Energy 108 (2016) 93–98

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Schlieren visualization of a GDI spray impacting on a heated wall: Non-vaporizing and vaporizing evolutions

L. Allocca*, M. Lazzaro, G. Meccariello, A. Montanaro

Istituto Motori, Consiglio Nazionale delle Ricerche, Napoli, Italy

ARTICLE INFO

Article history:
Received 4 May 2015
Received in revised form
9 September 2015
Accepted 13 September 2015
Available online 20 October 2015

Keywords:
Fuel injection
Wall impingement
Schlieren technique
Air–fuel mixture
Image processing

ABSTRACT

The DI (Direct Injection) in SI (Spark Ignition) engines is rapidly developing and seems very attractive offering the possibility of multi-mode operation, homogeneous and stratified charge, with valuable benefits respect to conventional PFI (Port Fuel Injection). One of the major drawbacks of the GDI-fueled engine is the impingement of liquid fuel on the combustion chamber walls that generally produces an increasing of HC emissions and detrimental effects on the combustion process, like soot formation in the wall guided engines due to the diffusive combustion of fuel film deposits on the piston head.

This paper investigates the structure of gasoline spray-wall interaction generated by a single-hole injector for GDI engines in an optically-accessible quiescent vessel. The axially-disposed hole diameter is 0.200 mm with a L/d ratio of 1.0 while the injection pressure and the wall temperature varied in the range of 10.0–20.0 MPa and ambient to 300 °C, respectively. Injection duration of 1.0 ms was investigated and the nozzle tip-wall distance was 22.5 mm.

Optical investigations were carried out at atmospheric backpressure by an in-line schlieren optical setup using a LED source while the cycle-resolved images of the evolving impact were captured by a C-Mos high-speed camera with a time resolution of 80 μs and a window size of 640 × 464 pixels. The optic-geometrical setup realized a spatial resolution of 0.039 mm/pixel.

The images were treated by a digital processing software for background subtraction and both liquid and vapor contour extractions. The spatial and temporal evolution of the liquid and vapor phases as a function of the wall temperature is described for the different operative conditions.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

The control of the pollutant emissions and of the fuel consumption in internal combustion engines are the more frequent requirements posed from the legislator for the safeguard of the community health. To fulfill such requests, new combustion approaches are investigated, based typically on improvements of the air–fuel mixing and the high-pressure injection of the fuel by common rail-based systems. For SI (spark ignited) engines, the attention is currently focused on the direct injection of the gasoline in the combustion chamber (GDI) because of their advantages, like higher compression ratio, zero pumping losses, and multi-mode operation with respect to the port-fuel injection configuration. GDI technology allows the reduction of HC and CO emissions, especially when the engine works at lean-mixture conditions. To take advantage of all the theoretical benefits derived from GDI applications, it is necessary to work in a stratified mode of the engine map and this requires a strict control of the air/fuel mixing process.

The fuel dispersion in the combustion chamber is governed by the nozzle design, the injection pressure and mainly the interaction of the fuel with the cylinder/piston walls [1–3]. Generally, the wall wetting has to be avoided inside a GDI engine because of its strong influence on the mixture formation and HC emissions.

The second generation of GDI injectors is characterized by a non-axisymmetric multi-hole architecture with a lack of adequate characterization and investigation [4–6]. The specific hole distribution, the orientation and the narrow spray angle cause a strong interaction between each single jet and with the piston wall. It is confirmed from experimental and numerical spray images available in literature [4,7,8].

* Corresponding author.
E-mail addresses: l.allocca@im.cnr.it (L. Allocca), m.lazzaro@im.cnr.it (M. Lazzaro), g.meccariello@im.cnr.it (G. Meccariello), a.montanaro@im.cnr.it (A. Montanaro).

http://dx.doi.org/10.1016/j.energy.2015.09.107
0360-5442/© 2015 Elsevier Ltd. All rights reserved.

The complexities of the spray-wall, the jet–jet or jet-flow field interactions, and their consequence on the combustion in the engine have led many researchers in changing toward simplified experimental configuration considering single-hole injectors and flat walls [9,10]. These configurations are useful for assessing fundamentals of the impact parameters on the mixture preparation and combustion process. Free-jet evolution before the impact, impingement and rebounding with the well-known sticking, spreading, rebounding and splashing regimes can be better isolated for the fuel behavior and the impact parameters [11–13]. Data collected are greatly useful for numerical simulation, too [14,15]. Last but not the least, the temperature of the plate, related with the chemical–physical properties of the fuel, determines the Nukyiama/Leidenfrost regimes [16].

In this work, a basic study of the structure of gasoline spray-wall interaction, generated by a single-hole injector for GDI engine, was investigated in an optically accessible quiescent vessel. Optical measures were carried out for diverse injection pressures and at atmospheric backpressure with the temperature of the wall ranging between 25 and 300 °C, representative of different engine-load conditions, by a direct schlieren optical setup using a LED source. The nozzle-wall distance was chosen as 22.5 mm characteristic of a typical average space at the injection timing in spark ignition engine. The images of the impact were captured by a synchronized C-Mos high-speed camera, window size 640 × 464 pixels, 80 μs time resolution, while the cycle-resolved images were treated by a digital processing software. Spatial and temporal evolution of the liquid and vapor phases as a function of the wall temperature is described in the paper for different operative conditions.

2. Set-up and measurements

2.1. Injection apparatus and test chamber

A pneumatic injection system pressurized the fluid at pressures up to 30.0 MPa and fed the injector. An external TTL signal started an ECU (Electronic Control unit) able to drive the injector and the acquisition system in a synchronous mode. Strategy type, injection duration and pressure were set via ECU. The tests were performed in an optically accessible high-pressure vessel where three orthogonal, 80 mm in diameter, quartz windows permitted the access to the investigated area, a forth one was for housing the injector holder. The vessel was kept at ambient temperature and atmospheric backpressure. A complete description of the experimental setup is reported in [17].

An 80 mm in diameter aluminum flat plate was positioned 22.5 mm downstream the injector tip facing orthogonal to the spray axis. The dish was heated in the range 25–300 °C by electric resistances and controlled in temperature by a J-type thermocouple located in its center at 1.0 mm from the wall surface. A Watlow series 985 thermostatic system fixed and controlled the temperature in the range ±1 °C.

A IHP-279 Magneti Marelli electroinjector was used, single-hole axially-disposed, 0.200 mm in diameter, L/d = 1 with a static flow of 2.45 g/s @100 bar while the exciting current profile was reproduced by the ECU. The profiles of the injection rate were determined by an AVL gauge system working on Bosch tube principle [18] with a total amount of fuel of 3.47 mg/str @ 10 MPa injection pressure and 1.0 ms nominal driving current (1.3 ms effective). Commercial gasoline was used as fluid [ρ = 760 kg/m^3@25 °C].

2.2. Optical set-up

Optical techniques are widely adopted to investigate the spray developments and air–fuel mixture formation [19]. In the present work, the explorations were performed by a schlieren set-up whose schematic view is reported in Fig. 1. An in-line lens-based configuration was arranged. The light source was a high intensity blue (in the web version) LED (52 lumen) with a circular pinhole of 1.0 mm in diameter placed close to the emitter. The light is firstly collimated using a 2 inches lens (L1) having a focal length of 200 mm and passes through the measurement volume, delimited by two quartz windows 80 mm wide and 30 mm thick. A second lens (L2), with a focal length of 500 mm, focuses the light beam in the object plane of the high-speed camera collecting optics. A horizontal knife-edge is placed in the focus plane for the schlieren fulfillment. The diameter of the lenses realized a 50 mm diameter parallel beam through the sample volume that is not tight fitting both the optical accesses and impingement plate diameters. The choice of the authors was to investigate half of the spray impact confiding in a symmetric distribution of the fuel during the event and in the average on several captures.

Finally, the images were captured by a C-Mos high-speed camera (Photron FASTCAM SA4) having a 90 mm macro-focal lens as collecting optics, operating in external mode and synchronized with the injection events. The images were acquired on a 640 × 464 pixels window size and with a time resolution of 80 μs. The resulting spatial resolution was 0.039 mm/pixel. Five consecutive events were acquired by the C-Mos camera for each injection condition for an evaluation of the jets spread. The images were stored on the remote computer for next treatments by digital processing software for extracting both the liquid and vapor contours.

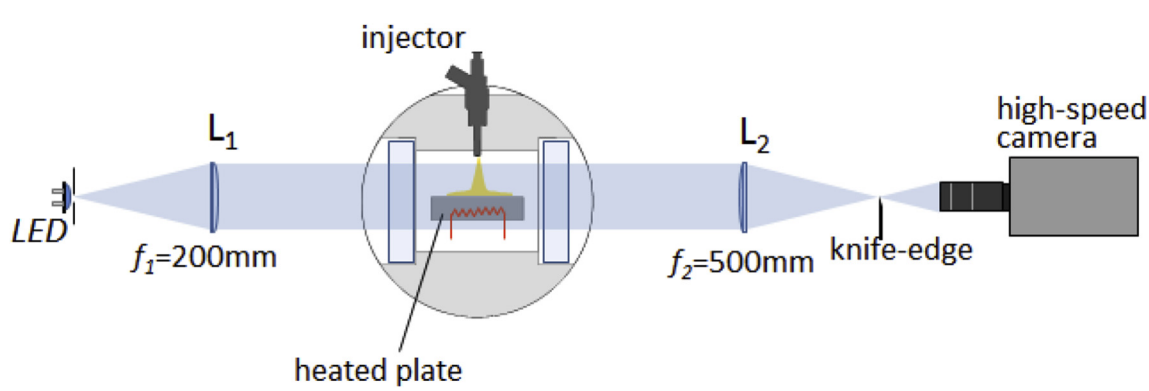

Fig. 1. Schematic of the Schlieren imaging optical set-up.

Download English Version:

https://daneshyari.com/en/article/1730903

Download Persian Version:

https://daneshyari.com/article/1730903

Daneshyari.com