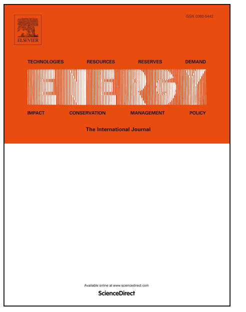

System model derivation of the CO_2 two-phase ejector based on the CFD-based reduced-order model

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Abstract

The developed reduced-order model (ROM) of the R744 two-phase ejector was presented in this paper. The proper orthogonal decomposition (POD) model was employed together with the radial basis function (RBF) to evaluate the ejector performance at the motive nozzle operating regime from 70 bar to 100 bar. The proposed model was built based on the full CFD model of the R744 two-phase ejector with homogeneous equilibrium flow assumption. The validation procedure was performed to evaluate the ejector nozzles mass flow rate discrepancies of ROM compared to the CFD results and experimental data. In addition, the accuracy analysis of the ROM flow field results compared to the CFD results was performed. The validation process based on the CFD results and experimental data indicated the high accuracy of ROM for both nozzles mass flow rate within ±10% for most of the investigated operating points. Hence, the high accuracy of the computed mass flow rates allows ROM implementation into the dynamic simulations of the refrigeration system to evaluate the ejector performance at given operating points with negligible time effort.

Keywords: carbon dioxide, refrigeration system, two-phase ejector, reduced-order model, ejector-based system, CFD modelling

1. Introduction

The recent restrictive legal regulations for environmental protection led to the design of modern comparative refrigeration systems that use natural refrigerants [1]. Carbon dioxide (denoted as R744) has been applied in vapour compression refrigeration for over 130 years, and it is classified as a non-toxic and non-flammable fluid with a low global warming potential index (GWP) of 1 and ozone depletion potential index of 0 [2]. However, the typical R744 direct expansion systems are characterised by relatively high thermodynamic losses in the high-pressure expansion valve, which is the primary motivation to search for system energy performance improvement [3]. Modern CO_2 refrigeration systems possess an additional liquid receiver to decrease the pressure ratio of the high-pressure expansion valve and the saturated flash gas from the receiver is either expanded to the medium-temperature evaporator pressure level or directly compressed to the high-pressure gas cooler pressure level by an additional compressor [4, 5]. However, there is still a considerable potential to improve the energy performance of such refrigeration systems. One of the solutions is the use of the two-phase ejector either as a main expansion device instead of the high-pressure expansion valve [6], or as a liquid ejector to recirculate the liquid refrigerant in the flooded evaporator [7].

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