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## Estimating Economical Thermal Insulation Thickness Using Artificial Intelligence Approach

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### 1. ABSTRACT

Due to the complexities in industrial processes and the variety of environmental conditions, it is necessary to use advanced methods to determine the insulation thickness. This study examines the use of artificial neural networks to predict the thickness of thermal insulation. In this regard, first, the thermal insulation data available in Iranian Petroleum Standard (IPS) with the code IPS-E-TP-700, is collected, and then the thickness of the insulation is predicted as a function of the outer diameter, thermal conductivity of the insulation and surface temperature. The statistical results show the high accuracy of the method used in predicting the thickness of the insulation, and the value of the regression coefficient and the relative error percentage for the tested data are 1.000 and 0.19, respectively. This approach not only helps to optimize insulation processes, but can also lead to cost reduction and increased safety in industrial operations.

**Keywords:** Artificial Neural Network, Insulation, Machine learning, Oil and Gas Industry, Modeling.

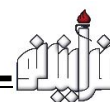
### 2. INTRODUCTION

Thermal insulation, as one of the essential components in the oil and gas industry, plays a key role in optimizing energy consumption, maintaining temperature, and enhancing the safety of equipment. Given that the processes of extraction, refining, and transportation of oil and gas are typically conducted at high temperatures and under harsh conditions, the use of appropriate thermal insulations can significantly prevent heat loss and improve system efficiency. In today's world, with increasing concerns about climate change and the need to reduce energy consumption, the importance of insulation in various industries, especially in the oil sector, has become more pronounced. Thermal insulations not only help reduce operational costs but also assist in maintaining temperatures within desirable ranges for industrial processes. This is particularly critical for sensitive equipment such as tanks, pipes, and furnaces that are exposed to high temperatures and temperature fluctuations. Furthermore, proper insulation can help mitigate risks associated with high temperatures, such as fires and explosions. In the oil industry, which deals with flammable and hazardous materials, safety is one of the top priorities. Therefore, the selection and installation of suitable thermal insulations can directly impact the safety of personnel and equipment [1, 2]. Thermal insulations are produced in various types, each with its own specific characteristics and applications. From mineral insulations like rock wool and fiberglass to organic insulations such as polyurethane and polystyrene foams, each of these materials is used in different conditions due to their unique properties [2, 3]. Mineral insulations are employed in refinery equipment and furnaces due to their heat and fire resistance, while organic insulations are used for pipe and tank insulation because of their lightweight and good thermal efficiency [3]. Determining the appropriate thickness of thermal insulation is one of the significant challenges in the design and

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implementation of insulation systems. This process requires considering several factors, including the type of insulation, operating temperatures, type of fluid, and industry standards. Accurate thermal calculations and the use of specialized software can assist engineers in determining the optimal insulation thickness, thereby achieving maximum efficiency and safety. In this context, thermal insulation is recognized not only as an economic solution for reducing energy costs but also as a vital tool for maintaining safety and efficiency in the oil and gas industry. Given the increasing importance of environmental and economic issues, this topic is significant not only for engineers and industry professionals but also for policymakers and researchers. Predicting the thickness of thermal insulations using artificial neural networks is one of the interesting and novel topics in the field of oil and gas-related sciences. Artificial neural networks, as a powerful tool in machine learning, have the capability to model complex and nonlinear relationships between inputs and outputs. Today, intelligent methods have wide applications in engineering sciences, especially in fields related to chemical and petroleum engineering [4]. By using experimental data and numerical simulations, neural networks can be trained to predict the optimal thickness of thermal insulations. This method can assist engineers and designers in making better decisions regarding material selection and thermal system design. In this study, data related to the optimal thickness of thermal insulations based on a function of the outer diameter, surface temperature, and thermal conductivity of the insulation were obtained from the IPS standard [3]. Subsequently, the optimal thickness of the insulation was estimated using the artificial neural network method.

### 3. MATERIALS AND METHODS

#### 3.1. Artificial neural network background

Artificial neural networks are inspired by the biological neurons in the human body, which become active under specific conditions, resulting in a corresponding action. Artificial neural networks consist of different layers of interconnected artificial neurons that are fed by activation functions, which help turn them on or off [4]. In summary, each neuron receives a weighted sum of the inputs and random weights, which is then augmented by a static bias value (unique to each layer of neurons). This sum is then passed through an appropriate activation function that determines the final value to be output from the neuron. Depending on the nature of the input values, various activation functions can be used. When the output from the final layer of the neural network is generated, a loss or error function (comparing input to output) is calculated, and backpropagation is performed to adjust the weights for minimal error. Finding the optimal weight values in the neural network is the primary focus of the overall operation. The structure of a neural network is illustrated in Figure 1.

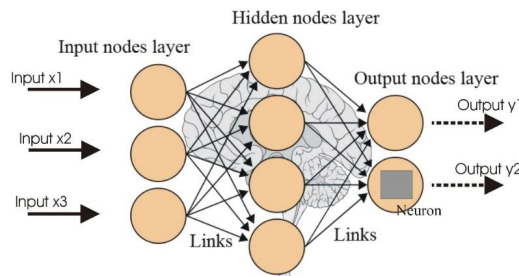


Figure1. The structure of a neural network.

#### 3.2. Data collection

The data used in this research were obtained from the IPS-E-TP-700 standard [3]. This standard contains a total of 768 data points, which include information on outer diameter (in millimeters), surface temperature (in degrees Celsius), thermal conductivity of the insulation (in W/(m·K)), and insulation thickness (in millimeters). The range of the available variables is shown in Figure 2. It is important to note that the data related to surface temperatures of 300 and 600 degrees Celsius were considered as test data to effectively evaluate the model.

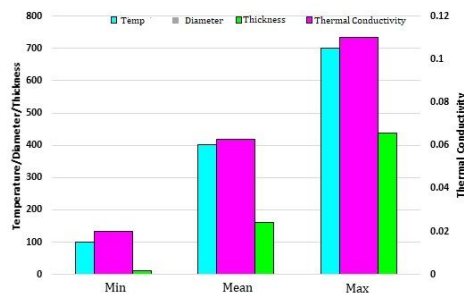


Figure 2. The range of the available variables

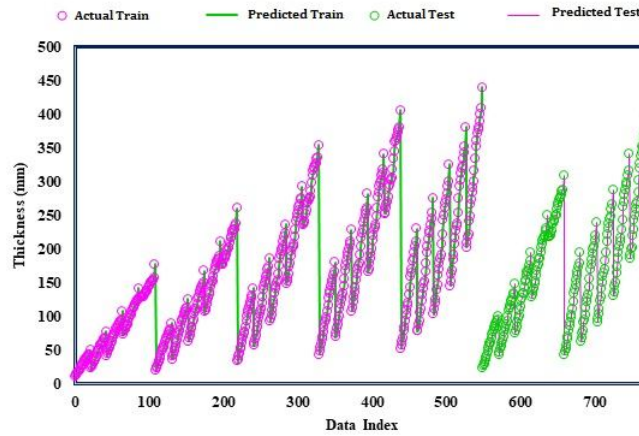


### 3.3. Model Development

To perform modeling using the artificial neural network method, MATLAB version 2016 was utilized. In this regard, the input data were first divided into two categories: training and testing. The data related to surface temperatures of 300 and 600 degrees Celsius were used to test the model’s performance, while the remaining data were employed for its training. In this study, the number of neurons in the hidden layer of the artificial neural network was set to 10, and the weight and bias parameters were optimized using the Levenberg-Marquardt algorithm. After constructing the model, various statistical evaluations, such as the coefficient of determination, percentage of relative error, and mean squared error, were conducted to assess its performance.

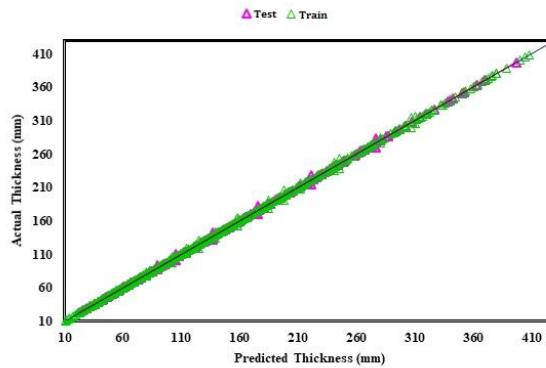
### 4. RESULTS AND DISCUSSION

Figure 3 shows the optimal insulation thickness based on the actual data and the values predicted by the artificial neural network model. As can be seen, the difference between the actual and predicted values is very minimal, indicating that the current model has successfully predicted the insulation thickness.



**Figure 3.** The optimal insulation thickness based on the actual data and the values predicted

Additionally, the regression plot of the neural network model for the test and training data is presented in Figure 4. The coefficient of determination obtained for both the test and training groups was 1.000, indicating the high accuracy of the proposed model.



**Figure 4.** Regression plot of optimal insulation thickness

The equation of the line between the actual data and the model for both the test and training groups is obtained as follows:

$$y = x - 0.0015 \tag{1}$$

In this formula, x represents the model output, and y corresponds to the actual data, which is very close to the line  $y=x$ .

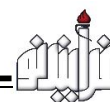


Table 1 presents the statistical evaluation of the neural network model, and as indicated, the accuracy of the proposed model is very high, showing an excellent match with the actual data.

**Table 1.** The statistical evaluation of the neural network model

Group	MSE	R <sup>2</sup>	MRE (%)
Test	1.98	1.00	0.19
Train	1.78	1.00	0.20
Total	1.93	1.00	0.19

Table 2 presents a comparison between the predicted values of the neural network model and the empirical relationship by Bahadori et al. [5]. As indicated, the accuracy of the present method is significantly higher than that of the empirical relationship.

**Table 1.** The statistical evaluation of the neural network model

Temperature	Conductivity	Diameter (mm)	Thickness (mm)	Thickness (current model)		Thickness (Bahadori et al. model)	
				Prediction value	Errorr %	Prediction value	Errorr %
100	0.02	168.3	31	31.00133	0.0043	31.37	1.19
300	0.03	114.3	56	56.001	0.0019	55	1.79
500	0.05	101.6	90	90.00	0.00082	89	1.11
700	0.08	273	214	213.99	0.0002	209	2.34

## 5. CONCLUSION

Predicting the thickness of thermal insulation for equipment in the oil and gas industry is recognized as a key factor in optimizing performance and reducing energy costs. In this study, the thickness of thermal insulations was predicted as a function of the outer diameter, thermal conductivity of the insulation, and surface temperature using an artificial neural network. The model parameters, including weights and biases, were optimally determined through the Levenberg-Marquardt algorithm. The statistical results and presented graphs indicate the high accuracy of the method used in predicting insulation thickness, with the coefficient of determination and the percentage of relative error for the tested data being 1.000 and 0.19, respectively. This approach not only aids in optimizing insulation processes but can also lead to cost reductions and increased safety in industrial operations.

## 6. REFERENCES

- [1] Zach J, Hroudová J, Brožovský J, Krejza Z, Gailius A. Development of thermal insulating materials on natural base for thermal insulation systems. *Procedia Eng*, 57, pp. 1288–94. 2013
- [2] Villasmil W, Fischer LJ, Worlitschek J. A review and evaluation of thermal insulation materials and methods for thermal energy storage systems. *Renew Sustain Energy Rev*, 103, pp. 71–84, 2019
- [3] Standard IP. Engineering standard for thermal insulations. Rep IPS-E-TP-700, Natl Iran Oil Company, Ahwaz, Iran 1996.
- [4] Baghban A, Ahmadi MA, Pouladi B, Amanna B. Phase equilibrium modeling of semi-clathrate hydrates of seven commonly gases in the presence of TBAB ionic liquid promoter based on a low parameter connectionist technique. *J Supercrit Fluids*, 101. 2015.
- [5] Bahadori A, Vuthaluru HB. A simple correlation for estimation of economic thickness of thermal insulation for process piping and equipment. *Appl Therm Eng*, 30, pp. 254–9, 2010.