Numerical and experimental study of aircraft engine ignition

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Abstract

The aim of this study is to develop and validate an ignition model, which could be combined with a RANS code to predict ignition/re-ignition of an aircraft engine. This model will be validated using a data base acquired on a test bench reproducing a simplified combustion chamber. A simulation of the two-phase flow inside the chamber will be performed and compared with experimental data.

Introduction

With the reduction pollutant emissins level, industrials must design novating combustion chamber, allowing lean combustion. In the cases of critical conditions, ignition can't be correctly predicted by current methods used in industry. A parametric experimental study on a real combustion chamber is very expensive. CFD remains the cheaper solution, although modeling of the two phase flow field inside the chamber is rather complex. Moreover, the complete modelling of ignition needs great computation cost, to take into account plasma effects and detailed chemistry schemes amongst other phenomena.

The solution proposed by ONERA is a simplified ignition model, which could be coupled with a RANS code, to simulate the ignition of a combustion chamber by a spark plug. Such a model had been developped through three thesis at ONERA. Quintilla[1] has developed a 0D ignition model, allowing to compute the temperature growth of the ignition kernel. Ouarti[2] used this model to perform a 2D axisymetric RANS simulation of ignition cases. Although these simplifications, ignition tendencies were well reproduced, and the model allowed to discriminate several cases for which ignition were possible or not. Recently, García-Rosa[3] developped an 1D ignition model, which enabled us to compute the growth of the ignition kernel. This model has been partially validated for gaseous, monodisperse and polydisperse two phase mixtures.

Materials and Methods

Experimental studies have been done on the ONERA MERCATO facility. The test rig is composed of a square section combustion chamber. The fuel is injected by a pressure-swirl atomizer. The injection system is the same as those used in real combustion chamber. Optical accesses allow measurements of the flow field thanks to LDA or PDI. To ignite the two-phase flow, a spark plug with variable positions is used.

Initial conditions for the ignition model, like the kernel size of the energy deposit, were obtained from high speed visualizations.

Measurement of the gas velocity field is done using LDA with oil seeding. PDI will give us the velocity and particle size distribution of kerosene. Moreover, for our test case, we performed gas velocity field measurement during stabilized combustion. These results will be useful to validate our simulation of combustion regime.

The simulations are made using the multi physics code CEDRE (ONERA). The CFD approach is decribed on figure 1.

Results and Discussion

The flow field of MERCATO is computed using RANS approach for the air, and a Lagrangian approach for the liquid phase. Simulation of non reactive cases have been performed. Results show good agreement with experimental data for air and liquid (see figure 2).

The ignition model has been validated for academic cases, and applied to the MERCATO configuration, for a 3D simulation.

Nomenclature

RANS	Reynods Average Navier Stokes
LDA	Laser Doppler Anemometry
PDI	Phase Doppler Interferometry

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Q flow rate [g·s^{-1}]

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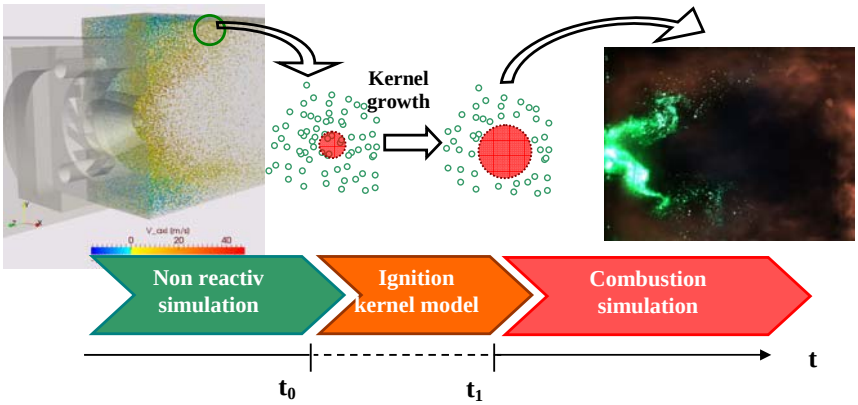

Figure 1. Sequence of an ignition simulation; on the left, lagrangian field of particle ; on the right, laser tomography image of two phase flow combustion (García Rosa)

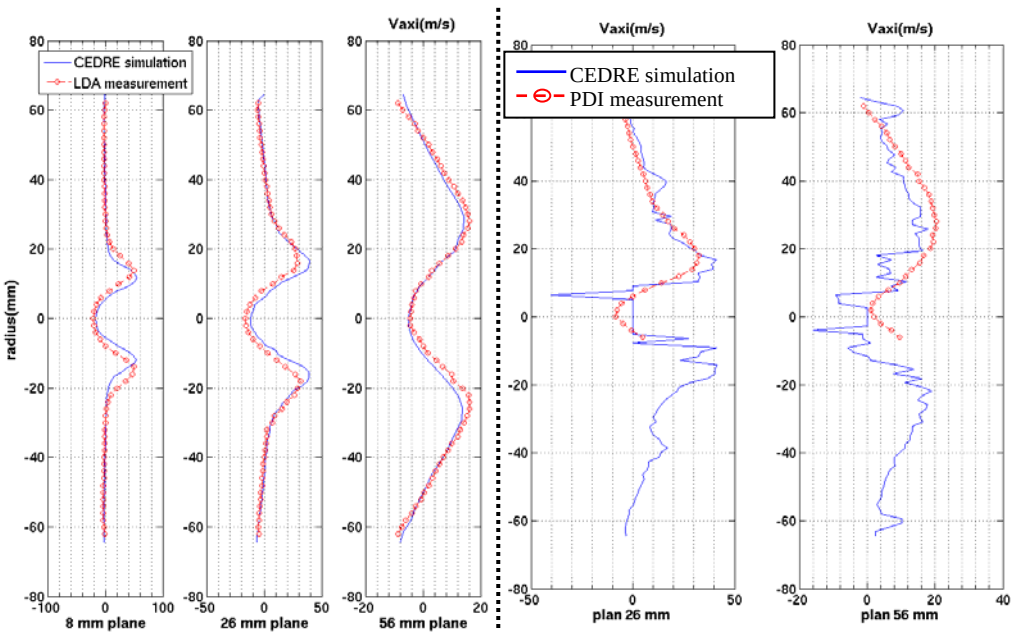

Figure 2. Comparison of RANS simulation and LDA (left) and PDI(right) measurements for several planes