

SPECIATION OF C5-C11 HYDROCARBONS GENERATED BY THE HCCI GASOLINE EXHAUST GAS ENGINE

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Abstract: A qualitative and quantitative analysis of toxic but currently non-regulated hydrocarbon chemical species ranging from C5 - C11 was studied which is generated from a modern gasoline direct injection (GDI) engine by using gas chromatography-mass spectrometry (GC - MS). The GDI engine has been operated under different engine speeds and different engine modes (SI and HCCI modes). HCCI has the ability to operate on lean combustion which leads to the reduction in engine pumping losses, and fuel consumption. However, HCCI mode has a high levels of unburnt HCs which leads to present heavier species such as Toluene, which is presented in higher concentrations under stoichiometric HCCI engine operation mode, while species such as benzene, are mainly found in the engine exhaust during SI engine operation. Engine speeds has high impact on engine tail pipe emissions for both engine modes. increasing engine speed leads to higher concentration in Benzene species while toluene was decreased and presented in higher concentration at low engine speed for both engine modes.

KEYWORDS: HCCI, SI HYDROARBONE SPECIATION GDI

1. Introduction

In terms of emissions, hydrocarbon speciation is a powerful tool to understand the complex reactions happening inside the cylinder during the combustion process and to observe the effects of varying the fuel composition, fuel additives, and emission control system. Using speciation data enables researchers and scientists to evaluate the relative reactivity of the exhaust and evaporative emissions. Different hydrocarbons in urban air form from differing levels of ozone (smog) which depend on the reactivity of these chemical compounds. To evaluate hydrocarbon impact on ozone formation, HC speciation is required which will also help to determine the presence of toxic emissions from the exhaust tailpipe. Using speciation data has helped researchers to make a number of non-proprietary observations about the relationships between fuel property modifications and automotive emissions [1-2]

Clarifying the hydrocarbon components in conventional gasoline fuel is considered to be the key step in speciation of HCs in the engine exhaust. By using the retention times of some known compounds chromatograms and the NIST library together, the peaks in gasoline chromatograms could be identified. The hydrocarbons in gasoline consist primarily of light aliphatic hydrocarbons (butane, pentane, methyl-pentane, hexane, methyl-hexane, heptane and octane) and aromatic compounds (toluene, xylenes and trimethyl-benzenes), with smaller amounts of olefin hydrocarbons (pentene, hexenes, heptenes, octenes and nonenes). The content of toluene in this fuel sample is 13% by volume, and iso-octane is 11% by volume.

2. Experimental Work

The hydrocarbon speciation of C5-C11 coming out of the V6 HCCI engine figure 1 was analysed and carried out using an on-line GC-MS. A Fisons 8000 series GC equipped with direct injector was connected to a Fisons MD 800 mass spectrometer, used as a detector. The gas samples were introduced via a heated line into a six-port Valco valve fitted with a 0.1 ml sample loop.

The fuel used for combustion investigation was analyzed by using another J & W scientific DB-1 column. This column gave details on the components (C5 to C11); presented in 95 RON unleaded commercial gasoline.



Figure 1: Schematic diagram of a V6 engine system

3. Results and Discussion

In general terms, the engine output emission concentration for all the studied chemical species were higher for HCCI combustion with the exception of benzene which was presented more in SI mode. The higher unburned hydrocarbon emissions under HCCI combustion are due to the lower in cylinder temperature and available energy to drive the complete oxidation reactions of the hydrocarbons part of the fuel and to also reduce hydrocarbon oxidation post combustion. On the other hand, the lower concentration of the rest of species under HCCI conditions can be attributed to i) the conversion of iso-octane to methane ii) a higher formation rate of toluene, p-xylene, naphthalene, methyl-naphthalene or any other compounds derived from benzene due to the higher presence of hydrocarbon to react with, and iii) the breakdown of the already formed toluene and p-xylene during SI combustion process producing benzene and ethylbenzene [3-7]. In SI mode as post-flame oxidation increases, the fraction of fuel paraffins to total hydrocarbons (THC) decreases because fuel paraffins are oxidised into smaller HCs (e.g. total olefins and methane). Benzene enrichment from aromatic fuels is of Benzene results from the incomplete combustion of toluene and other alkyl-benzenes.

The formation of benzene during combustion of the used fuel in this study which contain < 1.0 % explains the observed enrichment in the exhaust relative to other aromatic fuel components available in this commercial gasoline fuel. [8-10] Emission of benzene, increased by increasing the engine speed at SI mode on the other hand increasing speed at HCCI mode resulted in higher toluene species comparing to SI mode. Figure 2 this constitutes an appreciable fraction of the total emission. The HCCI mode follows the same trend, but since the combustion temperature of HCCI mode is always lower

than SI mode under the same engine conditions, the oxidation of fuel paraffins is less. As a result the amount of total olefins, methane and benzene are lower than in SI mode. For toluene as well as for the other aromatics (e.g. xylenes) except benzene, there is a decrease in the percentage concentrations in the exhaust due to the increasing engine speed for both modes. The level of the toluene compound in the emission in both modes was the highest figure 3. In SI mode the amount of toluene is always lower than in HCCI mode under the same engine conditions.

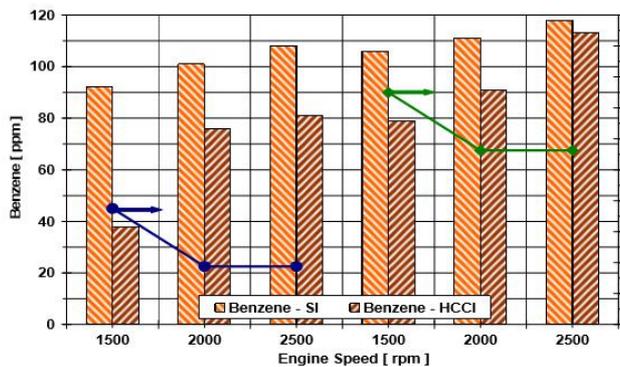


Figure (2) Benzene species at different engine speeds SI, HCCI

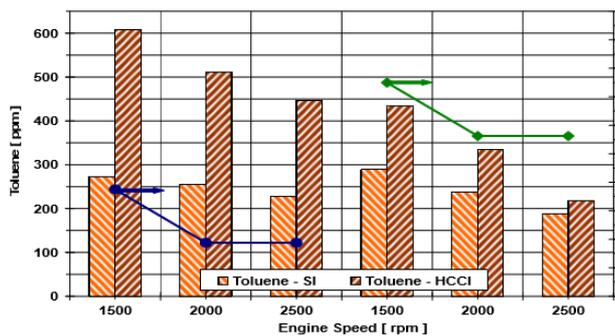


Figure (3) Toluene species at different engine speeds SI, HCCI

4. Conclusions

Exhaust hydrocarbons have been speciated, Species such as benzene, are mainly found in the engine exhaust during SI engine operation, while heavier species such as Toluene are presented in higher concentrations under stoichiometric HCCI engine operation, HC emissions, rise significantly in this region, which is very probably due to incomplete combustion. Data obtained on the contribution of C5 - C11 (indicator of the amount of unburned fuel) to the total exhaust hydrocarbons with variation in engine speed and for both SI and HCCI modes. The C5 - C12 ratio is frequently used to describe the extent to which fuels burn in an engine. In this investigation, it was found that in HCCI mode the proportion of species attributed to C5 - C11 in total HC is higher than in the SI mode.

5. References

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