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VIABILITY STUDY OF ETHYLENE (C_2H_4) AS AN ALTERNATIVE FUEL FOR GASOLINE ENGINE

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ABSTRACT

Ethylene (C_2H_4) a very important gaseous hormone commonly used in agriculture to enhance the ripening of fruits and to stimulate rubber tree to yield more latex. In industry, polymerized ethylene, which produced polyethylene, also called polythene; the world's most widely used plastic. As a source of hydrocarbons, the physical properties such as high in energy content compared to gasoline and highly flammable (classified by EU) are strong indications that the gas can be easily combusted. This paper is intended to publish the possibility of using the mentioned gas as a fuel in for gasoline-powered vehicle. The methodology used to evaluate the viability of the gas is by experimental approach. The test done on the engine as a unit by itself (using engine test bed) and engine fitted to a vehicle where a chassis dynamometer is engaged. As for on the road test, a gas kit was developed, complete with electronic control unit (ECU) to ensure proper controlled amount of ethylene being induced to the engine. The data mapping in the ECU is obtained from the performance test done on the engine test bed. Gas kit develop is being customized and fine-tuned to suit with the properties of ethylene and gasoline engine design. This is vital in order to come up with an optimized fuel-handling system to ensure maximum performance attained. All the work undertaken and performance data obtained were compared to gasoline-fuelled engine. In other words, the presentation of experimental results for ethylene is always compared to gasoline.

Keywords: *Alternative fuel, natural gas and engine performance*

1.0 INTRODUCTION

Ethylene is a chemical compound with the formula C_2H_4. As a petroleum base product, the gas is produced in the by steam cracking, an energy intensive process that involved temperature of 750-950^oC. Commonly used as hormone in agriculture to stimulate ripening of fruits harvested by releasing the gas in an enclosed space containing fruits. In rubber plantations, this gas is allowed to sip

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through into rubber tree from a pressurized canister, which will last for about three months per canister. By using ethylene as plant hormone, the rubber three can yield ten times more latex.

In petrochemical industry, polymerized ethylene is used to produce polyethylene, also known as polythene; the world's most widely used plastic. Ethylene is also an important element in the manufacturing of polystyrene, another important plastic. These plastic can last for years and therefore it also takes years to decompose if treated as trash. The environmental activist makes this as an issue today, and in United States, they urged the government to ban the used of these type of plastic.

Global ethylene production exceeded 75 million metric tones per year in 2005 [1]. If the banning of plastic is made as legislation, the world has another source of energy that can be utilized.

2.0 IMPORTANCE OF FUEL PROPERTIES

To undertake the potential of a fuel (any fuel) as a suitable substitute for an internal combustion engine, it is imperative for the evaluator(s) to firstly look into the physico-chemistry of the fuel in focus. These physico-chemical properties are of paramount in the evaluation of its preliminary performance and assist the evaluators to chart the next course of action.

Table 1 illustrates the physico-chemical properties found and used in the calculation of various operating parameters throughout the evaluation exercise. Physical properties 3), 5) and 7) are of strong indications that the gas can be easily combusted. The enthalpy of combustion indicates better combustibility of the gaseous fuel in conventional gasoline engines. The auto ignition property at 490^{o}C is well within the range of 400 to 600^{o}C, normally associated with gasoline fuel auto-ignition performance, in an SI engine. Another important property, which can be of help, is octane number. With the absence of this important property, its resistance to knock is not known.

Table 1: Ethylene physio-chemical properties [2, 3, 4]

No.	Property	Value
1	Molecular formula	C_2H_4
2	Molar mass	28.05 g/mol
3	Appearance	Colourless gas
4	Density and phase	1.178 g/L at 15^{o}C, gas
5	Std enthalpy of Combustion	-1387.4 kJ/mol (49.46 MJ/kg)
6	EU classification	Extremely flammable
7	Auto ignition temperature	490^{o}C
8	Flash point	Flammable gas

3.0 METHODOLOGY

The evaluation exercise involve laboratory experimental work and on the road test. The laboratory work involves engine test bed dynamometer and chassis dynamometer. The laboratory experimental work is to gauge some performance data from a test engine alternately – reference and test fuels. The laboratory work refers to the reference engine being simulated for operation throughout its prescribed operating (speed) range. The engine chosen, was a *Mitsubishi* 4G92 model – a close representation of the *Proton Waja* 1.6 litre vehicle, in which the on-road test is to be implemented upon completion of the laboratory work. This is a fuel injection engine and it is matched with an engine dynamometer (SAJ AWM 50) for cycle loading test.

The purpose of undertaking of a series of engine test is to gas ethylene's overall performance in unmodified engine. The parameters of interest to the evaluators are i) engine torque, ii) brake power iii) specific fuel consumption and iv) exhaust gas emission.

Engine test standard adopted are the BS 5514 Parts 1 to 6 (Reciprocating Internal Combustion Engine Performance) and SAE Standard Engine Power Test Code (SI and CI – gross power rating SAE J1995 June 1990).

4.0 LABORATORY ENGINE TEST

The first-phase of the laboratory trial is about characterizing the behavior of the engine fuelled with ethylene. These engine tests are meant towards the formulation of the engine "look-up" table or more precisely the ECU (engine control unit) look-up table. The whole experimental work is an iterative and statistical in nature where the important magnitude of the important parameters was acquired for the test engine. Figure 1 shows the set-up for the laboratory test.

Figure 1: Experimental set-up

4.1 Results and Discussion

Results presented is the phase three of the laboratory work, focusing on the behavior of the engine fuelled with ethylene at constant speed.

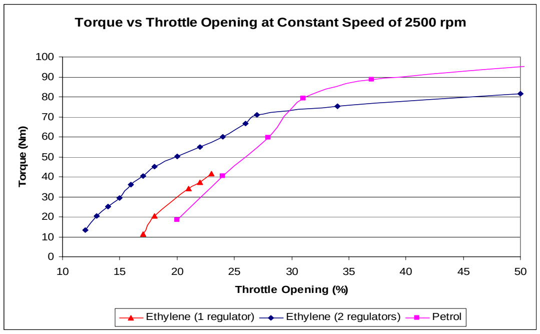

Figure 2: Torque profile at different throttle openings

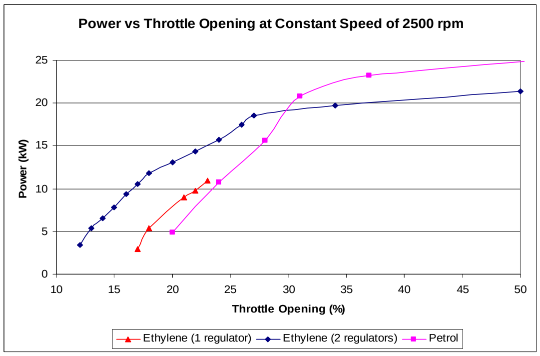

Figure 3: Brake power profiles at different throttle openings

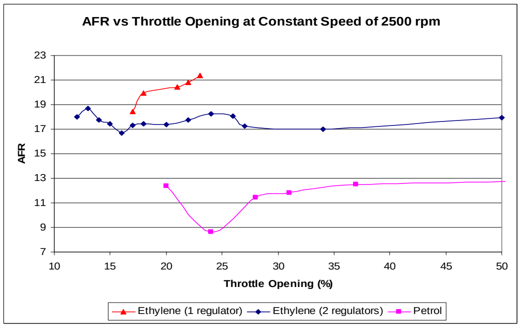

Figure 4: AFRs at different throttle openings

Figure 2 shows the torque profile between the two fuels set at a constant speed of 2500 rpm. Ethylene depicts high torque at low throttle opening whereas gasoline shows higher torque output beyond the 30% limit. Figure 3 is the computed values for brake power, which naturally indicate that it offers more engine output at low throttle opening, but as the throttle is widely open the output deteriorates slightly in relation to gasoline - an indication of flow resistance at opening of more than 30%. The different throttle openings it seems do not affect the air-fuel ratio for ethylene than that for gasoline, as shown in Figure 4.

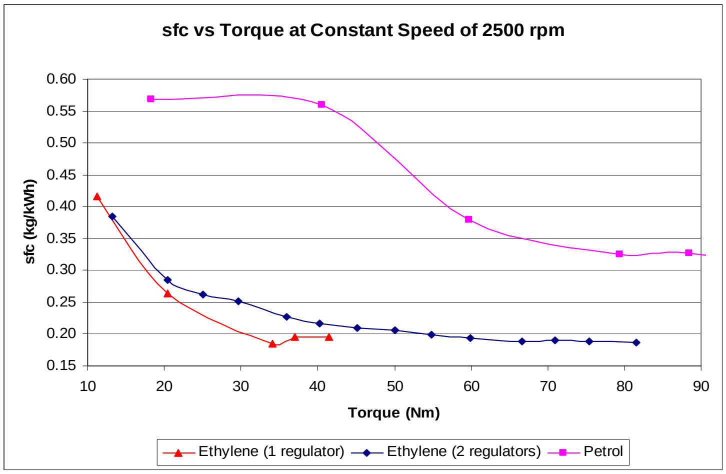

Figure 5: SFCs against engine load at 2500 rpm

Figure 5 illustrates the comparative evaluation between ethylene and gasoline from the perspective of specific fuel consumption. It clearly indicates the superiority of ethylene for fuel economy.

5.0 CHASSIS DYNAMOMETER TEST

In order to run the test a gas conversion kit complete with Ethylene Gas Vehicle (EGV) controller was develop. The guidelines for the development of the conversion kit are low-cost, simple and practical. The components of the EGV conversion kit consist of mixer, pressure vessel, ECU, proportional valve, pressure regulator, pipe work, solenoid valve petrol-gas switch and injector relay.

5.1 EGV Controller

The main task of EGV controller is to shut off the petrol supply, and to supply proportional amount of gas to the engine combustion space. The schematic diagram of EGV controller is shown in Figure 6. EGV controller takes inputs from:

- Selector switch.
  This switch manually selects either petrol (gasoline) or gas used for the engine.
- Car sensors and injection time

The EGV controller reads car sensors (especially engine speed) and injection time, and calculates the appropriate amount of gas supplied to the engine
- Gas pressure sensor.
  The EGV controller needs information about the current pressure and level of gas in the tank.

Outputs driven by EGV controllers are:

- LCD
  This LCD display current operation mode (petrol or gas), injection time, level opening of proportional valve, and gas level and pressure available in the tank
- Main valve
  This valve is used to open or close the gas supply from tank to the engine.
- Regulator valve
  This valve is used to maintain a supply of constantly low-pressure gas to the proportional valve before entering the engine.
- Proportional valve
  This valve controls the appropriate amount of gas flowing into the engine by opening its valve accordingly.
- Switch box
  In Petrol mode, the switch activates the injectors, whereas in Gas mode, the switch turns off the injectors.

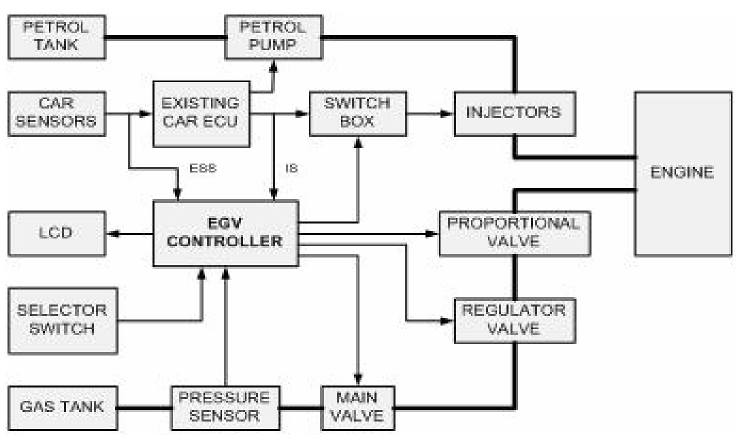

Figure 6: The schematic diagram of EGV controller

5.2 Gas Flow Control

In order to run the engine smoothly and continuously regardless off vehicle load, the amount of gas supplied into the engine's combustion chamber needs to be precisely controlled. Two basic parameters needed to regulate this gas supply are engine speed and injection time. Figure 7 shows relationship between level opening of proportional valve and injection time *Ton*, for any engine speed in the range of about 1000 rpm to 4500 rpm. This data has been successfully implemented in the EGV controller and carefully tested on the Proton WAJA car. Table 2 describes the range of engine speeds used in Figure 7.

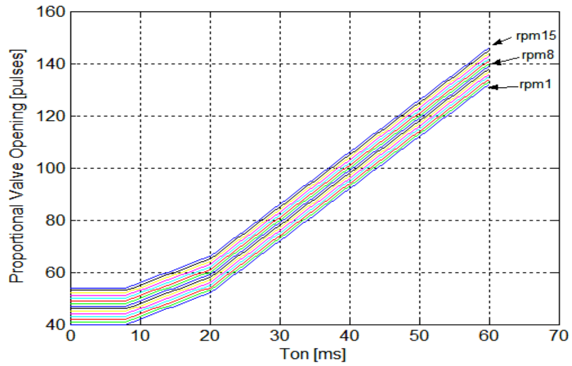

Figure 7: Proportional valve opening against injection time

Table 2: Range of engine speeds

No.	Engine Speed (RPM)
1	<=1000
2	1001 - 1250
3	1251 - 1500
4	1501 - 1750
5	1751 - 2000
6	2001 – 2250
7	2251 – 2500
8	2501 – 2750
9	2751 – 3000
10	3001 – 3250
11	3251 – 3500
12	3501 – 3750
13	3751 – 4000
14	4001 – 4250
15	> 4000

5.2 Results and Discussion

Figure 8 illustrates the brake power outputs in relation to the 1st, 2nd and 3rd gear setting. With the exception of the 1st gear, ethylene as fuel resulted in lower engine traction power for 2nd and 3rd gear.

Figure 9 illustrates the results of the higher gearshift. Here ethylene depicts slightly lower brake power output than gasoline. Figure 10 shows the results of investigation on the behavior of specific fuel consumption with vehicle speed subjected to the gear change. What this graph indicates are: i) higher fuel consumption for ethylene at low gear but ii) the reverse takes place when the engine was shifted to higher gear (3rd and beyond).

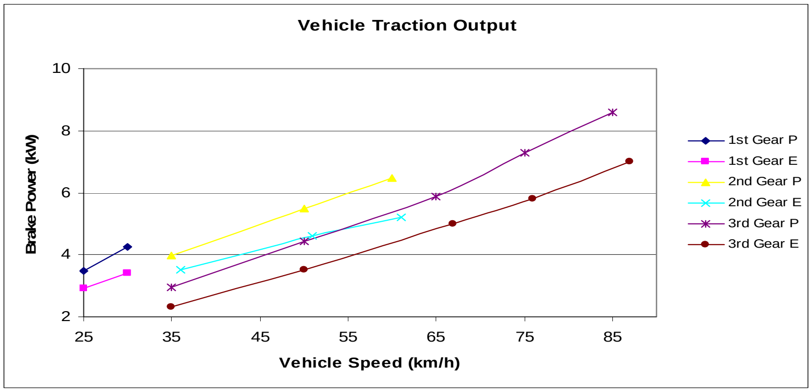

Figure 8: Vehicle speed from 25 to 85 km/h equivalent (1st, 2nd and 3rd gearshift)

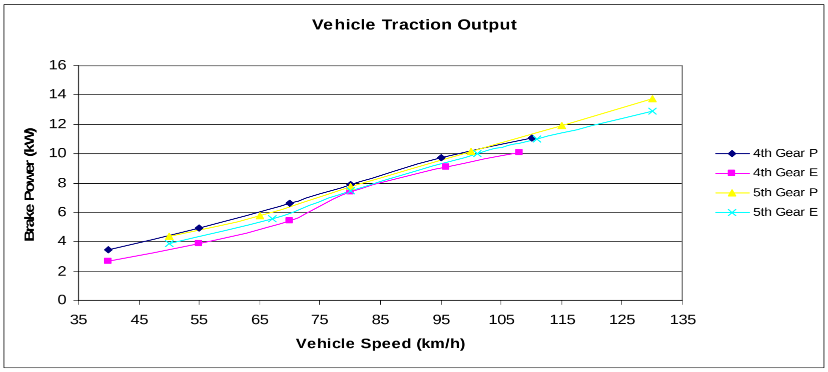

Figure 9: Vehicle speed from 35 to 130 km/h (on 4th and 5th gear)

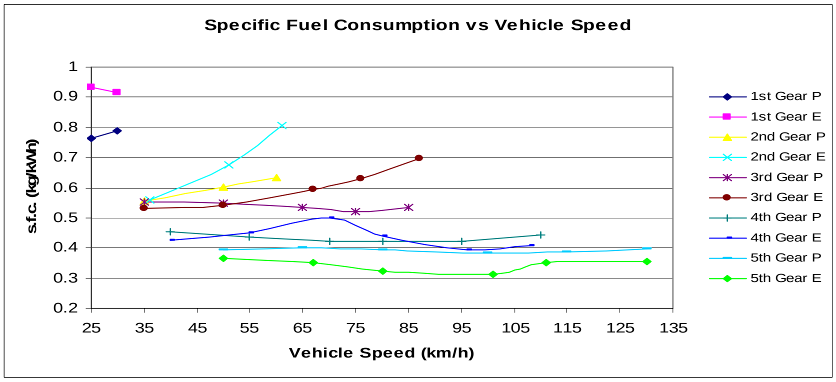

Figure 10: SFC profiles with gearshift ranging from 25 to 130 km/h

At low gear, the distance travel is about the same for ethylene and gasoline but ethylene demonstrates better range at high gear settings. A good example would be the 5th gear setting, where the mileage attained is noted at 32.5 km/kg (corresponding to 100 km/hr of Figure 11), in relation to gasoline which only clocked 26.8 km/kg.

6.0 ON-ROAD TRIAL

The on-road trial was implemented to gauge the actual performance of ethylene from the perspective of the range the fuel is able to cover, for one unit of fuel consumed. For this case, an appropriate denominator would be the mass (kg) rather than volume (liter) - to compare liquid fuel to gaseous fuel.

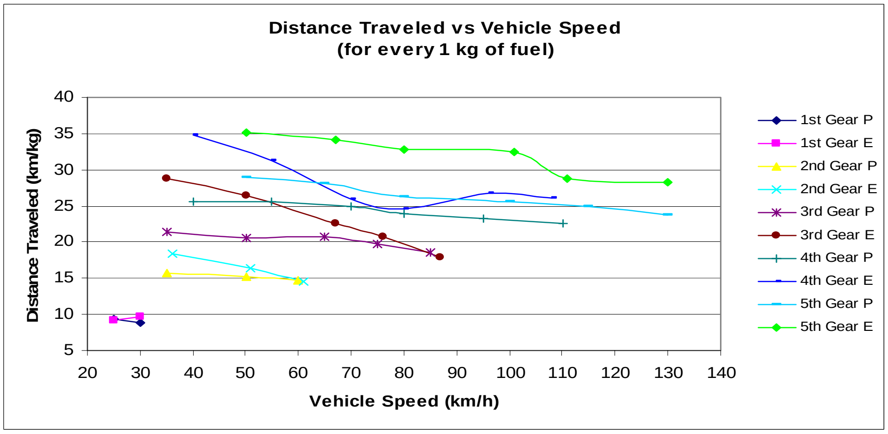

Figure 11: Variation in distance travel at different gearshift

This on-road vehicle trial program has indicated that one kg of ethylene is able to cover a distance of 26.3 km on the highway and 26.8 km on the federal road for one kg of the fuel used. In contrast, the vehicle running on similar route only managed to clock 17.0 km for one kg of the gasoline fuel consumed.

7.0 EMISSION TEST

The following graphs illustrate the emission test result of the test car (*Waja* 1.6) running on Rolling Road Dynamometer. The vehicle was tested without the post-treatment device (catalytic converter) installed. It was made without the catalytic converter fitted in order to observe the actual products of the emission without it being treated by the post-treatment device. Theoretically, if the emission constituents are condition it will lower their concentration to a much more acceptable level.

The results of Figure 12 and 13 indicate that NO_x concentration for ethylene combustion is higher than gasoline. This is to be expected as the engine on the experimental vehicle was set to operate in the lean mixture region. The vast improvements are those depicted by CO and CO_2 where drastic improvement is shown with the use of ethylene as shown in Figures 14 and 15 respectively.

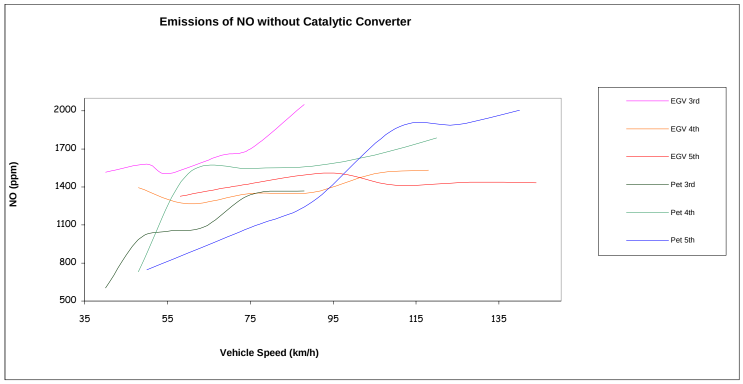

Figure 12: NO emission concentration profile against vehicle speed

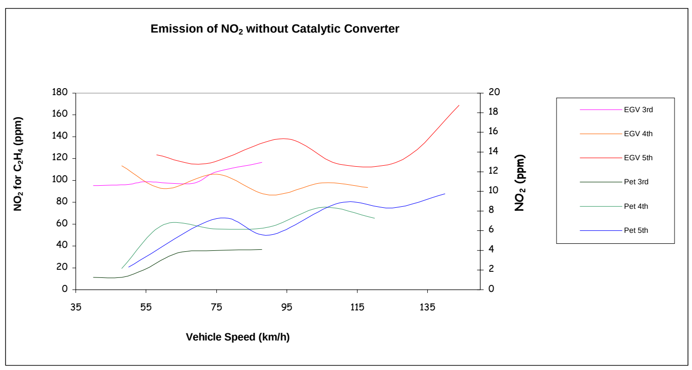

Figure 13: NO_2 emission concentration profile against vehicle speed

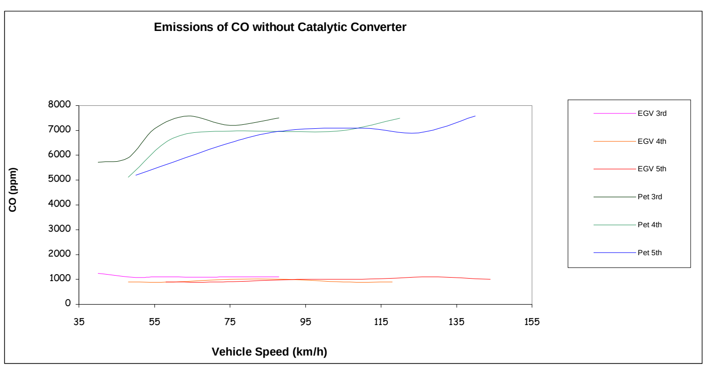

Figure 14: CO emission concentration profile against vehicle speed

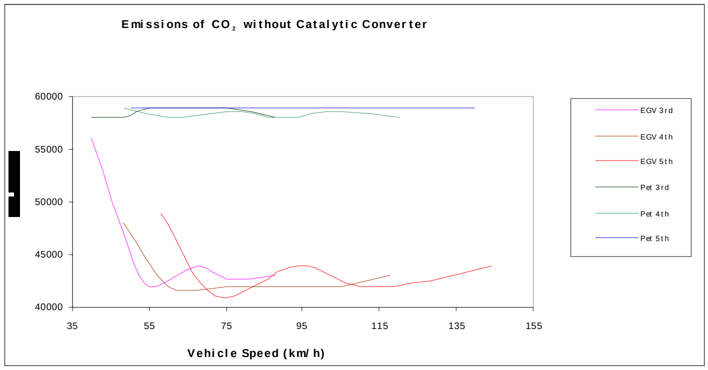

Figure 15: CO2 emission concentration profile against vehicle speed

8.0 CONCLUSIONS

From a series of laboratory work, conversion kit development work and on-road trials performed on the vehicle, the following conclusions are hereby derived:

- Ethylene is a technically viable fuel for SI engine.
- A conversion kit for *Proton Waja* 1.6 where ethylene can be filled and used has been successfully produced and test.
- Ethylene is noted to be comparable, if not better, to gasoline in terms of performance and emission
- Its strong point is its fuel economy
- In certain occasion the start of the car can be made without the assistance of gasoline.
- Less engine vibration which indicates that combustion is smooth and free of sporadic engine knock

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