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STRUCTURIZATION AND MODELLING OF TECHNICAL DEVICES OF HAZARDOUS PRODUCTION FACILITIES

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Abstract. *Every year, the problem of industrial safety is becoming increasingly relevant. The effective industrial safety management system (ISMS) organization becomes especially important for nuclear energy, chemical, petrochemical, oil and gas, mining, metallurgical industries, coal mines and other industries, including enterprises with hazardous production facilities (HPF). Any violation of operating modes, unaccounted technological and operational defects can lead to serious consequences and accidents, accompanied by significant material costs and technological disasters. An important place among the problems of industrial safety is the problem of trouble-free operation of technical devices (units, machines and mechanisms, technical systems and complexes, technological equipment, instruments and apparatus) of hazardous production facilities. However, existing approaches to solving this problem have limited application. The article proposes an effective solving method of the problem based on the use of graph models. The advantage of such modelling is the simplicity, clarity and ease of mathematical algorithmization of the studied production processes and technical systems.*

Keywords: *industrial safety, hazardous production facility, automated control system, graphs, modelling.*

The tasks of an automated industrial safety management system are the reducing industrial safety risks, labour intensity, reducing the time for processing information, accounting for hazardous production facilities and technical devices, automating maintenance processes and repairs of technical equipment and devices at hazardous production facilities.

We note the fact that the automation of solving industrial safety problems is mainly due to the automation of documentation support. Extremely little attention has been paid to the creation of automated control systems for maintenance and repair of equipment of hazardous production facilities (ACS MRE HPF). Although these issues are relevant to enterprises in many industries, the formalized mathematical description problems of the complex technological equipment structures, the implementation of computer models and computer monitoring of the HPF equipment state are not completely resolved [1-19].

The HPF technological equipment structuring

Recreating of the equipment structure, sets of interconnected nodes and details with associated information about the service life (nominal resources), as well as algorithms for taking into account the dynamics of downtime, operating hours, residual resources, is a necessary basis for solving the problem of the equipment state predicting, optimizing planning, and management repairs based on developed information and software. We used the following basic principles to the equipment structuring [20, 21]:

1. Equipment for mathematical modelling purposes is considered from a set-theoretic position.
2. Equipment is presented in the form of a multi-level hierarchical structure.
3. The equipment structuring is carried out to the level of further indivisible elements.
4. Each element (node) of the equipment is assigned an unambiguous correspondence with its identification number.
5. In addition to the identification number, each element (node) of the equipment has its own distinctive features, quantitative or weight characteristics, and a nominal resource.
6. An oriented graph is adopted as adequate to the concept of «structure» and the set-theoretic form of equipment representation.

7. The technological network structure is defined as the union of many graphs of technological equipment units.

Based on the principles formulated, we will show the main stages of computer modelling of the hazardous production facilities equipment for the gas pumping aggregate GPA-1 of Shurtanneftegaz JSC, shown in Figure 1.

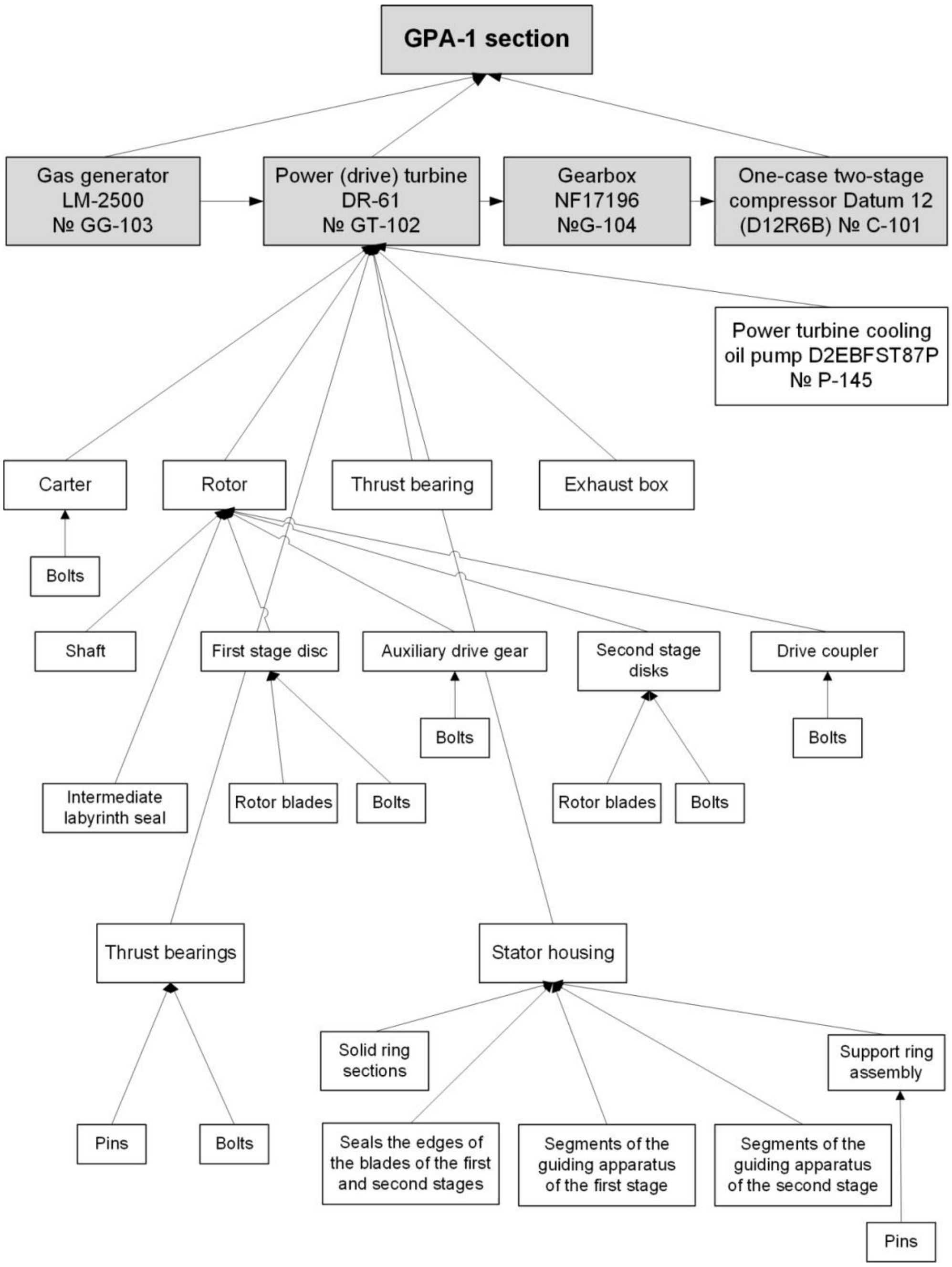

Fig. 1. Equipment for the gas pumping aggregate

The equipment structure

To represent the structure of equipment in computer memory, we use sets and graphs.

We introduce the notation. In this case, capital letters of the Latin alphabet will denote sets and lowercase - elements of sets.

A – 1st level «Workshop»;

B – 2nd level «Equipment»;

C – 3rd level «Equipment (auxiliary)»;

D – 4th level «Nodes»;

E – 5th level «Nodes»;
F – 6th level «Details»;
H – 7th level of «Fuel and Lubricants» (conditional level).
Given these designations, we describe the composition of the power turbine DR-61 № GT-102.

$$A= \{a_i\}, \text{ where } i=1$$

a_1 – workshop GPA-1;

$$B=(b_1, b_2, b_3, \dots, b_{11});$$

where the elements of the set B are the following units of basic equipment:
b_1 – single-case two-stage compressor Datim 12 № C-101
b_2 – power turbine DR-61 № G-102
b_3 – gas generator LM-2500 № GG-103
etc.

$$C = C^1 \cup C^2 \cup C^3 \cup ,\dots, \cup C^k ,$$

where C^i is the set of auxiliary units included in the i-th main equipment.
So, in the considered fragment

$$C^2=\{c^2{}_1\}$$

this is $c^2{}_1$ auxiliary equipment included in the power turbine DR-61 No. GT-102:
$c^2{}_1$ – a pump of cooling oil of power turbine P-145.
Many nodes, included in the units of the main equipment

$$D = D^1 \cup D^2 \cup D^3 \cup ,\dots, \cup D^k ,$$

where D^i is the set of nodes of the b_i -th basic equipment.
So, D^2 is a set of equipment nodes b_2, that is, a power turbine DR-61№ G-102:

$$D^2=\{d^2{}_1, d^2{}_2, d^2{}_3, \dots, d^2{}_{11}\},$$

where
$d^2{}_1$ – carter;
$d^2{}_2$ – turbine block casing;
$d^2{}_3$ – rotor;
$d^2{}_4$ – the bearing block cover;
$d^2{}_5$ – block radial and thrust bearings; $d^2{}_6$ – internal thrust bearing;
$d^2{}_7$ – external thrust bearing;
$d^2{}_8$ – front pillow block bearing;
$d^2{}_9$ – rear pillow block bearing;
$d^2{}_{10}$ – stator housing;
$d^2{}_{11}$ – exhaust box.
E is the second-level nodes set:

$$E=E^1 \cup E^2 \cup E^3 \cup ,\dots, \cup E^k ,$$

where E^i is the set of nodes of the second level, included in the i-th node of the first level.
So, the set

$$E^3=\{e_1{}^3, e_2{}^3, e_3{}^3, e_4{}^3\}$$

is the set of nodes included in the rotor, that is, in the 3rd node of the first level. The elements of the set are as follows:
$e_1{}^3$ – drive clutch;
$e_2{}^3$ – second stage disk;
$e_3{}^3$ – auxiliary drive gear;
$e_4{}^3$ – first stage disc.
F is the set of details included in the nodes:

$$F = F^1 \cup F^2 \cup F^3 \cup ,\dots, \cup F^i ,$$

where F^i is the set of details of the ith node.
For example, $F^3=\{f_1{}^3, f_2{}^3\}$ is the set of the drive clutch details: $f_1{}^3$ – bolt; $f_2{}^3$ – screw.
The equipment model is formed using the menu item «Structural Modeling - Loading Models». When selected, the window shown in Figure 2 will open.

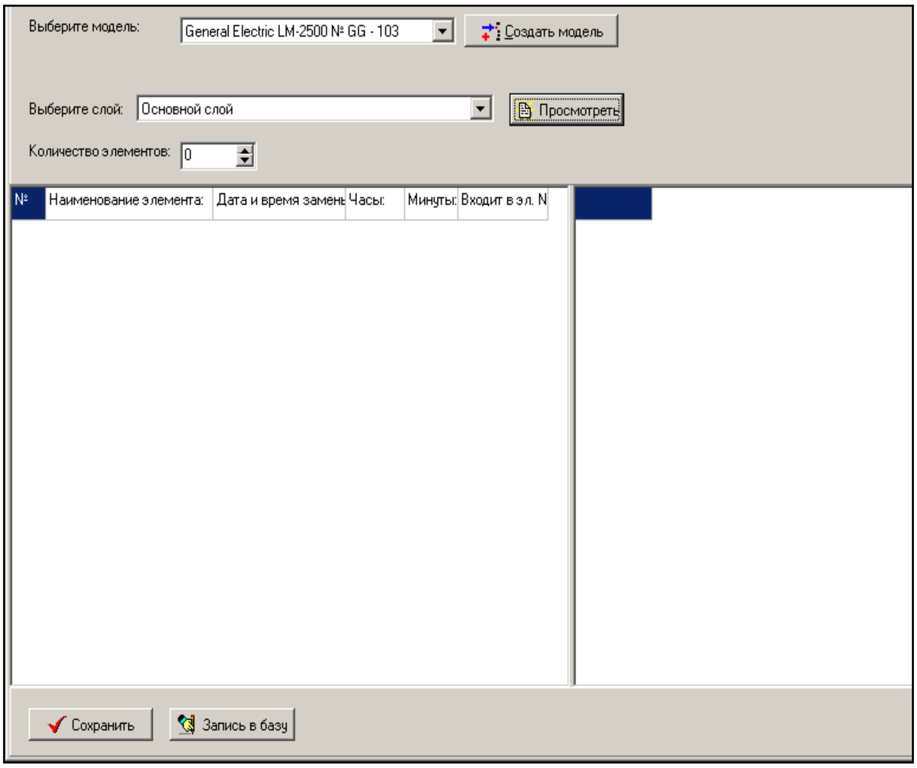

Fig. 2

To view and edit the model, you must select the equipment in the «Select model» list. For example, consider a power turbine. After selecting «DR-61 No. 102 Power Turbine» in the list and clicking on the «View» button, a list of the main components will open (Figure 3).
Since the equipment may include different levels of nodes and details, these levels can be viewed by selecting a different layer and clicking the «View» button. The table contains the following data:

• Name of the element;
• Date and time of replacement;
• Hours and minutes (nominal resource);
• Included in element No. (element number in which the current element is included).

We can edit the data and click the «Save» button.
To view the residual resource of nodes and details, we must select the menu item «Structural Modelling – Model Builder». This opens a window, shown in Figure 4. In this window, we can select the type of equipment «Power Turbine», and in the next window – «Power Turbine DR-61 No. 102».
As a result, the structure of the main components of the power mill and their residual resources will be displayed (Figure 5).
The used resource is shown in black and percent, and the remaining resource in white. This figure shows that the «Carter» node has almost exhausted its resource and is in a pre-emergency situation.

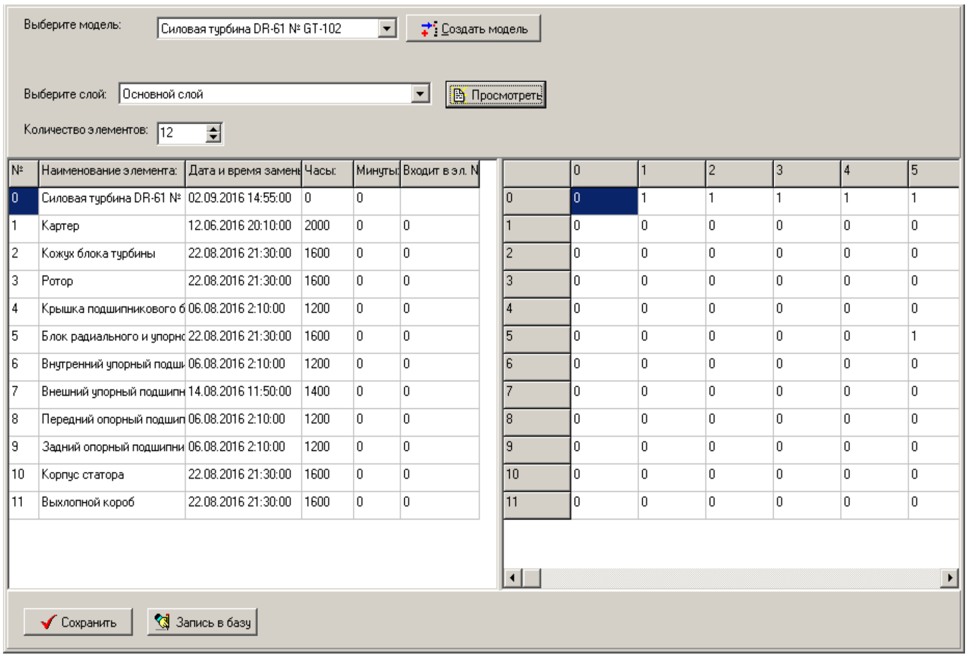
Выберите модель:
Силовая турбина DR-61 № GT-102
Создать модель
Выберите слой:
Основной слой
Просмотреть
Количество элементов:
12
№ | Наименование элемента | Дата и время замены | Часы | Минуты | Входит в эл. N
0 | Силовая турбина DR-61 № | 02.09.2016 14:55:00 | 0 | 0 |
1 | Картер | 12.06.2016 20:10:00 | 2000 | 0 | 0
2 | Кожух блока турбины | 22.08.2016 21:30:00 | 1600 | 0 | 0
3 | Ротор | 22.08.2016 21:30:00 | 1600 | 0 | 0
4 | Крышка подшипникового б | 06.08.2016 2:10:00 | 1200 | 0 | 0
5 | Блок радиального и упорнс | 22.08.2016 21:30:00 | 1600 | 0 | 0
6 | Внутренний упорный подш | 06.08.2016 2:10:00 | 1200 | 0 | 0
7 | Внешний упорный подшипн | 14.08.2016 11:50:00 | 1400 | 0 | 0
8 | Передний опорный подшип | 06.08.2016 2:10:00 | 1200 | 0 | 0
9 | Задний опорный подшипни | 06.08.2016 2:10:00 | 1200 | 0 | 0
10 | Корпус статора | 22.08.2016 21:30:00 | 1600 | 0 | 0
11 | Выхлопной короб | 22.08.2016 21:30:00 | 1600 | 0 | 0
| 0 | 1 | 2 | 3 | 4 | 5
0 | 0 | 1 | 1 | 1 | 1 | 1
1 | 0 | 0 | 0 | 0 | 0 | 0
2 | 0 | 0 | 0 | 0 | 0 | 0
3 | 0 | 0 | 0 | 0 | 0 | 0
4 | 0 | 0 | 0 | 0 | 0 | 0
5 | 0 | 0 | 0 | 0 | 0 | 1
6 | 0 | 0 | 0 | 0 | 0 | 0
7 | 0 | 0 | 0 | 0 | 0 | 0
8 | 0 | 0 | 0 | 0 | 0 | 0
9 | 0 | 0 | 0 | 0 | 0 | 0
10 | 0 | 0 | 0 | 0 | 0 | 0
11 | 0 | 0 | 0 | 0 | 0 | 0
Сохранить
Запись в базу

Fig. 3

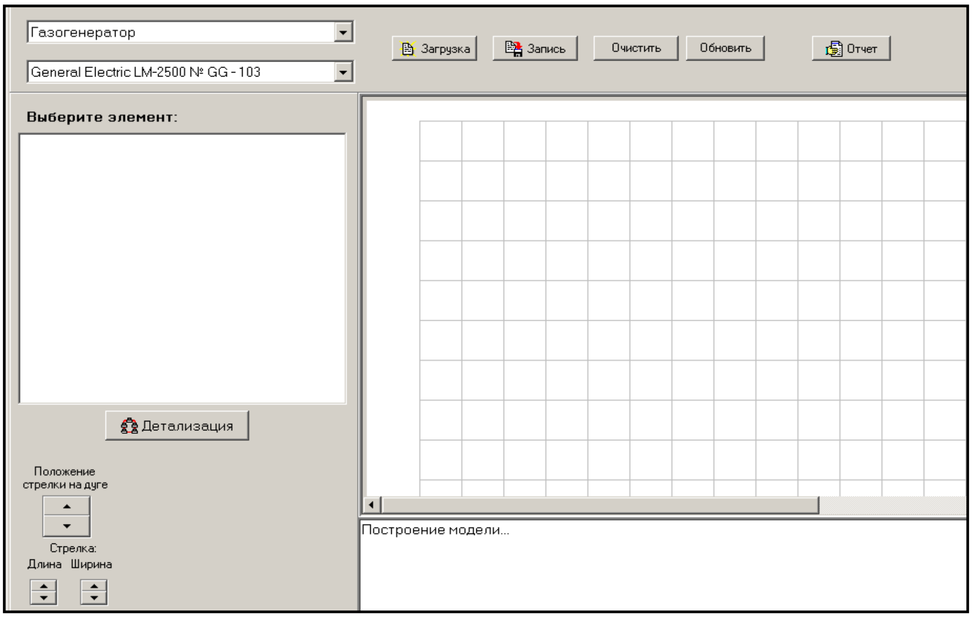
Газогенератор
General Electric LM-2500 № GG - 103
Загрузка
Запись
Очистить
Обновить
Отчет
Выберите элемент:
Детализация
Положение стрелки на дуге
Стрелка:
Длина Ширина
Построение модели...

Fig. 4

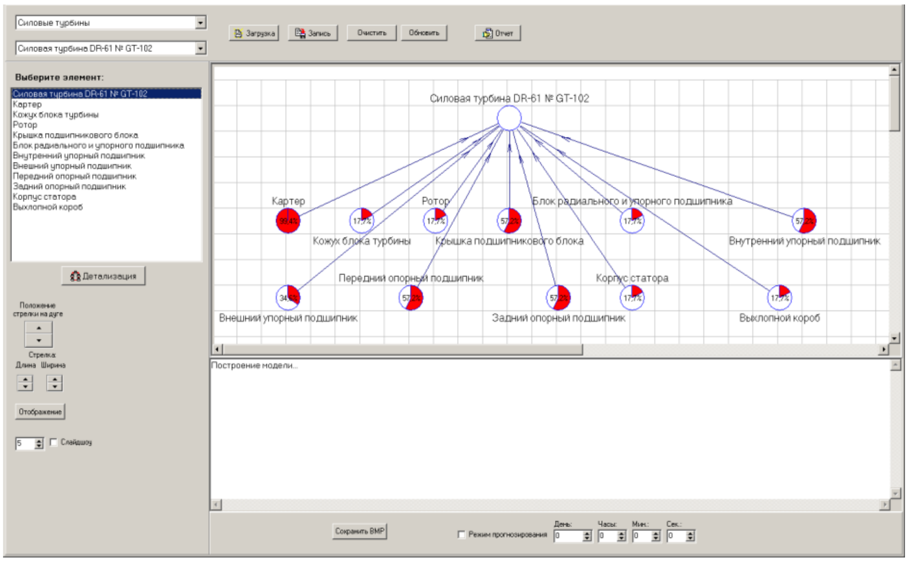

Fig. 5

Figure 6 shows the composition of the «Carter» node and its residual resources.

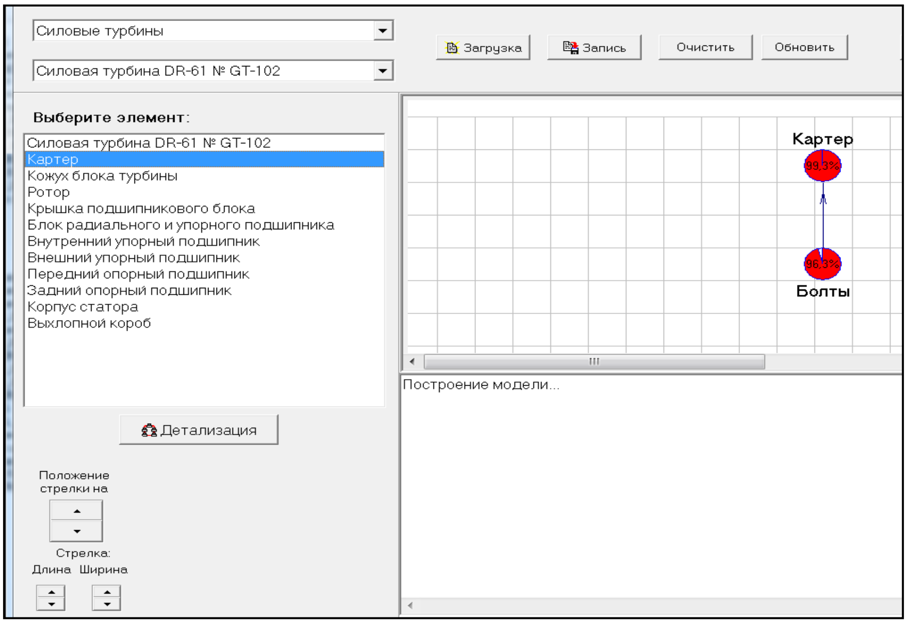

Fig. 6

Conclusions

Thus, the article formulates the principles and method of structuring the technical devices of hazardous production facilities and modelling the equipment, based on the set-theoretic approach and graphs.

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