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SYSTEM AND METHOD FOR TIP-IN KNOCK COMPENSATION

Background and Summary

Engines may use various forms of fuel delivery to provide a desired amount of fuel for combustion in each cylinder. One type of fuel delivery uses a port injector for each cylinder to deliver fuel to respective cylinders. Still another type of fuel delivery uses a direct injector for each cylinder.

Engines have also been described using more than one injector to provide fuel to a single cylinder in an attempt to improve engine performance. Specifically, in US 2005/0155578 an engine is described using a port fuel injector and a direct injector in each cylinder of the engine. In this system, transient errors in delivered fuel from the port injector, such as due to sudden airflow increases, can be addressed by subsequently delivering fuel of the same type from a direct cylinder injector.

However, the inventors herein have recognized a disadvantage with such an approach. Under such transient conditions where sudden load increases may occur, engine knock may be more likely. As such, even if the air-fuel ratio is correctly maintained, engine knock may still occur, thus reducing performance and driver satisfaction.

Another approach that utilizes multiple injection locations for different fuel types to reduce knock is described in the papers titled "Calculations of Knock Suppression in Highly Turbocharged Gasoline/Ethanol Engines Using Direct Ethanol Injection" and "Direct Injection Ethanol Boosted Gasoline Engine: Biofuel Leveraging for Cost Effective Reduction of Oil Dependence and CO2 Emissions" by Heywood et al. Specifically, the Heywood et al. papers describe directly injecting ethanol to improve charge cooling effects under various conditions, such as in response to a knock sensor or steady state operating conditions.

However, the inventors herein have recognized that transient engine knock may still occur during transient conditions, such as aggressive driver tip-ins, since the feedback information from the sensor become available too late to correct the combustion mixture during the transient and reduce knock. As such, performance and satisfaction may still be degraded.

Therefore, in one approach, a method of controlling an engine, the method comprising: providing fuel having a blend to a cylinder of the engine; actively varying said fuel blend in response to at least an operating condition; where during a transient operating condition, said blend is adjusted to increase a heat capacity of said fuel to reduce a tendency for knock.

In this way, it is possible to adjust the blend before the onset of knock, and thus improve performance. For example, it may be possible to continue engine boosting during the transient to thereby provide improved vehicle performance.

Description of the Drawings

Figure 1 is a block diagram of a vehicle illustrating various components of the powertrain system;

Figure 2 shows a partial engine view;

Figure 3 shows an engine with a turbocharger;

Figures 4-5 show example engine cylinder and port configurations;

Figure 6 shows two fuel injectors;

Figure 7 shows a fuel pump system;

Figures 8-10 shows fuel vapor purge system configurations;

Figures 11-12 shows high level flow charts for air-fuel ratio feedback control;

Figures 13-14 and 16 show high level flow charts for fuel type enablement;

Figure 15 shows graphs illustrating example ratios of fuel type enablement based on operating conditions;

Figures 16-18 show high level flow charts for engine starting and running operation;

Figure 19 shows a high level flow chart for engine starting taking into account fuel levels of different fuel types;

Figure 20 shows a high level flow chart for compensating for depleting a fuel source;

Figure 21 shows a graph illustrating different fuel injector characteristics for two example injectors;

Figure 22 shows a graph illustrating an example relationship of fuel injection as a function of knock tendency;

Figure 23 shows a high level flow chart of an alternative embodiment for controlling fuel injection of a first and second fuel type taking into account minimum pulse width issues and different fuel type characteristics;

Figures 24-25 show high level flow charts for controlling operation using water injection;

Figures 26-27 show graphs illustrating an amount of injection to reduce knock for varying water content and varying amounts of desired charge cooling;

Figure 28 shows a high level flow chart for controlling fuel type injection amounts (and relative amounts) and/or adjusting ignition timing to reduce knock;

Figure 29 shows graphs illustrating example knock control operation;

Figure 30 shows a high level flow chart for event-based engine starting;

Figures 31-34 shows high level flow charts for fuel vapor purging control, estimation, and adaptive learning;

Figure 35 shows a graph of an example injector characteristic;

Figures 36-38 show example fuel tank and pump configurations;

Figure 39 shows a high level flow chart for transitioning on a second fuel type;

Figure 40 shows example operation according to the routine of Figure 39;

Figure 41 shows a high level flow chart for selecting injection timing(s);

Figure 42 shows a graph illustrating example injection timing operation;

Figure 43 shows a graph illustrating fuel types and injection timings for various engine speed and load regions; and

Figure 44 shows a high level flow chart for controlling boost.

Detailed Description

Referring to Figure 1, in this example, internal combustion engine 10, further described herein with particular reference to Figures 2 and 3, is shown coupled to torque converter 11 via crankshaft 13. Torque converter 11 is also coupled to transmission 15 via turbine shaft 17. Torque converter 11 has a bypass, or lock-up clutch 14 which can be engaged, disengaged, or partially engaged. When the clutch is either disengaged or partially engaged, the torque converter is said to be in an unlocked state. The lock-up clutch 14 can be actuated electrically, hydraulically, or electro-hydraulically, for example. The lock-up clutch 14 receives a control signal (not shown) from the controller, described in more detail below. The control signal may be a pulse width modulated signal to engage, partially engage, and disengage, the clutch based on engine, vehicle, and/or transmission operating conditions. Turbine shaft 17 is also known as transmission input shaft. Transmission 15 comprises an electronically controlled transmission with a plurality of selectable discrete gear ratios. Transmission 15 also comprises various other gears, such as, for example, a final drive ratio (not shown). Transmission 15 is also coupled to tire 19 via axle 21. Tire 19 interfaces the vehicle (not shown) to the road 23. Note that in one example embodiment, this powertrain is coupled in a passenger vehicle that travels on the road.

In an alternative embodiment, a manual transmission operated by a driver with a clutch may be used. Further, various types of automatic transmissions may be used.

Figure 2 shows one cylinder of a multi-cylinder engine, as well as the intake and exhaust path connected to that cylinder. In the embodiment shown in Figure 2, engine 10 is capable of using two different fuels, and/or two different injectors in one example. For example, engine 10 may use gasoline and an alcohol containing fuel such as ethanol, methanol, a mixture of gasoline and ethanol (e.g., E85 which is approximately 85% ethanol and 15% gasoline), a mixture of gasoline and methanol (e.g., M85 which is approximately 85% methanol and 15% gas), etc. In another example, two fuel systems are used, but each uses the same fuel, such as gasoline. In still another embodiment, a single injector (such as a direct injector) may be used to inject a mixture of gasoline and such an alcohol based fuel, where the ratio of the two fuel quantities in the mixture may be adjusted by controller 12 via a mixing valve, for example. In still another example, two different injectors for each cylinder are used, such as port and direct injectors. In even another embodiment, different sized injectors, in addition to different locations and different fuels, may be used.

As will be described in more detail below, various advantageous results may be obtained by various of the above systems. For example, when using both gasoline and a fuel having alcohol (e.g., ethanol), it may be possible to adjust the relative amounts of the fuels to take

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