Influence of the needle lift motion on cavitating flow inside Diesel injector

R. Marcer*, C. Audiffren, B. Yerly
[1] Principia, Z.I. Athélia, 13705 La Ciotat FRANCE
richard.marcer@principia.fr, charles.audiffren@principia.fr, benoit.yerly@principia.fr

Abstract

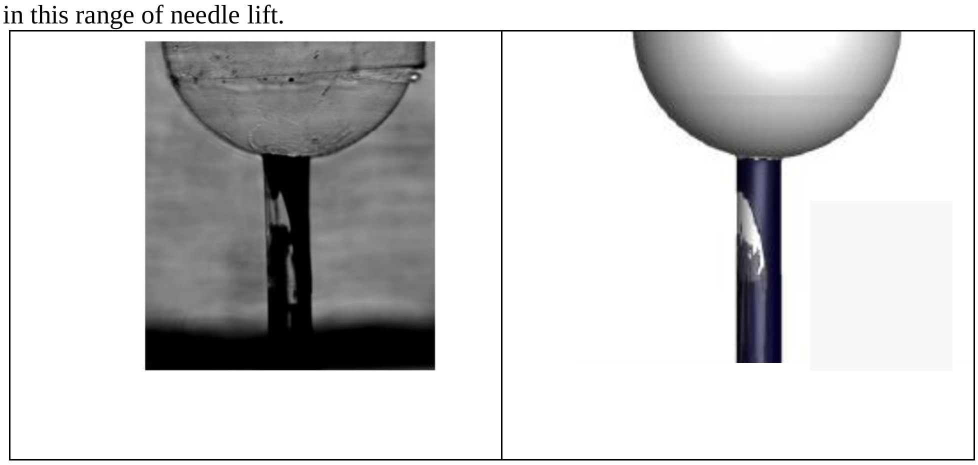
In Diesel injection the flow in the injector, and especially the cavitation development and its influence on the flow rate, is led by the needle lift according to an opening/closing motion cycle. The simulation of that kind of unsteady cavitating flow can be simulated with a CFD model considering a time-varying needle lift. However in this unsteady approach computational time may be large because of the small time steps that are required to represent the cavitation dynamics in the nozzle, especially if a complete needle lift cycle is considered. An interesting possible alternative may be the steady needle lift approach, meaning that the lift is considered as fixed for a given calculation. This approach helps to reduce the simulation time because it allows providing at convergence all the features of flow (including flow rate) for the considered lift, without having to simulate the previous transient opening phase of the lift motion (up to the considered lift). The question is whether the steady approach allows to reproduce the same results as unsteady approach, i.e. for a given needle lift, if simulated flow (flow rate, cavitation) is the same for the steady and unsteady approaches considering that the last one takes into account the dynamic aspects related to the lift motion.

In this study a one nozzle injector with an eccentricity of the hole is concerned. Numerical simulations are performed with both unsteady and steady approaches for the needle lift modeling. Validations of the numerical model based on comparisons with measurements of cavitation carried out at the LMFA [1], are presented.

Figure hereafter shows examples of comparisons of the cavitation pattern issued from experiments and from the computations, at high needle lift. In both cases the cavitation extents all along the hole but in a dissymmetrical way due to the eccentricity of the hole. It has been noted that at high needle lift (> 15% of the maximal lift), the steady approach gives very similar results according to the unsteady approach, for cavitation development as well as for the flow rate. So, at high lift, the motion of the needle has no influence on the flow.

However at lower needle lift (<15% of the maximal lift) cavitation and flow rate obtained with the two methods are significantly different (figure 3). The variable needle lift calculation shows a peak of the flow rate linked with a dynamic pulse of cavitation in the hole, responsible of a peak of liquid velocity in the contracted section. In this range of lift (5%<lift<15%), the steady approach is not able to put into evidence this transient development of the cavitating flow.

Moreover for very small lift (< 5% of the maximal lift) the steady method tends to overpredict the flow rate because dynamic effects related to the needle motion, which are important at such low lift, are not taken into account. Errors up to 20% on flow rate values are thus given by steady approach at low lift which turns out to be inaccurate in this range of needle lift.



Comparison LMFA measurements (left) and CFD (right) of the cavitation (in black) in the hole at high needle lift

[1] Loïc Mées, Marc Michard. Visualisation of cavitation in a transparent diesel injector nozzle. Laboratoire de mécanique des fluides et d'acoustique (LMFA), Ecole Centrale Lyon, CNRS, Université Claude Bernard and INSA Lyon. Private communication.

∗ richard.marcer@principia.fr