THE INTELLIGENT MONITORING AND EVALUATION OF THE PSYCHOPHYSIOLOGICAL STATE OF THE WORKERS EMPLOYED ON OFFSHORE OIL AND GAS PLATFORMS

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Abstract: Oil and gas companies have an urgent need for technologies that provide complete and reliable information about the actual state of health and safety of personnel. To solve this problem, the article proposes a concept solution for the development of a system monitoring of the psychophysiological health of workers employed on offshore oil platforms. The concept is based on a person-centered approach and allows monitoring of health of employees simultaneously linking them to the context of the environment. The urgency of the problem is confirmed by statistical data, according to which workers in the oil and gas industry are 8 times more likely to get injured. The article analyzes the specific features of the professional activity of the workers employed on offshore oil platforms and shows that the deterioration of their health and psychological condition due to the long-term “sea environment” is unavoidable. It offers to develop an intelligent system for monitoring the psychophysiological condition of workers employed on offshore oil platforms and to assess its suitability for their position with the reference to the Cattell test and fuzzy patterns recognition. The development and systematic operation of such a system may timely detect undesirable consequences for the health status of workers employed on offshore oil platforms and prevent wrong decisions due to the “human factor”.

Keywords: offshore oil platforms, human factor, oil workers health management, Cattell test, fuzzy patterns, decision making.

1. Introduction

Today, a significant number of skilled workers and specialists (oilmen) are involved in various operations and production processes implemented at geographically distributed offshore facilities and structures. Their functional duties and work activities are associated with potential hazards and health risks. Therefore, the tasks of improving the efficiency of employees’ health management and ensuring a safe working and living environment are the most important part of the oil and gas industry at all stages of the life cycle of oil and gas business. The problem of employees’ health management is of particular relevance in offshore oil and gas industry, which is classified as a high-risk segment [1]. According to the statistics provided by the Centers for Disease Control and Prevention (CDC), between January 2015 and January 2017, oil and gas workers were involved in 602 incidents, 481 hospitalizations and 166 amputations [2]. According to the statistics of the State Oil Company of the Azerbaijan Republic (SOCAR) [3], 32 accidents were registered in 2016–2018, 12 of which were fatal. The above statistics on accidents prove the need to develop an effective system for managing the health of human resources in oil and gas industry, particularly, in offshore industry.

At present, the Industry 4.0 characterized by the development of high technologies, the Internet of Things, nanotechnology, biotechnology, artificial intelligence, etc., has created innovative research trends to overcome these problems [4, 5]. This article proposes a new innovative approach to the prevention of accidents and incidents associated with human factor. It offers the conceptual framework of the intelligent system to monitor the health status of personnel on the platform and assess their ability to perform their duties based on artificial intelligence technology and a system analysis of specific characteristics of professional activity of each worker employed on the platform.

2. Methods

To date, a significant part of offshore oil facilities (hereinafter let’s use the term “offshore oil platforms”) are equipped for the residence and work of personnel. The technological work cycle on offshore oil platforms (OOP), associated with drilling, production, transportation, storage of oil and oil products, repair and maintenance of equipment and pumps, is rather complicated and fire hazardous [6].

As the result of the study of the professional activities of workers engaged in offshore development and operation of oil and gas fields through the prism of the impact of working conditions, daily life and external factors on their health, the following specific features are revealed [7, 8]:

– working and residing in restricted spaces and polluted environments increasing the risk of infectious diseases and danger to the workers’ life;

– twelve-hour shift work during a certain time interval (often two weeks), which is a source of psychosocial risks, stress, and depression;

– fatigue due to irregular working hours and stressful working conditions, assessed as one of the most dangerous risks of making mistakes and accidents;

– impact of hazardous contaminants on health and life, as well as harmful factors (industrial noise, vibration, risks of release of radioactive substances, etc.);

– “unsafe” behavior of offshore workers, which is one of the key reasons for making poor decisions and getting involved in emergencies;

– unfavorable external factors (cold, wind, fog, dust, rain, storm) affecting the physiological state, working capacity and labor productivity;

– deterioration of equipment, oil and gas leaks during their development, transportation and processing, jeopardizing the health and safety of workers;

– serious consequences of accidents (death and injury of people, damage to the environment, etc.), necessitating the improvement of methods for monitoring and control of health and safety of workers.

The multidimensional nature of the manifestations of human factor, serious and often unpredicted consequences of erroneous decisions made at facilities of increased danger, as well as poor knowledge about the nature and causes of this phenomenon, predetermine the need to develop new approaches to its study. Analysis of available definitions of this notion shows that the content of each of them is based on the characteristics of the object under study, the role of a person in hazardous production, the goal and the tasks to be solved. In this case, the specific research object is the employees related to various production processes on OOP equipped for human living and labor activity, i.e., shift workers. The goal of research is the development of modern technologies for managing the health and safety of shift workers, eliminating or minimizing the impact of human factor. Human factor on OOP refers to the possibility of person committing erroneous actions under certain conditions or making wrong decisions caused an incident. It is assumed that the likelihood of making erroneous decisions by any employees directly depends on the state of health affects his/her behavior, as well as on the nature of his/her actions and activity during the shift on platform. Therefore, the state of health, as the most important characteristic and main component of human resources, directly affects all his/her professional activities. Analysis of accidents' causes on OOP shows that most of them are associated with an unpredicted deterioration of workers' health, loss of consciousness, exhaustion, etc. Disorders in workers' health during their functional duties and living on OOP, in turn, can provoke "unsafe" behavior, affect their actions, decisions made, cause violation of ethics, safety measures and lead to incidents. Taking measures to preserve health at the workplace will allow workers to successfully cope with physiological, psychological and social stress and improve their functionality. In the given context, to prevent accidents on offshore platforms, it is important to systematically monitor the health status of the oilmen in the work environment (before and after the shift) and to determine their suitability for the position with a comprehensive assessment of the results.

The problem solution is reduced to the solution of two subtasks:

1. Systematic monitoring of employees and identification of psychological health conditions and deviations. It is possible to refer to various psychological tests for monitoring. In this article, it is considered appropriate to refer to the Cattell test for the monitoring of workers performing a certain task.

2. Assessment of the compatibility of the oilmen with their positions comprehensively approaching the monitoring results. The comprehensive approach to the monitoring results for assessing the compatibility of professional personnel with their positions is brought to the pattern recognition issue [9]. For this, the patterns of the position, and each staff member performing the task, are created based on their quality indicators in the Cattell test. For example: $V=\{V_g\}$, $g=\overline{1,n}$ is a set of duties on offshore platform; $L=(L_i)$, $i=\overline{1,16}$ indicates the evaluation criteria in the Cattell test.

Then, based on these criteria, each position can be described as $V_g=|L_{gi}|$, $i=\overline{1,16}$, and a person holding this position as $S_g=|L_{gi}|$, $i=\overline{1,16}$. The reference pattern of position can be described as a fuzzy pattern $\tilde{V}_g=\left\{\mu_{L_{gi}}(y)/y, i=\overline{1,16}\right\}$, and the real pattern of employee holding this position can be described as a fuzzy pattern $\tilde{S}_g=\left\{\mu_{L_{gi}}(y)/y, i=\overline{1,16}\right\}$.

To determine the degree of similarity of the reference and real fuzzy patterns, the degree of fuzzy inclusion into fuzzy situations is referenced. The similarity degree of fuzzy patterns $\theta\left(\tilde{S}_g,\tilde{V}_g\right)$ is calculated using the following formula [9]:

$$\theta\left(\tilde{S}_g,\tilde{V}_g\right)=\&\,\theta\left(\mu_{S_gL_i}(y),\mu_{VgL_i}(y)\right)=$$
$$=\underset{y\in Y}{\&}\left(\max\left(1-\mu_{S_gL_i}(y),\mu_{V_gL_i}(y)\right)\right)=$$
$$=\min_{y\in Y}\left(\max\left(1-\mu_{S_gL_i}(y),\mu_{V_gL_i}(y)\right)\right). \quad (1)$$

Based on the proposed approach, the establishment of a system for monitoring and assessing the health status of workers employed on offshore platform involves the development of the following modules:

– testing the offshore platform workers based on the Cattell test;

– generating a reference fuzzy pattern of each position on the offshore platform;

– generating a real fuzzy pattern of each worker based on the test results;

– calculating the degree of similarity of reference and real fuzzy patterns;

– developing the decision-making unite;

– obtaining the result.

3. Results

Using the Cattell test results, it is necessary to use the quality levels of natural language to assess the ability of workers employed on offshore platform performing their duties, which makes the fuzziness inevitable. Therefore, a fuzzy mathematical logic apparatus is used to assess the workers' professional qualities [10]. For the problem solution, the following input parameters are determined: linguistic variables; term-sets of linguistic variables; determination of affiliation functions. The 16 personal quality factors in the Cattell test correspond to linguistic variables. For each linguistic variable, the lowest factor value (weak), the average factor value (medium), the highest factor value (strong) are determined according to a 3-level unified quality measurement scale (UQMS), which generate the term sets of linguistic variables (**Table 1**).

Table 1
Linguistic variables of the Cattell test and their term-sets

Variables	Names of linguistic variables	Term-sets
L_1	unsociable/sociable	Unsociable, moderately sociable, sociable
L_2	intellect	Low intellect, intellectual development, high intellectual development
L_3	Emotionally intolerant/tolerant	Emotionally intolerant, somewhat emotionally intolerant, emotionally tolerant
L_4	subordinate/dominant	Subordinate, moderately authoritarian, authoritarian
L_5	restrained/emotional	Restrained, moderately emotional, emotional
L_6	sensitive/having high behavior standards	does not attempt to solve group problems, avoids responsibility, responsible
L_7	obedient/courageous	obedient, less courageous, brave
L_8	cruel/arrogant	Cruel, normal, arrogant
L_9	trusting/skeptical	trusting, less trusting, skeptical
L_{10}	practical/advanced imagination	Partly practical, with a creative imagination, with a very high creative imagination
L_{11}	outspoken/diplomatic	outspoken, partly diplomatic, diplomatic
L_{12}	confident/unconfident	confident, unconfident, anxious
L_{13}	conservative/radical	conservative, mediate, radical
L_{14}	conformism/non-conformism	not taking into account public opinion, sometimes taking it into account, always listening to public opinion
L_{15}	low self-control/high self-control	low self-control, moderate self-control, high self-control
L_{16}	relaxed/anxious	relaxed, moderately relaxed, anxious
y	Degree of compliance of the staff member with personal qualities	Not suitable, moderately compatible, compatible

The term-sets are expressed by the affiliation function corresponding to the quality levels of UQMS. Therefore, fuzzy sets are determined for term-set elements (**Table 2**).

For each quality level, an individual fuzzy value is defined from the set allocated within the interval [0, 1]. For this, it was considered expedient to take the value occupying the "medium position" compared to external values in the set of individual values, as a collective value [11].

Based on formula (1), according to the degree of similarity of reference and real fuzzy patterns, the inclusion limit ψ is determined for making decision on the compatibility of the workers employed on offshore platform for their position.

Assume that, in accordance with the management terms, [0.8; 1] is accepted for the term set "corresponds to the position" and $\psi \in [0.5; 0.79]$ is accepted for the term "moderately corresponds to the position". In this case, the following decision-making rules are included:

1. If $\theta\left(\tilde{S}_g, \tilde{V}_g\right) \geq \psi\left[0.8;1\right]$, then the real fuzzy pattern $\tilde{S}_g$ is completely similar to the reference fuzzy pattern $\tilde{V}_i$ and the relevant specialist "corresponds to the position".

2. If $\theta\left(\tilde{S}_g, \tilde{V}_g\right) \geq \psi\left[0.5;0.79\right]$, then the real fuzzy pattern $\tilde{S}_g$ is moderately similar to the reference fuzzy pattern $\tilde{V}_i$ and the relevant specialist "moderately corresponds to the position".

3. If $\theta\left(\tilde{S}_g, \tilde{V}_g\right) \leq \psi\left[0.1;0.49\right]$, then the real fuzzy pattern $\tilde{S}_g$ is not similar to the reference fuzzy pattern $\tilde{V}_i$ and the relevant specialist "does not correspond to the position".

When solving this issue, note that the requirements for meeting the criteria in the Cattell test may differ for each position (for example, the criterion sociable is rated as "strong" for the reference pattern for any position, whereas this criterion may be rated as "moderate" or even "weak" for another).

Table 2

Mathematical description of linguistic variables based on 3-dimensional UQMS

Intensity levels of linguistic variable "unsociable/ sociable"	Linguistic evaluation (UQMS)	Fuzzy set in the range [0, 1]	E1	E2	E3	Collective value (Levin)
unsociable	weak	[0.1–0.45]	0.45	0.40	0.35	0.40
less sociable	medium	[0.45–0.65]	0.55	0.60	0.65	0.60
sociable	strong	[0.65–0.99]	0.95	0.90	0.85	0.90

4. Discussion

The proposed approach to assessing the psychological health of workers of offshore platform can be considered as one of the solutions to the given problem. Thus, the following solutions to the problem stated are possible:

– some of the 16 criteria in the Cattell test may be considered significant, while the rest may be considered desirable or even insignificant, in accordance with the conditions of personnel management on the platform. In this case, the issue under consideration can be solved by bringing it to fuzzy multi-scenario decision-making methods [12];

– in accordance with the conditions of personnel management on the platform, it may be required to take into account the importance of their personal quality criteria in relation to each other. In this case, the problem can be solved by bringing it to the multi-criteria decision-making methods, taking into account the importance coefficients of the criteria [12];

– monitoring of the health status of the platform workers through IoT technologies [13], etc.

The solution of these issues refers to the perspective research fields of the authors.

5. Conclusion

The article highlighted the importance of the human factor in preventing the accidents on offshore platform. It was substantiated that the psychological health condition of each worker employed on offshore platform was important in making operational decisions, correctly understanding the situation faced by the platform workers on duty during the operation. In very this context, the issue of systematic monitoring of workers on duty and the assessment of their compatibility with the position was raised. The proposed approach to problem solution was based on the Cattell test, a method of fuzzy pattern recognition.

The proposed approach can allow for the timely detection of undesirable situations in terms of the mental health of workers employed on offshore platform, to prevent wrong decisions and can be considered as one of the possible solutions to prevent accidents on offshore oil and gas platform.

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