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DEVELOPMENT OF ADVISORY EXPERT SYSTEM AIDING MAINTENANCE OF SHIP POWER PLANT

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Abstract: *The process of managing all operations carried out during the ship power plant maintenance is complex and very troublesome for machinery engineers. Therefore, they need tools aiding undertaking their decisions. One of possible solutions is to develop the expert system supporting carrying out various maintenance activities. In this paper, assumptions and principles for the development of advisory expert system for ship power plants are presented. The main task of the elaborated advisory expert system is to give advice concerning the proceedings during assembling and dismantling the typical machine parts and connections.*

1. INTRODUCTION

During the maintenance of the ship power plant it is often necessary to carry out corrective maintenance. In most cases there are strict repair procedures available. But sometimes damages, which removal causes serious problems, occur. Knowledge of experienced engineers may be helpful in such cases. But there is not always a possibility to get their opinion. It is necessary then to acquire knowledge on a given subject from some other sources. This task may be little difficult as this knowledge may be in some handbooks, catalogues, etc. In such cases it is a huge aid to use expert systems. Such systems enable assembling all the dispersed knowledge in one place – knowledge base. Using such systems shall considerably speed up solving of the problems occurred.

The largest and most numerous uses among expert systems are advisory systems. Their task is to aid in solving defined problems by giving proper advice. A system of that type within the scope concerning the ship power plant maintenance was elaborated at the Gdynia Maritime University.

2. CHARACTERISTICS OF MAINTENANCE PROCESS OF THE SHIP POWER PLANT

The necessity of carrying out machines and equipment maintenance is caused first of all by wearing out their elements. Also damages occurred during their use have large impact. The aim of maintenance is mainly diminishing the intensity of wearing out process and reconstruction of the operation of the machines and equipment.

Maintenance procedures concern the activities of keeping structures, systems and components in good operating condition. It is an organized activity that involves both administrative and technical functions. Some common approaches to maintenance may be defined as follows [4]:

– preventive maintenance which calls for structures, systems and components to be opened out for inspection and overhaul at specified time periods, or after a specified number of running hours, in order to ensure that the structure/system/component is in a satisfactory condition for continued operation;

– condition-based maintenance in which of the need for maintenance is based on the performance or physical state of the structure/system/component, as determined by regular or continuous checks of applicable parameters (maintenance is only undertaken when conditions have approached or reached the lowest acceptable standard and before serious deterioration, breakdown or failure occurs);

– corrective maintenance which is sometimes referred to as unscheduled or breakdown maintenance (it is only carried out to restore a structure/system/component back to operational condition after a failure or malfunction).
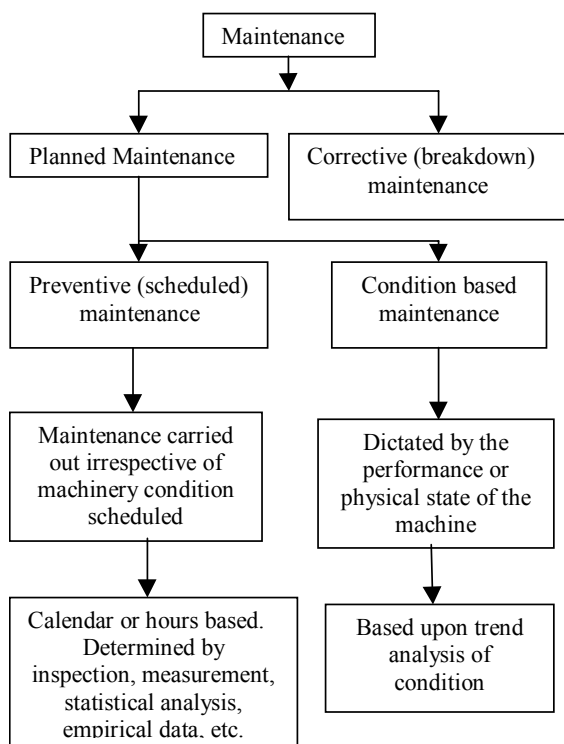
Fig.1. *Relationship between maintenance concepts[4]*

The relationship between these maintenance concepts is illustrated in Figure 1.

Maintenance process is a random process. It results from different scope of maintenance activities, conditions of maintenance and frequency of maintenance notifications. Depending on the kind and scope of damages to the element, a technical object may be in different states, such as:

- damage diagnostic - S_1,
- damage location - S_2,
- technical delay (necessity of venting, cooling down before dismantling, etc.) – S_3,
- disassembly – S_4,
- expectation for spare parts – S_5,
- regeneration of damaged part – S_6,
- replacement of part – S_7,
- assembly – S_8,
- regulation – S_9,
- inspection – S_{10}.

Figure 2 presents a graph of maintenance process of a technical object. The Maintenance process in a given case does not have to contain all the above mentioned states. The quantity of states which the technical object goes through changes depending on the maintenance kind. In case of preventive maintenance such states as damage location and regeneration of the damaged part will be missing. Also during repair maintenance not all the states of the maintenance process should take place, and for example after location of the damage, if it is possible, you can come directly to dismantling.
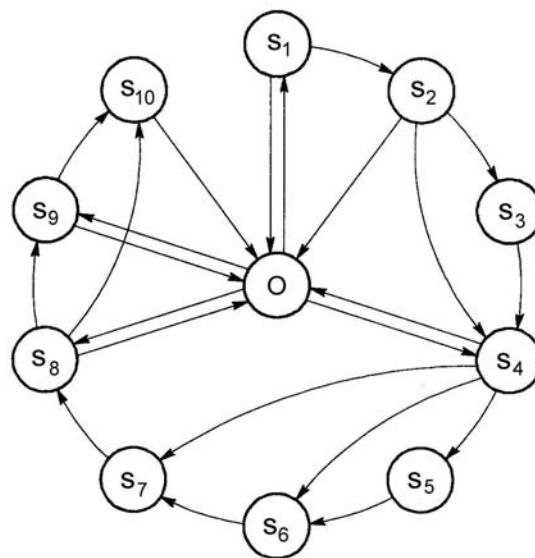

Fig.2. *Graph of maintenance process (O – operation use)[5]*

Different possible transitions of the elements to different states of maintenance and the operations which could be repeated are presented on the graph.

Due to the fact that dismantling, regeneration of damaged parts and assembly are the main states of the maintenance process, advice concerning these operations were contained in the elaborated advisory system.

3. WORKING PRINCIPLE OF ADVISORY EXPERT SYSTEM

The main task of the elaborated advisory expert system is to give advice concerning the proceedings during assembling and dismantling the typical machine parts and connections. Using this system you may also learn the rules concerning verification and regeneration methods. The system also enables acquiring information about the equipment necessary for assembling or dismantling a given part or connection.

Machine parts covered by advice in this system are as follows:

- shafts, axles and pins,
- rolling bearings,
- slide bearings,
- sleeves,
- gear wheels, chain wheels and pulleys.

Concerning the connections, the description contains the following kinds:

- bolted joints,
- parallel key joints,
- keyed joints,
- taper joints,
- splined couplings,
- forced-in joints,
- shrinkage joints.

The main element of the whole system is its knowledge base. It contains the whole knowledge necessary for carrying out the basic aim of the system – aid in solving repair problems. Creating this base required formalization of the acquired knowledge. With this aim it was recorded as the following types:

- general:
  - object
    (`Type of operation`,
    `Type of tool`,
    `Type of activity`,
    `Type of problem`,
    `Problem solution`,
    Drawing_file_1,
    Drawing_file_2,
    Drawing_file_3,
    Drawing_file_4).
- detailed:
  - object
    (`Disassembly`,
    `Angular grinder`,
    `Disassembly of bolted joints`,
    `Small bolts broken above a surface of material (d<10mm)`,
    `Filing the bolt for a spanner`,
    93,100,100,0).
  - object
    (`Disassembly`,
    `Pliers`,
    `Disassembly of bolted joints `,
    `Small bolts broken above a surface of material (d<10mm)`,
    `Strong grasp`,
    94,100,100,0).
  - object
    (`Disassembly`,
    `Device for electron discharge machining`,
    `Disassembly of bolted joints`,
    `Small bolts broken above a surface of material (d<10mm)`,
    `Cutting the bolt into pieces and removing`,
    100,100,100,0).
  - object
    (`Disassembly`,
    `Welding machine`,
    `Disassembly of bolted joints `,
    `Small bolts broken above a surface of material (d<10mm)`,
    `Welding on a bar`,
    98,100,100,0).
  - object
    (`Disassembly`,
    `Welding machine`,
    `Disassembly of bolted joints `,
    `Small bolts broken above a surface of material (d<10mm)`,
    `Welding on a nut to protruding part of the bolt`,
    99,100,100,0).
  - object

    (`Disassembly`,
    `Welding machine`,
    `Disassembly of bolted joints `,
    `Small bolts broken above a surface of material (d<10mm)`,
    `Driving a triangular mandrel into protruding part of the bolt`,
    62,100,100,0).
  - recommendations(`Welding on a bar`, `In such a case place a washer on the protruding part of the bolt and weld on a steel bar with help of which the screw is unscrewed. Putting on the washer secures against welding to the element from which it is being unscrewed`, [1,11,2,3],[2,3,1,11], [],[]).

Such a record of knowledge is defined as facts. These facts determine the connections between the objects. For example, the fact as:

  - object
    (`Disassembly`,
    `Welding machine`,
    `Disassembly of bolted joints`,
    `Small bolts broken above a surface of material (d<10mm)`,
    `Welding on a bar`,
    98,100,100,0).

may indicate that the welding machine is used to weld the bar in case of dismantling the screw connections when it comes to breaking the small screw on the protruding part of the material. Such connections may also indicate that problem solution of dismantling the screw connection in case of breaking a screw on the protruding part of the material is to weld the bar. The numbers included in the further part refer to the appropriate drawing files illustrating the situation.

The basic element of the knowledge base connecting all the facts with each other are the rules. Their task is to define the mutual relations between the facts. For example the rule such as:

recommendations(Text) :-
findall(T,recommendations(Text,T,_,_,_,_),
        Elements),
forall(member(Element, Elements),
write(Element)
) ~> String,
wtext((window_procedure,11000), String).

will connect the following fatcs:

(1) object(`Disassembly`,`Welding machine`, `Disassembly of bolted joints`,`Small bolts broken above a surface of material (d<10mm)`, `Welding on a bar`,98,100,100,0).

(2) recommendations (`Welding on a bar`, `In such a case place a washer on the protruding part of the bolt and weld on a steel bar with help of which the screw is unscrewed. Putting on the washer secures against welding to the element from

which it is being unscrewed.`,
[1,11,2,3], [2,3,1,11], [], []).

If out of the fact (1) would be chosen "Welding on a bar", will make the variable Text real which from that moment will have the value "Welding on a bar". The next orders of the rule will find in the database all the facts where the first segment is "Welding on a bar". After finding out the proper fact, a value of the variable T will be searched:

recommendations ("Welding on a bar", T,_,_,_,).

In the case of the fact (2) the variable T will have the following value:

"In such a case place a washer on the protruding part of the bolt and weld on a steel bar with help of which the screw is unscrewed. Putting on the washer secures against welding to the element from which it is being unscrewed."

In the end the value of the variable will be displayed in a proper window as solution of the presented problem.

After starting the system a window of choice appears (Fig. 3). This window enables preliminary formulation of the problem occurred and choice of proper maintenance method to come to the solution. To make it easy – after choosing every option – in the window **Prompt** a short commentary on its subject appears. Confirmation of the choice with the button OK causes passing to the next window. After choosing the option „ Mark if you do not know how: to carry out all the activities related to maintenance problem" a window will appear as in the figure 4. The sequence of choice is made according to the recommendations in the Dialogue Window. Formulating the maintenance problem is done through the subsequent choices beginning from the window **Operation**.

In this window the kind of operation of technical maintenance (assembly, disassembly) is defined. After making the choice in the next window – **Activities** – next options appear. Making the last choice causes passing to the next window where the solution of the problem is found (Fig. 5). The solution window is divided into two parts - **Dialogue Window** and **Graphical Window**. The Dialogue Window consists of three parts - **Preliminary activities**, **Recommendations** and **Remarks**. Preliminary activities point what actions should be taken before coming to the defined recommendations. Recommendations contain advice concerning the methods of solving the problem. The window Remarks contains additionally the hints helpful when carrying out defined activities. Footnotes referring to the

Graphical Window – Window 1, Window 2, Window 3, TABLES - will appear in these windows, precisely to the buttons contained in this window. After choosing the right button a graphic illustration of the given problem will be presented in the window. In some cases it is necessary to use additional tables. To this aim the button TABLES (Fig. 6) is used.

You may return to the initial window from each window using the button <<Back. Finishing the program work follows after choosing the button End.

Choosing the next option "Mark if you do not know how: to carry out the particular maintenance activity" in the initial window will make opening the window presented in Figure 7. In this case the initial window is the window **Activities** where the following options may be found:

– Assembly of joints,
– Assembly of subsystems and systems,
– Disassembly of joints,
– Disassembly of subsystems and systems,
– Verification of subsystems and systems,
– Regeneration of subsystems and systems.

Next choices are made as in the previous window. After making the final choice the passing to the next window is done as in Figure 5.

The third option of the initial window „Mark if you do not know how: to attend the particular machine part" makes passing to the window as in Figure 8. In this window coming to the solution starts from choosing by the user a program of machine part or connection. After having made the choice the next operation you are going to carry out is marked. The other choices are made depending on the arisen maintenance problem. The problem solution is in the window as in Figure 5 to which you pass after the final choice.

The last option in the initial window is "Mark if you do not know how: to use a working tool". Choosing such an option makes passing to the window as in Figure 9. Choosing first a machine part or connection and then the kind of operation you pass to the window **Tools**. In this window there are displayed all the tools necessary for carrying out the operation. After choosing one of them in the window **Application** it can be proved how they may be used. The final stage is to choose the proper use what makes displaying the scheme of the tool in the **Graphical Window** and description of its use in the **Dialogue Window**.
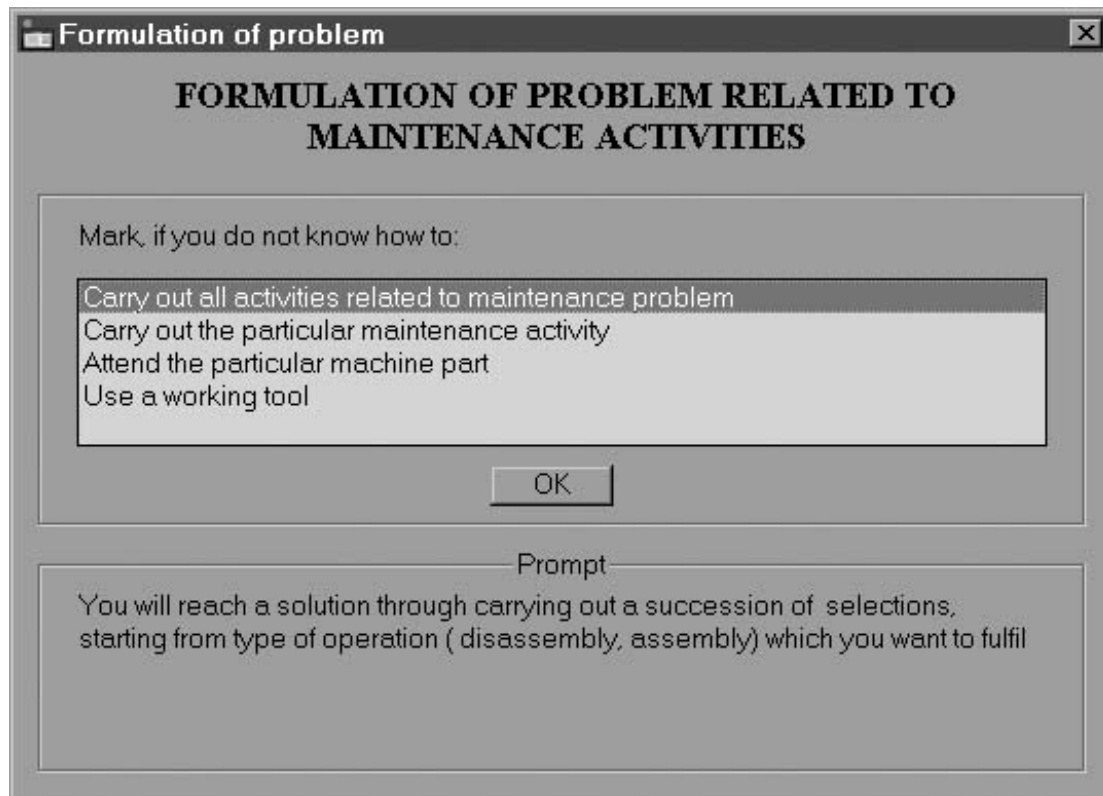
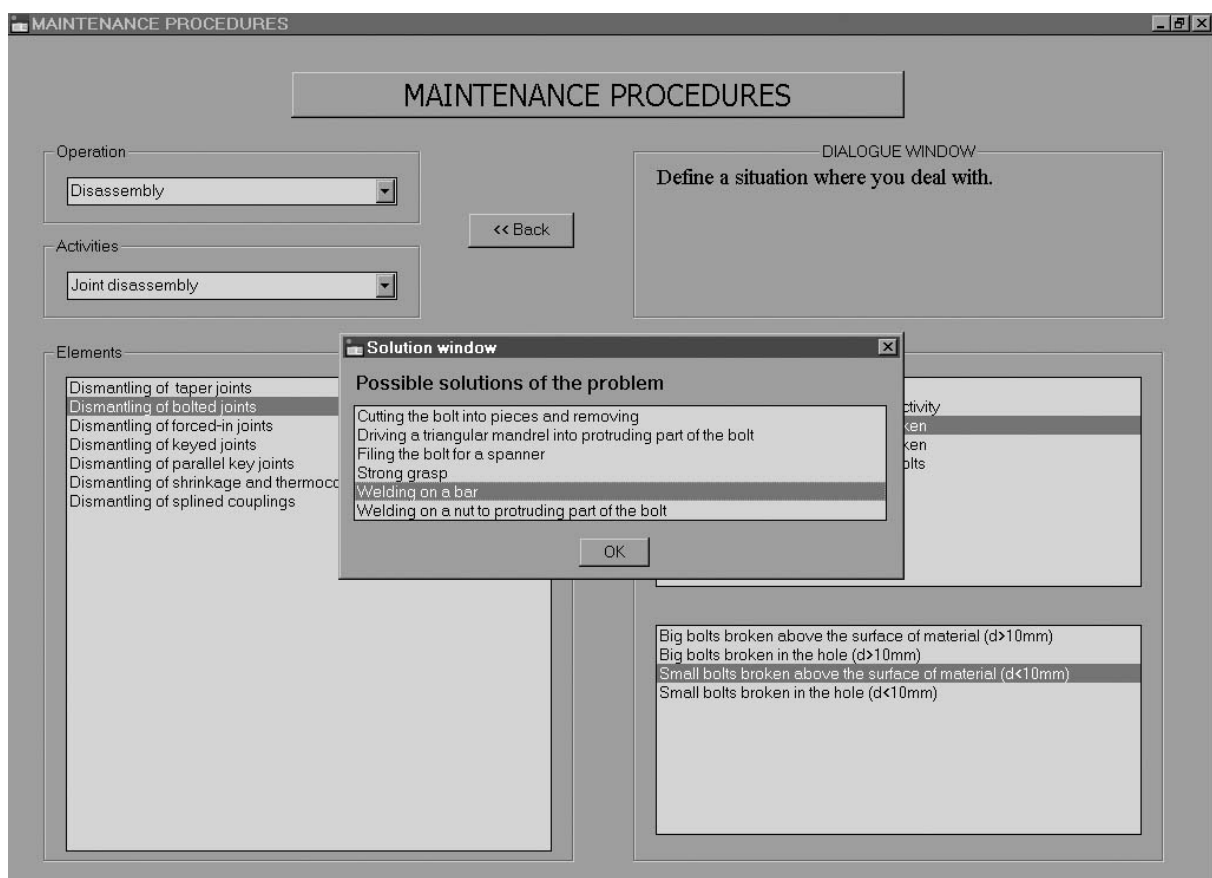Fig.3. *A screen for formulation of maintenance problem*

Fig.4. *A screen of maintenance problem after selection the first option in initial window*
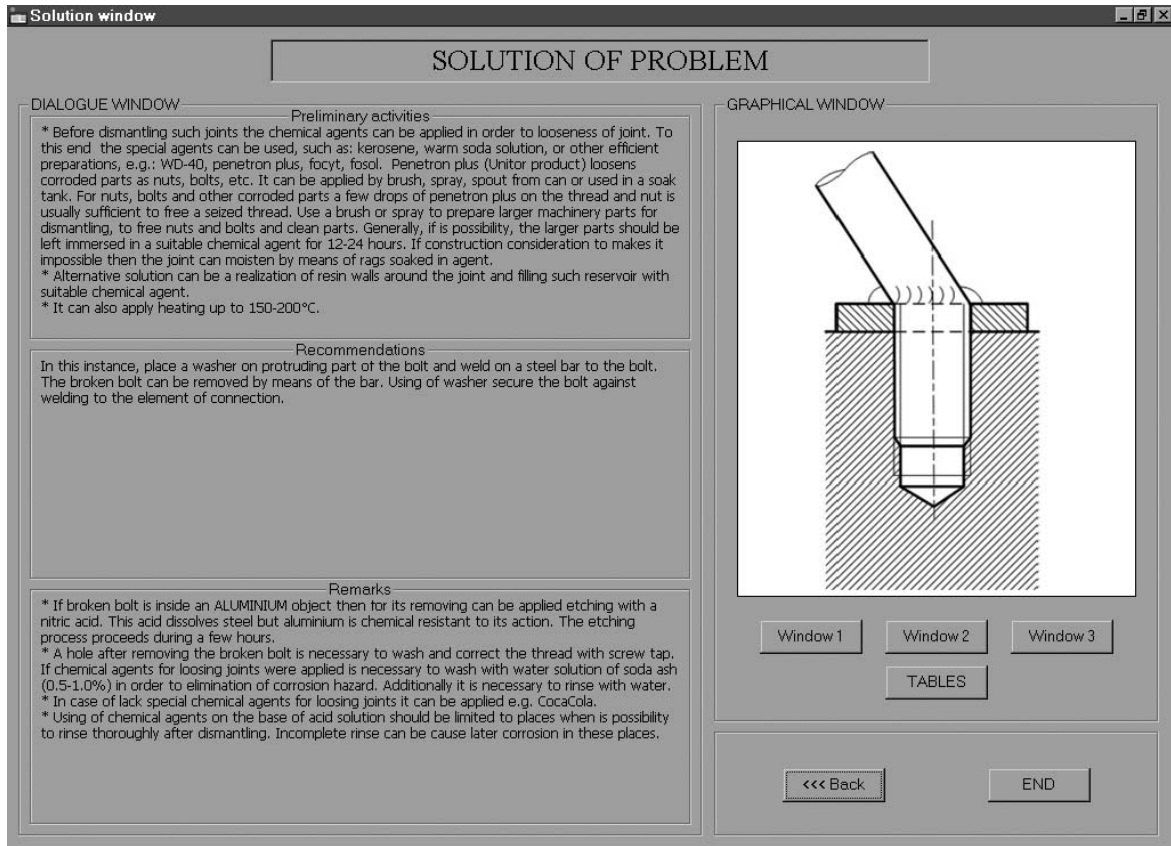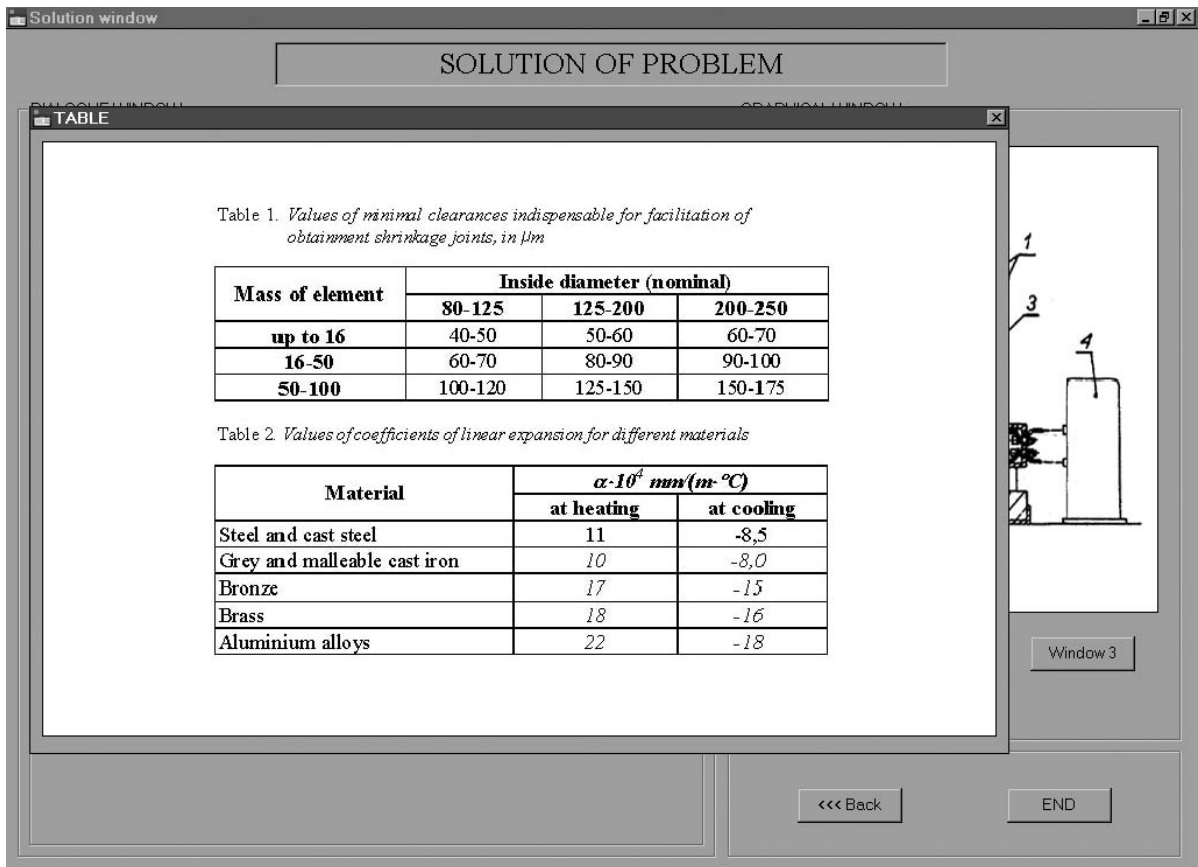
Fig. 5. *An example of solution screen*

Table 1. *Values of minimal clearances indispensable for facilitation of obtainment shrinkage joints, in μm*

Mass of element	Inside diameter (nominal)		
	80-125	125-200	200-250
up to 16	40-50	50-60	60-70
16-50	60-70	80-90	90-100
50-100	100-120	125-150	150-175

Table 2. *Values of coefficients of linear expansion for different materials*

Material	$\alpha \cdot 10^4 \ mm/(m \cdot ^\circ C)$	
	at heating	at cooling
Steel and cast steel	11	-8,5
Grey and malleable cast iron	10	-8,0
Bronze	17	-15
Brass	18	-16
Aluminium alloys	22	-18

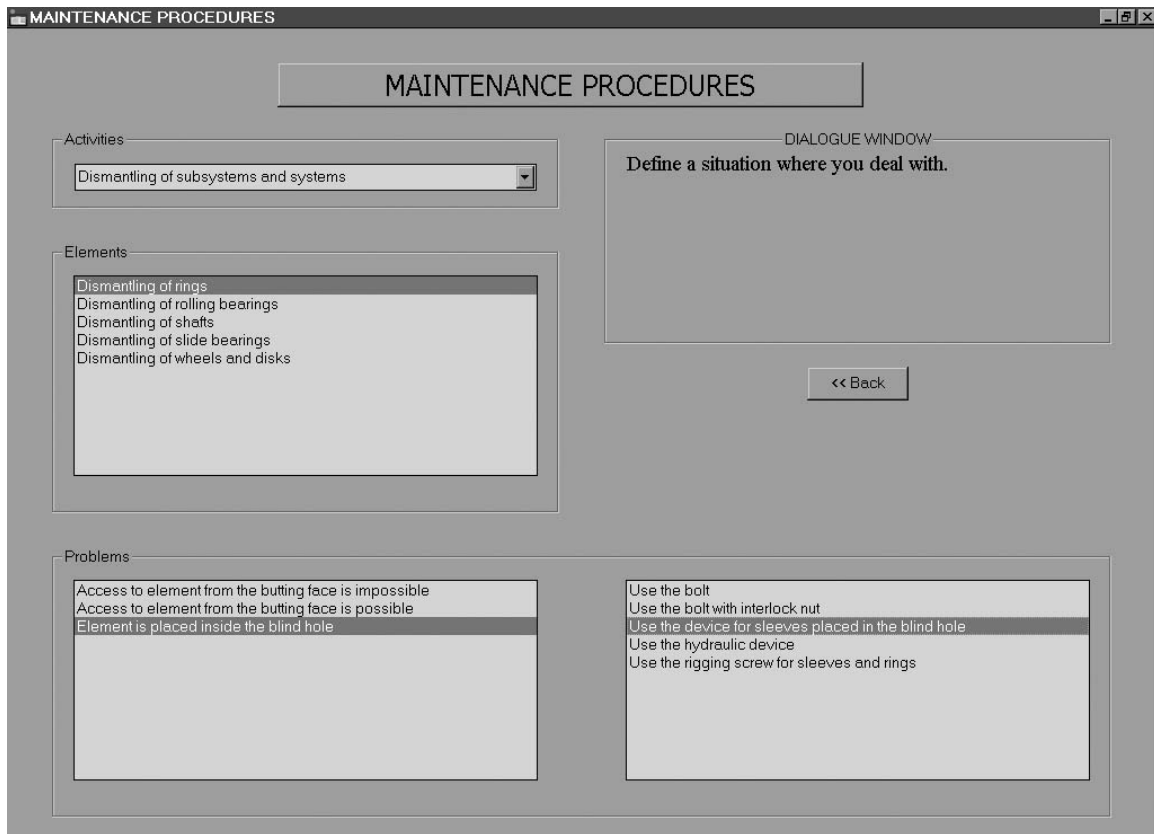Fig.6. *An example of tables inserted in programme*

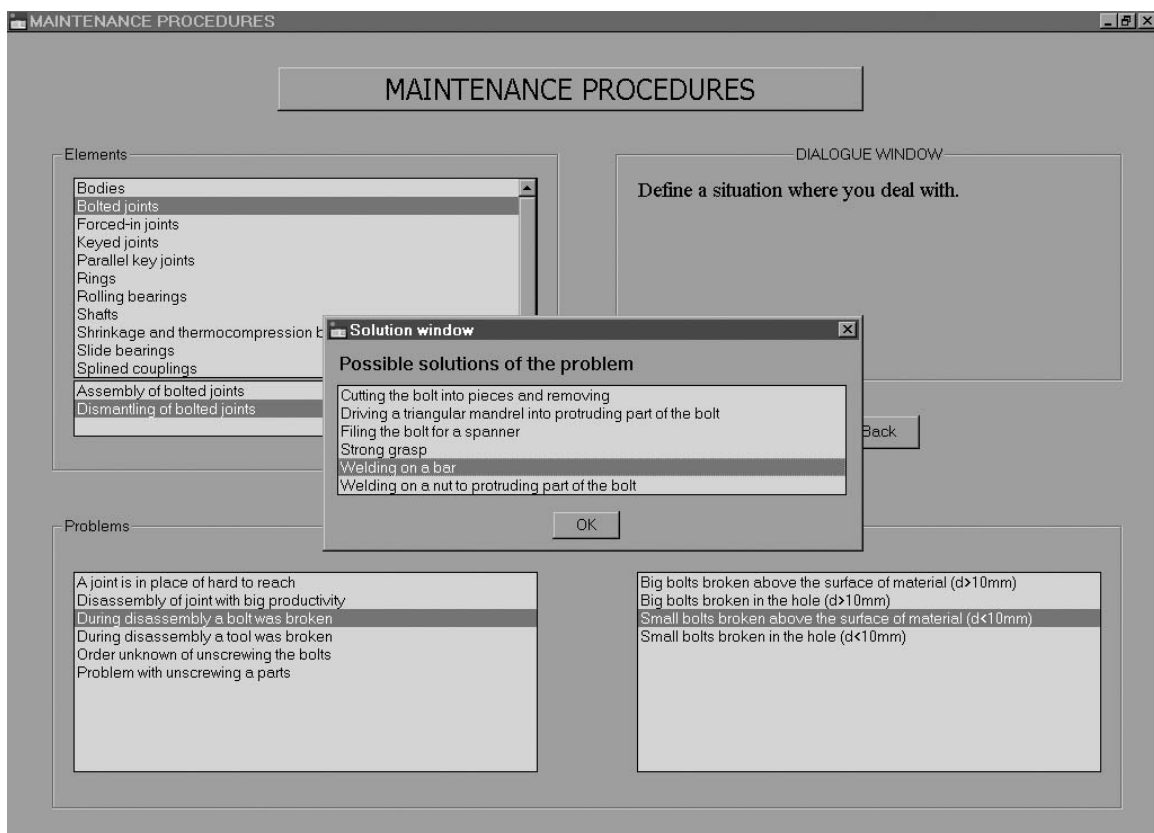Fig.7. *A screen of maintenance problem after selection the second option in initial window*

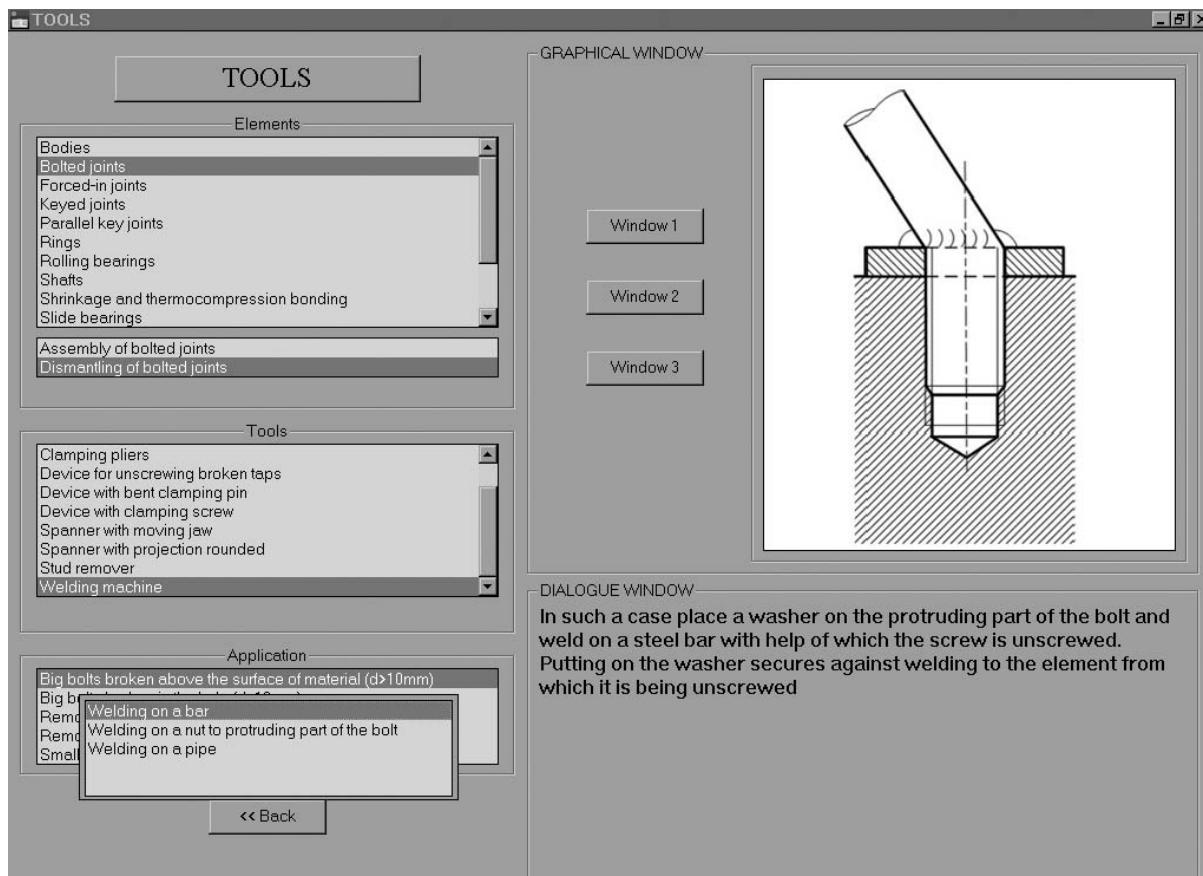Fig.8. *A screen of maintenance problem after selection the third option in initial window*

Fig.9. *A screen for selection of tools*

4. CONCLUSIONS

The works done concern the expert advisory system aiding to carry out the repair works in the ship power plant allow to conclude the following:
- acquiring detailed knowledge in a defined narrow field is very difficult due to its dispersion,
- a large part of the knowledge has not been yet formalized as it is acquired along with experience and passed in oral form,
- formalization of the possessed by the expert knowledge in a given field (also knowledge contained in other sources) in expert systems accelerates and makes it easy to solve the problems you come across,
- the elaborated advisory system may be used by less experienced operators carrying out repair works,
- the system is open-type and due to that it is possible to enlarge its knowledge base and thus increase its utility.

References

[1]   *A guide to managing maintenance.* The International Association of Classification Societies. Recommendation 74. April 2001.

[2]   Clocksin W.F., Mellish C.S.: *Prolog. Programming.* Helion. Gliwice 2003. (in Polish).

[3]   Kowalewski T. *Repair methods of machinery in ship power plant.* Praca dyplomowa magisterska. Wydział Mechaniczny. Akademia Morska. Gdynia 2004. (in Polish).

[4]   *Machinery planned maintenance and condition monitoring.* Notice No.1 to ShipRight Procedures Overview. Lloyd's Register of Shipping. July 2002.

[5]   Tarelko W. *Computer-aided decision-making process of maintainability design of power transmission system.* Wydawnictwo Uczelniane WSM w Gdyni. Gdynia 1998. (in Polish).