ANALYSING THE FUNCTIONALITY OF OIL WELL REHABILITATION EQUIPMENT FROM A SAFETY AND ENVIRONMENTAL PERSPECTIVE

Javahir Gasimova, Rafiqa Shahmarova, Saida Musavi
•
Azerbaijan State Oil and Industry University
gasymova1974@list.ru
Shahmarova_1970@mail.ru
saidamusavi@mail.ru

Abstract

One of the main directions of environmental protection and pollution prevention is the improvement of technological processes. The drilling of deep oil and gas wells is a very complex technological process, the violation of which can lead to various emergencies that pollute the environment. Therefore, well rehabilitation is becoming an increasingly important aspect of ensuring the sustainability and efficiency of the production process. This paper analyses the performance of equipment used in oil well rehabilitation. For this purpose, a classification of accidents in production and drilling wells is presented and a qualitative evaluation of the main oil well rehabilitation methods and the equipment used in this process (milling, capture, flushing tools and raisers) is carried out in order to determine their advantages and disadvantages.

Keywords: acid mudding, hydraulic fracturing, milling tools, trapping tools, plugging tools, reiber

I. Introduction

One of the reasons that reduce the efficiency of drilling and well operations is accidents. In oil and gas wells, an accident is an interruption of technological processes caused by the seizure or breakage of downhole tools and equipment, as well as the fall of individual parts and components downhole. Modern drilling is characterised by continuous increase of well depths, reduction of well diameter in the lower intervals, increase of complications. As a result, the likelihood of accidents in the operation of the above-mentioned wells (both producing and drilling wells) increases.

An important measure to reduce the accident rate is the prevention of accidents and complications, as well as systematic preventive maintenance. In order to inform the strategy of these measures, it is necessary to study the experience of accidents in the production and drilling of wells. This should be done by analysing accidents in wells:

- the location and depth of the emergency object in the well;
- the shape, size and diameter of the emergency object;
- the condition of the borehole walls,
- the physical and mechanical properties of the material of the emergency object and the degree of its adhesion;
- the degree of risk of gas and oil spillage, etc.

All of this is a sine qua non for the improvement of existing methods and the development of new methods and technical means to speed up the commissioning of idle wells at minimum cost. For this purpose, it is necessary to establish a classification of accidents in production and drilling wells, which is presented below:

1. downhole pipe accidents
2. accidents involving downhole motors, instruments (devices), packers and drill string threads;
3. accidents associated with geophysical surveys;
4. accidents involving rock destruction tools;
4. accidents involving cables, ropes, wires;
5. accidents related to foreign objects falling into the well;
6. fire and explosion accidents;
7. other.

However, the classification which groups objects into classes mainly on the basis of the type of emergency object is conditional and only acceptable for simple accidents, i.e. cases where there is a single type of emergency object in the well. For combined accidents, i.e. when a combination of accident objects is present in the well, this classification loses all meaning. Therefore, the classification should be based on a formal basis. Nevertheless, the proposed simple accident classification [1] is a guideline for the development, maintenance and improvement of the reliability, operational characteristics of downhole tools to prevent accidents. According to this classification, the data on the oil industry of the Commonwealth countries on the distribution of accidents, the corresponding volume of repairs and tripping operations are given in the form of a diagram in Fig. 1.

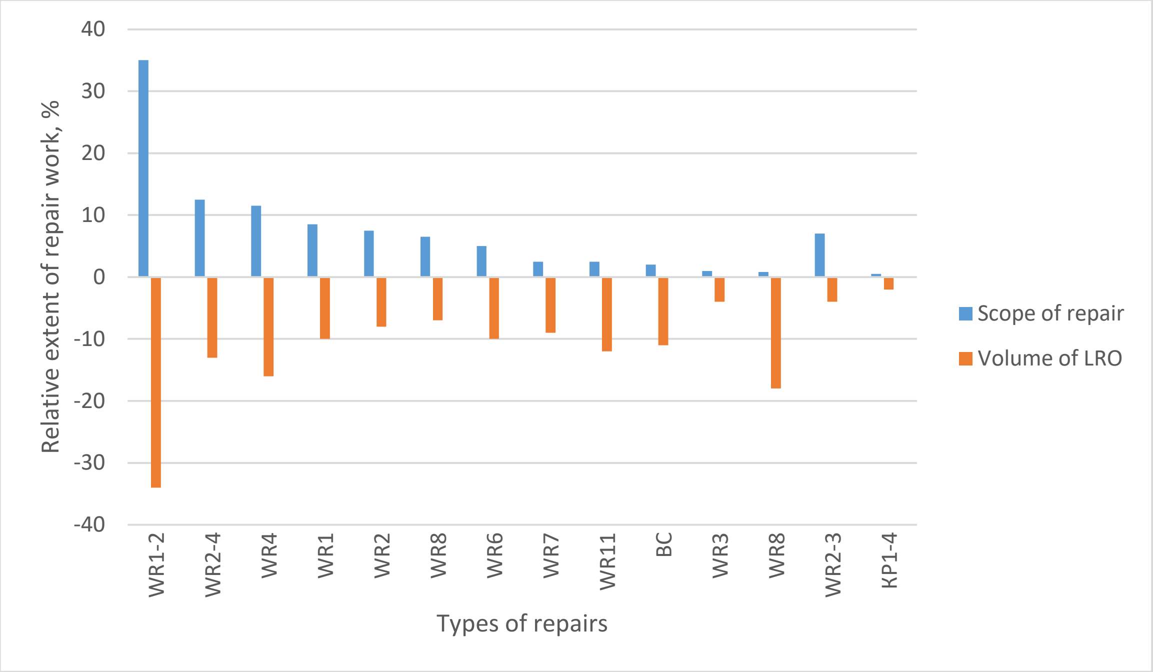


Figure 1: *Diagram of repair volumes and corresponding of repairs and corresponding launch and recovery operations (LRO):*
WR1-2 - separation of separate formations; WR2-4 - elimination of leakage by partial replacement of the production string; WR4 - transition to other horizons and connection of formations; WR1 - repair and insulation works; WR2 - elimination of leakage of the production string; WR8 - well exploration; WR6 - Complex of underground works for restoration of well performance using technical elements of drilling, including cabling of horizontal sections of the well; WR7 - Treatment of the formation zone at the bottom of the well and induction of flow; WR11 - preservation and re-conservation of the well; WR13 - other types of works; WR2-3 - elimination of leakages by running additional casing of smaller diameter; WR1-4 - cement ring construction behind production, intermediate casing, conductor.

In addition, oil wells are subject to a number of unfavourable factors such as clogging, corrosion and fouling. These problems can significantly reduce well performance. To overcome these problems, specialised equipment is used to restore well performance.

II. Methods

The following are the main methods of restoring the operability of oil wells and the equipment used.

I. Well flushing method.

Flushing an oil well involves:

- Transfer of hydraulic energy from pump to turbo or electric drill, bit, downhole motor;
- Cooling, lubrication and corrosion protection of the bit as the mud passes through the wellbore. Oxidative destruction of metal parts of the equipment occurs due to the action of oxygen dissolved in the mud, hydrogen sulphide and rock salts. Anticorrosive properties are imparted to the working drilling fluid by the addition of inhibitors:
- flushing of oil wells during drilling allows the reduction of abrasive wear during drilling by timely and proper cleaning of drilling fluid from solid particles of cuttings;
- facilitating the drilling process through the kinetic energy of the fluid as it leaves the drill bit and reducing the coefficient of friction. This is particularly effective when working in loose soils;
- pressurising the borehole to prevent gas and oil spillage and collapse of the borehole walls when working in unstable rock;
- temporarily maintaining the suspended state of the mud particles during pump shutdown (in an emergency situation). For this purpose, the drilling mud is given thixotropic properties by additives that allow it to transform from ash to gel;
- prevention of technological difficulties in the drilling process, including differential seizure of the drill string;
- strengthening the wellbore channel when working in weak and fractured rock by creating a reinforced clay crust;
- preserving reservoir productivity in the downhole zone.

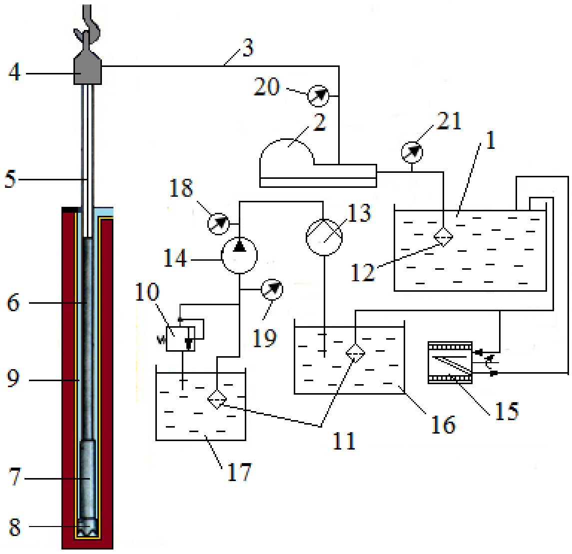


Figure 2: *Direct well flushing scheme:*
1 - mud tank; 2 - pump; 3 - flexible hose; 4 - swivel; 5 - drive pipe; 6 - drill string; 7 - hydraulic motor; 8 - drill bit; 9 - annular duct; 10 - safety valve; 11, 12 - filters; 13 - hydrocyclone; 14 - auxiliary pump; 15 - centrifuge; 16, 17 - sumps; 18-21 - pressure gauges.

The disadvantage is that sand plugs form during the drilling process as a result of the thermal effect on the reservoirs. As a result, additional time is spent flushing the well to "clean water" before reaming the casing. It is also important to note that the direct circulation method requires a large amount of working fluid, especially when drilling with a maximum diameter bit.

2. Acid dissolution - used to remove sediments and increase formation permeability. Analyses include evaluation of the concentration of acids used, depth of penetration and changes in well productivity.

Acid dissolution plays an important role in the oil and gas industry and is used to remove deposits and clean up wells. Specialist equipment is required to carry out this process effectively. Below is a list of equipment that can be used for acid dissolution in the oil and gas industry:

1. Acid pumps - must be corrosion resistant and capable of handling corrosive media.
2. Acid supply tanks - these are acid tanks and reservoirs for the storage and supply of acid solutions and metering systems for accurate and uniform acid distribution (Table 1).
3. Instrumentation - this includes instrumentation to monitor pH, temperature and acid concentration, as well as pressure and flow monitoring equipment: to ensure process safety and efficiency.
4. Acid resistant tubing and casing to ensure well longevity and safety.
5. Waste treatment equipment as part of the decontamination system to neutralise spent acid solutions.
6. Corrosion monitoring equipment to assess the effects of acid on equipment.

Table 1: *Volume of acid injected (m^3) per 1 m of uncovered formation thickness*

Number of treatments	Type of collector	
	Low permeable	Highly permeable
1	0,4 ÷ 0,6	0,7 ÷ 1,1
2 or more	0,6 ÷ 1,7	1,1-1,6

It is important to comply with safety and environmental standards when using acids in the oil and gas industry. Exact equipment requirements may vary depending on the specific process and field characteristics.

3. Hydraulic fracturing - used to increase permeability and improve production. This technique creates fractures in the rock to allow increased fluid (oil and gas) flow to the wellbore. When using this technique, it is necessary to determine the effect of pressure and volume of water used on the change in well production rate.

Here are some basic aspects of this technique:

- Fluid preparation. A special fluid known as "hydraulic fluid" is prepared at the surface. This fluid usually consists of water, additives to improve properties and, importantly, proppants (small particles that help prevent cracks from closing after flushing).
- Fluid injection. A hydraulic fluid under pressure is injected into the well. This creates fractures in the rock and increases the permeability of the formation.
- Proppant into the fractures. When fractures are created, proppant (particles such as sand or ceramics) is injected into the fractures to prevent them from closing after the fracturing process is complete.

The equipment used in hydraulic fracturing includes

- Hydraulic pumps to generate sufficient water pressure to overcome rock resistance.
- Special pumps to inject proppant into the fractures.
- Monitoring equipment, i.e. various tools such as seismic and sonic monitoring systems are used to control and optimise the process.

Drawbacks. Hydraulic fracturing is a complex and controversial technology, and its use requires a balanced approach that considers both economic benefits and environmental risks. There are concerns about potential negative environmental impacts such as groundwater contamination, seismic activity and others. Different countries and regions have different laws and regulations governing the use of fracking technology. The technology is a matter of public concern because of the environmental risks associated with it. Potential negative impacts must be considered when implementing this technology.

Depending on the type and degree of complexity of the accident, well repair and recovery operations are carried out mainly by destroying emergency equipment and by containment operations, which also include tackling operations.

The most common destruction methods are chemical, mechanical and thermal destruction of emergency objects in the well. The analysis of these methods shows the efficiency of the mechanical destruction method as the most economical and easy to use. Various types of milling cutters are widely used for this purpose.

At present, some experience has been gained in various oil regions of the country with the use of downhole cutters with a cutting part in the form of a reinforcement made of composite material [5.59]. However, the capacities of the country's machine-building industry are not sufficient. to meet the oil industry's ever-increasing demand for these tools. The situation is further aggravated by the low performance indicators of the tools produced by the machine-building industry of the CIS countries. This indicates that the process of interaction between the tools and the object to be destroyed is insufficiently studied, despite the fact that the milling process is similar to the well-studied processes of rock destruction by chisels and metal processing by cutting [7, 4].

Reserves for improving and increasing the efficiency of the milling process should be sought in the following directions

1. Research of composite materials, which are coated on the body of tools and form their cutting part;
2. Reliable theoretical and experimental modelling of the process of their interaction with the emergency object;
3. Synthesis of wear-resistant materials as armament with given properties, compatible constructive and technological parameters of their functioning; in borehole conditions.

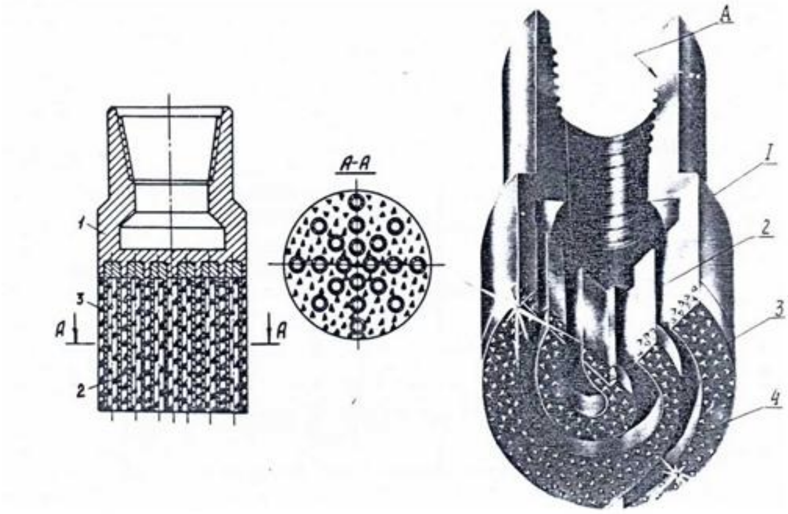
A number of works [2] are devoted to the study of various aspects of the production and operation of composite materials and the serviceability of composite products.

A significant increase in the cutting properties and wear resistance of tools can be achieved by proper orientation of shape-classified grains of solid filler material [6].

Ensuring and improving the cutting properties of milling tools in general is a complex set of different problems involving the implementation of a number of design, technological and operational measures [5]. The milling tools shown in (Fig.3) are the result of attempts to solve the problem of intensification of the milling process by appropriate design changes. The operational measures should include the prevention of thermal shock in the heating-cooling cycle (Fig.4) and thermal fatigue on the cutting surface of the tool, scattering [8] the values of mode-technological factors.

The kinetics of the wear processes of working bodies of tools such as downhole milling cutters and its interrelationship with the thermophysical processes accompanying tool operation are very complex and multifactorial. The study of this relationship in the thermal formulation is to solve contact thermodynamic problems with the phenomenon of wear. The solution of such a problem is ultimately reduced to the differentiation of complex integral equations with moving natural boundary conditions. Obviously, the complexity of both the formulation and the solution explains the absence of such studies. The authors [9] have attempted to solve such a problem in an experimental formulation, and their work differs favourably from previous studies in this direction.

It was found that, depending on the energy supplied to the bottom hole, pre-critical (moderate wear) and sub-critical (catastrophic wear) modes of tool wear are possible. The transition from one wear mode to the other is explained by the change in cooling conditions; at the transition there is a temperature jump (Fig.4) at the tool face, which in turn contributes to the change in the character of the wear process. Simultaneously with a sharp increase in temperature, there is a jump in power consumption (N ~ Fu, where N - power consumption, F - axial load, u - tool speed) at the transition to subcritical operation. Processing of the experimental results showed that in the subcritical mode the wear of the matrix of the cutting part of the tool increases 3-4 times. As a result, it was concluded that it is possible to solve the problem of automatic maintenance of the operating mode in the subcritical range without burns and catastrophic wear.



a *b*

Figure 3: *Downhole milling tools:*
a - with inserted metal tubes (I - casing, 2 - cutting: element, 3 - metal tubes);
b - with moulded cooling system (A - fixing thread, I - body, 2 - flushing hole
3 - cutting section, 4 - Archimedean spiral channel).

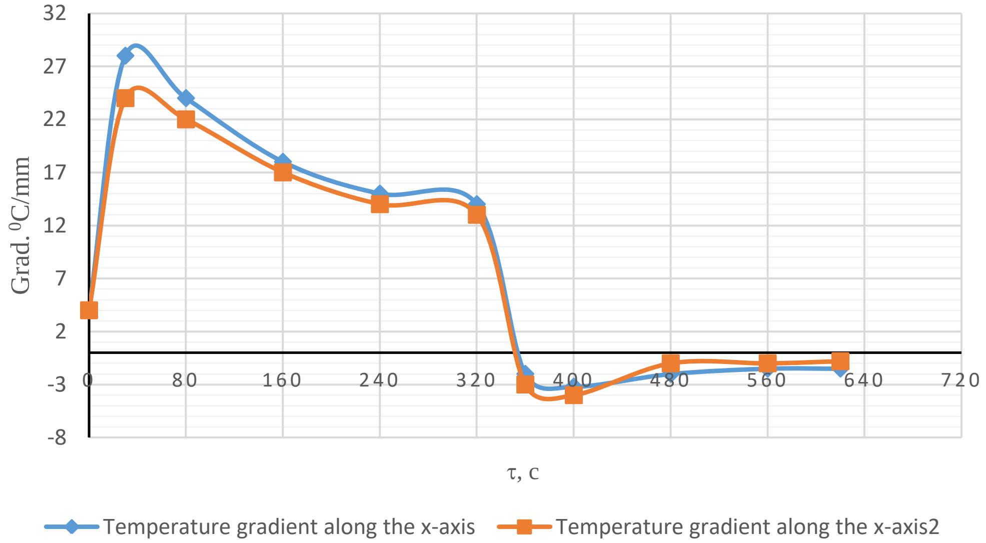


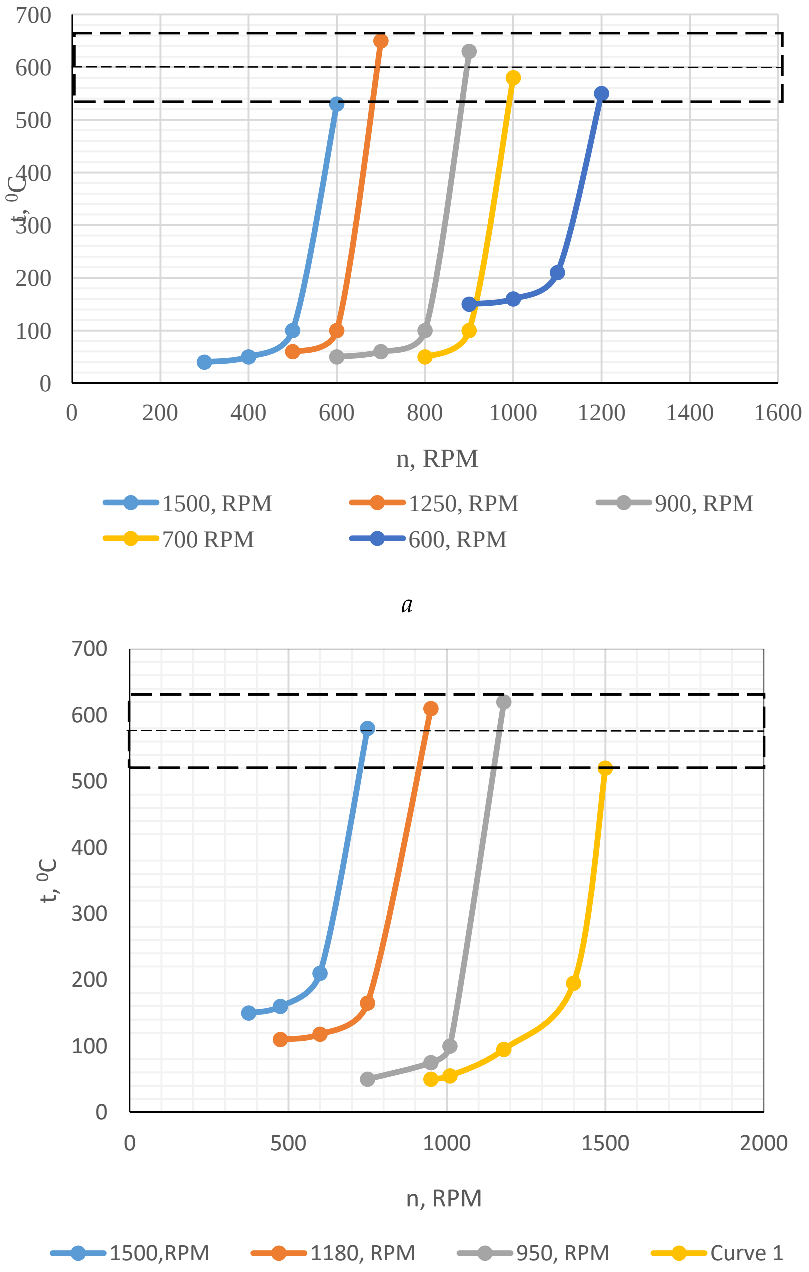
Figure 4: *Variation of temperature gradients in the heating/cooling cycle*

The disadvantage of this work is that the investigated factors do not include the flow rate of the flushing fluid, the flushing scheme and a number of other factors that significantly influence the intensity of the thermophysical process that develops during the destruction of an emergency object. However, the rheology of the flushing fluid, its composition and flow regime is one of the most accessible, universal and, in most cases, economical means of increasing the thermomechanical stability and wear resistance of cutting tools [3-5].

One of the most complex and labour-intensive types of work performed during overhaul is catching work [8,9]. The tools used for catching work are divided into three groups according to the principle of pipe gripping (Fiq.5):

- Tools with pay and wedge gripping devices;

- Tools with thread-cutting gripping devices;
- Other gripping tools.



a

b

Figure 5: *Bit temperature as a function of axial load (a) and drill speed (b)*

The efficiency of slotted tools, which are the most widely used in practice, is determined by the perfection of the design and kinematic characteristics of the gripping device, which determine the reliability of the adhesion of the slots to the surface of the pipe body for successful unscrewing. The main load-bearing node of the jaws is also the node of the gripping device, the reliability of which determines the operability of the tool design as a whole.

It should be noted that a number of theoretical and experimental works [3-7] are devoted to the study of the force and kinematic interaction of the gripping device with the surface of the pipe to be gripped. Due to a significant simplification of the force and geometrical relations of the interaction process, these works do not fully reflect the actual deformed state of the gripper elements and the surface of the catching pipe.

The main factors that determine the design characteristics of the gripper are the reduction of the specific pressure generated by the movement of the dies on the inclined support surface and the prevention of changes in the shape of the catching tube in the gripping zone. In addition, the requirements of the specified tool should be met without compromising the tool's load-bearing capacity.

One of such technical solutions in the specified direction is a downhole tool with a gripping device in the form of a spiral, developed in SOCAR. Such a design of the gripping device with optimum design parameters allows to increase the working area of contact with the pipe and thus to make full use of the rated load capacity of catching tools when eliminating complex accidents by applying maximum axial loads (Fig.6).

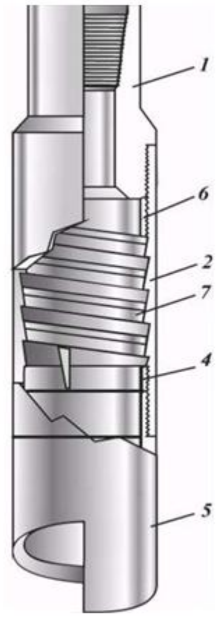


Figure 6: *Catch tool with spiral gripping device:*
1 – upper guide; 2 – housing; 3 – plate grid; 4 – limiting ring;
5 – guiding funnel; 6 – paker; 7 – spiral grid

The problem of increasing the load capacity of catchers with payload gripping devices should be solved by perfecting the process of interaction with the object to be caught. This interaction should not reduce the load-bearing capacity of the caught object in the gripping zone. As a result, the possibilities for increasing the load capacity of flame arresters, which is particularly important for preventing accidents in deep wells, are limited. Therefore, in order to increase the efficiency of catching operations in deep wells together with mechanical flame gripping devices, it is necessary to develop designs of catchers whose gripping devices do not deform their surface when interacting with the trapped pipe.

According to the existing classification of accidents [4], unlike the first (accidents with downhole pipes) and second (accidents with downhole motors, tools, packers and drill string bottoms) groups of accidents, other types of accidents are possible (third group - accidents with cables, ropes, wires, fourth group - other accidents), for the elimination of which downhole cleaning tools are used [6, 8].

This class of equipment includes tools that use the effect of physical fields (magnetic catchers, magnetic milling machines, etc.) to clean the borehole from small metal objects. Despite the fact that the performance of these tools has been studied by a number of authors [4, 5], the efficiency of their use in field practice is comparatively low.

In [5] the reasons for the unsatisfactory operation of magnetic cutters in connection with the increase of the borehole depth are considered, among which a special place is given to the breakaway force arising in the process of technological operation at the cleaning of the borehole from small metal objects.

In order to improve the efficiency of operation, it is considered necessary to make changes in the design of magnetic milling machines produced by the industry of the CIS countries. For this purpose, it is necessary, first of all, to study various factors that determine the design of magnetic milling machines and predetermine the efficiency of their application in deep boreholes. This problem is addressed in the paper [4.49], in which the results of studies on the dependence of the magnetic cutter attraction force on metal objects at different distances from the pole, the influence of the type of washing liquids and temperature on the tool traction characteristics are given.

It is expedient to continue research in this direction in order to meet the requirements of the practice of cleaning the borehole from metal objects.

Accident-free drilling is the main direction of the solution to the problem of improving the quality of drilling and is determined both by the perfection of accident prevention methods and by the adaptation of the measures adopted for this purpose to specific conditions. Among the accidents, the most common in practice (especially in deep wells) and requiring the application of very labour-intensive measures is the seizure of downhole equipment. Because of the time-consuming nature of stuck wells, the means and methods of both preventing and remedying this class of phenomena are constantly being improved [4]. A wide variety of methods are currently used to clear stuck wells. Depending on the situation in the well when a stuck well occurs, any one of these methods, or a particular sequential set of them, may be effective. This is usually the case when the choice of action or set of actions is appropriate to the conditions under which the seizure occurs and the nature of the process. As a rule, the technology of eliminating the seizure is based on the sequential application of means and methods, as well as on their alternation (especially in complex geological and technical conditions). In this case, in order to reduce both material and time costs, it is necessary to have a (theoretical) tool for choosing a rational strategy of tackling.

The use of special technical means (percussors, yasses, vibrators, etc.), the classification of which is given in Fig.7, is no less widespread among the methods of tackling liquidation. These technical means are mainly divided into surface and submersible ones. Surface equipment is not widely used because the depth at which it is effective does not exceed 200 metres. Submersible devices, both mechanical and hydraulic, are mainly used in deep drilling. The main requirements for submersible impact devices to ensure their effectiveness in tackling are

- simplicity of design;
- simple and accident-free application technology;
- the ability to apply shock impulses in the immediate vicinity of the tacking zone.
- possibility to regulate the impact force at the wellhead;
- possibility to apply repeated directional blows the required number of times both from top to bottom and from bottom to top to unseat the seized pipe string;
- reusability, etc.

At present both in domestic [7] and foreign field practice [3, 5] of liquidation of seizure phenomena various shock devices are used, satisfying to some extent the above-mentioned requirements. The main design characteristic of these devices is the dynamic load imparted to the seized part of the string. The application of dynamic load to the pipe string during attempts to release it contributes to the occurrence of significant stresses in it, which may lead to failure. Therefore, the study of the stress state of a tacked pipe string is of great practical interest [4, 6, 7].

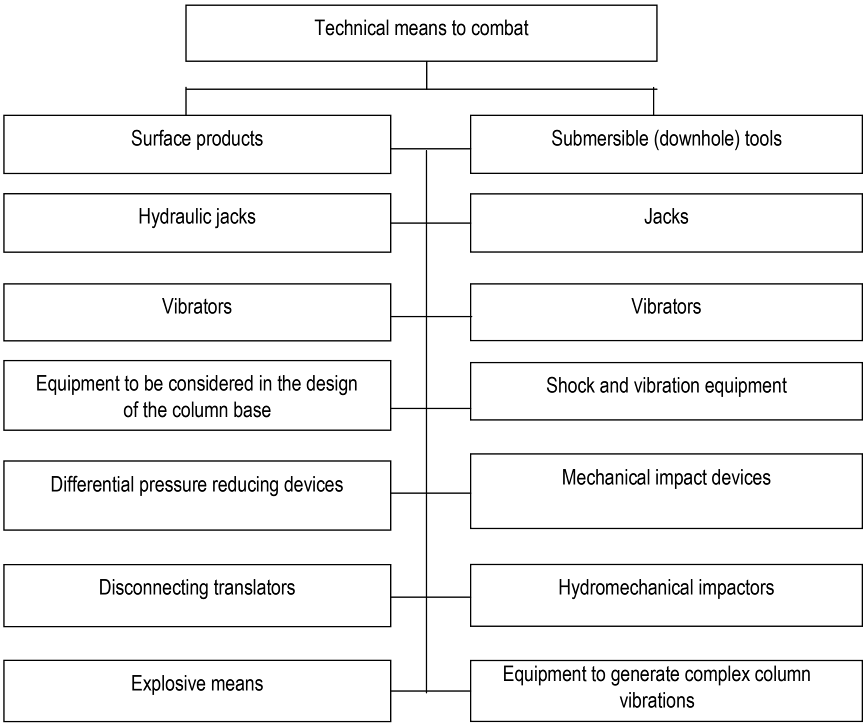


Figure 7: *Classification of technical means of removing tackle*

As a result of a certain class of theoretical and practical calculations, the authors [1-3] found that the dynamic coefficient decreases significantly with increasing well depth. This is explained by the fact that the static component of the total load absorbed by the string increases with increasing well depth. Furthermore, the determining parameters of the dynamic component are the speed of the drill string movement and the number of blows applied to the stuck part of the string. The disadvantage of this work is that it investigates the wave process induced by the application of impulse loads to the stuck part of the string in one direction (from top to bottom) and does not determine the number of blows required to complete the release without damage. However, the conclusions drawn from the results of the work, which consist in the need to impart a large variation in the amount of movement to the gripped part of the string in each test, within the limits allowed by the strength of the pipe, are very valuable and can be a starting point for the development of effective impact devices.

Wave processes in longitudinal elastoplastic impacts are also studied in [1-5]. The efficiency of impact devices used for tacking is also assessed by the possibility of disengagement of the tacked pipe string by impact in opposite directions. Therefore, modelling the tacking process by wave processes developed in one direction does not correspond to the physical model of the interaction between the impactor and the tacked part of the pipe string. This circumstance does not allow to use the models proposed by the above mentioned works to describe the dynamics of the interaction between the impactor and the seized part of the string. In order to accurately reproduce this interaction, it is necessary to develop and study its mathematical model, which provides for the excitation of wave processes developed in opposite directions.

Wells that are technically impossible or economically unviable to rehabilitate using the above methods are rehabilitated by sidetracking and drilling a second well. The rehabilitation of shut-in wells by sidetracking and drilling a second well is an important part of the package of measures aimed at stabilizing the level of oil production in long-developed areas. This method allows wells to be reworked in areas where the conditions and state of reservoir development make it difficult and unprofitable to drill new wells. Sidetracking and drilling a second well increases the number of producing wells at the expense of inactive and previously abandoned wells. This also allows the disturbed development network to be reestablished, corrections to be made to the previous development to be made and previously missed oil targets to be identified, ultimately increasing the oil recovery factor of old reservoirs. The issue of maximizing oil recovery in the late stages of field development has recently become of great national economic importance.

Since the development and introduction of the method of sidetracking and drilling of the second well into the practice of rehabilitation works, both the technology of the works and the technical means for their implementation have been significantly improved. This contributed to the wide application of the method in the oil fields of the North Caucasus and Azerbaijan and some other areas of the CIS countries [1-5], as well as abroad [6]. Recently, however, the volume of well rehabilitation using this method has decreased significantly due to the increase in well depths and the complexity of the operations. The complexity of the sidetracking process in deep wells places special demands on the development of technical means and technological measures for this purpose. It should be noted that the efficiency of sidetracking, in addition to the use of high-performance equipment and technology, is also significantly influenced by the correct choice of the object to be targeted [5.7]. This means that it is first necessary to assess the economic feasibility of this operation in accordance with the geological and technical characteristics of the wells. In studying this issue, criteria should be established for assessing the technical and economic feasibility in each individual case of workover or reworking of a well.

The problem of choosing the shape of the deflection surface of the deflection wedge is very controversial, and it should be solved not independently for the deflection wedge, but in the complex of problems related to obtaining a "window" of the required dimensions in the production line from the point of view of tool permeability. This means that, in order to obtain a "window" of the required dimensions with good permeability, it is necessary to develop compatible conditions "well design - deflector - ripple - technological factors". In [3], "tentative" attempts were made to develop these conditions, which would allow the shape and size of the deflector surface to be designed according to the "window" permeability criterion. According to the results of experimental studies with the design of the developed rayber, it was found that the most acceptable is the flat shape of the deflection surface, and the design of such a deflector was developed [4]. However, when flat wedges are used, the specific pressure generated during the operation of the rayber is greater on the wedge surface than on the pipe surface [8]. As a result, a strip of metal is cut from the wedge body rather than from the pipe wall, as was the case with the "window" cuts in the production string at Khydyzhenneft Oil and Gas Production Department.

After the deflector has been lowered and landed, a window is cut in the production string. Opening the "window" in the string is a very important operation. The degree of perfection of the working technology and structures, the equipment used for this purpose determine the configuration and dimensions of the "window" to be cut in the column. Conformity of the configuration and dimensions of the "window" to the further conditions of the second borehole conduction is estimated by the character of possibility of drilling tools and geophysical instruments used for various purposes during drilling.

Otherwise, as practice shows, the results of works are reduced to obtaining a "window" with wrong dimensions, which considerably complicates further work, obtaining a "window" with wrong dimensions can be promoted by such constructive features of cutting tools and deflectors.

In spite of the significant improvement of the second hole cutting process in recent years, it is not always possible to avoid additional time and costs due to possible complications [1-3].

The most common accidents and complications are 1) jamming of the cutting tool; 2) premature exit of the cutting tool behind the string; 3) breakage of drill pipes or breakage of the threaded connection; 4) displacement from the landing place or rotation of the deflector around the axis; 5) strong absorption of the mud.

In some cases, in order to obtain a high mechanical speed, the established rules for the technology of opening the "window" in the string are not respected. The mechanical opening speed depends on the load axis, the number of rotor revolutions, the steel grade and the condition of the production column, the pump capacity and the design features of the tool and the deflector. When designing the conditions for cutting a "window" in the string, it is necessary to provide such a combination of the above factors that would allow obtaining a "window" of the required configuration and dimensions and satisfy the criterion of absence of complications such as "tool jamming". In addition to the jamming of the tool with a full stop, there is often an instantaneous jamming and release of the tool. In this case, the tool works by jolts, as a result of which there is a phenomenon of torque impact, accompanied by the emergence in the drill pipes, reaching quite high values of stresses that can lead to the breakage of drill pipes [3].

Summarising the above phenomena, it can be concluded that the cause of complications and accidents when opening a "window" in the production string are design deficiencies of cutting tools and deflectors, their incompatibility with each other and with the well conditions, the lack of a reasonable process technology and of appropriate criteria for assessing the quality of the cut "window". A vector combining the design parameters of the borehole, cutting tool and deflector, as well as the technological parameters of window cutting, can serve as a state vector for the development of such criteria. Depending on the degree of compatibility of these parameters, the cut "window" can be of three classes: 1) "window" good - passable; 2) "window" satisfactory - passable, but with a risk of jamming; 3) "window" unsatisfactory - not passable for the cutting tool. Naturally, this poses the task of developing the necessary algorithm, in the state vector space for the possibility of designing the conditions of cutting through the "window" of good quality.

The main drawback of previous work in this area is that it has focused on the study of local problems in isolation, which has not allowed us to develop a set of measures to improve the quality of the "window". In particular, the design of the deflector [5] and the window cutting device [9] have been improved in order to obtain a full profile window equal to the line of the deflector chamfer and to prevent premature tool exit behind the column. The design of the deflector (although the degree of its manufacturability is relatively low) and the design of the device are both highly original.

However, the unconditional efficiency of their use together (or in combination with other designs) cannot be claimed. In order to assess the effectiveness of the interaction between the deflector and the cutting tool, [7.3] presents the results of experimental studies of five variants of their combinations. The aim of the experiments was to study the influence of the design of the applied technique on the length and shape of the "window" and to develop measures for selecting the most effective design of the cutting tool and deflector, as well as to determine the optimum mode of opening the "window".

Due to the fact that the designs and shapes of the cutting tools (Fig.8) and deflectors used are different, it is of great practical importance to determine the value of the areas where friction occurs. The area of friction where both the string and the deflector of cutting tools of different design rub against the wall of the production string in the process of opening the "window" determines "the value of the specific pressure at the points of contact between the interacting bodies.

Perfect are the designs of cutting tools that do not wipe the deflector, cut through the column to the end of the deflector bevel and create a high specific pressure on the friction surface at a relatively low load. The magnitude of this pressure is determined both by the geometric shape of the cutting part of the tool and the direction of the main vector of the forces acting on it as it cuts through the "window".

In order to ensure trouble-free operation of the drill string and avoid premature cutting tool exit, the authors [9] developed and tested a Drill Pipe Bending Straightener (DPBS) on a number of SOCAR wells. The use of the Drill Pipe Bending Rectifier (DPBR) when opening the "window" in cased wells prevents the premature exit of the cutting tool from the string, regardless of the axial loads, and makes it possible to reduce the resulting bending stresses in the drill pipe by about 10 times. It is recommended that the first drill pipe bending straightener be installed at a distance of (1.5-3) m from the cutting tool, and subsequent ones at a distance of 6 m from each other. However, these recommendations are not confirmed theoretically, which does not allow to adapt the arrangement of drill pipe straighteners to specific conditions of their operation in the process of opening the "window" in the production string.

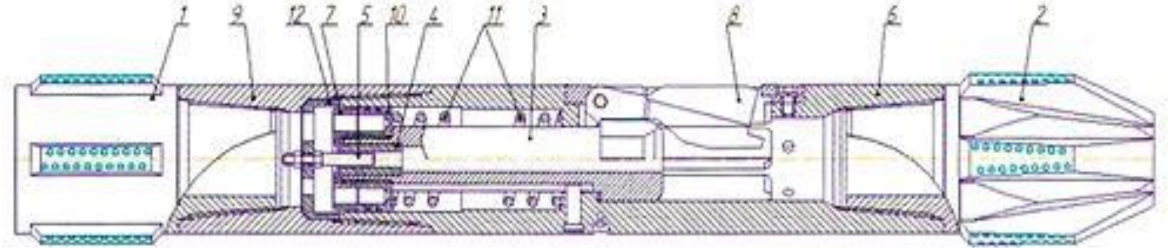


Figure 8: *Milling cutter with cutting centring direction:*
1 – upper centering device; 2 – lower centering device; 3 – shaft; 4 – shaft bushing; 5 – needle; 6 – housing; 7 – cover; 8 – blade; 9 – guide; 10 – piston; 11 – spring; 12 – grid

III. Results

The result of the analysis of the serviceability of tools used for carrying out repair and recovery operations in oil and gas wells will allow to determine the main directions of improvement of repair techniques and technology. Formation of a set of tasks to solve the problem of improving the efficiency of production of repair and recovery operations at emergency oil and gas wells.

Analysis of the performance of oil well rehabilitation equipment is a key element in improving the efficiency of production and ensuring stable operation of oil companies. The analysis includes the change in daily and annual production after the introduction of new equipment. It should be noted that efficient equipment also reduces well maintenance and workover costs.

The introduction of new technologies and the continuous improvement of equipment play a crucial role in achieving this goal. In the future, we can expect to see further development and innovation in well rehabilitation technology, leading to more efficient and sustainable oil production.

References

[1] Grudz, Volodymyr, Grudz, Yaroslav, Bevz, Volodymyr, Chernetsky, Mykhailo. Dynamic analysis of well equipment to produce oil. // J. Mining of Mineral Deposits. – 2020, Vol.14, N1. – Pp.82-89. DOI:10.33271/mining14.04.082.

[2] Bozorgian, Alireza. Investigation of Well Equipment in Oil Industry. // International Journal of Advanced Studies in Humanities and Social Science. 2020, Vol.9. – Pp.205-218. DOI: 10.22034/ijashss.2020.255356.1019.

[3] Abdollahbeigi M., Choobineh M.J., Nasrollahzadeh B., Nano Catalyst, Operation Mechanism and Their Application in Industry. // Australian Journal of International Social Research, 1(5) (2015), pp.1-6

[4] Mullakaev M.S., Abramov V.O., Abramova A.V.. Development of ultrasonic equipment and technology for well stimulation and enhanced oil recovery. // Journal of Petroleum Science and Engineering 125 (2019) 201–208.

[5] Guluyev G.A., Pashayev F.H., Jafarov J.M. Some Methods and Algoriths for Evaluation of Well Equipment and Regime Parameters in Rod, Depth Pump Oil Wells. // International Journal of Latest Engineering Research and Applications. – Volume – 08, Issue – 09, September 2023, Pp.8-18.

[6] Mukeshimana C. Application of the Model of Fuzzy Logic to Evaluate the Quality of Data Transfer in Networks of the Industrial Internet of Things. Computertoolsineducation, 2019, N 1, Pp.29–42.

[7] Meiyi Jiang. Discussion on the countermeasure of improving the development effect of oil well dynamic analysis. // E3S Web of Conferences 375, 2023 https://doi.org/10.1051/e3sconf/202337501037 ESAT 2023.

[8] Yang Haiwei. Application of oil-well dynamic monitoring data in oilfield development dynamic analysis [J]. Chemical Engineering and Equipment,2020 (04):58-59.

[9] Yang Lei. Application of oil-well dynamic monitoring data in oilfield development dynamic analysis. // [J]. China Petroleum and Chemical Standards and Quality, 2021, 41(20). – Pp.57-58.