Prediction of Ceramic's Mechanical Properties Based on Sintering Temperature using Neural Network

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Abstract – Ceramics is one of material which apply in many area. Thus, study of its properties is very important to fulfilled the properties requirement. The mechanical properties of ceramic such as flexural strength and hardness mainly depend on the sintering temperature and additive material. The experiments must be done to determine the best mechanical properties based on proportional sintering temperature and additive materials. Simulation for predicting mechanical properties of ceramics had been developed by using Artificial Neural Network. According to neural network simulation, the graphic of simulation result had same pattern to experimental data as the target. For predicting hardness, the Normalized Root Mean Square Error of network is 0 at training and 0.077 at validation part. This value is in line to its Coefficient Correlation which have value closed to 1. Meanwhile, the network can be used to predict flexural strength of ceramics excellently.

Index Terms – Artificial neural network, prediction, temperature, additive.

INTRODUCTION

Ceramic is one of the most important material in the world. There are several application which utilize ceramics, i.e. in sensor technology, electronic devices porcelain, etc. Thus, research for ceramics is important to fabricate the excellent their mechanical properties. These properties are affected on structure. While the structure is depending on the chemical composition and the following process. Thus, many experiments are needed to find proper properties

Besides, there is a simulation which similar to human neural which can be used to correlate between material compositions and following processes to it is mechanical properties. This method is called Artificial Neural Network (ANN). By using some accurate data, ANN can be used to predict mechanical properties of ceramics which are caused by chemical composition and processes

This study is discussing correlation between mechanical properties of ceramics to their chemical composition and following processes using ANN. The main ceramics which are studied had composition Al_2O_3 (90-45%), SiO_2 (10-45%), FeO_3 (0-1%), CaO (0-1%) dan TiO_2 (1-4%) which will be doped by Mullite ($3Al_2O_3.2SiO_2$). While mechanical properties of the ceramics restricted by hardness and flexural strength.

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METHOD

A. Database

Database is an important part for building the ANN. These data represent correlation between mechanical properties of ceramics as output of network and their chemical composition and processes as input of network. They used for training and validating the network. Thus, all of pairs are divided by two parts, 85% for training and 15% for validating.

B. Artificial Neural Network (ANN)

Architecture of ANN can be shown in Figure 1. It has three layers, that are input, hidden and output layer. Input of network represents Ratio of Mullite additive and temperature of sintering. Hidden layer contain hidden nodes which the number of nodes is tracked from 1 to 10. The output layer represents mechanical properties of ceramics.
Between each layer there are number which will counted and update in every epoch and called as weight. These weight will be adjusted until network gives the best of performance indicator. Hidden and output layers of this network have activation function for calculating the data from layer preceding layer and weight between them. Activation layer of hidden layer is tangent sigmoid and the output layer is linear. Backpropagation method is used for adjusting the weight and Lavenberg Marquardt (LM) as the training algorithm.

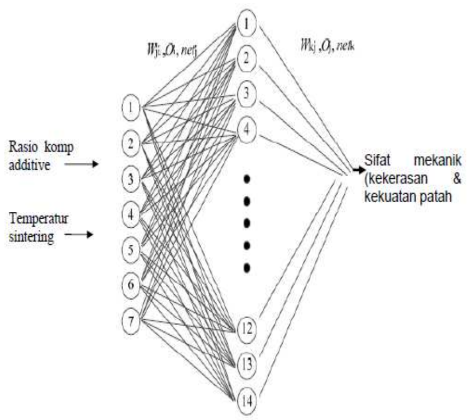

Figure 1. Architecture of Artificial Neural Network.

RESULT AND ANALISYS

Training and validating network for predicting hardness of ceramics had been accomplished. In training part, the network give NRMSE value of 0, which mean the minimum value of NRMSE. Simultaneously, network show best performance of coefficient ratio when it had raised 1. Moreover, at the validation part, the network also gives excellent performance when NRMSE value is 0.077 and R value is 0.94.

Figure 2 show the comparison of simulation results and target data. Those figure shows that the simulation data have same pattern to experimental data as target. They show that network can be used to predict the hardness properties of ceramics.

Prediction of flexural strength of ceramics also has been done when network has NRMSE 0 for training and 0.094 for validation. Also, performances in R value explain that network has R value 1 for training and 0.981 for validation. Thus, from these values, network can be confirmed that can be used to predict flexural strength of ceramics. Simulation of prediction network which is compared to experimental data as target can be shown on Figure 3.

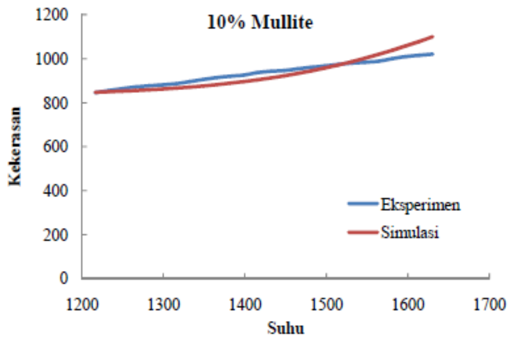

Figure 2. Comparison of simulation and target value for hardness prediction of ceramics

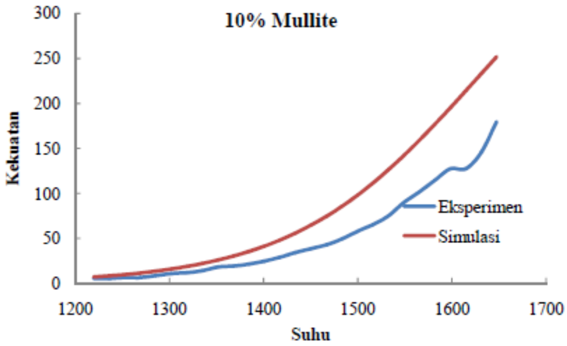

Figure 3. Comparison of simulation and target value for flexural strength prediction of ceramics

Conclusion

Neural network has been built to predict flexural strength and hardness of ceramics. Performance in training and validation prove that NN can predict both of these mechanical properties. NRMSE values are closed to 0 and R values are closed to 1.

References

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