Abstract

The purpose of the injection system in Diesel engines, and in general, of any Direct Injection engine, is the delivery of a high-quality air-fuel mixture, in such a way that an efficient combustion is achieved whilst pollutant and noise emissions are minimized. Computational Fluid Mechanics (CFD) techniques have been one of the key tools that helped fastest development of injection system over the last decades.

Among all processes that need to be included in computational models of sprays (cavitation, flow detachment, boundary layer development, etc.), the atomization or break-up of the liquid vein is probably the most complicated one. This is because physical phenomena that governs that process are not fully understood yet. Furthermore, the strong link existing between the flow inside the injector nozzle and the spray behavior is, in general, poorly simulated. The present Thesis has focused on these two aspects of the injection process: the atomization of the fuel, and seamlessly simulating the internal flow and the spray.

A new model, called Eulerian Spray Atomization (ESA), has been developed and implemented in the open source CFD software OpenFOAM ® to simulate the whole injection process. ESA model is based on a homogeneous flow description under an Eulerian framework; in other words, the air-fuel mixture is considered as a single fluid and the mixing process is modeled by means of two new transport properties: the liquid mass fraction and the interfacial surface density. The ESA model has been verified by comparison with Direct Numerical Simulations of Diesel sprays and with analytical solutions of simplified problems. It has also been validated with a large experimental database.

Thus, this work provides a new and valuable tool, the ESA model, that allows improving the understanding of direct injection processes. One of the outcomes obtained by using it is that, as a result of fuel being considered as a compressible fluid, the expansion process taking place inside the injector has a cooling effect, however the viscous friction at walls heats up the liquid. Another interesting finding is that lighter fuels atomize faster, therefore increasing the fuel temperature inside the injector is recommended in order to improve the atomization and so the combustion efficiency.