CFD-based shape optimisation of mixing section of R744 two-phase ejector

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ABSTRACT

In this paper, shape optimisation of a mixing section of a two-phase R744 ejector was performed. The optimised device was designed for a refrigeration system of a supermarket. The application of R744 ejector based refrigeration units is a good alternative for commonly used refrigeration systems with a HFCs as working fluids. Moreover, the ejector-based systems have potential to be more efficient comparing to popular booster systems [1]. The performance of the refrigeration systems with the ejectors strongly depends on the ejector performance. Recent studies showed that the mixing section geometry has the most significant influence on the overall ejector efficiency [2]. The optimisation of this part was performed by applying CFD model combined with a genetic algorithm.

The commercial Ansys Fluent solver was used to perform all the computations. The User-Defined-Function capability was used to reformulate the standard temperature-based energy equation. In the proposed approach, the energy equation was defined to be the enthalpy-dependent. Hence, the enthalpy and pressure were considered as independent variables [3]. Moreover, the real fluid properties were obtained by an implementation of NIST REFPROP database. To simulate a turbulence Realizable $K-\epsilon$ model was applied. The computational domain was simplified into 2-D axisymmetric approach. The numerical grids used for the computations consisted of almost ten thousand elements.

To automate the computation process, an in-house developed script was implemented. This script combined a mesh generation software Ansys ICEM CFD and Ansys Fluent solver. This allowed for the fully automated geometry and mesh generation, solver execution as well as post-processing. Then the post-pressed results files were transferred to the genetic algorithm control script to evaluate objective function. The objective function was formulated to maximise the ejector performance, i.e. the total device efficiency. Taking into account that the ejector operating conditions change during a typical refrigeration system operation, all the computations were performed to simulate at least two different loads of the system. Therefore, the objective function was evaluated as the average performance for the considered loading conditions.

The optimisation results showed the increase of the ejector efficiency. In consequence, the increase of the refrigeration system performance is also expected. Moreover, the analysis of the relative increase of the entropy rate inside the mixing section was lower comparing to the basic ejector configuration. Comparing the reference geometry with the optimised one, it can be seen that extension of the mixer as well as increase of the mixer diameter, improved the overall ejector efficiency by up to 10%.

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