On-Board Diagnosis of Vehicles Cooling System

M. Nemati
Elec. Eng. Dept.
Shahed University
Tehran, IRAN
Email: mohsen.nematee@yahoo.com

S. Seyedtabaii
Elec. Eng. Dept.
Shahed University
Tehran, IRAN
Email: stabaii@shahed.ac.ir

***Abstract*— On time recognition of vehicle cooling system faults prevents excessive air pollution and un-compensable engine damages. Lack of water, pump defect, thermostat malfunction, fan system failure and radiator clogging are among the most common types of faults; some of them are so critical that must be fixed immediately. In this paper, a diagnostic algorithm based on isolating of the cooling system fault from engine functioning is introduced, where the measurable engine body temperature stands for the most of the combustion parameters and their uncertainties. The fault isolation is also partially accomplished by introducing three distinctive temperature zones. An engine thermal simulator, which mimics a real engine, generates both nominal and faulty system states considering complete engine and cooling system tolerances. Extensive simulations are conducted for determination of the fault thresholds and certification of the validity of the algorithm.**

Keywords— fault diagnosis; engine cooling system; thermostat defect; radiator clogging

I. INTRODUCTION

Modern vehicle on-board diagnostics (OBD) system is designed to give a fault early warning and guide the technicians toward the exact source of difficulty to save the service time. Earlier versions of OBD's which all of the vehicles are equipped with simply illuminate a malfunction indicator without identifying the source of abnormality. Disclosing the source of faults needs new setups which are nowadays under research and development.

Motor vehicle cooling system is an assembly to ensure that the engine is maintained at its most efficient practical operating temperature. Cooling system malfunction results in increase in air pollution which is prohibited all around the world by law. One of such regulation requires a specific warm up period; otherwise the driving is prohibited [1]. When a thermostat is stuck open, there is an undesired coolant flow through the radiator which prolongs warm up time and have a negative impact on the vehicle exhaust gas emissions. Therefore, the US Environmental Protection Agency (EPA) requires that a failing thermostat to be detected by the vehicles on board diagnostics system (OBDII) [2].

Several inventions and papers have discussed the problem of faulty cooling system. Detection of faulty thermostat is the subject of [3, 4, 5, 6]. By monitoring an engine side coolant temperature and comparing it with normal situation it would be possible to identify faulty stuck open or stuck closed thermostat as the temperature profiles differ substantially [3]. Alternatively, the malfunction may be detected from a difference between the engine side and the radiator side coolant temperatures [5]. The normal working merits are derived experimentally based on the function of a healthy thermostat. In [6], a model based prediction of cooling water temperature is employed where the last predicted temperature is added by the temperature rising during a predetermined short period. The rate is calculated based on engine working condition including: the engine load (intake air volume), the vehicle speed and the intake air temperature.

Thermostat Fault Diagnosis and Isolation (FDI) using neural network has been studied in [7]. Inputs, including vehicle speed, engine speed are used for fault diagnosis. Extending engine cooling system fault from just a faulty thermostat to other components is investigated in [8] where sliding observer is used for state estimation. The vehicle is assumed to be in stand still. Similar investigation using fuzzy model has been reported in [9].

In this study, lack of water (in the engine passages) and stuck open thermostat are detected and the actual pump, thermostat, radiator and fan system thermal parameters are determined while engine is in its idle running condition. Engine and cooling system parameters are assumed uncertain within %2 of their nominals. Cooling system behavior is isolated from engine functioning, thus the number of uncertain parameters in the FDI model are reduced substantially. A MATLAB simulator has been developed which generates both nominal and faulty system states.

Section II briefly reviews the idea of FDI. In section III, vehicle cooling system components are described. Section IV elaborates the proposed method and the simulation outcomes are discussed in section V. Lastly, section VI concludes the findings.

II. FAULT DIAGNOSIS METHODS

Fault in a system may be in the form 1) Gross error: deviation of process parameters beyond their specified tolerance 2) Structural error: working failure of a process component and 3) Sensor and/or actuator error: control component malfunction [10].

A fault diagnosis and isolation method (FDI) is expected to be 1) Quick 2) Fault isolable 3) Robust (against noise and uncertainties) 4) Novelty identifiable (isolating known and

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Conference Chair
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M. Eshghi

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