"Distribution-nozzle" concept: a method for Diesel spray distribution in space for charge homogenization by late injection strategy

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Abstract

The paper presents results of experimental investigations of "distribution nozzle" consisting of a common-rail Diesel nozzle and of distribution element made of a highly porous, open cell structures (porous ring). Experimental investigations have been performed in a special low pressure injection chamber. A basic process concerns interaction of a high velocity Diesel jet with a porous structure. Especially a multi-jet splitting effect is responsible for a wide spatial spreading of the impinging Diesel jet. In the paper different aspects of Diesel jet distribution in space using a distribution-nozzle concept are discussed.

The main experimental observations on the fuel distribution in space by Diesel interaction with distribution element in form of thin porous ring or of small cylindrical obstacles are summarized as: significantly reduced axial penetration of jets after interacting with porous element; very wide radial spreading of jets created by Diesel jet interaction with porous element; initial Diesel jet velocity is significantly reduced after interaction with porous structure; initial jet distribution in space is three-dimensional; effect of a multi-jet splitting results in significantly increased jets surface area as compared to the surface area of initial Diesel jets; jet interaction with hot porous structure results in very rapid fuel vaporization inside and outside the porous element.

Introduction

One of the promising ways in development of direct injection Diesel engine is de-coupling of heat release from injection process for realizing of very efficient and clean combustion. These processes should be separated both in time, and in space for permitting of charge homogenization in the combustion chamber volume. Well homogenized charge, together with volumetric ignition source, is required for homogenization of combustion process characterized by an ultra-low emissions level. There are two possible ways for homogenizing of mixture and then homogenization of combustion process in Diesel engine:

- Pre-mixing strategies: decoupling of combustion from the injection (and mixing) process.
- Direct injection and late mixing strategies: acceleration and completing of mixing for late injection strategy.

Basic features of Diesel jet interaction with porous structure and a "distribution-nozzle" concept

The paper presents results of experimental investigations of common-rail Diesel jet impingement on highly porous, open cell structures as well as on small cylindrical obstacles. Diesel jet interaction with a porous structure results in a *multi-jet splitting* observed as "sun shining"-like structure is three dimensional in nature [1,2]. A multi-jet splitting is generated by a Diesel jet interaction with individual pore junctions of porous structures. The quality of the process is not significantly injection pressure dependent making the mixture homogenization possible at different engine operational conditions. A case of a porous ring is shown in figure 1.

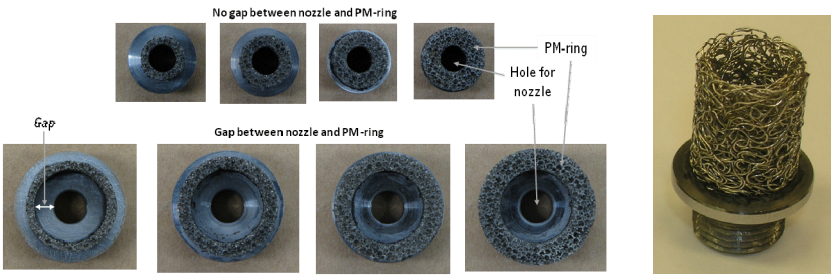

Figure 1. Different configurations of distribution elements (PM-rings) used in present investigation: left- foam structures; right-wire packing structure.

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Results and Discussion

The main experimental observations on the fuel distribution in space by Diesel interaction with distribution element in form of thin porous ring or of small cylindrical obstacles can be summarized as follows:

- significantly reduced axial penetration of jets after interacting with porous element
- very wide radial spreading of jets created by Diesel jet interaction with porous element
- significantly reduced Diesel jet velocity after interaction with porous structure
- initial jet distribution in space is three-dimensional
- significantly increased jets surface area as compared to the surface area of initial Diesel jets
- very rapid fuel vaporization on the hot porous element

In the case of combustion chamber a reduced axial penetration of jets significantly reduces wall impingement and wall wetting. This depends on the porous structure properties, especially on the number of pores and corres-ponding wall junctions available for interaction with Diesel jet. Probably the most important result of a multi-jet splitting for mixture homogenization in engine is very wide radial spreading of initial jets. Figure 2 shows two examples of the spreading.

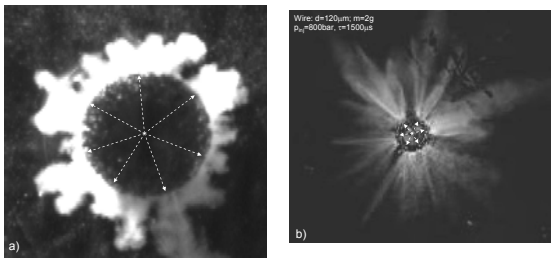

Figure 2. Radial and axial jet spreading by Diesel jet interaction with distribution element; a- PM-ring made of foam structure (injection in oil); b-PM-ring made of wire structure (injection in air); arrows indicate free jets

Diesel jet interaction with a porous structure results not only in significantly reduced jets penetration length but also in drastically reduced jet velocity. A free jet velocity at corresponding distance from the nozzle (without porous ring) is: 145m/s for 500bar, and 210m/s for 1000bar. After interaction with a porous ring the velocities are on the order of 40 to 60m/s (500bar), and for 1000bar on the order of 70 to 100m/s. Jets velocity decreases with increasing distance from the nozzle and for PM-ring is 4 to 5 times reduced as compared to the free jet velocity. The thicker porous ring (i.e. number of pores and corresponding number of wall junctions) the faster is deceleration of the jet being result of wider radial spreading of the initial Diesel jet. A wider radial and axial spreading of the jets results in significantly increased surface area promoting rapid fuel vaporization as well as quick mixing with air. For investigating of fuel vaporization on hot distribution element an injection process has been performed in chamber filled with cold nitrogen and the porous ring temperature could be increased up to 500°C. Especially visible is the effect of ring temperature on the resulting spreading of the fuel represented by a surface area, as presented in fig.3.

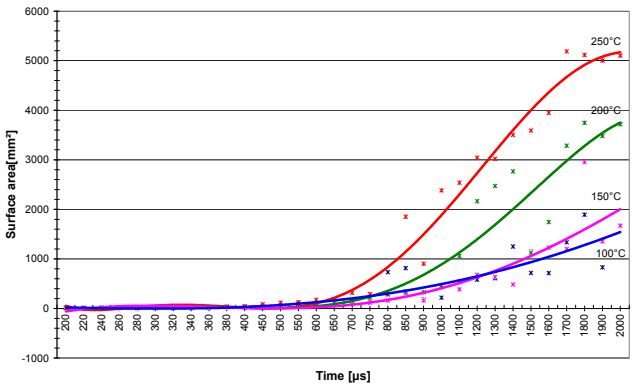

Figure 3. Surface area distribution for Diesel jets interaction with hot porous ring at different time instances after injection begin and different PM-ring temperatures

References

[1] Weclas, M. and Faltermeier, R., *Int. Journal of Engine Research* 8: 399-413 (2007).
[2] Weclas, M., *Journal of Porous Media* 11: 125-145 (2008).