Influence of cavitation on atomisation at low pressures using up-scaled and transparent nozzles

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Abstract

The influence of cavitation on atomisation was studied using up-scaled, optically transparent nozzles, injecting water at four different temperatures into air at ambient conditions. The flow inside the nozzle and atomisation were related using the cavitation length and cone angle as main experimental parameters. Results from these experiments, where the effects of the aerodynamic forces are small compared to the internal flow effects, show that the same length of cavitation leads to a similar degree of atomisation regardless of the pressure drop across the nozzle, fluid temperature or flow velocity inside the nozzle.

Introduction

Cavitation and turbulence play important roles in atomisation and spray behaviour [1, 2]. However, the individual contribution from each of them is not clearly understood [3]. The difficulty of defining the contribution of the former factors resides, mainly, in the arduousness of isolating cavitation from turbulence or vice versa since cavitation appears generally at high flow rates where turbulence is generally present too. Due to the fact that water vapour pressure is temperature dependent, it is possible to promote the appearance of cavitation inside the nozzle by modifying the temperature of the fluid [4]. This investigation influences the amount of cavitation in up-scaled and optically transparent nozzles by increasing the temperature of the fluid and relates it to atomisation using, among other parameters, the cavitation length and the cone angle of the spray.

Experimental set-up and procedure

The experimental set-up consists of optical transparent nozzles, one with a sharp inlet and the other with a rounded inlet, and a rig that injects water at controlled pressures and temperatures into ambient air. The test rig is equipped with a pump, a settling chamber to reduce turbulence upstream the nozzle, a 500 litre insulated reservoir with a heating element of 18 kW, a transparent observation chamber downstream the nozzle, and a pressure transducer at the nozzle inlet.

The experimental matrix is presented in Figure 1. The test matrix relates fluid temperature and the pressure drop along the nozzle for seven different conditions. The seven conditions differ among them by the length of the cavitation cloud measured from the inlet of the contraction zone of the nozzle, referred here as cavitation length (CA). The first experimental condition is set to have no cavitation inside the nozzle, achieving this by reducing the pressure in the nozzle after the slightest inception of cavitation is noticed. In the following conditions the cavitation length ranges from the inception of cavitation until the cavitation length is almost equal to the nozzle length. In the last condition a hydraulic flip is induced by moderately increasing the pressure in the nozzle after the farthest downstream border of the cavitation cloud reached the outlet of the nozzle. This transforms the atomising spray into a non-atomising jet.

The cone angle was determined from a series of photographs that were captured with a high speed camera using back light illumination and digitally processed using an edge detection algorithm.

Results and Discussion

Flow measurements, for every point contained in the test matrix (Figure 1), as a function of pressure at ambient temperature, are presented in Figure 2. It is observed that the flow increases proportional to the square root of the pressure drop along the nozzle until the cavitation length is almost equal to the nozzle length. A further increase on the pressure inside the nozzle leads to a hydraulic flip. Figure 3 and Figure 4 present a series of photographs of the sprays produced by the sharp inlet nozzle for two different temperatures and different cavitation lengths ranging from no cavitation to hydraulic flip. In these figures it is possible to observe that similar lengths of cavitation lead to sprays which are comparable among them, as can be corroborated in Figure 5. Figure 5 presents plots of the spray cone angle against liquid temperature measured at a distance of five nozzle diameters

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downstream the nozzle exit. These plots show that maintaining the cavitation length inside the nozzle as constant lead to a similar degree of atomisation, regardless fluid temperature, pressure drop or flow across the nozzle. It can be seen that an increase on cavitation inside the nozzle leads to higher cone angles and consequently a higher degree of atomisation.

Conclusions

Experiments to disclose the influence that cavitation has on atomisation were conducted, promoting cavitation inside the nozzle by means of modifying the temperature and consequently the vapour pressure of the injected liquid. Results indicate that, in systems where the effects of the aerodynamic forces are small compared to the internal flow effects, cavitation length can be correlated to atomisation regardless of the fluid temperature or the flow regime.

Acknowledgements

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References

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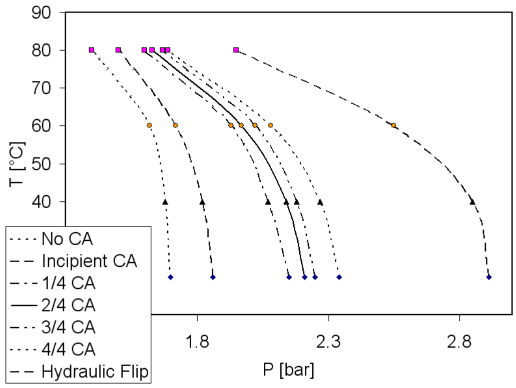

Figure 1. Test matrix (Sharp inlet nozzle)

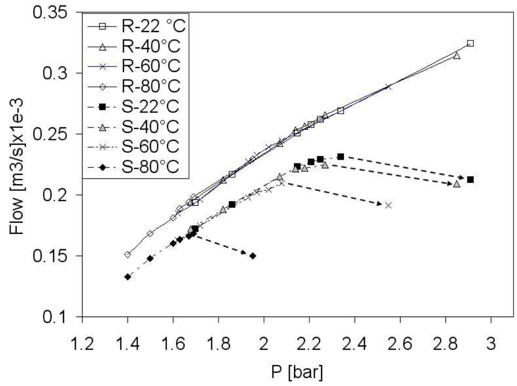

Figure 2. Flow measurements as function of pressure at four different temperatures for the sharp (S) and rounded (R) inlet nozzles

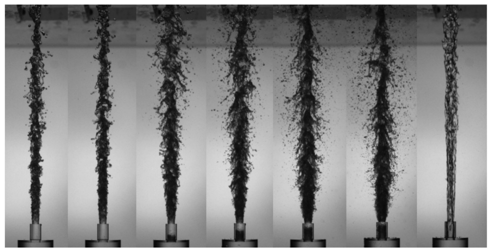

Figure 3. Photographs at 22 °C (Sharp inlet)

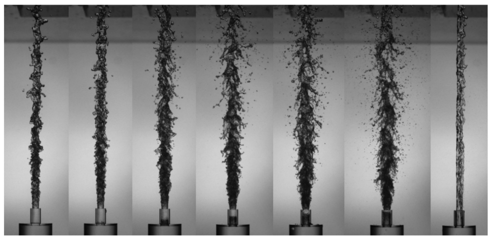

Figure 4. Photographs at 80 °C (Sharp inlet)

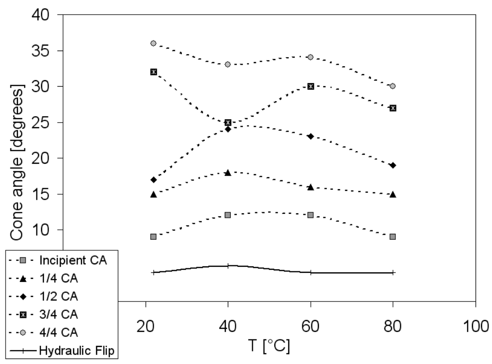

Figure 5. Cone angle as function of temperature at five diameters downstream the nozzle (Sharp inlet nozzle)