



Augmented Reality System and Maintenance of Oil Pumps

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ABSTRACT

Qualification of employees who operate technological processes directly influences the safety of production. However, the employees' qualification cannot completely exclude human factor. Today, there are many technologies that can minimize or eliminate human factor impact on production safety ensuring. The augmented reality technology is an example of this technology. Nowadays, the augmented reality technologies and industrial technologies integration process moves to a new level of development. These technologies have huge experience, which has been accumulated in a long period of time. -This new level turns available by this experience combination and integration; it brings additional profit to the enterprise and can be a basis for completely new technologies. This paper shows an example of combination of augmented reality technology and oil pumps maintenance. For researching of efficiency of augmented reality system for oil pump maintenance, the laboratory unit with Grundfos vertical electric centrifugal pump (CR15-4 A-FGJ-AE-HQQE) was used. The laboratory unit is a physical model of one of the continuous oil processes. The oil pump of this laboratory unit is object of this research. The algorithm of servicing of oil pump was developed. The test of system and algorithms were carried out with four groups of people: the first one had only instructions to use on hand, the second one only used the internal recommendations of the system, the third one used only the help of an expert, and the fourth used internal recommendations and, if necessary, contacted the expert. The results show the efficiency and actuality of augmented reality technology for maintenance of industrial equipment, especially for the equipment operated in remote Arctic conditions.

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1. INTRODUCTION

Oil and gas industry is a large, dynamic and complex sector that offers great employment opportunities for a large number of people all over the world. The oil and gas industry's prosperous development or retention will depend on the latest technological achievements implementation. Therefore, recently, it has been proposed to implement the augmented reality technologies in oil industry [1].

Analysts believe that production upgrading in the oil and gas industry is possible by the introduction of augmented reality technologies into production process. The Extension of capabilities of the oil industry will make it possible to find new solutions to the actual topical

issues such as exploration and production of hard-to-recover oil, the sea shelf fields construction, and transportation of oil from the Far North (in Russia) [2].

The use of augmented reality technology opens up medium-term prospects for employee's safety and efficiency improvement, and further with the digital double technology development, it would be possible to predict technical systems' failures, giving time for response or take measures for repair.

Any technical system, even the most reliable, requires qualified service and repair in case of failure. At the same time, due to the complexity and variety of equipment used in oil and gas industry, presence of a wide range of specialists is necessary. Otherwise, even one element failure will cause downtime enhance, which increases

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proportionally with the facility remoteness and logistics complexity.

Elimination of non-production time (equipment downtime required for repair and maintenance) is an urgent area to reduce costs in oil and gas sector. This is especially pronounced in terms of modern realities, when the general amount of hydrocarbon reserves includes more and more hard-to-recover reserves, and its extraction requires significantly more financial, material and labor resources [3].

According to expert estimates, the Russian oil enterprises suffer over 4.5 thousand downtime cases every year due to equipment failure. At the same time, the equipment repair costs are more than 2.5 billion Rubles. In this regard, the company loses the raw materials amounting up to 500,000 tons of oil [4]. In addition, the lost marginal income is about 3.8 billion Rubles. The described problem is gaining weight for the Russian oil and gas industry, as exploration and production moves to more and more remote and northern regions, including Arctic territories, where with the technology development, the “maximum automation and minimum people” paradigm becomes relevant [5].

-Operation in the remote Arctic territories is associated with a number of factors those determine the necessity of careful design and maintenance and repair measures planning:

- Short navigation period for marine transport. During the summer navigation period, a significant part of cargo can be delivered via the Northern Sea Route and river transport to such ports as Varandey, Dikson, Dudinka, Pevek, Tiksi, etc. Nevertheless, most of the year (up to 10 months of the year) the Arctic Ocean from Murmansk until Sakhalin is covered with ice. It is possible to deliver goods and food to the Arctic ports only during two months a year. Therefore, careful planning is necessary, as well as accounting for the supply of equipment and spare parts for remote oil and gas projects; poor development of ground communications and infrastructure. Despite the availability of waterways, most of cargo is delivered to the Yamal Peninsula by vehicle and winter roads, which are prepared, rolled snow and ice, artificially formed in some areas [6].

- Bad weather conditions. It is advisable to transport personnel to and from the work place by air or helicopter. For the significant distances, it is advisable to organize special advanced bases with residential premises, fuel and food supplies, because in the Arctic region due to storms and severe climatic conditions, non-flying weather conditions can last up to several weeks.

In connection with the above, the most popular solution in the field of augmented reality in the near future is to provide maintenance personnel with technological systems' operating data, equipment design and the procedure for its maintenance in case of malfunction. If there is not any described solution, then

the specialists' remote connection could be applied. He will be able to quickly study the collected data, visually inspect the equipment by means of camera in the headset and give detailed recommendations for troubleshooting. Previously, the situations like this required phone connection with specialist, instructions and regulatory documents study, as well as long correspondence with technical specialists and designers in case of unusual situation.

The oil pump maintenance is one of the important measures that can decrease oil pump failures. There are three methods of maintenance: by schedule, by operating time and by actual state [7]. The maintenance by schedule shows which type of equipment and when needs to be maintained. In this case the list of equipment specifying maintenance periods is issued. So, the positions and time periods are previously known. Moreover, the time intervals between repairs are strictly defined and do not depend on the current state of the equipment. During maintenance, according to the actual state, some parameters are monitored, and on this basis, it is determined whether equipment repair is necessary or not. This method of maintenance is the most preferred because repairs are carried out only when necessary [8].

However, this method of maintenance has a range of disadvantages. It is possible that the monitored parameters show an incomplete picture, wrong status of the pump. In this case, even after maintenance, the pump failure is possible and consequently, production process stops.

According to the statistics of one of the top-ranked oil producing companies, electrical centrifugal pumps account for 40% of all types of pumps [9]. Figure 1 shows the dependence of running hours on the number of pump repairs. As we can see this dependence is linear. Regardless of the type and brand of pump manufacturers, the number of repairs is directly proportional to the running time. This means that repair of pump equipment is carried out according to the operating time for failure and only in rare cases according to their actual condition, Figure 1.

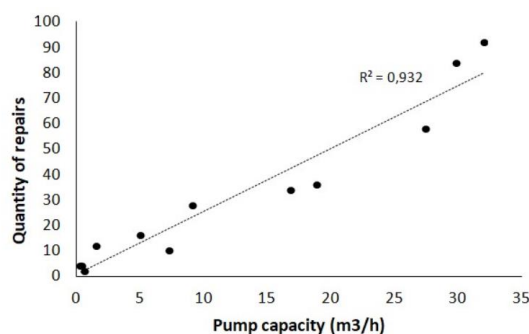


Figure 1. Dependence of the number of repairs on the pump capacity (for 6 months operation)

Furthermore, according Figure 2, the pump capacity is practically independent of average time spent on one repair.

Indirectly, we can conclude that the same type of repair operations are not affected at types and capacity, and therefore size of pumps. All in all, operator support system while repairing pump using template repairing function could show operator's efficiency, Figure 2.

Most customers are interested in less expensive pumps and lower maintenance costs during the pump lifetime. They are not interested in expensive pumps. Therefore, there is tendency to get more efficient repair.

The goal of this research is to determine the efficiency of implementing augmented reality system into the oil pump maintenance process.

2. LITERATURE REVIEW

In [10], the authors consider a photovoltaic pump station management platform using an augmented reality system with processing unit image processing (ARIMA) in an operator service application. This technological solution helps the operator in the station diagnostics and control. This support includes application of the augmented reality system covering all technological units as well as servicing algorithms specification using various modes and scenarios. Operational management and the station control is achieved by technological units' status monitoring in real time to make the workflow safe, uninterrupted and comfortable. The disadvantages of the authors' solution include the lack of adaptability of the user interface for the considered tasks and bulkiness of the control and monitoring devices.

In [11], the authors pay attention to the development and integration of virtual and augmented reality in hazardous industries, the education quality upgrade in educational institutions and training centers. The value of the study resides in the approach, which includes

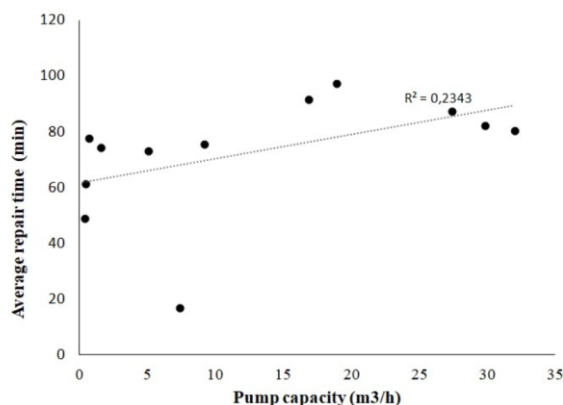


Figure 2. Dependence of the average repair time on the pump capacity

different points of view of the VR / AR systems development dynamics: technical and technological features; dangerous situations monitoring; improving production processes safety approaches. These approaches differ from the traditional ones; they are changing and improving with the VR / AR systems implementation and development of by sensors and diagnostic systems application for operating environment where technological operations are strictly carried out by personnel in accordance with certain scenarios and algorithms [12]. If the scenario was not executed according to the given algorithms, the specialists evaluated critical deviations from the rated values and applied more ergonomic and safe options of the equipment monitoring and control and control decreasing the influence of human factor. The authors note that the study is not a comprehensive one and its application is limited only to the construction area and further research should be focused on the safe and competent management of complex technological facilities in other sectors. Also, the study does not cover the laboratory studies of applications at the experimental, technical and operational levels, as well as the methods of influencing and assessment of VR / AR systems application in various projects and work scenarios.

In [13] the authors consider the VR / AR systems application in digital twins to improve the connection and interaction of physical and virtual realities. Moreover, their approach allows to increase the effectiveness of the digital twin system based on many sides comparison of the AR / VR systems' differences and similarities in the design, production, technological facilities maintenance. Based on the created VR and AR solutions in digital twins, a structure is proposed for integrating these systems into a five-dimensional digital twin, to increase the operator's ability to manage large amounts of interactive data and production scenarios. The program structure is built based on the operator's requirements. The concept of constructing AR / VR structures in digital twins proposed by the authors is presented as a literature review. Just like previous authors, the study lacks its own laboratory and experimental studies; therefore, this material should be regarded as reference information for their own test benches and applications development and can be used for solutions search in a particular production area.

In [14-15], the authors consider training VR simulator application for operation modeling, diagnostics and technological equipment repair. The simulator is purposed for oil and gas production sector specialists' training aimed to improve the safety and faultless production, capital and operating training costs reduction by saving on purchase of equipment physical samples for staff training. The following disadvantages of the equipment's physical version are noted: high risks; equipment failures due to specialist errors during

preparation; the impossibility of the equipment upgrading and the compelled purchase of newer models, etc. The authors argue that the training VR simulators will allow the specialists to have relevant equipment samples; perform manipulations without any risk for health; reduce training time by means of automation the operation process involving tools; application of various scenarios for the learner's skills development and his thinking strategies in non-standard situations. The study does not provide any statistical data on the studied object, the global experience of similar systems application and the experimental results are poorly described; that makes it difficult to reproduce the experiment and apply its results in order to improve the presented techniques.

3. METHOD

Augmented Reality (AR) overlays virtual 3-Dimensional (3D) objects on the real-world and gets inside training and education [16-17] area.

AR is a set of innovative techniques (e.g., real-time data acquisition, human computer interaction, scene capture, real-time tracking and registration, etc.), and can augment the view of physical world by embedding computer-generated elements or objects [18-19]. The goal of this technology is to put the virtual world on the screen and interact with it in real world [20].

With the advent of augmented reality (AR), the tendency to capitalize on immersive AR applications to create enabling environments for visualizing complex situations in the workplace, building knowledge on risk prevention and training has become apparent. AR technology can meet the goal of improving human perception of virtual prototyping with real objects. This gives the virtual world an improved connection with the real world, while maintaining the flexibility of the virtual world [21]. Via AR, the real environment can be augmented with text, labels, models, and videos, which will conduce to fewer mistakes, faster speed, and higher quality of the service process.

Instead of simply interacting with 3D content in a purely computer environment, users are now able to realize an extremely exciting, holistic and realistic experience based on synthesized digital and physical information about the world presented using more sophisticated software and hardware [22-23].

The use of augmented reality technologies in oil facilities is not so widespread, and is just about to be implemented. This is due to uncertainty in the technical aspects associated with the use and maintenance of systems based on augmented reality technology. In connection with the above, in the near future the most popular solution in the field of augmented reality will be to provide maintenance personnel with information on the operation of the technological system, equipment

design, and the way to maintain it in case of malfunction. If the current situation has not the described solution, then there is a possibility to connect specialist to the process remotely, who is able to examine the collected data quickly, provide the equipment visual inspection by means of camera in the headset and give detailed recommendations for troubleshooting. The specialist can give his recommendations on the screen and a person at site will see on the display equipped with AR [24].

Previously, such a situation required to call a specialist, studying instructions and regulatory documents, as well as lengthy correspondence with technical specialists and designers in case of an unusual situation.

The study examines the augmented reality technology effectiveness for oil pumps servicing. According to the method used in the study, the effectiveness analysis is carried out as follows:

1. Determination of the object to study. The research object should have several properties: it is a part of the technological process, service operations with the object are complex, i.e. its servicing implies a complex algorithm; moreover, the object should be of wide application at oil and gas industry facilities.

2. The object servicing algorithm development. When developing this servicing algorithm, the following manipulations with the object are mandatory: assembly/disassembly from any existing technological installation, the equipment parts replacement, the equipment actual status assessment according to the process parameters in real time mode.

3. Testing system components. At this stage, it checks the health of the system as a whole, the health of data transmission channels, as well as the health of individual system modules and the health of the modules in conjunction with each other.

4. Determination of the system efficiency. At this stage, the test was carried out with four groups of people: the first (No. 1) had only instructions to use on hand, the second (No. 2) used only the internal recommendations of the system, the third (No. 3) used only the help of an expert, and the fourth (No. 4) used internal recommendations and, if necessary, contacted the expert. During the experiment, some of the most important functions and actions for each group recorded the execution time of each operation. Function 1 - dismantling the pump, function 2 - removing the coupling guard, function 3 - removing two halves of the clutch, function 4 - removing the pin, function 5 - dismantling the engine section.

Thus, we expect to get a numerical expression of effectiveness for every of these four ways of the augmented reality application, by fixing the execution time of each function for each group of experimenters. Herewith, the method No1 that allows using only manuals for servicing and Internet does not use the

augmented reality system functionality; therefore, it is given as a standard for service comparison before the system is implemented and after its implementation. Method No 4, where for pump servicing they use just the expert assistance is also an extreme option. This is because in this method the augmented reality system provides the possibility of “single window” and a “single point of view” between the service engineer and the expert and then the expert, totally involved in the service process, obviously is not able to increase the system efficiency.

4. IMPLEMENTATION

The research team of Saint-Petersburg Mining University had carried out work on creating an AR application for servicing the Grundfos vertical electric centrifugal pump (CR15-4 A-FGJ-AE-HQQE) of the oil transfer demonstration unit (Figure 3). The laboratory unit consists of two tanks and pumps those transfer liquid from one tank to another, a heat exchanger, valves, sensors and actuators.

The system consists of four modules (Figure 4). The first one is the laboratory unit module. It consists of control elements and equipment which help collecting the technological processes data, acquire and transmit it to a higher level. For the purpose of implementation, the basic unified protocols should be used for low level equipment [25]. The OPC-protocols are used for integration in the system. The second module is data acquisition and storage. It is an important module and it combines different modules together. For example, the module of augment reality cannot be connected with controller and SCADA-system without this module element. The third module is the additional software. It can be used for linking AR-software and different analytical modules. For example, the analytical module can analyze the quality, and predict the quantity of maintenance, it can evaluate the service engineer's actions and advise them, etc. All the analytical functions are based on the high level calculations capacity.

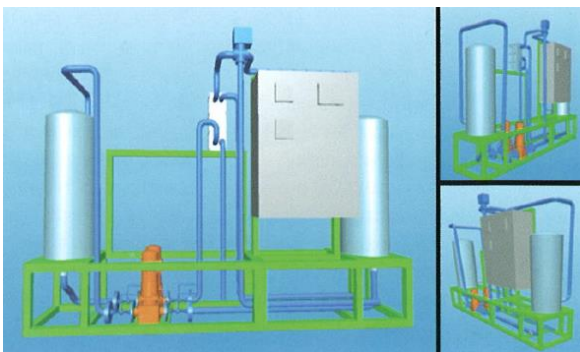


Figure 3. Laboratory unit

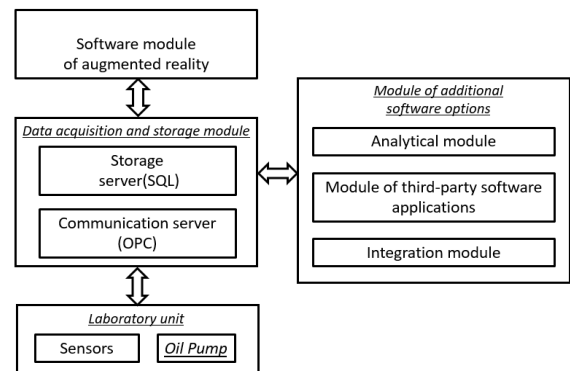


Figure 4. The system structure

Therefore, the divided architecture is more flexible and capable to adapt compared to a single one. The AR-system uses not just the technological system data, it can use the ERP-system data and other one. The other example of the analytical module is the maintenance steps templating inside the system. Many typical functions are realized in each maintenance project. Similar actions can be templated. Prior to the new project implementation, the system at the first step searches for the actions template. If the template is absent, you add this action as a new action, or change the template. The third module helps to link AR-module with other modules and systems. The fourth module is the AR-system software. It can be implemented on the different software platforms. In this project, The Unity with Vuforia is used.

The pump was dismantled by a technical specialist, each step was marked and recorded for further algorithm development. Then, the pump was assembled back recording the actions sequence. The assembly / disassembly algorithm was used to write a pump maintenance procedure for various technological operations on replacing consumables or cleaning deposits.

Figures 5 shows the system operation. Using the developed application, it is possible to carry out the unit/disassembly of the pump, assembly/ disassembly, monitor installation parameters, study the documentation and fill out a report (Figure 5).



Figure 5. The start window of the system

If it is necessary to repair the pump or carry out maintenance, and if the site service is impossible, the system will tell you what needs to be done to disconnect the pump from the production line (Figure 6).

To control the process parameters, the head of the workshop (unit) or someone else has no need to get up or call the operator room. All parameters of the sensors can be seen in the field, even if they are not indicated in field (Figure 7).

During the equipment repair (maintenance), there is no need to use paper instructions. All the necessary documentation and instructions are digitized and appear step-by-step, prompting not only the actions necessary to perform, but also the necessary tool for this (Figure 8).

Then remove the coupling guard which is shown on Figure 9.

At the next step remove the coupling assembly, unscrew 2 screws on each side of the coupling. Remove two halves of the clutch, which is already in a collapsible condition, Figure 10.



Figure 6. Removing pump from laboratory unit

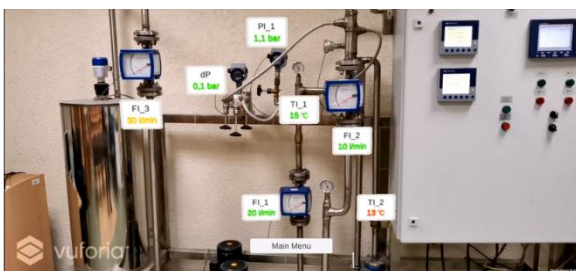


Figure 7. Processes parameters



Figure 8. Unscrew two screws of coupling guard

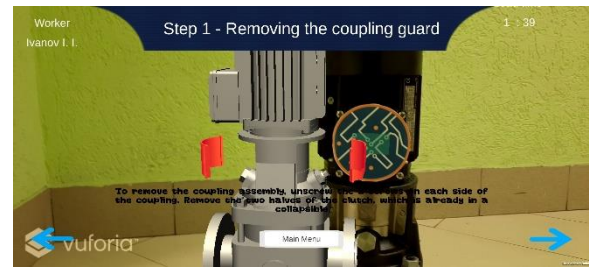


Figure 9. Removing the coupling guard

Now, open the way to the pin which connects the central and motor parts of the pump. Pull out the pin (Figure 11).

At this stage, the motor section (shown in Figure 12) is not connected to other parts of the pump, therefore, we take it out. At this step, the first stages of the analysis has been completed, and further actions will be finalized in the next version of the program. The pump is assemble by the reverse order (Figure 12).

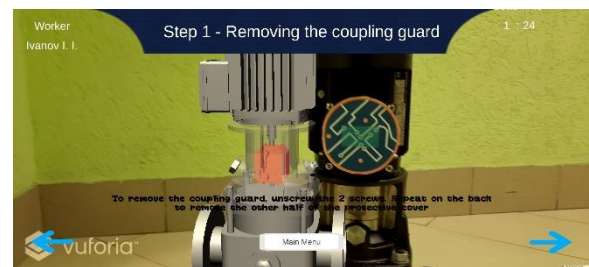


Figure 10. Removing two halves of the clutch

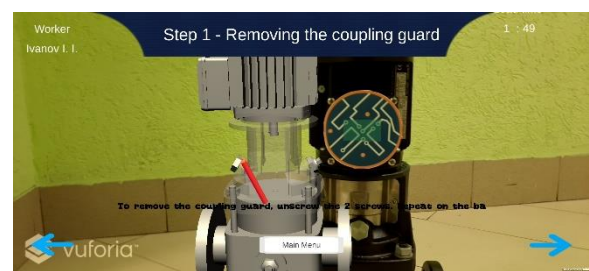


Figure 11. Removing the pin



Figure 12. Dismantling the engine section

The system developed several functions, the main ones of which are:

1. Visualization of user actions (tested in three forms - in the form of a video file, on a 3D team model displayed on top of a service part, in the form of highlighting (highlighting with light and color on a real object) of parts that require attention of service personnel (for example, highlight bolts, which you need to unscrew and the desired type of tool)
2. Display of process parameters - process parameters in real time and their values in history (in the form of trends or tables)
3. Displaying expert advice or creeping line tips
4. The possibility of video communication with the expert directly (organization of a single viewing window for the expert and service engineer)
5. The possibility of audio communication with an expert.
6. Information output of third-party applications and software modules (analytics, documentation of service information, etc.)

5. RESULTS

1. The object to study was to determine pump efficiency. It was a Grundfos vertical electric centrifugal pump (CR15-4 A-FGJ-AE-HQQE). Electrical centrifugal pumps are very popular and widely-spread in oil industry. Therefore, the testing of popular species of pumps is very important for this study.
2. The object servicing algorithm was developed.
3. The augmented reality system was developed and realized.
4. The system components were tested
5. The system efficiency was determined.

The test was carried out with four groups of people: the first (No. 1) had on hand only instructions to use, the second (No. 2) used only the internal recommendations of the system, the third (No. 3) used only the help of an expert, and the fourth (No. 4) used internal recommendations and, if necessary, contacted the expert. During the experiment, some of the most important functions and actions for each group recorded the execution time of each operation. Function 1- dismantling the pump, function 2- removing the coupling guard, function 3- removing two halves of the clutch, function 4- removing the pin, function 5- dismantling the engine section. The results of the system test are presented in Table 1.

6. DISCUSSION

The main hypothesis of the work is HM: The augmented reality system reduces the time for maintenance of oil

TABLE 1. Results of experiments

Function Number	Group Number	No 1, time, sec	No 2, time, sec	No 3, time, sec	No 4, time, sec
Experiment 1					
1		178	140	194	131
2		96	37	120	40
3		180	124	170	154
4		94	35	110	25
5		80	80	70	75
Total time		628	416	664	425
Experiment 2					
1		194	154	120	147
2		120	40	35	45
3		210	132	142	164
4		90	45	20	30
5		75	74	42	80
Total time		689	445	359	466
Experiment 3					
1		210	135	190	175
2		95	55	110	40
3		196	120	170	165
4		87	40	80	35
5		98	62	65	73
Total time		686	412	615	488
Experiment 4					
1		180	152	110	156
2		92	45	30	37
3		214	137	145	152
4		84	38	27	40
5		115	53	45	71
Total time		685	425	357	456

pumps. To prove this hypothesis, we put forward a number of auxiliary hypotheses. Hypothesis 1: the maximum time for system maintenance will be spent by group No. 1 (the group that serviced the pump only in accordance with the paper instructions). Hypothesis 1 was not confirmed in the first experiment. It turned out that group No. 1, which serviced the pump only in accordance with paper instructions, served the pump faster than the group that used only the help of an expert (No. 3). They wasted 628 and 664 seconds, respectively. Analyzing the results, it was found that this was caused by the fact that at first the subjects tried to figure it out

themselves and only in case of failure they used the help of an expert. Therefore, as a result, they spent more time than everyone else did. Hypothesis 1 has been adjusted and hypothesis 2 has been put forward: the maximum time for system maintenance will be spent by group No. 1 if group No. 3 (which used only expert help) will be given instructions to use expert help immediately. Hypothesis 2 was confirmed. In the second and fourth experiment, group 3 completed the task faster than everyone else did. However, at the same time, an expert was constantly involved; that is actually not the best solution. The fact that the group that used the internal instructions of the system and the expert's help at the same time involved the expert in all experiments only once could be considered as a proof. At the same time, the time to complete the task is not significantly longer than that in the group using only the experts help. Another hypothesis was hypothesis 3: a group that used internal recommendations and, if necessary, contacted the expert (No. 4) would complete the task faster than a group that used only system recommendations (No. 2). This hypothesis has been disproved. In all experiments, the group that used only the internal recommendations of the system (No. 2) completed the task faster than group No. 4. a number of reasons could be the cause of this: first, people in the fourth group reacted more slowly to the prompts of the system as a whole, and the second factor, the ability to contact an expert relaxed the participants and they turned to him even when it was not necessary and spent more time on the assignment. Group No. 1 presents an imitation of the work of service engineers without using an augmented reality system. In all four experiments, she showed the worst results compared to the averaged results for other groups. This fact is a proof of the main hypothesis - the Augmented Reality system reduces the time for maintenance of oil pumps.

7. CONCLUSIONS

In the era of information technologies development, more and more digital solutions find their application in industry, in particular oil and gas industry. One of the solutions is AR Augmented Reality Technology. The results show the effectiveness of using augmented reality technology for servicing oil pumps. Provided that there is a complete description of all the actions that must be performed during maintenance, visualization gives a significant reduction in the time spent on servicing one unit of pumping equipment. Connecting to an expert help system gives conflicting results, if there is a complete instruction, expert help increases the time it takes to carry out actions, but in situations of emergency and beyond the scope of the instructions, expert help will significantly increase the overall performance of the

system.

In further studies, according to the authors, it is necessary to further develop mechanisms involving an expert in the pump maintenance system. The correct distribution of the expert's time, the development of manipulators that can remotely carry out certain actions by the hands of a service engineer and the organization of a single view of the object are relevant issues for further research. In addition, there are others actual terms for future research, including the integration with other systems, positioning, markers, data storage and analysis etc.

8. REFERENCES

1. Litvinenko, V.S., "Digital economy as a factor in the technological development of the mineral sector", *Natural Resources Research*, Vol. 29, No. 3, (2020), 1521-1541. DOI: 10.1007/s11053-019-09568-4
2. Cherepovitsyn A.E., Lipina S.A., Evseeva O.O. "Innovative Approach to the Development of Mineral Raw Materials of the Arctic Zone of the Russian Federation", *Journal of Mining Institute*, Vol. 232, (2018), 438-444. DOI:10.31897/PMI.2018.4.438
3. Hongfang Lu, Lijun Guo, Mohammadamin Azimi, Kun Huang, «Oil and Gas 4.0 era: A systematic review and outlook», *Computers in Industry*, Vol. 111, (2019), 68–90. DOI: doi.org/10.1016/J.COMPIND.2019.06.00
4. Necci, A., Tarantola, S., Vamanu, B., Krausmann, E. and Ponte, L., "Lessons learned from offshore oil and gas incidents in the arctic and other ice-prone seas", *Ocean Engineering*, Vol. 185, (2019), 12-26. DOI: 10.1016/j.oceaneng.2019.05.021
5. Nedosekin A.O., Rejshahrit E.I., Kozlovskij A.N., "Strategic Approach to Assessing Economic Sustainability Objects of Mineral Resources Sector of Russia", *Journal of Mining Institute*, Vol. 237, (2019), 354-360. DOI: 10.31897/PMI.2019.3.354
6. Rob Montenegro, Nils Hökby, «Optimizing operational efficiency in submersible pumps», *World Pumps*, (2004). DOI: 10.1016/s0262-1762(04)00174-9
7. Zhukovskiy, Y. and Koteleva, N., "Development of augmented reality system for servicing electromechanical equipment", *Journal of Physics: Conference Series*, Vol. 1015, (2018), 042068. DOI: 10.1088/1742-6596/1015/4/042068
8. Dvornikov, M.V., Nutskova, M.V. and Blinov, P.A., "Developments made in the field of drilling fluids by saint petersburg mining university", *International Journal of Engineering*, Vol. 33, No. 4, (2020), 702-711. DOI: 10.5829/IJE.2020.33.04A.22
9. M. E. Haque, M. R. Islam, M. S. Islam, H. Haniu, M. S. Akhter, «Life cycle cost and energy consumption behavior of submersible pumps using in the Barind area of Bangladesh», *Energy Procedia*, Vol. 110, (2017) 479-485. DOI: 10.1016/j.egypro.2017.03.172
10. Benbelkacem, S., Belhocine, M., Bellarbi, A., Zenati-Henda, N. and Tadjine, M., "Augmented reality for photovoltaic pumping systems maintenance tasks", *Renewable Energy*, Vol. 55, (2013), 428-437. DOI: 10.1016/j.renene.2012.12.043
11. Xiao Li, Wen Yi, Hung-Lin Chi, Xiangyu Wang, Albert P.C. «A critical review of virtual and augmented reality (VR/AR) applications in construction safety», *Automation in Construction*, Vol. 86, (2018), 150-162. DOI:

- <https://doi.org/10.1016/j.autcon.2017.11.003>
12. Herbert, B., Ens, B., Weerasinghe, A., Billingham, M. and Wigley, G., "Design considerations for combining augmented reality with intelligent tutors", *Computers & Graphics*, Vol. 77, (2018), 166-182. DOI: 10.1016/j.cag.2018.09.017
 13. Index, in Digital twin driven smart manufacturing, F. Tao, M. Zhang, and A.Y.C. Nee, Editors. 2019, Academic Press.257-269 DOI: 10.1016/b978-0-12-817630-6.00026-6
 14. Garcia, C.A., Naranjo, J.E., Ortiz, A. and Garcia, M.V., "An approach of virtual reality environment for technicians training in upstream sector", *IFAC-PapersOnLine*, Vol. 52, No. 9, (2019), 285-291. DOI:10.1016/j.ifacol.2019.08.222
 15. Necci, A., Tarantola, S., Vamanu, B., Krausmann, E. and Ponte, L., "Lessons learned from offshore oil and gas incidents in the arctic and other ice-prone seas", *Ocean Engineering*, Vol. 185, (2019), 12-26. DOI: 10.1016/j.oceaneng.2019.05.021
 16. Radu I. Augmented reality in education: a meta-review and cross-media analysis. *Pers Ubiquitous Comput*, Vol. 18, No.6, (2014), 1533-1543. DOI:10.1007/s00779-013-0747-y.
 17. Azuma, R., Bailiot, Y., Behringer, R., Feiner, S., Julier, S. and MacIntyre, B., "Recent advances in augmented reality", *IEEE Computer Graphics and Applications*, Vol. 21, No. 6, (2001), 34-47. DOI: 10.1109/38.963459
 18. Marinin M.A., Khokhlov S.V., Isheyskiy V.A., "Modeling of the Welding Process of Flat Sheet Parts by an Explosion", *Journal of Mining Institute*, Vol.237, (2019), 275-280. DOI: 10.31897/PMI.2019.3.20.
 19. Jacobs, T., "Ar headsets give oil and gas sector the quicker fix", *Journal of Petroleum Technology*, Vol. 70, No. 7, (2018), 32-34. DOI: 10.2118/0718-0032-JPT
 20. X. Wang, S.K. Ong, A.Y.C. Nee, A comprehensive survey of augmented reality assembly research, *Advanced Manufacturing*, Vol. 4, No. 1, (2016), 122. DOI: 10.1007/s40436-015-0131-4
 21. Amelessodji Kokougan Etonam, Giulio Di Gravio, Patrick W. Kuloba, Jackson G. Njiri, «Augmented Reality (AR) Application in Manufacturing Encompassing Quality Control and Maintenance», *International Journal of Engineering and Advanced Technology*, Vol. 9, No. 1, (2019), 197-204. DOI: 10.35940/ijeat.A1120.109119
 22. Tanita Fossli Brustad "Preliminary Studies on Transition Curve Geometry: Reality and Virtual Reality", *Emerging Science Journal*, Vol. 4, No. 1, (2020). DOI: <https://doi.org/10.28991/esj-2020-01204>
 23. Mehmet Özüağ, İsmail Cantürk, Lale Özyılmaz, «A New Perspective to Electrical Circuit Simulation with Augmented Reality», *International Journal of Electrical and Electronic Engineering & Telecommunications* Vol. 8, No. 1, (2019), 9-13. DOI: 10.18178/ijeetc.8.1.9-13
 24. Wei Zhang, Xianzhao Yang, Tao Wang, Xueyuan Peng, Xiaolin Wang, "Experimental Study of a Gas Engine-driven Heat Pump System for Space Heating and Cooling", *Civil Engineering Journal*, Vol. 5, No. 10, (2019), 2282-2295. DOI: 10.28991/cej-2019-03091411
 25. Sunitha, R. and Chandrikab, J., "Evolutionary computing assisted wireless sensor network mining for qos-centric and energy-efficient routing protocol", *International Journal of Engineering, Transactions B: Applications*, Vol. 33, No. 5, (2020), 791-797. DOI: 10.5829/IJE.2020.33.05B.10

Persian Abstract

چکیده

صلاحیت کارکنانی که فرایندهای تکنولوژیکی را انجام می دهند به طور مستقیم بر ایمنی تولید تأثیر می گذارد. لیکن، صلاحیت کارکنان نمی تواند عامل انسانی را کاملاً مستثنی کند. امروزه فناوری های زیادی وجود دارد که می توانند تأثیر عامل انسانی بر ایمنی تولید را به حداقل رسانده یا از بین ببرند. فناوری واقعیت افزوده نمونه ای از این فناوری است. امروزه، ادغام فناوری های واقعیت افزوده و فناوری های صنعتی به سطح جدیدی از توسعه رسیده است. این فناوری ها تجربه ی شگرفی دارند که در مدت زمان طولانی انباشته شده است. این سطح جدید توسط ترکیب و یکپارچه سازی تجربه در دسترس قرار می گیرد، سود اضافی را برای شرکت به ارمغان می آورد و می تواند مبنایی برای فناوری های کاملاً جدید باشد. این مقاله نمونه ای از ترکیب فناوری واقعیت افزوده و نگهداری پمپ های نفتی را نشان می دهد. به منظور تحقیق در مورد کارایی سیستم واقعیت افزوده برای نگهداری پمپ روغن از واحد آزمایشگاهی با پمپ گریز از مرکز عمودی برقی Grundfos (CR15-4 A-FGJ-AE-HQQE) استفاده شد. واحد آزمایشگاهی یک مدل فیزیکی یکی از فرایندهای پیوسته ی روغن است. پمپ روغن این واحد آزمایشگاهی هدف این تحقیق است. الگوریتم سرویس پمپ روغن ایجاد شد. آزمایش سیستم و الگوریتم ها با چهار گروه از افراد انجام شده است: دسته ی اول فقط از دستورالعمل های در دست، گروه دوم فقط از توصیه های داخلی سیستم، دسته ی سوم فقط به کمک یک متخصص و گروه چهارم توصیه های داخلی و در صورت لزوم تماس با کارشناس را به کار می گرفتند. نتایج بهره وری و دقت فناوری واقعیت افزوده برای نگهداری تجهیزات صنعتی، به ویژه برای تجهیزات کار شده در شرایط دورافتاده قطب شمال را نشان می دهد.
