Characterisation of a Bio-Ethanol Direct Injection Spray Under Sub-Zero Conditions

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Abstract

Due to current dependence on depleting fossil fuel reserves, alternative fuels are being considered particularly for the transport sector. Suitable replacement fuels for gasoline are bio-fuels such as bio-ethanol. One of the obstacles preventing the wider use of pure bio-ethanol is its volatility which causes problems at low temperatures. To over come this, blends of bio-ethanol and gasoline - such as E85 (85 % ethanol and 15 % gasoline), are used which have increased volatility thereby increasing reliability during cold starts and running [1]. The addition of gasoline reduces the corrosive nature of ethanol by decreasing the amount of water absorbed by the resulting fuel. A lower air-to-fuel ratio is also required during cold start, thus increasing Unburnt Hydrocarbons (UBHC) and Carbon Monoxide (CO). This can be mitigated by exhaust after treatment systems; however the low system temperatures occurring during cold start and warm up cycles severely limits the effectiveness of these systems. This leads to an increase in UBHC and CO emissions of up to 15 times at -20 ^{o}C compared to that at 23 ^{o}C for gasoline G-DI engines [2].

The objective of this study is to assess the influence of sub-zero fuel temperatures on spray characteristics such as droplet size, velocity and spray pattern of E85 compared to gasoline sprays. Fuel temperatures as low as 243 K (-30 ^{o}C) were achieved. The data presented and analysed in this paper were obtained using a temporally and spatially resolved Phase Doppler Anemometry (PDA) system from fuel injections by a piezo controlled G-DI injector mounted in a constant volume, optical experimental facility.

The results are presented in terms of the spray kinematics and spray quality and are discussed and analysed through comparison with the benchmark spray at atmospheric conditions.

Introduction

Whilst the world's crude oil resources are diminishing, the use of all liquid fuels (including those for road transport) are set to increase globally by 25 % by 2030 [3] emphasising the need to find an alternative to fossil derived fuels. Bio-fuels such as ethanol are considered as possible alternatives to fossil-derived automotive fuel.

The use of gasoline–ethanol mixtures in spark ignition (SI) engines give rise to several problems related to the differing thermo-fluid properties of gasoline and ethanol. One of the key factors affecting the implementation of ethanol and ethanol blends as substitutes for gasoline is their increased latent heat of evaporation and flash point. These effects are exacerbated at sub-zero temperatures, and can lead to poor atomisation and thus ignition difficulties during cold starting of an SI engine [1]. Although the effects are reduced by the addition of 15 % gasoline to create E85, the effects are still significant enough to cause operational problems. Whilst the fuel rich mixture during the warm up period of an SI engine can increase unburnt hydrocarbon and carbon monoxide emissions, it has been shown that these emissions decrease with the use of high concentration blends of ethanol and gasoline [1]. The same study showed the potential for Nitrogen Oxides (NO_x) emissions to increase at higher concentrations of ethanol due to its higher oxygen content.

Results and Discussion

The transient DI spray from a Bosch hollow cone type injector was investigated using both two dimensional PDA and high speed imaging. The average images for E85 and gasoline data are presented in Figure 1. The temporally-resolved data is presented for 0.4 ms (mid spray development after start of injection (ASOI), and three fuel temperatures of 293 K (atmospheric), 258 K (-15 ^{o}C) and 243 K (-30 ^{o}C). The ambient air temperature was maintained at atmospheric temperature, and the injector line pressure and injection duration were 20 MPa and 0.3 ms respectively. The high speed imagery took a 'cut' though the centre plane of the spray, the spray structure has apparent asymmetrical structure due to the direction of the laser sheet (entering from the left hand side).

Both the velocity and the penetration of the gasoline sprays decrease as temperature decreases, which can also be seen in the E85 sprays. This reduction is a result of comparatively higher drag forces acting on the droplets, due to the larger mean diameters at lower temperatures, as well as lower initial exit velocities. However, the decrease in mean velocity with temperature appears to be more prominent in the gasoline sprays and requires further investigation. It can bee seen that a reduction in axial velocities of the E85 spray compared to the equiva-

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lent temperature gasoline spray has led to a decrease in shear gradient and reduction in entrainment , as reported by Wigley et al. [4]

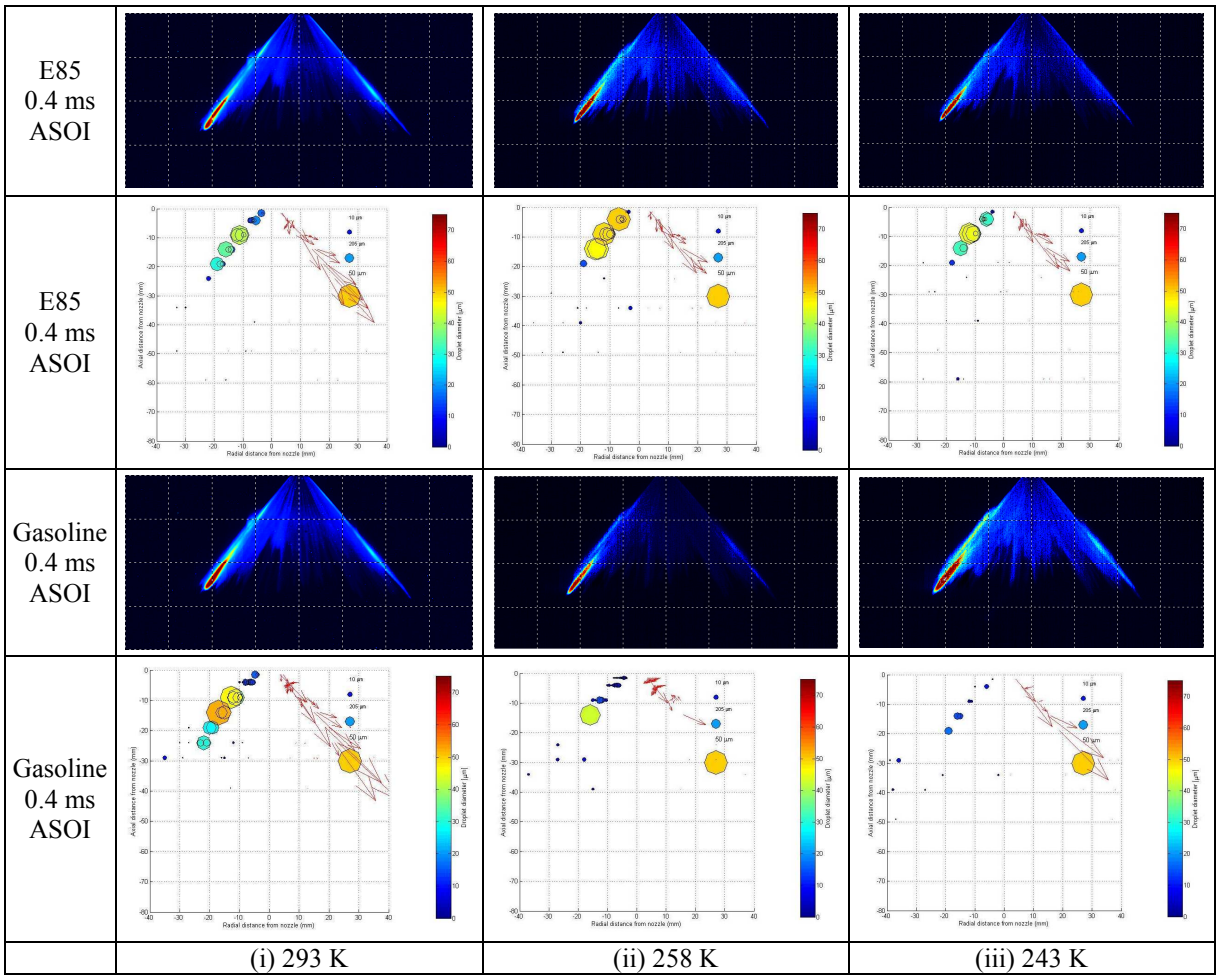

Figure 1. Comparison of a Gasoline and E85 spray PDA high speed image data under different fuel temperatures at 0.4 ms ASOI

Conclusions

This paper analysed the effects of sub-zero temperatures on gasoline and E85 sprays from a hollow cone, piezo injector suitable for automotive GDI applications. The following main conclusions can be drawn:

- A self consistent biofuel spray data-set is presented utilising three independent techniques.
- Sufficiently refined temporal and spatial resolution allow the dynamic spray characteristics to be identified
- The typical mean droplet size for gasoline is lower than that of E85 due to fluid properties affecting primary atomisation.
- As fuel temperature decreases, so too does droplet penetration and velocity and this effect is more prominent in the E85 sprays.

References

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