(12) UK Patent Application (19) GB (11) 2564691 (13) A

(43) Date of A Publication 23.01.2019

(21) Application No: 1711654.2

(22) Date of Filing: 20.07.2017

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

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

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

(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)

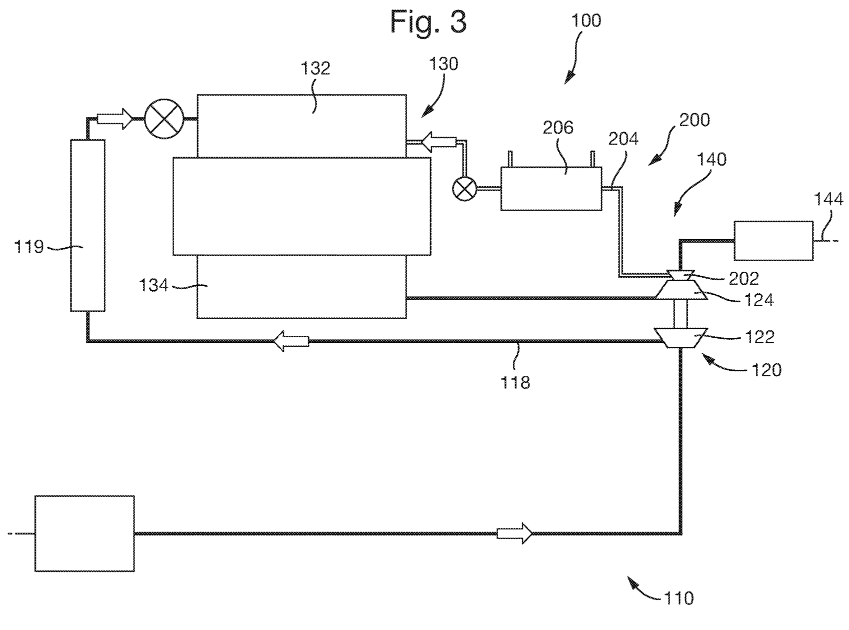
(56) Documents Cited:
EP 2330287 A1 **WO 2001/007774 A1**
CN 105840355 A **JP 2005299615 A**
US 20060248888 A1

(58) Field of Search:
INT CL **F02B, F02M**
Other: **WPI, EPODOC, Patent Full Text**

(54) Title of the Invention: **An EGR system**
Abstract Title: **An EGR system having a turbocharger with an auxiliary compressor**

(57) An engine assembly 100 comprises an Exhaust Gas Recirculation (EGR) system 200 having an EGR duct 204 that recirculates exhaust gases to an intake 132 of the engine assembly. A turbocharger assembly 120 comprises a compressor 122 that compresses inlet gases entering the engine assembly, a turbine 124 that expands exhaust gases leaving the engine assembly and drives the compressor, and an auxiliary (EGR) compressor 202 configured to compress the exhaust gases recirculated by the EGR duct. The auxiliary compressor is driven by the turbine and arranged on an opposite side of the turbine to the compressor. An EGR cooler reduces the temperature of the exhaust gases recirculated by the EGR duct after being compressed by the auxiliary compressor. The auxiliary compressor may define a bypass channel to permit exhaust gases to flow through the auxiliary compressor without being compressed.

Fig. 3



GB 2564691 A

Fig. 1

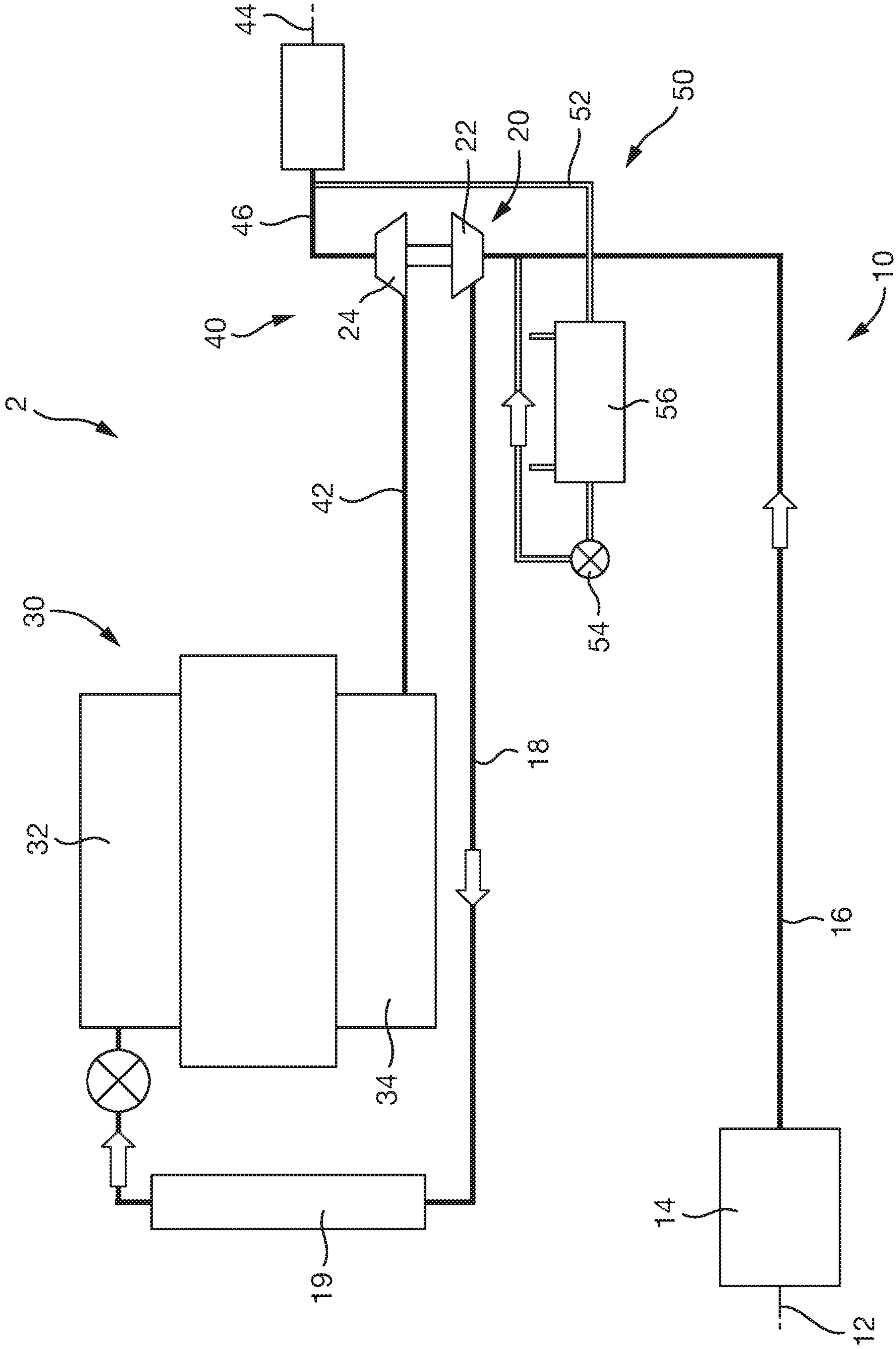
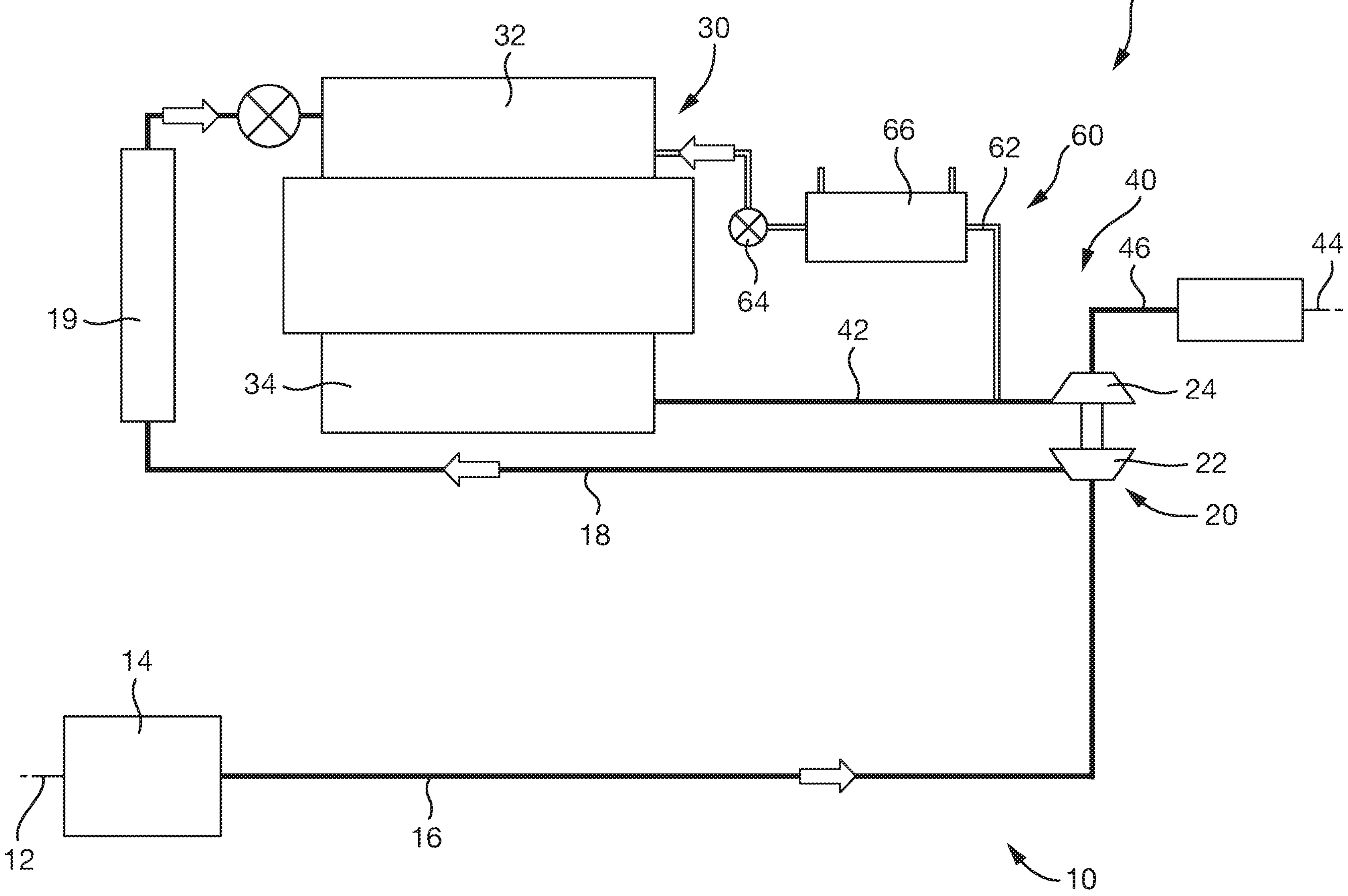


Fig. 2



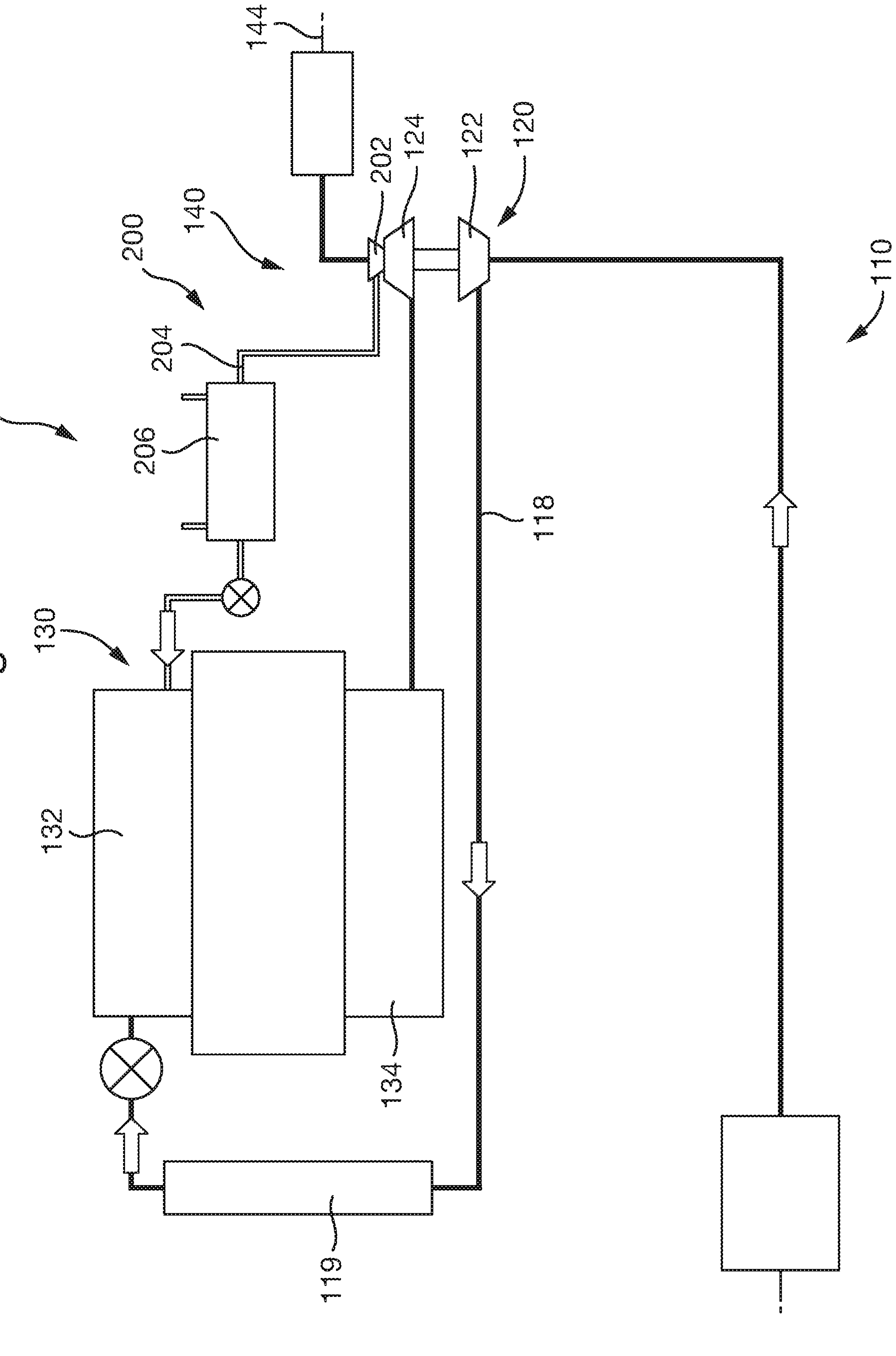
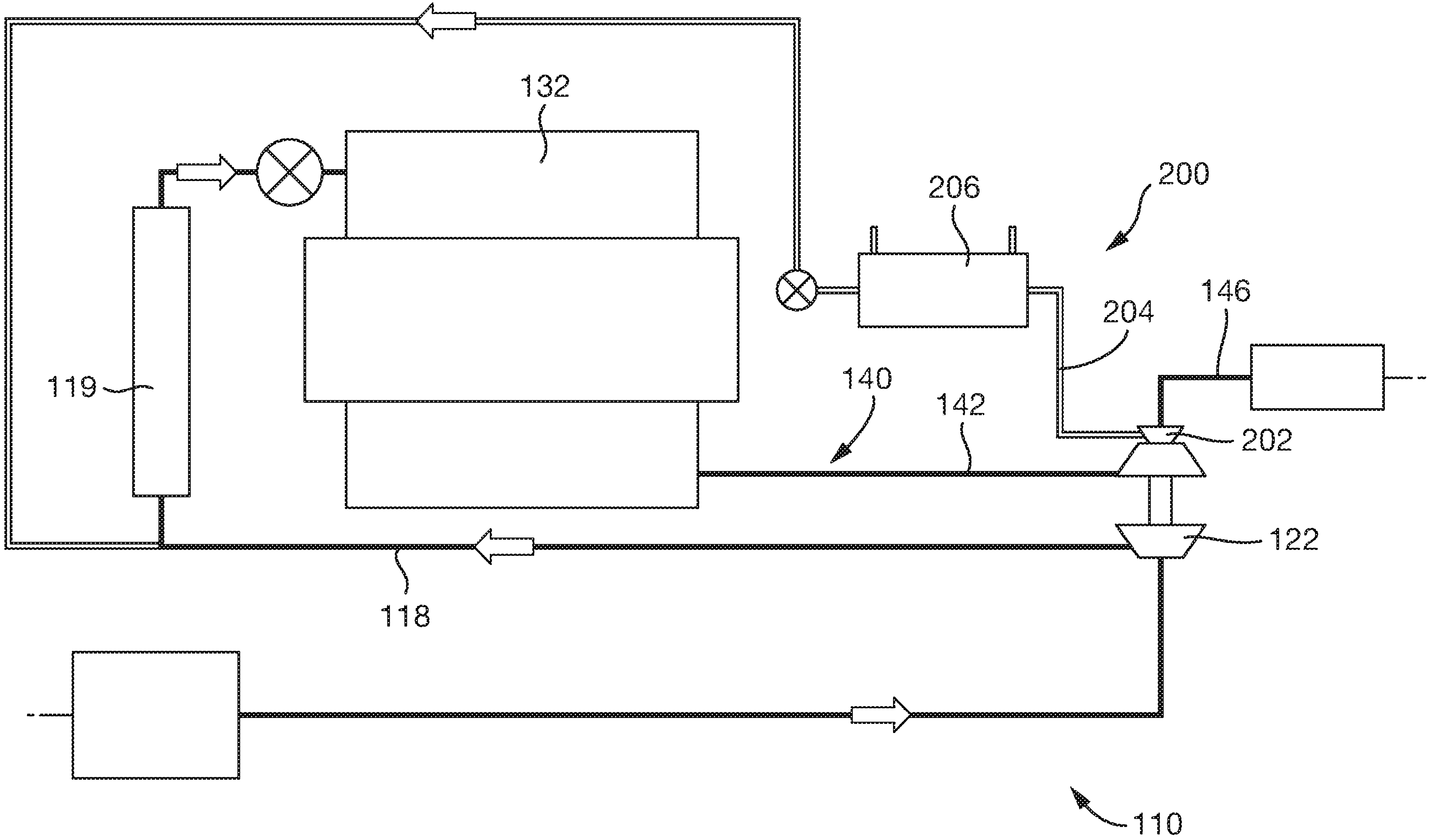


Fig. 3

Fig. 4



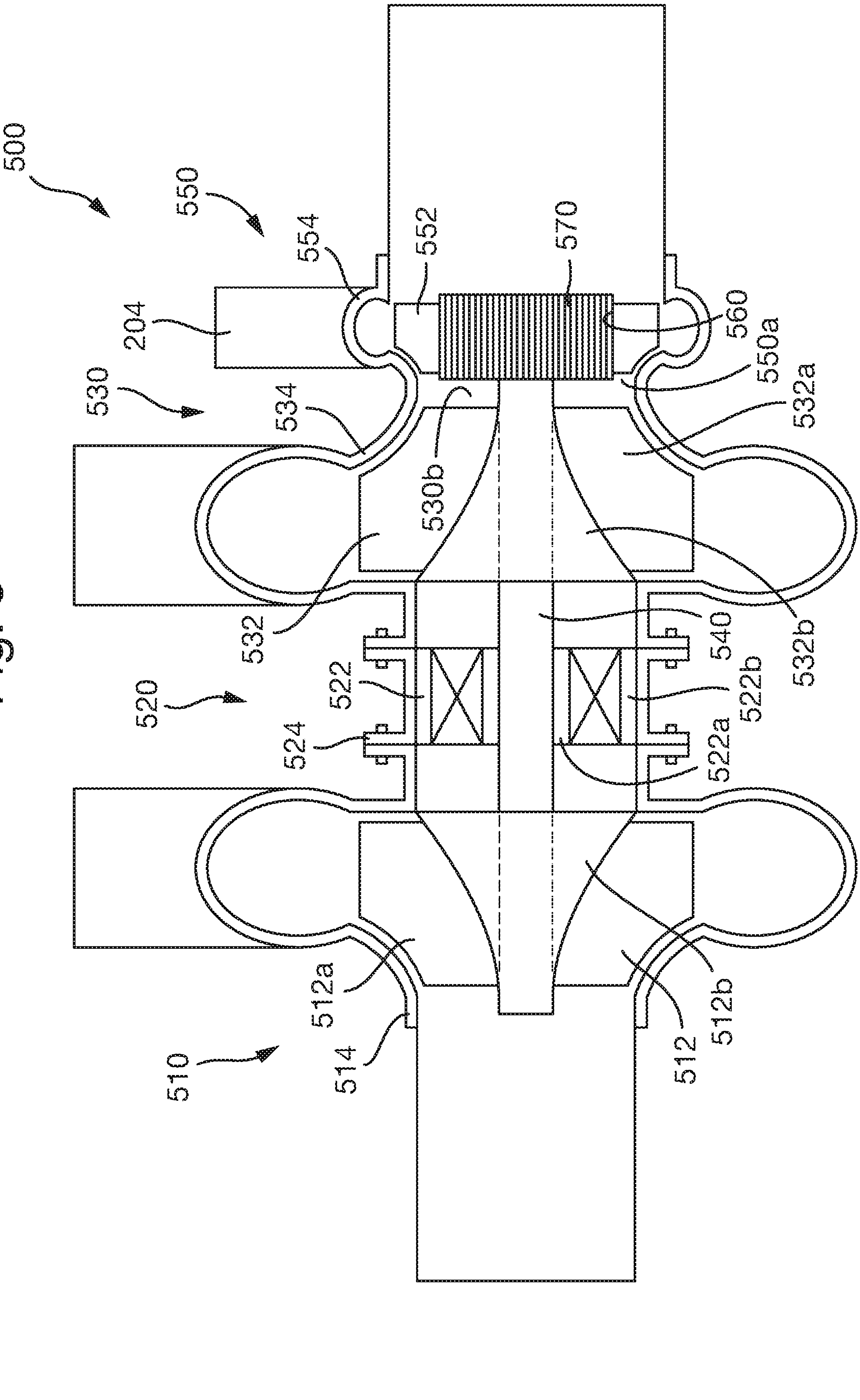

500
550
554
552
570
204
560
560a
550a
530
534
532a
530b
532
540
532b
520
522
522b
524
522a
510
514
512a
512
512b

Fig. 5

Fig. 6

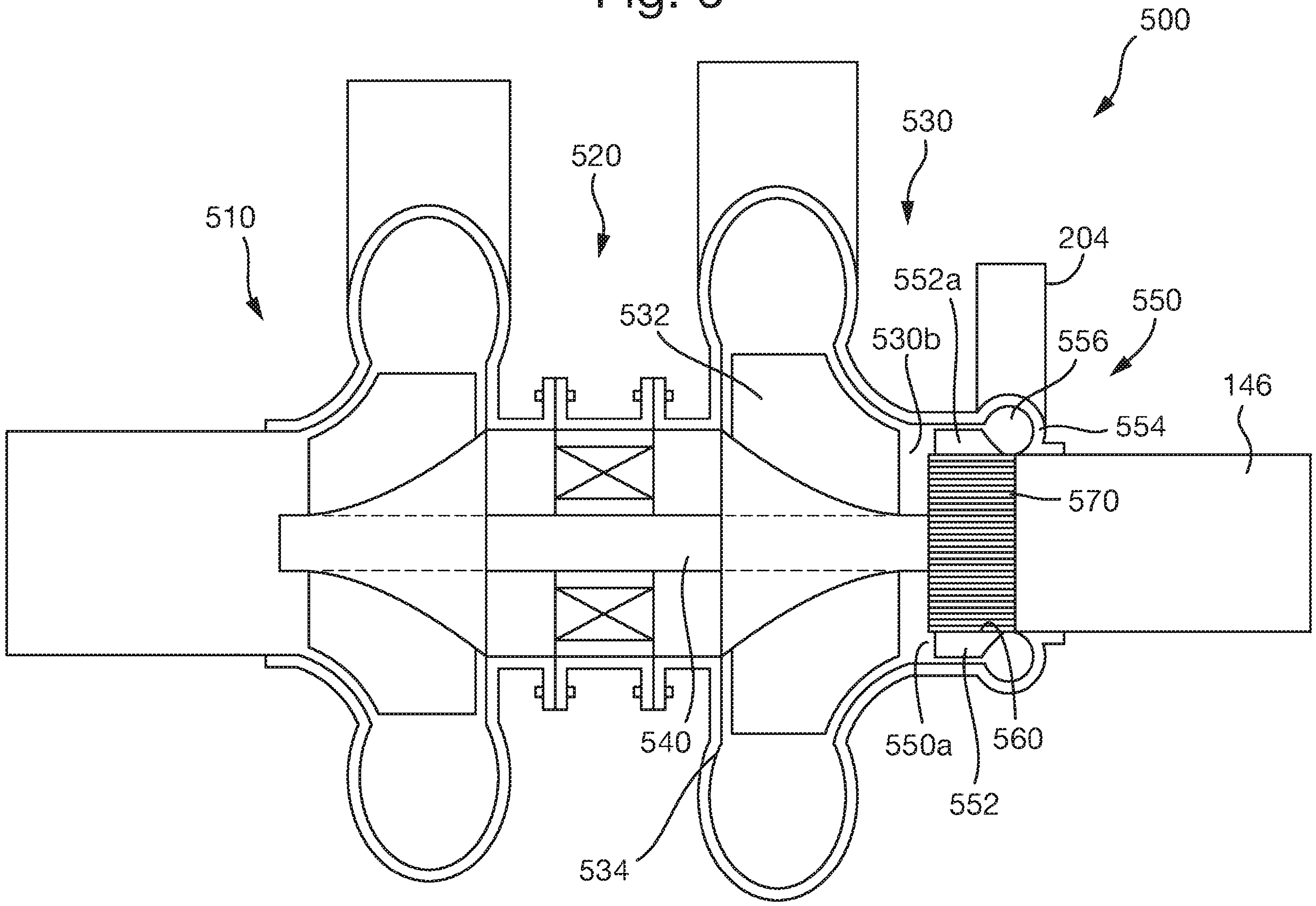
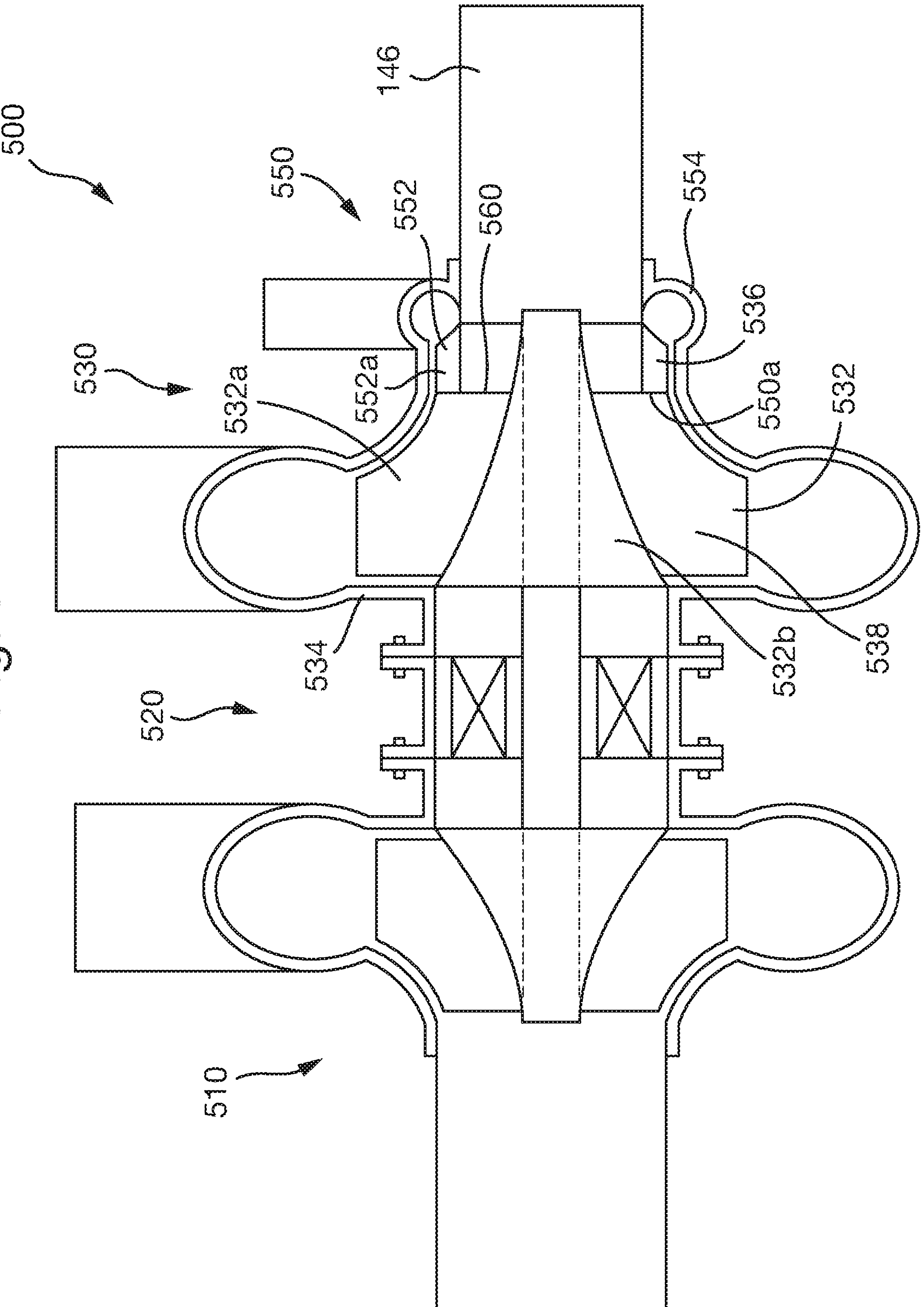

500
510
520
530
532
540
534
530b
552a
204
550
556
554
146
570
550a
560
552

Fig. 7


500
146
550
552
560
554
536
530
532a
552a
550a
532
534
532b
538
520
510

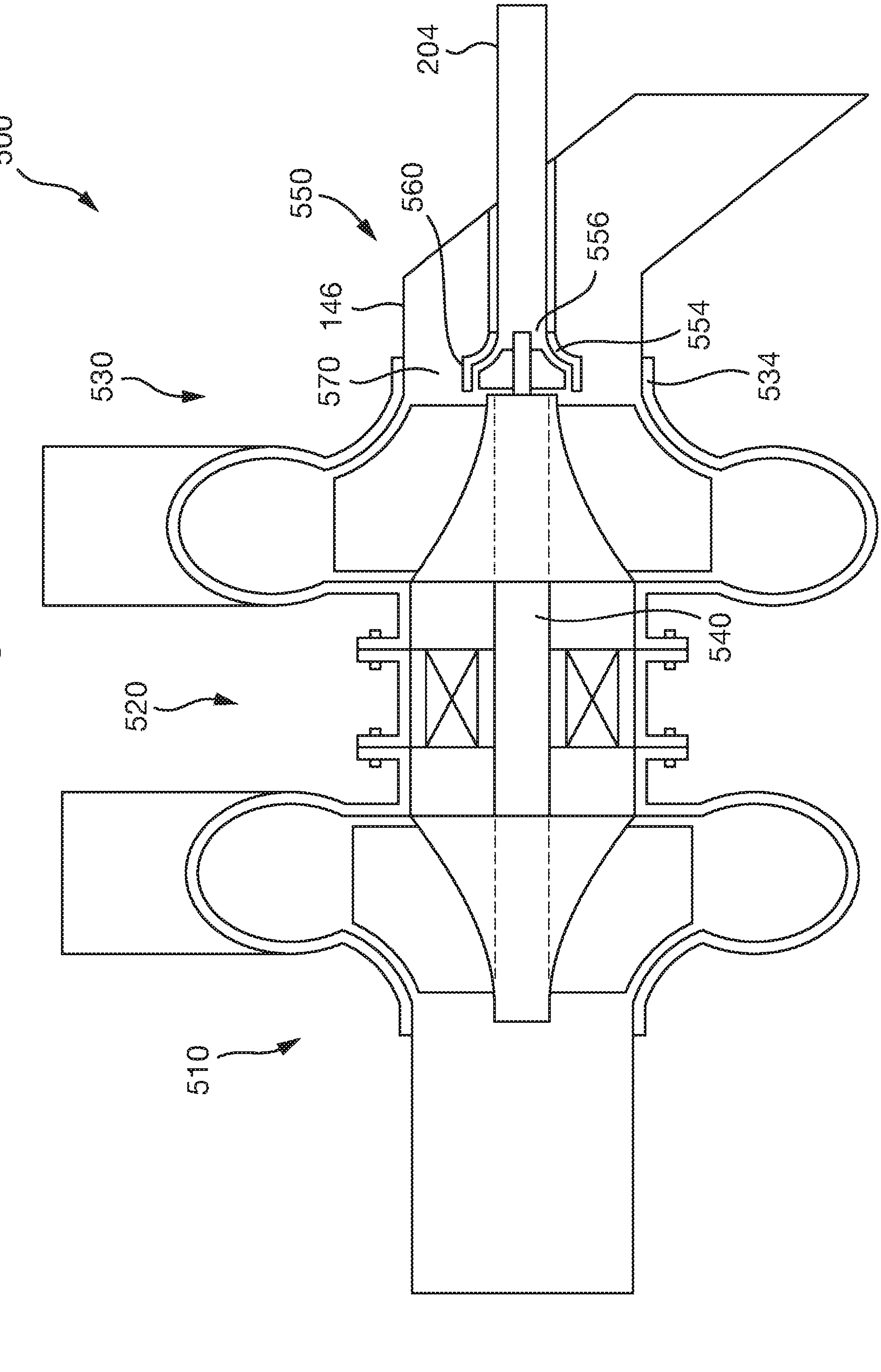


Fig. 8

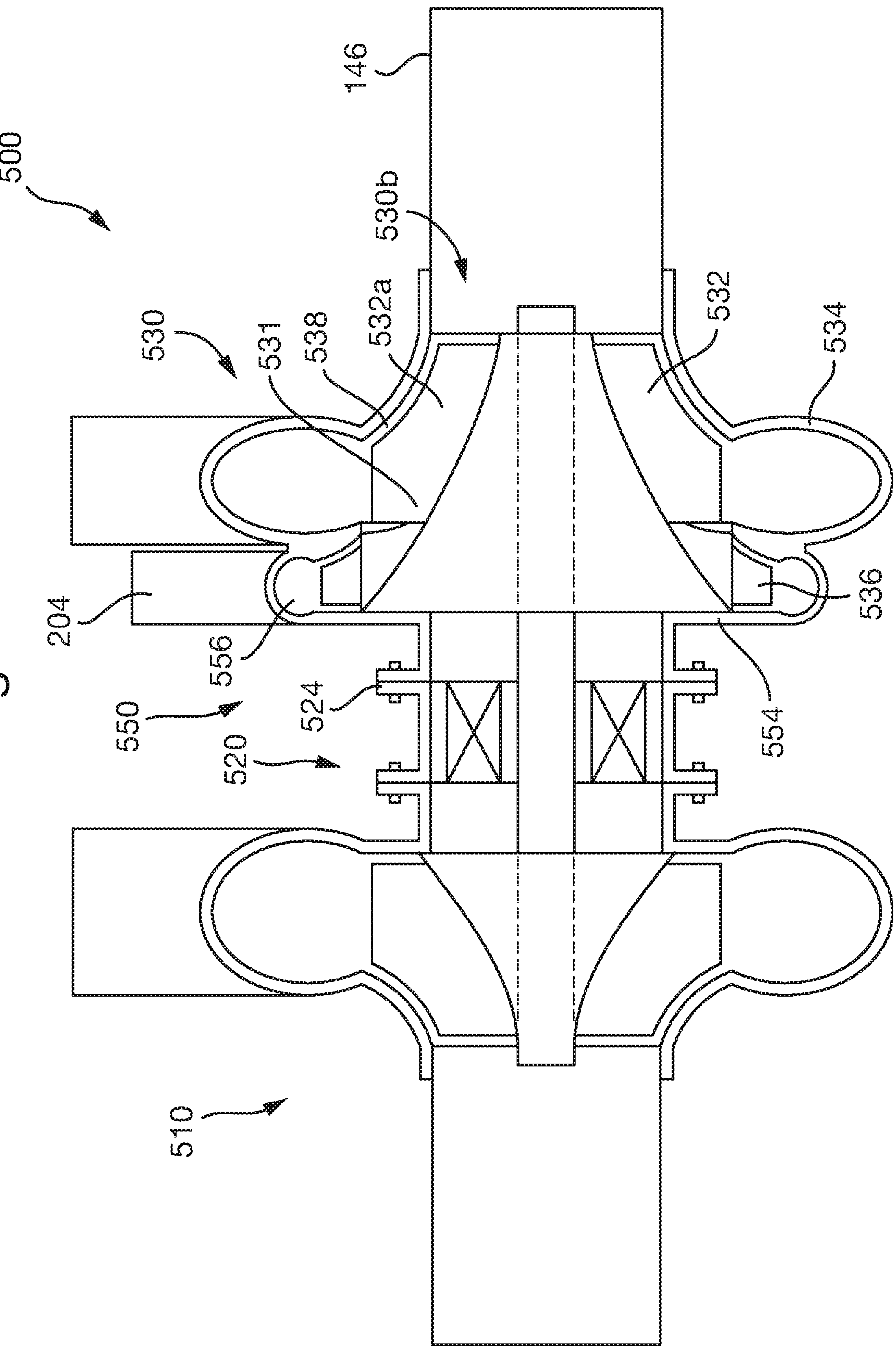

500
146
530b
530
531
538
532a
532
534
204
556
536
550
524
554
520
510

Fig. 9

An EGR system

Technical Field

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

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.

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 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.

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, 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.

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 an aspect of the present disclosure, there is provided a turbocharger assembly for an engine assembly, wherein the engine assembly comprises an Exhaust Gas Recirculation (EGR) system having an EGR duct configured to recirculate exhaust gases to an intake of the engine assembly, wherein the turbocharger assembly comprises: a compressor, configured to compress inlet gases entering the engine assembly; a turbine configured to expand exhaust gases leaving the engine assembly and drive the compressor; and an auxiliary compressor, e.g. an EGR compressor/pump, configured to compress the exhaust gases recirculated by the EGR duct, wherein the auxiliary compressor is driven, e.g. directly driven, by the turbine and wherein the auxiliary compressor is arranged on an opposite side of the turbine to the compressor.

The auxiliary compressor may be a radial compressor configured to receive exhaust gases flowing in a substantially axial direction and turn the exhaust gases to flow in a substantially radial direction at an outlet of the auxiliary compressor. Alternatively, the auxiliary compressor may be an axial compressor configured to receive and output exhaust gases flowing in a substantially axial direction.

The turbocharger assembly may further comprise a shaft. The compressor, the turbine and the auxiliary compressor may be provided on the shaft. The auxiliary compressor may be arranged on an opposite side of the turbine to the compressor along the shaft.

The auxiliary compressor may be configured to compress exhaust gases that have been expanded by the turbine, e.g. a portion of the expanded exhaust gases. An inlet of the auxiliary compressor may be arranged in an outlet from flow the turbine. Alternatively, the auxiliary compressor may be configured to compress exhaust gases that have been bled from the turbine upstream of a turbine outlet. The turbine may comprise a bleed port configured to bleed exhaust gases, e.g. a portion of the exhaust gases, from the turbine upstream of an outlet of the turbine into an inlet of the auxiliary compressor.

The auxiliary compressor may define a bypass channel configured to permit exhaust gases to flow through the auxiliary compressor without being compressed by the auxiliary compressor, e.g. bypassing the auxiliary compressor.

The bypass channel may be a central channel provided at or close to a central axis of the turbo charger. Alternatively, the bypass channel may be defined by the turbocharger assembly, e.g. between casings of the turbocharger assembly such as a turbine casings and an auxiliary compressor casing.

An inlet of the auxiliary compressor may define a substantially annular opening. An outer radius of the auxiliary compressor inlet may be greater than or equal to an outer radius of an outlet of the turbine.

The bypass channel may be defined radially inside of an inner radius of the auxiliary compressor inlet.

Alternatively, an outer radius of an inlet of the auxiliary compressor may be less than a radius of an outlet of the turbine. The turbocharger assembly may comprises a bypass channel defined radially outside of the auxiliary compressor. The turbocharger assembly may be configured such that a portion of the exhaust gases flows around an outside of the auxiliary compressor to bypass the auxiliary compressor. In other words, the bypass channel may be arranged about the auxiliary compressor, e.g. between the auxiliary compressor and an exhaust duct.

Exhaust gases that bypass the auxiliary compressor are not recirculated via the EGR duct.

A rotating component of the auxiliary compressor may formed integrally with a rotating component of the turbine. For example, the blades of the auxiliary compressor may be formed integrally with the blades of the turbine. Optionally the auxiliary compressor hub may be formed integrally with the turbine hub. In other words, a compressor wheel of the auxiliary compressor may be formed integrally with a turbine wheel of the turbine.

Alternatively, the rotating component of the auxiliary compressor, e.g. the blades and optionally the hub, may be coupled, e.g. directly coupled, to a rotating component of the turbine.

The auxiliary compressor may be configured such that an outlet pressure of the auxiliary compressor is substantially equal to, or greater than, an outlet pressure of the compressor.

The turbocharger may comprise a turbine housing configured to house the turbine. The auxiliary compressor may be provided within the turbine housing.

According to another aspect of the present disclosure, there is provided an engine assembly for a motor vehicle, the engine assembly comprising: an EGR duct configured to recirculate exhaust gases to an inlet of the engine assembly; and a turbocharger assembly having: a compressor configured to compress inlet gases entering the engine assembly; and a turbine configured to expand exhaust gases leaving the engine assembly and drive the compressor; and an auxiliary compressor configured to compress the exhaust gases recirculated by the EGR duct, wherein the auxiliary compressor is driven by the turbine, wherein the auxiliary compressor is arranged on an opposite side of the turbine to the compressor.

The compressor, the turbine and the auxiliary compressor may be provided on a shaft of the turbocharger assembly. The auxiliary compressor may be provided on an opposite side of the turbine to the compressor along the turbocharger shaft.

The auxiliary compressor may be configured to compress the exhaust gases that have been expanded by the turbine. In some arrangements, the auxiliary compressor may be configured to compress exhaust gases that have been bled from the turbine upstream of an outlet of the turbine.

The EGR duct may be configured to recirculate exhaust gases from a position downstream of the turbine, e.g. between an outlet of the turbine and an exhaust outlet of the engine assembly, to a position between an outlet of the compressor and an inlet manifold of the engine assembly. In this way, the recirculated exhaust gases may not pass through the compressor after being recirculated.

The engine assembly may further comprise an EGR cooler configured to cool the exhaust gases that have been compressed by the auxiliary compressor. In other words, the auxiliary compressor may be arranged between the turbine and the EGR cooler relative to the flow of recirculated exhaust gases.

The engine assembly may further comprise a charge air cooler configured to cool the inlet air compressed by the compressor. The EGR duct may be configured to recirculate the exhaust gases to a position between the charge air cooler and an inlet manifold of the engine assembly. In some arrangements, the EGR gases may be introduced into the inlet manifold. Alternatively, the EGR duct may be configured to recirculate the exhaust gases to a position upstream of the charge air cooler, e.g. between the compressor outlet and the charge air cooler. In this way, the recirculated exhaust gases may be cooled by the charge air cooler.

The turbocharger assembly may be configured such that an outlet pressure of the auxiliary compressor is substantially equal to, or greater than, an outlet pressure of the compressor, e.g. such that the pressure of recirculated exhaust gases introduced into the inlet of the engine assembly is substantially equal to, or greater than, the pressure of inlet air within the inlet.

According to another aspect of the present disclosure, there is provided an engine assembly for a motor vehicle, the engine assembly comprising: an EGR duct configured to recirculate exhaust gases to an inlet of the engine assembly; and an EGR cooler configured to reduce the temperature of the exhaust gases recirculated by the EGR duct; and a turbocharger assembly having: a turbine configured to expand exhaust gases leaving the engine assembly; and an auxiliary compressor driven by the turbine and configured to compress the exhaust gases recirculated via the EGR duct prior to the recirculated exhaust gases being cooled by the EGR cooler. In other words, the auxiliary compressor may be arranged between the turbine and the EGR cooler with respect to the flow of exhaust gases.

The turbocharger assembler may further comprise a compressor configured to compress inlet gases entering the engine assembly. The compressor may be driven by the turbine. The auxiliary compressor may be provided on the opposite side of the turbine to the compressor.

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 Recirculation (EGR) system having an EGR duct configured to recirculate exhaust gases to an intake of the engine assembly; and a turbocharger assembly comprising: a compressor, configured to compress inlet gases entering the engine assembly; a turbine configured to expand exhaust gases leaving the engine assembly and drive the compressor; and an auxiliary compressor configured to compress the exhaust gases recirculated by the EGR duct, wherein the method comprises: compressing a portion of the exhaust gas using the auxiliary compressor; recirculating the compressed portion of the exhaust gases via the EGR duct; and cooling the compressed portion of the exhaust gases using an EGR cooler provided in the EGR duct.

The method may further comprise mixing the recirculated exhaust gases with the compressed inlet gases within the intake system of the engine assembly.

The method may further comprise cooling the mixture of inlet and exhaust gases using a charge air cooler provided in the intake system.

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 embodiments of the invention. However, it is to be understood that, where it is technically possible, features described in relation to any aspect or embodiment of the invention may also be used with any other aspect or embodiment 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;

Figure 4 is a schematic view of an engine assembly comprising a turbine pumped exhaust gas recirculation system, according to another arrangement of the present disclosure;

Figure 5 is a schematic view of an exhaust gas recirculation apparatus, according to arrangements of the present disclosure;

Figure 6 is a schematic view of an exhaust gas recirculation apparatus, according to another arrangement of the present disclosure;

Figure 7 is a schematic view of an exhaust gas recirculation apparatus, according to another arrangement of the present disclosure;

Figure 8 is a schematic view of an exhaust gas recirculation apparatus, according to another arrangement of the present disclosure; and

Figure 9 is a schematic view of an exhaust gas recirculation apparatus, according to another arrangement of the present disclosure.

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 120, an engine 130, and an exhaust system 140.

The intake system 110, the turbocharger 120, the engine 130 and the exhaust system 140 are similar to the intake system 20, 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 turbine pumped EGR system 200 comprises an auxiliary compressor 202. The auxiliary compressor 202 is driven by a turbine 124 of the turbocharger 120 and is configured to compress the portion of exhaust gases to be recirculated by the turbine pumped EGR system 200. The auxiliary compressor 202 may therefore be referred to as an EGR compressor or an EGR pump. In the arrangement depicted in Figure 3, the auxiliary compressor 202 is provided downstream of a turbine 124 of the turbocharger 120, e.g. between the turbocharger turbine 124 and an exhaust outlet 144 of the exhaust system 140, with respect to the flow of exhaust gases through the exhaust system 140. In this way, the portion of the exhaust gases that is compressed by the auxiliary compressor 202 may have previously been expanded through the turbine 124.

In the arrangement depicted, the portion of the exhaust gases to be recirculated by the turbine pumped EGR system flows out of the turbine 124 via an outlet of the turbine before being directed into the auxiliary compressor 202. However, in other arrangements of the disclosure, the portion of the exhaust gases to be recirculated by the turbine pumped EGR system may be bled from the turbine at a position upstream of the turbine outlet and directed into the auxiliary compressor.

When the auxiliary compressor is configured to compress exhaust gases that have been (at least partially) expanded within the turbocharger turbine 124, an inlet pressure of the auxiliary compressor 202 may be substantially equal to an outlet pressure of the turbocharger turbine 124, or an intermediate pressure between the inlet pressure of the turbine and the outlet pressure of the turbine.

However, in other arrangements of the disclosure, the portion of the exhaust gases to be compressed by the auxiliary compressor 202 may be separated from the bulk flow of exhaust gases upstream of the turbocharger turbine 124, e.g. between an exhaust manifold 134 of the engine 130 and the turbine 124. In this case, the inlet pressure of the auxiliary compressor 202 may be substantially equal to the inlet pressure of the turbocharger turbine 124, or an intermediate pressure between the inlet and outlet pressures of the turbocharger turbine 124.

The turbine pumped EGR system 200 further comprises an EGR duct 204 configured to recirculate the exhaust gases that have been compressed by the auxiliary compressor 202 to the intake system 110. As shown in Figure 3, the exhaust gases recirculated by the turbine pumped EGR system 200 may be introduced at an inlet manifold 132 of the engine 130. Alternatively, as depicted in Figure 4, the recirculated exhaust gases may be introduced into a hot inlet duct 118 of the intake system 110, e.g. between a turbocharger compressor 122 and the inlet manifold 132 with respect to the flow of inlet air.

In the arrangement shown in Figure 4, the recirculated exhaust gases are reintroduced upstream of a charge air cooler 119, such that the recirculated exhaust gases are cooled by the charger air cooler 119 together with the inlet air. However, in other arrangements of the disclosure, the recirculated exhaust gases may be introduced downstream of the charge air cooler, e.g. between the charge air cooler 119 and the inlet manifold 132.

It may be desirable for the recirculated exhaust gases to be cooled before being reintroduced into the intake system 110 in order to increase the density of the intake gases within the inlet manifold 132. The turbine pumped EGR system 200 therefore comprises an EGR cooler 206 provided on the EGR duct 204. The EGR cooler 206 is provided downstream of the auxiliary compressor 202, e.g. between the auxiliary compressor 202 and the intake system 110, such that the recirculated exhaust gases are compressed before being cooled by the EGR cooler 206. In other words, the EGR compressor 202 may be provided between the exhaust system 140, e.g. a hot or cold exhaust duct 142, 146 of the exhaust system 140, and the EGR cooler 206.

With reference to Figure 5, in some arrangements, an auxiliary compressor 550 for compressing the recirculated exhaust gases may be provided as part of a turbocharger assembly 500 according to arrangements of the present disclosure. When the engine assembly 100 comprises the turbine pumped EGR system 200, the turbocharger assembly 500, according to the present disclosure, may be provided within the engine assembly 100 instead of the turbocharger assembly 20,120.

As shown in Figure 5, the turbocharger assembly 500 comprises a turbocharger compressor 510, a turbocharger bearing assembly 520, a turbocharger turbine 530, a turbocharger shaft 540 and the auxiliary compressor 550.

In the arrangement shown in Figure 5, the turbocharger compressor 510 is a radial outflow compressor. The turbocharger compressor 510 is configured to receive a substantially axial flow of inlet gases from cold inlet duct 116 and turn and compress the flow of inlet gases such that the compressed inlet gases are output from the compressor 510 in a substantially radial direction, e.g. relative to a central axis of the turbocharger shaft 540.

The turbocharger compressor 510 comprises a compressor rotor 512 and a compressor casing 514. The compressor rotor 512 is configured to rotate within the compressor casing 514 such that blades 512a of the compressor act on the inlet gases entering the compressor to compress the inlet gases and turn them to flow in a substantially radial direction. The compressor blades 512a are supported on a hub 512b of the compressor rotor 512, which is coupled to the turbocharger shaft 540.

The turbocharger turbine 530 comprises a turbine casing 534 and a turbine rotor 532 configured to rotate within the turbine casing 534. The turbine casing 534 may be separate to the compressor casing 514 and may be coupled, e.g. bolted to the compressor casing. Alternatively, the compressor casing and the turbine casing may be integral.

The turbine rotor 532 is configured such that exhaust gases passing between turbine blades 532a of the turbine rotor drive rotation of the turbine rotor 532 as the pressure of the exhaust gases reduces. The turbine blades are supported by a hub 532b of the turbine rotor that is coupled to the turbocharger shaft 540.

The turbocharger shaft 540 extends between the turbocharger compressor 510 and the turbocharger turbine 530 and transfers the power generated by the turbine to the compressor rotor 512. Rotation of the shaft 540 is supported by the bearing assembly 520.

The bearing assembly comprises a bearing 522, such as a roller bearing, a ball bearing, a journal bearing or any bearing suitable for supporting the rotation of the shaft, and a bearing housing 524. A rotating component 522a of the bearing is coupled to the shaft 540 and a static component 522b of the bearing is supported by the bearing housing 524.

In the arrangement shown in Figure 5, the bearing housing 524 is a separate component to the compressor housing 514 and the turbine housing 532 and is coupled to the compressor and turbine housings, e.g. using bolts and/or dowels. However, in other arrangements of the present disclosure, the bearing housing 524 may be integral with the compressor casing 514 and/or the turbine casing 534.

In the arrangement shown in Figure 5, the bearing assembly 520 is provided between the turbocharger compressor 510 and the turbocharger turbine 530, e.g. along the turbocharger shaft 540. However, it is equally envisaged that the bearing assembly 520 may be provided on the opposite side of the compressor to the turbine or on the opposite side of the turbine to the compressor, e.g. along the shaft.

As depicted in Figure 5, the auxiliary compressor 550 is arranged such that a portion of the exhaust gases flowing out of an outlet 530b of the turbine 530 flow into an inlet 550a of the auxiliary compressor 550. The auxiliary compressor 550 comprises a rotor 552 and a casing 554. The auxiliary compressor casing 554 may be integral with, e.g. part of, the turbine casing 534. In other words, the rotor 552 of the auxiliary compressor 550 may be provided within the turbine casing 534. Alternatively, in other arrangements of the disclosure, the auxiliary compressor casing 554 may be a separate component from the turbine casing 534 and may be coupled to the turbine casing using fasteners, such as bolts and/or dowels.

The auxiliary compressor rotor 552 is configured similarly to the compressor rotor 512. Blades 552a of the rotor 552 are configured to compress the exhaust gases flowing through the auxiliary compressor. As depicted in Figure 5, the auxiliary compressor 550 is a radial outflow compressor and the blades 552a of the auxiliary compressor are configured to turn the outlet flow from the turbocharger turbine 530 from a substantially axial direction to a direction having an increased radial component (relative to the central axis of the turbocharger shaft 540). In other arrangements, for example as depicted in Figure 6, the auxiliary compressor 550 may be an axial flow compressor configured such that the flow of exhaust gases has a substantially axial velocity during the time that the exhaust gases flow though the blades 552a of the compressor rotor, e.g. a radial component of velocity of the exhaust gases may remain substantially unchanged as the exhaust gases flow though the compressor.

With reference to Figure 5 and 6, regardless of whether the auxiliary compressor 550 is an axial flow compressor, or a radial outflow compressor, the casing 554 of the auxiliary compressor is configured to collect the compressed exhaust gases that have passed though the auxiliary compressor 550. The auxiliary compressor casing 554 defines an outlet 556 of the auxiliary compressor that delivers the compressed exhaust gases to the EGR duct 204. As depicted in Figure 5 and 6, the outlet 556 may be configured such that the flow of exhaust gases flowing through the outlet 556 is substantially radial, relative to the turbocharger shaft central axis. Alternatively, the outlet 556 may be configured such that the flow of exhaust gases flowing through the outlet 556 is substantially axial or has components in the axial and radial directions.

As depicted in Figures 5 and 6, the auxiliary compressor 550 is arranged on an opposite side of the turbocharger turbine 530 to the turbocharger compressor 510, e.g. along the shaft 540 of the turbocharger. The auxiliary compressor 550 may be arranged on an outlet side of the turbocharger turbine, e.g. adjacent to the outlet 530b of the turbocharger turbine. Furthermore, the auxiliary compressor 550 may be provided at or close to an inlet of the cold exhaust duct 146. For example, the auxiliary compressor 550 may be arranged such that an inlet 550a of the auxiliary compressor is arranged about an inlet to the cold exhaust duct. Exhaust gases flowing out of the turbocharger turbine outlet 530b that do not enter the inlet 550a of the auxiliary compressor may pass into the cold exhaust duct 146.

In the arrangements shown in Figures 5 and 6, the inlet 550a to the auxiliary compressor is substantially annular. An outer radius of the auxiliary compressor inlet 550a is equal to or greater than the outer radius of the turbine outlet 530b. Furthermore, as depicted in Figure 6, the outer radius of the auxiliary compressor inlet 550a may be equal to or greater than an outer radius of the cold exhaust duct 146.

In the arrangements shown in Figures 5 and 6, the auxiliary compressor 550 is spaced apart from the turbocharger turbine 530 along the turbocharger shaft 540. With reference to Figure 7, in other arrangements of the disclosure, the auxiliary compressor

550 may be coupled to, e.g. directly coupled to, or formed integrally with the turbocharger turbine. For example, the rotor 552 of the auxiliary compressor may be directly coupled to or integrally formed with the rotor 532 of the turbocharger turbine. In other words, the auxiliary compressor rotor may be formed by a compressor section 536 of the turbocharger turbine rotor in which the geometry of the blades 532a the turbine has been configured to recompress the exhaust gases and direct the recompressed exhaust gases towards the auxiliary compressor outlet 556. In such arrangements, the inlet 550a of the auxiliary compressor may be defined by the position at which an expander section 538 of the turbocharger turbine configured to expand the exhaust gases transitions to the compressor section 536 of the turbocharger turbine, within which the exhaust gases are recompressed.

As depicted in Figure 7, the compressor section 536 of the turbocharger turbine, may be arranged radially outside of an expander section 538, or a portion of the expander section, of the turbocharger turbine.

The blades 532a of the turbocharger turbine 530 may be integrally formed with blades 552a of the auxiliary compressor 550. Alternatively, the blades 552a of the auxiliary compressor may be separate from the blades 532a of the turbocharger turbine. For example, the blades 552a of the auxiliary compressor may be positioned between, e.g. angularly between, the blades of the turbocharger turbine, e.g. about the turbine rotor hub 532b.

The turbocharger assembly 500 may comprise a flow divider 560 configured to divide the flow exiting the turbocharger turbine, such that a first portion of the expanded exhaust gases flows into the inlet 550a of the auxiliary compressor, and a second portion of the expanded exhaust gases flow into the cold exhaust duct 146.

As depicted in Figures 5 and 6, the flow divider 560 may be formed by the auxiliary compressor 550, e.g. the rotor 552 and/or housing 554 of the auxiliary compressor. Alternatively, for example as depicted in Figure 7, the flow diver 560 may be formed by a portion of the turbocharger rotor configured to direct a first portion of the exhaust gases expanded by the turbocharger turbine into the auxiliary compressor, e.g. into the compressor section 536 of the turbocharger turbine, and direct a second portion of the expanded exhaust gases towards the cold exhaust duct 146.

As depicted in Figures 5 and 6, in some arrangements of the disclosure, the auxiliary compressor 550 defines a bypass channel 570 configured to allow the second portion of exhaust gases exiting the turbocharger, e.g. the portion of the exhaust gases not to be recirculated by the turbine pumped EGR system 200, to bypass the auxiliary compressor 550. In the arrangement shown in Figures 5 and 6, the bypass channel 570 is defined within the rotor 552 of the auxiliary compressor.

The bypass channel 570 is provided radially inside of the blades 552a of the auxiliary compressor rotor. The bypass channel 570 may be formed in a hub of the auxiliary compressor rotor or may be formed between the hub and the blades. Blade support elements (not shown) may extend across the bypass channel 570 between the hub and the blades. The blade support elements may be configured to provide minimal interference to the exhaust gases passing through the bypass channel 570.

In other arrangements of the disclosure, the bypass channel 570 may be defined between the rotor 552 and the casing 554 of the auxiliary compressor.

The flow divider 560 may be configured to separate the exhaust gases passing though the auxiliary compressor 550, e.g. being compressed by the auxiliary compressor, from the flow of exhaust gases passing though the bypass channel 570.

With reference to Figure 8, in some arrangements of the disclosure, the auxiliary compressor 550 may be arranged within the cold exhaust duct 146. An outer radius of the auxiliary compressor casing 554 may be less than an inner radius of the cold exhaust duct 146. In this arrangement, the bypass channel 570 is defined radially outside of the auxiliary compressor casing 554, e.g. between the auxiliary compressor casing 554 and the cold exhaust duct 146. The flow divider 560 is thereby formed by the auxiliary compressor casing 554.

As depicted in Figure 8, in such arrangements, the flow of compressed exhaust gases flowing though the outlet 556 of the auxiliary compressor 550 may be substantially axial. The EGR duct 204 is provided at least partially within the cold exhaust duct 146 and may extend along the cold exhaust duct coaxially with the cold exhaust duct 146. The EGR duct 204 leaves the cold exhaust duct 146 at a corner of the cold exhaust duct. In other arrangements, the auxiliary compressor 550 depicted in Figure 8 may be a radial outflow compressor and the EGR duct 204 may extend out of the cold exhaust duct 146 in a direction substantially perpendicular to a central axis of the cold exhaust duct 146.

In the arrangements depicted in Figure 8, the auxiliary compressor 550 is provided within the cold exhaust duct 146. However, in other arrangements, the auxiliary compressor 550 may be arranged within the turbine casing 534. In such arrangements, the bypass channel 570 may be defined between the auxiliary compressor casing 554 and the turbine casing 534.

With reference to Figure 9, in other arrangements of the present disclosure, the auxiliary compressor 500 is provided between the turbocharger compressor 510 and the turbocharger turbine 530, e.g. the turbocharger turbine 530 is provided on the opposite side of the auxiliary compressor to the turbocharger compressor 510. In other words, the auxiliary compressor is provided on an opposite side of the turbocharger turbine to the turbine outlet 530b.

As depicted in Figure 9, the auxiliary compressor rotor 552 is integrally formed with the turbine rotor 532. The auxiliary compressor rotor may be formed by a compressor section 536 of the turbocharger turbine rotor in which the geometry of the blades 532a of the turbine has been configured to recompress the exhaust gases and direct the recompressed exhaust gases towards the auxiliary compressor outlet 556, e.g. rather than the turbocharger turbine outlet 530b.

In the arrangement depicted in Figure 9, the auxiliary compressor casing 554 is integrally formed with the turbine casing 534. In other words, the auxiliary compressor rotor 552 is provided within the same casing as the turbocharge turbine rotor 532. However, in other arrangements, the auxiliary compressor 550 may comprise a separate casing component 554, which may be coupled to the turbine casing 534. For example, the auxiliary compressor casing 554 may be coupled between the bearing housing 524 and the turbine housing 534. Alternatively, the auxiliary compressor casing 534 may be formed integrally with the bearing housing 524. In other words, the auxiliary compressor rotor 552, or compressor section 536 of the turbine rotor 532, may be provided within the bearing housing 524.

The turbocharger turbine 530 is provided with at least one through channel 531, e.g. provided in the expander section 538 of the turbine rotor 542, configured such that a portion of the exhaust gases passes from the expander section 538 of the rotor 532 to the compressor section 536. The exhaust gases which flow to the compressor section 336 are then compressed and directed to the EGR duct 204 through the auxiliary compressor outlet 556.

The exhaust gases which flow to the EGR duct 204 therefore travel through at least a portion of the turbocharger turbine 530 in direction substantially opposite to the direction of the gases flowing to the turbine outlet 530b. This is different from the arrangements previously described, in which the direction of flow of exhaust gas towards the EGR duct 204, e.g. through the auxiliary compressor 550, and towards the cold exhaust duct 146, e.g. through the turbine outlet 530b, is similar.

The through channel 531 between the expander section 538 and the compressor section 536 may be configured such that the exhaust gases entering the compressor section 536 have not been expanded, e.g. within the expander section 538, before passing through the through channel 531 to the compressor section 536. In this way, a portion of the exhaust gases may effectively bypass the expander section 538. Alternatively, the through channel 531 and/or the blades 532a may be configured such that exhaust gases passing through the through channel 531 are at least partially expanded within the expander section 538 before passing into the compressor section 536.

Additional Statements of Invention

The following additional statements of invention are also included as part of this specification:

Statement 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; 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.

Statement 2. An EGR apparatus according to statement 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.

Statement 3. The EGR apparatus according to any of statements 1 to 2, wherein the bypass channel is substantially circular in cross section.

Statement 4. The EGR apparatus according to any of statements 1 to 3, wherein a radius of the bypass channel is less than a radius of a turbocharger turbine outlet.

Statement 5. The EGR apparatus according to any of statements 1 to 4, wherein the EGR compressor is coupled to the turbocharger turbine such that the EGR compressor is driven by the turbocharger turbine.

Statement 6. The EGR apparatus according to any of statements 1 to 5, wherein the EGR compressor further comprises:

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;

a turbine side of the housing facing 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.

Statement 7. The EGR apparatus according to statement 6, 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.

Statement 8. The EGR apparatus according to statement 6 or 7, wherein the flow divider is coupled to the plurality of EGR compressor blades, e.g. so that the flow divider rotates with the plurality of EGR blades.

Statement 9. The EGR apparatus according to statement 6 or 7, wherein the flow divider is coupled to the housing of the EGR compressor blades, e.g. so that the exhaust gas divider is stationary relative to the plurality of rotating EGR compressor blades.

Statement 10. The EGR apparatus according to any of statements 6 to 9, 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.

Statement 11. The EGR apparatus according to any of statements 1 to 10, wherein the EGR compressor is a radial outflow compressor. The plurality of EGR compressor blades may be impeller blades.

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

Statement 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 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.

Statement 14. An EGR system according to statement 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.

Statement 15. The EGR system according to statement 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, e.g. radial connectors/spokes, 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.

Statement 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 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.

Statement 17. A turbocharger assembly for an engine, wherein the engine comprises an Exhaust Gas Recirculation (EGR) system having an EGR duct configured to recirculate engine exhaust gases to an intake of the engine assembly, and wherein the turbocharger assembly comprises:

a primary compressor for compressing air into the intake; and

a rotor comprising a first turbine section configured to expand engine exhaust gases, and a second auxiliary compressor section configured to compress engine exhaust gases and direct them into the EGR duct, the first and second sections of the rotor being at least one of integrally formed with and directly coupled to one another.

Statement 18. The turbocharger assembly of statement 17, further comprising an exhaust gas outlet and an EGR outlet, wherein a portion of the exhaust gas expanded by the first section of the rotor flows through the exhaust gas outlet, and a remaining portion of the gas is compressed by the second section of the rotor and flows to the EGR duct through the EGR outlet.

Statement 19. The turbocharger assembly of statement 17 or 18, wherein the second section of the rotor is configured to compress the exhaust gases expanded by the first section of the rotor.

Statement 20. The turbocharger assembly of any of statements 17 to 19, wherein the rotor is configured such that a portion of the exhaust gases bypass the first section of the rotor unexpanded, and impinge on the second section of the rotor.

Statement 21. The turbocharger assembly of any of statements 17 to 20, wherein the rotor comprises turbine blades in the first section which merge into auxiliary compressor blades in the second section.

Statement 22. The turbocharger assembly of any of statements 17 to 21, wherein the turbocharger assembly further comprises a shaft, and wherein the rotor is mounted on the shaft.

Statement 23. The turbocharger assembly of any of statements 17 to 22, wherein the first and second sections of the rotor are provided consecutively on the shaft.

Statement 24. The turbocharger assembly of any of statements 17 to 23, wherein the second section of the rotor is provided on the opposite side of the first section relative to the exhaust gas outlet.

Statement 25. The turbocharger assembly of any of statements 17 to 23, wherein the first section of the rotor is provided on the opposite side of the second section relative to the exhaust gas outlet.

Statement 26. The turbocharger assembly of any of statements 17 to 25, wherein the rotor defines a bypass channel configured to permit exhaust gases to flow past the second section of the rotor without being compressed by the second section of the rotor.

Statement 27. The turbocharger assembly of any of statements 17 to 26, wherein the bypass channel is defined radially inside of an inner radius of the second section of the rotor.

Statement 28. The turbocharger assembly of any of statements 17 to 27, wherein the rotor is configured such that a portion of the exhaust gases flows around the outside of the second section of the turbine to bypass the second section.

Statement 29. The turbocharger assembly of any of statements 17 to 28, further comprising a common housing configured to house the first and second sections of the rotor.

Statement 30. The turbocharger assembly of any of statements 17 to 29, wherein the recirculated engine exhaust gas is introduced downstream of the primary compressor.

Statement 31. An engine having a turbocharger assembly according to any preceding statement.

Statement 32. A vehicle having a turbocharger assembly according to any preceding statement.

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.

Claims

1. A turbocharger assembly for an engine assembly, wherein the engine assembly comprises an Exhaust Gas Recirculation (EGR) system having an EGR duct configured to recirculate exhaust gases to an intake of the engine assembly, wherein the turbocharger assembly comprises:

a compressor, configured to compress inlet gases entering the engine assembly;

a turbine configured to expand exhaust gases leaving the engine assembly and drive the compressor; and

an auxiliary compressor configured to compress the exhaust gases recirculated by the EGR duct, wherein the auxiliary compressor is driven by the turbine and wherein the auxiliary compressor is arranged on an opposite side of the turbine to the compressor.

2. The turbocharger assembly of claim 1, wherein the turbocharger assembly further comprises a shaft, wherein the compressor, the turbine and the auxiliary compressor are provided on the shaft.

3. The turbocharger assembly of claim 1 or 2, wherein the auxiliary compressor is configured to compress exhaust gases that have been expanded by the turbine.

4. The turbocharger assembly of any of the preceding claims, wherein the turbine comprises a bleed port configured to bleed exhaust gases from the turbine upstream of an outlet of the turbine into an inlet of the auxiliary compressor.

5. The turbocharger assembly of any of the preceding claims, wherein the auxiliary compressor defines a bypass channel configured to permit exhaust gases to flow through the auxiliary compressor without being compressed by the auxiliary compressor.

6. The turbocharger assembly of any of the preceding claims, wherein an inlet of the auxiliary compressor defines a substantially annular opening, wherein an outer radius of the auxiliary compressor inlet is greater than or equal to an outer radius of an outlet of the turbine.

7. The turbocharger assembly of claims 5 and 6, wherein the bypass channel is defined radially inside of an inner radius of the auxiliary compressor inlet.

8. The turbocharger assembly of any of claims 1 to 5, wherein an outer radius of an inlet of the auxiliary compressor is less than a radius of an outlet of the turbine.

9. The turbocharger assembly of any of the preceding claims, wherein the turbocharger assembly comprises a bypass channel defined radially outside of the auxiliary compressor, wherein the turbocharger assembly is configured such that a portion of the exhaust gases flows around an outside of the auxiliary compressor to bypass the auxiliary compressor.

10. The turbocharger assembly of any of the preceding claims, wherein a rotating component of the auxiliary compressor is formed integrally with a rotating component of the turbine.

11. The turbocharger assembly of any of claims 1 to 9, wherein a rotating component of the auxiliary compressor is coupled to a rotating component of the turbine.

12. The turbocharger assembly of any of the preceding claims, wherein the auxiliary compressor is configured such that an outlet pressure of the auxiliary compressor is substantially equal to an outlet pressure of the compressor.

13. The turbocharger assembly of any of the preceding claims, wherein the turbocharger comprises a turbine housing configured to house the turbine, wherein the auxiliary compressor is provided within the turbine housing.

14. An engine assembly for a motor vehicle, the engine assembly comprising:

an EGR duct configured to recirculate exhaust gases to an inlet of the engine assembly; and

a turbocharger assembly having:

a compressor configured to compress inlet gases entering the engine assembly; and

a turbine configured to expand exhaust gases leaving the engine assembly and drive the compressor; and an auxiliary compressor configured to compress the exhaust gases recirculated by the EGR duct, wherein the auxiliary compressor is driven by the turbine, wherein the auxiliary compressor is arranged on an opposite side of the turbine to the compressor.

15. The engine assembly of claim 14, wherein the auxiliary compressor is configured to compress the exhaust gases that have been expanded by the turbine.

16. The engine assembly of claim 14 or 15, wherein the EGR duct is configured to recirculate exhaust gases from a position downstream of the turbine to a position between an outlet of the compressor and an inlet manifold of the engine assembly.

17. The engine assembly of any of claims 14 to 16, wherein the engine assembly further comprises an EGR cooler configured to cool the exhaust gases that have been compressed by the auxiliary compressor.

18. The engine assembly of any of claims 14 to 17, wherein the engine assembly further comprises a charge air cooler configured to cool the inlet air compressed by the compressor, wherein the EGR duct is configured to recirculate the exhaust gases to a position between the charge air cooler and an inlet manifold of the engine assembly.

19. The engine assembly of any of claims 14 to 17, wherein the engine assembly further comprises a charge air cooler configured to cool the inlet gases compressed by the compressor, wherein the EGR duct is configured to recirculate the exhaust gases to a position upstream of the charge air cooler.

20. The engine assembly of any of claims 13 to 19, wherein the turbocharger assembly is configured such that an outlet pressure of the auxiliary compressor is substantially equal to an outlet pressure of the compressor.

21. An engine assembly for a motor vehicle, the engine assembly comprising:

an EGR duct configured to recirculate exhaust gases to an inlet of the engine assembly; and

an EGR cooler configured to reduce the temperature of the exhaust gases recirculated by the EGR duct; and a turbocharger assembly having:

a turbine configured to expand exhaust gases leaving the engine assembly; and

an auxiliary compressor driven by the turbine and configured to compress the exhaust gases recirculated via the EGR duct prior to the recirculated exhaust gases being cooled by the EGR cooler.

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

an Exhaust Gas Recirculation (EGR) system having an EGR duct configured to recirculate exhaust gases to an intake of the engine assembly; and

a turbocharger assembly comprising:

a compressor, configured to compress inlet gases entering the engine assembly;

a turbine configured to expand exhaust gases leaving the engine assembly and drive the compressor; and

an auxiliary compressor configured to compress the exhaust gases recirculated by the EGR duct,

wherein the method comprises:

compressing a portion of the exhaust gas using the auxiliary compressor;

recirculating the compressed portion of the exhaust gases via the EGR duct; and

cooling the compressed portion of the exhaust gases using an EGR cooler provided in the EGR duct.

23. The method of claim 22, wherein the method further comprises:

mixing the recirculated exhaust gases with the compressed inlet gases within the intake system of the engine assembly.

24. The method of claim 23, wherein the method further comprises:

cooling the mixture of inlet and exhaust gases using a charge air cooler provided in the intake system.

Amendments to the Claims have been filed as follows :-

Claims

1. A turbocharger assembly for an engine assembly, wherein the engine assembly comprises an Exhaust Gas Recirculation (EGR) system having an EGR duct configured to recirculate exhaust gases to an intake of the engine assembly, wherein the turbocharger assembly comprises:

a compressor, configured to compress inlet gases entering the engine assembly;

a turbine configured to expand exhaust gases leaving the engine assembly and drive the compressor; and

an auxiliary compressor configured to compress the exhaust gases recirculated by the EGR duct, wherein the auxiliary compressor is driven by the turbine, wherein the auxiliary compressor is arranged on an opposite side of the turbine to the compressor, and wherein the auxiliary compressor is arranged to compress exhaust gases that have been expanded by the turbine.

12 04 18

2. The turbocharger assembly of claim 1, wherein the turbocharger assembly further comprises a shaft, wherein the compressor, the turbine and the auxiliary compressor are provided on the shaft.

3. The turbocharger assembly of any of the preceding claims, wherein the turbine comprises a bleed port arranged upstream of an outlet of the turbine for bleeding exhaust gases from the turbine into an inlet of the auxiliary compressor.

4. The turbocharger assembly of any of the preceding claims, wherein the auxiliary compressor defines a bypass channel arranged to permit exhaust gases to flow through the auxiliary compressor without being compressed by the auxiliary compressor.

5. The turbocharger assembly of any of the preceding claims, wherein an inlet of the auxiliary compressor defines a substantially annular opening, wherein an outer radius of the auxiliary compressor inlet is greater than or equal to an outer radius of an outlet of the turbine.

6. The turbocharger assembly of claims 4 and 5, wherein the bypass channel is defined radially inside of an inner radius of the auxiliary compressor inlet.

7. The turbocharger assembly of any of claims 1 to 4, wherein an outer radius of an inlet of the auxiliary compressor is less than a radius of an outlet of the turbine.

8. The turbocharger assembly of any of the preceding claims, wherein the turbocharger assembly comprises a bypass channel defined radially outside of the auxiliary compressor, wherein the turbocharger assembly is thereby configured such that a portion of the exhaust gases flows around an outside of the auxiliary compressor to bypass the auxiliary compressor.

9. The turbocharger assembly of any of the preceding claims, wherein a rotating component of the auxiliary compressor is formed integrally with a rotating component of the turbine.

10. The turbocharger assembly of any of claims 1 to 8, wherein a rotating component of the auxiliary compressor is coupled to a rotating component of the turbine.

11. The turbocharger assembly of any of the preceding claims, wherein the auxiliary compressor is configured such that an outlet pressure of the auxiliary compressor is substantially equal to an outlet pressure of the compressor.

12. The turbocharger assembly of any of the preceding claims, wherein the turbocharger comprises a turbine housing configured to house the turbine, wherein the auxiliary compressor is provided within the turbine housing.

13. An engine assembly for a motor vehicle, the engine assembly comprising:

an EGR duct configured to recirculate exhaust gases to an inlet of the engine assembly; and

a turbocharger assembly having:

a compressor configured to compress inlet gases entering the engine assembly; and

a turbine configured to expand exhaust gases leaving the engine assembly and drive the compressor; and

an auxiliary compressor configured to compress the exhaust gases recirculated by the EGR duct, wherein the auxiliary compressor is driven by the turbine, wherein the auxiliary compressor is arranged on an opposite side of the turbine to the compressor, and wherein the auxiliary compressor is arranged to compress the exhaust gases that have been expanded by the turbine.

14. The engine assembly of claim 13, wherein the EGR duct is configured to recirculate exhaust gases from a position downstream of the turbine to a position between an outlet of the compressor and an inlet manifold of the engine assembly.

15. The engine assembly of claim 13 or 14, wherein the engine assembly further comprises an EGR cooler arranged to cool the exhaust gases that have been compressed by the auxiliary compressor.

16. The engine assembly of any of claims 13 to 15, wherein the engine assembly further comprises a charge air cooler arranged to cool the inlet air compressed by the compressor, wherein the EGR duct is arranged to recirculate the exhaust gases to a position between the charge air cooler and an inlet manifold of the engine assembly.

17. The engine assembly of any of claims 13 to 15, wherein the engine assembly further comprises a charge air cooler arranged to cool the inlet gases compressed by the compressor, wherein the EGR duct is arranged to recirculate the exhaust gases to a position upstream of the charge air cooler.

18. The engine assembly of any of claims 13 to 17, wherein the turbocharger assembly is configured such that an outlet pressure of the auxiliary compressor is substantially equal to an outlet pressure of the compressor.

Intellectual Property Office

Application No: GB1711654.2 **Examiner:** Rachel Smith

Claims searched: 1-24 **Date of search:** 14 November 2017

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1, 2, 9, 12, 14, 17-20	CN 105840355 A (UNIV JILIN) See figure 1 and EPODOC abstract.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

F02B; F02M

The following online and other databases have been used in the preparation of this search report

WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
F02M	0026/34	01/01/2016
F02B	0037/007	01/01/2006
F02B	0037/12	01/01/2006
F02B	0037/16	01/01/2006
F02B	0037/18	01/01/2006
F02M	0026/07	01/01/2016
F02M	0026/08	01/01/2016
F02M	0026/09	01/01/2016

Intellectual Property Office

Application No:	GB1711654.2	**Examiner:**	Rachel Smith
Claims searched:	21-24	**Date of search:**	20 February 2018

Patents Act 1977
Further Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	21-24	CN 105840355 A (UNIV JILIN) See figure 1 and EPODOC abstract, noting EGR cooler 16 in EGR duct c, turbine 9, compressors 10, 11 and auxiliary compressors 8, 13.
X	21-24	JP 2005299615 A (MITSUBISHI HEAVY IND LTD) See figure 1 and EPODOC abstract, noting EGR cooler 3b in EGR duct, turbine 2a, compressor 2b and auxiliary compressor 3b.
X	21-24	US 2006/248888 A1 (BEHR GMBH & CO KG) See figure 2 and paragraphs 20, 22, noting turbine 4, compressor 7 and EGR cooler 16 in EGR duct 10 downstream of auxiliary compressor 13.
X	21, 22	WO 01/07774 A1 (US ENVIRONMENTAL PROTECTION AGENCY) See figure 3 and page 12 lines 2-13, noting turbine 27, compressor 19 and EGR cooler 42 in EGR duct downstream of auxiliary compressor 41.
X	21-24	EP 2330287 A1 (CATERPILLAR ENGINE CO & KG) See figure 1 and paragraphs 29-31, noting turbines 35, 95, 155, compressor 40, 100, auxiliary compressor 160 in EGR duct 140, 175, and EGR cooler 180.

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

F02B; F02M

The following online and other databases have been used in the preparation of this search report

Intellectual Property Office

WPI, EPODOC, Patent Full Text

International Classification:

Subclass	Subgroup	Valid From
F02M	0026/34	01/01/2016
F02B	0037/007	01/01/2006
F02B	0037/12	01/01/2006
F02B	0037/16	01/01/2006
F02B	0037/18	01/01/2006
F02M	0026/07	01/01/2016
F02M	0026/08	01/01/2016
F02M	0026/09	01/01/2016