EXPERIMENTAL CHARACTERIZATION OF NOZZLE FLOW EXPANSIONS OF SILOXANE MM FOR ORC TURBINES APPLICATIONS

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ABSTRACT

This paper reports extensive experimental results characterizing the supersonic expansion of organic vapor MM (hexamethyldisiloxane, $C_6H_{18}OSi_2$) in conditions representative of Organic Rankine Cycle (ORC) turbines operating conditions, in the close proximity of the liquid-vapor saturation curve.

Experiments were conducted on the Test Rig for Organic VApors (TROVA), at the Laboratory of Compressible fluid-dynamics for Renewable Energy Application (CREA Lab) of Politecnico di Milano. Two different planar nozzles were tested, featuring an exit Mach number of 1.5 and 1.6. Nozzle flow expansions were characterized by measuring total pressure, total temperature, static pressures along the nozzle axis and by performing schlieren visualizations. A wide range of inlet conditions was explored in order to systematically span the thermodynamic region included between the saturation curve and the critical temperature. This is indeed the typical operating region of ORC turbines. It was verified that the expansion is influenced by total inlet conditions because of the non-ideal nature of the flow.

Collected data were analysed with the purpose of assessing the influence of the following three parameters on pressure ratios along the nozzle axis: total temperature T_T, total pressure P_T and total compressibility factor Z_T. It was investigated whether parameter Z_T alone is sufficient to assess the level of non-ideality of a nozzle flow and thus, to characterize the expansion and predict pressure ratio and Mach number profiles.

The nozzle with exit Mach number equal to 1.5 was also tested in a previous experimental campaign [1] with siloxane fluid MDM (octamethyltrisiloxane, $C_8H_{24}O_2Si_3$). It was thus possible to carry out a comparison of two different organic vapors flowing in the same nozzle and sharing the same total reduced conditions. As expected, given that the two compounds belong to the same family and exhibit comparable molar masses and molecular complexities, the difference between the measured pressure ratios was around 1% for all considered cases. Moreover, ratios measured in the supersonic portion of the nozzle were always slightly higher for MDM with respect to MM. This is qualitatively consistent with predictions made by 1D nozzle theory coupled with the Van der Waals equation of state, since MDM molecular structure is slightly more complex than MM.

The present experimental investigation provides important validation data for the improvement of state-of-the-art thermodynamic models and of design tools for siloxane fluids in general and for siloxane MM in particular.

[1] A. Spinelli, G. Cammi, S. Gallarini, M. Zocca, F. Cozzi, P. Gaetani, V. Dossena and A. Guardone: "*Experimental evidence of non-ideal compressible effects in expanding flow of a high molecular complexity vapor*". In: Experiments in Fluids 59:126 (2018), https://doi.org/10.1007/s00348-018-2578-0