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Assessment of Exhaust Actuator Control at Low Ambient Temperature Conditions

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Abstract

Exhaust sensors and actuators used in automotive applications are subjected to wide variety of operating ambient conditions , the performance of these actuators is challenging especially at cold ambient operating conditions, active exhaust tuning valves with position sensors are used to adjust the sound levels, or noise, vibration and harshness (NVH) from a control unit within the vehicle that leads to an improved driving experience wherein the driver selects their preferred sound levels. However, the operating behavior is crucially influenced by the characteristics of the drive cycle and ambient temperature. The study in this paper is intended to evaluate the icing formation at the start of drive cycle and at different ambient temperature conditions. The test data were obtained through real road and chassis dyno testing at different ambient conditions. The results of the testing indicated that a drive cycle with low engine speed and engine load, like a typical city road and cold ambient temperatures, had a low probability of successful operation of active exhaust valves. However, information reported from the actuator could be used along with other engine parameters to evaluate the performance of the system. In this study, an example of how the water collected in the exhaust system on gasoline only powertrain impacts the performance of the exhaust tuning valve is discussed. Root cause analysis is provided, noise factors of valve freezing is also evaluated, control software strategy is presented with vehicle validation results.

Introduction

In high-powered internal combustion engines, variable exhaust pipe tuning systems are desired to control the noise output levels of motor vehicles equipped. Additionally, a vehicle operator's ability to adjust the sound levels, noise, vibration and harshness (NVH) from a control unit within the vehicle, would lead to an improved driving experience wherein the driver selects their preferred sound levels. variable exhaust tuning system comprises of a resonator and one or more mufflers fluidically connected to the resonator. A muffler includes one or more adjustable exhaust valves and the angle of the valve can be adjusted automatically with a motor responsive to settings by the vehicle operator. In the exhaust valve operation, opening of the adjustable exhaust valve will decrease back pressure in the muffler and resonator and increase the noise level, while further closing the valve will increase back pressure in the muffler and resonator and also decrease the noise level.

An issue that arises with the above-mentioned variable exhaust tuning systems is that one or more adjustable exhaust valves could become stuck open or closed or in a fixed position, causing performance issues related to engine performance or NVH. If one or more adjustable exhaust valves becomes stuck, driving experience is significantly impacted, and the variable exhaust tuning system would incur degradation due to undesirable buildup of exhaust gases and backpressure effects.

Freezing/icing is a known issue during cold ambient conditions . Problem caused by freezing of water from the exhaust impacts the performance of exhaust tuning valves. Therefore, a fundamental understanding of the active exhaust controls and the actuator that controls the duty cycle for the valves is important to assist active exhaust development. There are several software control attempts made to address issues related to variable exhaust tuning systems by Sheidler et al. [1] in U.S. Patent 6,662,554 B2. Therein, the sheidler et al. [1] patent provides teachings related to a damper for an exhaust system providing volume attenuation. Sheidler et al. [1] provides systems and methods to electronically or manually adjust the volume attenuation of exhaust gases from a combustion engine. Many issues, however, are associated with this method wherein the system would not be able to detect failed exhaust tuning valve systems due to condensation and ice when ambient air temperatures are below freezing.

The study here provides improved diagnostic and troubleshooting control methods for exhaust tuning valves with improved valve self-healing thereby preventing false errors from being latched, eliminating unnecessary effort from vehicle owners of driving error-latched vehicle to a service station and reduce unnecessary vehicle technician's effort for resetting and clearing faults latched. The introduction above is provided to introduce in simplified form a selection of concepts that are further described in the detailed description. . At cold temperatures , vehicles resulting in condensation in the exhaust tailpipes freezes and impedes the operation of the dual mode exhaust valves during warm-up. The study started of understanding the noise factor attributing the stuck fault

The next case covers the real blockage or stuck valve of the exhaust tuning valve due to broken linkage in the flap and ECU software fault actions at an ambient temperature of 30 degF.Graph 1 in Figure 19 shows the ambient temperature with vehicle data recorded at 30degF at the start of the test and the vehicle started and engine running at idle conditions with broken valve before the start of the test .The actuator stuck fault status of 16 is reported in graph 2 of Figure 19, it was observed that actuator reported a blockage status from the beginning of the test and continued to heal itself with the self-healing algorithm with repeated retries .As the exhaust temperature continues to rise during the warm engine operation at Idle , the actuator has no effect and continues to report a stuck status of 16 due to the presence of broken flap , actuator finishes running the self-healing routine at a test cycle duration of 633sec and the valve did not go back to its normal functioning mode as shown in graph 2 (evc11_status) Figure 19 , graph 4 signal extun_tm_cmd_vlv Figure 19 keeps track of the time from the engine start up time during a faulted state continues to increment until 500sec of check and decides to set a fault code , graph 5 Figure 19, DTC array dtc_p26fe_3 shows the fault code set when the actuator completes stuck status period and sets the P26fe DTC code at 633sec of the test cycle.

Summary/Conclusions

A diagnostic method was described in this paper for the detection of the stuck EXTUN valve caused due to icing conditions at low ambient temperatures. Experiments duplicating the error states were conducted, the results of these experiments were used to design new software algorithm that robustly diagnosed a stuck valve. The application of the proposed method is limited to cases where EXTUN valves are stuck due to icing at cold temperatures. The proposed method needs to be studied further on higher size engines operating at elevated back pressure and at higher thermal events with the use of exhaust tuning valve operation. The impact of tailpipe noise with a stuck valve and NVH design with EXTUN valves will be discussed in future works .EXTUN valve when coupled with other exhaust components such as gasoline particulate filter can create significant backpressure effects and can directly impact the regeneration of the soot , The findings of the filter soot loading with EXTUN valve is currently ongoing and the results would be discussed in future research publications.

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Definitions/Abbreviations

NVH - Noise, vibration and harshness
EXTUN - Active exhaust tuning
TWC - Three-way catalyst
UEGO - Universal exhaust Gas O2 emission Sensor
CMS - Catalyst Monitor Sensor
PWM - Pulse width modulated
MCT - Manifold Charge Temperature
MAP - Manifold Pressure
ECT - Engine Coolant Temperature
EGR - Exhaust Gas Recirculation
FMEM - Failure Mode Effect Management
FMEA - Failure Modes and Effects Analysis
ECU - Engine Control Unit