Evaluation of performance and emissions characteristics of methanol blend (gasohol) in a naturally aspirated spark ignition engine

Dima Alexandru, Dumitru Ilie, Tutunea Dragos
University of Craiova, Faculty of Mechanics
alexandru1dima@yahoo.com

Abstract. Alternative fuels for use in internal combustion engines have become recently in attention due the strict regulations regarding the environmental protection, emissions and to reduce the dependency of the fossil fuels. One choice is the use of methanol as it can be produce from renewable sources and blended with gasoline in any proportion. The aim of this study is to compare the effects of methanol – gasoline blends regarding performance, combustion and emission characteristics with gasoline. Five different blends M5, M10, M15, M20 and M25 were tested in a single cylinder spark ignition engine typically used in scooters applications. The experimental results in engine performance show a decrease of torque and power up to 10 %and in emissions characteristics a CO, CO2, HC. It can be concluded that gasohol is viable option to be used in gasoline engines to replace partially the fossil fuel.

1. Introduction
In the past decades global concerns have been rising to find solutions to the depletion of fossil fuels and to search for greener combustible fuels to be used in internal combustion engines. These problems have lead to the research of several possible renewable fuels like bioalcohols, vegetable oils and biodiesel to reduce the air pollution [1,2]. Among a variety of alcohols methanol, ethanol and butanol present the highest potential for use in transportation sector mainly because are cheap and have properties similar to gasoline [3,4]. Alcohols have a higher octane ratings, higher latent heat of vaporization and oxygen in their molecular structure leading to higher efficiency of combustion and low emissions [5]. In time researchers used M15 and M85 (USA in the early 1980s) while in China was used “low-content methanol gasoline” called gasohol with a methanol proportion under 50%. Gasohol was used directly in the engines without adjustment of engine configuration and recalibration of ECU. Siwale et al. [7] studied a blend of methanol-nbutanol-gasoline and found that the emission of NOx were higher that gasoline with the increase in spark timing. Canakci et al. [8] found that methanol–gasoline fuel blends reduce the emissions of CO and HC at the vehicle speed of 80 km/h. Wai et al. [9] studied the effect of methanol blends in internal combustion engines and found for M85 a reduction of emissions of CO and NOx by 23% and 80%. Hu et al. [10] studied the methanol addition in gasoline and found that methanol reduce the phase of rapid burning and also advances the start of combustion. The maximum pressure of the blends was higher comparative with gasoline. Bardaie et al [11] found for pure methanol (M100) a loss of power of 4–5% comparative with gasoline. Biligin and Sezer [12] observed the emissions characteristics and performance for methanol blends and found a maximum brake mean effective pressure for M5. Dai et al. [13] found that for M15 the
evaporative THC emissions increased by 63% and carbonyls increased by 19% comparative with gasoline. Palmer [14] found that 10% addition of alcohol to gasoline reduce the CO emissions by 30%. Yanju et al. [15] found the maximum pressure increase with methanol addition in the blend with the increase by 4-5° CA in ignition delay and by 5-6° CA in combustion duration for M85 compared to gasoline. Agarwal et al. [16] study the regulated and unregulated emissions on medium-duty transportation MPFI SI engine fuelled with M5 and M15 and found a reduction in emissions of benzene, iso-butylene, acetaldehyde, formic acid and nitrogen dioxide. Abu-Zaid et al. [17] studied the performance of a M3, M6, M9, M12 and M15 and found a maximum power output for M15 fuel blend. Tiegang Hu et al. [18] investigated on a three-cylinder engine the combustion and emission characteristics of methanol blends. The engine combustion was found better with the methanol addition into gasoline. During cold start the emissions of HC are reduced with 40% at 5 °C and 30% at 15 °C, CO with 70% for M30. In this study the effects of blending methanol and gasoline in a mono cylindrical engine are analyzed regarding emissions levels and performance.

2. Methods and materials

2.1. Fuels

In this study methanol was purchased from a regional supplier. Conventional gasoline and methanol – gasoline blends with five different substitution ratios of 5%, 10%, 15%, 20 % and 25% were prepared based on volume percentage basis and mechanical mixing. Fuel properties influence engine operations and performance. Physical properties of methanol vis-à-vis gasoline are shown in Table 1.

| Property                        | Gasoline | Methanol |
|--------------------------------|----------|----------|
| Molecular formula              | C4–C12   | CH3OH    |
| Molecular weight               | 95-120   | 32       |
| Oxygen content (%)             | 0        | 50%      |
| Density (kg/m³)                | 740      | 792      |
| LHV (MJ/m³)                    | 44.3     | 20       |
| Octane number                  | >90      | 111      |
| Auto-ignition temperature (°C) | 228-470  | 465      |
| Stoichiometric A/F ratio       | 14.8     | 6.47     |
| Latent heat (kJ/kg)            | 305      | 1103     |
| LHV of stoi-mixture (MJ/m³)    | 3810     | 3906     |

2.2. Engine stand

The engine tests were performed at the Faculty of Mechanics, University of Craiova using a single cylinder gasoline engine (Table 2). It is used an air cooled single cylinder 4 stroke engine with a 72 x 60 bore and stroke values and a compression ratio of 9.8:1, which recommends the engine as suited for the experiment [20] The engine was warmed up until it reached steady condition with gasoline and afterwards was fuelled with alcohol gasoline blend. After that, the engine was left to run with the gasohol until it reached steady state condition. For each test the engine needs to run again with gasoline to eliminate remaining gasohol from de fuel line system. In addition each test was repeated for at least three times to increase the accuracy of the experimental data recorded. The schematic of the experimental setup is shown in Fig. 1. A dynamic torque transducer for measuring the torque was fitted between the shaft that transmits the motion from the engine to the cinematic chain that leads to the braking system. A Stargas 898 gas analyzer was used to measure the gas emissions of the engine and engine parameters with compatibility of other devices or with a PC offering real time information as R.P.M., temperature of oil engine.
Table 2 Engine specifications

| Model                  | Honda CN 250                              |
|------------------------|-------------------------------------------|
| Engine type - Number of cylinders | Single cylinder, four-stroke              |
| Engine size - Displacement - Engine capacity | 244.00 ccm (14.28 cubic inches)          |
| Maximum power - Output - Horsepower | 17.00 HP (12.4 kW) @ 7000 rpm   |
| Maximum torque         | 21.00 Nm (2.1 kgf-m or 15.5 ft.lbs) @ 5000 rpm |

3. Results and conclusions
The present section shows the results obtained from the experiment conducted to analyze the behaviour of naturally aspirated spark ignited engine fuelled with gasoline and 5 different blends of 5,10,15,20 and 25 vol. % of methanol in gasoline, used as M5, M10, M15, M20, M25 further.

3.1. Engine performance
The energy performance of the engine concerning the torque and power are summarized in Fig. 2. and Fig. 3.

![Engine stand](image)

Fig. 1 Engine stand
1 – engine; 2 – soft coupling; 3 – bearings; 4 – torque transducer; 5 – bearings; 6 – soft coupling; 7 – disc brake; 8 – brake disc cooler.

![Evolution of engine power](image)

Fig. 2 Evolution of engine power for gasoline and methanol blends
The variation of engine torque and power is dependent by the quantity of methanol in the gasoline mixture. Increasing the fraction of methanol results in a decrease of performance, meaning lower value for the parameters examined previous at different speeds and loads of the engine. S. Liu et al. [21].

3.2. Exhaust emissions
The following figures, Fig. 4 – Fig. 6, show the variation of pollutant emissions versus the load of the engine for different engine speeds of 3600 and 4600 rpm, starting from where the load will be applied.

As it can be seen, the values of CO decrease once the percentage of methanol is increased. The effect is generated by the quantity of oxygen contained by the alcohol and by the carbon, that is found in greater proportion in gasoline rather than in methanol composition, [22].
Fig. 5 indicates the evolution of CO₂ emissions for two different engine speeds starting from 0 to 100 % load. It can be seen an increasing trend for the alcohol gasoline blends. At a high engine speed the emission value have a great value due to the quantity of air and fuel that increase the rate of complete combustion. Similar results were recorded with differences up to 13% higher CO₂ emissions for methanol-gasoline blends [23].

![Fig. 6 Methanol influence on HC emissions, a) 3600 rpm, b) 4600 rpm](image)

Fig. 6 depicts the evolution of HC emissions, which can rise rapidly due to incomplete combustion or heat losses in the cylinder. Increase of the HC emissions can be caused also by the existence of regional lean and rich mixtures in the combustion chamber. Experiments show a decreased value of the emissions when the gasoline is mixed with methanol, influenced by the carbon to hydrogen fuel ratio which is lower than in the case of gasoline, [24].

### 3.3. Conclusions

The purpose of present paper was to compare the performance and the emissions characteristics of the gasohol with the performance parameters obtained from the case of using gasoline as single fuel. The results showed in the above figures can sustain the possibility of usage of methanol blends as fuel for gasoline engines and also the idea of searching variations with other alcohols in order to obtain an alternative that could also satisfy the output given by the decrease of the energy performances. The results also show a decrease of the CO and CO₂ emissions and an equivalent variation of the HC emissions, which proves that the combination of these two could offer a viable solution.

### References

[1] M. Eyidogan, et al., Impact of alcohol–gasoline fuel blends on the performance and combustion characteristics of an SI engine, Fuel 89 (10) (2010) 2713–2720.

[2] Costagliola MA, De Simio L, Iannaccone S, Prati MV. Combustion efficiency and engine out emissions of a S.I. engine fueled with alcohol/gasoline blends. Appl Energy 2013;111:1162–71.

[3] M. Eyidogan, A. Ozsezen, M. Canakci, A. Turkcan, Impact of alcohol–gasoline fuel blends on the performance and combustion characteristics of an SI engine, Fuel (2010) 1–7.

[4] Avinash Kumar Agarwal, Himanshu Karare, Atul Dhar, Combustion, performance, emissions and particulate characterization of a methanol–gasoline blend (gasohol) fuelled medium duty spark ignition transportation engine, Fuel Processing Technology 121 (2014) 16–24.

[5] B. Celik, B. Ozdalyan, F. Alkan, The use of pure methanol as fuel at high compression ratio in a single cylinder gasoline engine, Fuel 90 (2011) 1591–1598.

[6] Xin Wanga, Yunshan Ge, Linlin Liu, Zihang Peng, Lijun Hao, Hang Yin, Yan Ding, Junfang Wang, Evaluation on toxic reduction and fuel economy of a gasoline direct injection- (GDI-) powered passenger car fueled with methanol–gasoline blends with various substitution ratios, Applied Energy 157 (2015) 134–143
Siwale L, Kristof L, Bereczky A, Mbarawa M, Kolesnikov A. Performance, combustion and emission characteristics of n-butanol additive in methanol–gasoline blend fired in a naturally-aspirated spark ignition engine. Fuel Process Technol 2014;118:318–26.

Canakci M, Ozsezen AN, Alptekin E, Eyidogan M. Impact of alcohol–gasoline fuel blends on the exhaust emission of an SI engine. Renew Energy 2013;52:111–7.

J. Wei, H. Liu, S. Li, R. Yang, J. Liu, Y. Wang, Effects of methanol/gasoline eblends on a spark ignition engine performance and emissions, Energy & Fuels 22 (2) (2008) 1254–1269.

T. Hu, Y. Wei, S. Liu, L. Zhou, Improvement of spark-ignition (SI) engine combustion and emission during cold start, fueled with methanol/gasoline blends, Energy & Fuels 21 (2001) 171–175.

Z. Bardeaie, R. Janius, Conversion of spark-ignition engine for alcohol usage comparative performance, Agricultural Mechanization in Asia, Africa, and Latin America 15 (2) (1984) 31–40.

A. Bilgin, I. Sezer, Effects of methanol addition to gasoline on the performance and fuel cost of a spark ignition engine, Energy & Fuels 22 (2008) 2782–2788.

Dai, P.P., Ge, Y.S., Lin, Y.M., Su, S., Liang, B., 2013. Investigation on characteristics of exhaust and evaporative emissions from passenger cars fueled with gasoline/ methanol blends. Fuel 113, 10e16.

F. Palmer, Vehicle Performance of Gasoline Containing Oxygenates, MI Mechanical, 1986. 33–46.

W. Yanju, L. Shenghua, L. Hongsong, Y. Rui, L. Jie, W. Ying, Effects of methanol/ gasoline blends on a spark ignition engine performance and emissions, Energy & Fuels 22 (2008) 1254–1259.

Avinash Kumar Agarwal, Pravesh Chandra Shukla, Jai Gopal Gupta, Chetankumar Patel, Rajesh Kumar Prasad, Nikhil Sharma, Unregulated emissions from a gasohol (E5, E15, M5, and M15) fuelled spark ignition engine

Abu-Zaid M, Badran O, Yamin J. “Effect of Methanol Addition on the Performance of Spark Ignition Engines”, Energy Fuels, 2004, Vol.18, pp.312–315.

Tiegang Hu, Yanjv Wei, Shenghua Liu, Improvement of Spark Ignition (SI) Engine Combustion and Emission during Cold Start, Fueled with Methanol/Gasoline Blends, Energy & Fuels, 21(1), 171-175, 2007

Vancoillie J, Demuynck J, Sileghem L, Van De Ginste M, Verhelst S, Brabant L, et al. The potential of methanol as a fuel for flex-fuel and dedicated sparkignition engines. Appl Energy 2013;102:140–9.

M. Balki, C. Sayin, The effect of compression ratio on the performance, emissions and combustion of an spark ignition (SI) engine fueled with pure ethanol, methanol and unleaded gasoline, Energy 71 (2014) 194-201

Liu Shenghua, Eddy R. Cuty Clemente, Hu Tiegang *, Wei Yanjv, Study of spark ignition engine fueled with methanol/gasoline fuel blends, Applied Thermal Engineering 27 (2007) 1904–1910.

S. Babazadeh Shayan, S. M. Seyedpour, F. Ommi, S. H. Moosavy, M. Alizadeh, Impact of Methanol–Gasoline Fuel Blends on the Performance and Exhaust Emissions of a SI Engine, International Journal of Automotive Engineering, Vol. 1, Number 3, July 2011

A. Elfasakhany, Investigations on the effects of ethanol/methanol/gasoline blends in a spark-ignition engine: Performance and emissions analysis, Engineering Science and Technology, an International Journal 18 (2015) 713-719

L. Siwale, L. Kristof, A. Bereczky, M. Mbarawa, A. Kolesnikov, Performance, combustion and emission characteristics of n-butanol additive in methanol–gasoline blend fired in a naturally-aspirated spark ignition engine, Fuel Processing Technology 118 (2014) 318–326