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An Object-Oriented Design of Expert System Software for Evaluating the Maintenance of Lined Equipment

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***Abstract*—The relevance of solving the problem of automating the process of assessing the condition of critical lined equipment has been described. The necessity of developing software to automate the process under consideration is substantiated. An object software model (including logical and physical models) for an expert system for assessing the condition of critical lined equipment has been developed and described. Based on the proposed object model, the expert system software was developed. This system allows generating control recommendations regarding the operating modes of critical lined equipment.**

Keywords—object-oriented design; software; maintenance; expert system; lined equipment.

I. Introduction

Industrial production is characterized by a high concentration of hazardous and critical equipment. One of the types of critical equipment at metallurgical and machine-building enterprises is lined equipment, which includes stationary and torpedo ladle cars, steel-teeming ladles. The requirements for diagnostics, monitoring and evaluation of the technical condition of lined equipment are constantly increasing [1-3], which necessitates the development of new systems and technologies and improvement of existing ones.

At present, the condition of critical lined equipment is assessed using means and systems whose operation under the industrial production conditions is characterized by an unacceptable level of measurement error [4-6]. In addition, the mode of operation of the lined equipment is selected by the technologist based on his personal experience. Also the process of weighing the cast iron in lined equipment is characterized by a sufficiently large measurement error introduced by the curvature of the railroad track and by other factors (subjective factor of a technologist), which causes the sampling of unreliable data on the weighing platform [7-8]. The known methods and systems for controlling the amount of pig iron in the lined equipment, based on the use of strain gauges [9-10], implement measurement methods characterized by low accuracy in determining the mass of cast iron in the lined equipment. However, they do not take into account the constant changes in the internal volume of the ladle car and the thickness of the slag layer on the metal surface. There is also a method for measuring the mass of cast iron, by the time of beginning and end of pouring of cast iron into the lined equipment. It is also characterized by an unacceptably large error, due to the different intensities of the fillings [11]. In addition, to implement this method, a technologist is involved, who introduces subjectivity into measurement and an additional error.

Due to these facts, there are problematic situations associated with a low level of objectivity in decision-making. Therefore, the research aimed at developing systems and tools for automating the assessment of technical condition and decision-making support during the operation of critical lined equipment is relevant.

II. Development of an Object Model for an Expert System for Evaluating the Condition of Lined Equipment

For the purpose of the tool support of the proposed method and neural network approach for assessing the condition of lined equipment [12-14], the authors have designed and developed a client-server software of the expert system that implements the technologist's graphical interface providing input of the initial data, parameters for calculating and displaying the obtained results.

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When designing the structure of the expert system software, an object-oriented approach was used [15-16]. Unified Modeling Language was used to create an object model of the software being developed [17].

The specification of the developed software combines the following models:

1. The use model as a description of software functionality from the point of view of the technologist responsible for monitoring the condition of lined equipment.

2. The logical model that describes the main abstractions of the diagnostic processes and the assessment of the technical condition of lined equipment, which provide the required functionality and their interaction;

3. The implementation model that defines the real organization of software modules and files in the software developed.

The use model in the form of a diagram of use cases describing the functionality of the system from the point of view of the technologist responsible for monitoring the lined equipment is shown in figure 1.

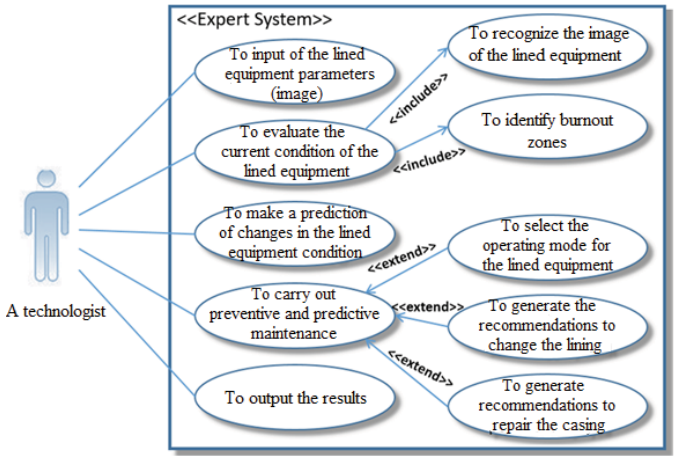

Fig. 1. The use cases diagram of the designed software.

The use model has 10 use cases and 1 actor (a technologist), between which an inclusion relationship (include and extend) is established. There are follow basic use cases “To input of the lined equipment parameters (image)”, “To evaluate the current state of the lined equipment”, “To make a forecast of changes in the lined equipment state”, “To carry out preventive and predictive maintenance” and “To output the results”.

The “To evaluate the current state of the lined equipment” use case includes the follows operations:

- To recognize the image of the lined equipment.
- To identify burnout zones.

The “Weight Estimation” use case is extended by the operations:

- To select the operating mode for the lined equipment.
- To generate the recommendations to change the lining.
- To generate recommendations to repair the casing.

In order to make the logical presentation and analysis of the structural and functional relationships between the software components of the expert system, a conceptual model is proposed in the form of a set of several class diagrams. One of the class diagrams of the logical model is presented in Fig. 2.

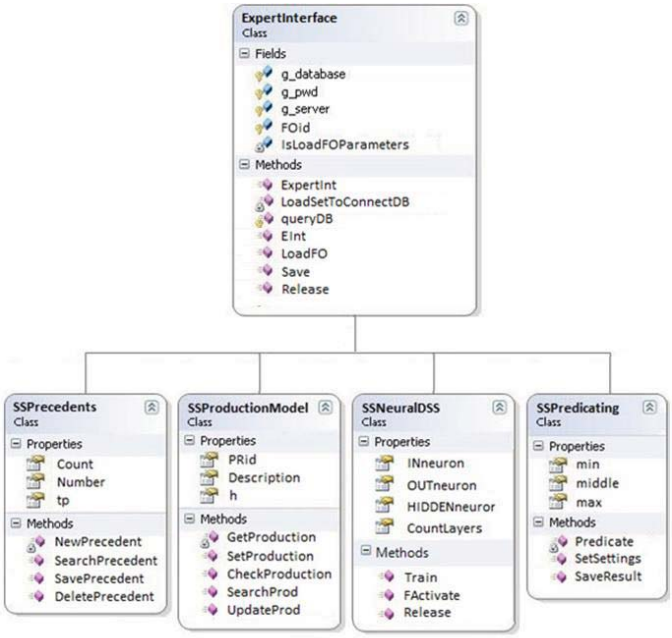

Fig. 2. The classes diagram of the designed software.

According to figure 2, the “SSPrecedents” class includes methods and properties for implementing the method of finding solutions for similar diagnostic situations with lined equipment proposed in [18].

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The" SSProductionModel" class implements the production method for solving diagnostic situations with the lined equipment.

The "SSNeuralDSS" class implements methods and properties for creating and training neural networks to support decision making in the diagnosis of the lined equipment.

The" SSPredicating" class contains fields for implementing the method for predicting changes in the condition of the lined equipment proposed in [14, 18].

To describe the real entities in the work, a physical design was performed and the implementation model presented in figure 3 was built. The model presents the features of the physical representation of the system, and establishes the dependencies between software components as well.

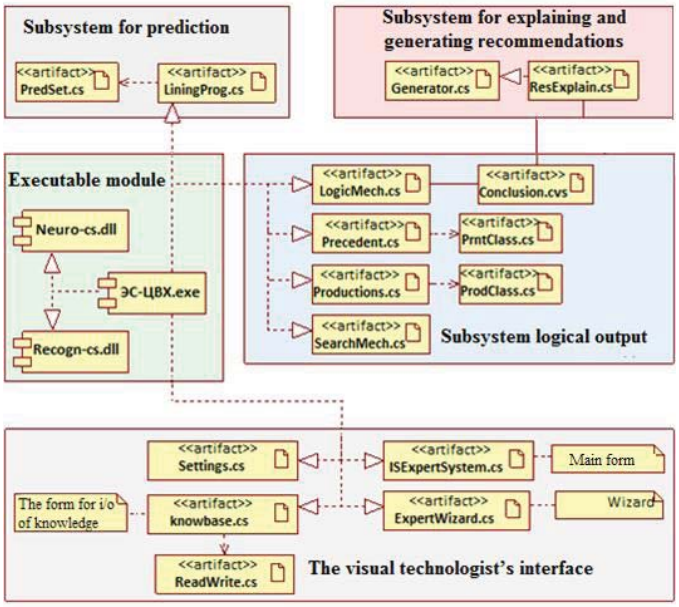

Fig. 3. The model of the implementation of the designed software.

III. Development of an Expert System Software for Evaluating the Condition of Lined Equipment

Based on the proposed object model, an expert system software was developed to evaluate the condition of lined equipment (figures 4,5). The development was carried out in Visual Studio 2010 using the C # programming language.

The functions of the developed expert system software are as follows:

- Receiving and input the primary data on torpedo ladle cars required to evaluate the condition of the ladle car.
- Analysis and quantitative assessment of the lining condition of the ladle cars based (figure 4) on the neural network approach proposed in [14].
- Quantitative assessment of the lining of the torpedo ladle car based on the weight of the empty torpedo ladle car before and after the transport of liquid iron (after each load) and the temperature of the body of the torpedo ladle car during transportation of liquid iron.
- Generating control recommendations regarding the technical condition of the lining and recommendations for repair and operating modes of torpedo ladle cars.

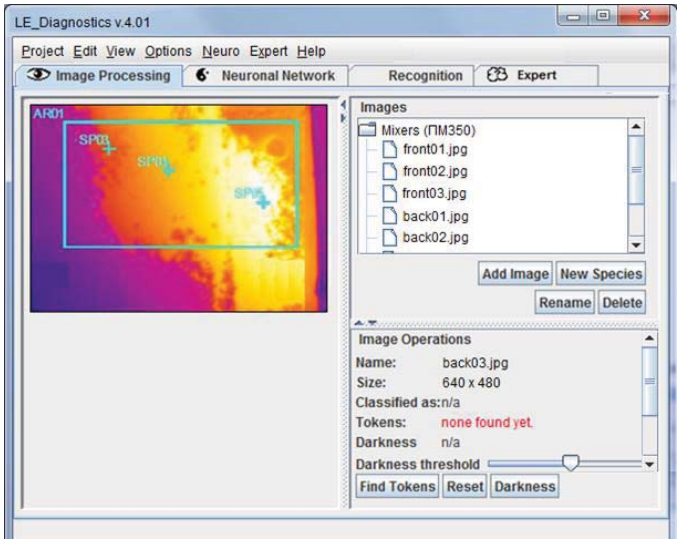

Fig. 4. A window of the developed software (image processing of lined equipment).

- Estimation of the cast iron weight based on primary data (figure 5).

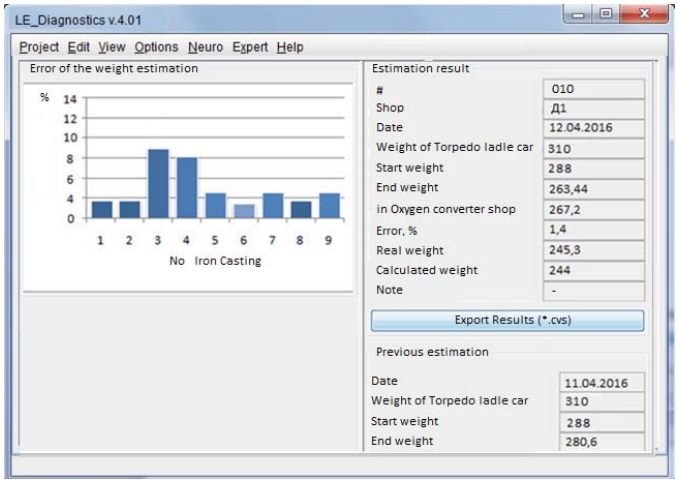

Fig. 5. A window of the developed software (estimation of the cast iron weight).

- Creating operating and reporting documentation for the process of transportation of liquid iron from the blast furnace shop to the converter shop and documentation regarding the technical condition of torpedo ladle cars .
- Editing the knowledge base and the accumulation of gained experience.

The developed software was tested in the conditions of the weighing facilities at the Alchevsk Iron and Steel Works, which uses torpedo ladle cars of the PM350 type to transport liquid iron from the blast furnace shop to the converter shop.

Table 1 demonstrates the comparative results of determination the operating modes of lined equipment.

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Analysis of the data from table 1 provides information about increased operativeness of determination the operating modes of lined equipment.

TABLE I. RESULTS OF CALCULATING THE OPERATIVNESS OF DETERMINING THE OPERATING MODES OF LINED EQUIPMENT

Lined Equipment	**Operativeness, average (min) (Basic diagnostic system)**	**Operativeness, average (min) (Diagnostic system with developed software)**
Torpedo ladle cars (type PM350)	84	15
Steel ladle (50 tonnes)	55	10
Immovable mixer MC-1300	108	33
Hot-metal car 100 tonnes	60	15

IV. CONCLUSION

Thus, the following results were obtained:

- An object model was proposed and described, reflecting the basic functions and entities of the expert system software for assessing the technical condition of critical lined equipment.
- An expert system software was developed. It implements the functions of its individual subsystems, which allows generating control recommendations regarding the technical condition of the critical lined equipment and the modes of its operation. The developed software was tested under the conditions of metallurgical production in the process of diagnostics of torpedo ladle cars PM350 at Alchevsk Iron and Steel Works.

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