

Hydrogen giving reduced carbon emissions from vehicles

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Abstract

Hydrogen is considered to be an ideal energy carrier for low-carbon vehicles in the near future. It can be produced from water by using a variety of energy sources, such as solar, wind and nuclear, and it can be converted into useful energy efficiently and without detrimental environmental effects. The only by-product is water or water vapour in fuel cell vehicles, but small amounts of NO_x are produced in combustion systems. Hydrogen can be used in any application in which fossil fuels are being used today, especially cars, buses and trucks. This paper considers how hydrogen can be combined with two other technologies; online vehicle monitoring and computer maps to give significant reduction in carbon emissions from combustion engines, especially on trucks.

Keywords: hydrogen on trucks; engine operation with hydrogen; CANbus; ADAS

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1 INTRODUCTION

Two technologies are currently being developed by several companies (www.airmaxgroup.com, www.thecell.com) to reduce carbon emissions from fleets of trucks. The first is online monitoring of vehicle and driver performance through sensors attached to the CANbus which controls all aspects of the subsystems' operations, including engine, acceleration, braking, fuel consumption etc. [1]. The second is ADAS, the Advanced Driver Assistance System (ADAS) developed by NAVTEQ [2]. This system is a map and positioning engine which uses a computer map of the vehicle's surroundings (horizon data) plus a global positioning system to advise the driver on approaching hills, traffic lights, curves and other road features which influence fuel consumption. NAVTEQ along with other companies have long recognized that digital maps can play a role as a 'sensor' that, when combined with other sensor inputs, can enable or support ADAS in a variety of value-adding ways. To illustrate, road slope information from the NAVTEQ map can inform a vehicle about upcoming hills and support adjustments to the engine throttle accordingly. This 'Predictive Cruise Control' application is an example of how maps can enable fuel savings within ADAS by allowing the engine to run optimally and avoid driver inefficiency. If hydrogen was also available to reduce carbon output from the truck, then three technologies could be combined to produce a substantial saving compared with current fleet operations. First, we consider the CANbus monitoring

system, then show how this can be combined with ADAS, and finally add in hydrogen to give further benefit.

2 CONTROLLER AREA NETWORK (CANbus) DIAGNOSTICS

Since 2003, vehicles have been built with an onboard communications protocol called CAN (Controller Area Network). CANbus is essentially an engineering standard for how computers and modules talk to one another via the serial data bus in a vehicle's wiring system. It is a high speed standard designed for powertrain control modules, antilock brakes and stability control systems.

The CANbus protocol was created back in 1984 by Robert Bosch Corp. in anticipation of future advances in onboard electronics. The first production application was in 1992 on several Mercedes-Benz models. By 2008, all new vehicles sold in the USA were required to have a CAN-compliant onboard diagnostic system.

Information in a CAN-equipped vehicle is shared over a serial data bus. The bus is the circuit that carries all the electronic chatter between modules (nodes). The bus may have one wire or two. If it has two, the wires are usually twisted to cancel out electromagnetic interference. The speed at which the bus carries information will vary depending on the 'class' rating of the bus as well as the protocol to which it conforms.

The CAN standard requires a ‘base frame’ format for the data. What this means is that for each distinct message sent or received by a module on the network, there is a beginning bit (called the ‘start of frame’ or ‘start of message’ bit), followed by an ‘identifier’ code (an 11-bit code that tells what kind of data the message contains), followed by a priority code (remote transmission request) that says how important the data are, followed by 0–8 bytes (1 byte equals to 8 bits) of actual data, followed by some more bits that verify the information (cyclic redundancy check), followed by some end of message bits and an ‘end-of-frame’ bit.

A major step forward in fuel conservation and driver training is the logging of key performance indicators (KPIs). This can include harsh braking, fast acceleration, idling time and constant speed events but also geo-coded excess fuel consumption and harmful emissions. By monitoring a large number of performance indicators, the fuel efficiency of a vehicle can be related to each individual driver. It can be shown that the best drivers use ~20% less fuel than the poor drivers. These KPI’s can be transmitted via GSM to form reports as illustrated in Figure 1. Figure 1a shows a report of incidents for a driver over a 1-month period. Figure 1b shows a fault report and Figure 1c informs a driver about his performance.

There have been five distinct steps in the evolution of remote vehicle diagnostics:

- (i) In the beginning, each vehicle manufacturer had unique proprietary diagnostic systems, in many cases even using

different systems for different models. This made access by independent systems very difficult.

- (ii) Over time, these unique proprietary diagnostic systems were consolidated into a number of different recognized ‘standards’; however, each manufacturer still tended to use their own particular flavour. Access by independent systems was still difficult, but at least, there was a common standard for diagnostic connectors.
- (iii) From 2001 onwards, the situation was rationalized by the mandatory On-Board Diagnostics (OBD) requirements, which imposed a common standard on all manufacturers for emission-related applications. Access to OBD data by a ‘common’ independent system became a practicable proposition. However, there are considerable differences between manufacturers concerning the scope of the information available via OBD: Manufacturers still retained the use of their diverse proprietary systems for internal ‘native’ vehicle applications (e.g. fault reporting).
- (iv) With increasing consolidation and globalization in the motor industry, the diversity of proprietary diagnostic systems in use is reducing, as manufacturers are increasingly adopting a unified ‘corporate approach’ across all model platforms.
- (v) We are witnessing the development of garage tools that can interpret data from the OBD port and through layers or gateways into cluster data from the main ECU data for reprogramming and adjustment and fine tuning. These are often diesel-specific and common rail-based. In

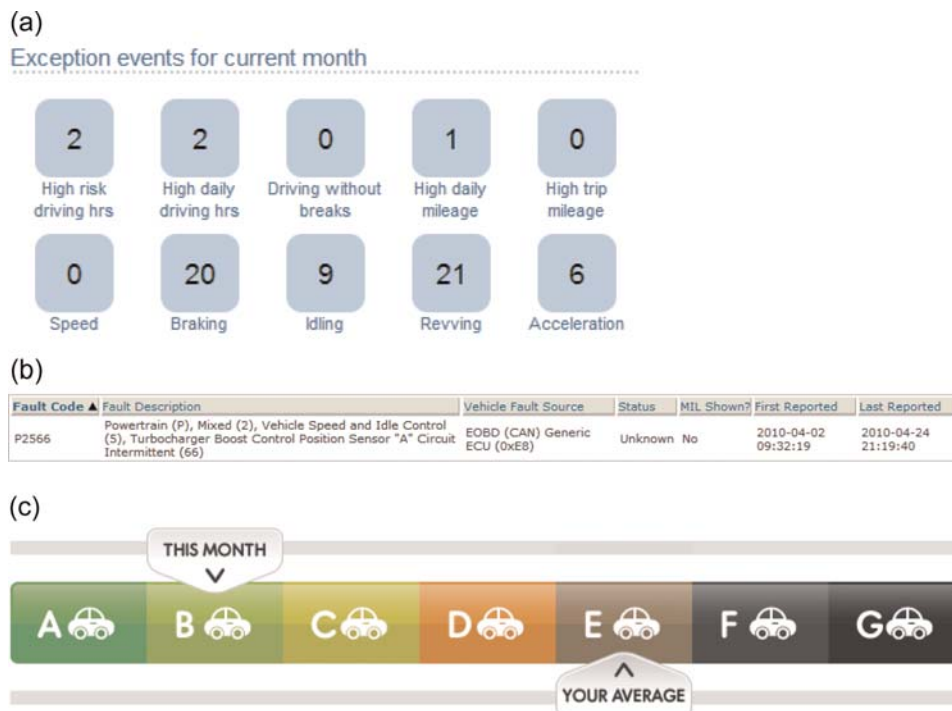


Figure 1. (a) KPI’s for a 1- to 2-day period for one vehicle; (b) Fault code and fault description reported remotely; (c) Eco driving report showing an improvement in driving technique but also compared against his peer group.

parallel, we are seeing drivers buying simple but specific OBD tools to identify faults and cancel service lights etc. With GSM and Wi-Fi, it is now possible to set exception alerts and full ECU integration routines while the car is driven.

3 ADVANCED DRIVER ASSISTANCE SYSTEM

Numerous possibilities exist for ADAS applications based on electronic map data, including:

- electronic stability control;
- lane departure warning;
- lane change and lane keeping assistant;
- curve warning system;
- drowsy driver detection;
- forward and side collision warning;
- intelligent speed advisory;
- black spot warning;
- blind spot detection;
- overtake assistant;

- powertrain control/fuel economy;
- adaptive front light systems;
- stop light and stop sign warning;
- geo-coded dual fuel management;
- LV air-conditioning management.

Figure 2 shows typical electronic horizon data set identifying the road ahead with attributes. The computer informs the truck driver to slow down well ahead and this action conserves fuel. In addition, the computer can send a message to the fleet supervisor monitoring the driver behaviour, so that improvements in driver fuel economy can be implemented.

The NAVTEQ Electronic Horizon™, which is based on NAVTEQ's patented Electronic Horizon algorithms, can thus be used to tell the vehicles of impending dangers, corners, cambers and black spots and road signs. The consequence is that a truck computer can calculate in advance the need for fuel input, or mode and even turn off the air-conditioning awaiting a pending junction to save energy.

Figure 3 shows several possibilities for improving fuel economy by the ADAS technology. A large improvement, from

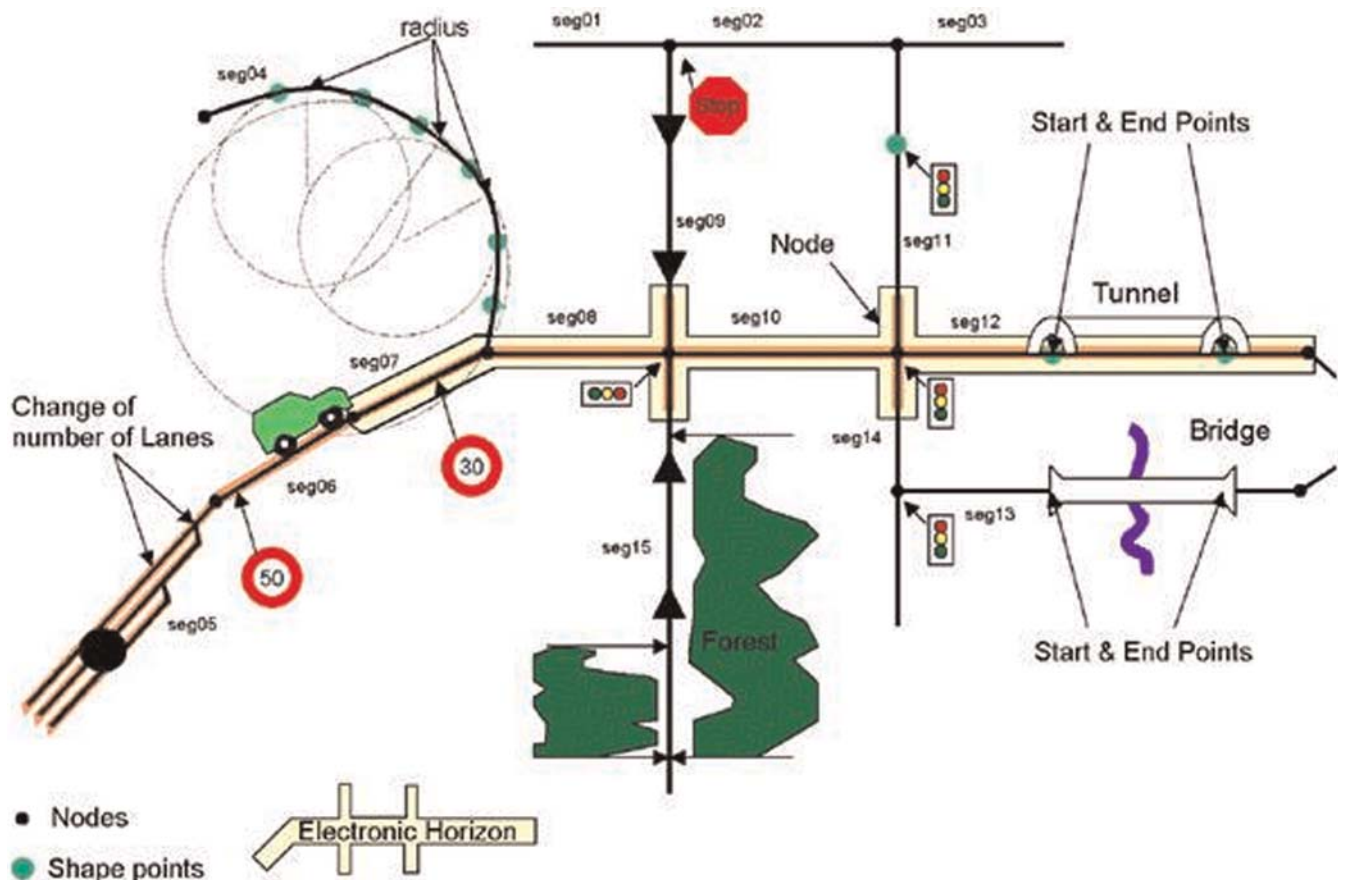


Figure 2. A typical electronic horizon data set identifying the road ahead with attributes. This is the image seen in the vehicle.

Maps Drive Increased Fuel Economy and Reduced Emissions

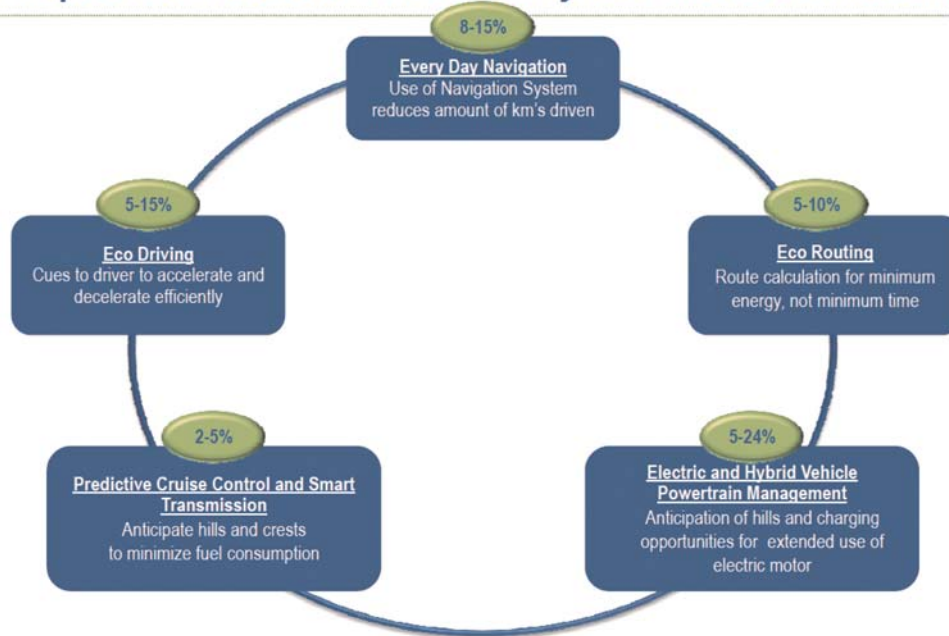


Figure 3. Gains in fuel economy from the ADAS system.

8 to 15%, stems from better navigation and routing. Eco-routing and eco-driving give smaller gains, from 5 to 15%. Predictive cruise control also gives significant benefit, from 2 to 5%. But the greatest possibility is to improve the efficiency of the drive-train. One of the simplest methods proposed for generating efficient truck engine performance is addition of hydrogen/oxygen mixtures to the air inlet.

4 HYDROGEN ADDITION

A number of early papers published results on hydrogen addition to combustion engines [3, 4]. More recently, many enthusiasts have added mixtures of hydrogen and oxygen produced from electrolysis, so-called HHO, to the air inlet of combustion engines, especially diesel trucks. There are claims that this addition gives lower emissions from the exhaust, improved power from the engine and improved fuel economy. Various theories of these effects have been put forward, but evidence has been difficult to confirm, especially because the engine manufacturers do not generally support such modifications. However, it is clear that there are various losses in the drive-train and there are improvements that can be made, including those that stem from hydrogen addition.

A typical truck modified for hydrogen addition is shown in Figure 4. An electrolyser system powered by the truck battery is used to generate HHO which are fed into the air inlet manifold of the engine.

A typical HHO generator system consists of a water-based electrolyte reservoir, one or more electrolyser cells connected to



Figure 4. The hydrogen generator is the box in front of the diesel fuel tank.

or mounted inside the reservoir and a gas pipe from the top of the reservoir to the engine air intake. The electrodes are connected to the truck battery and alternator through a relay and current-limiting electronics. When the engine is running, the relay switches power to the electrodes to begin the production of HHO. The negative pressure created by the engine draws in these gases which then aid the combustion of the diesel fuel in ways which have yet to be properly defined.

Results of testing on several trucks have shown several effects:

- (1) reduction in exhaust emissions;
- (2) improved engine power when the HHO is injected;
- (3) increased fuel economy under certain engine operating conditions, with 20% being a typical enhancement.

A detailed programme of research is now under way to confirm and explain these initial observations.

On the negative side, there are some disincentives:

- Some energy is lost in the electrolyser system because of ohmic heating etc.
- The engine CANbus system needs to be modified.
- The electrolyte needs regular topping up.
- The engine warranty may be invalidated.
- New insurance may be needed.
- Proper standardized investigations have not been carried out.

5 CONCLUSIONS

Trucks at present use enormous amounts of fossil fuel and produce excessive emissions of carbon and other pollutants. Three potential synergistic improvements are suggested:

- (1) The monitoring of truck data which allows driver training and improvement to give up to 20% less fuel usage.
- (2) The implementation of the electronic map system ADAS which allows the computer to optimize truck performance by 20%.
- (3) Addition of hydrogen to the engine to increase drive-train efficiency by an estimated 20%.

The conclusion is that it should be possible to improve truck fuel consumption through full adoption of these measures, while greatly improving emissions in advance of Euro6 regulations.

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