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Diagnostic Evaluation of Exhaust Gas Recirculation (EGR) System on Gasoline Electric Hybrid Vehicle

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Abstract

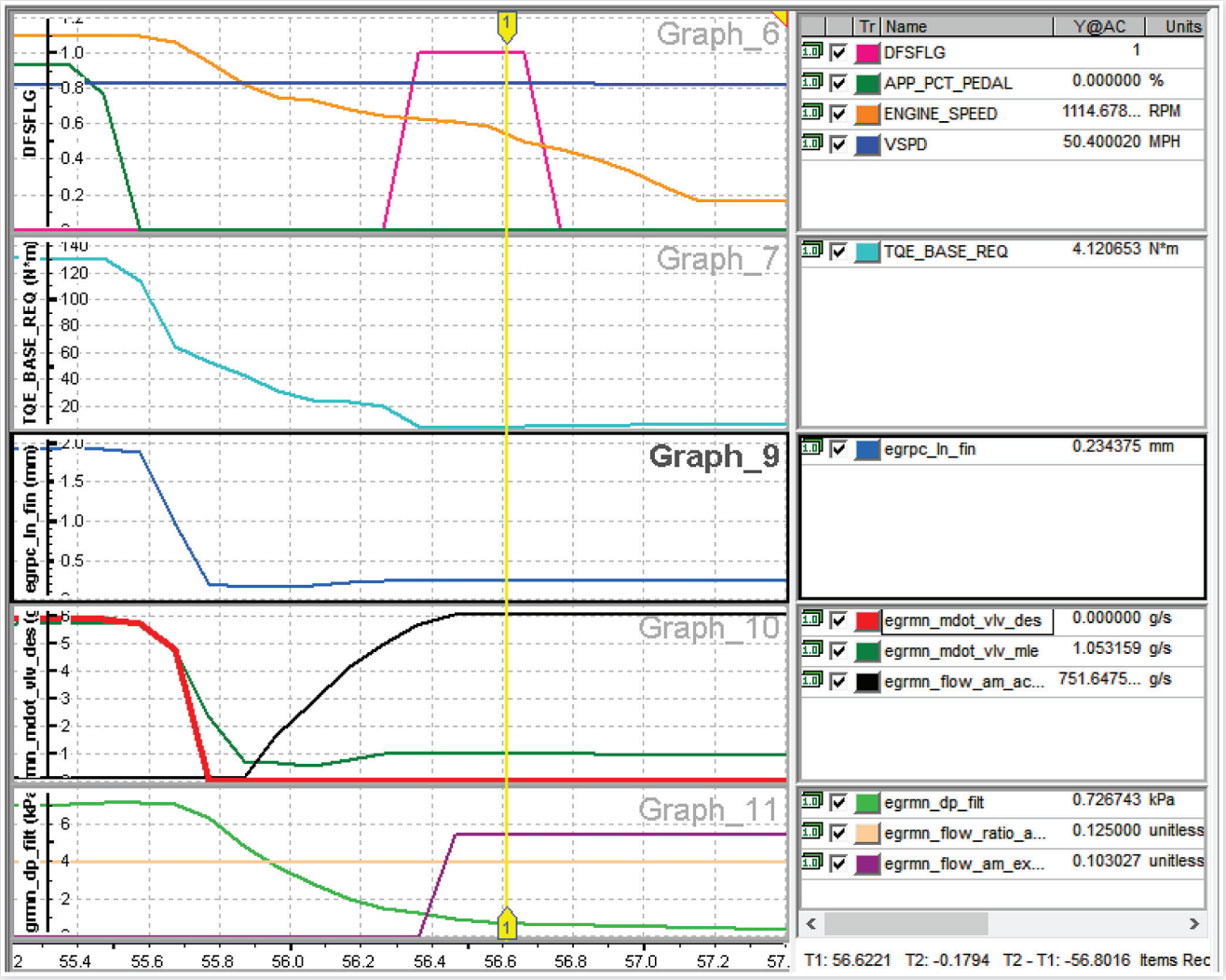
Diagnosing the Exhaust Gas Recirculation (EGR) Valve remains one of the most challenging problems in emissions control systems diagnostics. California Air Resources Board (CARB) has started imposing specific requirements on automotive companies since 2011 that required the integration of on-board diagnostics (OBD) monitor for the detection and reporting of this type of control malfunction. In this paper, some methodologies of EGR valve system monitoring are investigated and a novel approach is proposed that shows reliable detection capability compared to the other methods. The proposed method requires certain conditions during deceleration fuel shutoff events to intrusively reactivate the EGR system and determine the obstructed valve condition. The method was evaluated on a 2.5L iVCT engine in an experimental Ford Escape Full Hybrid Electric vehicle. Vehicle results are shown and discussed.

Introduction

Engine systems utilize recirculation of exhaust gas from an engine exhaust system to an engine intake system, a process referred to as exhaust gas recirculation (EGR), to reduce regulated emissions and gain fuel economy. An EGR valve would be controlled to achieve a desired intake air dilution for the given engine operating conditions. Traditionally, the amount of low pressure EGR (LP-EGR) and/or high pressure EGR (HP-EGR) routed through the EGR system is measured and adjusted based on engine speed, engine temperature, and load during engine operation to maintain desirable combustion stability of the engine while providing emissions and fuel economy benefits. EGR effectively cools combustion chamber temperatures thereby reducing NOx formation. In hybrid vehicles, EGR is continually scheduled when the vehicle is propelled using engine torque (engine is on) to increase fuel economy and engine efficiency. A diagnostic procedure is need to be periodically or opportunistically carried out to monitor operation of the EGR system when the valve is requested to be closed. Based on CARB regulations, the OBD II system shall detect a malfunction when either the EGR system has reached its control limits such that it cannot reduce EGR flow to achieve the commanded flow rate or, for non-feedback controlled EGR systems, the EGR system has maximum detectable EGR flow when little or no EGR flow is expected. One of the methods for detecting restrictions in the EGR system during steady-state engine operations relies on air pressure in the intake manifold , Air pressure in the engine intake manifold is monitored over a test period while an amount (determined based on engine operating conditions) of EGR is delivered to the intake manifold. Changes in the monitored air pressure are filtered through a lag filter process comprising a dynamic filter coefficient. The filtered air pressure is then compared to a dynamic threshold to determine presence of a restriction or leak in the EGR system. Many issues, however, are associated with this method wherein the system may not be able to detect undesired EGR flow occurring when EGR is not requested (e.g. valve is shut). In hybrid vehicles, during engine operation, EGR flow is commanded off during idle and boosted conditions only - however the idle time is severely limited. Some Ford hybrid vehicles are naturally aspirated (no boost) and the engine is commanded to shut-down at low torque demand conditions (idle/decelerations). There is limited to no opportunity to detect excessive flow faults when the EGR valve is expected to be closed. CARB Regulation states that the EGR valve is required to be monitored in "all conditions" including when the valve is commanded closed. The performance and robustness of this type of detection is problematic on hybrid vehicle due to limited engine operation time and the period of engine operation may not be sufficient to gather a complete set of data indicative of degradation of the EGR valve.

A new method is proposed to detect stuck EGR valve by estimating a ratio of accumulated difference between a measured EGR flow and an EGR limit to accumulated intake air flow, over a duration of time, and indicating EGR system degradation in response to the ratio being higher than a threshold. The magnitude of the ratio was used to indicate whether the obstructed EGR valve condition is present or not. A non intrusive diagnostics method is proposed that interfaces with an engine shut-down request, prior to engine spin-down, rotating the engine at an idling speed via an electric motor

FIGURE 7 Fault Detected once total airmass reached



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Nomenclature

The following symbols are used in this paper:

DFSFLG - Decel fuel shutoff requested State (unitless)

APP_PCT_PEDAL - Percent of total pedal travel (%)

ENGINE_SPEED - Engine Speed (rpm)

VSPD - Vehicle Speed (mph)

TQE_BASE_REQ - Requested base engine torque (Nm)

EGRPC_LN_FN - Linear EGR valve position (mm)

EGRMN_MDOT_VLV_DES - Desired EGR valve flow rate (g/sec)

EGRMN_MDOT_VLV_MLE - Maximum Likelihood estimate of EGR flow rate (g/sec)