11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20 - 25, 2014, Barcelona, Spain

CFD STUDY OF A CO_2 EJECTOR PERFORMANCE INSTALLED IN LARGE COOLING SYSTEMS WORKING AT DIFFERENT AMBIENT CONDITIONS

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Key Words: *CO2 ejector performance, two-phase ejector, refrigeration systems, CFD modelling.*

In this paper, performance of a two-phase ejector with CO_2 as a working fluid was studied using CFD modelling. The ejector is to be installed in refrigeration systems of supermarkets located in places of different annual ambient temperatures. Supermarket installations were selected because they represent buildings of large amounts of primary energy consumption. In addition, the refrigeration equipment installed in such systems contributes also to relatively large direct emission of greenhouse gasses through emissions of environmentally damaging refrigerants.

Currently, the working fluids in the mentioned installations are gradually replaced with the CO_2 that is thermodynamically efficient, natural, environmentally friendly (Ozone Depletion Potential = 0, Global Warming Potential = 1, non-toxic, non-flammable), inexpensive and easily accessible. However, at elevated ambient temperatures the HFC systems require slightly less energy compared to current CO_2 booster systems to provide the required cooling capacity, which obstructs phase-out of the HFC systems in hot climates. To eliminate this problem, the cooling systems are equipped with an ejector to reduce the throttling loss and increase the system energy efficiency to the values higher than for the ordinary CO_2 booster system and the HFC systems.

To study a design and then performance of CO2 ejector, a mathematical model of the compressible transonic two-phase flow of a real fluid was formulated [1]. In the proposed approach, a temperature-based energy equation is replaced with an enthalpy-based formulation, in which the specific enthalpy, instead of the temperature, is an independent variable . A thermodynamic and mechanical equilibrium between gaseous and liquid phases is assumed for the two-phase flow. Consequently, real fluid properties, such as the density, the dynamic viscosity and the diffusion coefficient, are defined as functions of the pressure and the specific enthalpy. The energy equation formulation was implemented in commercial CFD software and extensively tested for a two-phase flow of the CO_2 fluid with a phase change occurring in the ejector motive nozzle. In the model validation procedure that was performed for a number of geometries and operating conditions, a very satisfactory comparison between results of the experimental studies and computational modelling for the primary and secondary mass flow rates was obtained. In addition, the pressure distribution along the centre line of the ejector was also accurately predicted.

In the next step of the analysis, the flow irreversibility in such ejectors was studied [2]. An original approach was proposed to assess the contribution of the local irreversibilities to the overall entropy increase. A new factor was proposed to evaluate the ejector performance based on the reference entropy increase in a classic expansion valve. As a result, the mixer mass flux was found to significantly affect the ejector performance both locally and globally in a selected geometry working at different operating conditions.

Finally, the developed software was coded to automatically generate an ejector geometry, mesh, solver setup and the result postprocessing on the basis of the two commercial programs and in-house interface. In this manner, the developed model and the software can be effectively used in the ejector geometry optimisation computations.

The results obtained for varying geometrical parameters such as the mixer diameter and length, premixing chamber length, diffuser length showed a large influence on the ejector, and consequently, on the system performance. In addition, the study also showed that such devices must be individually designed for particular ambient conditions. As illustrated in Figure 1, an ejector design that showed good performance for hot climate conditions, can be choked in hot climate conditions.

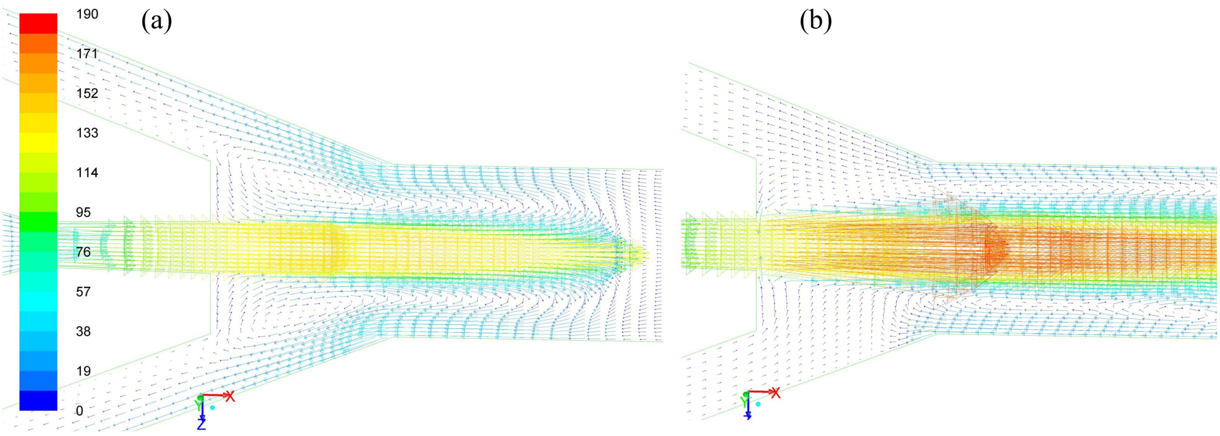

Figure 1: Velocity vectors for an ejector design working (a) incorrectly in typical cold ambient conditions and (b) correctly in typical hot ambient conditions.

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