MODEL IDENTIFICATION OF WOOD DRYING AND SHRINKAGE PROCESSES

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Abstract—In the drying process of wood, the controlling quantities are temperature and humidity, which in turn lead to changes in moisture content and further lead to drying of wood to produce dry shrinkage force. In this paper, the ARMA model is used to identify the process of temperature-moisture-moisture content, and then the control model of moisture content and shrinkage force is developed on the basis of the ARMA model.The results show that the combination of the ARMA model and the BP neural network can form a good control model for the drying shrinkage force, which can provide a feasible basis for the application of the ARMA model and the BP neural network in the drying shrinkage force of wood.

Index Terms—Wood drying, ARMA model, BP network, Dry shrinkage force

I. Introduction

At present, with the global forest resources becoming less and less and the accompanying ecological and environmental problems, how to efficiently utilize resources and improve the quality of wood processed products has attracted the attention of governments around the world. Regarding the shortage of forestry resources in my country and the problems of wasteful use, wood scientists have begun to pay attention to how to better improve the quality and use value of wood.

Wood drying is an important link in wood production and processing [1]. Its main task is to remove excess moisture in wood to adapt to different uses and quality requirements. The initial moisture discharged during wood drying is free water in the cell cavity, and the wood dimensions will not change as a result. But when the adsorbed water in the wood cell walls is drained out, the wood shrinks. The reason is that when the wood is drying, the water evaporates from the inside out, the adsorbed water on the cell walls becomes less and less, and the fibrils and microfibrils get closer and closer, resulting in a reduction in the size of the wood. The drying shrinkage of wood is an important physical property of wood, which varies with the direction of the wood grain. Studies have shown that the drying shrinkage of wood in the longitudinal direction is negligible, but the drying shrinkage in the transverse direction is very large, and its difference varies with the direction of the wood grain. The shrinkage in the chord direction is greater than that in the radial direction. Wood will produce drying shrinkage force due to drying shrinkage. The generation of this force will lead to defects such as cracking and deformation of the wood, which directly affects the size, shape and structural stability of the wood and wood products. It is a major problem faced by wood processing. . Therefore, monitoring and controlling the shrinkage force generated during wood processing and drying will have an important impact on improving the drying quality and utilization value of wood.

Because the drying and shrinkage process of wood is relatively complex, it involves multiple physical, chemical and material change processes. Therefore, it is impossible to describe this process by establishing an accurate mathematical model. The change process of drying shrinkage force of wood of different materials is also different, so it is necessary to use identification modeling method to determine the mathematical model of the controlled object. . Since the wood drying process involves various uncertainties such as hysteresis, nonlinearity, and time variation, the traditional method of system identification using excitation signal input is difficult to apply.

Artificial intelligence neural network is a bionic technology proposed based on the study of biological structure and function. It has fault tolerance and adaptive capabilities, nonlinearity, and distributed storage methods. General mathematical models can only map the relationship between two or three independent variables and dependent variables, but artificial intelligence neural networks can establish fitting relationships between multiple independent variables and multiple dependent variables. Therefore, the neural network can fully establish a suitable mathematical model for the complex drying process of wood.Combining artificial intelligence technology with wood processing will have a significant impact on the intelligence and production efficiency of wood processing.The positive impact will definitely promote the wood processing industry to produce higher quality products and save raw materials. Artificial intelligence technology is mainly used in wood moisture content prediction and drying room temperature humidity control during wood processing and drying to reduce problems such as cracking and deformation during wood drying.

In terms of wood drying applications, the main role of artificial intelligence is reflected in the accurate prediction of moisture content in the wood drying process and the intelligent control of the drying process. Conventional intelligent algorithms include BP neural network, ant colony algorithm, fuzzy algorithm, and some other methods are further improvements on these algorithms. Although the functions can be basically satisfied, the accuracy and precision are not high. Therefore, we can consider the complementary advantages of combining BP neural network with genetic algorithms, fuzzy algorithms, expert systems and other algorithms; by combining Internet communication and deep learning in the wood processing and drying process, the accuracy of prediction and control will be higher [2].

The ARMA model is called the autoregressive moving average model [3]. It is a very important model in studying time series. It is a combination of autoregressive and moving average models. The ARMA model has good fitting and prediction capabilities for smoothly changing time series, and is also very compatible with noise in sequence data. For the process of wood drying shrinkage, the control quantities are the temperature and humidity of the wood drying medium. The drying medium and the wood exchange heat and mass, which reduces the moisture content of the wood, thereby triggering the drying shrinkage effect. Temperature-humidity causes the moisture content to change. This physical process should be continuous and smooth, that is, no sudden and violent numerical fluctuations will occur during this process. That is to say, the moisture content in the wood must decrease or increase little by little, in two consecutive moments. There will be no sudden changes in moisture content. Therefore, this process is suitable for using the ARMA model to model the change process of temperature-humidity-moisture content. Later, the stability of the process of moisture content change will be tested through experimental data.

BP neural network is an intelligent numerical model that has been proposed and widely used in recent years. Because of its strong fitting ability and certain generalization ability, it is widely used in data analysis, model parameter identification and control, etc [4]. BP neural network uses the connection between multiple nodes and hidden layers, as well as the weight values between neurons, to analyze existing time series data, and uses the principle of backward feedback to continuously correct the parameters of neurons. The weight value achieves the greatest degree of fitting to the existing data [5]. Moreover, by adding internal hidden layers, it is possible to mine the deeper, abstract-level rules of the data itself and obtain good generalization capabilities. For the wood shrinkage process, the change process from moisture content to dry shrinkage force. Due to the characteristics of wood materials, when the moisture content changes, its dry shrinkage force may suddenly change at a certain moment, that is, it will fluctuate violently. , this situation is unfavorable for the identification method using the ARMA model. The BP neural network can just make up for this shortcoming.

This paper combines the characteristics of BP neural network and ARMA model to establish a mathematical model of the wood drying process to provide a basis for the control of the wood drying process.

II. ARMA model analysis

A general representation of the system equation of the ARMA model is

$$y(t) + a_1 y(t-T) + a_2 y(t-2T) + \dots a_n y(t-nT) = b_1 u(t-T) + b_2 u(t-2T) + \dots b_n u(t-mT) + e(t) \quad (1)$$

Here $y(t)$ is the output of the system, and $u(t)$ is the input to the system, and $e(t)$ is the data measurement noise ,t is the time,T is the sampling time, bn and an is the Coefficients for fitting time series models, no physical meaning determined. The ARMA model can be represented here in a more concise form.

$$A(q)y(t) = \sum_{i=1}^{nu} B_i(q) u_i(t - nk_i) + C(q)e(t) \quad (2)$$

Here the multiple input single output (MISO) case is considered, i.e. temperature and humidity are the 2 input vectors and water content is the output vector.$B(q)$ and $C(q)$ are the input vectors of temperature and humidity respectively. Here it is proposed to use a second order ARMA model to identify the data and the resulting expression for the transfer function in differential form is

$$Y(z) = \frac{b_1 z^{-1} + b_2 z^{-2}}{1 + a_1 z^{-1} + a_2 z^{-2}} U(z) \quad (3)$$

The main objective is therefore to obtain the four coefficients in the above differential model. The above model is fitted by regression in MATLAB using the armax function, where the maximum number of iterations is set to 50. The resulting model is a discrete transfer function expression in differential form with two inputs and a single output. Channel 1 (temperature - moisture content).

$$A(z)y(t) = B(z)u(t) + C(z)e(t) \quad (4)$$

of which

$$\begin{aligned} A(z) &= 1 - 1.868z^{-1} + 0.868z^{-2} \\ B(z) &= 0.0001403z^{-1} - 0.0001426z^{-2} \\ C(z) &= 1 - 1.673z^{-1} + 0.7009z^{-2} \end{aligned} \quad (5)$$

Channel 2 (humidity-moisture content)

$$A(z)y(t) = B(z)u(t) + C(z)e(t) \quad (6)$$

of which

$$\begin{aligned} A(z) &= 1 - 1.868z^{-1} + 0.868z^{-2} \\ B(z) &= 7.139e - 5z^{-1} - 6.767e - 5z^{-2} \\ C(z) &= 1 - 1.673z^{-1} + 0.7009z^{-2} \end{aligned} \quad (7)$$

The output of the 2nd order ARMA model used is shown in Picture 1 below, where the blue curve is the output of the ARMA model and the grey curve is the actual moisture content experimental data, and it can be seen that the data agrees to 95.24%. The iterative algorithm used here is least squares, with an iterative calculation error of $1e-5$.

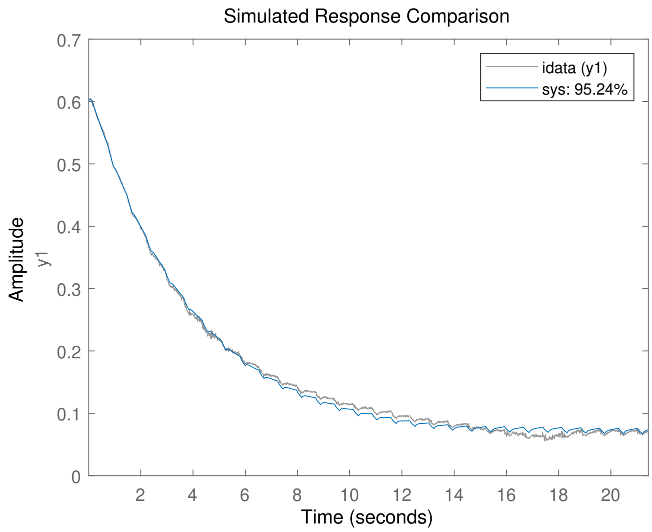

Fig. 1. Comparison of ARMA model output with experimental data

III. Bp neural network model parameter identification

As mentioned earlier, on the basis of the established ARMA time-series based model between temperature moisture and moisture content, a model of the relationship between moisture content and dry shrinkage force was established by identifying the experimental data and using the non-linear fitting capability of the Bp neural network to establish a fitted model between moisture content-dry shrinkage force. The temperature and humidity-moisture content models are then linked together with the moisture content-dry shrinkage force model to form a complete wood dry shrinkage force control model. The network structure uses one hidden layer with 150 neuron nodes and the training algorithm uses the trainlm algorithm.

IV. Discussin

The training process curve of the established Bp neural network for the experimental data between temperature and humidity and moisture content is shown in Picture 2 and Picture 3 below, and it can be seen that the final training output data has an accuracy of $10e-5$, which fully meets the requirements for establishing the control model.

V. Conclusions

Controlling the moisture content and drying shrinkage of wood is an important part of the industrial wood drying

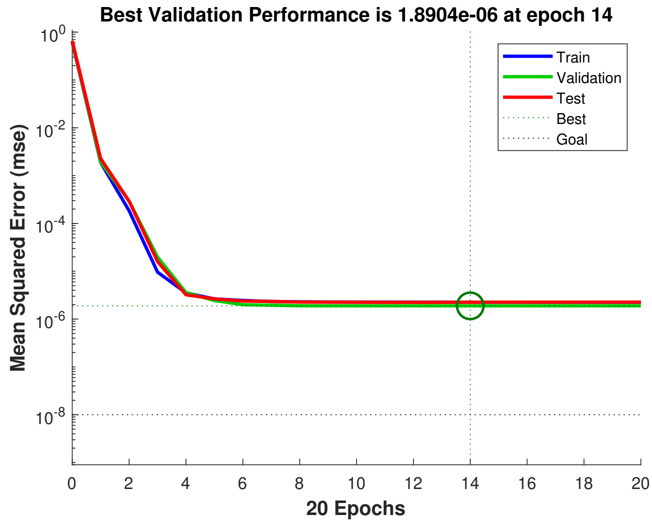

Fig. 2. Training process for fitting the temperature and humidity-moisture content Bp neural network

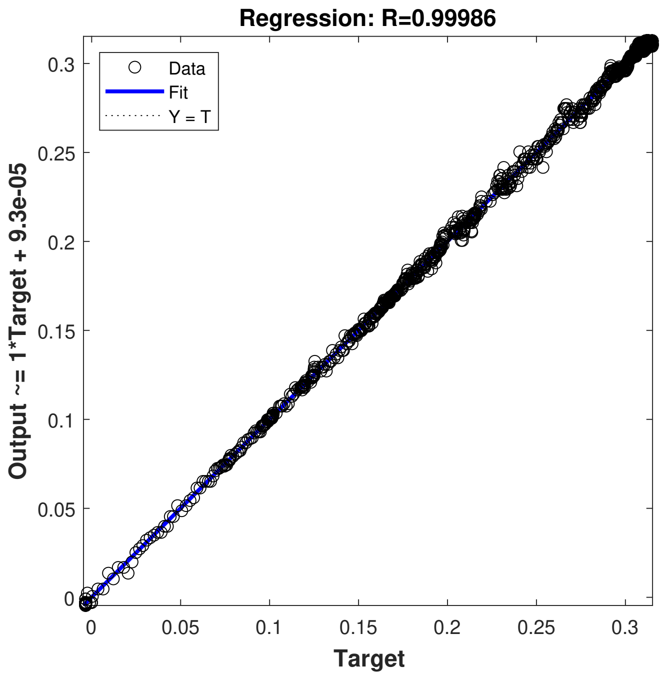

Fig. 3. Regression fit of the temperature, humidity and moisture content Bp neural network to experimental data

process and an important means to improve wood utilization and quality. This article focuses on the topic of wood drying shrinkage control through theoretical derivation, simulation analysis and experimental comparison,Mainly completed the following aspects of work:

It can be seen from the model data that the ARMA model has a high degree of agreement with temperature, humidity and moisture content data. The response degree and accuracy of the neural network to temperature, humidity and moisture content fully meet the requirements of the control model.

The combination of ARMA model and BP neural network can form a good shrinkage control model, which can provide feasibility basis for the application of ARMA model and BP neural network in wood shrinkage.

Considering the particularity of the wood drying shrinkage process and the complexity and uncertainty of the controlled object model, it is difficult to directly establish a mathematical model of the wood drying shrinkage process through theoretical analysis. Therefore, this article controls the wood drying shrinkage process through experiments. Through data analysis, a mathematical model of the moisture content change process based on ARMA time series was established, and the controller was designed based on this.

The basic BP neural network is optimized and trained on a large amount of existing experimental data to obtain a neural network model for wood drying shrinkage control. This neural network model is combined with the ARMA surface rate time series model obtained previously to establish Complete wood drying shrinkage control process simulation model.

The ideal process for drying wood is that the total stress in the board is not greater than the cross-grain tensile strength of the wood, that is, the maximum moisture content gradient is maintained without cracking the wood. At present, the most commonly used standard for drying sawn wood is still the moisture content standard. In future work, on the one hand, the concept of "shrinkage force" can be used to explore and develop a drying shrinkage force standard or stress standard for sawn wood drying to maximize drying. efficiency while ensuring drying quality.In the later stage, if conditions permit, research on the mechanical properties of the wood drying shrinkage process should be strengthened, and the ability to describe model uncertainty and fault tolerance should be increased based on mathematical modeling.

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