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Research on the operation of a device for influencing the bottomhole zone of wells in depleted fields

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Abstract. The development of wells in the late stages of oil and gas field development is complicated by contamination of the bottomhole zone with process fluids due to a significant decrease in reservoir pressure. Existing methods of cleaning tubing or drill pipes to restore permeability are often ineffective due to the small volume of these pipes, the lack of measurements of the pressure drops generated, and the use of special equipment and maintenance services. Therefore, the aim was to study a device for influencing the bottomhole zone of the formation, which involves conducting suction not through tubing, but through a production string, measuring the magnitude of depressions-repressions, as well as the possibility of performing these works directly by the drilling crew. Theoretical, experimental and industrial research made it possible to create a device, the advantage of which is that its use makes it possible to significantly increase the magnitude of the depressions created, measure the depressions created, and record the curve of reservoir pressure recovery during swabbing. In addition, no additional equipment (geophysical drawworks, packer, etc.) was used except for that available to the drilling crew or overhaul crew. Dynamic stimulation of the well was achieved by creating hydrodynamic cyclic loads (depressions, repressions) on the bottomhole zone of the formation in order to clean it from contamination. The possibilities of creating cycles of depression-repression, their magnitude, and the loads that arise during swabbing were investigated. The possibility of conducting hydrodynamic studies in unstable modes with the removal of the pressure recovery curve directly during the swabbing process was proven. In addition, during the well development process, the device design provided for hydrodynamic studies. The device was successfully implemented at two wells in the Carpathian Region

Keywords: colmatage substances; well development device; swab; depression; repression; hydrodynamic studies of wells

Introduction

Swabbing is one of the most effective methods for inducing flow in wells with low reservoir pressure. At the present stage, technologies for cleaning tubing are used. These technologies are often ineffective because they create cycles with insufficiently high levels of repression-depression. In addition, they require the use of special equipment that is not available at production or drilling companies. Oil and gas wells that are coming out of drilling or after repair, especially in depleted fields with low reservoir pressure, are often very difficult to develop. This is due to pollution of the bottomhole zone and, as a result, a significant decrease in their productivity. In such cases, it is only possible to induce inflow after applying intensification methods, such as creating cyclic depressions in the formation by swabbing. In addition, hydrodynamic studies involving the descent of a deep-sea pressure gauge are necessary to

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determine the degree of contamination in the bottomhole zone. These works are associated with additional costs, loss of time and increased costs of the process.

One of the problems that arise during the development of wells in depleted fields after they have been drilled or repaired is contamination of the bottomhole zone and, as a result, a significant reduction in their productivity. Scientists S.V. Matkivskyi & L.I. Matiishyn (2023) analysed the impact of contamination of the bottomhole zone on the productivity of production wells. The authors assessed how different types of contamination (e.g., mechanical particles, petroleum products, chemical components) reduce formation permeability and decrease well flow rates. Based on the results of modelling and analysis of experimental data, a methodology for assessing the technical condition of the bottomhole zone was proposed and measures for its cleaning were recommended, which contributes to improving production indicators.

Modern methods of well development are often based on scientific principles and research that allow the use of advanced technologies to optimise production. For example, studying the impact of fluid accumulation in the wellbore is critical to understanding which fluid removal techniques are best suited to specific operating conditions. In their work, scientists A.V. Ugrynovskyi *et al.* (2024) considered innovative technological solutions for removing fluid from gas well bottoms, in particular the use of foaming surfactants. They describe the equipment and automated systems for supplying surfactants, and analyse their effectiveness using the example of wells in the Carpathian deposits. The results of the research indicate the feasibility of implementing such systems to improve the stability of flooded wells.

The method of swabbing was discussed in this article. The use of swabbing as a method of well development remains relevant due to its simplicity and effectiveness in conditions where other methods may be unavailable or ineffective, so scientific research and practical experience in this area continue to be valuable for the development of oil and gas fields (Maut *et al.*, 2024). It is a traditional method of well development used to reduce the fluid level in the wellbore, thereby creating a depression that promotes the flow of hydrocarbons from the reservoir. This method uses mechanical impact on the liquid string with the help of special equipment called a swab. A swab is a device that is lowered into a well on a rope or pipe and, when moving upwards, creates a vacuum behind it, which extracts fluid from the rock and lowers the fluid level in the wellbore. This allows the hydrostatic pressure in the well to be reduced, which is crucial for ensuring the flow of hydrocarbons (Jara *et al.*, 2024). Known devices and methods for developing oil or gas wells by swabbing, containing a piston, are used to reduce bottomhole pressure by moving the swab (piston) in the well. When moving upwards, the swab (piston) blocks 90% to 100% of the cross-sectional area of the well tubing, and when moving downwards, it allows 50% to 70% of the fluid flow to pass through the passage channels. The disadvantages of these devices and methods of well cleaning are insufficient hydrodynamic impact on the bottomhole zone of the formation, long duration of the operation, its high cost, and the need for special preparation of the wellhead and tubing string.

There are also known devices for developing oil and gas wells by swabbing, which involve lowering the fluid level by reciprocating movements of a stage plunger in the well, which moves in the tubing. The disadvantage of these devices is that they do not provide for the removal of the colmatant extracted from the formation, which can return to the formation during the reciprocating movements of the plunger (Khan *et al.*, 2023). An analysis of scientific literature has revealed key problems in modern swabbing operations: ineffective cycles of repression-depression, contamination of the formation's bottomhole zone, weak hydrodynamic impact, duration of operations, and the need for complex preparation of the wellhead and underground equipment. In response to these challenges, the device under investigation offers an innovative solution**,** aimed at creating a more efficient and cost-effective method of swabbing. This will significantly improve the development of complex wells, especially in depleted fields. The purpose of the article was to study the operation of a device for influencing the bottomhole zone of wells in depleted fields, which makes it possible to perform swabbing in the production string, induce flow, cleaning the bottomhole zone of the formation from colmatant, as well as conducting hydrodynamic studies in the process of swabbing during drilling or major repairs using only the equipment available at the well for lowering and lifting operations.

Materials and Methods

The diagram of the device, the operation of which was investigated in this article, is presented in Patent No. 135359 (2019) and I.M. Kuper & B.I. Mykhailyshyn (2023). To clarify the characteristics of the device, a prototype and a stand for modelling its operating modes were manufactured. The prototype was tested in two stages: the first stage involved using the prototype with a gap between the sealing unit and the casing string; the second stage involved using the prototype without a gap between the sealing unit and the casing string. During the tests, the following parameters were determined: time (speed) of lowering and lifting operations; axial force during lowering and lifting; volume of displaced fluid through the tubing string. Based on the layout and preliminary calculations, the design and sketches of the main components and the general appearance of the device were developed. During the work, experiments were also carried out and calculations of the structural elements of the device were refined, namely: research to determine the piston stroke required to compress the rubber cuffs to the specified size and the force required for such compression to ensure a specified clearance in the annular space when transferring the device from the transport position to the working position; calculations of the geometric characteristics of the hydraulic cylinder and piston depending on the pressure force required to move the device to the working position; calculations of the shear elements of the device based on the conditions of moving to the working position at the optimum pressure and its removal; calculations of the strength of the structural elements of the device.

To study the change in the diameter of sealing sleeves due to their compression, special templates were made for different sizes of production strings. The device was connected to a hydraulic press and pressure was created in the cavity of the device before the sealing sleeve touched the inner surface of the template of the corresponding diameter. The working characteristics must be determined for each set of sealing sleeves. Based on the results of strength calculations, requirements for materials and components, fits and roughness of mating surfaces, and requirements for the accuracy of their mutual positioning were developed. The hardness of surfaces subject to heat treatment and the requirements for coating individual parts are determined using the NOVOTEST TS-R stationary Rockwell hardness tester (Ukraine) is equipped with two indenters – a ball with a diameter of 1.5875 mm and a diamond cone pyramid with an angle of 120°, test loads of 60, 100 and 150 kg. For parts that come into direct contact with the inner surface of the casing string and are subjected to maximum loads during the descent of the device and its subsequent movement in the string during operation, special alloy steels with cementation of the outer layer and subsequent hardening to a hardness of HRC 52...56 were selected. This technology allows for high surface layer hardness with a plastic core, ensuring strength and wear resistance under alternating loads of maximum values.

When designing the seals for the sealing unit of the device, it was taken into account that the seal material must provide high hardness, tear resistance, as well as high relative elongation values and resistance to aggressive environments at temperatures up to 120 °C. At the same time, the cuffs should have a low percentage of residual deformation to facilitate removal and lifting of the device to the surface. A set of working drawings for the device was transferred to the Dolynska Repair and Production Base of the Public Joint Stock Company Ukrnafta (RBB PJSC Ukrnafta), and the manufacture of a prototype was organised. Design supervision and support for the manufacture of all components of the device were carried out (Fig. 1). Particular attention was paid to the design features and manufacturability of the hydraulic cylinder, piston and centring device. The production of spare parts kits, tools and accessories for the device was also organised (Fig. 2).

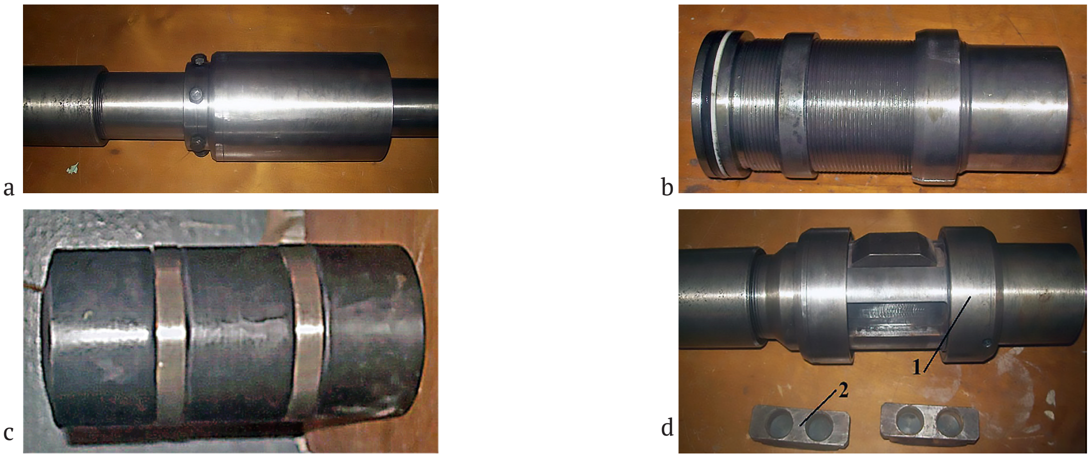

Figure 1. Components of the device

Note: a – device body with hydraulic cylinder; b – sealing sleeve diameter adjustment unit; c – sealing unit; d – centring device (1) with friction shoes (2)
Source: created by the authors

Figure 2. Set of spare parts for the device

Note: 1 – shear and locking screws; 2 – sealing and protective rings; 3 – shear saddles; 4, 5 – locking and limiting rings; 6 – templates for calibrating the outer diameter of sealing sleeves; 7 – special tool
Source: created by the authors

Preliminary tests were conducted on bench equipment in the laboratory (Fig. 3).

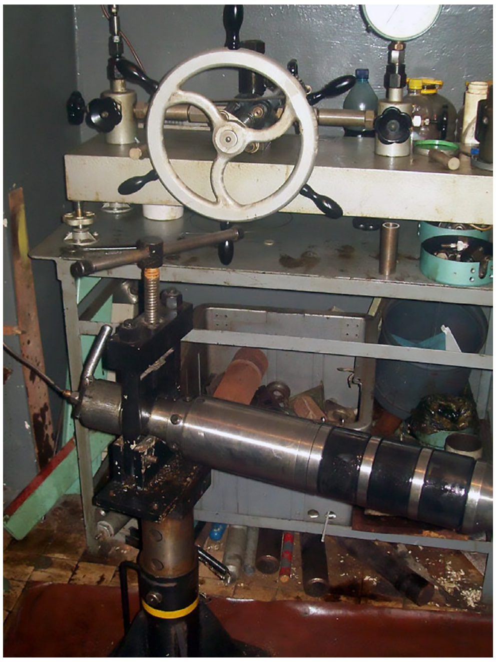

Figure 3. Preliminary testing of the device on a test bench
Source: created by the authors

The tests were conducted by creating pressure in the device cavity. Under pressure, the piston begins to move in the hydraulic cylinder, compressing the rubber sleeves to a specified diameter depending on the inner diameter of the production string and the required clearance between the string wall and the device. In the working position, the piston and cuffs were fixed by a locking device. The piston stroke and, accordingly, the diameter of the cuffs in the working position are adjusted using a special limiter. During testing, a series of cycles were performed to bring the device into working condition at different limiter positions, and the parameters and characteristics necessary for its adjustment before use on production strings of different internal diameters were determined.

Based on the data obtained, the operating characteristics of the device were determined for two sets of sealing sleeves for production tubing with diameters of 146 and 168 mm. After manufacturing and adjusting the device for a production string diameter of 146 mm and bringing it to working condition, experimental industrial tests were conducted. The purpose of the tests was to check the functioning and study the operating parameters of the device under various operating modes in real operating conditions. The technical characteristics of the prototype device for influencing the bottomhole zone of wells are given in Table 1.

Table 1. Main technical characteristics of the device

Technical characteristics	Numeric value
Diameter of the production string in which the device can be used, mm	146
Wall thickness of the production string, mm	from 6.5 to 10.7
Range of sealing unit diameter settings, mm	from 118 to 133
Pressure required to put the device into working position, MPa	10
Shear pressure of the valve assembly seat before lifting the device from the well, MPa	from 20 to 25
Principle of switching to working position	hydraulic
Overall dimensions, mm: ◈ outer diameter of the body ◈ outer diameter of the centraliser ◈ length	 118 140 1,515
Connection thread to the string TUBING GOST 633-80	73

Source: created by the authors

The first experimental industrial tests of the device were conducted to determine its performance and debug all its components in industrial conditions. In this regard, wells 2-Monastyrchany and 811 Pasichna, which had been inactive for a long time and in which no significant increase in flow rate could be expected as a result of the work, were used as test objects. The design of the 2-Monastyrchany well is as follows: a 324 mm conductor was lowered to a depth of 705 m and cemented to the well bottom. The 245 mm technical string was lowered to a depth of 4,221 m and cemented to the bottom. The 146 mm production string was lowered to a depth of 4,221 m and cemented to the bottom. The string was pressurised to 40.7 MPa. Steel grade of pipes for production strings D and E, wall thickness 9.5...10.7 mm. The drilled bottomhole depth was 4,221 m, and the artificial bottomhole depth was 3,850 m. The perforation interval was within the range of 3,603-4,221 m. The reservoir pressure was 19.2 MPa.

The production string was tested using a template with a diameter of 118 mm and a length of 2.5 m to a depth of 3,350 m. After that, a device with a Ukrainian-made AMT depth pressure gauge, a KTSZ-102-60M circulation valve and a pressure test saddle on an equal-strength tubing string with a diameter of 73 mm and a strength group of at least No. 80 was lowered into the well to a depth of 3,300 m. During lowering, the tubing was checked using a 59 mm diameter template. The lowered tubing string was pressure tested at 25 MPa. The bottomhole pressure at the installation site was 18.7 MPa, and the temperature was 87 °C. The weight of the tubing string before the start of testing was 28.5 tonnes.

The tests were conducted using the A-50 lifting unit. The pressure testing of the tubing, the transfer of the device from transport mode to working mode, and the cutting of the saddle were carried out using a CA-320 pump unit from the Kremenchug Automobile Plant. A tank with a total volume of 30 m^3 and a tanker truck were used to collect the fluid pumped out of the well. The wellhead was connected according to the diagram shown in Patent No. 135359 (2019) and in I.M. Kuper & B.I. Mykhailyshyn (2023). The swivel hose was inserted into the container. The tests were conducted in two stages: the first stage involved cyclical movement of the device in the production string with 40-second stops at the upper and lower points, and the second stage involved movement without such stops.

The device was also tested in well 811-Pasichna. The well design was as follows: a 324 mm conductor was lowered to a depth of 1,838 m and cemented to the bottom. The 245 mm technical string was lowered to a depth of 3,610 m and cemented to the bottom. The 168 mm production string was lowered to a depth of 1,901 m, and the 146 mm string was lowered to a depth of 1,901-3,970.29 m and cemented to the bottom. The string was pressure tested at 28.9 MPa. The steel grade of the production string pipes is D, E and K with a wall thickness of 8.9...10.7 mm. The drilled bottomhole depth was 4,400 m, and the artificial bottomhole depth was 3,970 m. Current state of the bottomhole: head of emergency tubing 73 – 3,661.3 m. The perforation interval is within 3,895-3,897 m. Reservoir pressure is 47.8 MPa at a depth of 3,960 m. The production string was cased with a 118 mm diameter and 2.5 m long casing to a depth of 3,350 m. After that, device -146 with an AMT depth pressure gauge, a KTSZ-102-60M circulation valve and a pressure testing saddle on an equal-strength tubing string with a diameter of 73 mm and a strength group of at least No. 80 was lowered into the well to a depth of 3,300 m. During lowering, the tubing was calibrated using a 59 mm diameter template. The lowered tubing string was pressure tested at 25 MPa. The bottomhole pressure at the installation site was 18.7 MPa, and the temperature was 87 °C. The weight of the tubing string before the start of testing was 28.5 tonnes. Work on the development of technical documentation, manufacture and implementation of a device for the development and exploration of wells was carried out at the Research and Design Institute of PJSC Ukrnafta (RDI PJSC Ukrnafta).

Results and Discussion

The results of studies to determine the piston stroke required to compress rubber cuffs to a specified size are shown in Table 2 and Figure 4.

Table 2. Research to determine the piston stroke required to compress rubber cuffs to a specified size

Casing string size	Inner diameter of the template, mm	Working stroke of the piston, mm (cuff set No. 1)	Working stroke of the piston, mm (cuff set No. 2)	Operating pressure, MPA
146 × 10.7	124.6	23	29	3.0
146 × 9.5	127	30	35	4.2
146 × 8.5	129	35	39	4.2
146 × 7.7	130.6	38	43	4.8
146 × 7.0	132	42	47	4.8

Source: created by the authors

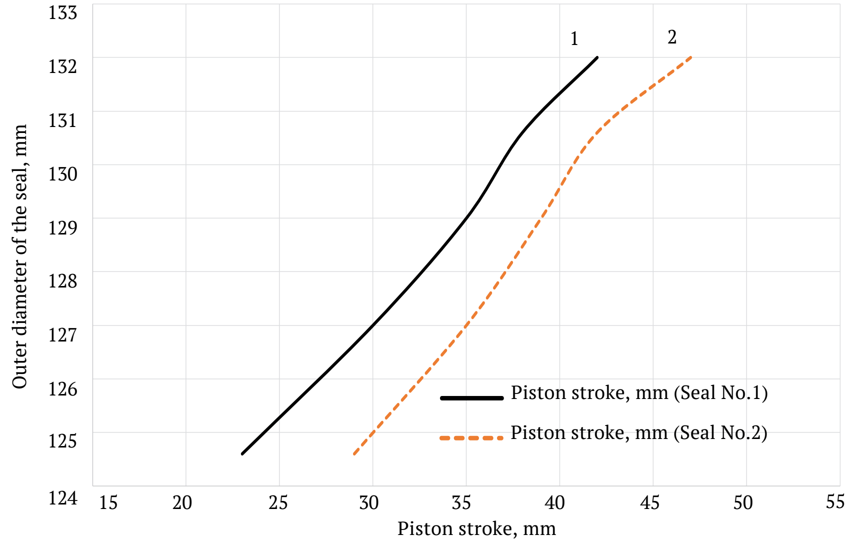

Figure 4. Dependence of the diameter of the sealing cuff of device -146 on the piston stroke with a pusher
Source: created by the authors

Taking into account the relevant calculations and preliminary design of components and parts, the configuration of the dimensions of each part and the design as a whole was refined. The geometric characteristics and main dimensions of the device components were determined. Table 3 shows the results of calculations of the axial force that arises during the operation of the device. The 2-Monastyrychany well was put into operation in 1991 with an initial gas flow rate of 150,000 m^3/day and condensate flow rate of 17 t/day. The initial reservoir pressure was 49.8 MPa. During 1991-1993, gas production declined significantly to 30,000 m^3/day and remained at this level until 2002. In 2003-2005, gas flow ranged from 17 to 9 thousand m^3/day at operating pressures of 3.5/7.0 MPa. During the first year of operation of the well, there was a sharp drop in reservoir pressure from 49.8 to 31.4 MPa, i.e. to the average for the deposit. Subsequently, with a decrease in withdrawals, the pressure decline slowed down somewhat, with the pressure measured in 2007 standing at 23 MPa.

Table 3. Calculation of loads during device operation using a typical well with averaged data as an example

Inner diameter of the well	m	0.126
Outer diameter of drill pipes	m	0.073
Drill pipe wall thickness	m	0.007
Swabbing depth	m	3,000
Liquid density	kg/m^3	1,000
Pipe material density	kg/m^3	7,850
Calculation results		
Pipe weight	kg	34,163.5
Annular space volume	m^3	24.838
Mass of the liquid in the annular space	kg	24,838.2
Volume of liquid in pipes	m^3	8.198
Mass of liquid in pipes	kg	8,197.76
Extra weight (from swab friction)	kg	200
Total weight on the hook	kg	67,399.5
Hook load	kN	661.19
Pipe area	m^2	0.00145
Pipe stresses	MPa	455.31

Source: created by the authors

The test results are shown in Table 4. As a result of the tests conducted on the release device, its performance in various operating modes was analysed. A total of 36 cycles were performed, each consisting of the device operating in two directions – up and down. At different stages of testing, the length of the working stroke varied and was 4 or 8 metres. At the same time, the number of cycles in the series varied from 5 to 15, which indicates the possibility of adjusting the swab operating mode depending on the specific conditions of the well.

Table 4. Results of testing device -146 in well 2-Monastyrchany

Stages of work	Start of the stage, h., min.	Working stroke of the device, m	Number of cycles	Lifting force on the hook without taking into account the weight of the tubing string, ts	Average lifting speed, m/s	Unloading of the tubing string during lowering, ts	Average lowering speed, m/s	Maxi mum depression, MPa	Maxi mum repression, MPa
1. Addition of 3.8 m^3 of formation water to the tubing string to a pressure of 1 MPa (device landing)	12. 32	-	-	-	-	-	-	-	-
2. Cyclical movements of the device in the production string (with 40-second stops at the upper and lower points)	12. 50	4	5	5.8	0.13	4.8	0.13	5	2.1
	13. 05	8	5	6.3	0.13	12.7	0.13	5.7	5.7
3. Cyclical movements of the device in the production string (without stopping at the upper and lower points)	13. 22	8	15	7.6	0.18	4.9	0.40	9.0	5.4
4. Stop to stabilise pressure	13. 35	-	-	-	-	-	-	-	-
5. Cyclical movements of the device in the production string (without stopping at the upper and lower points)	14. 28	8	15	8.0	0.20	6.7	0.50	8.7	5.6
6. Cyclical movements of the device in the production string (with 40-second stops at the upper and lower points)	14. 42	8	5	7.1	0.13	7.7	0.26	8.9	6.1
7. Stop to stabilise pressure	14. 55	-	-	-	-	-	-	-	-
8. Addition of 0.41 m^3 of formation water to the tubing string to a pressure of 8 MPa (circulation valve pin cut)	15. 15	-	-	-	-	-	-	-	-
9. Lifting the device from the well	15. 54	-	-	-	-	-	-	-	-

Source: created by the authors

During the analysis of the device's speed characteristics, it was found that its average upward speed varied between 0.13 and 0.20 m/s, and its downward speed varied between 0.13 and 0.50 m/s. An increase in lowering speed to 0.50 m/s may be associated with a reduction in hydraulic resistance when lowering the swab. At the same time, such variability in the speed regime is an important factor affecting the efficiency of the drilling process, as it determines the dynamics of pressure changes in the well. Analysis of the forces acting on the device hook made it possible to assess the load on the swab and the characteristics of fluid lifting. When moving upwards, the force varied from 5.8 to 8.0 tf, indicating variable hydraulic resistance. During downward movement, unloading occurred, ranging from 4.8 to 12.7 ts. Such an increase in force load during the lowering of the swab may be associated with the peculiarities of fluid movement in the well, as well as with possible hydrodynamic effects affecting the process of unloading the fluid column.

An important indicator of the effectiveness of the swab is the depression created on the formation, which was recorded using a depth manometer. It varied between 5.0 and 9.0 MPa, indicating a significant reduction in reservoir pressure and the potential for intensified hydrocarbon inflow into the well. At the same time, the significance of the repressions that arose during the lowering of the swab ranged from 2.1 to 6.1 MPa. High repression values may indicate a temporary decrease in fluid inflow due to the effect of pumping fluid back into the formation, which requires optimisation of the swabbing parameters.

Variation of the device speed over a wide range allows the process to be adapted to different hydrodynamic conditions. The maximum force on the hook when lifting up to 8.0 tonnes indicates the device's ability to operate under conditions of significant hydraulic resistance. High values of repression during downward movement can negatively affect pumping efficiency, requiring adjustment of the speed mode. Optimisation of the device's motion control algorithm minimises the negative impact of repressive processes and ensures a stable flow of fluid. Thus, the test results confirm the effectiveness of swabbing as a method of intensifying inflow and indicate the need for further research on optimising the device's operating modes. During the tests, pressure changes were recorded over time using a pressure gauge located below the device. This entry is shown in Figure 5.

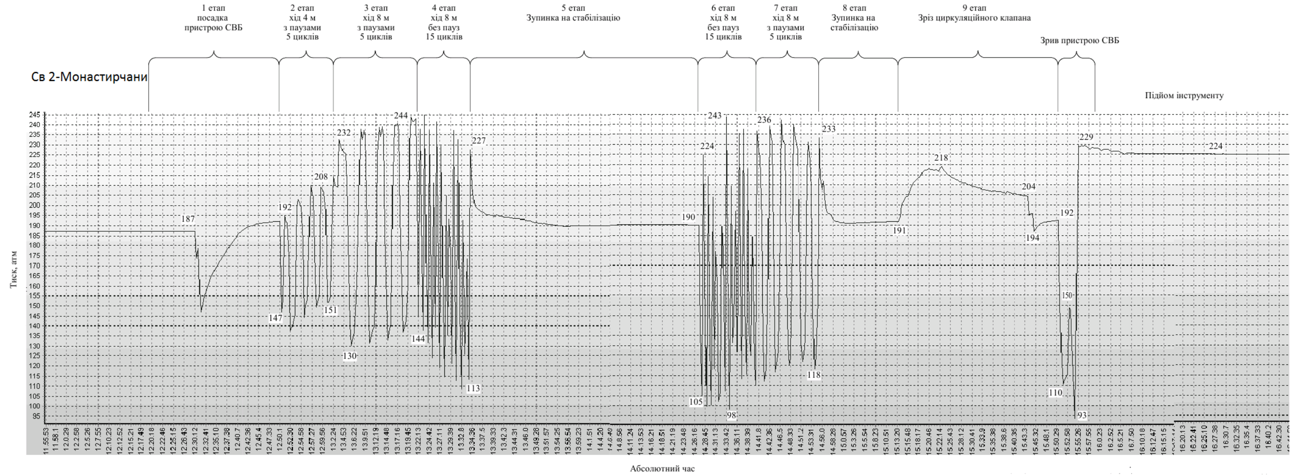

Figure 5. Recording of pressure changes over time using a depth manometer during experimental industrial testing of device -146 in well 2-Monastyrchany

Source: created by the authors

Processing the pressure change curve during the creation of depression-repression cycles makes it possible to establish the filtration characteristics of the formation and their changes as a result of the work carried out. In fact, the recovery curves of reservoir pressure were recorded in each cycle of depression-repression creation. The results of the device testing were similar to those obtained in the 2-Monastyrchany well. Effective well development methods depend on creating a depression, which is the process of reducing the pressure inside the well to a level below the formation pressure. This can be achieved by several methods: replacing the fluid in the well with a fluid of lower density, aerating the fluid, or using gas cushions, instantaneous depression methods, deep pumps, swabs, buckets, jet devices, and capillary systems. Each of these methods has its own characteristics and can be selected depending on the specific characteristics of the well and the formation. Researchers Y.A. Shumakov *et al*. (2022) analysed practical approaches to solving flow assurance problems during testing and cleaning of gas wells.

This is especially true for wells located in depleted fields with low reservoir pressures. The development of such wells requires the search for effective methods of influencing the bottomhole zone, inducing inflow, and conducting hydrodynamic studies. The article by O.G. Semenyaka *et al*. (2019) discussed the modern approach to the operation of wells with reduced reservoir pressure, which requires the implementation of new technical solutions. The aim of their research was to experimentally evaluate the technology for developing wells at the final stage of their development, with an emphasis on selecting the optimal technical approach for extracting reservoir fluid under low pressure conditions. The implementation methodology involves the use of innovative equipment that allows foam to be generated for the purpose of cleaning the bottomhole and wellbore. Future research into the device could consider the use of reagents that form foam.

Another important aspect is development after hydraulic fracturing, as noted by R. Shidhani *et al*. (2022). According to M.A. Myslyuk & V.P. Kravets (2024), well development within the West Khrestishchensky field is carried out immediately after hydraulic fracturing, which increases the efficiency of hydrocarbon flow from productive horizons. Industrial results of development were systematised based on actual data, including examples of successful flow recovery after propant injection. Correlation analysis has established statistically significant relationships between hydraulic fracturing technology parameters and well development efficiency, confirming the feasibility of an integrated approach to well completion and commissioning. The device under study should be used after hydraulic fracturing of the formation for rapid development of the well.

Such technological processes are usually performed separately from each other. At the same time, service production facilities, additional service personnel and technological and transport equipment are involved. All this leads to a significant increase in the cost of well development and exploration. This is discussed in the article by X. Zheng *et al*. (2022). The authors analysed the current challenges facing oil and gas production engineering, including the increasing complexity of technologies, insufficient progress in digital transformation, and the lack of key technical support for energy conservation and emissions reduction. Swab combines several technological processes that significantly reduce the cost of the work performed. Numerous variations and improvements in swabbing are described in the scientific literature. An analysis of the articles was conducted in comparison with the research device. In the article by J. Zhu *et al*. (2019), which reflects the non-stationary processes of plunger operation in gas wells, the authors focused on accurately predicting the dynamics of fluid and gas interaction under variable pressure conditions. However, unlike a computer model, which is mainly used for analytical or simulation planning, the device under study implements the physical creation of depression and repression cycles in real well conditions with simultaneous recording of hydrodynamic characteristics, which is advantageous in an operational environment where unpredictable factors often reduce the effectiveness of preliminary calculations.

Scientists Z. Zhang *et al*. (2022) described the impact of swabbing on long-term well productivity. In particular, the results show that incorrect or excessive drilling can lead to contamination of the formation and a reduction in its permeability due to mechanical damage to the rock. This is confirmed by the significant levels of repression recorded during the swab studies. In this context, the developed device is distinguished by its ability to precisely regulate the speed of movement, which allows limiting the amount of repression and avoiding exceeding critical loads on the formation structure. Scientists A. Mohammad & R. Davidrajuh (2022) described that the effectiveness of swabbing can vary significantly depending on the specifics of the well and the characteristics of the formation. An important aspect is choosing the right type of swab and its size, which best matches the diameter of the well and the physical properties of the extracted fluids. The research demonstrated a significant influence of the working stroke length on the force and speed of the device. This indicates the need to select the optimal drilling parameters for each specific well, taking into account its hydrodynamic characteristics. Compared to their recommendations for modelling, the device under study already integrates on-site pressure measurement capabilities thanks to a built-in depth manometer, which allows theoretical hypotheses to be tested in practice in real time.

Researchers N. Seymour *et al*. (2023) examined the problem of ‘swabbing’ in wells, which occurs due to deformation and blockage of the annular space by the seal, causing significant delays and costs. To address this issue, the authors developed and validated a predictive numerical model that simulates the physical basis of the swabbing effect and helps optimise seal design. The model was verified through physical testing and demonstrated high accuracy in predicting flow velocity, enabling engineering teams to effectively identify swabbing risks and improve seal designs to increase their resistance. The numerical model can be integrated into the device under investigation to improve the design of the device seal. Another aspect that is important to consider when drilling is the temperature of the fluid in the well, as noted in the work of M. Khaled *et al*. (2023). In this regard, it is important to emphasise that special heat-resistant materials were selected for the seals and working components of the device under study, capable of functioning at temperatures up to 120 °C, as confirmed by tests in wells with temperatures up to 87 °C. X. Luo *et al*. (2019) in their review of vortex instruments for fluid extraction emphasised the prospects for automation and continuous process control. At the same time, the practical application of such systems requires complex infrastructure, which has been avoided in the developed device – autonomy and compatibility with basic drilling equipment are significant advantages in cases of limited technical support.

Swab testing, as a method of well development, is used not only for practical purposes to increase well productivity, but also as a means of conducting geological and petrophysical studies. Scientist J. Gagnon (2023) wrote that it can provide important information about the characteristics of the formation, such as permeability, porosity, and the presence of certain deposits in the pores. During the drilling process, when fluid is extracted from the well, a depression is created, causing fluids from the formation to move towards the well. This makes it possible to investigate how easily fluid penetrates through the formation, which is a direct indicator of its permeability. The data obtained during the research on changes in depression within the range of 5.0-9.0 MPa allows to conclude that suction can be used not only as a means of extracting fluid, but also as a tool for assessing reservoir characteristics. Research by S. Abbasova & S. Abbaszade (2023) demonstrates how analysis of data on fluid extraction rate and pressure generated can be used to assess these petrophysical properties of the formation. Similar observations were made during experimental tests, when changes in the speed of the swab affected the level of depression created. This confirms the conclusions about the possibility of using swab testing as a method for diagnosing reservoir conditions and determining the effectiveness of fluid penetration into the well.

Swabbing is also used to assess the condition of wells, in particular to identify areas of colmatage. Colmatation can significantly reduce well efficiency by reducing oil or gas flow. The use of swabbing allows you to identify areas where there is a significant drop in pressure, indicating possible areas of colmatation. Research by C. Liao *et al*. (2023) presented methods for interpreting swabbing data to identify these critical zones. Experimental studies have observed significant unloading during downward movement, which may indicate the presence of zones with increased fluid resistance or reduced permeability at certain intervals of the well. This confirms the possibility of using swab data to assess the condition of the formation and identify problem areas in the well.

In summary, these studies not only help to optimise the use of swabbing in practice, but also provide a deeper understanding of the processes occurring in wells and ways to control them and minimise potential risks. Swabbing is an effective method not only for stimulating fluid flow, but also for conducting geological, petrophysical and diagnostic studies of wells. The advantage of the device under study is that its use does not require additional equipment (compressor, pump unit, geophysical drawworks, packer, etc.) other than that available to the drilling crew or overhaul crew. Dynamic stimulation of the well is achieved by creating hydrodynamic cyclic loads (depressions, repressions) on the bottomhole zone of the formation in order to clean it from colmatant. In addition, during the well development process, the device design provides for hydrodynamic studies. The device can be used for well development as well as for influencing the bottomhole zone of the formation before or after hydraulic fracturing, acid treatment, treatment with surface-active substances, etc., for the purpose of preliminary cleaning of the bottomhole zone.

Conclusions

The operation of a device for influencing the bottomhole zone of wells was investigated. Bench and industrial tests proved the possibility of swabbing a well directly in the production string and conducting hydrodynamic studies directly during the swabbing process. Based on the results of these studies, a device was designed and manufactured, and tested in the 2-Monastyrchany and 811-Pasichna wells. The possibility of drilling a well using a drilling rig or lifting unit was proven.

The depression created in the formation, which was recorded using a depth manometer built into the device, varied between 5.0 and 9.0 MPa, indicating a significant reduction in bottomhole pressure and the potential for intensified hydrocarbon flow into the well. At the same time, the significance of the repressions that arose during the lowering of the swab ranged from 2.1 to 6.1 MPa. Analysis of the forces acting on the hook during operation of the device made it possible to assess the load on the swab and the characteristics of fluid lifting. When moving upwards, the force varied from 5.8 to 8.0 tf, indicating variable hydraulic resistance. During downward movement, unloading occurred, ranging from 4.8 to 12.7 ts. Such an increase in force load when lowering the swab is associated with the peculiarities of fluid movement in the well, as well as with possible hydrodynamic effects.

Variation of the device speed over a wide range allows the process to be adapted to different hydrodynamic conditions. The maximum force on the hook when lifting up to 8.0 tonnes indicates the device's ability to operate under conditions of significant hydraulic resistance. Adjusting the speed of the device allows you to change the values of depression and repression on the layer. The results of experimental industrial tests in the well confirmed the operability and efficiency of the device in creating a hydrodynamic effect (cycles of depressions and repressions) on the bottomhole zone of the formation. The possibility of conducting hydrodynamic studies during the use of the device was also successfully tested. In the future, it is planned to investigate the operation of the device in combination with other intensification methods.

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Conflict of Interest

None.

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Дослідження роботи пристрою для впливу на привибійну зону свердловин виснажених родовищ

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Анотація. Освоєння свердловин на пізній стадії розробки нафтових і газових родовищ ускладнено забрудненням привибійної зони технологічними рідинами в зв'язку зі значним зменшенням пластового тиску. Існуючі методи свабування в насосно-компресорних чи бурових колонах труб для відновлення проникності часто виявляються малоефективними з причини малого об'єму цих труб, відсутності замірів створюваних перепадів тиску та використання спеціального обладнання і сервісного обслуговування. Тому метою було дослідження пристрою для впливу на привибійну зону пласта, які передбачають проведення свабування не через колону насосно-компресорних труб, а через експлуатаційну колону, вимірювання величини депресій-репресій, а також можливості виконання цих робіт безпосередньо буровою бригадою. Проведені теоретичні, експериментальні й промислові дослідження дали можливість створити пристрій, перевагою якого є те, що його використання дає можливість суттєво збільшити величину створюваних депресій, проводити замір створюваних депресій, знімати криву відновлення пластового тиску під час свабування. Окрім того не застосовується додаткова техніка (геофізична лебідка, пакер тощо) окрім тієї, яка є в розпорядженні бригади бурової чи бригади капітального ремонту. Динамічне збудження свердловини досягається створенням гідродинамічних циклічних навантажень (депресій, репресій) на привибійну зону пласта з метою очищення її від забруднень. Було досліджено можливості створюваних циклів депресій-репресій, їх величини, а також навантажень, які виникають під час проведення свабування. Доведено можливість проведення гідродинамічних досліджень на неусталених режимах зі зняттям кривої відновлення тиску безпосередньо в процесі проведення свабування. Окрім того, у процесі освоєння свердловини конструкція пристрою передбачає проведення гідродинамічних досліджень. Пристрій успішно впроваджений на двох свердловинах родовищ Прикарпаття

Ключові слова: кольматуючі речовини; пристрій освоєння свердловин; сваб; депресія; репресія; гідродинамічні дослідження свердловин