NUMERICAL INVESTIGATION OF MIXING IN INTERMITTENT JETS

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Abstract Simulations of an incompressible liquid turbulent jet are performed with the aim of investigating the mechanisms responsible for generating flow structures that act to increase the passive scalar mixing. The framework uses the Large Eddy Simulation approach to account for turbulence and the Volume of Fluid method to represent the liquid phase.

INTRODUCTION

Today, many internal combustion engines are subject to increasing demands of efficiency and reduced level of emissions. This is especially true for automotive engines where emission requirements are frequently regulated. It is therefore important to consider the prerequisites for a favorable combustion, one of which is the process of delivery and vaporization of liquid fuel. By changing the conditions associated with fuel injection one can influence the generation of different flow structures and thereby alter the in-cylinder state prior to ignition.

As many studies have shown, increased jet mixing rates and ambient fluid entrainment can be attained due to unsteady injection boundary conditions. Musculus [1] derived a 1D model for the turbulent decelerating jet, showing the evolution of an entrainment wave. Hu et al. [2] showed the separation of coherent vortical structures at the tail of a jet, after the end of injection, by vortex core rendering. With the capacity of modern fuel injectors to be controlled in injection duration and frequency, the understanding of the mixing governing mechanisms is important, in search of different optima.

METHODOLOGY

A liquid jet is injected into a domain of ambient fluid (see Figure 1). The injection cross-section is circular with diameter D. The injection scheme consists of a periodic repetition of T1 (injection duration) and T2 (non-injection duration). The cross-streamwise size of the computational domain is 8D x 8D and the length in the streamwise direction is 24D. The run cases will represent a variation of Weber number, Reynolds number, density ratio and injection scheme parameters.

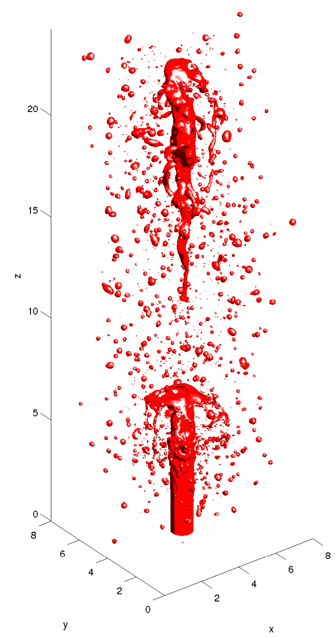

Figure 1. Illustration of jet break-up.

The semi-compressible three dimensional Navier-Stokes equations are solved using a higher order finite difference code.

The computations use Large Eddy Simulation (LES) to account for turbulence and Volume Of Fluid (VOF) to account for the liquid break-up.
The mechanisms at work are to be studied through the contribution of the different terms in the vorticity transport equation (eq 1) to the strength and formation of large scale vorticies.

$$\frac{\partial \omega_i}{\partial t} + u_j \frac{\partial \omega_i}{\partial x_j} = \omega_j \frac{\partial u_i}{\partial x_j} - \omega_i \frac{\partial u_j}{\partial x_j} - \varepsilon_{ijk} \frac{\partial (1/\rho)}{\partial x_j} \frac{\partial p}{\partial x_k} + \frac{\mu}{\rho} \frac{\partial^2 \omega_i}{\partial x_j^2} \quad (1)$$

One may note the contribution to vorticity production through the left hand side terms, of which the first two are the vortex stretching term and the dilation term respectively. The paper will consider the size and distribution of each term during the evolution of the break-up dynamics.

AIM OF THE PAPER

The main aim of the present work is to study the mechanisms that control the mixing processes of the intermittently injected turbulent incompressible jet. The paper considers the effects of intermittent injection on the initial break-up of a fuel jet and its subsequent mixing with the surrounding ambient fluid. The character of intermittent injection is compared to that of the quasi-steady jet in terms of ambient air entrainment and fuel jet break up rates.

References

[1] M. Musculus. Entrainment waves in decelerating transient turbulent jets. *J. Fluid Mech.* **638**: 117–140, 2009.
[2] B. Hu, M. Musculus and J. Oefelein. The influence of large-scale structures on entrainment in a decelerating transient turbulent jet revealed by large eddy simulation. *Phys. Fluids* **24**: 045106, 2012.