Fuel Economy Validation of the Smart Microhybrid System for Used Cars

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ABSTRACT
We developed a smart microhybrid system for used cars to improve fuel efficiency via the OBD-II interface. The proposed smart microhybrid system can accurately measure the amount of fuel that is saved by stopping engine idling and estimates the amount of fuel that is consumed when the engine begins to start. It automatically determines when is optimal to stop or start the engine using various driving status. The system was implemented and tested in a used car. Experimental results show that it outperforms conventional cars not equipped with the smart microhybrid system in fuel economy. We will massively reduce CO$_2$ by using smart microhybrid systems and prove the possibility of the CDM (clean development mechanism) project.

Categories and Subject Descriptors
H.4 [Information Systems Applications]: Miscellaneous

General Terms
Design

Keywords
microhybrid, fuel economy, idling stop, used car, clean development mechanism, greenhouse gas

1. INTRODUCTION
Presently, a variety of efforts are being made in the transportation field to reduce the greenhouse gases. In particular, much effort has been made in improving fuel efficiency, as a part of the efforts which are microhybrid systems [1].

In automobiles, a microhybrid system automatically shuts down and restarts the internal combustion engine (ICE) to reduce the amount of time that the engine spends on idling, thereby reducing fuel consumption and emissions. This is most advantageous for vehicles which spend significant amounts of time on waiting at a traffic light or frequently stopping in a heavy traffic.

Recently, a microhybrid system has been applied to improve the fuel efficiency of the IC engine by various car makers especially in Europe. Researches on a technology to accurately detect and analyze the reduction of the greenhouse gas, however, are not sufficient yet. Our smart microhybrid system was developed to prove the effectiveness of the fuel saving and the CO$_2$ emission reduction.

For non-electric vehicles (called microhybrid systems) fuel economy gains from this technology are typically in the range of 8 to 20 percent. This technology can be now found in most types of car and is especially popular in Europe. It will surely become even more widespread once new CO$_2$ legislation is enforced across Europe [2].

In this paper, we propose the information and communication technology (ICT) that is converged with idling stop systems, which is called a smart microhybrid system for used cars that can measure the amount of fuel saved by stopping engine idling. The proposed system enables the possibility of the clean development mechanism (CDM) project of the United Nations Framework Convention on Climate Change (UNFCCC) [3].

In section 2 of the paper, we describe the design and implementation of our smart microhybrid system. The method for measuring reduction of greenhouse gas (GHG) by idling-stop will be presented in Section 3 and we will provide the experimental results in Section 4. Finally, Conclusions will be drawn in Section 5.

2. SMART MICROHYBRID SYSTEMS

2.1 Background and objective
About 5 million microhybrids had been sold worldwide by the end of 2011, and the majority of them in Europe, said Kevin See, an analyst at Lux Research, which just published a new report on microhybrids. Kevin See expects the market to grow to 39 million vehicles in 2017 [4].

Many people think that long term use may wear out the components in microhybrid implementations which require a starter motor, but this is not true [5]. Mazda i-stop used in their Mazdas3/Axela line (in Enurope and Japanese domestic market) uses combustion to restart their engine by sensing the position of the piston in the cylinder. They claim quieter and quicker engine restart within 0.35 seconds [6].
Due to the cost and energy, microhybrid systems are popular all over the world as shown in Table 1.

As shown in Table 1, microhybrid systems are applied to new cars. However, the number of used cars is larger than the number of new cars by 98% and the lifecycle of a car is longer than 10 years. Therefore, we need to bring the solution of the microhybrid system for used cars into focus.

In this paper, we handle the microhybrid system for used cars and prove the effectiveness of energy savings in the ICE car.

### 2.2 Design of the smart microhybrid system

Microhybrid technologies that are applied to used cars are quite different from them that are for new cars. Current microbid commodities for the after-market lack intelligence and employ hairy wires that cause frequent breakdowns.

In this paper, we propose the smart microhybrid technology for used cars to save oil and reduce CO\(_2\) emission. From 2007 in Korea, the microhybrid system for used cars has appeared in sight, however its technology is as simple as a remote control system. Also the legacy microhybrid system for used cars needs to modify the cars and to install a bunch of equipment. In addition, it cannot prove the effectiveness of fuel economy. However our proposed smart microhybrid system offers a simple installation and can measure and analyze the fuel consumption using OBD-II as shown in Fig. 1.

Our smart microhybrid system is designed and developed to be able to check various conditions such as warming up state and overloaded state to reduce much amount of GHG emission.

In order to realize smart engine-off operation, at least five decision operations are required. They are idling state, warming up state, air-conditioner on state, parking state, and overloaded state as shown in Fig. 2. It is important to have the smart microhybrid system smarter for higher fuel efficiency and better convenience.

First, we present the idling state defined in our microhybrid system. In a used car, it is difficult to exactly decide when it is the idling state, because we can only get indirect information for used cars. To overcome this problem we handle a lot of parameters obtained from the car via OBD-II to decide idling state, i.e. speed, break pedal, and out-turbin speed. After we decide idling state we cannot shutdown engine immediately. Because the amount of fuel being used to restart the engine is much larger than the amount of fuel consumption in idling state less than 3 to 5 seconds as shown in Fig. 3. In the case of the overloaded state and the warming up state we don't shutdown the engine although the engine is in the idling state. Incomplete combustion occurs in the warming up state or overloaded engine state thereby producing more GHG emission.

Second, because of various driving patterns according to female or male and unskilled or skilled, the presented technology is required to be much smarter. For example, if an unskilled woman is parking a car with frequent idling, the car may be turned off by a misprediction. However our mi-
microhybrid system notices the driving situation and it does not shutdown the engine.

3. METHOD TO MEASURE REDUCTION OF GHG

Presently, a variety of efforts are being made in the transportation field to reduce the GHGs. In particular, many efforts have been made in improving fuel efficiency. GHG reduction improves fuel efficiency. However, research on a technology to accurately measure and analyze the reduction of the GHG are not sufficient yet.

In this section we introduce a method to make it possible to measure the amount of GHG that is not exhausted during stopping engine idling, in order to be admitted as a Clean Development Mechanism (CDM) business by reducing the amount of GHGs (mainly carbon dioxide) using an idling stop system.

Fig. 4 is a diagram illustrating the configuration of an apparatus to measure the amount of reduced GHG during stopping engine idling in our microhybrid system [7].

In our paper, it is assumed that the vehicle described hereafter is a car equipped with the smart microhybrid system.

In Fig. 4, the following conditions should be satisfied while an ignition switch is turned on to automatically stop the engine when the car stops to wait for the traffic lights. That is, an output signal of a vehicle velocity sensor should indicate zero, an output signal of a brake sensor should indicate that the brake pedal is pressed down. When the driver removes the foot from the brake pedal and presses down the acceleration pedal subsequentially, a condition to restart the stopped engine is satisfied.

In other words, the system automatically determines when the engine stops or starts on the basis of the signals from the ignition switch, velocity sensor, accelerator sensor, and brake sensor. This method of controlling automatic idling stop is well known to those skilled in the art.

As shown in Fig. 4, the fuel consumption amount measurer of the smart microhybrid system can calculate the amount of fuel by communicating with ECU via CAN during driving.

With the aid of the fuel consumption amount measurer, the greenhouse gas exhaust reduction calculator can calculate the amount of GHG that is reduced by idling stop of our test car, using the following Eq. (1), on the basis of information from the fuel consumption amount measurer and an engine stop-continued time from the ECU.

\[
\text{Exhaust reduction of GHG by idling stop} = C \times (E - R),
\]

where \(E\) and \(R\) denote for the amount of fuel estimated to be consumed during idling and the amount of fuel consumed for engine restart, respectively. The constant \(C\) in Eq. (1), which is a part making the exhaust reduction of greenhouse gas equivalent to the amount of fuel consumed by combustion, depends on the types of fuel. The amount of fuel consumed of a vehicle equipped with an ICE is sub-
4. EXPERIMENTAL RESULTS

We have experimented with a used car equipped with the smart microhybrid system. The test car is Kia's Pride 2008 (4DR Gasoline 1.4 DOHC LX) as shown in Fig. 6. The specifications of the test car are 15.1km/ℓ of gas mileage and 158g/km of CO₂.

In order to verify the fuel economy obtained by the smart microhybrid system, we took a driving test on heavy traffic roads in Daejeon city and Seoul city. For the smart microhybrid system, many driving tests have been carried out in Gangnam-gu Seoul and in Daejeon. Fig. 7 shows the driving path in Seoul. The test car equipped with the smart microhybrid system departed Gangnam-gu office at 20:17:05 and arrived at the place again at 21:34:09. It took 1 hour 17 minutes 4 seconds for 10.7km.

Total 35 engine-stops were occurred, excluding the departure stop and the arrival stop. The total duration of the engine stops was 1778.4 seconds. The 1452.81 cc of fuel consumption was measured and 325 g/km of CO₂ was emitted while driving the car. The gas mileage was 7.36km/ℓ. For the 1778.4 seconds of engine stop time, 426.9 cc of fuel was saved and 1021.6 g of CO₂ was reduced. Without the smart microhybrid system the fuel economy may be 5.7km/ℓ, which was estimated by the system that can measure the amount of fuel by communicating with ECU via OBD-II. Owing to the smart microhybrid system the fuel economy for the used car was increased by 29.4% in the driving path shown in Fig. 7.

The fuel economy of the smart microhybrid system for the used car was increased from 6.9% to 29.40%. In the Fig. 8 we can find out that the harder the heavy traffic is, the better the fuel economy is.
5. CONCLUSIONS

The smart microhybrid system for used cars is designed, implemented, and tested in an actual car produced in Korea. The system is developed to improve fuel efficiency and to offer drivers better convenience. The proposed system can measure the amount of saved fuel by stopping the engine and consumed fuel by starting the engine, and show it to user in a real time whereas the system employs a simple installation with the OBD-II interface. Using various sensors that are provided via OBD-II, the system intelligently determine when is optimal to stop or start the engine. Experimental results show that it outperforms conventional cars not equipped with the smart microhybrid system in the fuel economy. We will massively reduce CO$_2$ by using smart microhybrid systems and prove the possibility of the CDM(clean development mechanism) project.

6. REFERENCES


