DEVELOPMENT OF AN ARTIFICIAL NEURAL NETWORK TO PREDICT THE CORROSION RATE IN CARBON STEELS UNDER ATMOSPHERIC CONDITIONS

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Atmospheric corrosion of carbon steel under atmospheric conditions is a complex, nonlinear process. It involves a large number of interacting and varying factors: material composition, location of exposure, temperature, relative humidity, wet-dry patterns, amount of precipitation, concentration of main pollutants, etc. The most important variables were chosen from a data mining that was carried out with experimental results that were documented worldwide. The resulting statistical correlations served as the basis for the modelling of the artificial neural network (ANN). Although the modelling of the ANN is still being improved, the results show a R-square value of 0.94244 indicating that the ANN model has a good fit for the predicted corrosion rate. A global sensitivity analysis (GSA) and the development of a Graphical User Interface are the final purpose of this study.

Keywords: corrosion rate, artificial neural network (ANN), data mining

Introduction. Atmospheric corrosion is considered as an electrochemical nonlinear and complex phenomenon, which is mostly depending on external factors and material properties: material composition, location of exposure, temperature, relative humidity, wet-dry patterns, amount of precipitation, concentration of main pollutants, etc.

Carbon steel is the most basic structural material internationally; from raw material, processing and assembly of components, to transportation and storage of finished products; during its service process, it is exposed to different degrees of atmospheric corrosion. Carbon steel is, essentially, an Fe-C alloy, with a fairly simple chemical composition and contains very small amounts of elements such as Si, Mn, S, and P.

The purpose of this study is to develop a practical artificial neural network (ANN) model for predicting the atmospheric corrosion rate of carbon steel. ANNs, as one of the most powerful algorithms of machine learning models, have been widely applied for metal sciences and atmospheric corrosion fields due to their advantages. The typical benefits are as follows: (1) ANN is a nonlinear model, which is easy to use and understand compared to statistical methods, and (2) ANNs allow the modelling of physical phenomena in complex systems without requiring explicit mathematical representations. Several studies show that neural network models had a reliable prediction with a small error and a large coefficient of determination value (R2). Eventually, an ANN-based equation and a graphical user interface (GUI) tool are established to predict the atmospheric corrosion rate of carbon steel.

Data Collection. A set of 1700 measured data samples of the atmospheric corrosion under various climate conditions in 38 countries worldwide were used to build up the ANN model. Only the analyses of carbon steels, without coatings or inhibitors, exposed to natural environmental conditions were taken into consideration. The data were obtained from reliable scientific articles as well as from international corrosion programs (MICAT, ISOCORRAG, ICO/UNECE). Six parameters named VEL, T, RH, TOW, KOPPEN, Cl− and SO2, were involved as input parameters where the atmospheric corrosion rate, as the output variable, was measured based on the weight loss of carbon steel samples and reported in μm/year.

Data mining. As a preliminary step to the construction of the ANN model, data mining was carried out to confirm the non-linearity of the problem and to gain a prior understanding of the correlation of each variable with the corrosion rate. Data mining was carried out in the Orange Data Mining program. Histograms and normal distribution curves of experimental dataset confirmed de normality and non-lineally of the corrosion rate vs the input parameters. The relationships between the atmospheric corrosion rate of carbon steel and the five input parameters was studied with scatter plots, headmaps, bloxplots and Radviz projection.

Proposed ANN Model. An ANN model comprises an input layer, which contains input parameters, single or multiple hidden layers, and an output layer, which holds the output result. Neurons transfer signals to other neurons based on the signals they receive from other neurons. Each neuron is connected to other neurons in the network through these synaptic connections, whose values are weighted. An activation function in the network determines the transformation of the weighted sum of the input into an output from a node or nodes in a layer of the network. Since this study focuses on the prediction problem, the hyperbolic tangent sigmoid function is employed and the Levenberg-Marquardt algorithm was utilized for regulating weights and biases of the model. To optimize the performance of the predictive model, an efficient ANN model has to be determined using trial-and error process. The optimum ANN model contains largest R2 and smallest MSE after training process was chosen. It should be noted that the proportion, 70%, 15%, and 15% of the dataset, was employed in training, testing, and validation, respectively. Figure 1 shows the structure of the proposed ANN model. In this model, 5 neurons in the input layer denote the five input variables, 30 neurons in the hidden layer and one neuron in the output layer represents the atmospheric corrosion rate of carbon steel. It should be noted that the developed ANN model and its performance were conducted using MATLAB.

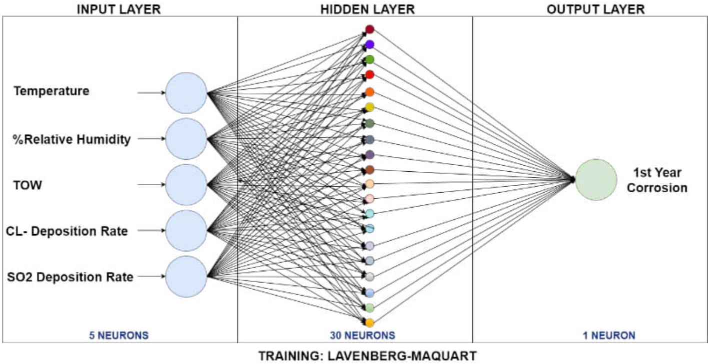

Fig. 1. ANN model.

Results and Discussion. Figure 2 shows the regression of the developed ANN model, in which the output and target results are highly matched. The R2 values for training, testing, validation, and all-data regression are 0.886, 0.69265, 0.94244, and 0.87193, respectively. It is observed that the R2 values were mostly close to unity, highlighting that the proposed ANN model has a good performance. In other words, the ANN model was highly reliable in predicting the atmospheric corrosion rate of carbon steel.

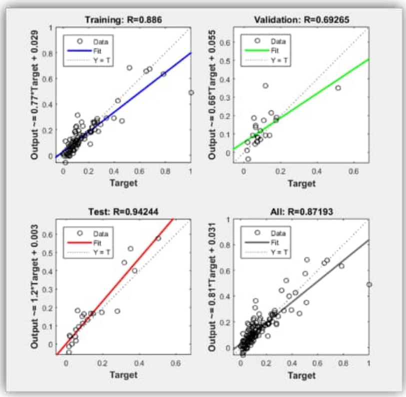

Fig. 2. Regression results of the optimal ANN model.

The database is still growing so a better model of ANN is expected. The results obtained from the best ANN model will be compared with the regression models and existing formulas.

ANN Interactive Graphical User Interface (GUI). In this study, a practical GUI tool will be constructed simplify calculating the atmospheric corrosion rate. This tool will be accessed freely. Users can will easily obtain the output by clicking on the "Predict" button after putting all input parameters. It will take less than one second to obtain the result. This GUI tool is freely available and the results will be reliable and can be used worldwide as the training data of the model is taken from international studies considering a wide variety of atmospheric parameters.

Conclusion and prospect. A practical ANN model was developed to predict the atmospheric corrosion rate of carbon steel based on a set of 1700 experimental data samples. Additionally, a data mining was performed to evaluate the effects of input parameters on the atmospheric corrosion rate. The study continues to develop, but the preliminary results yield good estimates. The methodology created will serve for the creation of new ANNs in the field of materials science and the study of corrosion.

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