EQUILIBRIUM MODEL OF TWO-PHASE TRANSONIC COMPRESSIBLE CO_2 FLOW THROUGH HEAT PUMP EJECTOR AND ITS EXPERIMENTAL VALIDATION

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ABSTRACT

The main aim of this study is to simulate numerically thermodynamic processes occurring during an operation of the ejector working as a part of the heat pump system and to validate the developed model using the experimental data of two-phase flow with a phase change. To achieve the goal, the considered ejector was modelled as a 3-D object using a commercial code Fluent. However, the software is not capable of solving the analysed problem directly. For example, the density variations are limited to an ideal gas equation of state in two-phase compressible flow. In addition, the enthalpy is treated as the temperature-dependent quantity only. Moreover, the preliminary tests with Euler-Euler and mixture multi-phase models available in Fluent revealed a number of numerical problems including extremely poor convergence of the solution. In some cases, even though a very low values of the under-relaxation factors were applied, the solution diverged.

For these reasons, the density and the speed of sound definitions were adopted using the User Defined Function capabilities. To compute both properties, the real gas relations based on the REFPROP libraries were used [1]. In the next step, a determination of these quantities was speeded up by their approximation over the entire range of the operating parameters. The property approximation within individual grid cells was performed using a linear combination of bilinear functions. As a result, the working fluid was treated in the model as a highly compressible medium. The remaining properties such as the dynamic viscosity, the specific heat and the thermal conductivity were determined using the real fluid properties as well.

In modelling of the multi-phase flow, it is assumed that the two-phase mixture is homogeneous and both phases are in the thermodynamic equilibrium. Hence, both phases share the same pressure, velocity, turbulence kinetic energy and turbulence dissipation rate fields. Moreover, the thermal enthalpy of the real fluid instead of the temperature was used as an independent variable in the energy equation. The real fluid enthalpy-based energy equation was defined using a general transport equation that can be customized by the user. Therefore, to develop the energy equation, both the diffusion and the source terms were modified. Apart from the enthalpy-based energy equation, the developed model included continuity and momentum equations and turbulence model. For turbulence modelling, the $k - \epsilon$ RNG model was employed, because it works very well for this kind of applications [2].

The methodology proposed in this paper is capable of modelling and simulating the two-phase flow that is typical for the considered CO_2 ejector. In addition, the developed model can also be successfully used to simulate the single- and the two-phase flows of different working fluids as well.

REFERENCES

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