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SYNTHESIS OF EXPERT SYSTEM AND ARTIFICIAL NEURAL NETWORK FOR DETERMINING THE MECHANICAL PROPERTIES OF THE RESEARCHING OBJECT

This article describes the method that is designed to determine the properties of steels. The structure of the expert system which designed to determine the nominal values of the properties of steels is developed. The fragment of the steels knowledgebase which contains the set of rules of steels properties is shown. The neural network is developed to refine upon the values of the steels properties. The results of simulations of the developed neural network are shown. The authors note the low standard error of the neural network.

Keywords: *neural network, multilayer perceptron, expert system, knowledgebase, steel properties.*

Introduction

The level of the industrial development of countries is characterized by the amount the variety of the production and its quality indicators. The lack of a quality control at the enterprise can be the reason of the breaking the work conditions of the equipment and its untimely breaking down. Such situation cause damage and serious consequences, such as: explosive situations, fire, poisoning the environment and the accidents. Thus the problem of safety at the enterprise is closely connected with the problems of the quality control under production of metallurgy.

The means of solving this problem is to use of the objective methods of control, for example, metallographic analysis [1]. The necessity of the elaboration of the method of automation quality control of steel is caused by the increased requirements to the steels quality of different groups and classes.

Metallographic analysis of steels consists of getting the microscope image of steel microstructures and its recognition. Therefore, identification of the steel properties is made by processing metallographic images and determination the quantitative characteristics of steels from these images [2, 3]. At present «Video-Test»,VisionPE software are used to work with steel microstructures images [4 – 6]. One of the main disadvantages of the existing software is too low recognition accuracy of metallographic images.

Therefore, the problem of increasing the accuracy of determining the characteristics and properties of steels is important. To solve this problem it is necessary to develop a new methodology for evaluating the steels quality. To process the metallographic images the method of determining the quantitative characteristics of the steels is used. This method provides the recognition accuracy over than 90%.

But this method can determine only the quantitative characteristics of steels, such as grain size, and can not determine the steel properties (steel strength limit etc.).

Synthesis of expert system and artificial neural network

To determine the properties of steels the specialized method was developed. This method is based upon the usage of the intellectual technology. This method consists of two stages.

1. Determination of the nominal figures of values of steels properties and the group of steel with the help of the expert system.

2. Evaluation of steels properties by the neural network which defines the property values of steels.

The structure of the expert system which is designed for determination of the nominal figures of values of steels properties and the group of their usage is shown on fig. 1.

The database contains information on the parameters of the metallographic analysis, the chemical composition of steels and their characteristics. The expert system includes the knowledge base of steels and a logical conclusions module. According to input mechanism the expert system works in the following way:

1. Process engineer establishes the necessity of the identification of the properties of steel the expert system.

2. Logical conclusions module performs the search of solutions in the knowledge base according to the algorithm and provides a specific interface for the introduction of the requested data.

3. Logical conclusions module asks the database to choose the properties required to the steel for the carrying out of the users request.

4.The database answer which is obtained is a list of steels where steels are arranged according to the time for the metallographic analysis request.

5. Finishing the work the expert system user can request the order of all arguments.

The separate module of teaching is used to maintain the knowledge base and fill it with new information about steels and their properties. Another component of the expert system is the user's interface which is necessary for proper data transferring during metallographic analysis.

One of the most important parts of intelligent system is the knowledge base (KB), which contains some procedural information of domain. Designing the knowledge base the problem of choosing the most adequate model representation of procedural knowledge is the most important. Based on the characteristics of the metallographic analysis, one can formulate the requirements which are necessary for the model of procedural knowledge.

1. To provide the possibility of modifying some knowledge independently of the other one (for example, due to the continuous expansion of the nomenclature of chemical substances, due to the development of research methods, etc.).

2. To decrease the time of finding information to intensify the formation of expert conclusions.

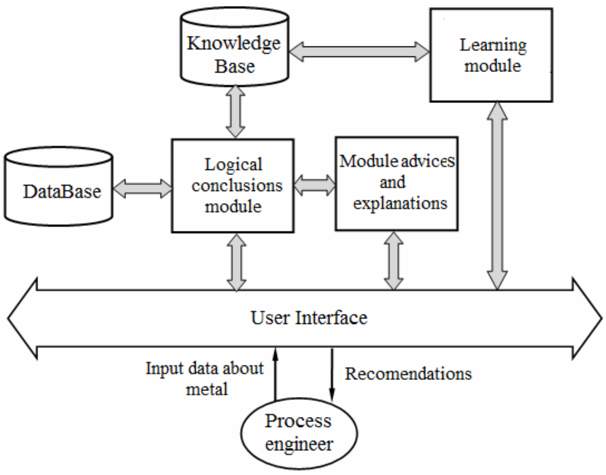

Fig. 1. Structure of the expert system

The productional model qualifies these requirements [7]. Records of this productional model are given below:

$$Pr = \langle num_{Pr}; L; A \Rightarrow h; MD_{Pr}; MND_{Pr} \rangle, \quad (1)$$

where num_{Pr} – the name of the production (which is used as a serial number of the production); L – application area of products ("chemical area", "physical area, etc.); A⇒h – the production core, where A={An} – the set of assumptions which describe some situations, h={hj}, – a set of hypotheses that are considered in the process of inference; MD_{Pr} and MND_{Pr} – a measure of confidence and a measure of distrust in the hypothesis h respectively.

This expression is an interpretation of the production core:

$$\text{IF} \quad A1\, \text{and / or} ... An \quad \text{THEN}\, h_j. \quad (2)$$

This model of knowledge describes the regulations for determining following properties of steel: σ_B – tensile strength of steel; σ_T – yield strength of the steel; σ_5 – elongation of the steel; gr – a group of steel.

The model of knowledge describes the regulations for steels of various purposes. The following is a fragment of the knowledge base according to a production model:

< **1**; mechanical properties of steel; IF mr = «Ст0» THEN σ_B = 300 MPa, σ_5 = 22%, gr = «constructional»; 1; 0 >
< **2**; mechanical properties of steel; IF mr = «Ст1кп2» THEN σ_B = 400 MPa, σ_5 = 33%, gr=«constructional»; 1; 0 >
< **3**; mechanical properties of steel; IF mr = «Ст1сп» THEN σ_B = 320-420 MPa, σ_5 = 30%, σ_T = 190-220 MPa, gr = « constructional »; 1; 0 >
< **4**; mechanical properties of steel; IF mr= «Ст2кп» THEN σ_B = 420 MPa, σ_5 = 32%, gr =«constructional»; 1; 0 >
< **5**; mechanical properties of steel; IF mr = «Ст3пс» THEN σ_B = 490 MPa, σ_5 = 25%, gr =«constructional»; 1; 0 >
< **6**; mechanical properties of steel; IF mr = «Ст4сп» THEN σ_B = 420-540 MPa, σ_5 = 23%, σ_T = 240-270 МПа, gr = « constructional»; 1; 0 >
< **7**; mechanical properties of steel; IF mr = «Ст5сп» THEN σ_B = 640 MPa, σ_5 = 19%, gr =«constructional»; 1; 0 >
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.
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< **n**; mechanical properties of …; …; …; …; >

The model shows that the value MD_{Pr} = 1, and MND_{Pr} = 0, which is explained by the fact that data about the nominal properties of steel were obtained from the standards.

Thus, the model was developed to give the possibility to develop a knowledge base about the steel for the expert system which is designed to define the properties of steel and its group of usage.

To determine the properties of steels the specialized method was developed. This method is based upon the usage of the intellectual technology. This method consists of two stages.

1. Determination of the nominal values of steels properties and the group of steel using the expert system.

2. Evaluation of steels properties by the neural network which defines the property values of steels.

Steel properties defined by expert system are nominal values, which are described in international standards. However, the values of these properties can be changed and this fact is explained by the presence of nonmetallic inclusions and other defects.

As for the second stage of the method it is designed to evaluate the properties of steels on the base of existing defects in the steel. To solve this problem one use the multilayer neural network.

Let the nominal values of steel properties to be the set of input values X, and the calculated values of the properties are the set Y. Then:

$$Y_i = f(X_i), \quad (3)$$

where Yi – a vector of output values;

Xi – vector of input variables.

$$X = \{mr, Su, Ox, P, ph, \sigma_{Bn}, \sigma_{Tn}, \sigma_{5n},\} \quad (4)$$

$$Y = \{\sigma_B, \sigma_T, \sigma_5\}, \quad (5)$$

where mr – steel grade;

Su – the value of the contents of sulfides in the steel;

Ox – the value of the contents of oxides in the steel;

ph – the value of the phase relations in the steel;

σ_{Bn} – nominal tensile strength of steel;

σ_{Tn} – the nominal yield strength of the steel;

σ_{5n} – nominal value of elongation of the steel;

σ_B – adjusted value, the tensile strength of steel;

σ_T – adjusted value of the yield point of the steel;

σ_5 – adjusted value of elongation of the steel.

The neural network performs the tasks of the definition of the output vector Y elements (fig. 2).

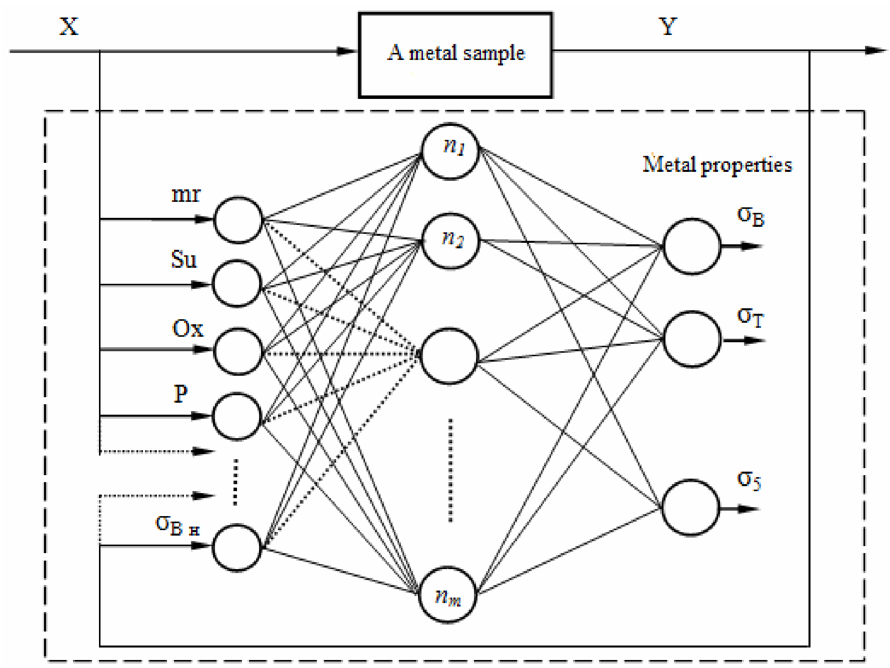

Fig. 2. Structure of the neural network (multilayer perceptron for determining steel properties)

The neural network has the structure of a multilayer perceptron [8]. The number of neurons in the input layer depends on the number of defects in the steel and the characteristics that affect the properties of steels (nonmetallic inclusions, etc.).

The size of the hidden layer increases in relation to the input layer. It occurs due to the allocation of the parameters from the characteristics of the phase ratio in the steel (ferrite and pearlite phases). Ratio of phases is used to evaluate the steel properties. And it is known that the value of carbon depends on the ratio of phases too. The size of the output layer is determined by the number of the steel properties. Training the neural network is done by the back-propagation algorithm with a sigmoid activation function [8, 9].

$$y_j = \frac{1}{1 + e^{-x_j}}. \quad (6)$$

Measuring the quality of recognition was performed by calculating the mean-square error:

$$E = \frac{1}{n}\sum_{i=1}^{n}(y_i - y(k_i))^2, \quad (7)$$

where E – Error Detection; yi – the value of the i-th network output for pattern recognition; y(ki) – the value of i-th output standard network, which corresponds to a class of images.

The change graphs of the learning error and the recognition error of the neural network are shown in fig. 3.

The test samples contains information about 290 samples (pieces) of steels. For 282 samples (pieces) the properties have been identified correctly.

Training and testing neural networks were carried out using the software developed by the authors.

To prevent the retraining process a value of the optimal number of training epochs was determined on the basis of the change graphs. The number of the epochs was 370 and at the same time the mean square error (MSE) was E = 0,157.

Conclusion

Thus the method of the determination of metal values was elaborated. This method is based on the analysis of the different types of the defect and characteristics of metals with the help of the expert system and the neural network. This help to automatize the process of making decision under choosing the group of metal.

Adequacy of this method is confirmed by the low value of the mean-square error of the neural network.

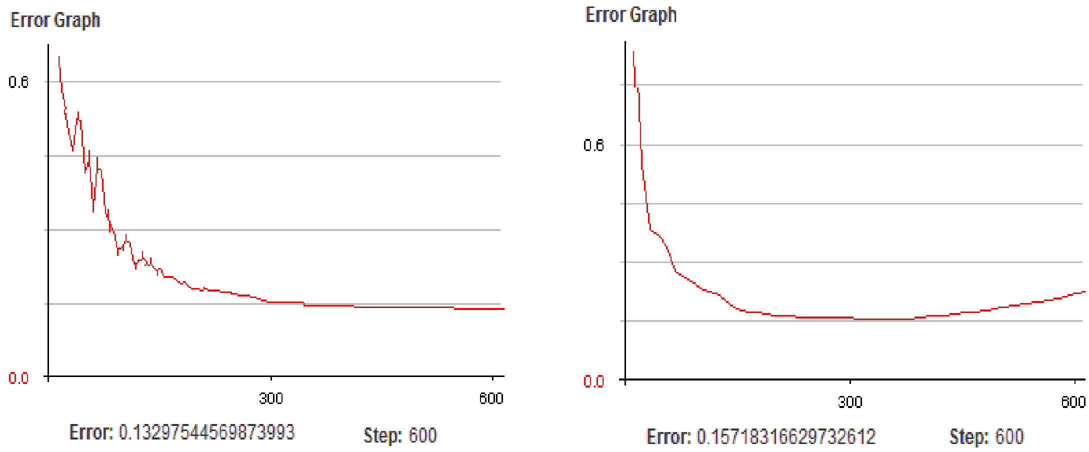

Fig. 3. The change graphs of the learning error and the recognition error

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СИНТЕЗ ЕКСПЕРТНОЇ СИСТЕМИ І ШТУЧНОЇ НЕЙРОННОЇ МЕРЕЖІ ДЛЯ ВИЗНАЧЕННЯ МЕХАНІЧНИХ ВЛАСТИВОСТЕЙ ОБ'ЄКТА ДОСЛІДЖЕННЯ

В.О. Ємельянов

У даній статті описується метод, який призначений для визначення властивостей сталей. Розроблено структуру експертної системи, яка призначена для визначення номінального значення властивості сталей. Показано фрагмент бази знань сталей, яка містить набір правил про властивості сталей. Розроблена нейронна мережа для уточнення значень властивостей сталей. Показані результати моделювання розробленої нейронної мережі. Автор відзначає низьку середньоквадратичну похибку нейронної мережі.

Ключові слова: *нейронна мережа, багатошаровий персептрон, експертна система, база знань, властивості сталі.*

СИНТЕЗ ЭКСПЕРТНОЙ СИСТЕМЫ И ИСКУССТВЕННОЙ НЕЙРОННОЙ СЕТИ ДЛЯ ОПРЕДЕЛЕНИЯ МЕХАНИЧЕСКИХ СВОЙСТВ ОБЪЕКТА ИССЛЕДОВАНИЯ

В.А. Емельянов

В данной статье описывается метод, который предназначен для определения свойств сталей. Разработана структура экспертной системы, которая предназначена для определения номинального значения свойства сталей. Показан фрагмент базы знаний сталей, которая содержит набор правил о свойствах сталей. Нейронная сеть разработана для уточнения от значений свойств сталей. Показаны результаты моделирования разработанной нейронной сети. Автор отмечает низкую среднеквадратическую ошибку нейронной сети.

Ключевые слова: *нейронная сеть, многослойный персептрон, экспертная система, база знаний, свойства стали.*