Summary of the Deliverable 2.4:

Flow measurements (SPIV, high speed imaging, x-ray) for cavitation inside a submerged discharge orifice

provided by ESR 6 under the guidance of Dr Ioannis Karathanassis and Prof Manolis Gavaises, CITY, University of London, November 2018

On the deliverable 2.4 for ESR6, the work package was focusing on the capturing and recognition of the high transient cavitation phenomena developing inside a diesel injector nozzle. For this purpose three different techniques were employed: Shadowgraphy, XPCI and PIV.

Firstly, an enlarged model of a diesel injector with length of 5mm and diameter of 1.5mm (similar to the one described in [1]) was set-up in order to study the two phase flow and the cavitation structures developing in an injector nozzle, through various conditions. The test cases were performed under steady flow conditions circulating Diesel fuel in a closed hydraulic circuit. Through the shadowgraphy technique raw images were acquired for multiple test cases, with different needle lifts and Cavitation and Reynolds numbers. The post processing of each data set highlighted the formation of transient cavitation structures in three distinct areas within the injector hole and upstream sac volumes. By examining the different test cases, it was observed that the different Cavitation and Reynolds numbers were affecting the cloud cavity length and development dynamics. Additionally, the 0.5mm needle lift was observed to lead to string cavitation near the needle-seat location, while, on the contrary, no such structures were visible for needle lift of 1mm.

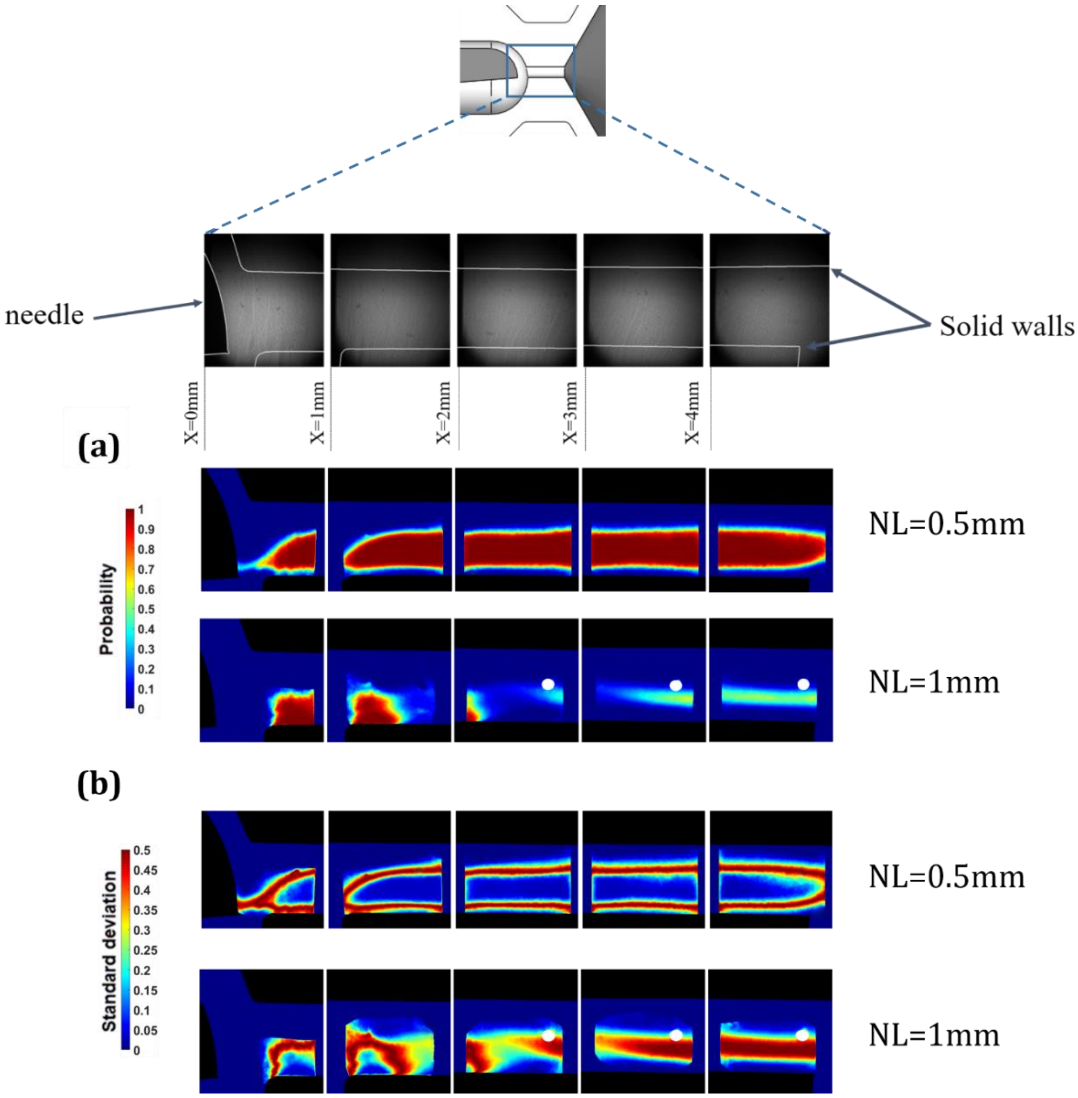

Figure 1: (a) Mean and (b) standard deviation images two different needle lifts (NL), with same CN and Re (CN=4.0, Re=35500)

Secondly, the High-Speed X-Ray Phase Contrast-Imaging (XPCI) technique was used for the visualization of the cavitation phenomena inside an enlarged model of a diesel injector nozzle (similar to [1] and [2]). Once again the circulating fluid was Diesel fuel, which was used not only in the typical commercial form, but also additised, containing quaternary ammonium salt (QAS) additives. The selection of additives was based on their ability to make the fuel viscoelastic, and therefore, to affect its rheological behavior [3]. The experimental cases were conducted for multiple operating conditions, with Cavitation Number varying between 1.6 and 7.7, Reynolds number between 18K-35.5K and different needle lifts. This led to multiple datasets of cavitation structures, which were captured utilizing a white X-Ray beam of 6keV, at 67890 fps with exposure time of 347ns. From the experiments, through proper post processing [4], it was derived that the distance between the needle and the entrance of the orifice is important to the formation of cavitation structures inside the orifice, defining if the cavitation will be created only due to the abrupt geometrical constriction or if a strong, secondary swirling flow will be developed. Additionally, the addition of additives was found to suppress the cloud cavitation structures and enhance the string cavitation, while the viscoelasticity of the fuel seems to lead to a less turbulent flow in the orifice. Lastly, the temporal and spatial resolution of the dataset was used to calculate the periodicity parameters of the vortical cavities formation and collapse, in correlation to the flow conditions.

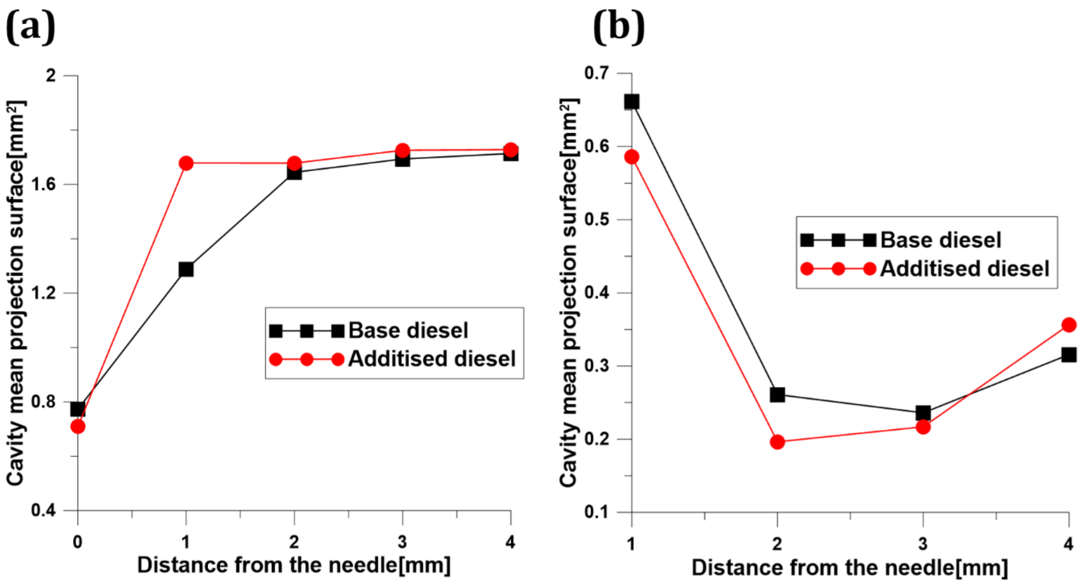

Figure 24: Mean projection surface in mm² for two types of diesel (base and additised) and for (a) CN=7.7, Re=35500 and NL=0.5mm and (b) CN=4.0, Re=35500 and NL=1mm. The two different trends are attributed to the different behaviour of the additised diesel in respect to different main forms of cavitation

In the final section, the Particle Image Velocimetry was utilized for the visualization of the fluid flow velocity field. However, the cavitation hindered the identification of the position of the particles between the consecutive frames, and therefore, the velocity field was investigated right before the formation of cavitation. For this section also, two types of Diesel were used and the Cavitation number was almost invariant while the Reynolds number was being monitored based on the pressure difference. Images were collected with 200000 fps and with a shutter speed of 200 ns for side view and 500 ns for top view. To achieve the high frame rates Shimadzu HVS-X2 was utilized, able to capture 10 million fps with resolution of 250*400 pixels.

[1] N. Mitroglou, V. Stamboliyski, I. K. Karathanassis, K. S. Nikas, and M. Gavaises, "Cloud cavitation vortex shedding inside an injector nozzle," *Exp. Therm. Fluid Sci.*, vol. 84, pp. 179–189, 2017.

[2] P. Koukouvinis, N. Mitroglou, M. Gavaises, M. Lorenzi, and M. Santini, "Quantitative predictions of cavitation presence and erosion-prone locations in a high-pressure cavitation test rig," *J. Fluid Mech.*, vol. 819, pp. 21–57, 2017.

[3] R. Barbour, R. Quigley, and A. Panesar, "Investigations into Fuel Additive Induced Power Gain in the CEC F-98-08 DW10B Injector Fouling Engine Test," *Sae*, no. 2014-01–2721, 2014

[4] P. Kovesi, "Image Features from Phase Congruency," *Tech. Rep. 95/4, Univ. West. Aust.*, 1995.