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CuO (copper oxide) Nanoparticle Production and Determination of Heat Transfer Coefficient

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ABSTRACT : *In our work, CuO (copper oxide) nanoparticle production was performed. Heat transfer coefficients (h) were determined using pure water, ethanol and ethylene glycol materials together with CuO nanoparticles. It was observed that the number of Reynolds changes between 846 and 2292 in the experiments performed.A predictive model was obtained by using the support vector machine (SVM) regression for the calculated heat transfer coefficient of nano fluid.The mean absolute error (MAE) and the root mean square error (RMSE) error analyzes were performed for the predictive model in SVM regression. In SVM regression, normalized poly kernel was used as kernel function.*

KEYWORDS: *nano fluid, nano material, heat transfer coefficient, support vector machine regression*

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I. INTRODUCTION

It is important to be able to use the energy in a more beneficial way by increasing the heat transfer in the in-pipe flows. Because, with the technological developments, there is an increasing energy demand in the industry sector. For this reason, researchers have been working on new generation heat transfer fluids in recent years [1].Today, nanotechnological developments have allowed the production of particles in nanometer dimensions, thus adding particles into the fluid. In particular, the techniques used in the production of metallic nanoparticles; micro emulsion technique, gas phase production technique, inert gas condensation, chemical vapor condensation and hydrogen reduction technique [2].These produced nanoparticles (1-100 nm in size) can be used to obtain new fluids by mixing certain basic fluids such as water, synthetic oil and ethylene glycol with specific volumetric and mass proportions with conventional heat transfer fluids. These fluids are called nanofluids. Choi [3], the first to use the term nanofluid as the fluid in which the nanoparticles are suspended, observed that the thermal conductivity of the basic fluid nearly doubled when the nanoparticle was added in small volumetric ratios (less than 1%).

Nanoparticles that help improve heat transfer; In the effect on the properties of nanofluid, it is very important to prepare the nanofluids, the thermophysical properties of nanofluids and the heat transfer measurement techniques correctly.Zhu et al. [4] obtained non-agglomerated and stable Cu nanofluids with $CuSO_4 \cdot 5H_2O$ and $NaH_2PO_2 \cdot H_2O$ by one-step method. The thermal conductivity of nanofluid prepared with Cu and ethylene glycol of 0.3% volumetric ratio was 40% improvement.Eastman et al. [5] is a one-step method for producing nanostructures containing various nanoparticles such as TiO_2, CuO and Cu. This method has also been used to synthesize sub-nanoparticles [6]. In this method, the nanoparticles are heated by the heat obtained from the electrode and then condensed into the liquid chamber in the vacuum chamber to produce nanofluids. The thermos physical properties of nanofluids are very important for heat transfer applications. The thermophysical properties contain different parameters. These; specific heat capacity, viscosity, thermal conductivity and heat transfer coefficients. Heat transfer of nanofluids is best analyzed by heat transfer coefficient [7].Nguyen et al. [8] studied the nanofluid composition of aluminum-water to see the effect of particle size on viscosity. In their study, they obtained the same results for particles with 36 and 47 nm in 4% volumetric ratio. They stated that the higher the particle size, the higher the viscosity, and the more viscosity of the fluid.

Because the solid conductivity of the solid metals is higher than the basic fluid, the small solid metals introduced into the fluid increase the thermal conductivity [9].Xie et al. [10] have observed the effect of particle size on the thermal conductivity by producing a particle size of 26 to 600 nm of non-oxide ceramic nanoparticated nanofluid (SiC) and Al_2O_3 nanoparticle having a particle size of 1.2 to 3.02 nm.

Support vector machine (SVM) regression is a computational intelligence method such as artificial neural network.Artificial Neural Networks (ANN) are briefly developed by inspiring the human brain; parallel and distributed information processing structures are composed of process elements connected by means of weighted links and each having their own memory; in other words, computer programs that mimic biological neural networks [11].In the literature, there are several studies related with the estimation of nanofluids properties by ANN. Uysal and Korkmaz, in the rectangular cross-section, the quantitative analysis of Ag-MgO / water hybrid nanofluidic flow by convective heat transfer and entropy production characteristics. The Reynolds number ranged from 200 to 2000. Ag-MgO / water used Artificial Neural Networks to predict entropy production of hybrid nanofluidic flow [12]. In their study, Kılıç et al. Investigated the quantitative investigation of heat transfer and fluid flow from a heated surface, using nanofluids and pulsed jets. They obtained a predictive model in ANN with the obtained values [13].

In this study, CuO nanoparticles were produced and then SEM images of the produced particles, FTIR (Fourier Transform Infrared Spectroscopy) Analysis, X-ray diffraction method analysis (XRD), X-ray spectroscopy (EDS or EDX) analysis, Ultra-violet visible light (UV -Vis) and Thermogravimetry (TG) Differential Thermal (DTA) analysis and measurements were carried out. Nanofluids were obtained by using Nano particles produced with Pure Water, Ethanol and Ethylene Glycol materials and experiments were carried out to determine the heat transfer coefficients by passing the fluid through the experimental setup. In all experiments, the Reynolds number ranged from 846 to 2292. For the heat transfer coefficient obtained for CuO, a predictive model was created by using SVM regression. The error analysis of the predicted model was performed.

II. MATERIAL AND METHOD

In this study, heat transfer coefficients were calculated after the production of a nanofluid at different pHs. For predicted heat transfer coefficients, a predictive model was developed by using ANN.

2.1. CuO Nanofluid Production

CuO particle production 3,633 grams (0.02 mol) Copper Acetate dissolved in 100 ml ethanol in ultrasonic bath for 30 minutes and the solution formed. 8 grams (0.2 mol) of NaOH (Sodium Hydroxide) in 200 ml of distilled water was then dissolved in an ultrasonic bath for 30 minutes. The resulting mixtures were then combined and stirred in the magnetic stirrer for 1 hour.In order to obtain the mixture at different pH ratios, ammonia was added to the mixture with 10 ml beaker to obtain mixtures at different pH ratios. The mixture was allowed to settle for 20 hours after preparation. After the resting process was completed, filter paper was placed in the funnels and the material was subjected to drying at 50 ^oC, and the resulting material was heat treated at 450 ^oC for 1 hour. SEM images of the material produced, FTIR (Fourier Transform Infrared Spectroscopy) Analysis, X-ray diffraction method analysis (XRD), X-ray spectroscopy (EDS or EDX) analysis, Ultra-violet visible light (UV-Vis)) and Thermogravimetry (TG) Differential Thermal (DTA) analysis measurements were performed and nano particle production was found to be successful.

Materials used for the production of nanofluids after production of nanoparticles; 57.1% Pure Water, 28.6% Ethylene Glycol, 14.8% Ethanol and nano materials produced in 0.1% of the mixture of nano particles are added after 45 minutes in an ultrasonic mixer by mixing the mixture in an additional 15 minutes in a fish mixer to be used in the nanoactive test setup has become available.The pH values determined for the nanoparticles are varied before the production of CuO nanofluids at different pHs. The reason for this is the change in the content of the fluid produced since different materials are used when producing nano fluid.

After determining the density of the produced nanofluids, the pH of the nanofluids produced in the pH meter is determined. Experiments were performed for 5 different Reynolds values between 846 and 2292 values for the produced nanofluids and the temperature values of the fluid at 5 minute intervals from the inlet, outlet temperature and pipe surface were measured with the help of Thermo Couples until the temperatures were stable. Heat transfer coefficient and heat transfer coefficients were calculated with the obtained data. The experimental set-up for the heat transfer coefficient calculation is shown in Figure 1.

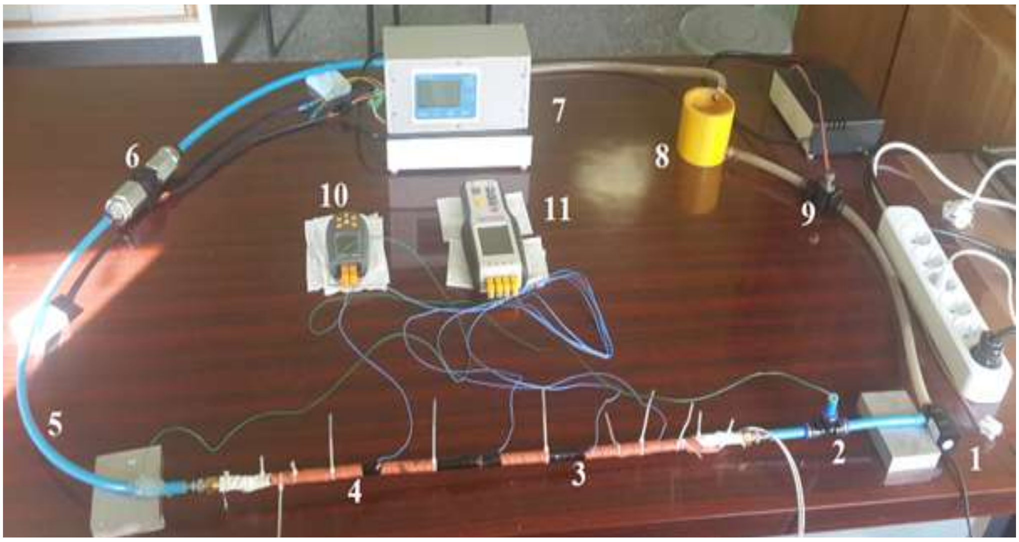

Fig.1. Data-logger unit for monitoring solar PV plants
1-Pump, 2-T Connection reducer elbow pipe, 3-Heat Band, 4 -Copper pipe, 5-Plastic pipe 6- Flow Measurement Electronic device sensor, 7-Flow Measurement Electronic device, 8-Fluid reservoir, 9-Flow Adjustment Valve, 10-Fluid Thermometer and 11-Thermocouple

As shown in Fig. 1, the flow rate of the flow rate is adjusted by means of a flow rate control valve. Temperature measurements were taken from 4 different points on the surface of the pipe with the help of the thermocouples of the nanofluids passing through the copper pipe through laminar flow. The inlet and outlet temperatures of the nanofluid to the copper tube were measured by means of a fluid thermometer. The volume flow rate of the nanofluid was determined by means of the flow meter.

2.2. Heat Transfer in Nanofluids

Heat transfer between all environments and environments where there is a temperature difference occurs. In the case of a stationary solid or a fluid, the term transmission is used when the heat transfer occurs because of the temperature difference. Furthermore, when a surface and a fluid in motion are at different temperatures, the heat transfer between them is referred to as the term transport. All surfaces with finite temperature emit energy in the form of electromagnetic waves. The heat exchange between two surfaces of different temperature, if there is no barrier to seeing each other, is called radiation [13].

The transmission indicates the energy transfer due to the temperature difference in an environment. Heat conduction can be fully explained by Fourier's law. A body having a fixed cross-sectional area; one dimensional, steady state heat transmission is expressed by the following equation.

$$q_x'' = -k\frac{dT}{dx}, q_x'' = -k\frac{T_2 - T_1}{L} \tag{1}$$

Transport is a combination of mass movement, the mixing of macroscopic parts of hot and cold fluid elements, heat conduction in the cooling medium, and energy storage. This is called natural (or free) convection if the charge forces due to the density differences caused by the lack of temperature in the fluid are associated with the convection event. Besides, flow; if it occurs with an external effect such as a fan, pump or atmospheric wind, this is called forced convection. Heat transfer from a hot object to the refrigerant fluid is associated with the following equation, known as Newton's Cooling Law [14].

$$q'' = h(T_s - T_\infty) \tag{2}$$

Investigators studying the effects of nanofluids on heat transfer have observed that not only thermal conductivity, but also the heat transfer coefficient, is too large in the nanocomposed fluid as in Figure 2.[14].

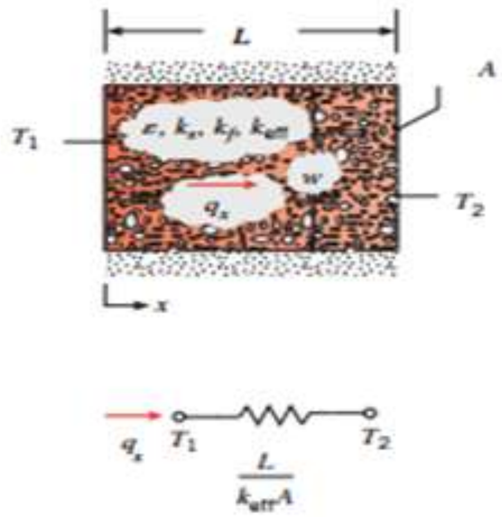

Fig.2. Heat transfer properties of nanofluids

To adapt the heat transfer properties of the suspension obtained with mixtures of liquids and solids, it can be formulated as follows.

$$q_x = \frac{k_{eff} A}{L}(T_1 - T_2) \tag{3}$$

If fluid motion is negligible, the above equation is valid when the heat transfer in the environment is neglected. Effective thermal conductivity at equality. Effective thermal conductivity varies with the porosity or volume fraction of the medium. In addition to these properties, it depends on the thermal conductivity of the solid and liquid. Experimental studies conducted by different researchers have shown that the increase in the heat transfer coefficient of the nanofluids is higher than the thermal conductivity in both laminar and turbulent flow conditions.The basic law of transport was declared by Newton before Fourier's transmission law was proposed, and it was named Newton's law of cooling.

$$Q = hA(T_w - T_f) \tag{4}$$

In the above formula, Q is the heat transfer between the wall and the moving liquid. A is the common surface area between solid and liquid. T_w is the average temperature of the surface and T_f is the average of the inlet and outlet temperature of the liquid [14].

In circular pipes; The Nusselt number is a constant in fully developed flow situations where laminar flow and constant surface heat flux (q_s = constant); It does not depend on Reynolds or Prandtl numbers [14]. The conductivity coefficient k value was calculated according to the following formula.

$$Nu = \frac{hD}{k} = 4.36 \tag{5}$$

2.3. Modeling of Data with SVM regression

Support Vector Machine (SVM) is a classification and regression method that combines theoretical solutions with numerical algorithms. In statistical learning theory, this technique has been developed as a learning algorithm based on Structural Risk Minimization (SRM) rather than Empirical Risk Minimization (ERM). SRM induction principle provides a formal mechanism to determine the optimal model complexity, depending on the Vapnik-Chervonenkis (VC) dimension for the finite samples [15]. Compared to classical neural networks, SVM can achieve a single global optimal solution and does not encounter size problems. These attractive features often make SVM a preferred technique. SVR is featured with the capability of capturing nonlinear relationship in the feature space and thus is also considered as an effective approach to regression analysis. The following sketches the basic idea of SVR. For more detailed illustration of SVR, please refer to Burges [16].

In the system, SVM regressionwas modeled as thirteen inputs and one output. Reynolds number (Re), duration (t), fluid velocity (V), hydrogen power value (pH), fluid inlet temperature (Tg), outlet temperature (Tc), inlet and outlet temperature average (Tavg1), (T1,2,3,4) surface temperature average (Tavg2) and heat conduction coefficient (k) of the fluid were used as inputs. The heat transfer coefficient (h) of the fluid is used as outputs information. The input layer of the model, which consists of 5 layers in total, contains 13 neurons for the input, the first hidden layer 6 neurons, the second hidden layer 6 neurons, one neuron for the third hidden layer, and the output layer contains only one neuron. The structure of the SVM regression model is given in Figure 3.

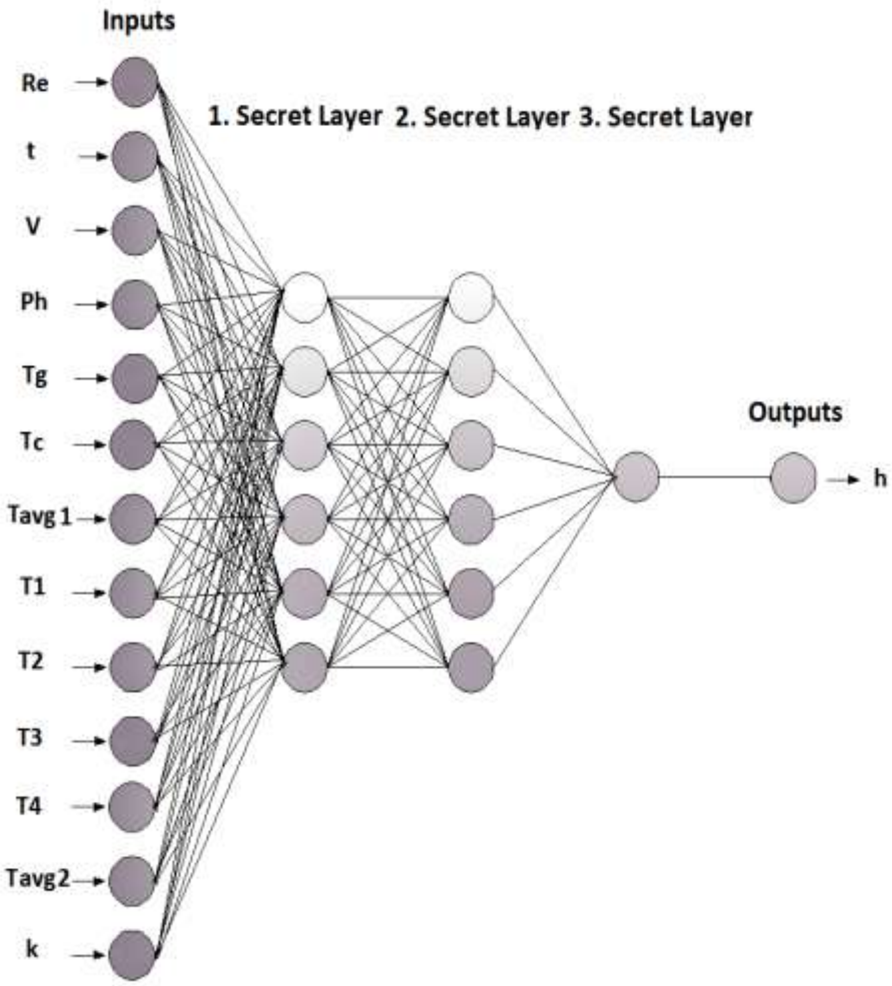

Fig. 3. Predictive model structure

MATLAB 2016a software is used for modeling of heat convection values with artificial neural network. The information set has 280 input and output information. Of these, 200 were used in the training process. 80 were used in the test procedure. Feed Forward Back Propagation (forward feed and back propagation) algorithm is used as learning algorithm. Levenberg Marquardt algorithm was used for training.The mean absolute error (MAE) and the root mean square error (RMSE) were analyzed to determine the accuracy of the predictive model obtained with SVM regression. Error analysis is shown in Table 1.

Table 1. Accuracy Criteria and Formulas

Accuracy Criteria	*Formulas*	*Parameters*
MAE	$\frac{\lvert P_1 - A_1\rvert + \ldots.. + \lvert P_n - A_n\rvert}{n}$	P: Predicted Value A: Actual Value n: Total Estimated Value
RMSE	$\sqrt{\frac{(P_1 - A_1)^2 + \ldots.. + (P_n - A_n)^2}{n}}$	P: Predicted Value A: Actual Value n: Total Estimated Value

In SVM regression, h estimates were performed using normalized poly kernel.The formulation of the normalized polycrystalline is given in the equation below.

$$K(x,y) = \frac{((x.y)+1)^{d}}{\sqrt{((x.y)+1)^{d}((y.y)+1)^{d}}} \quad (6)$$

The value of d in Equation (6) is degree of polynomial.

III. RESULTS

In this study, the heat transfer coefficient of CuO nanofluids in various pHs for nanofluids obtained by using nanomaterials produced increases with Reynolds number between 800 and 2300. Figure 4 shows that there is an inverse relationship between pH and heat transfer coefficient (h). The reason is that the fluid used to raise the pH levels while producing nanomaterials; Since 25% is NH_3 and 75% water, the specific heat of the fluid is lower than that of CuO nanofluids.

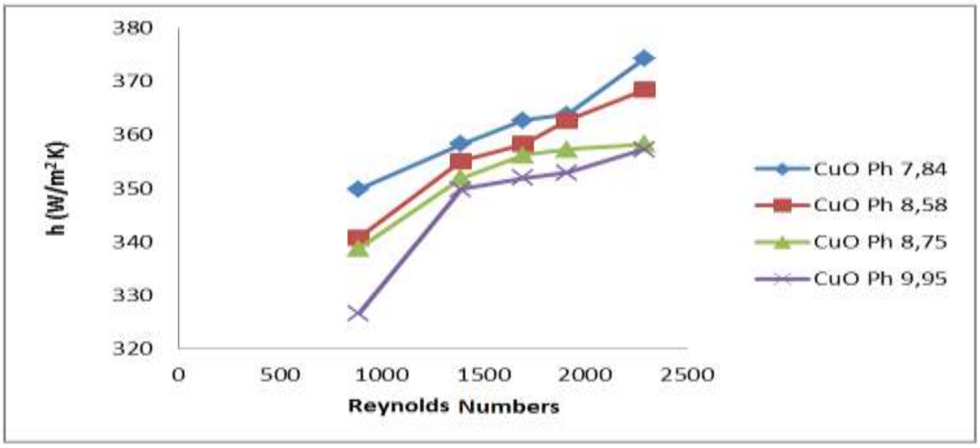

Fig. 4. Variation of heat transfer coefficient for CuO pH values by Reynolds number

The error rates for ANN models created for heat transfer coefficients of CuO nanofluids are shown in Table 3.

Tablo 3.SVM regressionError rates

Error Analyze	Error Rate
MAE	0.6499
RMSE	0.771

Figure 5 shows experimental and predictive heat transfer coefficients.

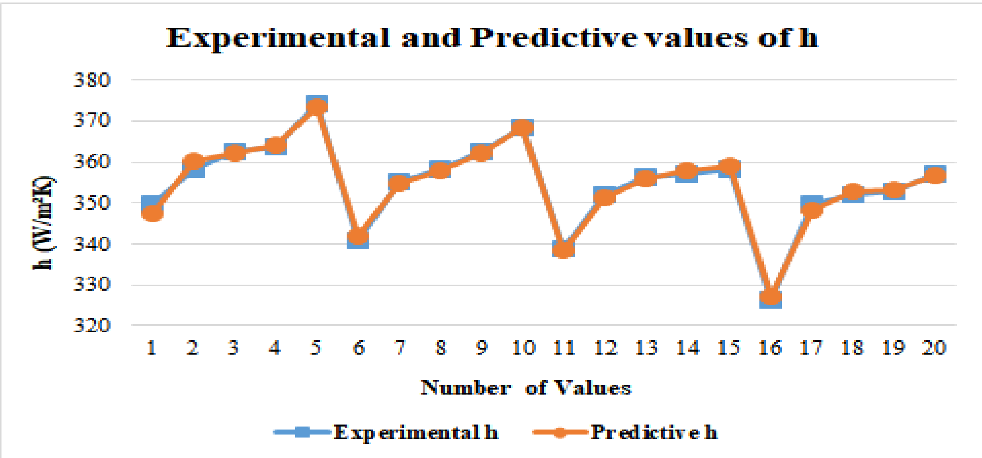

Fig. 5.Estimated h values obtained using SVM regression

IV. CONCLUSION

In this study, CuO nanoparticles were produced. Heat transfer coefficients were calculated by using the nanoparticles produced by using pure water, ethanol and ethylene glycol material with the nanoparticles produced. As the Reynolds number increased, the heat transfer coefficient of nano fulids increased in accordance with the calculations. When the pH values increased, it was observed that the heat transfer coefficient of the nanofluids decreased.When the values in Figure 4 are transferred to Table 4, this change is seen more clearly.

Table 4. Change of heat transfer values of CuO nanofluid

Re	CuO 7.84(h)	CuO 8.58(h)	CuO 8.75(h)	CuO 9.95(h)
887	349,821	340,722	338,764	326,565
1391	358,328	355,090	351,910	349,821
1695	362,738	358,328	356,163	351,910
1912	363,857	362,738	357,242	352,963
2290	374,253	368,406	358,328	357,242

The network has been trained to improve the predictive ability of SVM regression. The predicted and the actual measured h values are similar. It was concluded that for the predictive model of h is a successful modeling according to the error analysis results of ANN (Table 3).As shown in Figure 5, the experimental and predictive h values are very close to each other.

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