ASSESSING THE EFFECTS OF DROPLET BREAKUP AND DROPLET VAPORIZATION MODELS ON THE NUMERICAL SIMULATION OF SPRAY FORMATION

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This paper presents the modelling strategy developed at Laboratoire de Combustion et Systèmes Réactifs (LCSR) in the domains of secondary atomization and turbulent vaporization. This procedure is based on experimental simplified setups[1-3] which have permitted to characterize accurately the physical processes under controlled environment. It was then possible to control independently the temperatures (liquid and gas temperatures), the pressure (up to supercritical conditions), turbulence intensity, compounds... These simplified experimental configurations have also permitted to establish detailed databases for the elementary phenomena. These databases have been used for developing empirical correlations taking into account all independent physical parameters. The models obtained with this procedure have been implemented in CFD codes, and used in a first time with a numerical configuration similar to the simplified experimental setup. The physical conditions are then identical to those experimentally explored (temperatures, pressure, velocity...). These simplified computations carried out have then permitted to verify the model behaviour and its couplings with other laws already present in the CFD codes. This procedure has also permitted to adjust constants existing in the numerical models for a better reproduction of the elementary phenomenon (in comparisons with the experimental databases) with the largest possible range of physical conditions. In a second time, calculations have been performed using a more complex and realistic configuration. The influence of the numerical models newly introduced in the CFD codes on the whole process has been systematically studied.

Concerning the secondary atomization process, the experimental results are issued from an experimental study previously conducted at LCSR[1, 2] which has permitted to characterize the phenomenon in terms of breakup mode, breakup initiation time and secondary droplet distributions, depending on Reynolds and Weber numbers and liquid/gas viscosity and density ratios. Experimental conditions have also permitted to explore the droplet breakup in supercritical conditions. The numerical model[4, 5] obtained with these experimental results has then been introduced in the SNECMA CFD code THÉSÉE[6]. After the validation stage, computations carried out have permitted to reproduce the ONERA's MASCOTTE configuration[7] (Fig. 1 and 2). This complex experimental setup is particularly dedicated to the study of elementary processes taking place in the combustion chamber of a real cryotechnic H_2/O_2 (gaseous hydrogen/liquid oxygen) rocket engine. This experimental configuration is composed of a single coaxial element (Fig. 1) introducing liquid oxygen (LOX) by the inner part surrounded by a high velocity gaseous hydrogen (GH_2) jet (up to 300 m/s). Computations carried out have then permitted to reproduce accurately the spray properties such as the arithmetic and the Sauter (Figs. 3 and 4) mean diameters, the spray length and penetration and the final droplet distributions. Concerning the continuous phase, the secondary atomization model mainly influences the gaseous oxygen mass fraction in the computational domain. This gaseous oxygen is issued from the gasification of the liquid oxygen spray. Indeed, the secondary atomization model has permitted to increase the vapour production and to obtain values generally measured in such systems. The influence of initial droplet size introduced in the computational domain of final spray properties has also been

numerically studied (Figs. 3 and 4). An other important part of the numerical study is related to the characterization of the spray formation dynamic. Indeed, the development of the liquid droplet spray is of importance for characterizing the ignition in the case of computations under reactive conditions.

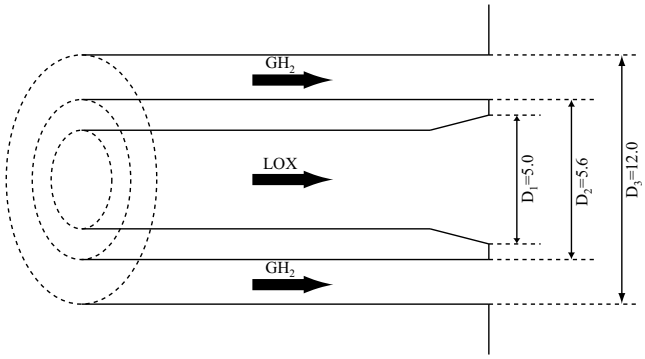

Figure 1: Geometry of the coaxial injector (values in mm)

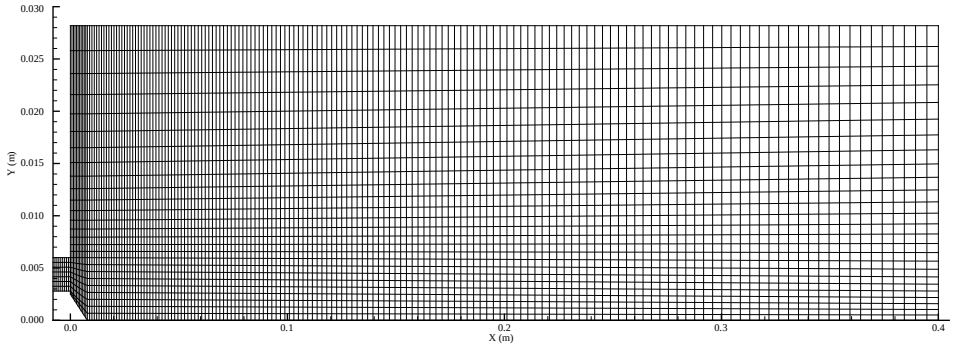

Figure 2: Computational domain

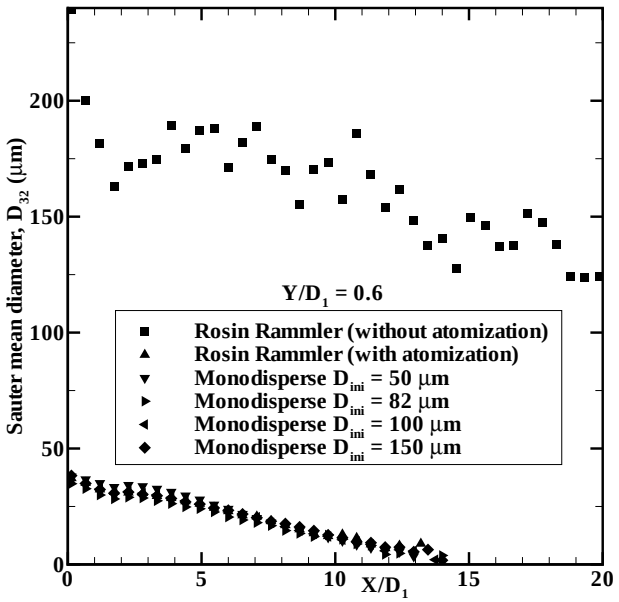

Figure 3: Axial evolution of Sauter mean diameter, D_{32}, at Y/D_1=0.6; D_1 is the liquid oxygen injection diameter

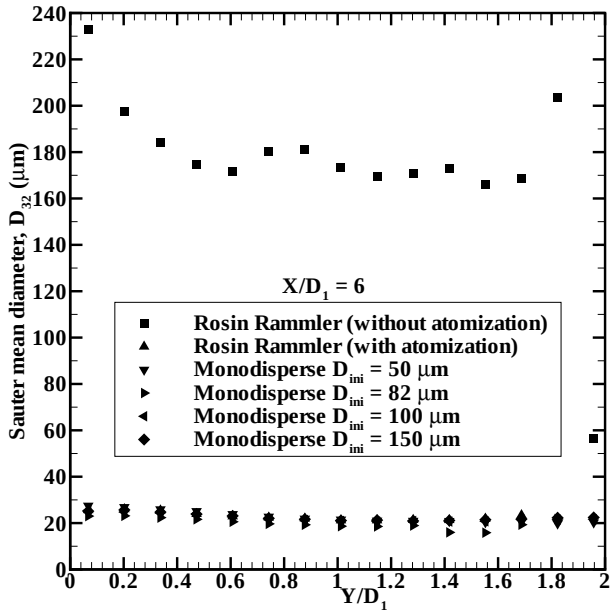

Figure 4: Radial evolution of Sauter mean diameter, D_{32}, at X/D_1=6.0; D_1 is the liquid oxygen injection diameter

Concerning the turbulent vaporization, the model is issued from an experimental study which has permitted to correlate the vaporization rate with the liquid properties (density, viscosity, thermodynamic properties...), turbulence conditions and Schmidt and turbulent Reynods numbers[3]. This correlation can be considered as a correction of the usual D^2 law, taking into account the turbulence effects. The numerical model has been introduced in the MSD code from ONERA[8] and used with the MASCOTTE configuration[7] as previously presented. The numerical results have shown a good reproductivity of the turbulent vaporization process in comparison with experimental databases. This reproductivity is particularly good for the values of the vaporization rate (Fig. 5) and for the temporal evolutions of the droplet temperature (Fig. 6).

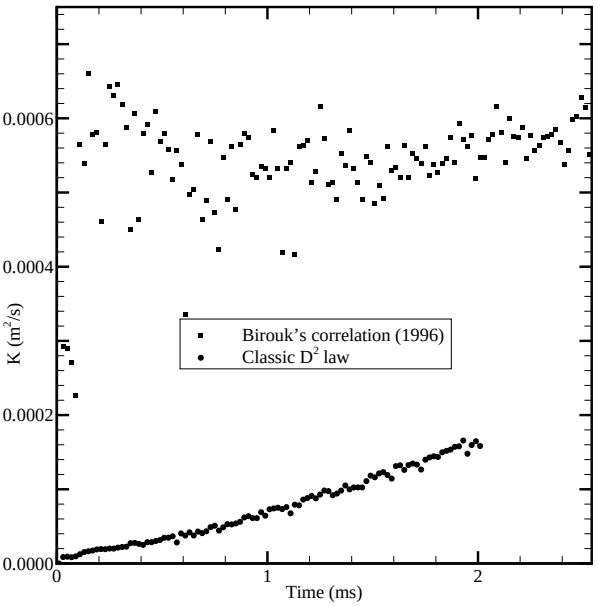

Figure 5: Temporal variation of the droplet vaporization rate

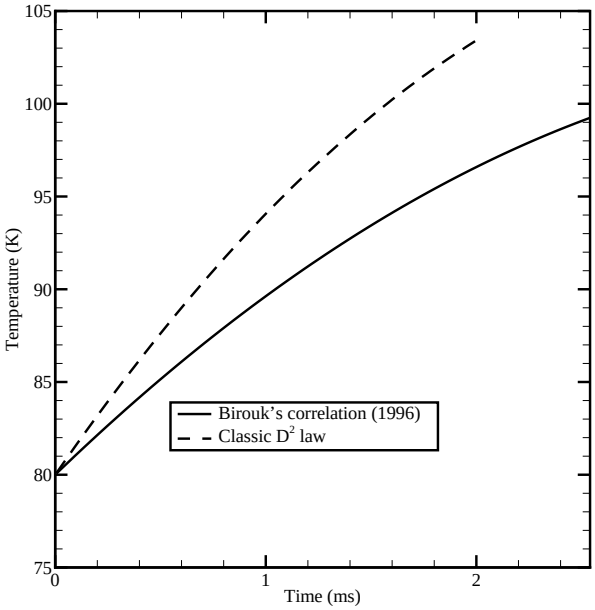

Figure 6: Temporal variation of the droplet temperature

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