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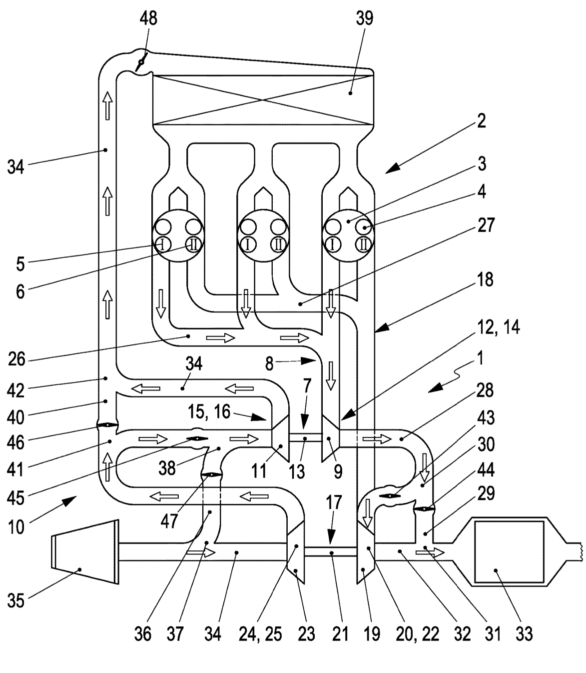
(54) Title of the Invention: **Forced induction device for a combustion engine, combustion engine and method for operating a combustion engine**
Abstract Title: **Forced induction device for a combustion engine having two exhaust turbochargers**

(57) The invention relates to a forced induction device for a combustion engine, having a first exhaust turbocharger 7 and a second exhaust turbocharger 17, exhaust gas from the combustion engine 2 from first outlet port 5 flows through the first exhaust turbocharger 7, exhaust from a second outlet port 6 flows through the second exhaust turbocharger 17. Downstream of a first turbine 9 of the first turbocharger 7 and upstream of a second turbine 19 of the second exhaust turbocharger 17, a first connecting duct 28, allows supply of the second turbine 19 with exhaust gas from the first turbine 9. The first connecting duct 28 connected to a bypass duct 29 at a first branch 30, the bypass duct 29 connecting to a tailpipe line 32 downstream of the second turbine 19 and includes a control valve 44 for blocking or opening the first bypass duct 29.

Fig. 1



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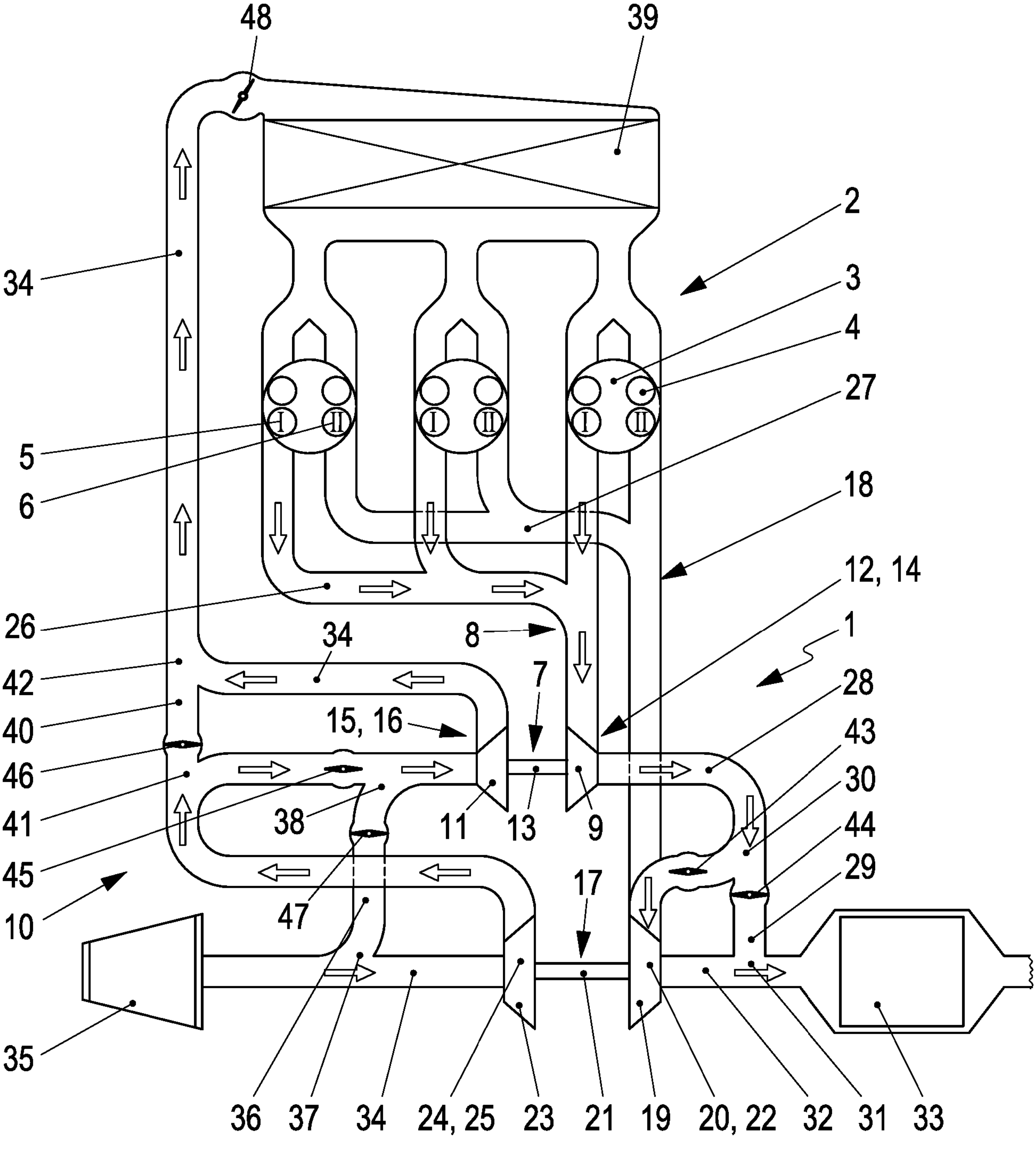
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Fig. 1

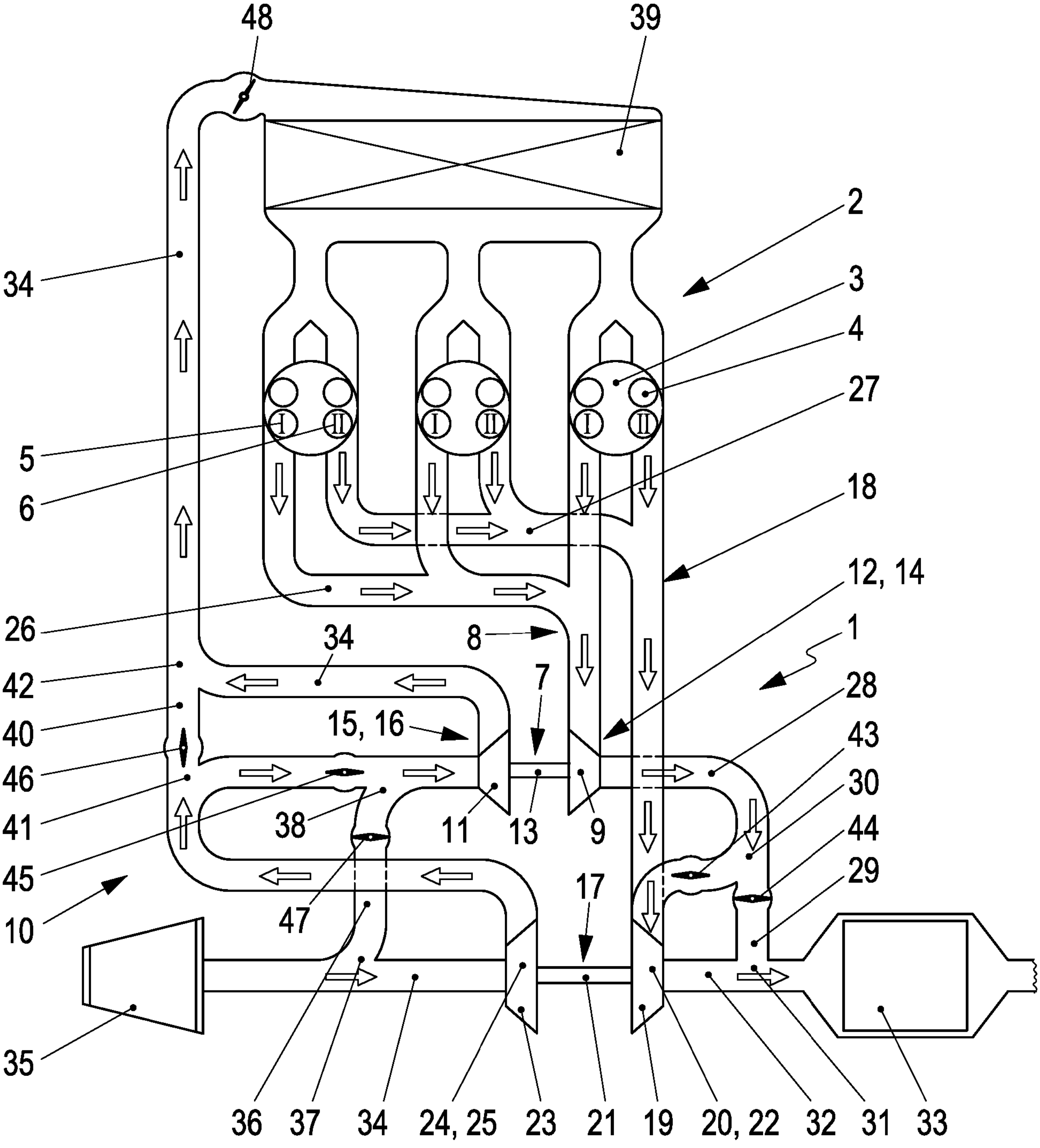
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Fig. 2

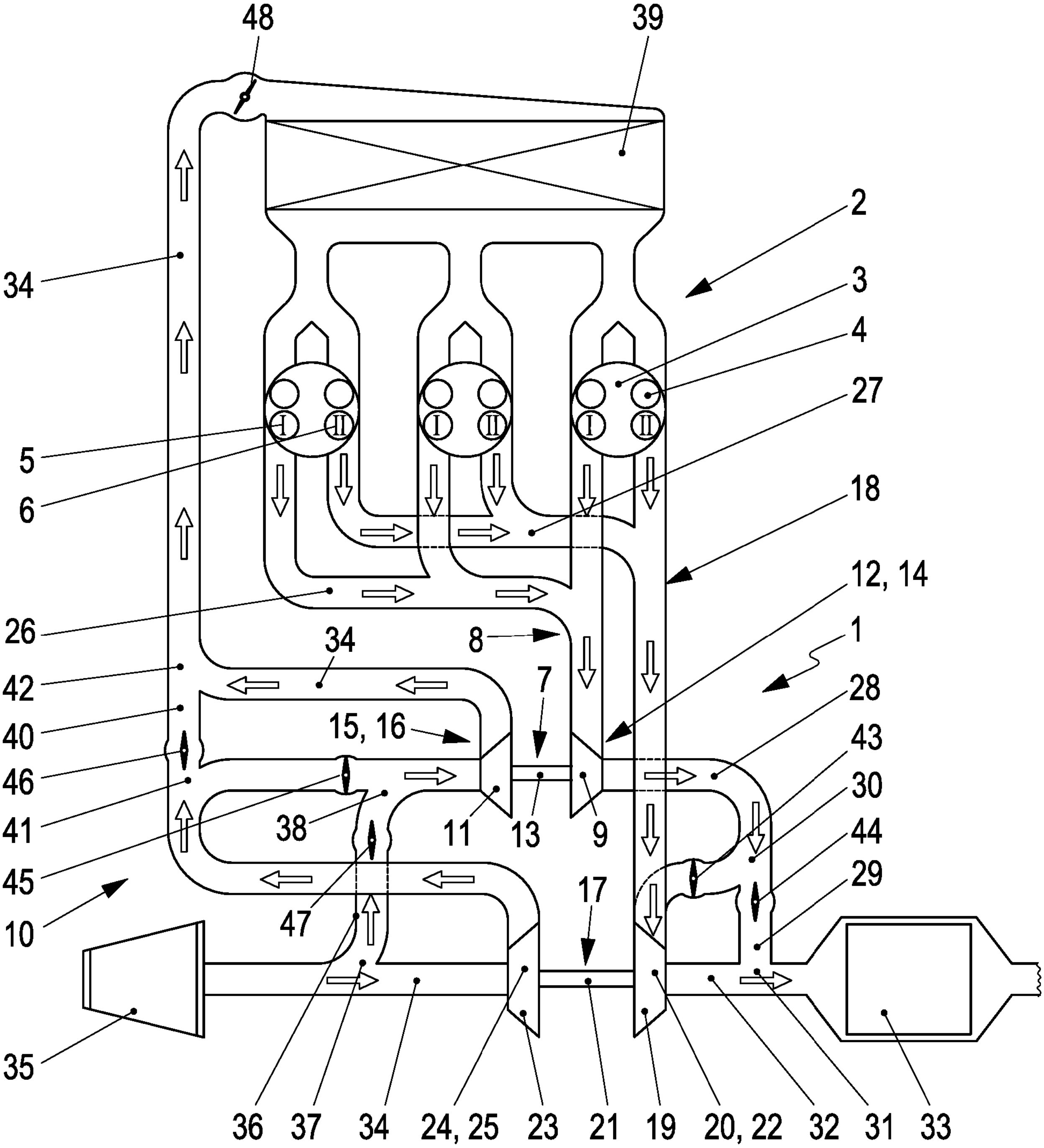
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Fig. 3

Forced induction device for a combustion engine, combustion engine and method for operating a combustion engine

The invention relates to a forced induction device for a combustion engine. The invention furthermore relates to a combustion engine and to a method for operating a combustion engine.

Fundamentally, exhaust turbocharging requires that a sufficiently rapid response be achieved by the exhaust turbocharger. An exhaust turbocharger which is too small ensures a rapid response but can make available fresh air or combustion air to the combustion engine to only a limited extent in the upper speed and/or load range. A large exhaust turbocharger, which can make available sufficient combustion air, has a poor response owing to a high mass moment of inertia of its rotor assembly.

For the time being, a combination of two exhaust turbochargers is therefore being used in the construction of combustion engines. Various arrangements of the exhaust turbochargers relative to one another and positioning of the various control elements at different branches and entries of a duct system fluidically connecting the two exhaust turbochargers to one another are formed. In particular, the aim is to combine two traditional forced induction methods, sequential charging and 2-stage charging, in such a way that a desired operating behavior of the combustion engine can be brought about.

Thus, German Laid-Open Applications DE 10 2011 008 566 A1, DE 10 2011 107 120 A1 and EP 2 402 576 A1 and European Patent EP 1 519 017 B1 disclose forced induction devices having two exhaust turbochargers arranged in series, the turbines of which are arranged in such a way in an exhaust line of the combustion engine and the compressors of which are arranged in such a way in an intake section of the combustion engine that single, parallel or serial operation of the two exhaust turbochargers is implemented in different operating ranges of the combustion engine. The exhaust line has a single exhaust manifold, which is fluidically connected to the combustion engine in such a way that all the outlet ports of the combustion engine are connected to the exhaust manifold in a manner which allows through flow. In other words, this means that exhaust gas from the individual cylinder head or the individual outlet ports first of all flows through this single exhaust manifold before it flows through the turbines into the exhaust line in accordance with a valve configuration.

Patent DE 10 2008 036 308 B4 discloses a combustion engine having two exhaust turbochargers, a first exhaust turbocharger and a second exhaust turbocharger. At least two outlet ports, a first outlet port and a second outlet port of the cylinder head are formed per cylinder head of the combustion engine, wherein the first exhaust turbocharger is connected to the first outlet ports in a manner which allows through flow and the second exhaust turbocharger is connected to the second outlet ports in a manner which allows through flow. With the aid of a selector valve, it is also possible to admit exhaust gas flowing through the second outlet ports to the first exhaust turbocharger. Moreover, a variable valve timing system is provided, with the aid of which it is possible, by changing a timing of the outlet valves constructed with the variable valve timing system, to modify a corresponding time of admission to the corresponding turbine. When one of the exhaust turbochargers is bypassed, there is no longer a flow through it, and its rotor assembly comes to a halt, and therefore its mass moment of inertia must be overcome when exhaust gas is admitted to it when stationary. This leads to a delayed response.

European Patent EP 1 400 667 A1 has disclosed a forced induction device for a combustion engine. Here too, at least two outlet ports, a first outlet port and a second outlet port of the cylinder head are formed, wherein the first exhaust turbocharger is connected to the first outlet ports in a manner which allows through flow and the second exhaust turbocharger is connected to the second outlet ports in a manner which allows through flow. A valve timing system for shutting down outlet valves is provided, said system being fluidically connected to the second exhaust turbocharger. However, it is not possible to operate the two exhaust turbochargers independently of one another in a sequential charging mode with this forced induction device. Thus, it is not possible here to use the two exhaust turbochargers efficiently.

The present invention seeks to provide a forced induction device which can be operated efficiently, or provide a useful alternative. In addition, the invention seeks to develop a combustion engine which has an improved response while simultaneously having a high power. The invention also seeks to specify a method for operating a combustion engine efficiently.

According to aspects of the invention, this can be achieved by a forced induction device having the features of Patent Claim 1. Moreover, a combustion engine having the features of Patent Claim 8 is specified. In addition, a method for operating a combustion engine having the features of Patent Claim 13 is specified. Advantageous embodiments comprising expedient and nontrivial developments of the invention are specified in the respective dependent claims.

The forced induction device according to an aspect of the invention for a combustion engine comprises a first exhaust turbocharger and a second exhaust turbocharger. A first exhaust line, in which a first turbine of the first exhaust turbocharger is mounted in a manner which allows through flow, is formed. With the aid of the first exhaust line, which, upstream of the first turbine, has a first exhaust manifold, which can be connected to a first outlet port of a cylinder head of the combustion engine, it is possible for the first turbine to be supplied exclusively with exhaust gas emerging from the first outlet port. The second exhaust turbocharger is mounted in a second exhaust line, which is formed independently of the first exhaust line and which, upstream of the second turbine, has a second exhaust manifold, which can be connected to a second outlet port of the combustion engine. Downstream of the first turbine and upstream of the second turbine, a first connecting duct which allows through flow is formed to supply the second turbine with exhaust gas emerging from the first turbine. At a first branch, this first connecting duct has a first bypass duct, which is connected to the connecting duct in a manner which allows through flow and by means of which it is possible to bypass the second turbine. For this purpose, the first bypass duct issues at a first entry into a tailpipe line formed downstream of the second turbine. Arranged in this first bypass duct is a second control valve for blocking or opening the first bypass duct. To enable the second turbine to be bypassed, i.e. exhaust gas which flows through the first turbine cannot flow through the second turbine, the first connecting duct has a first control valve, which can block or open the first connecting duct. In aspects of the invention, the first turbocharger is of smaller design, ie has a smaller mass moment of inertia, and therefore requires less energy to spin up, than the second turbocharger.

An advantage of the forced induction device according to the invention is that, in a low load and/or speed range with the second outlet valves shut down, the exhaust gas flowing out of the combustion engine can be passed completely to the first turbine and, when the first connecting duct is closed by means of the first control valve, this exhaust gas can be admitted to the second turbine, ensuring that a rotor assembly of the second exhaust turbocharger is already performing a rotary motion in this operating range and its mass moment of inertia can be overcome. In a full load range, in contrast, it is possible, with a first connecting duct opened by means of the first control valve, for the second turbine to be supplied exclusively with exhaust gas from the second outlet ports and thus to be operated up to its choke limit independently of exhaust gas flowing through the first turbine. As a result, it is possible to achieve the full maximum power both of the first turbine and of the second turbine. When both turbines are operating at their maximum power, their compressors can also operate at maximum power, thus making it possible to achieve a very high boost pressure in the fresh air that can be fed to the combustion engine.

In other words, this means that the first exhaust turbocharger can be operated at its inherent full power in a low speed and/or load range, and both exhaust turbochargers can likewise be operated at their inherent full power in the full load range. Thus, the maximum power of the first exhaust turbocharger can be fully obtained in the low speed and/or load range, as can the maximum power of both exhaust turbochargers in the full load range and/or at high speeds, and therefore the forced induction device is designed for efficient operation.

To enable a compressor power of the second compressor of the second exhaust turbocharger produced by virtue of the turbine work of the second turbine to be used also in the low speed and/or load range of the combustion engine, the forced induction device has an intake pipe, which can be connected to the combustion engine, for supplying fresh air, wherein the first compressor of the first exhaust turbocharger is arranged in the intake pipe downstream of the second compressor. This means that the fresh air drawn in by the first compressor flows through the second compressor while, at the same time, owing to the rotation of the second compressor due to its being driven by the second turbine, this fresh air is precompressed.

In a medium speed and/or load range, it is sufficient if it is primarily the second exhaust turbocharger which delivers fresh air. To ensure that there are no flow losses of the fresh air delivered in this way, at least some of this fresh air is diverted past the first compressor with the aid of a third bypass duct. This third bypass duct is formed in such a way as to branch off from the intake pipe downstream of the first compressor and upstream of the second compressor and to issue into the intake pipe downstream of the first compressor. A flow path in the intake pipe, which is formed between the first compressor and the second compressor, remains open to enable the first compressor to operate in the absence of a vacuum by being rotated by the first turbine. Any available compressor power of the first compressor is used, and the fresh air quantity compressed by the first compressor is fed downstream of the third control valve to the intake pipe formed downstream of the first compressor.

To make it possible also for both compressors to operate independently of one another and in parallel, which is efficient especially in a full load range and/or at high speeds of the combustion engine, a second bypass duct is formed to partially bypass the second compressor. The second bypass duct is designed to branch off from the intake pipe at a second branch upstream of the first compressor and to issue into the intake pipe at a second entry downstream of the second compressor, downstream of the third entry and upstream of the first compressor. For this purpose, it is advantageous if a third control valve is formed in the intake pipe downstream of the second compressor and upstream of the second entry, and a fifth control valve, in particular in the form of a nonreturn throttle valve, is arranged in the second bypass duct to avoid a possible vacuum.

In principle, it is possible with the forced induction device according to the invention to achieve three-stage charging with the aid of two exhaust turbochargers, wherein at least one of the exhaust turbochargers in each of the three stages produces a maximum power that can be achieved up to a surge limit. In addition, a response of the exhaust turbochargers is significantly improved owing to rotation of the rotor assemblies of the exhaust turbochargers over the entire operating range, since the mass moment of inertia of said chargers is at least very largely overcome and a bearing assembly associated with the respective rotor assembly is advantageously substantially in a condition of mixed or liquid friction owing to continuous rotation from the beginning of operation of the combustion engine, provided that plane bearings are used for support, as is customary.

A combustion engine according to the invention comprises a cylinder head, wherein the cylinder head has one inlet port per cylinder, a first outlet port and a second outlet port. The first outlet port can be opened and closed with the aid of a first outlet valve and wherein the second outlet port can be opened and closed with the aid of a second outlet valve. With the aid of an engine control unit of the combustion engine, a variable valve timing system assigned to the combustion engine is formed for varying valve timings of the valves and for shutting down the second outlet valve, and wherein the combustion engine is assigned a forced induction device, which is designed in accordance with one of claims 1 to 7.

The advantage of the combustion engine according to the invention is efficient operation. Thus, for example, in a low load range, in which an exhaust gas mass is only small in comparison with higher loads, operation of the first exhaust turbocharger at maximum power should be brought about, it being possible to supply a sufficient charge air quantity to the combustion engine in this operating range, while, at the same time, owing to the flow through the second turbine, the rotor assembly of the second turbocharger can at least partially overcome its mass moment of inertia, thus eliminating or at least reducing "turbo lag" during a change in the load and/or speed.

Further advantages, features and details of the invention will become apparent from the following description of preferred illustrative embodiments and with reference to the drawing. The features and combinations of features mentioned above in the description and the features and combinations of features mentioned below in the description of the figures or shown exclusively in the figures can be used not only in the respectively indicated combination but also in other combinations or in isolation without exceeding the scope of the invention. Elements which are the same or functionally identical are assigned identical reference signs. For reasons of clarity, the elements may not be provided with their reference sign in all the figures but they do not thereby lose their association. In the drawing:

Figure 1 shows, in a schematic diagram, a combustion engine according to the invention having a forced induction device according to the invention in a first operating interval,

Figure 2 shows, in a schematic diagram, the combustion engine according to the invention having the forced induction device according to the invention in a second operating interval,

and

Figure 3 shows, in a schematic diagram, the combustion engine according to the invention having the forced induction device according to the invention in a third operating interval.

Figure 1 shows, in a schematic diagram, a forced induction device 1 according to the invention for a combustion engine 2, such as a diesel engine or a spark ignition engine of a motor vehicle, in particular a passenger vehicle. By way of example, the combustion engine 2 is in the form of a 3-cylinder engine.

That is to say, it could likewise have a different number of cylinders.

One cylinder 3 of the combustion engine 2 has two inlet ports 4, each provided with an inlet valve (not shown specifically), and two outlet ports, a first outlet port 5 and a second outlet port 6, each provided with an outlet valve (not shown specifically). To allow clear differentiation and association of the individual outlet ports with exhaust lines of the kind described below, the outlet ports 5, 6 of each cylinder 3 are additionally designated by a I or II in the figures.

The combustion engine 2 is furthermore assigned an engine control unit (not shown specifically) and a variable valve timing system (not shown specifically). With the aid of the engine control unit, ignition times and injection quantities, for example, are controlled. The variable valve timing system can likewise be controlled with the aid of the engine control unit. That is to say, depending on different parameters, such as engine speed or quantity of fuel injected, an opening and/or closing time assigned to the valves can be changed. Complete valve shutdown can also be performed. In the case of valve shutdown, the port assigned to the valve is closed, independently of the charge exchange in the combustion engine 2.

The forced induction device 1 comprises a first exhaust turbocharger 7 having a first turbine 9, which is arranged in a first exhaust line 8 of the combustion engine 2, and a first compressor 11, which is arranged in an intake section 10 of the combustion engine 2. The first turbine 9 comprises a first turbine casing 12, which allows through flow and in which a first turbine wheel 14 connected for conjoint rotation to a first shaft 13 of the first exhaust turbocharger 7 is rotatably mounted.

The first compressor 11 comprises a first compressor casing 15, which allows through flow and in which a first compressor wheel 16, which is likewise connected for conjoint rotation to the first shaft 13, is rotatably mounted. The first compressor 11 is used to feed compressed air to the combustion engine 2.

The forced induction device 1 furthermore comprises a second exhaust turbocharger 17, which has a second turbine 19 arranged in a second exhaust line 18 of the combustion engine 2. The second turbine 19 also comprises a second turbine casing 20, which allows through flow and in which a second turbine wheel 22, which is connected for conjoint rotation to a second shaft 21 of the second exhaust turbocharger 17, is rotatably mounted. The second exhaust turbocharger 17 also has a second compressor 23 having a second compressor casing 24, which allows through flow and in which a second compressor wheel 25, which is connected for conjoint rotation to the second shaft 21, is rotatably mounted. By means of the second compressor 23 too, compressed air can be fed to the combustion engine. Like the first compressor 11, the second compressor 23 is likewise arranged in the intake section 10.

The first outlet ports 5 are connected fluidically, in other words in a manner which allows through flow, to a first exhaust manifold 26 of the first exhaust line 8. The first exhaust manifold 26 is designed to receive exhaust gas from the combustion engine 2, said gas flowing out when the first outlet ports are opened, and carries said exhaust gas to the first turbine 9.

The second outlet ports 6 are connected fluidically, in other words in a manner which allows through flow, to a second exhaust manifold 27 of the second exhaust line 18. The second exhaust manifold 27 is likewise designed to receive exhaust gas from the combustion engine 2, said gas flowing out when the second outlet ports are opened, and carries said exhaust gas to the second turbine 19.

Downstream of the first turbine 9 and upstream of the second turbine 19, the first exhaust line 8 and the second exhaust line 18 are connected with the aid of a first connecting duct 28 in a manner which allows through flow. This connecting duct 28 connects a first outlet port (not shown specifically) of the first turbine casing 12 to a second inlet port (not shown specifically) of the second turbine casing 20, allowing at least some of the exhaust gas fed to the first turbine 9 to flow through the second turbine 19.

To enable flow through the second turbine 19 by the expanded exhaust gas flowing out of the first turbine 9 to be partially or completely prevented, a first bypass duct 29 is designed to branch off from the first connecting duct 28 at a first branch 30 downstream of the first turbine casing 12 and upstream of the second turbine casing 20. It issues into a tailpipe line 32 of the combustion engine 2 at a first entry 31 downstream of the second turbine casing 20 and upstream of an exhaust gas aftertreatment unit 33 arranged in the tailpipe line 32.

The intake section 10 has the two compressors 11, 23, wherein the second compressor 23 is arranged upstream of the first compressor 11 in an intake pipe 34 of the intake section 10. To enable the first compressor 11 to draw in fresh air, which is filtered with the aid of an air filter 35 arranged in the intake pipe 34 upstream of the second compressor 23, independently of the second compressor 23, a second bypass duct 36 is formed downstream of the air filter 35 and upstream of the second compressor 23, branching off from the intake pipe 34 at a second branch 37. The second bypass duct 36 issues at a second entry 38 formed in the intake pipe 34 upstream of the first compressor casing 15 and downstream of the second compressor casing 24.

The intake pipe 34 is connected downstream of the first compressor 11 to a charge air cooler 39 of the combustion engine 2, which is arranged upstream of the inlet ports 4 in order to cool the compressed intake air. Thus, compressed and cooled air can be fed for combustion to the combustion engine 2 via the inlet ports 4 when the inlet valves are open. A throttle valve 48 for setting a particular fresh air quantity is formed downstream of the third entry and upstream of the charge air cooler 39.

To enable fresh air compressed and delivered by the second compressor 23 to be diverted past the first compressor 11, a third bypass duct 40 is formed upstream of the second entry 38 and downstream of the second compressor casing 24, branching off from the intake pipe 34 at a third branch 41 and issuing into the intake pipe 34 at a third entry 42 downstream of the first compressor casing 15.

In order to implement different operating states of the forced induction device 1, various control valves are used. A first control valve 43, with the aid of which the first connecting duct 28 can be opened or closed, is positioned at the first branch 30. A second control valve 44, by means of which exhaust gas can be allowed to emerge or can be prevented from emerging from the bypass duct 29 into the tailpipe line 32, is likewise formed at the first entry 31.

A third control valve 45, which is formed at the second entry 38, can block or enable fresh air induction from the second bypass duct 36 by the first compressor 11. Moreover, a fresh air mass flow delivered by the second compressor 23 can flow directly into the third bypass duct 40 with the aid of a fourth control valve 46 arranged at the third branch 41. Alternatively, if the third bypass duct 40 is closed by the fourth control valve 46 at the third branch 41, the fresh air quantity delivered by the second compressor 23 flows through the first compressor 11, in which it is additionally compressed in accordance with the compression ratio of said compressor.

The first compressor 11 and the second compressor 23 can be driven by the respectively corresponding first turbine 9 and second turbine 19. The first turbine 9 and the second turbine 19 are driven by the exhaust gas from the combustion engine 2, which flows through them. The turbine wheels 14, 22 are supplied with the exhaust gas and thus made to rotate, with the result that the compressor wheels 16 and 25 are driven by means of the first shaft 13 and the second shaft 21, respectively.

The control valves 43, 44, 45, 46 can open the ducts and pipes associated therewith between two extreme positions, a fully closed position and full opening, depending on requirements. For the purpose of setting, the control valves 43, 44, 45, 46 are connected to an open-loop and closed-loop control device (not shown specifically) of the combustion engine 2.

A self-regulating nonreturn throttle valve 47 is furthermore arranged in the second bypass duct 36, downstream of the second branch 37 and upstream of the second entry 38.

A variable valve timing system (not shown specifically), with the aid of which the second outlet ports 6 can be held closed in a certain operating state of the forced induction device 1, is assigned to the combustion engine 2.

The three different operating states of the combustion engine 2 which can be achieved with the forced induction device according to the invention are described below by means of figures 1 to 3. For the operating states illustrated, the statement applies that ducts through which there is flow in the respective operating state have arrows pointing in a corresponding direction of flow. Ducts through which there is no flow or which are closed are illustrated without arrows.

A first operating state of the forced induction device 1 is shown in figure 1. In this operating state, the second outlet ports 6 are fully closed with the aid of the variable valve timing system. That is to say that the outlet ports 6 are not opened, even in an exhaust phase of the combustion engine 2, and all the exhaust gas flows out exclusively via the first outlet ports 5. Thus, the exhaust gas is admitted to the first turbine 9. This has the effect that the first turbine wheel 14 is set in rotation and that the first compressor wheel 16 is likewise set in rotation via the first shaft 13 connected for conjoint rotation to the first turbine wheel 14 and the first compressor wheel 16 and can draw in fresh air.

The first control valve 43 opens the first connecting duct 28, while the second control valve 44 blocks the first bypass duct

29, with the result that all the exhaust gas flowing out of the first turbine 9 is fed to the second turbine 19 and acts on the second turbine 19, with the result that the second turbine wheel 22 is likewise set in rotation.

In this first operating range, however, the exhaust gas quantity and the exhaust gas pressure applied to this exhaust gas quantity is just sufficient to bring the first turbine 9 to a corresponding delivery speed. Thus, the second turbine wheel 22 is acted upon by an exhaust gas quantity which has already been expanded through the first turbine 9, which is just sufficient to set the second turbine wheel 22 in rotation. Via the second shaft 21, which is connected for conjoint rotation to the second turbine wheel 22 and the second compressor wheel 25, the second compressor wheel 22 is likewise set in rotation, with the result that the fresh air quantity flowing through the second compressor 23 has at least a slight pressure increase before it undergoes a further pressure increase in the first compressor 11. However, a rotor assembly of the second exhaust turbocharger 17 is set in rotation, ensuring that its mass moment of inertia is at least partially overcome.

At this point, it may be mentioned that the mass moment of inertia of an exhaust gas turbocharger is determined by the weight of its rotor assembly, which is made up of the compressor wheel, the turbine wheel and the shaft connecting the two wheels for conjoint rotation.

In the intake section 10, the first compressor 11 delivers fresh air from the part of the intake pipe 34 formed downstream of the first compressor 11. The nonreturn valve 47 closes the second bypass duct 36, with the result that all the fresh air quantity delivered by the first compressor 11 can flow via the second compressor 23. Precompression of the fresh air owing to the second compressor 23 is slight. The third bypass duct 40 is closed, with the result that all the fresh air drawn in can be fully compressed in the first compressor 11 and does not in part directly enter a part of the intake pipe 34 formed between the charge air cooler 39 and the third entry, which has only a slight boost pressure produced by the second compressor 24. In this low load and/or speed range, the second outlet valve 6 is thus shut down and expanded exhaust gas from the first exhaust gas turbocharger 7 flows through the second exhaust turbocharger 17.

By way of example, this operating state can be established at a low load and/or in a low speed range, e.g. at about 1200 - 2200 rpm, of the combustion engine 2.

Figure 2 shows schematically a second operating state of the forced induction device 1. This operating state is preferably established at a medium load and/or in a medium speed range, e.g. at about 2200 - 4500 rpm, of the combustion engine 2. The position of the control valves which is explained in greater detail below is to be set when the first turbine 9 has reached its surge limit. This means that the power of the first exhaust turbocharger 7 cannot be increased despite an increased exhaust gas mass flow. On the contrary, there are power losses in the exhaust turbocharger above the surge limit, owing to the excessive exhaust gas mass flow through the turbine.

In this operating state, the second outlet ports 6 are fully opened with the aid of the variable valve timing system. That is to say that exhaust gas which flows out of the first outlet ports 5 acts on the first turbine 9, and the exhaust gas which flows through the second outlet ports 6 acts on the second turbine 19. Thus, both the first turbine wheel 14 and the second turbine wheel 22 receive a flow of exhaust gas, which has a certain exhaust gas backpressure formed in this second operating range. This exhaust gas backpressure is higher than the exhaust gas backpressure in the first operating range.

The first control valve 43 opens the first connecting duct 28, while the second control valve 44 blocks the first bypass duct 29, with the result that all the exhaust gas flowing out of the first turbine 9 continues to be fed to the second turbine 19 and acts on the second turbine 19 in addition to the exhaust gas flowing out of the second exhaust manifold 27.

In the intake section 10, the first compressor 11 continues to deliver fresh air from the part of the intake pipe 34 formed downstream of the first compressor 11. The nonreturn valve 47 in the second bypass duct 36 is closed, while the fourth control valve 46 now opens the third bypass duct 40. The third control valve 45 likewise continues to be set so as to open a segment of the intake pipe 34 formed between the first compressor 11 and the second compressor 23. This means that now only some of the charge air drawn in and compressed by the second compressor 23 is passed via the first compressor 11, thus ensuring that the rotor assembly of the first exhaust turbocharger 7 can continue to perform a rotary motion.

In this second operating state, the second compressor 23 delivers the necessary fresh air quantity to be made available to the combustion engine 2.

In this medium load and/or speed range, which characterizes the second operating state, there is likewise a flow of expanded exhaust gas from the first exhaust turbocharger 7 and additionally a flow of exhaust gas flowing out of the second outlet port 6 through the second exhaust turbocharger 17.

A third operating state of the forced induction device 1 is shown in figure 3. This operating state corresponds to operation of the combustion engine 2 at full load and/or high speeds, e.g. at about 4500 - 7000 rpm. The position of the control valves which is explained in greater detail below should be set when the second turbine 19 has likewise reached its surge limit.

In this operating state, the second outlet ports 6 are likewise opened with the aid of the variable valve timing system. In contrast to the first operating state and to the second operating state, the first control valve 43 at the first branch 30 now blocks a flow path of the exhaust gas through the first connecting duct 28 to the second turbine 19. However, the second control valve 44 is set to open the first bypass duct 29, with the result that the exhaust gas flowing through the first turbine 11 is diverted past the second turbine 19 into the tailpipe line 32 downstream of the second turbine 19 and upstream of the exhaust gas aftertreatment unit 33. In this operating state, boost pressure control can be performed with the aid of the first control valve 43.

This means that the first exhaust line 10 and the second exhaust line 18 are only now fluidically connected to one another in the tailpipe line 32. The entire exhaust gas flow is divided between both exhaust turbochargers 7, 17.

The third control valve 45 is closed, with the result that the flow path between the first compressor 11 and the second compressor 23 is blocked. The nonreturn valve 47 is open, thus allowing the first compressor 11 to draw in and compress fresh air independently of the second compressor 23.

This circuit configuration corresponds to sequential charging, since both exhaust turbochargers 7, 17 are acted upon completely independently of one another and operate completely independently of one another. Thus, in the third operating range, which shows a full load and/or high speed range, only exhaust gas flowing out of the second exhaust port 6 flows through the second exhaust turbocharger 17.

Patent claims

1. A forced induction device for a combustion engine, having a first exhaust turbocharger and a second exhaust turbocharger, wherein exhaust gas from the combustion engine emerging from a first outlet port of a cylinder of the combustion engine can be channeled to flow only through the first exhaust turbocharger, and exhaust gas from the combustion engine emerging from a second outlet port of the cylinder can be channeled to flow only through the second exhaust turbocharger, and wherein, downstream of a first turbine of the first turbocharger and upstream of a second turbine of the second exhaust turbocharger, a first connecting duct, which allows through flow, is formed for supplying the second turbine with exhaust gas emerging from the first turbine, and the first connecting duct is connected to a first bypass duct at a first branch allowing through flow, wherein the first bypass duct issues at a first entry into a tailpipe line formed downstream of the second turbine in order to bypass the second turbine, and this first bypass duct has a second control valve for blocking or opening the first bypass duct, wherein, to avoid admission of exhaust gas flowing through the first turbine to the second turbine, the first connecting duct has a first control valve, which can block or open the first connecting duct.

2. The forced induction device as claimed in claim 1, wherein the forced induction device has an intake pipe, which can be connected to the combustion engine, for supplying fresh air to the combustion engine, wherein a first compressor of the first exhaust turbocharger is arranged in the intake pipe downstream of a second

compressor of the second exhaust turbocharger, and wherein the intake pipe is formed upstream of the second compressor and downstream of the first compressor.

3. The forced induction device as claimed in claim 2, wherein a third bypass duct, which branches off from the intake pipe downstream of the first compressor and upstream of the second compressor and issues into the intake pipe downstream of the first compressor, is formed to divert some of the fresh air compressed with the aid of the second compressor past the first compressor.

4. The forced induction device as claimed in claim 2 or 3, wherein a second bypass duct is formed to partially bypass the second compressor, wherein the second bypass duct branches off from the intake pipe at a second branch upstream of the first compressor and issues into the intake pipe at a second entry downstream of the second compressor and upstream of the first compressor.

5. The forced induction device as claimed in claim 3 or 4, further comprising a fourth control valve formed in the third bypass duct for selectively bypassing the first compressor .

6. The forced induction device as claimed in claim 4 or 5, further comprising a third control valve, which is formed in the intake pipe downstream of the second compressor and upstream of the second entry, and a fifth control valve, which is formed in the second bypass duct to selectively control flow through the two compressors independently of one another.

7. The forced induction device as claimed in one of the preceding claims, wherein the first exhaust turbocharger is of smaller design than the second exhaust turbocharger.

8. A combustion engine having a cylinder, wherein the cylinder has an inlet port, a first outlet port and a second outlet port, wherein the first outlet port can be opened and closed with a first outlet valve and wherein the second outlet port can be opened and closed with a second outlet valve, and wherein an adjustable variable valve timing system is provided for varying valve timings of the valves and for shutting down the second outlet valve, and wherein the combustion engine comprises forced induction device, wherein the forced induction device is in accordance with one of claims 1 to 7.

9. The combustion engine as claimed in claim 8, wherein the second outlet port is closed with the aid of the outlet valve in a lower speed and/or load range of the combustion engine.

10. The combustion engine as claimed in claim 8 or 9, configured to operate with the second outlet port being opened with the outlet valve in a medium speed and/or load range and at full load and/or high speeds of the combustion engine.

11. The combustion engine as claimed in one of claims 8 to 10, wherein valve timings of the first outlet valve can be adapted in a lower speed range in accordance with a load demanded.

12. The combustion engine as claimed in one of claims 8 to 11, wherein the variable valve timing system is configured to allow communication with a closed-loop and open-loop control system of the combustion engine in order to adjust valve timings and/or to shut down outlet valves.

13. A method for operating a combustion engine, which combustion engine comprises a forced induction device having a first exhaust turbocharger and a second exhaust turbocharger, and wherein the combustion engine further comprises at least one cylinder having a first outlet port and a second outlet port, and a variable valve timing system of the combustion engine allows at least shutdown of an outlet valve which opens or closes the second outlet port, wherein

a) the second outlet valve is shut down and expanded exhaust gas from the first exhaust turbocharger flows through the second exhaust turbocharger in a low load and/or speed range,

b) expanded exhaust gas from the first exhaust turbocharger and, additionally, exhaust gas flowing out of the second outlet port flows through the second exhaust turbocharger in a medium load and/or speed range,

c) only exhaust gas flowing out of the second outlet port flows through the second exhaust turbocharger in a full-load and/or high speed range.

14. The method as claimed in claim 13, wherein the first control valve is used for boost pressure control.

15. A forced induction device, substantially as hereinbefore described with reference to the accompanying drawings.

16. A combustion engine, substantially as hereinbefore described with reference to the accompanying drawings.

17. A method for operating a combustion engine, substantially as hereinbefore described with reference to the accompanying drawings.

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Claims searched:	1 to 12	**Date of search:**	18 December 2015

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 to 12	CN1737346 A (DENG) - See figure and WPI abstract (2006-416050)
X	1 to 12	US2011/020108 A1 (AXELSSON et al) - See figures and paragraphs 5 to 13
X	1 to 12	US2011/296828 A1 (AN et al) - See figures and paragraphs 23 to 34
X	1 to 12	GB2472829 A (CAVALLO et al) - See figures and page 12 line 10 to page 14 line 18
X	1 to 12	US2008/216795 A1 (DIETZ et al) - See figures and paragraphs 15 to 21

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F02D

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

WPI, EPODOC

International Classification:

Subclass	Subgroup	Valid From
F02D	0009/04	01/01/2006