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DEVELOPMENT OF A HIGH PRESSURE CHAMBER FOR SPRAY VESSELS

R Ramasamy, P Saranya, T Banu

Department of Aeronautical Engineering, Nehru Institute of Technology,
Kaliyapuram, Coimbatore 6411 05, Tamilnadu, India

***Correspondent Email: athisayas@gmail.com**

ABSTRACT

The analysis of gasoline-ethanol blend sprays in engine-like conditions is of fundamental importance for the study and development of engines. The development of spray characteristics concepts requires an efficient investigation and improvement of the applied systems. For a correct understanding of the processes inside the combustion chamber of an internal combustion engine, especially for smaller sizes of engines, a system is necessary which allows a fast adaptation to the desired parameters and efficient conduction of the experiments. For this purpose, a High-Pressure Chamber (HPC) in a 1:1 scale for small-bore engines (piston displacement approximately 76 mm) with variable optical access (6 windows) has been developed. A high-pressure chamber (HPC) has been designed for the purpose of spray characteristics studies at elevated pressures. The present HPC is designed as a versatile tool and includes the features of a well-defined core region, fast pressurize, ability to vary pressure and clearance, optical accessibility, and capability for piece measurement.

Keywords: High pressure chamber/vessel; fuel spray; internal combustion engine; optical access; clearance

INTRODUCTION

Alcohols have been suggested as an engine fuel almost since automobile was invented (Withrow and Boyd, 1931). 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. As fuel, it is renewable and having a higher octane rating than gasoline with similar storage and dispensing and can be mixed with conventional fuels (diesel fuel or gasoline) (Abata et. al, 1978). It is known as the most suited fuel for spark-ignition (SI) engines (Einecke et. al, 2000 and Thiele et. al, 2002) and can be used in SI engines as pure or by blending with gasoline (Sherman and Stadtmuller, 1987, Einecke et. al, 2000 and Ohmori et. al, 2001). Ethanol can be blend with gasoline at low concentrations without any modification to be used in SI engine (Ohmori et. al, 2003). Ethanol–gasoline blends (gasohol) can be used as fuel in order to substitute some part of gasoline in engine applications (Abata et. al, 1978). It was reported that using gasoline–ethanol blends including ethanol at low concentrations could improve engine performance and exhaust emissions (Einecke et. al, 2000, Thiele et. al, 2001, Saga et.al, 2001 and Ohmori et. al, 2003); such as increasing the octane rating, which is particularly important in unleaded fuel, and reduce carbon monoxide (CO) emissions from the engine (Li et. al, 1991).

Gasahol gain importance within these recent years as alternative fuel due to this high octane number, especially with ethanol which has low carbon (Ahmadi,and Sellens, 1993). This led the gasohol (a mixture of 10% alcohol with 90% gasoline) to be a commercial fuel in over 35 countries of the World including the USA, Canada and (Li et. al, 1991). For combustion applications, drop size distribution, spray angle and penetration factor control the fuel distribution in the combustion chamber (Datta and S.K. Som, 1999 and Seneschal et. al, 2003). So, numerous experimental studies have been performed and theoretical models development to understand the critical mechanisms controlling spray combustion as the spray characteristics like mean drop diameter and spray cone angle play an important role in the process of combustion within a gas turbine combustor (Karimi et. al, 2006). In order to design a combustor using this liquid fuel, processes involving spray formation, droplet evaporation, spray ignition and combustion must be well understood. This multitude of processes makes spray combustion a difficult phenomena to understand.

To analyze these spray characteristics according to the injection duration under ambient pressure conditions and the injection timing in the visualization engine are significant. In order to investigate this spray behavior, the spray velocity can be obtained through the PIV method as a useful optical diagnostics technology and the vorticity can be calculated from the spray velocity component (Amirruddin et. al, 2009) As for the spray properties of different blends of ethanol–gasoline (25%, 50%, 75% and 100% ethanol) as well as pure gasoline can be visualized under various ambient conditions by means of high-speed schlieren photography technique with a comparative analysis of blended fuels and gasoline sprays applied (Tennison and Reitz, 2001).

The motivation of this study is to improve the understanding of spray combustion characteristics. This will include spray angle, penetration length, droplet size, spray patterns, and vaporization rate for varies type of injector. This proposal begins with a brief review of the spray combustion literature, research needs and current problem are defined. Experimental methods are discussed. And, finally the summary of this proposal and the expected findings will be presented and discussed.

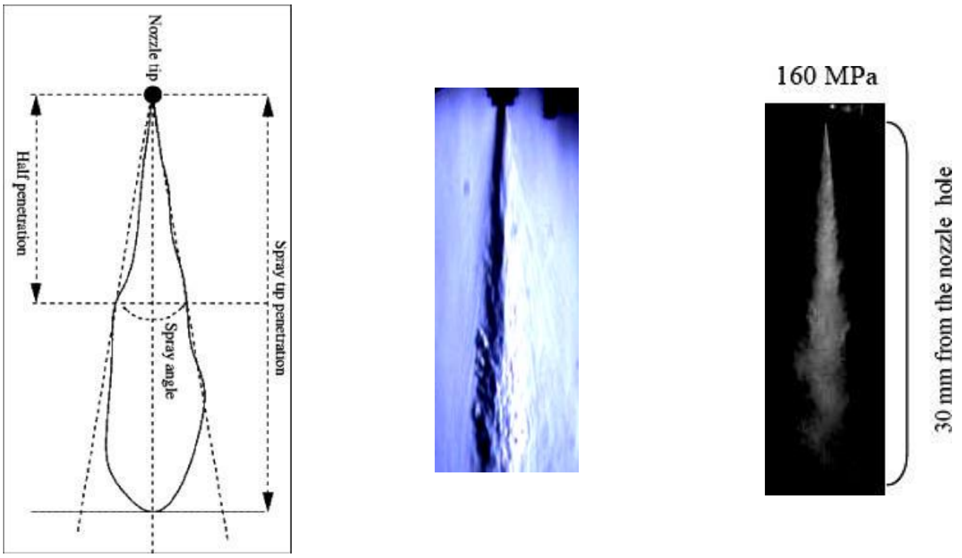
FUEL SPRAY PARAMETERS

For combustion applications, drop size distribution, spray angle and penetration factor control the fuel distribution in the combustion chamber (Li et. al, 1991 and Ahmadi, and Sellens, 1993). So, numerous experimental studies have been performed and theoretical models development to understand the critical mechanisms controlling spray combustion as the spray characteristics like mean drop diameter and spray cone angle play an important role in the process of combustion within a gas turbine combustor (Datta and S.K. Som, 1999). In order to design a HPC using ethanol blend as fuel, processes involving spray formation, droplet evaporation, spray ignition and combustion must be well understood. This multitude of processes makes fuel spray characteristics as shown in Table 1 and combustion as a difficult phenomenon to understand.

Spray features which will be considered are spray tip penetration, spray cone angle and spray tip velocity (Figure 1) which are measured directly from spray images.

Table 1: Spray Characteristics

Injector Design: · Nozzle geometry · Opening time · Closing time · Pintle bounce · Driver capacity delay	**Injection conditions:** · Fuel rail pressure · Injection duration · Injection rate · Single vs. Split injection	**Fuel type:** · Viscosity · Specific gravity · Surface tension · Fuel volatility	**Ambient conditions:** · Pressure · Temperature · Density · Airflow field
Spray structure: · Fuel mass distribution · Spray asymmetries · Offset from injector axis · Collapse vs. Non-collapse	**Spray configuration:** · Cone angle · Penetration · Spray diameter · Wetted footprint	**Droplet characteristics:** · Size · Velocity · Momentum · Weber number · Time history · Spatial distribution	**Others:** · Sac spray · Spray finger · After-injection spray · Spray-to-spray variation · Injector-to-injector spray variation · Spray torque for swirl injector



(a) **(b)** **(c)**

Figure 1: Spray characteristics (a) Spray Features (Seneschal et. al, 2003); (b) Schlieren Image (Amirruddin et. al,2009); (c) Spray images taken at in-cylinder pressures of 2 MPa (Karimi et. al, 2006).

HPC WITH OPTICAL ACCESS

Figure 2 shows the HPC with optical access. The chamber body is made of stainless steel (X2CrNiMo19-14-4) and equipped with six cleanable optical windows made of BK7 and PMMA (Plexiglas). These are four sides rectangular (104 x 80 mm), one round bottom with diameter of 76 mm and an 76 mm diameter optic cylinder installation to emulate CNG-DI chamber cylinder for wetted effect observation as shown in Figure 3. The windows are pressed on the surface of window support by six 5 mm hex-head socket bolts (M4, pitch: 1 mm, length: 30 mm) with PTFE (Fluolion Integra Blue with thickness of 1 mm) as a gasket between the window and its support.

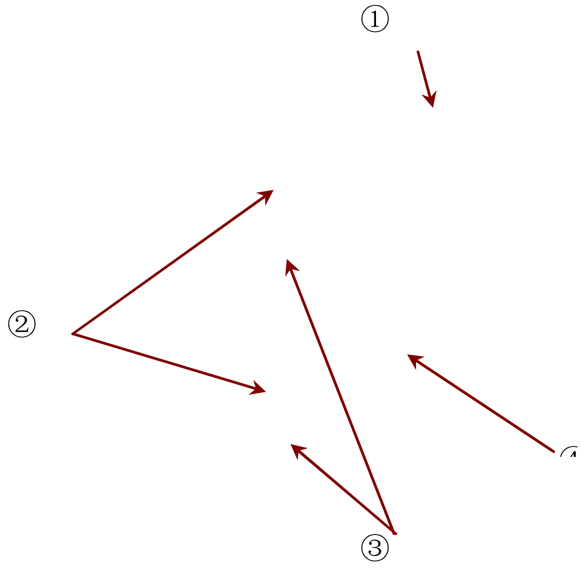


Figure 2: High-pressure chamber with optical access. ①Injector port. ② Windows /Optical access. ③ Window Body. ④Fuel and pneumatic access.

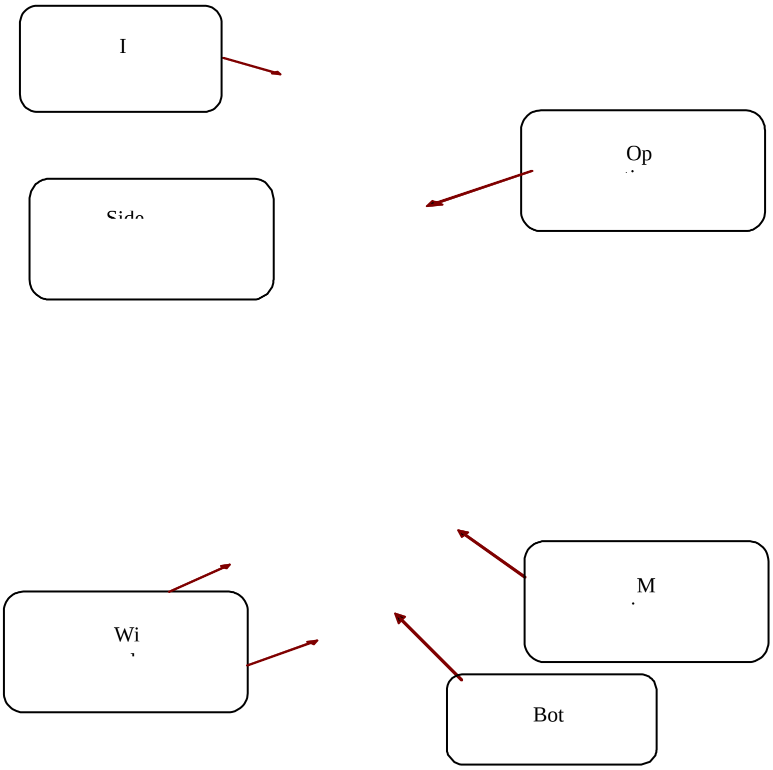


Figure 3: Schematic drawings of the HPC with optical access.

Criteria of the windows for optical access are according to optical qualities such as index of refraction, transparency absorption, UV, colour and homogeneity; and mechanical qualities and physic such as lightness, scratch resistance, impact resistance, ability to be pierce and chemical resistance. BK7 and PMMA (Plexiglas) have been chosen because of different reasons. BK7 is, a strong material (high resistance against pressure) but expensive. Meanwhile PMMA is a very common matter with good optician's properties as shown in Table 2.

Table 2: PMMA and BK7 Mechanical Properties

Characteristic Materials	Young Modulus (Nm^2)	Poisson Coefficient	Volume Weight (kg.m^3	Thermal expansion's coefficient (Kdeg)	Elastic limit (N_m^2)
PMMA	2.5 x 10^9	0.4	1200	7 x 10^5	5.5 x 10^7
BK7	8.5 x 10^{10}	0.21	2510	8 x 10^5	6.5 x 10^9

In PMMA materials, the 5 mm thickness is chosen as the best value for side and bottom windows where else in BK7 sheet, the 3 mm thickness is the best value after considering the good optical properties provided by the curve and the cylinder wall as shown in windows thickness analysis in Table 3. At the top of the chamber, a cover which comes with several different positions (50°, 55°, 60°, 65°, and 90°) of injector ports is designed for a working injection pressure between 60-160 MPa and in cylinder pressure between 1.6-6 MPa. By reducing the thickness of the window, a large aperture of the optical window which is sufficient for video camera visualization, the non-linear laser spectroscopy and scattering experiments can be obtained. Down, at the bottom part of the chamber, a porous plate is installed leading to a small reservoir with the same diameter of the plate for the evacuation remnant fuel or gas.

Table 3: Windows Thickness Analysis

Thickness (mm)	Von Misses max (Nm^2) x 10^7			Displacement max (mm)		
	Cylinder (BK7)	Side PMMA	Bottom PMMA	Cylinder (BK7)	Side PMM	Bottom PMMA
1	4.01	19.6	25.50	0.018	11.30	18.10
2	2.05	10.6	13.10	0.092	7.82	7.75
3	1.35	5.81	6.99	0.0061	3.90	3.22
4	1.04	3.20	5.46	0.0047	1.51	2.18
5	0.86	2.83	3.99	0.0039	0.71	1.32

CONCLUSION

Developing a high-pressure chamber (HPC) with optical access which has a large aperture of the optical window which can be used for the various kinds of laser and X-ray spectroscopy is crucial in exploring the spray research. The high pressure chamber component layout, window sealing methods, bigger access window design and targeting methods all worked in unison for further progressing.

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