TURBULENT FLOW FIELD MEASUREMENTS IN A FAN-STIRRED COMBUSTION VESSEL

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Abstract This study is part of a project that aims at getting a better understanding of the interaction between flame and turbulence. An accurate description of the interactions requires a prior characterization of the turbulent flow field in the combustion vessel. The objective of the present work is to provide a precise characterization of the turbulence parameters. Spatial integral length scales and turbulence intensity will be particularly investigated.

CONTEXT

Over the past decades, improving fuel consumption of internal combustion engines and accordingly reducing pollutant emissions has become a major societal issue. One of the most promising ways to reduce emissions among powertrain technologies is engine downsizing. However, many technical difficulties related to severe operating conditions (high pressure, high temperature and high dilution rate) still need to be overcome to achieve high performances. A thorough understanding of the flame propagation in such conditions and of the combustion processes occurring within the cylinder is still a challenging issue for designing more efficient engines. This involves complex interactions between fluid dynamics, thermodynamics and chemical processes. In this study, we essentially focus on flame/turbulence interactions.

EXPERIMENTAL SETUP

Turbulent premixed flames are studied in a spherical combustion chamber, as already done in similar studies in literature [1, 2, 3, 4]. Turbulence is generated by six identical four-blade fans located close to the wall in the combustion chamber and positioned in an octahedral configuration (see figure 1). This experimental setup allows to vary easily the turbulence characteristics by changing the fan speed, pressure and temperature conditions, and thereby exploring extensively the different regimes of the turbulent premixed combustion. The objective of the present paper is to investigate the effects of the thermodynamical conditions and the rotational fan speed on the turbulence characteristics. The vessel is equipped with four windows (inner diameter of 70mm) allowing a full visualization of the central zone of the chamber. Velocity fluctuations are measured via both Laser Doppler Velocimetry and Particle-Imaging Velocimetry. On the one hand, 2D-field of the mean and the RMS (Root-Mean-Square) velocities in the spherical vessel are obtained from 2D-PIV. On the other hand, two-component LDV is used for local measurements of the mean and RMS velocities.

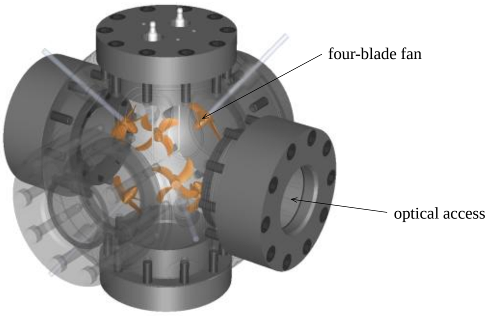

Figure 1. Scheme of the turbulent vessel

RESULTS

Combustion diagrams are built on homogeneity and isotropy assumptions. As shown in Figure 2, the present experimental setup allows to create a nearly homogeneous turbulence in a central area of about 45mm diameter. Measurements obtained from the different techniques are compared and their limitations are highlighted. Figure 3 presents a comparison between LDA and PIV results. Values of U_{rms} and V_{rms} are nearly equal whatever the fan speed, this confirms the isotropy assumption. However, the turbulent fluctuations, determined by PIV are up to 20% smaller compared to the LDV results. This deviation may be due to the lower spatial resolution of PIV compared to LDV, which causes a low-pass filter on the velocity fluctuations.

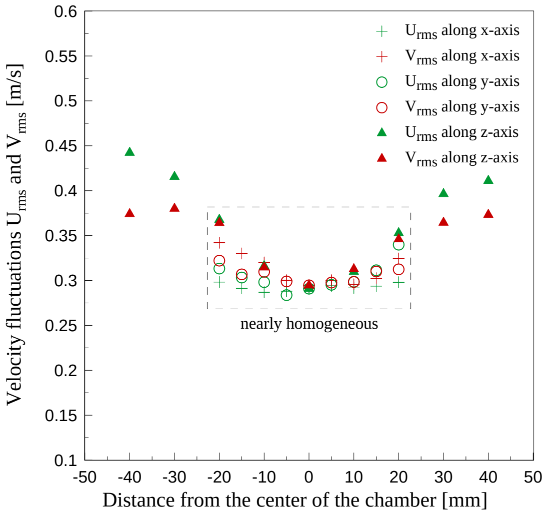

Figure 2. Evolution of the velocity fluctuations along the x, y, z-axis

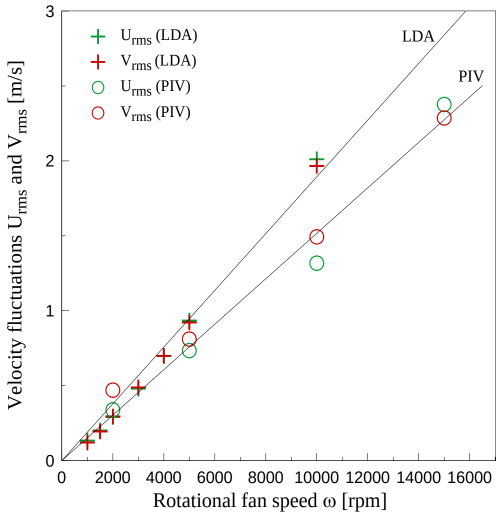

Figure 3. Effect of the rotational fan speed on velocity fluctuations

Power spectral density functions are also investigated. Effect of the rotational fan speed is presented in Figure 4. As the fan speed increases, the $k^{-5/3}$ inertial range becomes larger and higher frequencies fluctuations appear.

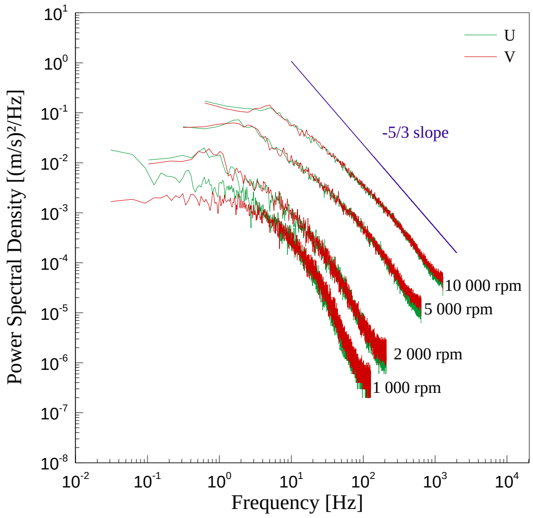

Figure 4. Power spectral density functions at different fan speeds

Conclusion underlines that the turbulence is nearly homogeneous and isotropic in the central measurement region. The integral length scale is found to be independent of the fan speed and of the pressure. Changes in the RMS turbulent velocity affecting the flame front will be achieved by changes in the rotational speed of the fans. This study is the basis of the investigation of interactions between flame and turbulence. Different combustion regimes could be explored from the wrinkled to the corrugated flames. The influence of turbulent parameters (such as turbulence intensity and integral length scale) on the flame properties (turbulent flame velocity, flame wrinkling…) will be investigated in a further work.

References

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