Nafta-Gaz 2024, no. 4, pp. 202–210, DOI: 10.18668/NG.2024.04.02

Development of the strategy for implementation of repair and restoration works in oil and gas wells

Przygotowanie strategii prowadzenia prac naprawczych i rekonstrukcyjnych w odwiertach naftowych i gazowych

Ramiz Hasanov, Tila Qasimova, Musa Kazimov

Azerbaijan State Oil and Industry University

ABSTRACT: The repair and restoration work implemented in inactive well stocks has led to the resolution of clustering issues based on their purpose. It has been determined that in case of clusters of accident-prone wells, the implementation of repair and restoration works and their return to the operational fund, must be carried out based on economic and technical efficiency. The corresponding analysis revealed that clusters characterizing the accident rates include issues with downhole pipes, downhole motors, tools and devices, packers, bottom hole drill pipes, cables, ropes, wires, and others types of accidents. This paper presents the accumulated results of realized RRW (repair restoration works) based on field experience for formalization and automation in developing decision-making technologies and selecting accident elimination strategy in appropriate field conditions. Various technologies have been developed for the elimination process, using appropriate equipment. Repair and restoration work for corresponding codes is proposed based on field statistical information. The economic feasibility of the obtained results and their application are classified on the basis of boundary conditions defined by developed logical stages. The logical stages are drawn up using information about field parameters, including well conditions, the location of the accident object in the well, realized technology, and appropriate technical means. As a result of the analysis of SOCAR (State Oil Company of Azerbaijan Republic) fund of accident-prone wells, 24 possible options for the implementation of RRW have been identified for the aforementioned clusters. Lists of the existing tool park, functional design parameters, and technological modes necessary for each accident cluster have been determined to implement decision-making technologies.

Key words: well, elimination of accidents, repair restoration works (RRW), technology, RRW automated strategy, decision making, efficiency.

STRESZCZENIE: Prace naprawcze i rekonstrukcyjne prowadzane w nieaktywnych odwiertach eksploatacyjnych pozwoliły rozwiązać problem grupowania odwiertów w zależności od ich przeznaczenia. Ustalono, że w przypadku klastrów odwiertów narażonych na uszkodzenia, realizacja prac naprawczych i rekonstrukcyjnych oraz ich powrót do eksploatacji musi odbywać się w oparciu o efektywność ekonomiczną i techniczną. Przeprowadzona analiza wykazała, że klastry odznaczające się wysokim wskaźnikiem awaryjności obejmują awarie rur wiertniczych, silników wgłębnych, narzędzi i urządzeń, pakerów, rur wydobywczych, kabli, lin, przewodów oraz inne rodzaje awarii. Niniejszy artykuł przedstawia zgromadzone wyniki prac naprawczych i rekonstrukcyjnych w oparciu o doświadczenia terenowe, w celu formalizacji i automatyzacji opracowywania technologii decyzyjnych i wyboru strategii eliminacji awarii w odpowiednich warunkach terenowych. Opracowano różne technologie procesu eliminacji, przy użyciu odpowiedniego sprzętu. Prace naprawcze i rekonstrukcyjne wraz z odpowiadającymi im kodami zostały zaproponowane w oparciu o dane statystyczne z terenu. Możliwość wdrożenia uzyskanych wyników z ekonomicznego punktu widzenia i ich zastosowanie są klasyfikowane na podstawie warunków brzegowych określonych przez opracowane etapy logiczne. Etapy logiczne są opracowywane z wykorzystaniem informacji o parametrach terenowych, w tym warunkach odwiertu, lokalizacji obiektu podatnego na awarie w odwiercie, wdrożonej technologii i odpowiednich środkach technicznych. W wyniku analizy zestawu odwiertów SOCAR (State Oil Company of Azerbaijan Republic) podatnych na awarie zidentyfikowano 24 możliwe opcje wdrożenia prac naprawczych i rekonstrukcyjnych dla wyżej wymienionych klastrów. W celu wdrożenia technologii decyzyjnych określono listy istniejącego parku narzędzi, funkcjonalne parametry projektowe i tryby technologiczne niezbędne dla każdego klastra awarii.

Słowa kluczowe: odwiert, eliminacja awarii, prace naprawcze i rekonstrukcyjne (RRW), technologia, zautomatyzowana strategia RRW, podejmowanie decyzji, wydajność.

Corresponding author: T. Qasimova, e-mail: *tagieva89@list.ru*

Article contributed to the Editor: 31.07.2023. Approved for publication: 03.04.2024.

Introduction

The success of repair and restoration work (RRW) implemented in the relevant situation of oil and gas production depends on its information support and the technology employed. The basis of this support lies in the statistics of field experience accumulated from RRW implementations. The field-statistical data from RRW experiences serves as the basis for the formalization and automation in decision-making technology for selecting accident elimination strategies in appropriate field conditions (Hasanov, 1992). It is known that different emergency situations may arise depending on the technological operation being carried out in the well. In oil and gas field practice, various methods of accident elimination are typically employed depending on the specific situation in the well. A set of appropriate equipment is required to implement these different technologies. Field statistical information is utilized to produce repair and restoration works according to the corresponding codes for these operations. Economic feasibility of the obtained results and their application should be analyzed. For this purpose, appropriate options with positive outcomes, according to the logical scheme, must be developed (Figure 1). Drawing up a logical scheme requires consideration of field, including well parameters, accidental objects, applied technologies, and appropriate technical means.

Problem Statement

The aim of this study is to develop and investigate decision-making technologies for eliminating accidents in wells. To achieve this, a technology procedure for the decision-making process was developed, which includes processing field data on technogenic reasons for shutdown wells.

The RRW classification for eliminating these bottlenecks was provided, and the codes of RRW applicable to shutdown wells were defined. Factors characterizing well systems and the implementation of work according to the field situation were established. A list of metric parameters and design properties for oil and gas wells was analyzed to eliminate accidents with existing tools. The technology for assessment of RRW efficiency was vector defining of the well state for each RRW code determining their usage and classification. The logical decision-making scheme and the effectiveness of the implemented activities are determined by the condition of the well - the object of the accident system (Table 3) and the design and operational characteristics of the equipment used to eliminate the accident (Nifontov and Kleschcenko, 2005). Based on field experience, the well-accident facility system is characterized by the appropriate factors.

This analysis allows us to formulate a Formal Model with the corresponding state vector to classify the results of each code version of RRW implementation (Table 2).

The content of Table 4 allows us to formulate a Formal Model of each code version of RRW implementation with the corresponding state vector for classifying their results (Table 5).

Discussion of results

As can be seen from Tables 4 and 5, based on the results of the implementation experiment, 24 code variants were identified, each with a certain number of implementations characterized by a corresponding state vector. Each state vector enables classification of RRW outcomes into positive and negative and the selection of economically viable options among the positive implementations. Since the effectiveness of measures taken to eliminate accidents depends on random factors, the result of each of them is random. In this case, it is necessary to conduct numerous experiments to determine a certain regularity in order to anticipate potential RRW outcomes and to formulate precise accident elimination plans. To solve this problem, pattern recognition methods are employed (Zozulya et al., 2002). These methods involve classifying objects based on factors that determine relevant classes and satisfy the conditions of awareness. The information content of the factors selected for the study can be evaluated in different ways. For example, the information content of factors in pattern recognition, such as conditional entropy, backward divergence, dispersion measure, etc., was characterized (Hasanov et. al., 2008). Before determining a measure of awareness, factors are usually selected for study by one of the nonparametric criteria that do not require

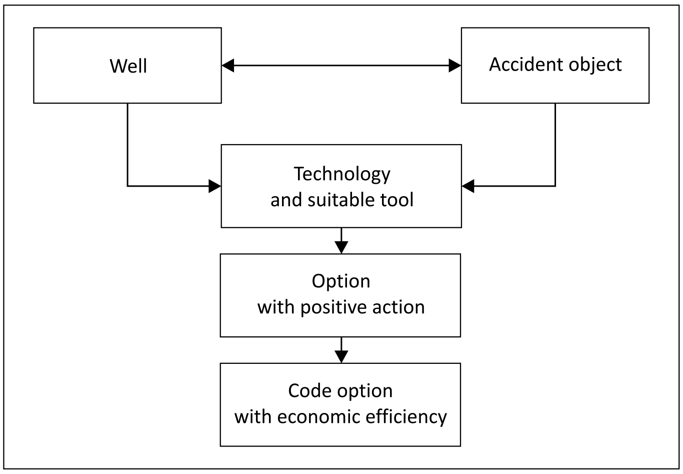


Figure 1. Logical procedure for determining the economic efficiency of code option for RRW implementation

Rysunek 1. Logiczna procedura określania efektywności ekonomicznej opcji kodu przy realizacji prac naprawczych i rekonstrukcyjnych

Table 1. Classification of RRW implementation
Tabela 1. Klasyfikacja realizacji prac naprawczych i rekonstrukcyjnych

Type of RRW		Accident code	Type of tool used		Code of working tool used	Tool used	Sequence for tool using
Elimination of accidents	1. Involving pipes 2. Involving the engine	1-A 2-B	1. Threaded fishing tools	– fishing socket	01	K KS	10 11
				– fishing tap	11	– universal tap for production well UTP – special tap for production well STP – universal tap for drilling well UTD – special tap for connection STC	12 13 14 15
	3. Involving cables 4. Other	3-C 4-D	2. Fishing tools	– internal pipe fishings – external pipe fishings – barbell fishing	02 12 22	Mechanical threaded fishing: – freed – non-freed – pipes up to 48 mm – pipes over 48 mm	16 17 18 19
				– fishing for ECP (electric centrifugal pump)	32	– for the flange – for the capsule – for shaft – for the cable	20 21 22 23
				– fishing for drill pipe	42	– mechanical threaded fishing – with spiral fishing element	24 25
				– well bottom motor fishing	52	– turbo drill – electro drill	26 27
				– magnetic fishing	62	– permanent magnet – electromagnetic	28 29
			3. Milling tools		03	– bottom hole – circular – conical – the pilot – sectional and plugin – magnetic	30 31 32 33 34 35
			4. Complex pipe cutter		04	– PC tubes for mechanical movement – drill pipes for hydraulic movement	36 37
			5. The set of equipment necessary for cutting the side track barrel		05	– incision through the slit window – incision through the circle window	38 39
			6. Auxiliary tools		06	– hydraulic jack screw – spider tool – percussion tool – Sludge trap tool	40 41 42 43

the factor scale to be divided into ranges. Based on the application of the non-parametric Wilcoxon-Mann-Whitney test for a number of code options given in the Table 2, informative factors and, according to the designed program (Figure 2), the classification functions of the results of the RRW for these codes (to solve the discriminant functions) were synthesized (Kagarmanov et. al, 2007). However, as the necessary information is collected, the availability of the algorithm and the corresponding computer program is shown in the block diagram (Figure 3), which allows, without much difficulty, to develop classification functions to evaluate the results of implementing RRW according to the appropriate code option.

Table 2. Repair and restoration works options

Tabela 2. Opcje prac naprawczych i rekonstrukcyjnych

Elimination of accidents with pipe fishing sockets	Elimination of accidents with pipe fishing taps	Elimination of accidents with fishings	Elimination of accidents with milling machines	Elimination of accidents with pipe cutters	Elimination of accidents with auxiliary tools	Elimination of accidents with the second barrel	Elimination of accidents with an electriccentrifugal pump	Elimination of accidents with turbo drill and electro drill	Elimination of accidents with a milling engine	Elimination of wells with engines of side track barrel	Elimination of accidents with percussion tool	Elimination of accidents with cable holders	Elimination of accidents by hooking with cables	Elimination of accidents with cables for drilling the second barrel	Elimination of other accidents with pipe cutters	Elimination of other accidents with milling tools	Elimination of other accidentswith auxiliary tools	Elimination of other accidents with the second barrel	Elimination of other accidents with magnetic fishings
A0110 A0111	A1112 A1113 A1114 A1115	A0216 A1216 A0217 A1217 A4216 A4217 A4225	A0330 A0331 A0332 A0333 A0334	A0436 A0437	A0641 A0642	A0538 A0539	B3220 B3221 B3222 B3223	B5226 B5227	B0330 B0331 B0332 B0333 B0334	B0538 B0539	B0642	C3223	C0640	C0538 C0539	D2218 D2219	D0330 D0335	D0640	D0538 D0539	D6228 D6229

Table 3. Data of well system – accident object

Tabela 3. Dane systemu odwiertu – obiekt awarii

№	Labeling of factors	X_i
1	Well diameter	X_1
2	Well wall condition (open barrel)	X_2
3	Well depth	X_3
4	Location of the object in the well	X_4
5	Location of accident object in the barrel well	X_5
6	Tackiness degree	X_6
7	Determination of oil and gas occurrence	X_7
8	Geometric dimensions of accident object	X_8
9	End of the accident object	X_9
10	Physio-mechanical properties of the accident object	X_{10}
11	Parameters characterizing the design and operational properties of the tool	$X_{11}\ldots X_n$

Table 4. Design and constructive characteristics of tools

Tabela 4. Charakterystyka projektowa i konstrukcyjna narzędzi

№	Tool	Parameters according to ISSN	
		Naming	Marking
1	Fishing socket (K)	1. Internal diameter 2. Taper of the fishing thread 3. Length of the fishing thread	X_{11} X_{12} X_{13}
2	Fishing socket (KC)	4. Number of longitudinal grooves for chip exit 5. Maximum load capacity	X_{14} X_{15}
3	Fishing tap	6. Tool weight 7. Initial axial load 8. End axial load 9. Tool rotation speed 10. Consumption of washing liquid	X_{16} X_{17} X_{18} X_{19} X_{20}
4	Released pipe fishing	11. Diameter of internal centering device 12. Mechanical indicators of the thread (hardness after quenching) 13. Distance from the end of the funnel CP to the end of the tap	X_{21} X_{22} X_{23}
5	Non-releasable pipe fishing	14. Size of the approach (distance from the end of the tap to the place of its attachment to the tool) 15. Number of mechanical threaded fishing 16. Number of level parts in the catching mechanism 17. Hardness of the surface of the fishing sockets	X_{24} X_{25} X_{26} X_{27}
6	Fishing with spiral handle	18. Length of fishing sockets steps 19. Angle of coverage of objects with box taps 20. Length of the fishing sockets 21. Diameter with fishing sockets closed 22. Diameter when holding elements	X_{28} X_{29} X_{30} X_{31} X_{32}
7	External milling machine	23. Material of the tool housing 24. Diameter of the longitudinal channel of the liquid flow 25. Bevel angle of the surface of fishing sockets	X_{33} X_{34} X_{35}
8	Circular milling	26. Axial load of the tool during pipes opening 27. Torque 28. Internal diameter	X_{36} X_{37} X_{38}
9	Cone milling machine	29. Taper of screw thread 30. Length of screw thread 31. Number of views 32. Number of turns 33. Type of reinforcement	X_{39} X_{40} X_{41} X_{42} X_{43}
10	Pilot milling machine	34. Height of reinforcement 35. Number of washing channel 36. Scheme of the arrangement of channels	X_{44} X_{45} X_{46}

cont. Table 4/cd. Tabela 4

№	Tool	Parameters according to ISSN	
		Naming	Marking
11	Sectional and plug-in milling	37. Tool inner diameter 38. Internal screw pitch 39. Taper of the milling tools 40. Ratio of the length of the tool to the length of the conical part 41. Tip diameter	X_{47} X_{48} X_{49} X_{50} X_{51}
12	Magnetic milling	42. Tip length 43. Number of incisors 44. Working pressure for bringing the claws into working condition 45. Pump supply 46 Arrangement of magnets in the grappling mechanism	X_{52} X_{53} X_{54} X_{55} $X56$
13	Complex pipe cutter	47. Number of magnets in the grappling mechanism 48. Material for production of magnets 49. Load carrying capacity of magnets	X_{57} X_{58} X_{59}
14	Hydraulic jack	50. Positioning levels of magnets in the holding mechanism 51. Design of the braking mechanism 52 Specific load weight	X_{60} X_{61} X_{62}
15	Mechanisms for releasing seized pipes	53. Length of the rod of incisors 54. Diameter of the rod of incisors	X_{63} X_{64}
16	Fishing for rods	55. Length of the cylinder of the jack 56. Number of hydraulic anchors	X_{65} X_{66}
17	Fishing for electric centrifugal pump	57. Armature extension pressure 58. Pressure of disruption of object	X_{67} X_{68}
18	Fishing for the housing of the electric centrifugal pump	59. Number of blows before mastering 60. Weight of the hammer 61. Load capacity	X_{69} X_{70} X_{71}
19	Fishing flange	62. Collet diameter 63. Number of tiers	X_{72} X_{73}
20	Fishing shaft	64. Distance between bars of individual tiers 65. Dimensions of the catcher auger	X_{74} X_{75}
21	Fishing for drill pipes	66. Dimensions of spring 67. Number of collet fingers 68. Collet feather length	X_{76} X_{77} X_{78}
22	Fishing for turbine drill	69. Spring dimensions 70. Number of grips 71. Taper of funnel	X_{79} X_{80} X_{81}
23	Fishing for electric drills	72. Dimensions of the spring lantern 73. Length of receiving tube 74. Principle of action (articulated or non-articulated)	X_{82} X_{83} X_{84}
24	Fishing lines	75. Manufacturing cost of the tool 76. The result of work with the tool 77. Cost-effectiveness of the tool	X_{85} X_{86} X_{87}

Table 5. State vectors of code options

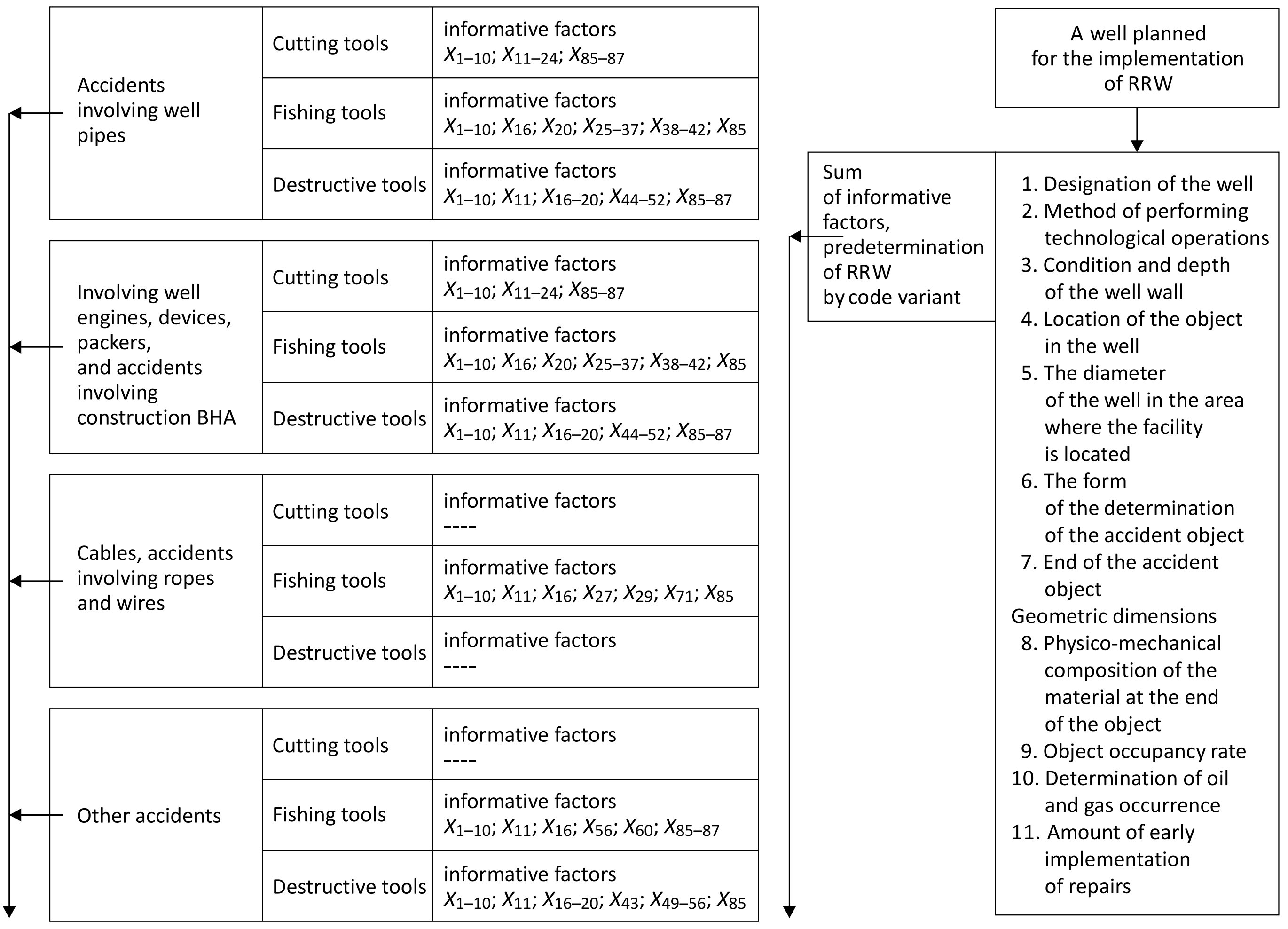
Tabela 5. Wektory stanu dla opcji kodowych

№	Tool	Factors
1	Fishing socket (K)	$X_1 – X_{10}, X_{11} – X_{20}, X_{85} – X_{87}$
2	Fishing socket (KC)	"---------" "---------"
3	Fishing tap	$X_1 – X_{10}, X_{11} – X_{24}, X_{85} – X_{87}$
4	Released tube fishing	$X_1 – X_{10}, X_{16}, X_{20}, X_{25} – X_{35}, X_{11}, X_{85} – X_{87}$
5	Unreleased tube fishing	$X_1 – X_{10}, X_{16}, X_{20}, X_{25} – X_{37}, X_{85} – X_{87}$
6	Spiral tube fishing	X1 – $X_{10}, X_{11}, X_{16}, X_{20}, X_{37} – X_{42}, X_{85} – X_{87}$
7	Circular milling cutter	X1 – $X_{10}, X_{11}, X_{16}, X_{18} – X_{20}, X_{43} – X_{48}, X_{85} – X_{87}$

cont. Table 5/cd. Tabela 5

№	Tool	Factors
8	External milling machine	X1 $- X_{10}, X_{11}, X_{16}, X_{18} - X_{20}, X_{43} - X_{48}, X_{85} - X_{87}$
9	Conical milling cutter	$X_1 - X_{10}, X_{11}, X_{16}, X_{18} - X_{20}, X_{43} - X_{48}, X_{85} - X_{87}$
10	Pilot milling machine	$X_1 - X_{10}, X_{11}, X_{16}, X_{18} - X_{20}, X_{43}, X_{51}, X_{52}, X_{85} - X_{87}$
11	Sectional and seated milling machine	$X_1 - X_{10}, X_{11}, X_{16}, X_{18}, X_{53} - X_{55}, X_{85} - X_{87}$
12	Magnetic milling machine	$X_1 - X_{10}, X_{11}, X_{16}, X_{56} - X_{60}, X_{85} - X_{87}$
13	Complex pipe cutter	$X_1 - X_{10}, X_{11}, X_{16}, X_{19}, X_{20}, X_{55}, X_{61} - X_{64}, X_{85} - X_{87}$
14	Hydraulic jack	$X_1 - X_{10}, X_{11}, X_{16}, X_{65} - X_{68}, X_{85} - X_{87}$
15	Impact of pathogens (impact tool)	$X_1 - X_{10}, X_{11}, X_{16}, X_{69} - X_{11}, X_{85} - X_{87}$
16	Fishing for barbells	$X_1 - X_{10}, X_{11}, X_{16}, X_{25} - X_{25}, X_{71}, X_{72}, X_{85} - X_{87}$
17	Fishing (cable) for electric centrifugal pump	$X_1 - X_{10}, X_{11}, X_{16}, X_{25}, X_{27}, X_{29}, X_{71}, X_{85} - X_{87}$
18	Fishing for electric centrifugal pump housing	$X_1 - X_{10}, X_{16}, X_{71}, X_{76} - X_{78}, X_{85} - X_{87}$
19	Fishing for flange	$X_1 - X_{10}, X_{11}, X_{71}, X_{76} - X_{78}, X_{85} - X_{87}$
20	Fishing shaft	$X_1 - X_{10}, X_{11}, X_{16}, X_{25}, X_{27}, X_{29}, X_{25}, X_{35}, X_{43}, X_{44}, X_{47}, X_{71}, X_{79}, X_{85} - X_{87}$
21	Fishing for drill pipes	$X_1 - X_{10}, X_{11}, X_{16}, X_{25}, X_{27} - X_{25}, X_{33} - X_{35}, X_{71}, X_{80}, X_{85} - X_{87}$
22	Fishing for turbine excavators	$X_1 - X_{10}, X_{11}, X_{16}, X_{18} - X_{20}, X_{43}, X_{44}, X_{47}, X_{80}, X_{85} - X_{87}$
23	Fishing for electric drills	$X_1 - X_{10}, X_{11}, X_{16}, X_{18} - X_{20}, X_{43}, X_{44}, X_{47}, X_{71}, X_{83}, X_{85} - X_{87}$
24	Fishing grab hooks	$X_1 - X_{10}, X_{11}, X_{16}, X_{71}, X_{84} - X_{87}$

Figure 2



Accidents involving well pipes	Cutting tools	informative factors $X_{1–10}; X_{11–24}; X_{85–87}$
	Fishing tools	informative factors $X_{1–10}; X_{16}; X_{20}; X_{25–37}; X_{38–42}; X_{85}$
	Destructive tools	informative factors $X_{1–10}; X_{11}; X_{16–20}; X_{44–52}; X_{85–87}$
Involving well engines, devices, packers, and accidents involving construction BHA	Cutting tools	informative factors $X_{1–10}; X_{11–24}; X_{85–87}$
	Fishing tools	informative factors $X_{1–10}; X_{16}; X_{20}; X_{25–37}; X_{38–42}; X_{85}$
	Destructive tools	informative factors $X_{1–10}; X_{11}; X_{16–20}; X_{44–52}; X_{85–87}$
Cables, accidents involving ropes and wires	Cutting tools	informative factors ----
	Fishing tools	informative factors $X_{1–10}; X_{11}; X_{16}; X_{27}; X_{29}; X_{71}; X_{85}$
	Destructive tools	informative factors ----
Other accidents	Cutting tools	informative factors ----
	Fishing tools	informative factors $X_{1–10}; X_{11}; X_{16}; X_{56}; X_{60}; X_{85–87}$
	Destructive tools	informative factors $X_{1–10}; X_{11}; X_{16–20}; X_{43}; X_{49–56}; X_{85}$

Sum of informative factors, predetermination of RRW by code variant

A well planned for the implementation of RRW

1. Designation of the well
2. Method of performing technological operations
3. Condition and depth of the well wall
4. Location of the object in the well
5. The diameter of the well in the area where the facility is located
6. The form of the determination of the accident object
7. End of the accident object

Geometric dimensions

8. Physico-mechanical composition of the material at the end of the object
9. Object occupancy rate
10. Determination of oil and gas occurrence
11. Amount of early implementation of repairs

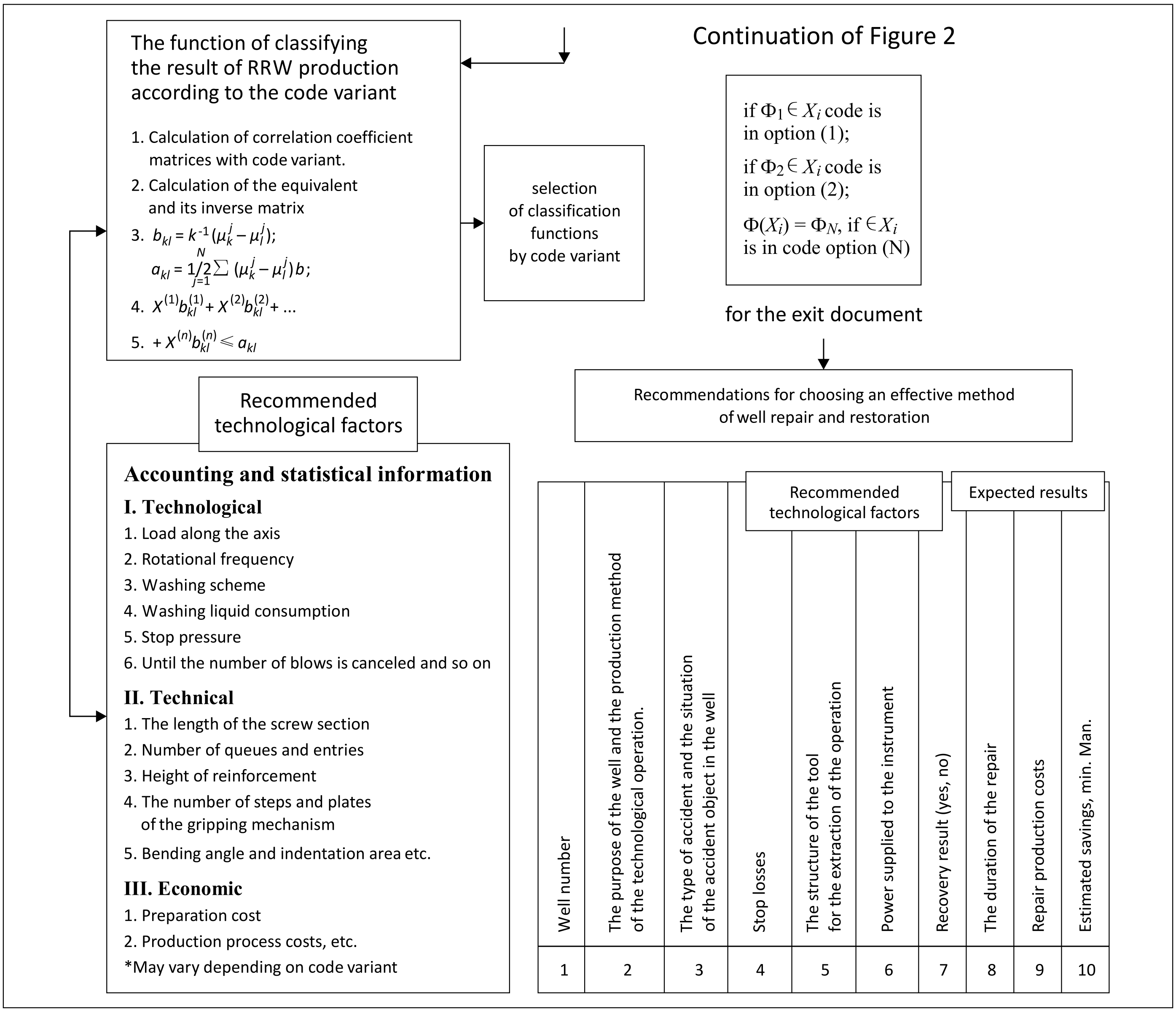


Figure 2. Extended logic diagram of method selection for RRW implementation

Rysunek 2. Rozszerzony schemat logiczny wyboru metody realizacji prac naprawczych i rekonstrukcyjnych

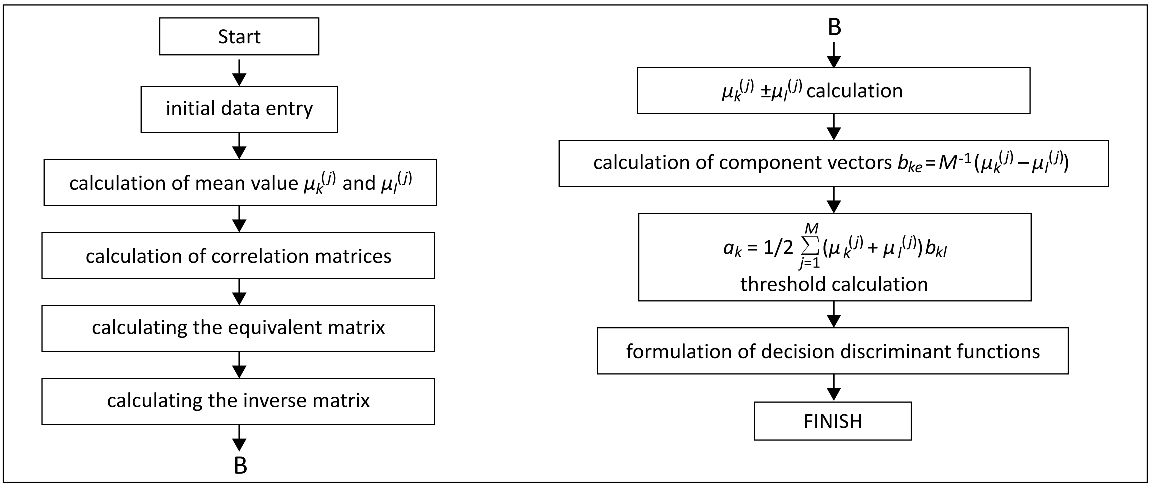


Figure 3. Block diagram of the discriminant function method

Rysunek 3. Schemat blokowy metody funkcji dyskryminacyjnej

Conclusions

1. Based on field-specific factors, accident data from selected production wells are categorized into ranges using a non-parametric criterion for study.
2. By employing the non-parametric Wilcoxon-Mann-Whitney test for a number of code options, different decision rules can be obtained for the analyzed database informative factors. Subsequently, the classification functions of the results of the RRW for these codes were synthesized according to the developed program.
3. This algorithm facilitates the development of classification functions to evaluate the results of implementing RRW according to the appropriate code option with minimum difficulty.

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Tila QASIMOVA, M.Sc.
Doctoral student at the Department of Oil Mechanics
Azerbaijan State Oil and Industry University
16/21 Azadliq Ave, AZ1010, Baku, Azerbaijan
E-mail: *tagieva89@list.ru*

Prof. Ramiz HASANOV, Ph.D.
Professor at the Department of Oil Mechanics
Azerbaijan State Oil and Industry University
16/21 Azadliq Ave, AZ1010, Baku, Azerbaijan
E-mail: *ramiz.hasanov52@gmail.com*

Musa KAZIMOV, Ph.D. candidate
Assistant Professor at the Department
of Oil Mechanics
Azerbaijan State Oil and Industry University
16/21 Azadliq Ave, AZ1010, Baku, Azerbaijan
E-mail: *musa.kazimov50@mail.ru*