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THE EXPERT SYSTEM OF THE OIL RIG DRILLING WINCH

Abstract. Topicality. The increasing complexity of oil rig drilling operations requires reliable and intelligent tools for timely detection and elimination of equipment failures. Winch brake malfunctions pose a significant risk to operational safety, making the development of automated diagnostic systems a critical task. **The subject of the research** is models, methods and tools for building an expert system for automated diagnostics of faults in winch brakes of drilling rigs on oil platforms, as well as the processes of detection, interpretation and support for making corrective decisions in real time. **The purpose of this article** is to develop a knowledge-based expert system capable of detecting winch brake disorders in oil rig drilling operations and supporting automated corrective decision-making. The proposed system is based on a rule-based knowledge representation using IF and THEN inference mechanisms and heuristic frames that integrate technological parameters and their dynamic changes. Artificial intelligence techniques are applied to enable adaptive learning from previously encountered operational scenarios and to update the knowledge base. **The following results** were obtained. A knowledge-based expert system for oil rig drilling winch diagnostics was developed. The system successfully identifies potential brake failures and recommends corrective actions based on expert-defined rules. Experimental evaluation demonstrates improved accuracy and efficiency in fault detection and decision support. **Conclusion.** The developed expert system ensures effective detection of winch brake disorders, enhances operational efficiency, and increases the reliability and safety of oil rig drilling equipment.

Keywords: artificial intelligence (AI); expert system (ES); oil rig; oil rig drilling winch (ORDW); intelligent decision support.

Introduction

Problem relevance. The modern oil rig has a complex sensor system. It is used for diagnostic and control in the working process of the oil production. The oil rig has different telemetry systems. For example, thermomanometeric submersible telemetry system is used to measure the following parameters in the process of oil production; temperature of the stator winding of a submersible electric motor (SEM), fluid temperature at the pump intake, fluid pressure at pump intake, SEM oil pressure, vibration acceleration of the SEM in the axial, and radial directions etc**.**

This is a small part of a complex sensor-actuator system on an oil platform. For more effective control of this system, it is advisable to develop an expert system based on the principles of artificial intelligence. [1].

Literature review. The application of expert systems and knowledge-based technologies in the oil and gas industry has been widely investigated, particularly in the context of drilling process optimization, decision support, and operational safety.

The first group of studies focuses on the development of expert systems for the automatic control of drilling fluid properties. [2] This work demonstrates how rule-based reasoning and encoded expert knowledge can be used to support decision-making and automate critical drilling operations. Such systems reduce human error and improve process stability, providing a conceptual and methodological foundation for applying expert systems to other drilling subsystems, including drilling winches.

Another important research direction is represented by studies on expert systems for the selection and design of enhanced oil recovery (EOR) technologies. [3] These systems model complex engineering decision processes using knowledge-based rules and algorithms. The presented approaches are relevant to the current study, as they illustrate how expert systems can formalize engineering expertise and support multi-criteria decision-making, which is essential for selecting braking strategies and friction materials in Oil Rig Drilling Winch systems.

A broader perspective is provided by review papers that analyze the role of expert systems in petroleum engineering for technical decision support and production optimization. This work [4] summarizes the advantages, limitations, and future trends of intelligent systems in oil and gas applications. They emphasize the potential of expert systems to enhance reliability, safety, and efficiency of complex industrial equipment, directly supporting the motivation for developing an expert system for Oil Rig Drilling Winch operation and failure prevention.

Overall, the reviewed literature confirms the relevance and feasibility of applying knowledge-based expert systems to drilling equipment. However, limited attention has been given to expert systems specifically dedicated to drilling winch braking mechanisms, which underlines the novelty and practical significance of the present study.

The purpose of the research is to develop a knowledge-based expert system capable of detecting winch brake failures during drilling operations on an oil platform and supporting automated corrective decision-making.

1. Expert system development principles

Expert industrial systems are capable of solving management tasks as human experts. The practice of operating automated process control systems based on expert systems has confirmed their high efficiency mainly due to the greater feasibility of the solutions obtained.

The level of complexity of modern technological objects, the uncertainty of the environment of their functioning, the large dimension of management tasks does not allow creating such a general knowledge base expert system. The way out of this situation is to develop more dynamic and flexible expert system that operate in real-time mode and react quickly to changing conditions of the process. In addition, it is necessary to periodically update the knowledge base expert system depends on the analysis of trends in the parameters of the technological process, to predict the possible evolution of the process and generate the appropriate solution.

For the realization of the suggested concept of artificial intelligence based expert system, the following main principles are defined [5].

1.1. Decomposability of intelligence. There is need for reasonable fragmentation of the global intelligence into a set of specific intelligences during development of distributed control system on the basis of intelligent Systems network. Each of those specific intelligences deal with a limited and specific area of Problems and tasks. The decomposition can be accomplished by natural or artificial manner.

1.2. Possibility of coordinating intelligences. Decomposability of intelligence, distributed nature of information, control, and decision-making process requires the provision of necessary conditions for integrating specific intelligences during specific problem-solving processes. Possibility of coordinating and integrating specific intelligences allow successful decision-making under condition of insufficient information.

1.3. Non-additive nature of system's intelligence. The intelligence of the system is not additive regarding to its components' intelligences. Data communication and new data generation cause the intelligent potential of the system to exceed the total intelligence of its components.

1.4. Possibility of information communication between nodes. In hierarchical network knowledge communication is performed both between the levels of hierarchy (vertically) and between nodes of the same level (horizontally).

1.5. Adaptability. The network is subject by difficult demands on the reliability and vitality of system. It must preserve its functional capabilities. Also, the accordance between algorithms of control of current situations and objects' states must be provided. AI systems, functioning in real time, forming and realizing control actions directly on control objects require high System reliability. In case of failure of some node, restoring of functional capabilities of the system must be provided by reconfiguration of structure. It is necessary to provide the mechanism of database and knowledge base updating.

1.6. Possibility of working in multiple modes. Local Systems included distributed control system can solve different content and form Problems. Considering the entities of Problems and users' requirements, the multimode working (batch processing, operative access, real time) is necessary.

1.7. The open nature of system. As a rule, on the system's creating stage the limited problem area for control object is examined. During evolution of object, new problems occur, requires coordination with the earlier considered and solved problems, i.e. object's development requires an adequate development of control system. Taking this into account, AI system must be created as an open system with the modular structure, providing the possibility for new Systems integration.

1.8. Intelligent nature of nodes. Existing nodes and new created nodes must have their own intelligences and be interconnected with other nodes through communication network in the limits of their powers, competence and implemented functions.

1.9. Distributed nature of system. It is necessary to provide flexible distribution of intelligence, Information, and computation resources among the nodes of expert systems network. In order to rationally use the computational resources at different levels of hierarchy and increase functional capabilities of system, it is necessary to effectively use the capabilities of Controllers. Also, intelligent Systems of information collecting and processing, problem-solving of diagnosing and Information preparing for experts' system on the low level of hierarchy helps to logically utilization of computational resources.

The logical conclusion of this reasoning can be stated as: in order to make wider use of real-time expert systems, it is necessary to develop an expert system that can simply adapt to a wide class of production processes, having a convenient, user-oriented dialog interface, simple means of access to the database for its automated correction.

2. Architecture of expert system for oil rig drilling winch

The suggested concepts and principles of ES were laid on the bases of expert Systems network building for the OIL RIG DRILLING WINCH (ORDW). The characteristic features of the object have close interconnections between units, where changing of the working mode of one unit influences the others' modes, that leads to necessity of mutual adjustment of working modes of interconnected units**.**

The control decisions are made under conditions of high degree of uncertainty, incompleteness, inaccuracy of initial Information, technological processes descriptions, fuzziness of desired goals, limitations, and possible effects of decision-making [6]. Proceeding from the indicated specifications of oil rig drilling winch, the architecture of distributed intelligent control system is defined in the form of hierarchical network, the nodes of which are local expert Systems, and connections between them provide the data and knowledge communication as shown in Fig. 1.

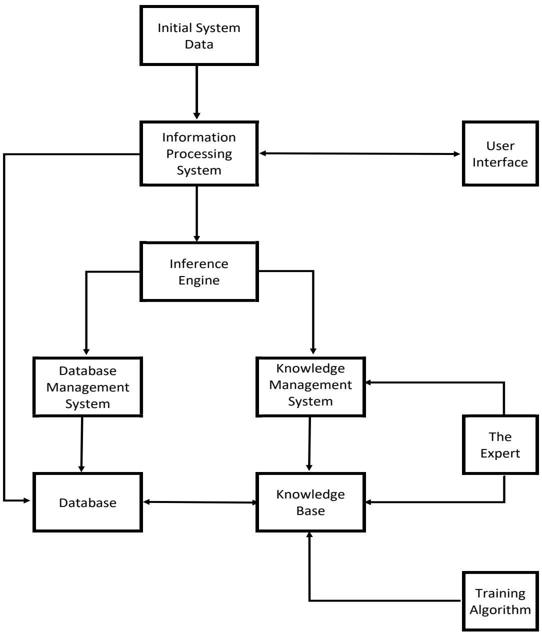

Fig. 1. Architecture knowledge based Expert System

3. Application of expert system to the oil rig drilling winch

The drilling winch or drawworks is an integral part of the drilling rig, this equipment performs the function of carrying out tripping operations of drilling and casing pipes, delivering rock cutting tools to the bottom of a well, and other works related to the movement of cargo. The design of the draw-works consists of two main parts; lifting and transmission, the operating functions are reflected by their names.

All elements are mounted on a welded frame, and control is made from a special remote. The drive of the draw-works can be manual, hydraulic or electric, which is undoubtedly a more convenient option. Draw-works is provided by using two types of brakes; tape as a main, and hydraulic or electric works as auxiliary brake. The functional purpose of the tape brake is to control and correct the speed of descent and braking, keeping the weight of the pipe string and feeding the chisel.

Friction plays a negative role in the pillow-blocks of the modern draw-works. Additional ways of avoiding or minimize friction from the parts of the draw-works and provide the accurate motion of the knots should be explored. The knots frictions operating in the void may cause the heating of the details as well as the unexpected disobeys. But operating of some details of the winch are impossible without high frictions process. For example, brakes, frictions muff, belt and cable transformations, fixative thread means and so on. The operating surfaces of Oil Rig Drilling Winch (ORDW) are coated by a special material called friction material and possess higher friction coefficient.

While friction materials are in operated at high temperature because of the contacts occurring in the friction surfaces. In some cases, this temperature may rise to 1200□C. This is one of the typical problems in the designing of the friction constructions in finding out the proper friction material (FM). Frequently for lack of the proper choosing of FM the friction constructions become invalid before expiration. It is result of distorting of the other equipment for the friction construction. The restoration of such worthy equipment demands much expenses.

So, the necessity of working out on new diagnostic expert system (ES) for the promotion of the friction construction must be of great value. The knowledge base (KB) expert system could accumulate quite perfect information about friction materials and friction construction. Information about all the features of FM have been stored in the knowledge base of this system, so that the ES can answer to any question put forward [7].

The flow chart in Fig. 2 shows the objective description and productive rules of ES in detecting the disorders of the brake's failure in the drilling winches and the ways of their elimination, has been illustrated in the following table.

Fig. 2. Oil Rig Drilling brake's failure disorders and their elimination ways

This paper analyzed the detecting of the disorders appearing in the friction constructions of the drilling winches and working out of the expert system of their elimination, which comprises a clause of the expert system. Knowledge base expert system is created, and its roles are defined by using IF and THEN.

Table 1 shows the object description and productive rules of ES in detecting the disorders in the drilling winches and the ways of their elimination. The objects of the ORDW considered for compiling the disorders are followings; Brake (B), Shoe (SH), Hose (H), Tape (T),

Table 1 – **Compiling rules of the ES for the oil rig drilling winch**

Disorders			Reasons		The eliminating ways	
1.	IF	the winch brakes disobey	AND	the shoes are worn	THEN	the shoes are to be renewed
2.	IF	the cracks seem in the pulley	AND	the brake is weakened	THEN	the pulley should be restored
3.	IF	the winch brake refuses	AND	oil leaked into the touched surfaces	THEN	the oil should be removed, and the surfaces are to be dried up.
4.	IF	the winch brake refuses	AND OR	the stretching of the tapes is weakened at the ends there is no enough force in regulating handle	THEN	the nut should be fixed in the balancer and pneumatic brake must be put into operation.
5.	IF	the winch brake refuses	AND	there is no sufficient force in regulating handle	THEN	the pneumatic brake should be put into operation.
6.	IF	the shoes have been leaked off in one of the tapes	AND	the tapes fixing is not provided equally to the level tapes	THEN	the shoes must be renewed
7.	IF	the winch brake refuses	AND	the fixing springs are out of order	THEN	the pulley is to be restored
8.	IF	the brake winch refuses	AND	the brake pulley has been eaten off more than normal	THEN	the pulley is to be restored
9.	IF	the balance regulator is out of order	AND	the brake's decline is not determined	THEN	the balancer is to be regulated
10.	IF	the winch brake refuses	AND	the hose is turn and operating of the pneumatic cylinder is disturbed	THEN	the hose is to be changed and the work of the pneumatic cylinder is to be regulated
11.	IF	the winch brake refuses	AND OR	there is no sufficient air in the system the balance regulator is out of order	THEN	air should be added into the system
12.	IF	the winch brake refuses	AND	the operating handle turns more than normal	THEN	the nuts are to be fixed
13.	IF	the winch brake refuses	AND	the touching surfaces are being heated more than normal	THEN	after 20 candles the hydrodynamic brake is to be put into operation, the descending speed is to be limited

Brake Pulleys (BP), Fixing Springs (FX), Balancer (Ba), Touching Surfaces (TS), System (S), and Friction Materials (FM).

The advantages of this system are to use the information obtained directly and subjective measures carried out by the observations of the operative personal. A characteristic feature of the proposed knowledge base is that its constituent rules based on the concept of heuristic frames are a combination of both the technological parameters and parameters reflecting their changes. This allows us to predict the course of the technological process and implement control in real time

Discussion of results

The results obtained in this study confirm the effectiveness of applying a knowledge-based expert system for enhancing the operational safety and reliability of the Oil Rig Drilling Winch. The implementation of rule-based IF–THEN logic enabled systematic identification of winch brake–related disorders and supported timely automatic corrective actions, which reduces the likelihood of critical failures during drilling operations.

The analysis demonstrated that integrating expert knowledge on brake failure mechanisms and preventive measures into the system allows formalization of operational experience that is usually dependent on human operators. In particular, the evaluation and selection of friction materials for braking pads using the expert system proved to be a significant factor in improving braking performance and operational stability of the drilling winch. This confirms that material-related parameters should be treated as critical decision variables within intelligent control systems for drilling equipment.

Furthermore, the discussion highlights that while the current rule-based expert system provides deterministic and reliable decision-making, its effectiveness can be further enhanced by incorporating fuzzy logic. Such integration would allow the system to better handle uncertainty, incomplete sensor data, and borderline operating conditions. The proposed extension with additional sensors and fuzzy inference mechanisms is expected to increase the level of autonomous control, improve early detection of hazardous states, and overall strengthen the robustness of the Oil Rig Drilling Winch expert system in real-world operating environments.

Conclusions

Knowledge based Expert System with Artificial Intelligence for Oil Rig Drilling Winch has presented in this study. Winch brake's failure related disorder were studied, and prevention measures were programmed to the Expert System for automatic correction. Expert System was implemented with IF and THEN logic to keep safe Oil Rig Drilling Winch from failures. Friction material and construction was also analysed using knowledge based Expert System. The selection of friction material has importance in Oil Rig Drilling Winch processes. The material selection for braking pad was evaluated with knowledge based Expert System. To accurately protect ORDW from disorders, fuzzy logic can be included to the knowledge based Expert System. More sensors where feasible, can be attached to ORDW to optimally detect possible danger which can cause for winch brake's failure. Fuzzy logic integration to the existing system will increase efficiency of the expert system and increase its capability of autonomous control over Oil Rig Drilling Winch operation.

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ЕКСПЕРТНА СИСТЕМА БУРОВОЇ ЛЕБІДКИ НАФТОВОЇ ВИНТОВОЇ ВИШКИ

Ф. Алієв

Анотація. Актуальність теми. Зростаюча складність бурових операцій на нафтових платформах вимагає надійних та інтелектуальних інструментів для своєчасного виявлення та усунення несправностей обладнання. Несправності гальм лебідки становлять значний ризик для безпеки експлуатації, що робить розробку автоматизованих діагностичних систем критично важливим завданням. **Предметом дослідження** є моделі, методи та засоби побудови експертної системи для автоматизованої діагностики несправностей гальм лебідки бурових установок на нафтових платформах, а також процеси виявлення, інтерпретації та підтримки прийняття коригувальних рішень у реальному часі. **Метою статті** є розробка експертної системи, заснованої на знаннях, здатної виявляти несправності гальм лебідки під час бурових операцій на нафтових платформах та підтримувати автоматизоване прийняття коригувальних рішень. Запропонована система базується на представленні знань на основі правил з використанням механізмів виводу ЯКЩО та ТОДІ та евристичних фреймів, які інтегрують технологічні параметри та їх динамічні зміни. Застосовуються методи штучного інтелекту для забезпечення адаптивного навчання на основі раніше виявлених операційних сценаріїв та оновлення бази знань. **Отримані результати**. Була розроблена експертна система, заснована на знаннях, для діагностики лебідок бурових платформ на нафтових платформах. Система успішно виявляє потенційні несправності гальм та рекомендує коригувальні дії на основі правил, визначених експертами. Експериментальна оцінка демонструє підвищену точність та ефективність виявлення несправностей та підтримки прийняття рішень. **Висновок**. Розроблена експертна система забезпечує ефективне виявлення несправностей гальм лебідки, підвищує експлуатаційну ефективність та збільшує надійність та безпеку бурового обладнання на нафтових платформах.

Ключові слова: штучний інтелект (ШІ); експертна система (ЕС); бурова установка; лебідка для буріння нафтових платформ (ЛБНП); інтелектуальна підтримка рішень.