

Effect of Fuel Properties on Exhaust Emissions during Warm-Up Process

¹Rosli Abu Bakar and ²Beny Cahyono

¹Department of Mechanical Engineering,
University Malaysia Pahang, Pahang, Malaysia

²Department of Marine Engineering,
Sepuluh Nopember Institute Technology of Surabaya, Surabaya, Indonesia

Abstract: Problem statement: Increasing air pollutions the big problem form internal combustion engines. Several attempts have been done to get a cleaner combustion process, one of which is the use of fuel ethanol in gasoline engines. **Approach:** The addition of ethanol in fuel will be change fuel properties. **Results:** To know the effect of fuel properties on engine performance and emissions produced, in this study was conducted tests against some root material, which is 95 octane gasoline, ethanol/gasoline 10, 20% ethanol, ethanol 30%, when the warm-up process. **Conclusion/Recommendations:** Result from this research, addition of ethanol in the fuel produces emissions of HC and CO is higher at the start, but with increasing time engine running the addition of ethanol to reduce emissions.

Key words: Fuel properties, exhaust emission, gasoline engine, gas chromatography

INTRODUCTION

Automotive development as a means of transportation, so enable people in performing a job. Beside simplify the activity, the use of vehicles also cause a very bad impact on the environment, particularly flue gas from burning fuel that does not decompose or be burned perfectly. As known that the fuel combustion process of internal combustion engines produce exhaust gases containing CO, NO₂, HC, C, H₂, CO₂, H₂O and N₂, where many environment polluting. Elemental Carbon Monoxide (CO) which affect the health of living things deserve special study, because the elements of carbon monoxide from burning toxic to human blood during respiration, as a result of reduced oxygen in the blood tissue. Amount of CO present in the blood, the duration of inhaled and respiratory rate determines the amount carboksihemoglobin (combination of hemoglobin/carbon-monoxide) in the blood and if the amount of CO has already reached a certain amount/saturation in the body, it will cause death.

In addition to CO gas, some gas from burning a very disturbing health of NO_x, HC, CO. NO_x gases can cause shortness of breath in patients with asthma, often because difficulty sleeping cough and also cause fog. NO_x is a gas that is colorless and odorless, has no taste and quick to react with the O₂ and turn into NO₂. NO₂

Gas (nitrogen dioxide), can also damage lung tissue and if the joint H₂O will form a nitric acid (HNO₃), which in turn can cause acid rain which is very harmful to the environment. NO_x gas is formed due to high temperatures. Hydrocarbon (HC) is a less harmful gas for human life, but of a mixture of the cause of the haze of smoke (Smog). Emission of hydrocarbons contained in exhaust gas in the form of unburned petroleum. Hydrocarbons contained in the evaporation process of fuel in the tank, carburetor and gas leakage through the gap between the cylinder and the piston goes into the crank shaft which is called blow by gases.

In the combustion process is needed oxygen. The experts have identified that consists of air, Oxygen (O₂) as much as 21%, Nitrogen (N₂) 78 and 1% other gases. Theoretical perfect combustion ratio is obtained with air/fuel (Air to fuel ratio) is 14.7 and is often referred to as the stoichiometry and often referred to also as the ratio of Lambda = 1. Air to Fuel Ratio (often abbreviated AFR)> 14.7 referred to as Lean Combustion whereas otherwise known as Rich combustion.

In an ideal combustion process will produce H₂O, CO₂ and N₂, but in practical combustion in the engine is not perfect even in machines with high Technology. In the above diagram can be seen, the black line is the line where the combustion stoichiometry is more or less value will be obtained and be the emission standard.

Corresponding Author: Rosli Abu Bakar, Department of Mechanical Engineering, University Malaysia Pahang, Pahang, Malaysia

Table 1: Fuel properties

Property item	Test fuel				Method
	E 0	E10	E20	E30	
Density (kg L ⁻¹ at 15.5°C)	0.7575	0.7608	0.7645	0.7682	ASTM D 4052
Ron (octane number)	95.4000	98.1000	100.7000	102.4000	ASTM D 2699
RVP (kPa at 37.8°C)	53.7000	59.6000	58.3000	56.8000	ASTM D 5191
Sulfur (wt%) Washed	0.0061	0.0055	0.0049	0.0045	ASTM D 5453
Gum (mg/100 mL)	0.2000	0.2000	0.6000	0.2000	ASTM D 381
Unwashed gum (mg/100 mL)	18.8000	17.4000	15.0000	14.4000	
Lead content (g/L)	<0.0025	<0.0025	<0.0025	<0.0025	ASTM D 3237
Corrosivity (3 h at 50°C)	la	la	la	la	ASTM D 130
Distillation temperature (°C)					ASTM D 86
IBP	35.5000	37.8000	36.7000	39.5000	
10 vol%	54.5000	50.8000	52.8000	54.8000	
50 vol%	94.4000	71.1000	70.3000	72.4000	
90 vol%	167.3000	166.4000	163.0000	159.3000	
End point	197.0000	197.5000	198.6000	198.3000	
Heating value (cal g ⁻¹)	10176.0000	9511.0000	9316.0000	8680.0000	
Carbon (wt%)	86.6000	86.7000	87.6000	86.0000	
Hydrogen (wt%)	13.3000	13.2000	12.3000	13.9000	
Residue (vol%)	1.7000	1.5000	1.5000	1.5000	
Color	Yellow	Yellow	Yellow	Yellow	Visual

In addition to the regulated pollutants-Carbon Monoxide (CO), Hydrocarbons (HC), nitrogen oxides (NO_x) and carbon dioxide (CO₂)-emissions of benzene and methane (from the gasoline cars) and toluene (from the diesel cars) were measured online by Chemical Ionisation Mass Spectrometry (CI-MS) (Saxer *et al.*, 2003 for nonregulated emission measurements with warm engine).

Ethanol has advantages to prove its attraction. Table 1 shows the properties of ethanol and gasoline. It can be used as an additive or an alternative fuel for gasoline engines. With the addition of ethanol into gasoline, the fuel economy and thermal efficiency are improved and because of the high octane number, engines are allowed to operate under a higher compression ratio. Compared with gasoline, the lower boiling point, faster flame propagation speed, high oxygen content (50 wt%) and simple chemical structure of methanol all help to reduce the CO and Hydrocarbon (HC) emissions, Hu *et al.* (2007). But NO_x emissions do not always decrease; Liu *et al.* (2007) observed an increase by 5-10%. However, the addition of methanol may cause a slight power loss, a cold start problem in deep cold conditions and the risk of a vapor block in hot weather. Power loss can be solved by prolonging the injection pulse width or by enlarging the injector's flow flux; the cold start and vapor block problems can be settled by providing particular methanol/gasoline blend fuels for summer and winter. Other disadvantages such as toxicity, separation from gasoline, erosion on plastic and rubber and so on can be solved by strictly sealing the fuel supply system, adding additives in fuel blends and changing to antierosion parts, respectively.

Jia *et al.* (2005) influence of ethanol-gasoline blended fuel on emission characteristics from a four-stroke motorcycle engine. The results indicate that CO and HC emissions in the engine exhaust are lower with the operation of E10 as compared to the use of unleaded gasoline, whereas the effect of ethanol on NO_x emission is not significant. Furthermore, species of both unburned hydrocarbons and their ramifications were analyzed by the combination of Gas Chromatography/Mass Spectrometry (GC/MS) and Gas Chromatography/Flame Ionization Detection (GC/FID).

Al-Hasan (2007) study focuses on measurement of the engine exhaust emission and fuel consumption during engine warm-up period. In this study show that as the ambient temperature increases the concentration of both hydrocarbon and carbon monoxide and fuel consumption decreases while the carbon dioxide increases. Also, the time required for the engine to fully warm-up is shortened.

In previous studies, the Research Octane Number (RON) of the gasoline has been changed due to the addition of ethanol. The more ethanol added, the higher the RON; e.g., the RON values are 95, 98, 101, 102 and 105 for non-oxygenated unleaded gasoline, gasoline with 10, 20, 30% v/v ethanol blends and pure ethanol, respectively, Hsieh *et al.* (2002). Thus, the results previously obtained may not accurately represent the commercial gasoline in which the typical RON value ranges from 92-98. Octane number is also an impartment parameter for vehicle combustion. Al-Farayedhi (2002) showed decreases in CO and HC emissions along with but higher NO_x emission with increasing octane number of the fuel. The combustion duration becomes prolonged as octane number

increases; longer combustion duration may result in low thermal efficiency and increased fuel consumption, Shen *et al.* (2008). Moreover, gasoline with a high octane number is suitable for vehicles with a high compression ratio. The compression ratios of motorcycles (8-10:1) are less than those for gasoline cars (9-12:1). High-ethanol content gasoline (>15% v/v) may not be suitable for motorcycles due to its high octane number.

In this study, to investigate the effects of the ethanol/gasoline properties on Spark Ignition (SI) engine emission at warm-up process, especially unburned-Hydrocarbon emission, three typical methanol/gasoline blends of E0, E10, E20 and E30 were tested. An emission in the exhaust gas is measured by a portable gas analyzer Kane OIML CLAS 1 (N0356). The working principle of the tool is based absorbstivitas wave infrared radiation from the gas detection. Gas analyzer can detect CO₂, CO, HC and Air fuel ratio.

MATERIALS AND METHODS

Experiment will be done at port-injection gasoline engines four cylinders connected by eddy current dynamometer, as shown at Fig. 1. Engine data is shown in the Table 2. In this experiment done on the unload engine, or it can be called free running. From experiment will be found is an rpm engine, exhaust emissions and fuel consumption.

Table 2 Engine specification

Engine parameter	Value
Bore (mm)	81.000
Stroke (mm)	77.500
Displacement (cm ³)	1.597
Number of cylinder	4.000
Connecting rod length (mm)	118.100
Max. intake valve open (mm)	7.095
Max. exh. valve open (mm)	7.095
Intake valve open	140.000
Close	580.000
Exhaust valve open	520.000
Close	160.000



Fig. 1: Engine and dynamometer

Fuel consumption is measured using a measuring cup with a volume of 100 mL, duration of fuel use in measuring with a stop watch. An emission in the exhaust gas is measured by a portable gas analyzer Kane OIML CLAS 1 (N0356). The working principle of the tool is based absorbstivitas wave infrared radiation from the gas detection. Gas analyzer can detect CO₂, CO, HC and Air fuel ratio.

Exhaust gas emissions, engine speed and fuel consumption collect at forth time condition, in the 5, 10, 15 and the last is 20 min after engine start. Fuel used is petroleum for comparison and also different Ethanol/petroleum blend E 10, E20 and E30. To get the same environmental conditions, testing is done in the morning. This is also done to ensure the condition of engine cold conditions.

RESULTS AND DISCUSSION

Influence of emission: Ethanol addition greatly influences fuel properties, such as shown in Table 1. Ethanol causes fuel experiencing significant changes, such as changes in octane number, density, heating value and also the oxygen content. Fuel properties Changes influenced in the burning process. In this study will be discussed about addition effect of ethanol in gasoline fuels on the emissions that occur during warm-ups.

Oxygen content in the ethanol caused improves combustion process. Yung *et al.* (2009) shows oxygen contain ethanol will cause air-fuel ratio to be increased. But in this study showed different results, ethanol addition in the fuel causes the fuel mixture becomes richer. This can be seen in Fig. 5. Where for 300 sec up to 600 sec, running engine use ethanol fuel make reduce air-fuel ratio, this condition shown if fuel mixture become richer. But with increasing time, fuel composition changes become lean. Results of experiments conducted with 300-600 sec early show a very significant change. At 300 sec from the start, the addition of ethanol in the fuel causes the combustion process produces many un-burned hydrocarbons and carbon dioxide.

Higher concentration of ethanol in the fuel causes un-burn hydrocarbon increases. With increasing time for warm-up, un-burn hydrocarbon decreased (Fig. 3). In this study, when engine uses gasoline fuel produce 315 ppm HC At the 300 sec warm-up and 243 ppm at 1200 sec. Addition of 10% ethanol will produce 364 ppm HC at 300 sec and 330 ppm for 1200 sec, while 30% addition of ethanol in fuel has produce 391 ppm HC at 300 sec and 120 ppm at 1200 sec. HC will be more produced by getting additional fuel ethanol compared with gasoline fuel for the early start, but after 300 sec warm-up process of the addition of ethanol will produce smaller HC.

At the start use ethanol fuel requires more fuel compared gasoline. This show in Fig. 5, addition of ethanol in the fuel causes the air-fuel ratio is lower. Amount of fuel in the combustion chamber at engine start resulted in a lot of fuel can't burned completely. Higher amount of un-burn fuel can increase HC and CO produced in the combustion process. Apart from the number of fuel can not burn completely, HC at the start to be more in the causes of the condition of the engine is still cold. The condition of the engine is still cool cause oil film that coats the piston and cylinder wall is high. These conditions resulted in front flame much oil trapped in the film thereby increasing the formation of un-burned hydrocarbons.

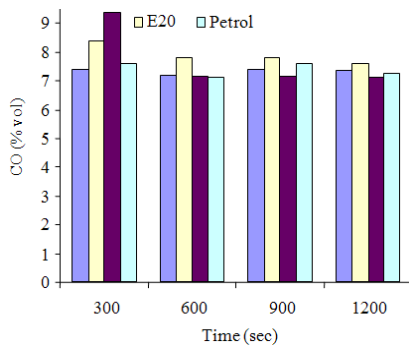


Fig. 2: CO emission from different time warm-up

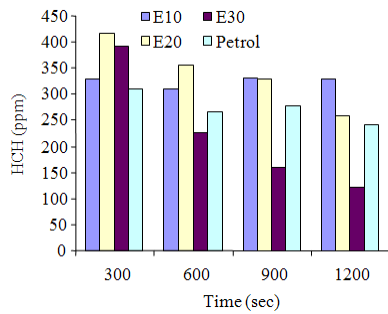


Fig. 3: Hydrocarbon at warm-up

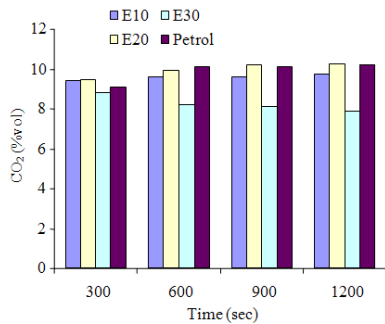


Fig. 4: CO₂ at different time warm-up

Besides influence in the HC, ethanol addition also affects on CO produced. In this study, ethanol/gasoline blend produce higher CO, in Fig. 2 show, at 300 sec the highest CO emissions produced by the ethanol/gasoline 30%. After 600 sec of warm-up, increasing concentration of ethanol in the fuel will reduce CO produced.

Increasing CO in combustion production at the warm-up shows incomplete combustion process, this is strengthened by the combustion temperature is lower (Fig. 4).

Effect of fuel properties on combustion temperature:

Fuels with low heating value lower will result in a low temperature combustion process. This can be seen in Fig. 7 which shows the effect of changes in fuel properties on the lubricating oil temperature. The addition of 10% ethanol has a lubricating oil temperature highest during 300 and 600 sec the engine at the start. After 900 sec, the highest temperature occurred on gasoline fuel. Generally, the higher concentration of ethanol in fuel, oil temperature will be lower.

The amount of fuel into the combustion chamber also affects the combustion temperature. The use of ethanol in fuel will increase the amount of fuel into the combustion chamber; this is the show in Fig. 6.

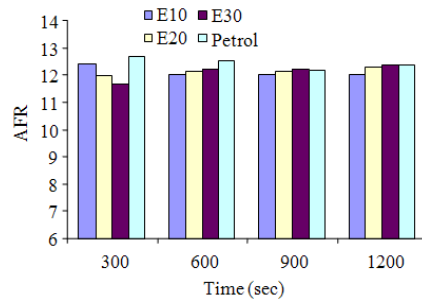


Fig. 5: Air-fuel ratio

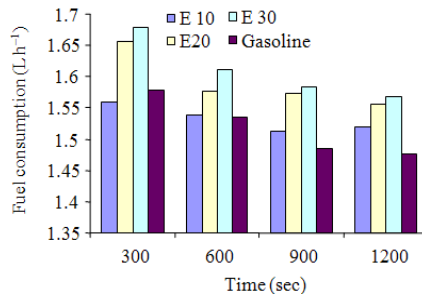


Fig. 6: Fuel consumption

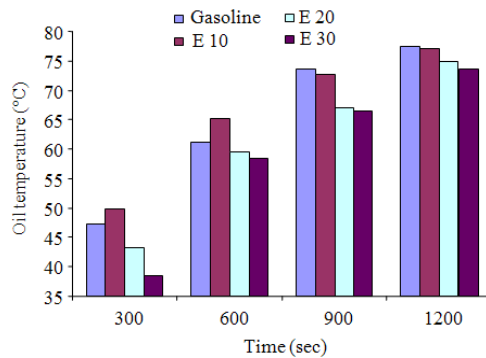


Fig. 7: Oil temperature

At start of 30% ethanol has higher fuel consumption. Too much fuel in the combustion chamber will cause the combustion process is less than perfect. With the number of un-burnt fuel, energy is released in combustion will also be reduced.

CONCLUSION

Results from this study indicate that fuel properties have been affects to engine emission during warm-ups. With ethanol addition in the fuel increased fuel consumption and air-fuel ratio is getting rich and reduce combustion temperature. Ethanol addition at the start will generate higher emissions, both CO and HC. But with increasing operation time, ethanol addition will be reducing emissions.

REFERENCES

Al-Farayedhi, A.A., 2002. Effects of octane number on exhaust emissions of a spark ignition engine. *Int. J. Energy Res.*, 26: 279-89. DOI: 10.1002/er.783

Al-Hasan, M., 2007. Evaluation of fuel consumption and exhaust emissions during engine warm-up. *Am. J. Applied Sci.*, 4: 106-111. DOI: 10.3844/ajassp.2007.106.111

Hsieh, W.D., R.H. Chen, T.L. Wu and T.H. Lin, 2002. Engine performance and pollutant emission of an SI engine using ethanol-gasoline blended fuels. *Atmos. Environ.*, 36: 403-410. DOI: 10.1016/S1352-2310(01)00508-8

Hu, T., Y. Wei, S. Liu and L. Zhou, 2007. Improvement of Spark-Ignition (SI) engine combustion and emission during cold start, fueled with methanol/gasoline blends. *Energy Fuels*, 21: 171-175. DOI: 10.1021/ef0603479

Jia, L.W., M.Q. Shen, J. Wang and M.Q. Lin, 2005. Influence of ethanol-gasoline blended fuel on emission characteristics from a four-stroke motorcycle engine. *J. Hazardous Mater.*, 123: 29-34. DOI: 10.1016/j.jhazmat.2005.03.046

Liu, S., E.R.C. Clemente, T. Hu and Y. Wei, 2007. Study of spark ignition engine fueled with methanol/gasoline fuel blends. *Applied Therm. Eng.*, 27: 1904-1910. DOI: 10.1016/j.applthermaleng.2006.12.024

Saxer, C.J., A.M. Forss, M. W. and N.V. Heeb, 2003. Benzene emission factors of the latest diesel-and gasolinefuelled passenger cars within the common artemis driving cycle. *Avignon France*, 2: 153-159.

Shen, Y., S. Shuai, J. Wang and J. Xiao, 2008. Effects of gasoline fuel properties on engine performance. *SAE International*. DOI: 10.4271/2008-01-0628

Yung, Y.C., J.H. Tsai and H.L. Chiang, 2009. Effects of ethanol-blended gasoline on air pollutant emissions from motorcycle. *Sci. Total Environ.*, 407: 5257-5262. DOI: 10.1016/j.scitotenv.2009.06.017