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Research Article

Utilizing an Artificial Intelligence Model to Estimate Performance Coefficients in Absorption Cooling Systems

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Abstract

Absorption cooling system is a cooling method used to transfer heat from one environment to another. This system involves a cooling cycle based on a chemical reaction between two different fluids that absorb and expel heat. Generally, the absorption cooling system includes a cooling fluid and an absorbent fluid that absorbs heat. Artificial intelligence is a field of science and engineering that aims to enable computer systems to have human-like intelligence. This discipline aims to enable computers to perform complex tasks such as data analysis, pattern recognition, learning, problem solving and decision making. In this context, a study was conducted focusing on the change of inlet and outlet pressure values of the generator in the absorption cooling system and the prediction of the system performance (COP) value using artificial intelligence models. This research focuses on analyzing the inlet and outlet pressure values of the generator of the absorption cooling system through an artificial intelligence model and predicting and controlling the system performance. Artificial intelligence can be an effective tool for understanding and optimizing complex thermodynamic processes, offering significant potential for improving energy efficiency and system performance.

Keywords: Artificial intelligence, Absorption cooling, COP

Absorbsiyonlu Soğutma Sisteminde Performans Katsayısının Yapay Zeka Modeli ile Tahmini

Öz

Absorpsiyonlu soğutma sistemi, ısıyı bir ortamdan başka bir ortama aktarmak amacıyla kullanılan bir soğutma yöntemidir. Bu sistem, ısıyı emen ve dışarı atan iki farklı akışkan arasındaki kimyasal reaksiyona dayanan bir soğutma döngüsü içerir. Genel olarak, absorpsiyonlu soğutma sistemi, bir soğutma akışkanını ve ısıyı emen bir absorban akışkanını içerir. Yapay zeka, bilgisayar sistemlerinin insan benzeri zekaya sahip olma amacını taşıyan bir bilim ve mühendislik alanıdır. Bu disiplin, bilgisayarların veri analizi, örüntü tanıma, öğrenme, problem çözme ve karar verme gibi karmaşık görevleri gerçekleştirebilmesini hedefler. Bu bağlamda, absorbsiyonlu soğutma sistemindeki jeneratörün giriş ve çıkış basınç değerlerinin değişimi ile sistem performansının (COP) değerinin yapay zeka modelleri kullanılarak tahmin edilmesine odaklanan bir çalışma yürütülmüştür. Bu araştırmada, absorpsiyonlu soğutma sisteminin jeneratörünün giriş ve çıkış basınç değerlerinin yapay zeka modeli aracılığıyla analiz edilmesi, sistem performansının öngörülmesi ve kontrol edilmesi üzerine odaklanılmıştır. Yapay zeka, kompleks termodinamik süreçlerin anlaşılması ve optimize edilmesi için etkili bir araç olabilir, bu da enerji verimliliği ve sistem performansının artırılması açısından önemli bir potansiyel sunar.

Anahtar Kelimeler: Yapay zeka, Absorbsiyonlu soğutma, COP

1. Introduction

The absorption refrigeration system is a technology based on the evaporation and condensation principles of a refrigerant (usually a water-ammonia couple) to transfer heat and provide cooling. This system works by using a thermochemical process [1],[2] instead of using a mechanical compressor. An absorption cooling system usually consists of five main components:

Generator: This component provides the evaporation of ammonia and the separation of pure ammonia gas. It usually works at high temperature and provides energy.

Absorber: Absorber is a component in which ammonia is reabsorbed and recovered with water solution. When ammonia gas comes into contact with the water solution, it dissolves into water and turns into a solution.

Heat Exchangers: The heat exchangers in the system are the components where the heat is transferred and exchanged. Heat transfer takes place through heat exchangers, where ammonia and water are transferred to each other or to the surrounding environment.

Evaporator: Evaporator is the component used to create the cooling effect. In the evaporator, as the ammonia-water solution evaporates, heat energy is absorbed and cooling is provided by lowering the ambient temperature.

Condenser (Condenser): Condenser is a component in which gaseous ammonia condenses and turns into liquid form. The condensation process removes the heat from the environment, causing the temperature to rise.

The absorption cooling system can be fed from different energy sources such as natural gas, solar energy or waste heat as a heat source. Therefore, it is advantageous in terms of energy efficiency and environmental sustainability. However, it may have a more complex structure and higher costs [3],[4].

Because the operation of this system is based on heat transfer principles, it can provide energy efficiency compared to traditional compressor cooling systems that need electrical energy for the cooling process. Therefore, absorption cooling systems can be preferred in applications with energy saving potential [5-7].

Such refrigeration systems are widely used in large-scale applications such as hotels, hospitals, industrial facilities or on-site air conditioning systems. Absorption cooling offers advantages such as energy efficiency, sustainability and reduction of environmental impact.

Artificial intelligence is a technology designed to emulate or demonstrate the human-like intelligence and learning abilities of computer systems. Artificial intelligence uses algorithms and models so that computers can perform complex tasks, make decisions, and learn. The main purpose of artificial intelligence is to imitate human-like intelligence features. This includes skills such as language comprehension, image recognition, voice recognition, natural language processing, pattern recognition, prediction, decision making. Artificial intelligence usually analyzes data, recognizes patterns, makes decisions and learns new information [8].

Machine learning, one of the subfields of artificial intelligence, is a technique that enables computer systems to learn from experience. Machine learning enables a model to recognize statistical patterns and relationships by analyzing data to perform a specific task. Deep learning, on the other hand, is a subfield of machine learning in which deep structured learning models called artificial neural networks are used [9].

Artificial intelligence is applied in many fields. For example, it is used in areas such as automation, health, finance, transportation, games, security, and natural language processing. For example, many applications such as automated tools, personal voice assistants, recommendation systems, image recognition software, and weather forecast models use artificial intelligence [10].

Artificial intelligence offers the potential of computer systems to solve complex problems, increase efficiency and create new opportunities.

2. Material Metod

2.1. Absorption cooling system

Absorption refrigeration cycles are systems that perform cooling using a solution between ammonia (NH_3) and water (H_2O). Figure 1 shows the absorption cooling system and the system loop.

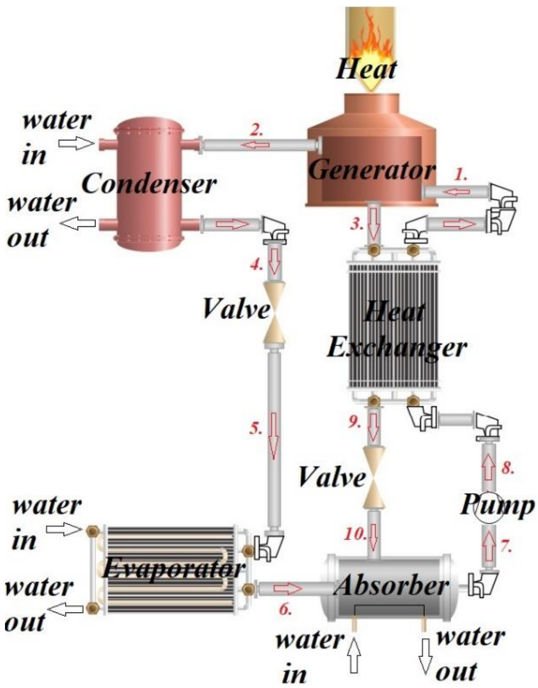

Figure 1. Absorption cooling system.

The way the system works is as follows. First, in the generator, the solution is heated to obtain pure ammonia. The heating process evaporates the ammonia, thus generating pure ammonia gas and forming the remaining water solution. Pure ammonia gas leaving the generator is condensed in the condenser. Condenser is a heat exchanger in which gaseous ammonia turns into liquid form by cooling. Meanwhile, heat is absorbed from the environment and this heat is thrown out. The condensed ammonia liquid goes to the evaporator through an expansion valve. The expansion valve reduces the pressure of the liquid ammonia, providing a pressure drop at its inlet to the evaporator. In the evaporator, liquid ammonia evaporates under low pressure and temperature conditions. Meanwhile, the evaporator absorbs heat from the environment, which cools the surrounding environment. After the ammonia vapor exits the evaporator, it goes to a component called an absorber. In the absorber, the ammonia vapor comes into contact with the water solution and is absorbed by the water. In this process, ammonia recycles into solution and leaves the absorber as solution. The solution leaving the absorber returns to the generator and the cycle starts over.

2.2. Neural network model

Artificial neural networks (ANNs) are information processing systems used in artificial intelligence and machine learning. ANNs are mathematical models inspired by the neural networks of the human brain. These models can identify patterns and relationships, solve complex problems, and make predictions by analyzing data [11].

ANNs consist of nodes (neurons) and the connections between these nodes. Each node receives input data, processes that data, and produces an output. This is done by multiplying the input data by weights and passing it through an activation function. The weights are the values determined during the learning process of the ANN, and these values are determined by an optimization process that aims to produce outputs suitable for the data [12].

The MATLAB program employed a Neural Network application for the modeling, training, and testing phases of the artificial neural network. Constructing this model involved determining various parameters: the network type, input and output data for training, training and learning algorithms, performance function, the configuration of input and output layers, the potential hidden layers, if included, and the activation function. Specifically, the multilayer feedforward backpropagation algorithm, a widely-used method for predictions based on datasets, was selected as the network type. The input layer was composed of generator input, output pressure, and temperature values, while the output layer focused on the coefficient of performance (COP). Figure 2 illustrates the structure of the resulting artificial neural network model.

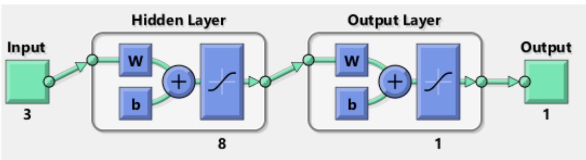

Figure 2. Created artificial neural network model.

According to the created network model, momentum coefficient, learning coefficient and number of cycles parameters can be found in order to realize the training. For training, 200 data were taken from the cooling system. As a result of the training; The ROC (Receiver Operating Characteristic) curve regression graph for the training, validation and test sets is shown in Figure 3. According to this graph, learning was successfully performed with a value of 0.99705, validation of 0.99644, and testing of 0.99752.

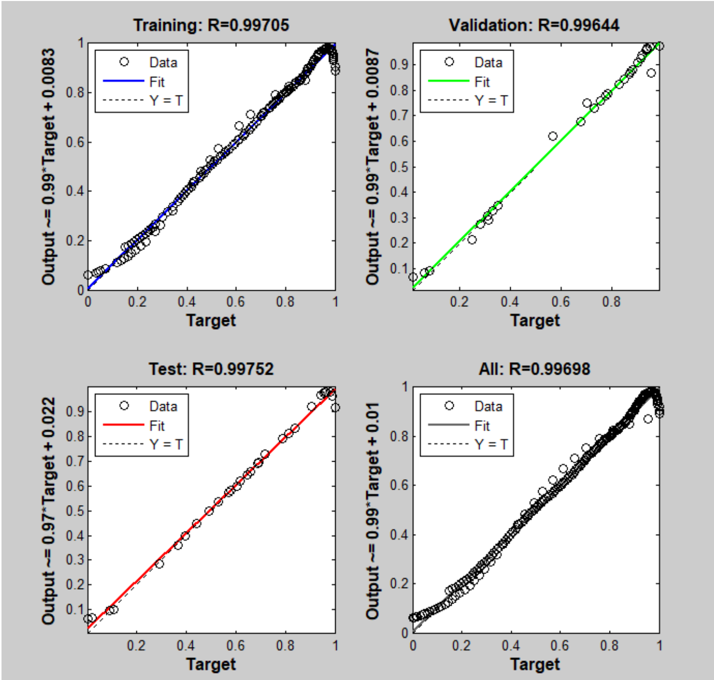

Figure 3. ROC curve.

At the same time, the training performance according to these data is shown in Figure 4.

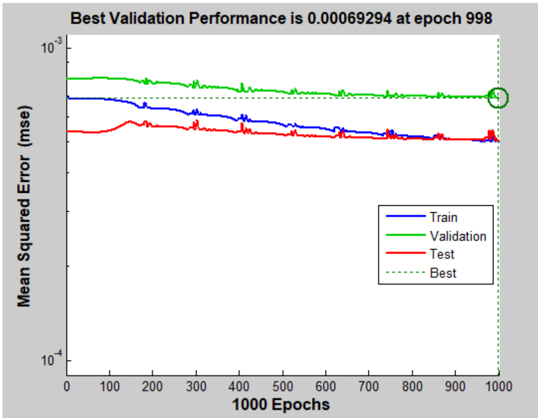

Figure 4. Performance curve.

At the end of the training, the test process was carried out so that the artificial neural network could predict the output according to the input data.

Simple error deviation value was used as in Equation 1 to measure the estimation accuracy. Here (e) error, (x) predicted values and (xi) actual values [13].

$$e = x - x^1 \qquad (1)$$

The percent error (% p) of the estimation values can be calculated as in Equation 2.

$$p = \frac{e}{x^1} x100 \qquad (2)$$

One of the error criteria used to measure the consistency of prediction results in artificial neural networks is the Mean Squared Error (MSE) method, as shown in Equation 3.

$$\text{MSE} = \frac{1}{n}\sum_{i=1}^{n}(x - x^{\prime})^2 = \frac{1}{n}\sum_{i=1}^{n}(e)^2 \quad (3)$$

According to the artificial neural network training results, the test data, the estimated values of the fuel amount of the network and the real values measured, the deviation amounts between the measured and predicted demand quantities, and the percentage error amount were calculated. Accordingly, the mean square error value was found to be 0.000569.

In Figure 5, the actual values of the 30 test data we reserved for estimation and the data values predicted by the artificial neural network as a result of the training are shown graphically. According to this graph, it is seen that the prediction result is close to the true values and the artificial neural network has been successfully trained and yielded results.

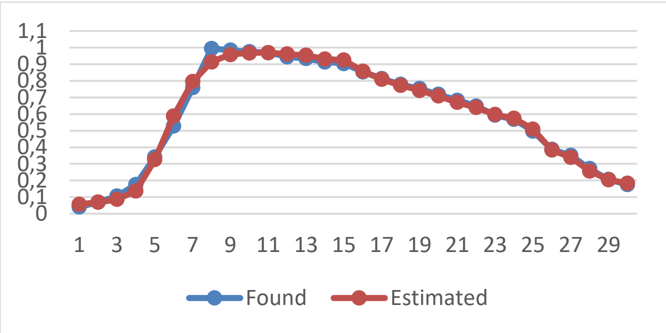

***Figure 5.** The actual values and the data values predicted by the artificial neural network as a result of the training*

3. Conclusion

Labus et al. used four empirical models to predict absorption cooler performance: adapted Gordon-Ng model, characteristic equation model, multivariate polynomial model and artificial neural network model using experimental data and examined in detail [14]. Şencan et al. used Artificial Neural Network to determine the thermodynamic properties of LiBr-water and LiCl-water solutions. Accordingly, the coefficient of multiple determination (R2 value) between the real data and the ANN predicted data was found to be approximately 0.999 for the enthalpy of LiBr-water and LiCl-water solutions [15].

The artificial neural network model gives positive results in solving problems related to many variables that do not have a linear relationship between them. Here, the prediction results of the artificial neural network are compared with the measured data on how the efficiency of the system will change according to the change in the input and output pressure and temperature data values of the generator, which is a part of the absorption. cooling system. Accordingly, generator inlet pressure, outlet pressure and temperature values constitute the input of the artificial neural network and the output of the system efficiency (COP). A dataset of 200 entries was managed, including 155 for training, 15 for validation, and 30 for testing. The neural network model was trained using training data and when tested with separated test data, the predicted values exhibited a minimum mean square error (MSE) of 0.000569. Using this model, the efficiency of the cooling system was predicted with a remarkable accuracy of 99%.

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