MODELING BOUNDARY LAYER FRO POINT OF VIEW COMBUSTION OF LIQUID AND SOLID FUELS

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Introduction

Combustion processes of fuels always occur in gas-phase. Then the gas-phase occurs as homogeneous or heterogeneous mixture. In the first situation, a course of combustion processes is controlled by kinetics of chemical reactions, in second one, combustion processes run most slowly down. With reference to liquid fuels, vaporization processes of fuel occur, and with reference to solid fuels - decomposition of the solid phase occurs. Decomposition processes need a lot of heat, they run slow down than processes in gas phase.
Influence of pressure on combustion processes of liquid fuels and solid differs from the influence on combustion processes of gas fuels. Pressure increasing decreases the intensity the decomposition both the liquid phase, as and the solid one. Flow of combustion gases intensifies combustion processes.

Experimental

Apparatus and Procedures

Researches were carried with LDV (the Laser Doppler Velocimeter) and PDPA (Phase Doppler Particle Analyzer) the laser and PIV (Particle the Image Velocimetry) equipment. The schema of the laser-measuring-system presents Fig. 1, and PIV - Fig. 2. View of the PIV system presents Fig. 3. Measurement LDV-PDPA realizes in the measuring-space which is intersection of two laser beams: zero Doppler. This space occurs in the area of optical focusing point of the laser-transmitter and has a shape of the rhomboid body.
The general PIV technique involves a multiple exposure photograph of a flow. A photographic image of the particles is obtained for a plane of particles, which has dimensions: the high of an illuminating laser sheet, the width of the image plane, and the thickness of the laser sheet. The light source is controlled to allow two exposures of the particle field to be recorded. The time between the exposures is controlled.

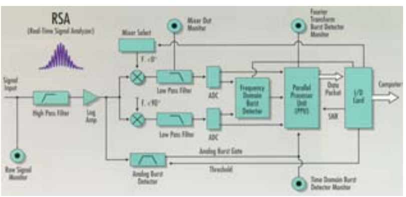
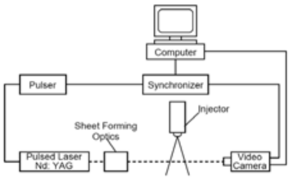


Fig. 1 Outline of LDV-PDPA laser system.

The view of the laser with Bragg Cell presents Fig. 4, the view of the measuring-space and the test chamber presents Fig. 5.



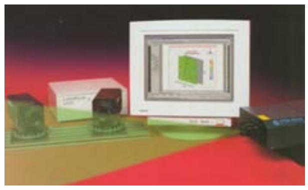


Fig. 2 Outline of PIV system Fig. 3 View of PIV system.

Fig. 4 Laser and Bragg Cell equipment.

Fig. 5 View of LDV-PDPA laser system with for research chamber.

In research of the combustion process of the high speed film camera was used too.

Results and Discussion

Example-research results of the PIV velocity field present Fig. 6. Fig. 7 presents research results with the LDV and PDPA. Fig. 8 presents linear and volumetric droplets distribution as well the Rosin-Rammler dependence. Fig. 9 presents course of combustion process of liquid fuel in the constant volume chamber.

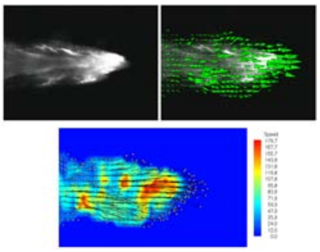


Fig. 6 PIV velocity field for liquid fuel spray.

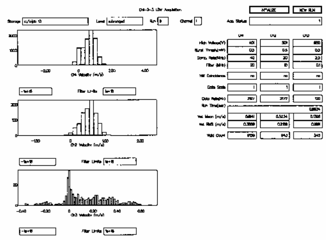


Fig. 7 LDV-PDPA velocity field.

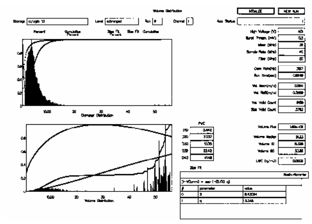


Fig. 8 Linear, volumetric distribution and Rosin-Rammler dependence.

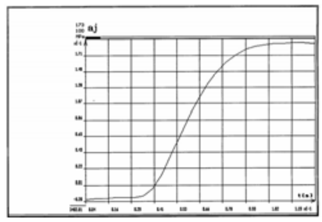


Fig. 9 Course of liquid fuel combustion process in constant volume chamber.

Fig. 10 to presents the view of burnt stripe of solid fuel flown with parallel stream of combustion gases.

Fig. 10 Cross-section of burnt stripe of solid fuel.

Figs. 11 presents cross-section of the boundary layer. Three kinds of boundary layer: laminar, transient and turbulent layers are shown.

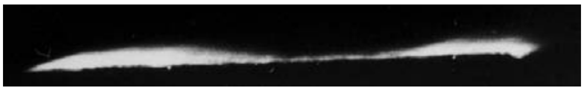


Fig. 11 Cross-section of the boundary layer. for burnt stripe in Fig. 10.

The comparison of burnt of stripe cross-section and the boundary-layer presents Fig. 12.

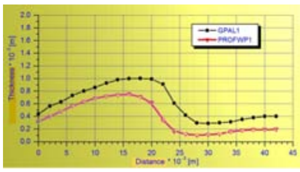


Fig. 12 The comparison of burnt of stripe cross-section and the boundary-layer.

Modeling

Basic assumes of a theoretical model:
- Combustion processes of liquid fuels and solid depend on the boundary layer.
- The velocity of the stream of gases intensifies combustion processes and influences on the thickness of the boundary layer.
- The influence of the pressure on combustion processes of liquid and solid fuels is multiple and relevant with the influence of the stream gases velocity and is relative to the fuel kind.
- The intensification of the decomposition process the fuel connected with pressure increasing of the makes away the flame front from fuel surface.
- The kind of the boundary layer reflects phenomena in the combustion processes of liquid and solid fuels.

Equation of heat balance for the fuel droplet:

$$r^2 \frac{d}{dr}\left(\lambda \frac{dT}{dr}\right) + 2r\,\lambda \frac{dT}{dr} - \frac{\dot{m}\, h_l}{4\pi} \frac{d\left(c_{pg} T\right)}{dr} = 0, \qquad (1)$$

where:
r – linear rate of surface displacement of phase border,
λ – coefficient of thermal conductivity,
T – temperature,
$\dot{m}$ – mass-flow rate of stream of reaction products of liquid phase decomposition,
h_l – decomposition heat of liquid phase,
c_{pg} – specific heat of combustion gases at constant pressure.

Temperature distribution in gas phase of combustion zone presents Fig. 13.

The model takes into account processes occurring in liquid/solid and gas phase, particularly heterogeneous processes of the decomposition individual phase components. The model inclusive processes occurring in gas phase which influence on decomposition processes of the liquid phase. These processes refer to real conditions, during fuel injection to the combustion chamber when droplets are blown by the gas stream and the piston engine movement occurs.

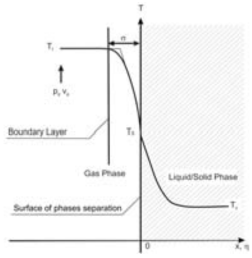


Fig.13 Theoretical model of heterogeneous combustion processes.

Droplets because of their comparatively large inertia are not raised by the gas stream. Especially with reference to turbulent flow, large differences in velocity of gas stream and droplets occur. If the decomposition rate of droplets from the liquid to gas phase smaller than the combustion rate, this is followed by the flame quenching. However the combustion rate can be indeed intensified at the occurring of turbulence stimulation of the gas stream of flowing fuel droplets.

Conclusion

The close relationship between the boundary (laminar, transient and turbulent) layer and the combustion rate of liquid fuels, as well as solid occurs, whereupon data Fig. 10 and 11 point.

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