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# Performance analysis of single-stage refrigeration system with internal heat exchanger using neural network and neuro-fuzzy

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ABSTRACT

In this study, artificial neural networks (ANNs) and adaptive neuro-fuzzy (ANFIS) have been used for performance analysis of single-stage vapour compression refrigeration system with internal heat exchanger using refrigerants R134a, R404a, R407c which do not damage to ozone layer. It is well known that the evaporator temperature, condenser temperature, subcooling temperature, superheating temperature and cooling capacity affect the coefficient of performance (COP) of single-stage vapour compression refrigeration system with internal heat exchanger. In this study, COP is estimated depending on the above temperatures and cooling capacity values. The results of ANN are compared with ANFIS in which the same data sets are used. ANN model is slightly better than ANFIS for R134a whereas ANFIS model is slightly better than ANN for R404a and R407c. In addition, new formulations obtained from ANN for three refrigerants are presented for the calculation of the COP. The $R^2$ values obtained when unknown data were used to the networks were 1, 0.999998 and 0.999998 for the R134a, R404a and R407c respectively which is very satisfactory.



## 1. Introduction

Heat flows naturally from a hot to a colder body. In refrigeration system the opposite occurs, i.e., heat flows from a colder to a hotter body. This is achieved by using a substance called a refrigerant, which absorbs heat and hence boils or evaporates at a low pressure to form a gas. This gas is then compressed to a higher pressure, such that it transfers the heat it has gained to ambient air or water and turns back (condenses) into a liquid. In this way heat is absorbed, or removed, from a low temperature source and transferred to a higher temperature source [1,2].

Single-stage refrigeration cycle with internal heat exchanger is shown in Fig. 1. At state 1–2, low pressure liquid refrigerant in the evaporator absorbs heat from its surroundings, usually air, water or some other process liquids. During this process it changes its state from a liquid to a gas, and at the evaporator exit it is slightly superheated. At state 2–3, the superheated vapour enters the compressor where its pressure is raised. There will also be a big increase in temperature, because a proportion of the energy input into the compression process is transferred to the refrigerant. At state 3–4, the high-pressure superheated gas passes from the compressor into the condenser. The initial part of the cooling process (3–3a) desuperheats the gas before it is turned back into liquid (3a–3b). The cooling for this process is usually achieved by using air or water. A further reduction in temperature happens in the pipe work and liquid receiver (3b–4), so that the refrigerant liquid is sub-cooled as it enters the expansion device. At state 4–1, the high-pressure sub-cooled liquid passes through the expansion device, which both reduces its pressure and controls the flow into the evaporator [1,2].

The use of ANN and ANFIS for modelling and prediction purposes is becoming increasingly popular in the last two decades. Navarro-Esbrı et al. [3] have proposed neural network model of a variable speed vapour compression refrigeration system. Chilled water temperature inlet, condensing water temperature inlet, refrigerant evaporator outlet temperature and compressor rotation speed are used as the input parameters. Cooling load, the electric compressor power, and temperature of the chilled water outlet are outputs of the model. A good agreement between experimental values and those predicted by the model has been obtained [3]. Swider [4] predicted the coefficient of performance by using cooling capacity and the chilled water and the cooling water inlet temperatures variables.

Yao et al. [5] presented a new approach for load prediction with high precision using RBF neural network (RBFNN) with combined residual error correction. The RBFNN is chosen to forecast the air-conditioning load due to its rapid learning and generality. Wu et al. [6] used artificial neural network (ANN) to predict the performance of gas cooler in carbon dioxide transcritical air-conditioning system. The designed ANN was trained by performance test data under

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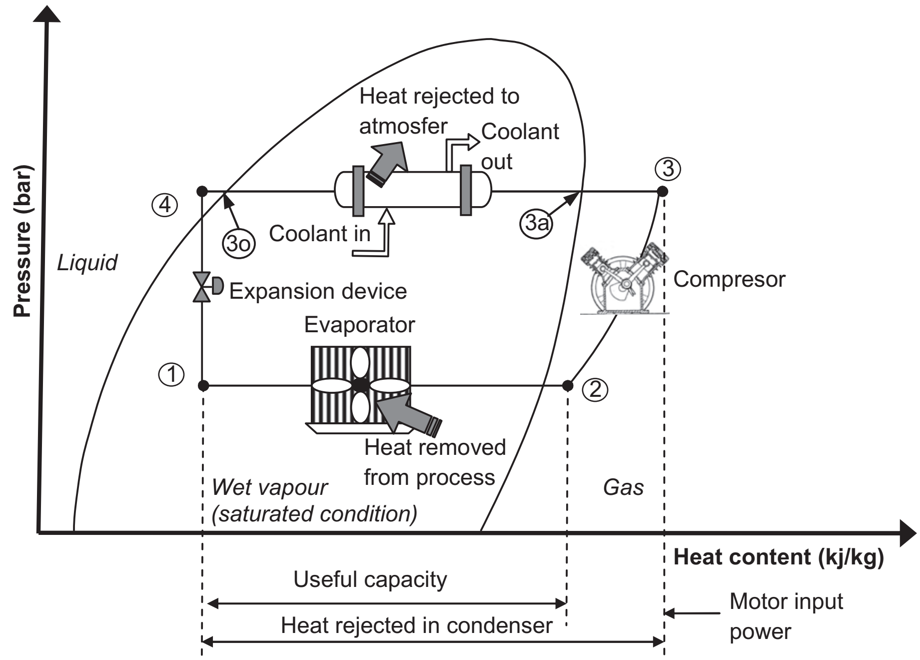


**Fig. 1.** Single-stage refrigeration cycle with internal heat exchanger.

varying conditions. The deviations between the ANN predicted and measured data are basically less than ±5%. The well-trained ANN is then used to predict the effects of the five input parameters individually. The predicted results show that for the heat transfer and $CO_2$ pressure drop the most effective factor is the inlet air velocity, followed by the inlet $CO_2$ pressure and temperature.

Abbassi and Bahar [7] used neural network for the modelling and control of evaporative condenser cooling load. The result shows that the neural network can effectively model such an HVAC apparatus. The ANN modelling approach has been applied to the automotive air-conditioning (AAC) system by Hosoz and Ertunc [8]. Various performance parameters of the system, namely the compressor power, heat rejection rate in the condenser, refrigerant mass flow rate, compressor discharge temperature and coefficient of performance have been predicted using three input parameters, namely the compressor speed, evaporator capacity and condensing temperature.

Arcaklioglu et al. [9] have investigated the performance of a vapour compression heat pump with different ratios of R12/R22 refrigerant mixtures using artificial neural networks (ANNs). Experimental studies were completed to obtain training and test data. Mixing ratio, evaporator inlet temperature and condenser pressure were used as input parameters, while the outputs are the coefficient of performance (COP) and rational efficiency (RE). It is shown that the $R^2$ values are about 0.9999 and the RMS errors are smaller than 0.006. Esen et al. [10] proposed a comparison of artificial neural network (ANN) and adaptive neuro-fuzzy inference systems (ANFISs) applied for modelling a ground-coupled heat pump system (GCHP). The aim of this study is to predict system performance related to ground and air (condenser inlet and outlet) temperatures by using desired models. The simulation results show that this structure based ANFIS model can be used as an alternative way in these systems.

Ertunc and Hosoz [11] predicted the performance of an evaporative condenser using both artificial neural network (ANN) and adaptive neuro-fuzzy inference system (ANFIS) techniques. ANN and ANFIS models of an evaporative condenser were developed to predict the heat rejection rate, temperature of the leaving refrigerant along with dry and wet bulb temperatures of the leaving air stream. The statistical prediction performances of both models are measured in terms of correlation coefficient, mean relative error, root-mean square error and absolute fraction of variance. Although the predictions of both models yielded a good statistical performance, the accuracies of ANFIS predictions were usually slightly better than those of ANN ones.

Zhao and Zhang [12] used the neural network approach for the performance evaluation of fin-and tube air-cooled condensers which are widely used in air-conditioning and refrigeration systems. Inputs of the neural network include refrigerant and air-flow rates, refrigerant inlet temperature and saturated temperature, and entering air dry-bulb temperature. Outputs of the neural network consist of the heating capacity and the pressure drops on both refrigerant and air sides. The trained NN models approach desired values with high accuracy.

Yang et al. [13] used neural network model to simulate the compressor performance of single and variable speed compressors. The compression ratio, condensation temperature, and frequency (frequency for variable speed compressor only) are selected as the input parameters of the volumetric efficiency neural network model. The condensation temperature, evaporation temperature, and frequency (frequency for variable speed compressor only) are selected as the input parameters of the isentropic efficiency neural network model. Yilmaz and Atik [14] proposed the modelling of a mechanical cooling system with variable cooling capacity by using artificial neural network. The network, which has three layers as input, hidden layer and output, has one input and four output cells.

**Table 1**
Input and output parameters.

| Refrigerants | Input parameters | Output parameters |
|---|---|---|
| R134a | Cooling capacity ($Q$) | Coefficient of performance (COP) |
| R404a | Condenser temperature ($T_C$) | |
| R407c | Evaporator temperature ($T_E$) | |
| | Superheating temperature ($T_{SH}$) | |
| | Subcooling temperature ($T_{SC}$) | |