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Study on gasoline engine diagnosis based on exhaust gas composition

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ABSTRACT:
The internal combustion engines (ICEs) emit substances such as CO, CO_2, NO_x, HC, Pb, CFC and sulfur compounds during the operation of engines. These compounds are all harmful to the environment which is one of the culprits that cause a number of diseases in humans. However, the engine exhaust gas composition is the basis for the analysis and evaluation of the engine's quality. The proposal of this paper is to use is to diagnose gasoline engine through exhaust gas measurement components. An exhaust gas measuring system is set up for measurement and analysis. Two gasoline engines of vehicles are selected to measure and compare quality based on measured exhaust components. The evaluation results have shown that the exhaust gas components of the gasoline engine clearly reflect the quality of the engine systems such as the fuel injection system, the ignition system, the idle valve control system, etc.
KEYWORDS: *Gasoline engine, Diagnosis, Exhaust gas component, Engine quality.*

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I. INTRODUCTION

The problem of environmental pollution from vehicles is an important issue to be solved in order to create environmentally friendly vehicles. The experiment was devoted to the analysis of gas composition of engines working at different modes in order to specify the particularity of LPG system tuning and to obtain data for the evaluation of environmental pollution by numerical car dynamics models. A nominated for experiments with an internal combustion engine working in different modes, searching to specify the particularity of LPG system coordination was suggested tto evaluate the environmental pollution, using the dynamics models of cars driving under different conditions, and performed to work with a classical fuel – gasoline or diesel [1]. A linear algebra approach was taken, and this lends itself to a structured examination of what information might be obtained from the discarded relationships when the problem is over-constrained, and in particular, information about the consistency of the date. The methods to examine storage and release mechanisms within after-treatment devices, such as oxygen storage/release in three-way catalysts, soot oxidation in particle filters and water condensation/evaporation were developed [2]. The problem of diagnostic informativeness of exhaust gas temperature measurements in turbocharged marine internal combustion engines was propose to extend the parametric methods of diagnosing workspaces in turbocharged marine engines by analysing time-histories of enthalpy changes of the exhaust gas flowing to the turbocompressor turbine [3]. The technology of marine engine diagnostics making use of dynamic measurements of the exhaust gas temperature was propose to measure exhaust gas temperature dynamics for qualitative and quantitative assessment of the enthalpy flux of successive pressure pulses of the exhaust gas supplying the marine engine turbocompressor [4]. The diagnostic merits of high-speed (HS) exhaust gas temperature and pressure measurements for indexing engine stability and identifying abnormal combustion cycles were proposed through experimental investigations on a low speed, single-cylinder engine. The thermodynamic simulation of the engine and the HS thermocouple was used to provide theoretical support for the discussion by comparing measured and simulated “actual” exhaust temperature and identifying the flow, heat transfer, and thermodynamic influences that act as limits to the thermocouple's dynamic performance [5]. The model-based methods of fault detection and diagnosis for the main components of gasoline and diesel engines, such as the intake system, fuel supply, fuel injection, combustion process, turbocharger, exhaust system and exhaust gas aftertreatment were proposed to discuss the advanced supervision, fault detection and diagnosis methods [6]. The results of fuel component tests and content of solid particles in exhaust gases of combustion engines powered with mixtures of diesel oil and fatty acid methyl esters were propose to provide reductions in greenhouse gas emissions and an increase in the share of renewable energy resources in the total energy consumption [7]. The exhaust emissions from farm vehicles based on research performed under field conditions (RDE) according to the NTE procedure were analyze. The modification of the measurement and exhaust emissions calculation methodology has been proposed for farm vehicles of the NRMM group [8]. The objective of this paper is to diagnose gasoline engine through exhaust gas measurement components. A gas measuring system is set up for measurement and analysis. Finally, the exhaust gas components are analyzed and evaluated for the quality indicators of the gasoline engine.

II. THEORETICAL BASIS OF EXHAUST GAS COMPOSITION DIAGNOSIS

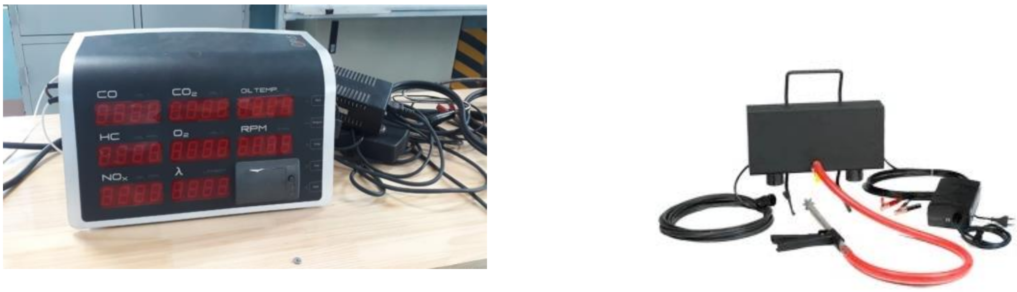
Exhaust gas composition reflects the state of the engine in terms of preparation and combustion of the mixture, it depends on factors such as: Mix ratio and the degree mixing of the fuel with the air. The fuel system and intake, exhaust gas, engine temperature, ignition system operating status, quality of compression process (in Diesel engines), fuel quality, etc. determine the operating engine state. Exhaust gas composition is also an output parameter that reflects the general condition of the engine assembly, it does not indicate damage, but it allows to evaluate the quality of combustion, engine power. Some expressions of the state of the engine based on the exhaust gas composition are expressed as (i) if the exhaust gas has a high amount of oxygen and unburnt fuel, there is a possibility of evaporation, poor mixing of the mixture or due to the engine not working; (2) when accelerating suddenly, we do not see the amount of CO and unburnt fuel (gasoline) increase, it can be concluded that the acceleration system works poorly or does not work; (3) if the CO composition does not change significantly, it can be said that the program body engine control system is good; (4) the CO component in the idle state of the engine increases, the engine idling control system is not good; (5) when the HC component increases, the ignition system, fuel injection system, gas distribution mechanism, etc. have problems.

One of the most effective ways to resolve emissions issues is by sampling the exhaust gases [9]: (1) High HC emissions indicate unburned fuel; (2) High CO levels indicate partially burnt fuel or oil; (3) High NOx levels are normally caused by high combustion temperatures and pressures, slightly lean AFR, and excessively advanced ignition timing; (4) Tailpipe emissions readings low in HC and CO levels with high NOx emissions are typically NOT caused by a defective converter. The low HC and CO readings indicate that the converter is functioning. The root cause of the problem is an engine which is emitting excessively high NOx emissions. These high NOx emissions may reduce the durability and efficiency of the converter.

III. EXPERIMENT SETUP

The measuring equipment of ICE exhaust gas composition opus 400

The measuring equipment of ICE exhaust gas composition opus 400 are shown in Figure 1. It could be measured the exhaust gas components of the internal combustion engine using gasoline, diesel, LPG, CNG, etc.: CO, HC, CO_2, O_2, NO_x, AFR.



(a) Collection of measurement data (b) Measurement of smoke opacity of diesel engines - OPUS100

Figure 1. Measuring equipment of ICE exhaust gas composition opus 400

The measuring equipment opus 400 consists of measuring sensors such as an engine oil temperature sensor, an engine speed sensor including battery clamp revolution (RPM), exhaust gas component measurement sensor; a processor and a collection of measurement data; measurement of smoke opacity of diesel engines - OPUS100. Technical data opus 400 is shown in Table 1.

Table 1. Technical data opus 400 [10]

	Range	Accuracy +/-abs (+/-rel.)	Resolution
CO	0 - 10 vol. %	0.02 % (3 %)	0.01
10.01% -15%	5%		
HC	0 - 2000 ppm	4 ppm (3%)	1
2001-5000 ppm	(5%)		
5001-15000 ppm	(10%)		

CO_2	0 - 16 vol. %	0.3 (3%)	0.01
16.01%-20%	(5%)		
O_2	0 - 25 vol. %	0.02% (1%)	0.01
Lambda	0,6 - 1,7	0.001	
AFR	0-35	0.01	
NOx	0 - 5000 vol. ppm	1	
Rpm	0 - 9999 r/m	1	
(2/4 stroke)			
Oil temperature	0 - 160oC	1	
Warm-up time	Full accuracy in 2 minutes.		
Response time	< 5 sec. to 95 % of measured value		
Pump capacity	5-7 l/min, minimum		
Max exhaust gas temp	400o C		
Hose and Probe	7 m gas sampling hose with stainless steel probe		
Optical bench	Non-dispersive infrared (NDIR)		
Solid state detector			
Printer	Thermal Printer		
Accessories	Bluetooth		
RPM by Battery voltage measurement, Piezo electric, OBD			
IR temperature			
Sensor for oil dip-stick or IR			
Power supply	100-240 VAC. 50-60 Hz., 10-30 VDC		
Size (WxHxD)	400x240x260		
Operating conditions	Relative air humidity: up to 90 % Atmosph. ambient pressure: 750 mbar – 1100 mbar Power variation: 230 VAC -15% to +10% 50 Hz +/- 2%		

Installation of measuring equipment

Installing equipment and taking measurements including Step 1: Install sensors including lubricating oil temperature sensor, engine speed sensor, standardize and install a sensor to measure the engine's exhaust gas composition; Step 2: Carry out measurements at different ICE loads; and Step 3: conduct measurement and analysis. Equipment installation of engine exhaust components is shown in Figure 2.

IV. RESULTS AND DISCUSSION

Measuring conditions, the engine operates in different engine load modes such as idle engine mode; medium load mode; full load mode. The measurement results were conducted on two types of vehicles such as Toyota Fortuner SUV (Sport Utility Vehicle) vehicle produced in 2018 and Ford Laser Sedan Vehicle produced in 2001, as shown in Table 2.

Figure 2. Equipment installation

Table 2. Measurement results of two types of vehicles

n_e (rpm)	CO %Vol	CO_2 %Vol	HC ppm	O_2	λ
Toyota Fortuner SUV (Sport Utility Vehicle) vehicle produced in 2018					
800	0.43	13.2	195	0.54	0.965
2200	0.03	14.23	185	1.21	1.002
3500	0.06	14.62	182	1.23	1.094
Ford Laser Sedan Vehicle produced in 2001					
760	1.81	12.95	388	0.57	0.954
2200	0.27	13.4	192	1.29	1.094
3500	0.63	13.65	121	0.73	1.011

From the results of Table 1, we see that the engine speed range with Toyota Fortuner changes from n_e=2200 rpm to n_e=2500 rpm, the CO amount and other components changes very little which can be said that the programmed engine control system or engine control system using ECU (Electronic Control Unit) is good, other system of the engine such as the ignition systems and the fuel injection system are good. The engine has not yet reached the period of maintenance and repair of these systems. However, the engine speed range with Ford Laser changes from n_e=2200 rpm to n_e=2500 rpm, the CO amount and other components changed relatively large, especially, especially the CO amount is relatively high at idling speed that leads to the engine control system according to the program in this mode is not optimal, the ignition system and fuel injection system have reached the period of maintenance and repair of these systems. For the 2001 Ford Laser, the HC amount is 388ppm which is relatively large, and the fuel mixture for the unburnt engine is still very large. The engine idle control system does not work efficiently.

V. CONCLUSION

In this study, a gas measuring system is set up for measuring the exhaust gas components of a gasoline engine. Two types of vehicles such as Toyota Fortuner SUV (Sport Utility Vehicle) vehicle produced in 2018 and Ford Laser Sedan Vehicle produced in 2001 are selected to measure and evaluate the engine quality of the engine based on the exhaust gas components. The CO amount and other components of Toyota Fortuner changes very little at the engine speed range of n_e=2200 rpm ÷ n_e=2500 rpm. However, the CO amount and other components of Ford Laser changed relatively large at the engine speed range of n_e=2200 rpm ÷ n_e=2500 rpm. The quality of Ford Laser engine is worse than that of Toyota Fortuner engine according to the results of measurement of exhaust gas composition.

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