Investigation of the stirring process in a turbulent jet by means of Particle Image Velocimetry

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Combustion problems involve strong coupling between chemistry, transport and fluid dynamics therefore turbulent combustion prediction is a very broad subject. The difficulties are a result of several factors.

First, it is important to recognize that the overall combustion process depends on several distinctly different physical mechanisms. These include turbulent stirring, molecular diffusion, and the reaction kinetics. Further complicating the issue is the extreme range of length and time scales over which these processes act. Turbulent stirring acts on scales ranging from the integral scale down to the Kolmogorov scale.

For these reasons, a complete description of the stirring process is the basis for the evaluation and verification of non-premixed diffusion controlled combustion processes. In the paper, the characterization of the interface kinematics is analyzed in detail.

The characterization of the interface kinematics is a crucial point for the evaluation of non-premixed diffusion controlled combustion processes. When a non-diffusive tracer is introduced into part of a gaseous flow, it determines the establishment of an interface defined as the surface of the flow where the concentration of the tracer is discontinuous passing from zero to a finite value on an infinitely thin interval. In other words, an interface is the place of the points in space where the tracer concentration gradient is infinite.

The relevance of the interface comes from the consideration that it can be considered a direct marker of the evolution of the stirring process and, for this reason, of the diffusive mixing one.

Experimental evaluation of the interface is discussed in relation of an experimental test rig, which has been purposely designed in order to be suitable for the experimental/numerical comparison. The technique of particle seeding and of optical characterization on the interface is thoroughly described in order to stress the constraints and difficulties, which have to be faced to obtain both single and statistical characterization of the interface and hence of the stirring process.

Some comparison between the different fluid-dynamic structures, obtained in properly conditions, has been reported here to give some results about the effect of the jet velocity on the interface structure. Furthermore the results of the PIV measurements were analyzed for characterize the whole velocity field.

The measurement methodology must be able to evaluate some fluid-dynamics quantities, which are relevant for which regard the stirring process itself.

The present paper reports flow visualizations and PIV measurements of a 3-D transitional jet issued into a confined space. The study is motivated by the fact that some studies on the stirring process in the past have been conducted for two-dimensional configurations.

The experimental results, suggest that ensemble of structures, i.e. a simple multi-scale system, can be used in order to explore all possible evolution of the system itself. This tool can be exploited to identify mixing isothermal regimes and to give statistical averages of the most relevant parameter affecting the stirring/mixing process.

Furthermore, it was observed that there is an increase in the number of vortical structures per unit length for increasing the local Re-values, indicating an increased vortex formation frequency with increasing Re. As a result, the distance between the two consecutive vortical structures decreases with increasing Re. Moreover, a PIV analysis has been carried out to characterize the velocity field in the experimental apparatus and to identify the contours of the material surface. Differences in statistical properties between the various conditions of the jet flows were reported.

The differences are related to the differences in structure between the various cases.

Primary coherent structures occur in the near field of the presented cases, which can be revealed by the instantaneous velocity field.

Data have been presented for the instantaneous velocity profiles for fixed longitudinal coordinate. Results reveal a close coupling between the mean velocity distribution and the turbulence intensities.

The effect of the Reynolds number depends on the region of the jet considered. In the interface region, where the moments are higher, its effects can be seen more clearly. The length of the potential core region decreases with increasing Reynolds number.

Moreover another important issue in the analysis of the stirring process is the Lagrangian evaluation of some peculiar characteristics like the 'stretching' and 'folding' of material surfaces.

These kinds of phenomena were analyzed by evaluating the instantaneous mean velocity at different y-positions to show the various features of the stirring process as a function of the different feeding conditions.