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TEST STAND FOR MODELLING OF COMBUSTION PROCESSES OF LIQUID FUELS

Antoni Jankowski

Air Force Institute of Technology
Ksiecia Boleslawa Street 6, 01-494 Warsaw, Poland
tel.: +48 22 6851111, fax: +48 22 8364471
e-mail: antoni.jankowski@itwl.pl

Abstract

Boundary layer is a reflection of the phenomena occurring in the combustion of liquid fuels with perpendicular to the surface of adding mass. For study the influence the thermal boundary layer on the process of combustion a special test stand has been developed, in which the flow of the medium with the addition of mass can be realized. Quartz windows and magnesium oxide powder, which is added for allow visualization of the airflow stream. Quartz windows are placed in the sidewalls of the chamber. The paper presents the test stand. The test stand consists of the following main components: test chamber, the main air preparation module, auxiliary air preparation module, module of particulate cartridge, air compressor, compensation tank, control unit and accessories in the form of filters, valves, pressure gauges and automatic control. Velocity of flow through the test chamber is controlled with air pressure from air preparation units and with the location of the regulatory fin at the end of the measuring chamber. The cartridge unit produces a homogeneous mixture of MgO particulates in air. Test results of the axial velocity profile at a distance of L=0.35 m obtained with LDA and PDPA laser equipment and ANSYS FLUENT numerical computations. Important for the combustion process is laminar boundary layer in laminar flow and laminar sublayer in turbulent flow.

Keywords: *combustion processes test stand for combustion modelling, laser method, Laser Doppler Velocimeter, Phase Doppler Particle Analyser, ANSYS FLUENT*

1. Introduction

Boundary layer is a reflection of the phenomena occurring in the combustion of liquid fuels with perpendicular to the surface of adding mass. For study the influence the thermal boundary layer on the process of combustion a special test stand has been developed, in which the flow of the medium with the addition of mass can be realized. Quartz windows and magnesium oxide powder, which is added for allow visualization of the airflow stream. Quartz windows are placed in the sidewalls of the chamber. This way of organizing research allows determining the real value of the flow velocity at the designated points of measurement using laser measurement systems LDV (Laser Doppler Velocimeter) and PDPA (Phase Doppler Particle Analyser) [7, 8, 10, 12]. In this paper test stand to study the combustion process in the conditions of the model are presented. The test results under the model conditions will be used in calculations of numerical modelling with the use of ANSYS FLUENT [1, 2]. The test stand reflects the combustion processes which occur in the boundary layer [10].

Combustion processes are the subject of modelling using computer programs. In this regard, widely distributed computational codes are fluid dynamics (CFD – Computational Fluid Dynamics). Modelling of combustion processes is of interest to a number of authors [2, 3, 4, 5, 6, 15].

2. Test stand and test results

In Fig. 1 test stand is shown, and in Fig. 2 – scheme. The test stand consists of the following main components: test chamber, the main air preparation module, auxiliary air preparation module, module of particulate cartridge, air compressor, compensation tank, control unit and accessories in the form of filters, valves, pressure gauges and automatic control.

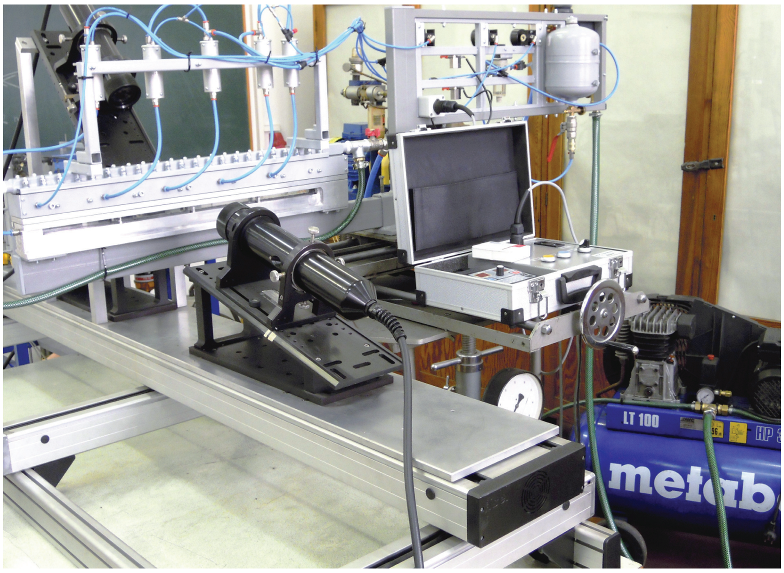

Fig. 1. Picture of test stand for modelling of combustion processes

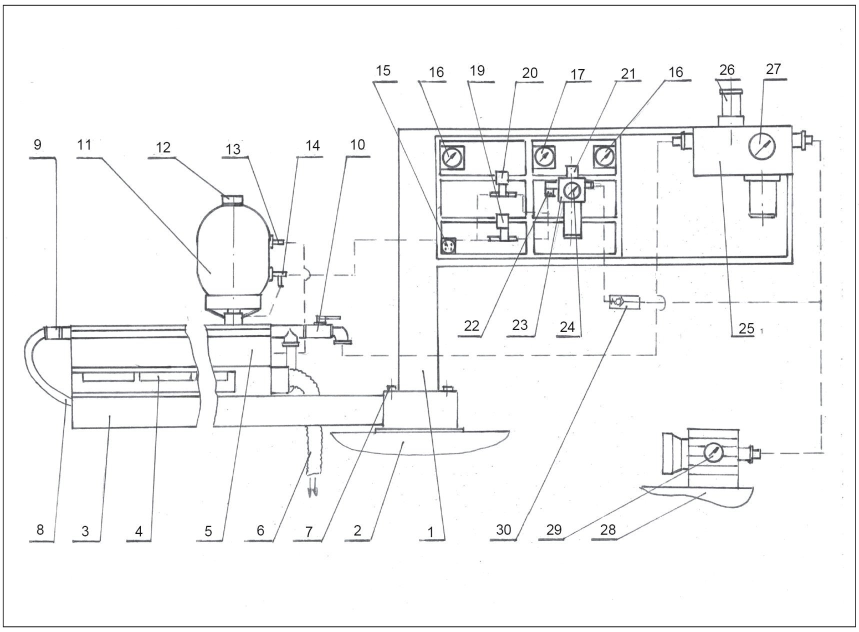

Fig. 2. Scheme of the test stand: 1 – supporting frame of test stand , 2 – measuring table with possibility of sliding horizontal and vertical, 3 – supporting bar of the measuring chamber, 4 – measuring window, 5 – unit of the measurement chamber, 6 – pipe line of ventilating hood of the powder, 7 – screws fixing the supporting bar, 8 – air pipe line connecting the inlet to the inlet chamber, 9 – inlet nozzle, 10 – valve, 11 – powder cartridge, 12 – stopper 13 – powder outlet port 14 – air supply connector, 15 – electrical connector , 16 – gauge air pressure in the mixing chamber, 17 – gauge air pressure in the measuring chamber, 18 – gauge pressure of powder carrier, 19 – 1 control valve , 20 – 2 control valve , 21 – pressure adjustment knob, 22 – nozzle with variable throttle section, 23 – auxiliary service unit, 24 – pressure gauge, 25 – main unit of air preparation, 26 – air pressure adjustment knob, 27 – pressure gauge, 28 – compressor with balance tank, 29 – pressure gauge, 30 – feedback valve 31 – inlet chamber, 32 – diffusers, 33 – mixing chamber 34 – inlet nozzle of powder, 35 – insert, 36 – measuring chamber, 37 – insert with porous element, 38 – body of measuring chamber, 39 – nozzle of air flow velocity control, 40 – screw of adjusting of nozzle position of , 41 – control fin, 42 – quartz pane, 43 – inlet nozzle of measuring chamber 44 – connecting screws, 45 – connection ventilation pipe line, 46 – ventilating hood, 47 – outlet filter, 48 – removable pipe line of mixing chamber, 49 – removable pipe line the measuring chamber 50 – spraying device of powder, 51 – mixing nozzle

The most important unit of test stand is test chamber, which is shown in Fig. 3, and its design – in Fig. 4.

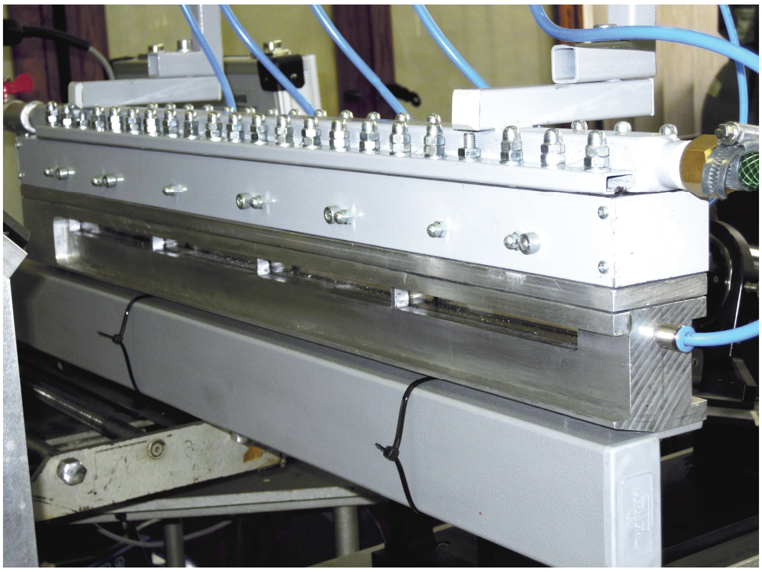

Fig. 3. Test chamber

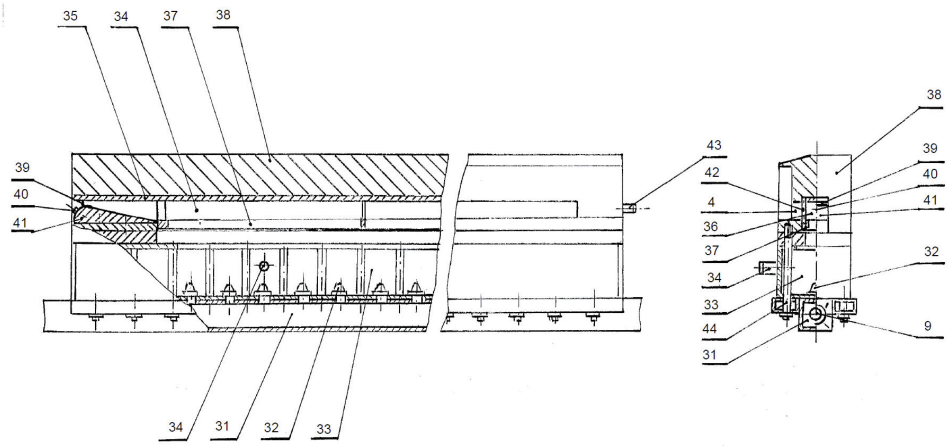

Fig. 4. The design of test chamber (indications according to Fig. 2)

The test chamber consists of an inlet chamber, the mixing chamber and measuring chamber. The air from the main air preparation unit is supplied to the inlet chamber at its two opposite sides. Through the diffuser in the lower part of the mixing chamber, air goes from the inlet chamber to the mixing chamber. In the mixing chamber, air is mixed with MgO particles supplied by the nozzles in the chamber wall. Then the grid separating the mixing chamber from the measuring chamber passes into the measuring chamber. At the same time, the measuring chamber is supplied air mixed with particles from the particle cartridge unit. Velocity of flow through the test chamber is controlled with air pressure from air preparation units and with the location of the regulatory fin at the end of the measuring chamber. The cartridge unit produces a homogeneous mixture of MgO particulates in air. After opening the valve, an outflow of MgO particulates to the mixing chamber and the measuring chamber occurs. The MgO particulates to mix with the air used air from the auxiliary unit of air preparation. The air pressure from the auxiliary air preparation unit should be higher than the pressure of main air preparation unit to allow for delivery of the mixture into the mixing chamber.

The test chamber air supply consists of an air compressor, operated by an electric motor and with the balance tank having a volume of 80 dm^3. Fig. 5 shows a scheme of the pneumatic system.

Fig. 6 shows the blocks of main and auxiliary air preparation.

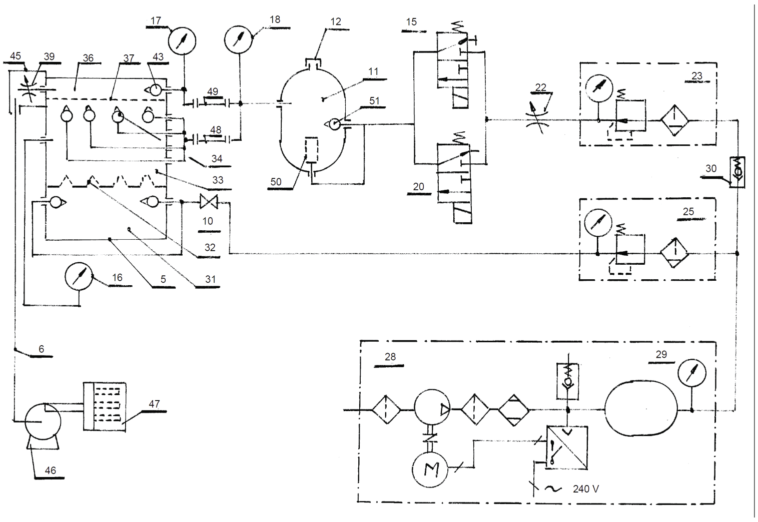

Fig. 5. Schema of the pneumatic system of test stand (indication according to Fig. 2)

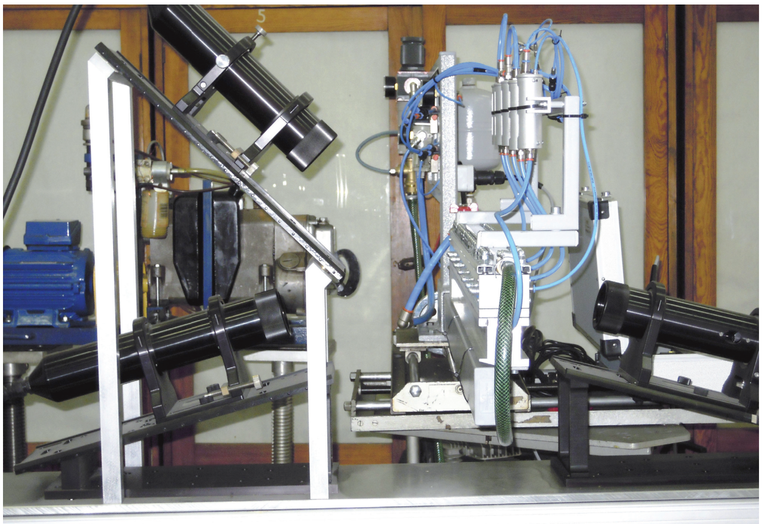

Fig. 6. Blocks of main and auxiliary air preparation

All components of the air supply unit were placed on a one frame, and on the other frame – sliding connected to the test chamber was placed. The frame of the test chamber can be slide relative to the frame of the air unit is attached to the measurement table. The slope of 15 ° test chamber allows that laser beam going into the chamber can be set at an angle of 90 ° with respect to the measurement windows. This facilitates measurements using laser devices. The figures 7 and 8 show the equipment with measuring devices and during the tests with the use of laser equipment.

Test results of medium flow velocity profile were performed along the length of the channel of the test stand in several measuring points along the height and compared with the results of computer simulations. Fig. 9 shows example of the results of measurements of stream velocity at a distance of 350 mm. At smaller distances, flow simulations give higher top velocities of flow from the identified experimentally and with increasing distance from the beginning of flow simulation results were better matched to the measurement results.

3. Conclusions

Boundary layer is the flow region directly adjoining to the liquid fuel surface, in which stream of fluid flows parallel to it where the changes occur in the fluid parameters, such as speed, temperature, pressure, density, etc. perpendicular to the surface [10].

Boundary layer is always at the fuel injection into the combustion chamber, i.e. upon relative movement of the fuel and the gas medium.

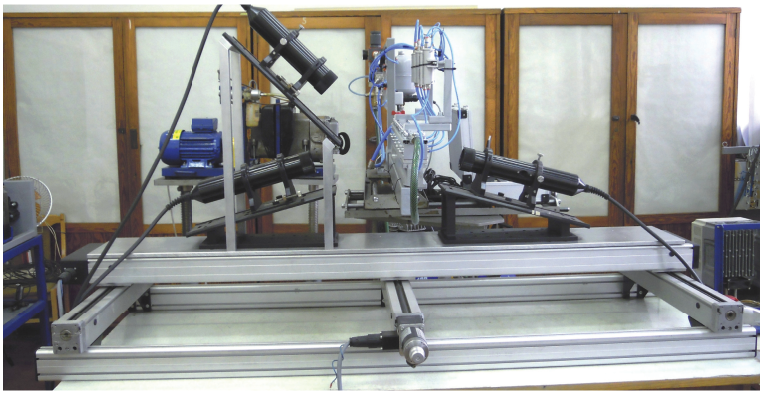

Fig. 7. The test stand with the laser-measuring device

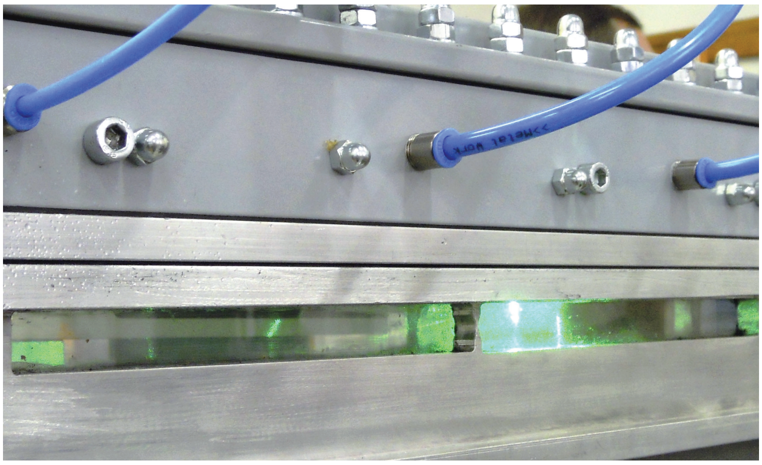

Fig. 8. Test chamber during testing with the use of laser device; visible reflections of the laser beam

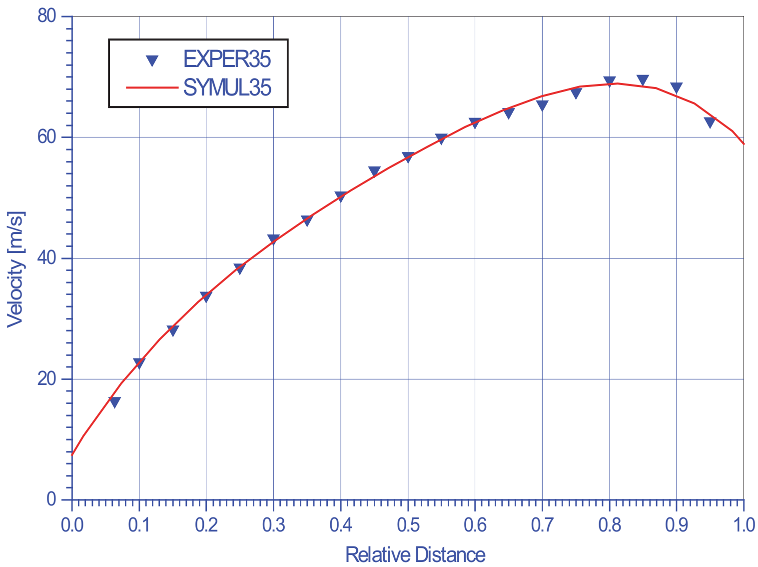

Fig. 9. Test results of the axial velocity profile at a distance of L=0.35 m obtained with LDA and PDPA laser equipment and ANSYS FLUENT numerical computations

The developed test stand allows the measurement of the parameters of the boundary layer along the surface of the fuel in the conditions with addition of the mass perpendicular to the surface of the fuel in the modelling conditions.

Fundamental measurements of the boundary layer parameters relate to the velocity distribution. The combustion process is also important to determine the parameters of the thermal boundary layer.

Important for the combustion process is laminar boundary layer in laminar flow and laminar sublayer in turbulent flow.

Bibliografia

[1] *ANSYS FLUENT 12.0 Theory Guide*. 2009.

[2] Chrigui, M., Sadiki, A., Janicka, J., Hage, M., Dreizler, A., *Experimental and Numerical Analysis of Spray Dispersion and Evaporation in a Combustion Chamber*, Atomization and Sprays, Vol. 19, pp. 929-955, 2009.

[3] Chryssakis, C., Assanis, D. N., *A Unified Fuel Spray Breakup Model for Internal Combustion Engine Applications,* Atomization and Sprays, Vol. 18, pp. 375-427, 2008.

[4] Costa M., Iorio, B., Sorge, U., Alfuso, A., *Assessment of a Numerical Model for Multi-Hole Gasoline Sprays to be Employed in the Simulation of Spark Ignition GDI Engines with a Jet-Guided Combustion Mode,* Proceedings SAE2009 Powertrains, Fuels and Lubricants Meeting, Florence (Italy), SAE Paper 2009-01-1915, 2009.

[5] Gao J., Moon S., Zhang Y., Nishida K., Matsumoto Y., *Flame Structure of Wall Impinging Diesel Fuel Sprays Injected by Group-Hole Nozzles,* Combustion and Flame, Vol. 156, pp.1263–1277, 2009.

[6] Genzale, C. L., Reitz, R. D., Musculus, M. P. B., *Optical Diagnostics and Multi-Dimensional Modeling of Spray Targeting Effects in Late-Injection Low-Temperature Diesel Combustion,* SAE International Journal of Engines, Vol. 2, pp. 150-172, 2010.

[7] Jankowski, A., *Laser research of fuel atomization and combustion process in the aspect of exhaust gases emission*, Journal of KONES Powertrain and Transport, Vol. 15, No. 1, pp. 119-126, 2008.

[8] Jankowski, A., *Laser research of fuel atomization and combustion process in the aspect of exhaust gases emission*, Journal of KONES Powertrain and Transport, Vol. 15, No. 1, pp. 119-126, 2008.

[9] Jankowski, A., Sandel, A., Seczyk, J., Jankowska-Sieminska, B., *Some problems of improvement of fuel efficiency and emissions in internal combustion engines,* Journal of KONES Internal Combustion Engines, Vol. 9, No. 3-4, pp. 333-356, 2002.

[10] Jankowski, A., *Study of the influence of pressure, speed and type of gas stream on the combustion process, S*cientific Papers of the Air Force Institute of Technology, Issue 28, (in Polish) Warsaw 2010.

[11] Jankowski, A., Czerwinski, J., *Memorandum of Prof. A. K. Oppenheim and an example of application of the Oppenheim correlation (OPC)* for the heat losses during the combustion in IC-engine,* Journal of KONES, Vol. 17, No. 2, pp. 181-104, 2010.

[12] Jankowski, A., *Laser Research of Fuel Atomization and Combustion Processes in the Aspect of Exhaust Gases Emission,* Journal of KONES Powertrain and Transport, Vol. 15, No. 1 pp. 119-126, Permanent Committee of KONES, Warszawa 2008.

[13] Jankowski, A., *Some Aspects of Heterogeneous Processes of the Combustion Including Two Phases*. Journal of KONES. Internal Combustion Engines. Vol. 12, No. 1-2, pp. 121-134, Permanent Committee of KONES, Warszawa 2005.

[14] Payri, F., Lujan, J. M., Guardiola, C., Rizzoni, G., *Injection Diagnosis through Common-Rail Pressure Measurement,* Proceedings of the Institution of Mechanical Engineers, Part D, Journal of Automobile Engineering, Vol. 220 No. 3, pp. 347-357, 2006.

[15] Xia, J., Luo, K. H., *Conditional Statistics of Inert Droplet Effects on Turbulent Combustion in Reacting Mixing Layers,* Combustion Theory and Modelling, Vol. 13, pp. 901-920, 2009.