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Performance enhancement and emission reduction of used motorcycles using flexible fuel technology

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ABSTRACT

In Vietnam, the primary energy consumption has increased rapidly over the past decade, and the government promotes the vehicle emission standards and the development of renewable energy to complement fossil fuel. In concert with the government policy on these problems, motorcycle manufacturing companies have applied new technologies to reduce pollution emissions and fuel consumption. However, these technologies been applied only to new vehicles before selling on the market; as a result, they cannot solve the primary inducement due to a large quantity of used motorcycles in Vietnam. This research has developed a new fuel system that enables used gasoline motorcycles to operate on 100% ethanol, a type of renewable energy, which is widely used as a proportion in spark ignition engines. The research results showed satisfactorily that the motorcycles retrofitted the new fuel system can reduce significantly emission and fuel consumption.

1. Introduction

The motorcycle is the primary transportation in Vietnam, contributing remarkably to the economic and social development of Vietnam. There are about 40 million motor vehicles; consequently, the emissions from motorcycles are the main pollution sources in this country. In order to improve the air quality, the Vietnam government has declared a policy to minimize the emissions from major sources by applying Euro II Standard for new vehicles since 2007 [1]. The emission standard will continue to tighten in 2017 when the Euro III will become effective as of 2017. The main emissions from gasoline vehicles compose of NOx, CO, CO_2, and unburned hydrocarbons (HC). The reaction mechanism leading to emissions of HC, CO, and NOx from modern vehicles has been researched and described obviously by John Heywood [2,3]. Incomplete combustion causes for the formation of HC and CO in vehicle exhaust. Meanwhile, NO formation occurs primarily as a result of the thermal dissociation of molecular oxygen to give oxygen atoms reacting with nitrogen molecules to give NO. This is known as the Zeldovich mechanism [2]. The development of emission standards and emission control technologies for gasoline engines have led to control NOx, CO, CO_2, and HC as described in Fig. 1 [4].

Recently, renewable energy has been considered as the best method to solve not only the fossil fuel depletion crisis but also vehicle emissions. In Vietnam, there are a lot of studies on using renewable energy to replace fossil fuels [5]. Especially, ethanol has been focused as a major source to apply to the internal combustion engine (ICE) to replace conventional energy and contribute to develop agriculture in the countryside. For instance, some experimental studies on using ethanol–gasoline fuel blends on motorbike [6,7] were carried out to evaluate the effects of the ethanol ratio of the mixture on the engine performance, emissions and material comparability. The results showed that the ICE of motorcycles can operate smoothly with low ethanol content. However, to apply to high ethanol content, the fuel system must be modified in order to response the effect of stoichiometric ratio. In addition, some parts of fuel system should be changed to adapt the safety and the long life operation.

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EUROPEAN UNION

EUROPE - Euro 2 & Euro 3 emission limits for 2 and 3-wheeled vehicles and quadricycles

		Class	CO (g/km)	HC (g/km)	NOx (g/km)
Limit values for motorcycles (2-wheels) for TA and COP					
A (2003)	TA: 01Apr04	I (< 150 cc)	5,50	1,20	0,30
Euro 2	FR: 01Jul05	II (≥ 150 cc)	5,50	1,00	0,30
B (2006)	TA: 01Jan06	I (< 150 cc) UDC cold [1]	2,00	0,80	0,15
Euro 3	FR: 01Jan07	II (≥ 150 cc) UDC+EUDC cold [2]	2,00	0,30	0,15
C (2006) GTR 2 [3]	Alternative TA: 01Jul07	V max < 130 km/h	2,62	0,75	0,17
Limit values for tri- and quadricycles for TA and COP					
A (2003)	TA: 01Jan03		7,00	1,50	0,40
Euro 2	FR: 01Jul04		2,00	1,00	0,65
Proposal	TBD			1,00	0,25
			1,00	0,15	0,65

[1] Test cycle = ECE R40 (with emissions measured for all 6 modes – sampling starts at T=0)
[2] Test cycle = ECE R40 + EUDC (emissions measured for all modes – sampling starts at T=0) with a max speed of 120 km/h
[3] UN/ECE GTR2 is an alternative TA procedure for Euro 3 stage (Directive 2002/51/EC), based on harmonized WMTC test cycle

Other items: In-Use Compliance: 30.000 km (Euro 3 stage)
CO_2 and Fuel Consumption measurement required from Euro 3 stage
TA of replacement and retrofit of catalytic converter as separate technical units

Propoposal for new regulation 2wheels (L3e) 4wheels (L7e) quad

Stage	Application date	Class / Testcycle	CO	HC	NOx
Euro 4/5	01Jan16 New 01Jan17 Current	L3E > 50 cc WMTC	1,14	0,17	0,09
Euro 5/6	01Jan20 New 01Jan21 Current	L3e > 50 cc WMTC	1,00	0,10	0,06

- Anti tampering measures introduced
- Mandatory introduction of OBD Stage I
- Evaporative emissions requirements defined
- Revised test procedure for mopeds, Euro 3 in 2012 and Euro 4 in 2015
- Durability requirements
- Additional legislation for 4-wheel mini-cars, off-road quads, hydrogen-powered motorcycles, tri- and quadricycles
- Hybrid motorcycle provisions should be considered as well
- Off-road quads are excluded from this regulation

Fig. 1. Euro emission standard for motorcycle [4].

This research aims to develop a new fuel system for the used motorcycles in order to flexibly use either ethanol or gasoline for these motorcycles. Because of the difference between physical–chemical properties of ethanol and gasoline, including density, kinematic viscosity, calorific value and latent heat of vaporization, it is necessary to modify the structure of the engine's fuel system in order to reserve performance and emission. Theoretical computation on rebuilding the main jet element of the carburetor was conducted. Based on theoretical computation results, the bore of main jet of the carburetor must be modified so the fuel system would be suitable for using ethanol. The performance and emission of the engine using ethanol were evaluated after the modification [4]. The study results are the foundation for applying widely ethanol as the renewable energy to replace fossil fuel in order to solve the energy crisis and develop agriculture.

2. Theoretical and experimental methods for modifying ICE – fuel system

2.1. Mechanical modifications required for using ethanol as a fuel in a gasoline engine

According to the chemical equation for the complete combustion of the fuel, the air–fuel ratios (stoichiometric ratio A/F) to achieve the complete burning of the fuel and ethanol are 14.7:1 and 9:1, respectively. This fuel property requires carburetor fuel-rate adjustments to achieve maximum engine efficiency. Consequently, the amount of air required for completed combustion of 1 kg of ethanol is less than that of gasoline. This problem results in modifying the carburetor of the fuel system in order to respond with both gasoline and ethanol. The modification is calculated based on the air and fuel flows through a carburetor as shown in Fig. 2. The theoretical speed of the fuel flowing through the main jet of a carburetor is defined in Eq. (1) [4]:

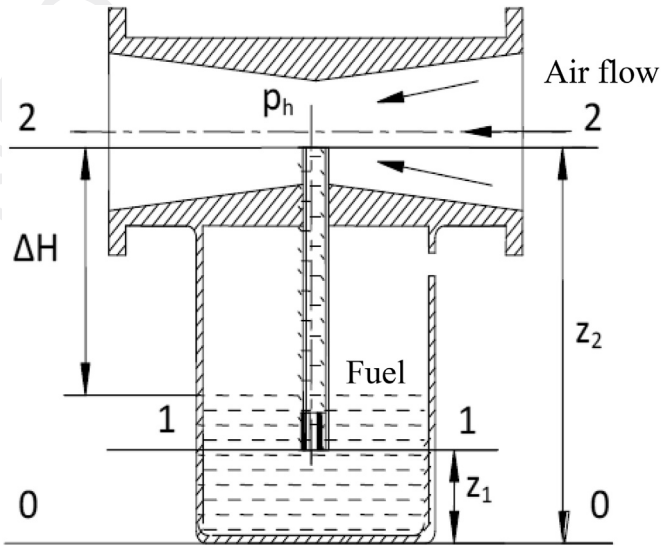

Fig. 2. Mass of fuel calculated diagram.

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