VISUALIZATION AND ANALYSIS OF THE GASOHOL BLENDS FUEL SPRAY PATTERN

MUHAMMAD ASHRAF ALI ZUBIR

This thesis is submitted as partial fulfillment of the requirements for the award of the Bachelor of Mechanical Engineering with Automotive

Faculty of Mechanical Engineering
Universiti Malaysia Pahang

DECEMBER, 2010

SUPERVISOR'S DECLARATION

I hereby declare that I have checked this project report and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

Signature : ……………………...
Name of Supervisor : TN HAJI AMIRRUDDIN ABDUL KADIR
Position : DEPUTY DEAN (ACADEMIC & STUDENT DEVELOPMENT AFFAIRS)
Date : 6 DECEMBER 2010

STUDENT’S DECLARATION

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Signature : ………………………….
Name : MUHAMMAD ASHRAF ALI ZUBIR
ID Number : MH08009
Date: : 6 DECEMBER 2010

SECOND EXAMINER'S DECLARATION

I hereby declare that I have checked this project report and in my opinion, this project is adequate in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering

Signature :………………………
Name of Examiner's: PROF. DR. KORADA VISWANATHA SHARMA
Position : LECTURER
Date : 6 DECEMBER 2010

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ABSTRACT

Operation of flex fuel vehicles requires operation with a range of fuel properties. The significant differences in the heat of vaporization and energy density of E0-E100 fuels and the effect on spray development need to be fully comprehended when developing engine control strategies. Limited enthalpy for fuel vaporization needs to be accounted for when developing injection strategies for cold start, homogeneous and stratified operation. Spray imaging of gasoline injectors with fuels ranging from E0 to E75 was performed in an ambient pressure and temperature.

ABSTRAK

Operasi kenderaan berbahan bakar flex memerlukan operasi dengan pelbagai sifat bahan bakar. Perbezaan yang signifikan di dalam kepadatan pengewapan panas dan tenaga bahan bakar antara E0 hingga E100 dan pengaruh terhadap perkembangan semburan perlu difahami sepenuhnya ketika mengembangkan strategi mesin kawalan. Entalpi yang terhad untuk pengewapan bahan bakar harus diambil kira di dalam memajukan injeksi semasa penghidupan yang sejuk, homogen dan operasi bertingkat. Semburan pencitraan dari penyuntik petrol dengan bahan bakar bermula dari E0 sehingga E75 yang dijalankan pada tekanan dan suhu atmosfera.

TABLE OF CONTENTS

CHAPTER 4:

CHAPTER 5:

APPENDIX

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Fuel spray combustion is one of the most important phenomena in gas turbine and internal combustion engine. Evaporation of fuel spray has a very important impact on processes of turbulence mixing, ignition and combustion. The fuel-injection process is critical to attaining high fuel efficiency and low emissions in modern engines. Accurate control of fuel injection parameters (timing, delivery, flow rate, pressure, spray geometry, etc.) is the most effective means to influence fuel and air mixing and to achieve both clean burning and high efficiency.

The impingement of fuel spray onto interposed surfaces in an IC engine, equipped either with a direct or an indirect injection system, is a fundamental issue affecting mixture preparation prior to combustion and, therefore, also affecting engine performance and pollutant emissions. In this context, the development of fuel injection systems relies on accurate knowledge of the fluid dynamic and thermal processes occurring during spray/wall interaction. Injection systems however, are very complex and the background physics requires fundamental studies, performed at simplified flow geometries. In particular, the impact of individual droplets has been extensively used to describe the behavior of spray impact and to predict its outcome, despite the known fact that a spray does not behave exactly as a summation of individual droplets; then, researchers incorporate all the governing parameters. The present paper offers a critical review of the investigations reported in the literature on spray-wall impact relevant to IC engines, in an attempt to address the rationale of describing spray-wall interactions based on the knowledge of single droplet impacts. Moreover, although the review was first aimed at fuel-spray impingement in IC engines, it also became relevant to provide a systematization of the current state of the art, which can be useful to the scientific community involved with droplet and spray impingement phenomena.

1.2 PROBLEM STATEMENT

The physics of spray atomization and its influence on combustion, pollutant formation, and fuel efficiency are not well understood, and final tuning of the engine is a trial-and-error procedure. The video imaging has been used to investigate the spray development.

1.3 OBJECTIVES

The objective of this project is to:

1.3.1 Investigate fuel pattern of different fuel blends using optical measurement.

1.3.2 To analyze quantitative result.

1.4 SCOPES OF WORK

The scopes of the study are:

1.4.1 Setup test rig for experimental.
1.4.2 Choosing fuel mixture (E75, E50, and G100).
1.4.3 Describe spray characteristic such as spray angle, spray tip penetration and spray width.
1.4.4 To visualize the fuel spray development.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

The literature review had been carry out with reference from sources such as journal, books, thesis and internet in order to gather all information related to the title of this project. This chapter covers about the previous experiment doing by researcher and to go through the result by experimental and numerical. Today, people around the world use fossil fuels for energy production, the reserves of these petroleum-based fuels are being rapidly depleted. It is also well-known that the future availability of energy resources as well as the need of reduced emissions of CO2 and pollutants promotes an increased utilization of regenerative fuels. Alcohols, such as ethanol which is a colorless liquid with mild characteristic odor and can be produced from coal, natural gas and biomass, have high octane rating and can be used as one of the realistic alternative fuels. Moreover, ethanol has higher heat of vaporization compared to gasoline, which means that freezes the air allowing more mass to be drawn into the cylinder and increases the power output. Besides that, ethanol has antiknock properties that improves engine efficiency and gives higher compression ratios. Just for these reasons, adaptation of the commercial gasoline engines to fuels with various ratios of ethanol and gasoline are of current interest and numerous attempts have been done on this topic by researchers around the world in the past decade. Since the spray properties play an important role on engine air-fuel mixing and subsequent combustion, an in-depth understanding of the spray characteristics of the ethanol–gasoline blends is of necessity and significance (Jian Gao et.al,2007) .

2.2 FUEL INJECTION AND SPRAY RESEARCH

It is critical to attain the high fuel efficiency and low emissions in modern engines in fuel-injection process. The most effective means to influence fuel and air mixing and to achieve both clean burning and high efficiency is an accurate control of fuel injection parameters such as timing, delivery, flow rate, pressure, spray geometry and so on. The physics of spray atomization and its influence on combustion, pollutant formation, and fuel efficiency are not well understood unfortunately, and final tuning of the engine is a trial-and-error procedure. The development of several novel diagnostic techniques that use x-rays to study the detailed structure of fuel sprays have been developed by Argonne scientists. X-rays are highly penetrative in materials with low atomic numbers; therefore, they do not encounter the multiple scattering problems typical of diagnostic methods that use visible light. Argonne has developed a non-intrusive absorption technique that yields a highly quantitative characterization of the dynamic mass distribution in the spray from both diesel and gasoline engine injectors by using highly time-resolved monochromatic x-rays generated at the Advanced Photon Source (APS) (Gurpreet Singh, 2010).

2.2.1 Diesel Sprays

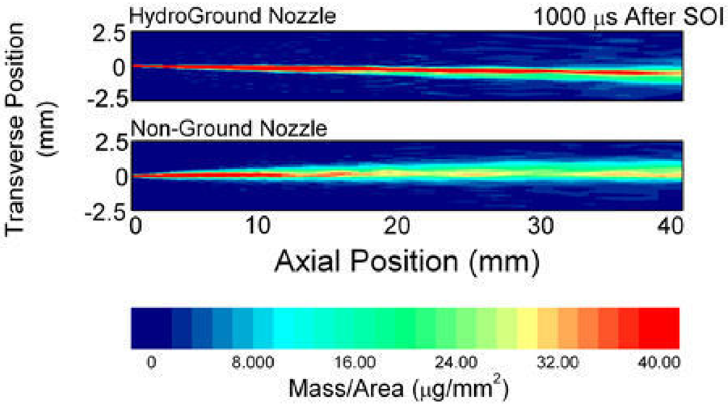


Figure 2.1: The effects of nozzle geometry on the structure of sprays.

Source: Gurpreet Singh (2010)

There is more fuel efficient in diesel engines than their gasoline counterparts. Because of that wider adoption of diesels in the United States it would decrease the nation's petroleum consumption. Although the diesels is more fuel efficient, they emit much higher levels of pollutants, especially particulate matter (PM) and nitrogen oxides (NOx). The exploration of ways to reduce pollution formation in the engine using clean combustion strategies have been done by researchers in Argonne's Engine and Emissions Research group. By controlling the fuel spray and fuel/air mixing the development of clean combustion can be achieved. The quantitative measurements of the mass distribution within fuel sprays have been obtained with very precise time resolution. Besides that, the density of the fuel can be calculated at any position and time within the spray, a result that proved for the first time that sprays from modern diesel injectors are atomized only a few millimeters from the nozzle. Other than that, the speed of the spray core can also be measured, includes at the trailing edge and within the body of the spray itself. The supersonic sprays generate shock waves in the spray chamber, which have been quantitatively measured for the first time. Sprays from nozzles with different internal structure have also been quantitatively measured under identical experimental conditions; the resulting differences in the mass distributions of the sprays will prove very useful to spray modelers trying to understand the effects of nozzle geometry on the structure of sprays (Gurpreet Singh, 2010).

2.2.2 Gasoline Sprays

Gasoline Direct Injection (GDI) engines are still new in US market. These engines inject the fuel directly into the engine cylinder rather than into the intake port. These engines also can achieve higher fuel efficiency, but they depend on a precise fuel/air mixture at the spark plug to initiate ignition. These things lead to more stringent requirements on spray quality and reproducibility. Gasoline Direct Injection (GDI) also enables new combustion strategies for gasoline engines. Such “lean burn” engines may achieve efficiencies near that of a diesel while producing low emissions. Again, this advanced combustion strategy relies on precise mixing of the fuel and air to achieve clean, efficient power generation.

Argonne's fuel injection and spray researchers are studying the process of gasoline injection to enable these advanced combustion strategies. They have performed the first quantitative, dynamic three-dimensional reconstruction of a fuel spray, which revealed the striking asymmetry of sprays from a prototype gasoline injector. They also have worked with several US manufacturers to help them understand the performance of their injectors, and have assisted in the development of a new GDI injection system, from prototype to final production design (Gurpreet Singh, 2010).

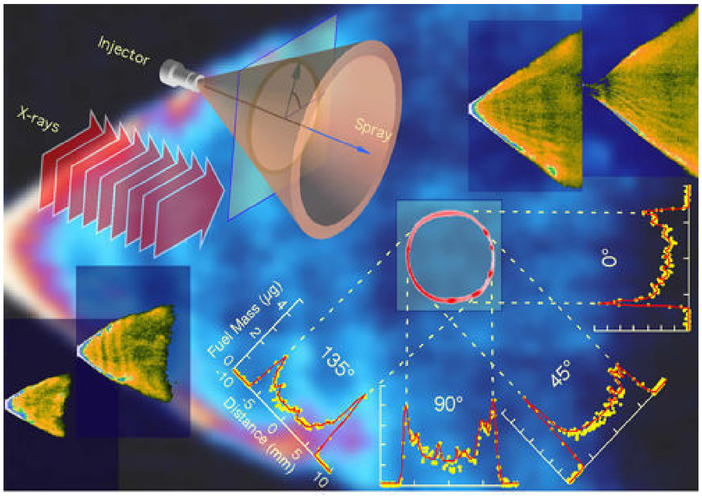


Figure 2.2: Gasoline Direct Injection (GDI) injection.

Source: Gurpreet Singh (2010)

2.2.3 Alternative Fuel Sprays

In United States, non-petroleum fuels are gaining popularity. In order to vary the proportions, ethanol is being blended with gasoline, and biodiesel can be found today at pumps across the country. These fuels actually can help us reduce our nation's dependence on petroleum, but their effects on engine performance and emissions are still not well understood.

The physical properties of these alternative fuels can vary quite dramatically from those of petroleum fuels. Ethanol has significantly less energy per gallon than gasoline, and biodiesel has a much higher viscosity than diesel. Changes such as these require the engine to adapt to the fuel in ways that have not previously been necessary. These changes also fundamentally alter the operation of fuel injectors and the structure of spray in ways that are not well understood. These uncertainties are preventing the adoption of new clean combustion strategies in both gasoline and diesel engines.

Argonne's researchers are studying the fuel injection process using fuels such as biodiesel, vegetable oils, pyrolysis oil, ethanol, and butanol, with the goal of understanding how changes in fuel properties affect the spray, combustion, and ultimately, the operation of the engine. The researcher's experiments have discovered structural differences between sprays of conventional fuels and biodiesel, revealing that biodiesel sprays require more time to atomize and produce more compact sprays with higher density (Gurpreet Singh, 2010).

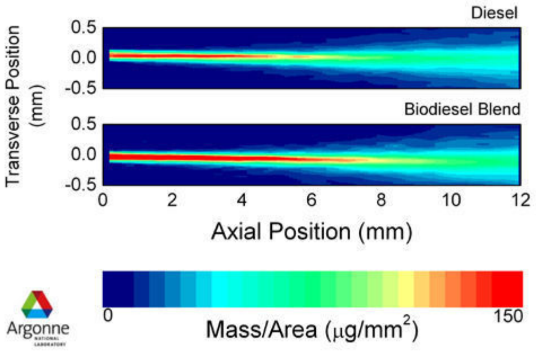


Figure 2.3: Comparison of conventional fuel and biodiesel.

Source: Gurpreet Singh (2010)

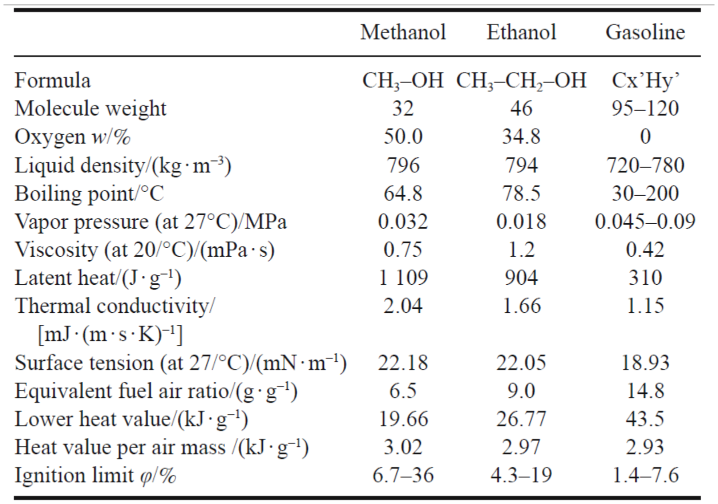
2.2.4 Ethanol

Ethanol is also known as ethyl alcohol or grain alcohol. Ethanol contains hydrogen and carbon like gasoline, but the difference between them is ethanol contains oxygen in its chemical structure. This oxygen makes burning fuel cleaner than gasoline (Missouri Department of Natural Resources, 2009)

2.2.5 Ethanol/gasoline fuel blend

Ethanol is primarily produced from corn in the United States. Ethanol is denatured at the ethanol plant to prevent ingestion. The denaturing agent most often used is some type of hydrocarbon such as gasoline. Denatured ethanol may contain 2 to 15 percent gasoline, making it an ethanol and gasoline fuel blend. For example, E85 contains 85 percent ethanol and 15 percent gasoline. Other blends may include E10, which contains 10 percent ethanol and 90 percent gasoline, and E15, which contains 15 percent ethanol and 85 percent gasoline. Spills and fires involving ethanol and gasoline blends should be treated differently than traditional gasoline spills and fires (Missouri Department of Natural Resources, 2009).

Table 2.1: Fuel properties of methanol, ethanol, and gasoline.



	Methanol	Ethanol	Gasoline
Formula	CH_3–OH	CH_3–CH_2–OH	Cx’Hy’
Molecule weight	32	46	95–120
Oxygen *w*/%	50.0	34.8	0
Liquid density/(kg · m^{-3})	796	794	720–780
Boiling point/°C	64.8	78.5	30–200
Vapor pressure (at 27°C)/MPa	0.032	0.018	0.045–0.09
Viscosity (at 20/°C)/(mPa · s)	0.75	1.2	0.42
Latent heat/(J · g^{-1})	1 109	904	310
Thermal conductivity/ [mJ · (m · s · K)$^{-1}$]	2.04	1.66	1.15
Surface tension (at 27/°C)/(mN · m^{-1})	22.18	22.05	18.93
Equivalent fuel air ratio/(g · g^{-1})	6.5	9.0	14.8
Lower heat value/(kJ · g^{-1})	19.66	26.77	43.5
Heat value per air mass /(kJ · g^{-1})	3.02	2.97	2.93
Ignition limit φ/%	6.7–36	4.3–19	1.4–7.6

Source: Wang Xibin et.al (2007)

2.3 SPRAY CHARACTERISTICS AND ATOMIZATION PERFORMANCE OF GASOLINE FUEL

The spray characteristics and atomization performance of gasoline fuel (G100), bioethanol fuel (E100), and bioethanol blended gasoline fuel (E85) in a direct injection gasoline injector in a gasoline engine had been investigated by the researcher. The characteristics of overall spray and atomization such as an axial spray tip penetration, spray width, and overall SMD were measured experimentally and predicted by using KIVA-3V code.

The appearance timing of the vortices and the development process and in the test fuels were very similar. The numerical results had described the experimentally observed spray development such as pattern and shape, the beginning position of the vortex, and the spray breakup on the spray surface. In the observation, the increment of injection pressure induced the occurrence of a clear circular shape in the downstream spray and a uniform mixture between the injected spray droplets and ambient air. The axial spray tip penetrations of the test fuels were similar, while the spray width and spray cone angle of E100 were slightly larger than the other fuels. In terms of atomization performance, the E100 fuel among the tested fuels had the largest droplet size because E100 has a high kinematic viscosity and surface tension (Su et.al, 2009).

2.3.1 Experimental setup and procedure

Figure 2.4 shows the schematic of the high pressure swirl injector. The diameter of nozzle exit orifice at the injector is 1.0 mm and operated by varying electric voltages. This apparatus has a conical type air core at the center axis in the nozzle. The purpose is to atomize at a lower injection pressure compared to a conventional port fuel injector. The injection timing and energizing duration of the test injector were controlled by an injector driver (TEMS, TDA-3200H) and a digital delay/pulse generator (Berkeley Nucleonics Corp., Model 555)(Su et.al, 2009).

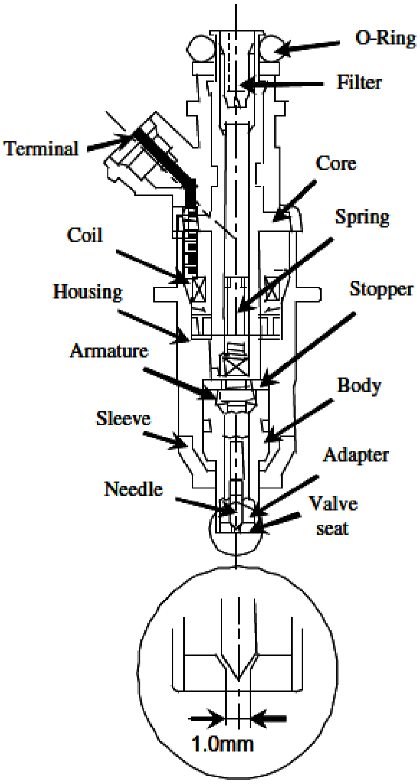


Figure 2.4: Test injector

Source: Su et.al (2009)