An exhaust gas recirculation (EGR) system for an engine with a variable geometry turbocharger (18) incorporates a master rotary electric actuator (REA) (50) with a microprocessor controller (53) receiving condition signals (46, 48a-c) from sensors (48) associated with the turbocharger and the engine control unit (ECU) (54) and positioning the turbine inlet nozzle (44) geometry of the turbocharger in response to a predetermined matrix of the condition signals. A slave REA (52) is connected through an internal processing unit (58) to the controller to position an EGR valve (34). The processing unit provides an actual position signal to the controller which responds with a desired position signal based on the predetermined condition signal matrix. The processing unit engages the slave REA to position the EGR valve.
INTELLIGENT ELECTRIC ACTUATOR FOR
CONTROL OF A TURBOCHARGER WITH AN
INTEGRATED EXHAUST GAS RECIRCULATION
VALVE

CROSS REFERENCE TO RELATED
APPLICATIONS

[0001] This application claims the priority of copending
application Ser. No. 60/186,648 filed on Mar. 3, 2000 having the
same title as the present application.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention

[0003] The present invention relates generally to control
of turbochargers used in engines with Exhaust Gas Recirculation
(EGR) systems, and more particularly, to an intelli-
gent electric actuator with diagnostics and memory capa-
BILITIES using turbocharger rotational speed, air and EGR gas
temperatures, and air and EGR gas pressures, for control of
a variable geometry turbocharger with integrated EGR
valve.

[0004] 2. Description of the Prior Art

[0005] Commercial diesel vehicles typically employ tur-
bochargers for increased efficiency of the engine. Further,
the regulatory requirements for decreases in federal NOx
emissions levels for year 2002, and beyond, diesel engines
have made engine air systems control a more complex and
important part of overall engine performance. Control of
the turbocharger and EGR systems of the engine comprise the
primary means for such air systems management.

[0006] A turbocharger’s useful life is, among other things,
largely a function of the speed/duty cycle to which it is
subjected, specifically with respect to the fatigue life of the
turbine wheel and compressor wheel (or perhaps an internal
component of the turbocharger). It is very difficult to know
exactly what particular speed/duty cycle the turbocharger is
subjected to for any given application. This therefore makes
it very difficult to predict what the useful life of the turbo-
charger will be with respect to fatigue related failures.
Therefore, fatigue failures of turbocharger wheels can and
do occur without notice. Proactively replacing the turbo-
charger at a “safe” accumulated time is not cost effective and
results in excessive downtime of the engine.

SUMMARY OF THE INVENTION

[0007] The present invention is applicable to a controlled
turbocharger such as, but not limited to, a wastegated
 turbocharger or a variable geometry inlet nozzle turbo-
charger (VGT) with an actuator to operate the wastegate or
VGT vane set. By inputting the turbocharger’s shaft speed,
air gas temperatures, air gas pressures, EGR gas tempera-
tures, and EGR gas pressures into the intelligent electric
actuator, this data can then be used as to better control the
actuation of the wastegate or VNT nozzle set.

[0008] The software employed by the controller is
designed such that various min/max speeds, temperature and
pressure thresholds are pre-set with the subsequent excur-
sions of speed, temperature and pressure recorded as these
thresholds are achieved and/or exceeded.

[0009] An array of thresholds is pre-determined for the
particular application. This data is stored in the actuator’s
memory for future use. By defining the fatigue life of the
compressor wheel or turbine wheel for a given wheel design,
size, material, etc., and having the specific fatigue life
information programmed into the REA, several advantages
exist.

[0010] From the inputs of speed, temperature and pres-
sure, the electric actuator is better used to more precisely
control the turbocharger’s wastegate or VGT nozzle set. This
information is also used to control EGR percentage directly
and therefore control engine out emission level more pre-
cisely.

[0011] Once a predetermined number of speed, tempera-
ture and/or pressure thresholds have been achieved, the
electric actuator can, in various embodiments, control (reduce)
the speed of the turbocharger by predicting when a
wheel fatigue failure is imminent.

[0012] Once a predetermined number of speed, tempera-
ture and/or pressure thresholds have been achieved, the
electric actuator can, in various embodiments, trip a switch
to notify the operator to “replace the turbocharger” by
predicting that a fatigue failure is imminent.

[0013] The electric actuator can store into memory opera-
tional field data for future use in maintenance profiling of
specific turbocharger operating conditions of various applica-
tions (on-highway truck, inner-city truck, pleasure craft,
tug boat, front-end loader, bulldozer, mine truck, excavator,
gen-set, etc.).

[0014] The speed/duty cycle data stored in the electric
actuator can be downloaded and used in the warranty
adjudication process or as a diagnostic tool for failure
evaluation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] These and other features and advantages of the
present invention will be appreciated as the same become
better understood by reference to the following Detailed
Description when considered in connection with the accom-
panying drawings, wherein:

[0016] FIG. 1 is a schematic illustration of an internal
combustion engine having a variable geometry turbocharger
with an integrated EGR valve actuated according to the
present invention;

[0017] FIG. 2 is a block diagram of the control structure
for the turbocharger and actuators incorporating the present
invention;

[0018] FIG. 3 is an exemplary pictorial view of an engine
with a turbocharger employing actuators incorporating the
present invention in conjunction with an EGR system.

DETAILED DESCRIPTION OF THE
INVENTION

[0019] Referring now to FIG. 1, an internal combustion
engine having a turbocharger and an EGR system is sche-
matically illustrated. Engine 10 includes an intake manifold
12 and an exhaust manifold 14. In the illustrated embed-
ment, the engine includes a turbocharger 16, generally
comprising a turbine contained in a housing 18 and a
compressor contained in a housing 20, for compressing the intake air of engine 10. The intake air is heated during the turbocharger compression process and must be cooled to satisfy engine durability and performance requirements. That cooling is accomplished by routing the air discharged from the turbocharger 16 to a charger air cooler (CAC) 22 via conventional conduits or ducting 24. The intake air is then routed from the CAC to the intake manifold of the engine via conventional conduits or ducting 30.

[0020] Engine 10 also includes an EGR system. The EGR system includes a control valve 34, integrated into the turbocharger in accordance with the present invention, that regulates the proportion of exhaust gas that is taken from the exhaust manifold and either returned to the engine induction system for mixing with the intake air that has passed through the CAC, or directed to the turbine of the turbocharger. The control valve 34 routes a portion of the exhaust gas received into the turbine housing from the exhaust manifold through the EGR system.

[0021] The EGR system also includes an engine mounted EGR cooler 38 or heat exchanger for cooling the exhaust gas passing through the system. By providing a heat exchanger in the EGR conduit or ducting 40, the efficiency of engine 10 is improved. Other advantages, such as a reduction in NOx and PM emissions and in fuel consumption also result from the presence of the heat exchanger 38. The exhaust gas passing through the heat exchanger 38 is then combined with the intake air that has passed through the CAC in an EGR mixer 42. The mixture of the intake air and exhaust gas leaves the mixer 42 and enters the intake manifold of the engine.

[0022] A variable geometry nozzle 44 in the turbocharger is utilized for back pressure in the turbine housing inlet and exhaust manifold. A speed sensor 46 determines the rotational speed of the turbocharger shaft and pressure/temperature sensors, generally designated 48 provide temperature and pressure in the inlet and outlet of the compressor, the inlet and outlet of the turbine and at the outlet of the EGR flow control valve for EGR differential pressure determination. A first rotary electric actuator (REA) 50 controls the nozzle vanes of the variable geometry inlet nozzle to the turbine. A second REA 52 controls the EGR valve which may be of comparable structure to that defined in the copending patent application carrying docket number 90099039 and entitled TURBOCHARGER WITH INTEGRATED EXHAUST GAS RECIRCULATION VALVE having a common assignee with the present application, the disclosure of which is incorporated herein by reference.

[0023] As shown in FIG. 2, the REAs are interconnected in a master/slave arrangement. The first REA for controlling the VGT vane position incorporates a microprocessor controller 53 which receives inputs from the EGR pressure and temperature sensor 48a, the turbine outlet pressure and temperature sensor 48b, the turbine inlet pressure and temperature sensor 48c, the compressor outlet pressure and temperature sensor 48d and the compressor inlet pressure and temperature sensor 48e. The engine operating condition is provided from the engine control unit (ECU) 54 through a CAN 2.0B interface to the microprocessor and an input from the speed sensor is provided from the turbocharger. Based on a predetermined matrix of sensor input conditions mapped to engine operating requirements, the microproces-
cessing means positioning the second adjusting means responsive to the desired position signal.

2. An EGR system as defined in claim 1 wherein the first adjusting means comprises a rotary electric actuator connected through a crank arm (56) to the variable geometry inlet nozzle (44).

3. An EGR system as defined in claim 2 wherein the second adjusting means comprises a rotary electric actuator connected through a crank arm (60) to the EGR valve (34).

4. An EGR system as defined in claim 1 wherein the turbocharger condition signals are selected from the group of compressor inlet pressure, compressor inlet temperature, compressor outlet pressure, compressor outlet temperature, turbine inlet temperature, turbine inlet pressure, turbine outlet temperature, turbine outlet pressure, EGR pressure, EGR temperature and turbocharger shaft speed.

5. A method for controlling Exhaust Gas Recirculation (EGR) in an internal combustion engine having a variable geometry turbocharger, the method comprising the steps of:

- receiving a plurality of engine condition signals through the controller;
- determining a desired setting for the variable geometry of the turbocharger based on a predetermined matrix of the turbocharger and engine condition signals;
- controlling the geometry of the turbocharger to the desired setting with the master actuator;
- providing an actual position signal of a slave actuator connected to an adjustable EGR valve through a processor to the controller;
- determining a desired position of the EGR valve based on the predetermined matrix of turbocharger and engine conditions signals;
- providing a desired position signal from the controller to the processor; and
- controlling the position of the EGR valve by the slave actuator through the processor.

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