Specialized computer system to diagnose critical lined equipment

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Abstract. The paper presents data on the problem of diagnosing the lining condition at the iron and steel works. The authors propose and describe the structure of the specialized computer system to diagnose critical lined equipment. The relative results of diagnosing lining condition by the basic system and the proposed specialized computer system are presented. To automate evaluation of lining condition and support in making decisions regarding the operation mode of the lined equipment, the specialized software has been developed.

1. Introduction
In the course of industrial production, dangerous and critical production facilities and machinery are used. Lined equipment, including torpedo ladle cars, hot-metal cars and steel ladles, is considered to be critical equipment at heavy industry and machinery building facilities [1-2]. In order to prevent accidents with such type of equipment and maintain industrial safety at the production facility, a growing number of diagnostic operations and technologies to control technical condition of lined equipment are applied in production units [3-5], which, in turn, require development of new and improvement of existing technical means and information technologies.

Nowadays there are different automated systems that possess a wide range of functions to diagnose and monitor the condition of critical equipment; however, as a number of sources claim [6-8], existing systems do not provide diagnostics of the given lined equipment in the real-time mode without stopping its exploiting. It should be mentioned that modern automated systems are unable to provide complete complex (qualitative and quantitative) automated evaluation of the lining condition, which leads to a low level of objectiveness and quality of the decisions taken while exploiting the equipment. That is why, scientific research to create new systems and technologies for diagnosing lined equipment is relevant.

2. The structure of specialized computer system to diagnose critical lined equipment
A specialized computer system to diagnose critical lined equipment presents a combination of technical and software tools as well as a human technician. Figure 1 presents the proposed structure of the specialized computer system to diagnose critical lined equipment.
Figure 1. Proposed structure of specialized computer system to diagnose critical lined equipment.

According to the structure in figure 1, the system under development includes the following:

1. Thermal imagers to create thermogram images (f(x,y)) of lined equipment. Thermograms are collected by thermal imagers at the monitoring workshop of lined equipment.

2. The technician’s computer with specialized software (figure 2) to automate evaluation of lining condition and support in making decisions regarding the operation mode of the lined equipment.

   2.1. A data collection module designed to form initial data (thermograms) to diagnose the condition of lined equipment.

   2.2. A software operation and construction module designed to select and structure methods and models for diagnostics of lined equipment.

   2.3. A software analyzer of thermogram images – a module designed to apply the proposed by authors intelligent methods and models of thermograms images processing [9, 10] in order to diagnose the lining condition.

   2.4. A decision support system (DSS) - a program to operate knowledge in the process of technical diagnostics of lined equipment in order to support decision-making concerning selection of the operation mode of lined equipment.

   2.5. - Knowledge base (KB) - storage of information that includes recommendations and/or knowledge received after technical diagnostics of lined equipment.

   2.6 Database - storage of information about diagnostic operations for different types of lined equipment.

   2.7. User’s interface allowing interaction between a technician and the software.
The technician’s functions include collection and uploading of primary data into the specialized computer system to allow software to determine technical condition of the lining by processing images of thermograms and to provide required support when making decisions concerning the lined equipment operation mode by implementing the suggested method [9, 10].

3. Experimental research of developed computer system to diagnose critical lined equipment

In order to control effectiveness of proposed solutions, a specialized computer system of technical diagnostics of critical lined equipment was developed. Experimental researching of the developed system were carried out in the shop of weighing facilities of “Alchevsk Iron&Steel Works”. The specialized computer system implemented at “Alchevsk Iron&Steel Works” was developed as the following software-hardware combination: the technician’s computer with developed software (processor - Intel Core i5 2.4 GHz; operating memory - 4 GB DDR3), thermal imagers FLIR GF309.

The proposed solutions were used to determine and evaluate burnout zones of lining. Thermal imagers were used to form thermograms’ images for the following 4 types of critical lined equipment used at “Alchevsk Iron&Steel Works”: immovable mixer MC-1300, torpedo ladle car PM350, hot-metal car 100 tonnes, steel ladle 50 tonnes. On completion of this stage, the developed software was used to recognise the thermograms’ images, which is demonstrate in figure 3.
Figure 3. Thermograms of lined equipment (lining burnout zones): a - torpedo ladle car PM350 and its thermal image; b - steel ladle 50 tons and its thermal image.

During the experimental evaluation of effectiveness of the developed software, a number of experiments aimed at diagnostics of different types go critical equipment were conducted.

During the experimental evaluation of effectiveness of the developed specialized computer system, the index of statistical reliability of lining condition diagnostics was calculated as a degree of correspondence between the number of identified lining burnout zones according to the thermal image and the number of really existing lining burnout zones, proved in the course of the experiment. Statistical reliability of lining burnout zones determined by thermal images is calculated as:

\[
D_{dp} = \frac{N}{N_{\Sigma real}},
\]

where \( N, N_{\Sigma real} \) - the number of identified burnout zones according to the thermal images which were proved in the course of the experiment.

Also the operativeness of the technical diagnostics was calculated. It is proposed to use the approach which evaluates the operativeness of diagnostics of the lining condition for a given software-hardware combination of the specialized system describes above.

Table 1 illustrates the results of identifying images of critical lines equipment thermograms with determination of basic indicators of diagnostic efficiency.

Analysis of the data from table 1 provides information about increased effectiveness of critical lined equipment diagnostics in comparison with the standard diagnostic system, which is expressed in increased reliability and efficiency of determining burnout zones in the course of diagnostics.
### Table 1. Relative results of diagnostics lining condition by basic system and developed specialized computer system

| Lined equipment                  | Basic diagnostic system (pyrometers to determine burnout zones) | Developed specialized computer system (developed software analyzer to determine burnout zones) |
|---------------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
|                                 | Statistical reliability | Operativeness, average (min) | Statistical reliability | Operativeness, average (min) |
| Immovable mixer MC-1300         | 0.90                         | 62                           | 0.93                         | 25                           |
| Torpedo ladle cars (type PM350): |                                                                               |                                                                               |
| #1                              | 0.86                         | 70                           | 0.96                         | 25                           |
| #2                              | 0.88                         | 65                           | 0.92                         | 30                           |
| #3                              | 0.88                         | 73                           | 0.96                         | 28                           |
| #4                              | 0.87                         | 80                           | 0.94                         | 33                           |
| Hot-metal car 100 tonnes        | 0.85                         | 30                           | 0.97                         | 15                           |
| Steel ladle 50 tonnes           | 0.89                         | 27                           | 0.96                         | 13                           |

### 4. Conclusion

The following results were received in the course of the study:

1. The structure of the specialized computer system to diagnose critical lined equipment has been proposed and described.
2. A specialized computer system to diagnose critical lined equipment has been developed and implemented in the shop of weighing facilities of Alchevsk Iron&Steel Works.

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