INTERNAL COMBUSTION ENGINE

The present invention concerns an internal combustion engine having the features of the classifying portion of claim 1. Internal combustion engines of the general kind set forth have at least one piston-cylinder unit, a turbocharger and a catalytic converter, wherein the catalytic converter is connected between the at least one piston-cylinder unit and an exhaust gas turbine of the turbocharger.

The catalytic converter upstream of the compressor has the advantage that a residue of chemical energy of the fuel-air mixture which was not converted in the at least one piston-cylinder unit can be liberated. The liberation of that residual energy increases the temperature of the exhaust gas flow whereby the effect of the turbine of the turbocharger is improved.

That is also the case when that improved effect of the turbine is not necessary at all, for example if a power output of the internal combustion engine is to be reduced or at least not increased. The result of this is that the residual chemical energy is lost and even additional measure have to be taken to regulate the power output of the internal combustion engine.

The object of the present invention is to make the residual chemical energy useable more frequently than in the state of the art.

That object is attained by the features of claim 1.

That is effected by an electrical machine being provided, which is connected to the shaft.

That is achieved in that the electrical machine can be driven in a generator mode while the described improvement effect on the exhaust gas turbine of the turbocharger is not necessary or wanted. In such cases therefore the residual chemical energy can be converted into electrical energy whereby the overall degree of efficiency is improved.

The term electrical machine is used to denote any machine which is capable of generating electrical energy from mechanical energy. In the usual case such a machine will also be capable of generating mechanical energy from electrical energy although that is not absolutely necessary for the invention.

The invention can preferably be used in relation to stationary engines and marine applications. It can be used in particular in relation to gas engines which preferably drive a generator for power generation (so-called gensets). It can also be used in relation to dual-fuel engines. The invention can be used in relation to internal combustion engines having 8, 10, 12, 14, 16, 18, 20, 22, 24 or more cylinders.

Advantageous embodiments of the invention are defined in the appendant claims.

It can be provided that the electrical machine is connected by means of a coupling or directly to the shaft.

Particularly preferably there can be provided a compressor of the turbocharger, that is driven by the shaft. In cases in which the power output of the internal combustion engine is to be increased the electrical machine can be used as a drive for the compressor in order to increase the charge pressure and thus the power output of the internal combustion engine.

It is possible to provide a mixing device for adding a fuel to an exhaust gas flow upstream of the catalytic converter. In that way the enthalpy in the exhaust gas flow through the catalytic converter can be increased, which in turn increases the energy liberated in the catalytic converter. That promotes the action of the exhaust gas turbine whereby it is possible to achieve a higher charge pressure and thus a further increase in power output of the internal combustion engine.

Preferably there can be provided an open-loop or closed-loop control device connected to the electrical machine.

There can also be provided a mixing device connected to the open-loop or closed-loop control device for producing a fuel-air mixture and the open-loop or closed-loop

control device can be adapted to activate the mixing device and the electrical machine as a drive while the at least one piston-cylinder unit is in a state in which no combustion takes place.

By a fuel-air mixture already being conveyed through the catalytic converter before starting heat is produced in the catalytic converter by liberation of the residual chemical energy (enthalpy) of the fuel-air mixture, and the catalytic converter can be held at operating temperature by means of that heat. When then the internal combustion engine is started the positive effect of the catalytic converter on the exhaust gas turbine occurs immediately as less energy is lost for heating the environment (that is to say the catalytic converter). The turbocharger therefore responds more quickly whereby the starting performance is improved.

Particularly preferably the mixing device can be arranged in flow relationship between the at least one piston-cylinder unit and the catalytic converter. In that way the enthalpy of the fuel-air mixture conveyed through the catalytic converter can be influenced in a particularly simple and specifically targeted fashion.

It will be appreciated that the fuel-air mixture can also be produced in another way. For that purpose on the one hand the mixing device can simply be that which produces the mixture for the piston-cylinder units. Such a mixing device can be of such a configuration and arrangement that the mixture is already present before passing into the compressor (mixture-charged engines). However open-loop controlled or closed-loop controlled valves at the piston-cylinder units themselves or in a feed conduit to same can also be used (air-charged engines).

To reduce the resistance when the fuel-air mixture is conveyed through the catalytic converter it is possible to provide a by-pass conduit for by-passing the at least one piston-cylinder unit, which is connected in flow relationship to a feed conduit for air or fuel-air mixture to the at least one piston-cylinder unit and a connecting conduit between the at least one piston-cylinder unit and the catalytic converter. That is advantageous in particular in the case of internal combustion engines with a rather

small number of piston-cylinder units as then there is a lesser probability of inlet and exhaust valves for a piston-cylinder unit being open at the same time.

To prevent a substance flow flowing through the by-pass conduit during the combustion mode of the internal combustion engine a shut-off valve can be provided in the by-pass conduit.

Further advantages and details of the invention will be apparent from the Figure and the related specific description. Single Figure 1 shows a diagrammatic view of an embodiment of an internal combustion engine according to the invention.

Air A (generally ambient air) is drawn in and compressed in a compressor 7 of the turbocharger 4. The compressed masses pass by way of the feed conduit 15 into the piston-cylinder units 2, in which respect purely by way of example four respective piston-cylinder units 2 are illustrated here. It will be appreciated that a fuel-air mixture has to be provided for combustion in the piston-cylinder units 2. That can be implemented either by a gas mixer (not shown) which is connected upstream of the compressor 7 (mixture-charged engines), or the gas mixer can be arranged in the feed conduit 15 (air-charged engines). Alternatively or additionally open-loop controlled or closed-loop controlled fuel introduction devices can be fitted directly at the piston-cylinder units 2.

After combustion in the piston-cylinder units 2 the content thereof is discharged from the piston-cylinder units 2 and fed to the catalytic converter 5 by way of a connecting conduit 16. After flowing through the catalytic converter 5 the flow of substance flows to the exhaust gas turbine 3 of the turbocharger 4 and finally issues in the form of exhaust gas. The turbine 3 is connected by way of a common shaft 9 to the compressor 7 of the turbocharger 4 so that the turbine 3 drives the compressor 7 for producing the charge pressure.

The electrical machine 8 is also connected to the shaft 9. If for example the power output of the internal combustion engine is to be reduced the electrical machine 8 can be operated in a generator mode whereby energy is taken from the turbocharger 4.

The consequence of this is that the charge pressure produced by the turbocharger 4 and thus the combustion power output of the internal combustion engine 1 falls. The energy taken from the turbocharger 4 is converted into electrical energy by the electrical machine 8 and can be stored. In that case this gives an improvement in the overall degree of efficiency.

To increase the power output of the internal combustion engine 1 the electrical machine 8 can also be operated as a drive to improve the efficiency of the compressor 7. In that way the charge pressure and accordingly the combustion power output of the internal combustion engine 1 can be increased. Particularly fast changes in load can be more easily implemented by that active approach with less of a time delay.

The delayed load pick-up performance in the cold operating condition which was further reduced by the addition of thermal mass of the catalytic converter 5 can be more than compensated by the electrical drive of the turbocharger 4.

A further possible way of improving the action of the turbocharger 4 provides adding fuel F to the substance flow passing through the catalytic converter 5. The effect of the exhaust gas turbine 3 is improved by the increased enthalpy, and that also results in an increased charge pressure and an increased power output. That addition of fuel is effected by way of the mixing device 13 arranged in the connecting conduit 16.

It will be appreciated that the measures of operating the electrical machine 8 as a drive and adding fuel F to the exhaust gas flow can be combined.

The mixing device 13 can also be used to keep the catalytic converter 5 at operating temperature if the at least one piston-cylinder unit 2 is not in a combustion mode of operation. For that purpose the electrical machine 8 is also used as a drive in order to convey a substance flow through the catalytic converter 5 while the mixing device 13 adds fuel F to that flow. Heat is generated by the resulting catalytic reaction in the catalytic converter 5 whereby the catalytic converter 5 is heated before starting of the internal combustion engine 1. Upon starting of the internal combustion engine 1 the full enthalpy of the flow discharged from the piston-cylinder units 2 can then

immediately serve to improve the effect of the exhaust gas turbine 3 without the catalytic converter 5 having to be again raised to operating temperature.

In addition a by-pass conduit 14 can be provided, which connects the feed conduit 15 and the connection conduit 16. In that way it is possible to reduce the resistance which arises by virtue of the substance flow being conveyed into the piston-cylinder units 2 through the turbocharger 4 driven by the electrical machine 8. That by-pass conduit 14 however is not absolutely necessary as the air can also be conveyed to the catalytic converter through piston-cylinder units 2.

It is also to be noted in this respect that the mixing device 13 for the purposes of heating the catalytic converter 5 does not have to be arranged exclusively at the location illustrated. For example it could also be arranged in the feed conduit 15 or in an upstream position at the compressor 7. Finally it is also possible not to use a separate mixing device 13 for that purpose. For, it is also possible to use a device which serves to produce the fuel-air mixture for combustion in the piston-cylinder units 2.

Preferably a shut-off valve 17 can be provided in the by-pass conduit 14. That can be shut off during operation so that there is no direct substance flow between the feed conduit 15 and the connecting conduit 16.

There is provided an open-loop or closed-loop control device 18 which is connected on the one hand to the electrical machine 8 and on the other hand to the mixing device 13. That open-loop or closed-loop control device 18 provides for control over the described operating modes of the electrical machine and the heating operation which has also been described. For the sake of clarity the additional connection between the open-loop or closed-loop control unit 18 to the shut-off valve 17 is not shown. The open-loop or closed-loop control unit 18 can open the shut-off valve 17 in the shut-down condition of the internal combustion engine 1 whereby the by-pass conduit 14 can serve for the described purpose. The open-loop or closed-loop control device 18 can then close the shut-off valve 17 during operation.

A further advantage of an electrical machine 8 according to the invention which is connected to the shaft of the turbocharger 4 is that in the shut-down condition of the internal combustion engine 1 the exhaust tract and optionally the piston-cylinder units 2 can be pumped free of fuel-air mixture (so-called "purging"). That can be effected after a normal stop to operation of the internal combustion engine 1 or after a failed attempt at starting.

CLAIMS

1. An internal combustion engine comprising:

- at least one piston-cylinder unit (2),

- a turbocharger (4) having a shaft (9) driven by an exhaust gas turbine (3), and

- a catalytic converter (5) connected between the at least one piston-cylinder unit (2) and the exhaust gas turbine (3),

characterised in that there is provided an electrical machine (8) connected to the shaft (9).

2. An internal combustion engine as set forth in claim 1 characterised in that there is provided a compressor (7) of the turbocharger (4), that is driven by the shaft (9).

3. An internal combustion engine as set forth in claim 1 or claim 2 characterised in that there is provided a mixing device (13) for adding a fuel (F) to an exhaust gas flow upstream of the catalytic converter (5).

4. An internal combustion engine as set forth in one of claims 1 through 3 characterised in that there is provided an open-loop or closed-loop control device (18) connected to the electrical machine (8).

5. An internal combustion engine as set forth in claim 4 characterised in that there is provided a mixing device (13) connected to the open-loop or closed-loop control device (18) for producing a fuel-air mixture and that the open-loop or closed-loop control device (18) is adapted to activate the mixing device (13) and the electrical

machine (8) as a drive while the at least one piston-cylinder unit (2) is in a condition in which no combustion takes place.

6. An internal combustion engine as set forth in claim 5 characterised in that the mixing device (13) is arranged in flow relationship between the at least one piston-cylinder unit (2) and the catalytic converter (5).

7. An internal combustion engine as set forth in claim 5 or claim 6 characterised in that there is provided a by-pass conduit (14) for by-passing the at least one piston-cylinder unit (2), that is connected in flow relationship to a feed conduit (15) for air or fuel-air mixture to the at least one piston-cylinder unit (2) and a connecting conduit (16) between the at least one piston-cylinder unit (2) and the catalytic converter (5).

8. An internal combustion engine as set forth in claim 7 characterised in that a shut-off valve (17) is provided in the by-pass conduit (14).

ABSTRACT

INTERNAL COMBUSTION ENGINE

An internal combustion engine comprising at least one piston-cylinder unit (2), a turbocharger (4) having a shaft (9) driven by an exhaust gas turbine (3), and a catalytic converter (5) connected between the at least one piston-cylinder unit (2) and the exhaust gas turbine (3), wherein there is provided an electrical machine (8) connected to the shaft (9).

(Figure 1)

Fig. 1