housing 370. The rotor 310 is configured to compress the expanded exhaust gases that are exhausted from the turbocharger turbine 250. The housing 370 is configured to house the rotor 310 such that a turbine side of the rotor 310 is exposed to the flow of expanded exhaust gases flowing from the turbocharger turbine 250. The housing 370 may be configured to enclose one or two sides of the rotor 310 provided that at least the turbine side of the rotor 310 is exposed to the expanded exhaust gases, such that the expanded exhaust gases can be compressed by the EGR compressor 260.

An attachment end of each of the plurality of EGR compressor blades 350 is attached to the hub of the rotor 310 such that each of the plurality of EGR compressor blades 350 are held in a fixed position relative to each other when the rotor 310 is rotating.

The turbocharger shaft 300 extends through the EGR compressor 260. The rotor 310 of the EGR apparatus 270 is coupled to the turbocharger shaft 300 by one or more EGR compressor connectors 360. The one or more EGR connectors 360 are radial connectors (e.g. spokes) configured to connect the hub of the rotor 310 (i.e. the inner circumference of the rotor 310) to the turbocharger shaft 300. The one or more EGR connectors 360 may be a single EGR connector 360 providing a single connection between the hub and the turbocharger shaft 300. Alternatively, the hub may be connected to the turbocharger shaft 300 using a plurality of EGR connectors 360. The connection between the hub and the turbocharger shaft 300 provided by the one or more EGR connectors 360 enables the EGR compressor 260 to be driven by the turbocharger shaft 300. The energy extracted from the exhaust gases by the turbocharger turbine 250 is used to generate torque on the turbocharger shaft 300 thereby driving the turbocharger compressor 240 and the EGR compressor 260, both of which are connected to the turbocharger shaft 300.

19 06 18

The EGR compressor 260 may alternatively be driven without having a connection to the turbocharger shaft 300. In this alternative arrangement, the plurality of EGR compressor blades 350 and the plurality of turbocharger turbine blades 290 are coupled together. The coupling together of the plurality of EGR compressor blades 350 and the plurality of turbocharger turbine blades 290 provides a means for the plurality of EGR compressor blades 350 to be driven by the plurality of turbocharger turbine blades 290, without requiring one or more EGR connectors 360 to connect the hub of the rotor 310 to the turbocharger shaft 300. The energy extracted from the exhaust gases by the turbocharger turbine 250 is used to generate torque on the plurality of turbocharger turbine blades 290, and because the plurality of EGR compressor blades 350 are coupled to the plurality of turbocharger turbine blades 290, this torque is transferred to the plurality of EGR compressor blades 350 thereby providing a driving force to the EGR compressor 260.

An inner circumference of the rotor 310 (e.g. the hub to which the plurality of EGR compressor blades 350 are connected) defines an outer circumference of the bypass channel 320 through which a bypass flow of expanded exhaust gases flows from the turbocharger turbine 250. The EGR channel 330, through which the EGR compressor flow of expanded exhaust gases flows from the turbocharger turbine 250, is defined as an area between the inner circumference of the rotor 310 and an outer circumference of the rotor 310. The outer circumference of the bypass channel 320 may also be defined by the inner circumference of the housing 370.

A radial cross section of the bypass channel 320 may, for example, be substantially circular or elliptical in shape.

When the EGR apparatus 270 is mounted on the turbocharger shaft 300, the bypass channel 320 is defined as an area between the inner circumference of the housing 370 or the rotor 310 and the outer circumference of the turbocharger shaft 300.

The flow divider 340 of the EGR apparatus 270 provides a barrier between the bypass channel 320 and the EGR channel 330 and thereby divides the expanded exhaust gases flowing from the turbocharger turbine 250 into a bypass flow and an EGR compressor flow. The bypass flow bypasses the EGR compressor 260 and passes to the exhaust outlet 114 through the bypass channel 320. The EGR compressor flow is compressed by the EGR compressor 260 and is directed into the EGR duct 210. That is, the expanded exhaust gases flowing from the turbocharger turbine 250 are separated into a bypass flow and an EGR compressor flow by the flow divider 340. The bypass flow of expanded exhaust gases is directed into the bypass channel 320 of the EGR apparatus 270 and out of the exhaust outlet 114 via the cold exhaust duct 109 thereby bypassing the rotor 310. The EGR compressor flow of expanded exhaust gases is directed into the EGR channel 330 of the EGR apparatus 270 and into the EGR duct 210.

19 06 18

The flow divider 340 is coupled to the hub such that the flow divider 340 rotates at the same rotational frequency as the plurality of EGR compressor blades 350. Alternatively, the flow divider 340 may be coupled to an inner edge of the housing 370, wherein the inner edge on the housing 370 is an edge between the bypass channel 320 and the EGR channel 330, such that the flow divider 340 is stationary relative to the plurality of EGR compressor blades 350 when the plurality of EGR compressor blades 350 are rotating.

With reference to Figures 3 and 4, the EGR duct 210 is arranged between the EGR apparatus 270 and a hot inlet duct 107 of the engine assembly 100. The EGR duct 210 is configured to recirculate the EGR compressor flow of expanded exhaust gases, which have been divided from the bypass flow of expanded exhaust gases by the flow divider 340, to the hot inlet duct 107 by means of the EGR compressor 260. That is, the EGR compressor flow of expanded exhaust gases, that have been expanded by the turbocharger turbine 250, are compressed by the EGR compressor 260 before being reintroduced to the hot inlet duct 107 of the intake system 110 through the EGR duct 210. The compressed EGR compressor flow is therefore mixed with compressed inlet gases that have been compressed by the turbocharger compressor 240 at a point after the turbocharger compressor 240.

Advantageously, by compressing the recirculated EGR compressor flow at the exhaust system 104 side of the EGR duct 210, the additional burden of compressing the recirculated EGR compressor flow is removed from the turbocharger compressor 240. The reduced burden of the turbocharger compressor 240 also provides the advantage of mitigating the formation of condensation in the area of the turbocharger compressor 240, which could cause deterioration of the turbocharger compressor 240, and in particular blades of the turbocharger compressor 240.

The EGR compressor 260 can provide a further advantage of recirculated EGR compressor flow at a higher pressure compared to that of a conventional EGR system recirculating expanded exhaust gases directly from a turbine of a turbocharger. Therefore, the compressed EGR compressor flow can be reintroduced to the engine assembly 100 at times of higher engine operating loads compared to a conventional EGR system. For example, the EGR compressor 260 allows for recirculated EGR compressor flow to be reintroduced to the engine assembly 100 at higher inlet manifold 111 pressures compared to that of conventional high pressure EGR systems.

19 06 18

A further advantage of the EGR compressor 260 is a significant reduction in sensor and control requirements. This advantage is realised due to the compressed EGR compressor flow being mixed with compressed inlet air at similar temperatures and pressures to each other. In a conventional EGR system, on the other hand, recirculated exhaust gases and inlet gases are mixed at more varied temperatures and pressures.

The recirculated exhaust gases may be reintroduced to the hot inlet duct 107 at a point between a charge air cooler 118 and the turbocharger compressor 240 of the intake system 110, wherein the charge inlet cooler 118 is arranged at a point along the hot inlet duct 107 between the intake manifold 111 and the turbocharger compressor 240.

Alternatively, the recirculated exhaust gases may be reintroduced directly into the inlet manifold 111 of the engine assembly 100 through the EGR duct 210 without having been mixed with inlet gases or cooled by the charge air cooler 118. Advantageously, by reintroducing the compressed EGR compressor flow directly into the inlet manifold 111, issues relating to transient control are reduced or avoided.

The EGR duct 210 further comprises an EGR valve 220 configured to control the flow of recirculated gases through the EGR duct 210, and an EGR cooler 230 arranged upstream of the EGR apparatus 270 configured to cool the recirculated exhaust gases before reintroducing the recirculated exhaust gases to the engine assembly 100.

In a particular arrangement as illustrated in Figure 4, the EGR compressor 260 is a radial outflow compressor. An alternative arrangement is illustrated in Figure 5, in which the EGR compressor 260 is an axial flow compressor.

It will be appreciated by those skilled in the art that although the invention has been described by way of example, with reference to one or more exemplary examples, it is not limited to the disclosed examples and that alternative examples could be constructed without departing from the scope of the invention as defined by the appended claims.

19 06 18

Claims

1. An Exhaust Gas Recirculation (EGR) apparatus for an engine assembly, wherein the engine assembly comprises:

an exhaust gas duct configured to direct exhaust gases flowing from the engine to an exhaust outlet;

an EGR duct configured to recirculate exhaust gases to an air inlet of the engine by means of the EGR apparatus comprising:

a turbocharger turbine arranged in the exhaust gas duct, wherein the turbocharger turbine is configured to expand the exhaust gases flowing through the exhaust gas duct; and

an EGR compressor arranged between the turbocharger turbine and the EGR duct, wherein a rotor of the EGR compressor at least partially defines a bypass channel which provides a passage for a flow of expanded exhaust gasses to bypass the EGR compressor and pass to the exhaust outlet without being compressed by the EGR compressor.

2. An EGR apparatus according to claim 1, the EGR apparatus further comprising:

a flow divider for dividing the expanded exhaust gases from the turbocharger turbine into:

a bypass flow, which bypasses the EGR compressor and passes to the exhaust outlet through the bypass channel; and

an EGR compressor flow which is compressed by the EGR compressor and is directed into the EGR duct.

19 04 18

3. The EGR apparatus according to any preceding claim, wherein the EGR compressor further comprises:

a plurality of EGR compressor blades;

a housing configured to house the plurality of EGR compressor blades; and

a turbine side of the housing adjacent to the turbocharger turbine, wherein the turbine side of the housing is configured to expose the plurality of EGR compressor blades and the bypass channel to exhaust gases that are exhausted from the turbocharger turbine such that exhausted exhaust gases flow through the plurality of EGR compressor blades and the bypass channel.

4. The EGR apparatus according to claims 2 and 3, wherein the flow divider is configured to provide a barrier between the plurality of EGR compressor blades and the bypass channel such that the EGR compressor flow passes through the plurality of EGR compressor blades into the EGR channel and the bypass flow passes through the bypass channel into the exhaust outlet.

5. The EGR apparatus according to claim 3 or 4, wherein the flow divider is coupled to the plurality of EGR compressor blades.

6. The EGR apparatus according to any of claims 3 to 5, wherein the flow divider is coupled to the housing of the EGR compressor blades.

7. The EGR apparatus according to any of claims 3 to 6, the turbocharger turbine further comprising a plurality of turbocharger turbine blades, wherein

the plurality of EGR compressor blades are connected to the plurality of turbocharger turbine blades such that the plurality of EGR compressor blades are driven by the plurality of turbocharger turbine blades.

8. The EGR apparatus according to any preceding claim, wherein the bypass channel is substantially circular in cross section.

19 04 18

9. The EGR apparatus according to any preceding claim, wherein a radius of the bypass channel is less than a radius of a turbocharger turbine outlet.

10. The EGR apparatus according to any preceding claim, wherein the EGR compressor is coupled to the turbocharger turbine such that the EGR compressor is driven by the turbocharger turbine.

11. The EGR apparatus according to any preceding claim, wherein the EGR compressor is a radial outflow compressor.

12. The EGR apparatus according to any of claims 1 to 10, wherein the EGR compressor is an axial flow compressor.

13. An EGR system for an engine assembly, wherein the EGR system comprises:

an air inlet duct configured to direct inlet air to an air inlet of the engine via a turbocharger compressor;

an exhaust gas duct configured to direct exhaust gas flowing from the engine to an exhaust outlet;

an EGR duct configured to recirculate exhaust gases to the air inlet of the engine by means of an EGR apparatus;

a turbocharger turbine arranged in the exhaust gas duct, wherein the turbocharger turbine is configured to expand the exhaust gases flowing through the exhaust gas duct; and

an EGR compressor arranged between the turbocharger turbine and the EGR duct, wherein a rotor of the EGR compressor at least partially defines a bypass channel which provides a passage for a flow of expanded exhaust gasses to bypass the EGR compressor and pass to the exhaust outlet without being compressed by the EGR compressor.

14. An EGR system according to claim 13, wherein the EGR compressor flow is recirculated through the EGR duct and reintroduced to the air inlet duct at a point between the turbocharger compressor and the engine.

15. The EGR system according to claim 13 or 14, the EGR system further comprising:

a turbocharger shaft configured to connect together the turbocharger compressor, the turbocharger turbine and the EGR compressor; and

one or more EGR compressor connectors configured to connect the turbocharger shaft to the plurality of EGR compressor blades such that the plurality of EGR compressor blades are driven by the turbocharger shaft.

19 04 18

16. A method of operating an engine assembly, wherein the engine assembly comprises:

an exhaust gas duct configured to direct exhaust gases flowing from the engine to an exhaust outlet; and

an EGR duct configured to recirculate exhaust gases to an air inlet of the engine by means of an EGR apparatus comprising:

a turbocharger turbine arranged in the exhaust gas duct, wherein the turbocharger turbine is configured to expand the exhaust gases flowing through the exhaust gas duct;

an EGR compressor arranged between the turbocharger turbine and the EGR duct; wherein a rotor of the EGR compressor at least partially defines a bypass channel which provides a passage for a flow of expanded exhaust gasses to bypass the EGR compressor and pass to the exhaust outlet without being compressed by the EGR compressor.

wherein the method comprises:

channelling a bypass flow of expanded exhaust gasses into the bypass channel thereby bypassing the EGR compressor.