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(54) **SYSTEM AND METHOD FOR EXTRACTING PROPULSION ENERGY FROM MOTOR VEHICLE EXHAUST**

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See application file for complete search history.

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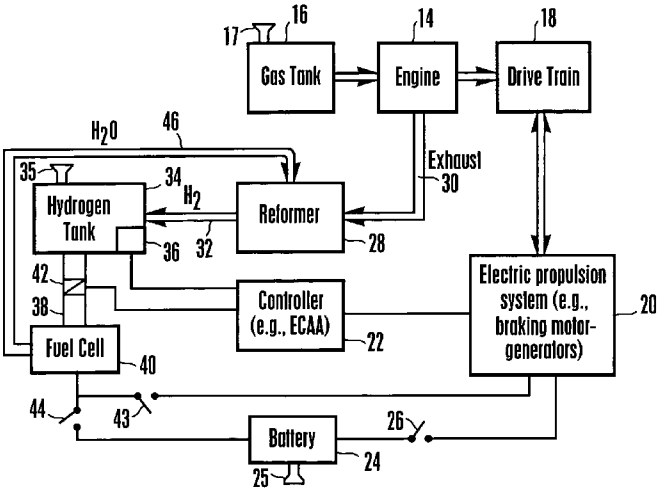
(57) **ABSTRACT**

Vehicle engine exhaust is sent to a reformer, which produces hydrogen from fuel remaining in the exhaust. The hydrogen is stored in a hydrogen tank, and is used by a fuel cell to produce electricity to recharge the vehicle battery and/or to supply propulsion current to an electric propulsion system to propel the vehicle in lieu of using the engine.

27 Claims, 1 Drawing Sheet



system

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Figure 1
vehicle

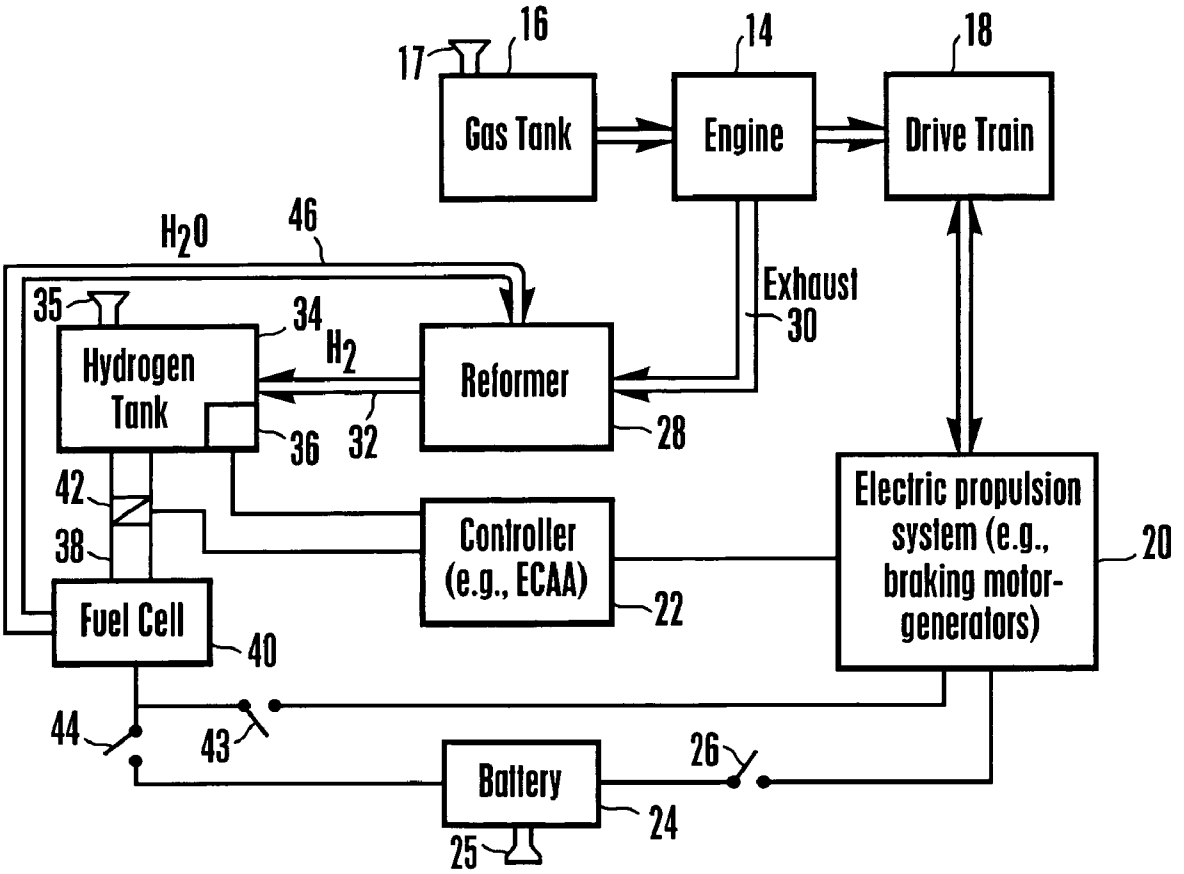

Figure 2
system

SYSTEM AND METHOD FOR EXTRACTING PROPULSION ENERGY FROM MOTOR VEHICLE EXHAUST

FIELD OF THE INVENTION

The present invention relates generally to motor vehicles.

BACKGROUND OF THE INVENTION

The importance of energy conservation goes without saying. Not only must fossil fuels be conserved for future use, but limiting the amount of fossil fuels that must be burned appears to be highly beneficial for the environment. However, many proposals for improving vehicle energy consumption efficiency cannot be realistically implemented any time soon. Hence, the present invention.

SUMMARY OF THE INVENTION

A vehicle has an internal combustion engine that includes an exhaust pipe. The vehicle also has a drive train which is couplable to the engine and an electric propulsion system that likewise is couplable to the drive train. The vehicle may also include a battery. The invention in one aspect includes a reformer connected to the exhaust pipe for producing hydrogen from exhaust gases from the engine. A hydrogen tank can store the hydrogen for use thereof by a fuel cell to produce electricity to recharge the battery and/or to supply propulsion current to the electric propulsion system.

In some implementations a controller selectively causes the electric propulsion system or the engine to activate the drive train. A valve may be interposed in a fluid path between the hydrogen tank and fuel cell, and the controller can control the valve to open and close the fluid path based at least in part on an amount of hydrogen in the hydrogen tank. Further, if desired a switch may be interposed in an electrical path between the fuel cell and electric propulsion system, with the controller controlling the switch. Also, if desired a controller-controlled switch can be interposed in an electrical path between the battery and electric propulsion system, and yet another controller-controlled switch may be interposed in an electrical path between the battery and fuel cell.

In another aspect, a method for activating a vehicle drive train to propel a vehicle includes providing an internal combustion engine couplable to the drive train, and providing an electric propulsion system that is also couplable to the drive train. Electricity is generated using exhaust gas of the engine to recharge a battery which is connectable to the electric propulsion system, and/or to provide propulsion current to the electric propulsion system.

In still another aspect, a vehicle propulsion system includes internal combustion means for producing torque to actuate a drive train, and electric drive means for producing torque to actuate the drive train. Means are provided for producing electricity using hydrogen gleaned from an exhaust of the internal combustion means.

The details of the present invention, both as to its structure and operation, can best be understood in reference to the accompanying drawings, in which like reference numerals refer to like parts, and in which:

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic representation of a motor vehicle; and

FIG. **2** is a block diagram of the present system, with double lines indicating mechanical couplings and single lines indicating electrical connections.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** shows a motor vehicle **10** that may use the present propulsion system to cause one or more wheels **12** to rotate and move the vehicle **10**. The vehicle **10** may be an automobile, truck, motorcycle, or other wheeled vehicle. The present principles also apply to non-wheeled vehicles including boats, aircraft, or other vehicles that use an internal combustion engine.

FIG. **2** shows that the present propulsion system includes an internal combustion engine **14** that can be a four stroke (e.g., gasoline) engine or two stroke (e.g., diesel) engine. The engine **14** receives hydrocarbon fuel from a gas tank **16** (that can be filled at a service station with gas through a filler pipe **17**), and the engine outputs torque to a drive train **18** that can include a combination of components known in the art, e.g., crankshafts, transmissions, axles, and so on.

Additionally, the propulsion system can include an electrical propulsion system **20** such as braking motor-generators, sometimes referred to as "regenerators", in accordance with hybrid vehicle principles known in the art. Briefly, braking motor-generators work in response to signals that can be sent from a controller **22**, such as might be implemented in an engine control module (ECM). When a brake pedal is depressed by a driver, the ECM activates the braking motor generators (by, e.g., supplying field current to them), which act as electro-magnetic brakes in cooperation with complementary structure on the wheels or axle or other part of the drive train **18** to slow the vehicle down. In this mode, the braking motor-generators act as generators, outputting electricity to a vehicle battery **24** through a main battery switch **26** that is controlled by the controller **22** to shut the switch. If desired, the battery **24** also can be recharged at a service station through a recharging line **25**. On the other hand, the controller **22**, which also controls the engine **14**, can cause the engine **14** to stop and/or to be disengaged from the drive train **18** to conserve fuel, and instead cause the battery **24** to supply propulsion power through the switch **26** to the braking motor-generators, which act as motors to cause the complementary structure in the drive train **18** to turn.

The controller **22** may be implemented by any suitable processing apparatus, including a digital signal processor (DSP) or computer microprocessor, to execute the logic set forth further below. The logic below may be implemented by plural controllers.

Thus far, a so-called "hybrid" vehicle has been described. In accordance with the present invention, however, in addition to the power sources discussed above, the exhaust from the engine **14** is supplied to a reformer **28** through an exhaust pipe **30**. According to reformer principles known in the art, the reformer **28** produces hydrogen from the exhaust gases, e.g., from unburnt fuel that remains in the engine exhaust. As critically recognized herein, the exhaust from the engine is hot, facilitating performance of the reformer **28**.

Hydrogen from the reformer **28** is directed through a hydrogen line **32** to a hydrogen tank **34** for storage. If desired, in addition to receiving hydrogen from the reformer **28**, the hydrogen tank **34** can be filled at a service station with hydrogen through a filler pipe **35**. The hydrogen tank **34** may include a detector **36** that generates an electrical signal representative of the amount of hydrogen in the tank, and this signal may be sent to the controller **22**. Hydrogen from the tank **34** can be supplied through a fuel cell line **38** to a fuel cell **40**, which uses the hydrogen to generate electricity in accordance with fuel cell principles known in the art. A valve **42** such as a solenoid valve may be controlled by the controller

22 in accordance with logic below to selectively block or unblock the fuel cell line 38. Water can be returned from the fuel cell 40 if desired to the reformer 28 through a water line 46.

Further, the present invention recognizes that the exhaust gas that remains after being stripped of hydrogen in the reformer 28 possesses newly exposed carbon bonds, and consequently may be recycled back to the engine 14 from the reformer 28 for further combustion.

As shown in FIG. 2, the fuel cell 40 can output propulsion current to the electric propulsion system 20 through a fuel cell switch 43, which is controlled by the controller 22. Also, if desired the fuel cell 40 can output recharging current to the battery 24 through a recharging switch 44, which is controlled by the controller 22 to recharge the battery 24. In some implementations the fuel cell 40 can output current directly to the electrical propulsion system 20 as shown as well as to the battery 24, or it may output current only to the electrical propulsion system 20, or it may output only recharging current to the battery 24.

The switches discussed above may be electro-mechanical or electrical, e.g., they may be implemented by field effect transistors (FET).

With the above system architecture in mind, the controller 22 can cause the drive train to be powered by the engine 14, with the reformer 28 producing hydrogen for storage in the hydrogen tank 34 and with the switches 26, 43, 44 open and valve 42 shut. If the controller 22 determines that the state of charge of the battery 24 and operational mode (including demanded speed, etc.) of the vehicle 10 warrant it, the controller 22 can decouple the engine 14 from the drive train 18 and close the battery switch 26 cause the battery 24 to supply propulsion current to the electric propulsion system 20.

Yet again, regardless of whether the battery 24 can be used in the particular implementation to propel the vehicle, the controller 22 can, when conditions warrant and the amount of hydrogen in the hydrogen tank 34 indicates a sufficient amount of hydrogen, cause the valve 42 to open. This ports hydrogen to the fuel cell 40, which outputs electricity. The controller 22 may cause the recharging switch 44 to close to recharge the battery 24 from the fuel cell 40, and/or it may case the fuel cell switch 43 to close to send propulsion current to the electric propulsion system 20 (in which case the engine 14 would be decoupled from the drive train 18).

While the particular SYSTEM AND METHOD FOR EXTRACTING PROPULSION ENERGY FROM MOTOR VEHICLE EXHAUST as herein shown and described in detail is fully capable of attaining the above-described objects of the invention, it is to be understood that it is the presently preferred embodiment of the present invention and is thus representative of the subject matter which is broadly contemplated by the present invention, that the scope of the present invention fully encompasses other embodiments which may become obvious to those skilled in the art, and that the scope of the present invention is accordingly to be limited by nothing other than the appended claims, in which reference to an element in the singular is not intended to mean "one and only one" unless explicitly so stated, but rather "one or more". It is not necessary for a device or method to address each and every problem sought to be solved by the present invention, for it to be encompassed by the present claims. Furthermore, no element, component, or method step in the present disclosure is intended to be dedicated to the public regardless of whether the element, component, or method step is explicitly recited in the claims. Absent express definitions herein, claim terms are to be given all ordinary and accustomed meanings that are not irreconcilable with the present specification and file history.

I claim:

1. A vehicle having an internal combustion engine including at least one exhaust pipe, a drive train couplable to the engine, an electric propulsion system couplable to the drive train, and at least one battery, comprising:

at least one reformer connected to the exhaust pipe for producing hydrogen from hydrocarbons in the exhaust gases from the engine;

at least one hydrogen tank for storing the hydrogen; and

at least one fuel cell connected to the hydrogen tank for using the hydrogen to produce electricity to recharge the battery, supply propulsion current to the electric propulsion system, or recharge the battery and supply propulsion current to the electric propulsion system.

2. The vehicle of claim 1, wherein the electricity from the fuel cell is propulsion current supplied to the electric propulsion system to activate the drive train to propel the vehicle.

3. The vehicle of claim 1, wherein the electricity from the fuel cell is recharging current supplied to the battery to recharge the battery.

4. The vehicle of claim 1, comprising at least one controller selectively causing the electric propulsion system or the engine to activate the drive train.

5. The vehicle of claim 4, comprising at least one valve interposed in a fluid path between the hydrogen tank and fuel cell, wherein the controller controls the valve to open and close the fluid path based at least in part on an amount of hydrogen in the hydrogen tank.

6. The vehicle of claim 5, comprising at least one switch interposed in an electrical path between the fuel cell and electric propulsion system, the controller controlling the switch.

7. The vehicle of claim 5, comprising at least one switch interposed in an electrical path between the battery and electric propulsion system, the controller controlling the switch.

8. The vehicle of claim 5, comprising at least one switch interposed in an electrical path between the battery and fuel cell, the controller controlling the switch.

9. A method for providing energy to propel a vehicle, comprising:

providing an internal combustion engine couplable to a drive train;

providing an electric propulsion system couplable to the drive train; and

generating electricity at least in part using hydrocarbons in the exhaust gas of the internal combustion engine to undertake at least one of:

recharge a battery connectable to the electric propulsion system, and

provide propulsion current to the electric propulsion system; wherein said generating includes sending the exhaust gas to a reformer and providing hydrogen from the reformer to a fuel cell operative to generate at least a portion of the electricity.

10. The method of claim 9, comprising storing hydrogen from the reformer until such time as it is determined to produce electricity using the fuel cell, and then sending hydrogen to the fuel cell.

11. The method of claim 9, wherein the act of generating produces propulsion current for the electric propulsion system.

12. The method of claim 9, wherein the act of generating produces recharging current for the battery.

13. A vehicle propulsion system, comprising:
internal combustion means for producing torque;
electric drive means for producing torque; and
means for producing electricity using hydrogen gleaned from a reformer disposed to receive at least a portion of the hydrocarbons in an exhaust stream of the internal combustion means.

14. The system of claim 13, wherein the means for producing electricity generates propulsion current that is sent directly to the electric drive means.

15. The system of claim 13, wherein the means for producing electricity generates recharging current that is used to recharge at least one battery.

16. The system of claim 13, wherein the means for producing electricity includes at least one fuel cell receiving hydrogen and producing electricity.

17. The system of claim 13, wherein the means for producing electricity includes at least one tank interposed between the reformer and the fuel cell; said tank configured to store hydrogen.

18. The system of claim 17 wherein the tank is connected directly to a hydrogen output of the reformer.

19. In a vehicle having an internal combustion engine including at least one exhaust pipe, a drive coupleable to the engine, an electric propulsion system coupleable to the drive, and at least one battery, a combination comprising:
a reformer connected to the exhaust pipe for producing hydrogen from hydrocarbons in the exhaust gases from the engine;
a tank for storing the hydrogen; and
a fuel cell connected to the tank for using the hydrogen to produce electricity to recharge the battery, supply propulsion current to the electric propulsion system, or produce electricity to recharge the battery and supply propulsion current to the electric propulsion system.

20. The combination of claim 19 further comprising a channel for providing water directly from the fuel cell to the reformer.

21. The combination of claim 19 further comprising a controller to receive a fuel supply signal from a detector on the tank and provide a signal to a valve to regulate fuel flow between the tank and the fuel cell.

22. The combination of claim 19 further comprising a channel for providing at least a portion of the exhaust gas output from the reformer to the internal combustion engine to provide additional fuel to the engine.

23. The combination of claim 21 further comprising at least one switch connected to the controller for switching the battery output between the fuel cell and the electric propulsion system.

24. The vehicle of claim 1 further configured to apply at least a portion of said exhaust gases to heat said reformer to improve the hydrogen conversion performance of said reformer.

25. The vehicle of claim 1 wherein said internal combustion engine is a two-stroke engine.

26. The vehicle of claim 1 wherein said internal combustion engine is a four-stroke engine.

27. A method for propelling a vehicle, comprising:
providing an internal combustion engine configured to be couplable to a drive train of said vehicle;
providing an electric propulsion system configured to be couplable to the drive train, said electric propulsion system including a fuel cell;
providing exhaust gases from said internal combustion engine to a reformer, wherein said exhaust gases include unburned hydrocarbons;
heating said reformer using said exhaust gases;
converting at least a portion of said unburned hydrocarbons to hydrogen in said reformer;
providing said hydrogen to a storage tank; and
providing said hydrogen stored in said storage tank to one of said fuel cell or said internal combustion engine as a fuel to facilitate propelling said vehicle.

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