

Development of Exhaust and Evaporative Emissions Systems for Toyota THS II Plug-in Hybrid Electric Vehicle

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Naoya Takagi, Takashi Watanabe, Shunsuke Fushiki, Makoto Yamazaki, Shuichi Asou and Yuusaku Nishimura
Toyota Motor Corporation

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ABSTRACT

Exhaust and evaporative emissions systems have been developed to match the characteristics and usage of the Toyota THS II plug-in hybrid electric vehicle (PHEV). Based on the commercially available Prius, the Toyota PHEV features an additional external charging function, which allows it to be driven as an electric vehicle (EV) in urban areas, and as an hybrid electric vehicle (HEV) in high-speed/high-load and long-distance driving situations.

To reduce exhaust emissions, the conventional catalyst warm up control has been enhanced to achieve emissions performance that satisfies California's Super Ultra Low Emissions Vehicle (SULEV) standards in every state of battery charge. In addition, a heat insulating fuel vapor containment system (FVS) has been developed using a plastic fuel tank based on the assumption that such a system can reduce the diffusion of vapor inside the fuel tank and the release of fuel vapor in to the atmosphere to the maximum possible extent.

As a result, these measures have enabled the mass-production of the world's first PHEV that satisfies California's SULEV and zero evaporative emissions standards.

INTRODUCTION

As a measure to counter concerns over the depletion of fuel oil resources and rising CO₂ levels that are blamed for global warming, Toyota has developed a PHEV based on the 3rd generation Prius, which is capable of being charged from household electrical outlets.

OUTLINE AND CHARACTERISTICS OF TOYOTA PHEV

Figure 1 shows the Toyota PHEV. It can be charged from household electrical outlets, and features greater battery capacity and power.

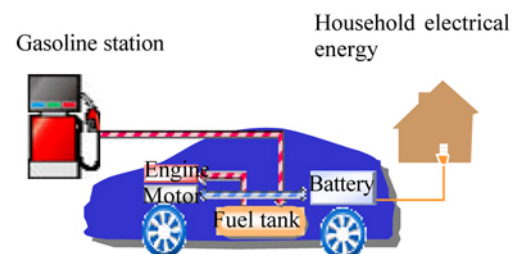


Fig.1. Toyota Plug-in Hybrid Electric Vehicle

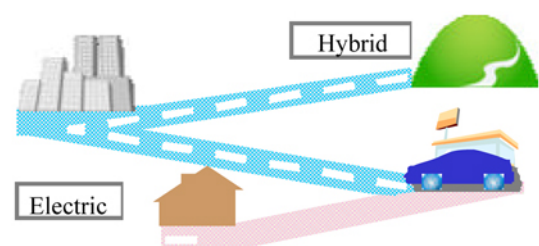


Fig.2. Example Usage Scenarios of Toyota PHEV

Figure 2 shows example usage scenarios of the Toyota PHEV. It can be driven as an EV in daily driving and as an HEV at high speeds and over long distances. As a result, it

contributes to energy diversification, and substantially reduces CO₂ emissions.

Figure 3 shows the state of charge (SOC) and driving modes. The driving mode is switched according to the SOC, and the vehicle can be driven as an EV in charge depleting (CD) mode until the SOC reaches a predetermined value. The available battery power is around 40 kW and the engine is started up once the required power exceeds this level. When the SOC falls below a predetermined value, the vehicle can be driven as an HEV in charge sustaining (CS) mode.

Figure 4 shows the specifications of the engine and battery.

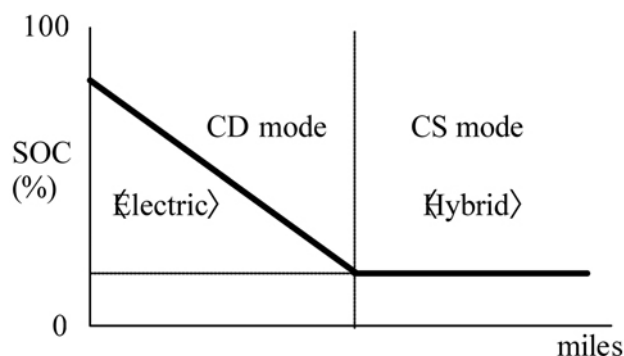


Fig.3. SOC and Driving Modes (image)

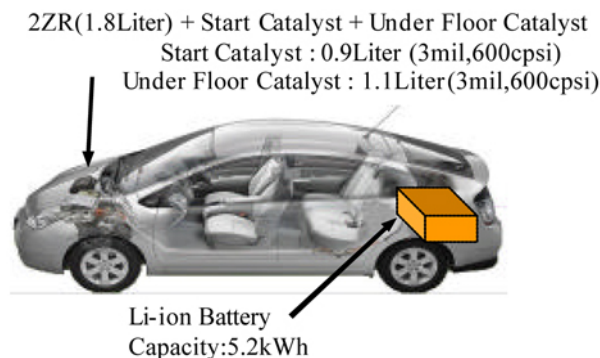


Fig.4. Specifications of the Engine and Battery

AIM OF DEVELOPMENT

The aim was to develop an appropriate exhaust and evaporative emissions systems for the characteristics of the Toyota PHEV, in order to mass -produce the world's first PHEV that satisfies California's SULEV and zero evaporative emissions standards.

DEVELOPMENT OF EVAPORATIVE EMISSIONS SYSTEM

1. ISSUE AND REQUIREMENTS

Its longer EV driving range means that the engine in a PHEV operates less frequently, thereby reducing the opportunity for purging fuel vapor trapped in the canister. The evaporative emissions system must satisfy evaporative emissions standards, have no adverse effects on the engine, and add minimum weight.

2. CURRENT STATUS

By increasing the battery power, the vehicle can be driven as an EV in most town areas. Since the engine is not started up, the evaporative emissions system must prevent the release of fuel vapor to the atmosphere even when there is no opportunity to perform purging.

3. RESULTS OF STUDY

Table 1 compares three evaporative emissions systems based on the performance required by a PHEV: a system that combines a normal fuel tank with a highly efficient canister, a bladder tank (vapor reducing fuel tank) system, and a Fuel Vapor-containment System (FVS).

A FVS was considered to be the most appropriate system for a PHEV because the evaporative emissions system must be feasible, even without the opportunity to perform purging when the vehicle is driven as an EV, as well as, from the standpoint of meeting zero evaporative emissions standards.

However, conventional FVS use a steel tank, which is detrimental in terms of weight, and ease of installation. As shown in Table 2, changing the tank material to plastic would resolve virtually all of these issues, but would reduce pressure resistance performance. This made it important to control changes in tank pressure.

Figure 5 shows the result of a diurnal breathing loss (DBL) test using a steel FVS. A DBL test evaluates evaporative emissions based on changes in ambient temperature during the course of a day. The tank pressure increases according as the fuel temperature increases. Therefore, the feasibility of insulating the tank to reduce the temperature of the fuel and minimize changes in internal pressure was studied.

Table 1. Comparison of EVAP Systems

System	Characteristics	Effects on the engine	EVAP
		Low purge opportunity	Zero
Normal fuel tank with a highly efficient canister	Purge efficiently with a heat storage canister	+	+
Bladder tank	Vapor reducing fuel tank	++	++
FVStank	Fuel vapor generation suppression	+++	+++

Good +++ ← → + Bad

Table 2. Issues of FVS

System	Material	Resist pressure	Weight	Installation	Change scale
FVS tank	Steel	+++	+	+	+
	Plastic	+	+++	+++	++

Good +++ ← → + Bad

Figure 6 shows the structure of the FVS with the plastic tank and heat insulation. It is basically the same as a steel FVS, but uses a plastic tank instead of steel, and has heat insulation covering the outside.

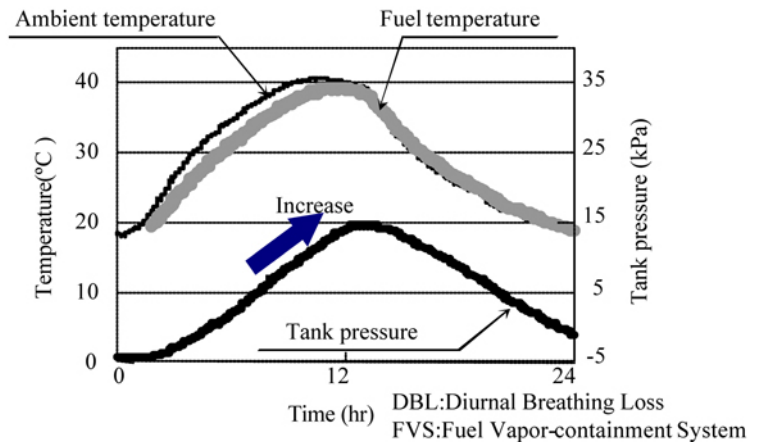


Fig. 5. Results of a DBL Test Using a Steel FVS

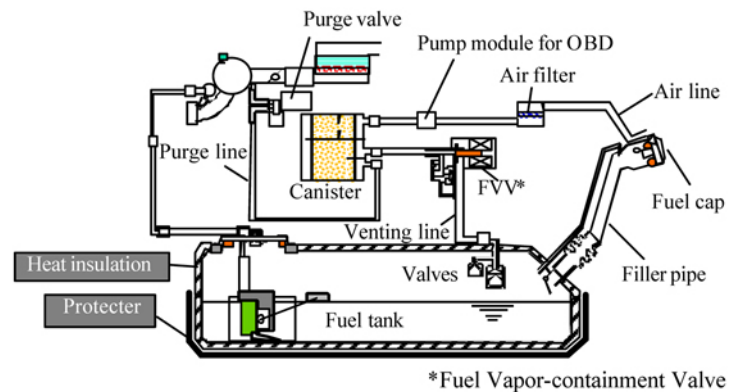


Fig. 6. FVS with the Plastic Tank and Heat Insulation

First, the fuel temperature for reaching the upper pressure target of a plastic tank was calculated. Figure 7 shows fuel tank temperature in relation to fuel tank pressure. The maximum fuel temperature was determined to be 36°C based on the plastic tank's pressure upper target of 15 kPa.

Subsequently, the insulation material for achieving a maximum fuel temperature of 36°C was studied. Figure 8 shows the conditions for calculating the heat insulation performance when the ambient temperature is increased from 18.3°C to 40.6°C over 12 hour period. Figure 9 indicates two types of different insulation materials and their thicknesses with relation to fuel temperature.