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Introduction to Smart Oil and Gas Wells: Drilling, Completion and Monitoring Solutions

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Abstract

The aim behind this study is to provide the reader with a preliminary overview of the "Smart Wells" technologies; starting with the drilling operations, then completion stage and finally the day-to-day monitoring systems. The paper outlines the smart technologies elements, benefits and their operational procedures. It begins with elaborating on the definition of the smart well as well as the importance of applying smart concepts and technologies to the wells in the oil and gas industry. Then, the different ways of applying the smart technologies and their properties are explained. The paper provides a comprehensive overview about the technologies associated with smart wells in the drilling, completion and monitoring. The paper also focuses on reviewing the various phases of the well and the advantageous smart solutions available for each phase. It also clarifies the pre-job planning steps to be taken by the operator for each phase. In addition to that, the monitoring procedure as well as the installation procedures is going to be reviewed. Finally, for each technology discussed in this paper, the advantages are going to be elaborated. The knowledge presented in this study can be used as an introductory to apply smart methodologies and solutions to the oil and gas industry.

Keywords: Smart Wells; Drilling; Monitoring Solutions; Unconventional reservoirs.

Introduction

Improving the productivity of the oil and gas wells has always been a priority for the energy operators. This has become even more important recently especially with the fact that most of easy conventional reservoirs have been already developed and produced [1]. The growing demand of oil and gas makes it imperative to develop the unconventional reservoirs in order to supply enough energy to the world. In fact, that is associated with increase in the drilling and work over costs while drilling in deep waters, as well as other offshore and the horizontal wells. Unconventional reservoirs are usually high risk and require huge early investments in order to be developed which drive the investors away from investing on them. In addition to that, unconventional reservoirs are complicated, hard to develop and most of the time uneconomical to invest in. Smart ways and methods are needed to increase the profitability of such projects. Therefore, it is essential to develop "smart" ways to produce oil and gas from unconventional reservoir.

Smart wells would increase the profitability of the investment by driving the cost to be effective. They also are capable of increasing the Net Present Value (NPV) by reducing the number of drilled wells, work overs and intervention operations. Smart wells have the ability to optimize the overall productivity by controlling the production and injection zones and delay the breakthroughs of gas and water. They also are capable of avoiding/delaying water/gas coning and sand production. That eventually leads to an increase in the productivity of the well (Figure 1). In addition to that, operators can increase the drainage area and production zones with less number of wells by applying smart drilling methods. Another important smart aspect is to be able to collect data while the well is on production without the need to shut-in for intervention or data collecting campaign. That prevents losing oil for interventions and improving the overall economics of the development. Smart well technologies insure an efficient and economical solutions for most of the drilling and production issues and reduce the OPEX cost of the operators for intervention operations to the well significantly.

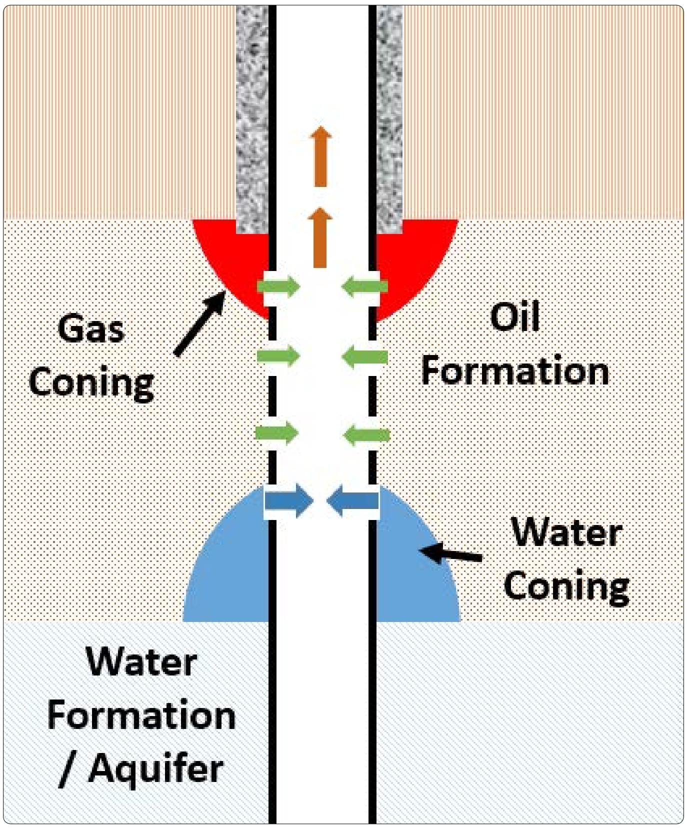

Figure 1. Water and Gas coning.

Therefore, the well has to be completed from the beginning in a "smart" way to insure maximum productivity and profitability thru various stages of the well life. As a result, service companies and research institutes are working hard to develop smart technologies in all stages like drilling, completion and monitoring the well while on production. These advanced technologies stand out with their abilities of controlling the fluid in the wellbore, monitoring the performance of the well through collecting and analyzing the wellbore parameters and more other abilities and advantages, which is going to be discussed further in this paper.

Definition of Smart Wells

Lots of papers and researches define "smart well" as a well that equipped wit h pre-installed high-tech devices in the wellbore that help in monitoring and controlling the well from the surface electrically or hydraulically. They also would have the ability to self-control, collect and analyze the data. However, this paper would take the term and expand it more to start while drilling the well and try to apply smart ways in drilling the wells. The idea of smart wells started with real-time gauges, which can be installed down hole to read the pressure and temperature. Nowadays, there are several available smart technologies that can be applied and depend on many properties; pressure, temperature, fluid composition and characterization. They also depend on the objective of the operators; water shutoff, gas shutoff, eliminating conning effects or maintaining the pressure. Generally, smart wells have the ability to monitor the performance, collect and analyze down whole data.

Smart Drilling

Since most of the easy oil and gas reservoirs are already developed, the need of smart ways to access unconventional reservoirs is undoubted. The best way to achieve a "smart well" is to think smartly from the beginning. Therefore, smart technologies have to be applied in the early stages of the well, precisely when drilling the well. To drill smartly, the ultimate objective is to reduce drilling cost by reducing the well count and access most of the pay zone with the drilled wellbore [2]. In another word, it is a goal for the operators to apply new economical smart methods to drill a well that is capable of producing an amount of production equal to more than one well if drilled in a conventional way. The paper chooses to start with a smart drilling method that has a promising future in adding smart and economical values to the well; that method is the Fishbone. This drilling method is one of the smart newly developed technologies that are used in drilling the horizontal wells. Fishbone can be obtained by drilling each branch (rib) using the advanced rotary steerable drilling systems or by installing numbers of ribs inside the drill pipe which penetrate the formation with the help of the acid stimulation operation (Figure 2). Fishbone technology helps in connecting far points of the formation directly to wellbore and achieving a larger drainage area. The ribs help in achieving more exposure, which leads to increase the production from a single well. They also help in increasing the Net Present Value (NPV) of oil and gas horizontal production wells by increasing the productivity of the well especially in low-permeability reservoirs and challenging formations. In addition to that, the number of drilled wells is less with fishbone technology because the larger drainage area achieved from one fishbone well. Another main advantage is insuring the right placement of the fracture, assure fracture opening and increase the efficiency of fluid transportation from the reservoir to the wellbore, unlike multi and hydraulic fracture methods. That would lead to a delay in the decline of the productivity of the well [3]. Moreover, fishbone operations are considered more efficient compared to multi and hydraulic facture when it comes to operation time and overall project economics [4]. However, pre job designing has to be precise in obtaining the number, length and angles of the ribs to optimize production from the reservoir and to avoid accessing unwanted formations/features. That would be obtained from understanding the reservoir characterizations and using simulation software to predict the optimal fishbone design [5]. Fishbone can be considered as a type of commingle production since it can access different zones especially in compartmentalized reservoirs.

On the other hand, with this kind of drilling methods, which allow extra accessibility to different zones in the reservoir, it is essential to take into consideration the downsides of them. Some serious production issues can occur such as cross flowing between different zones, early water/gas breakthrough and high-unwanted water/gas production. Therefore, the zonal isolation methods have to be applied and installed in those kinds of wells to avoid such issues. The next section of this research is going to elaborate more on those kinds of isolation systems.

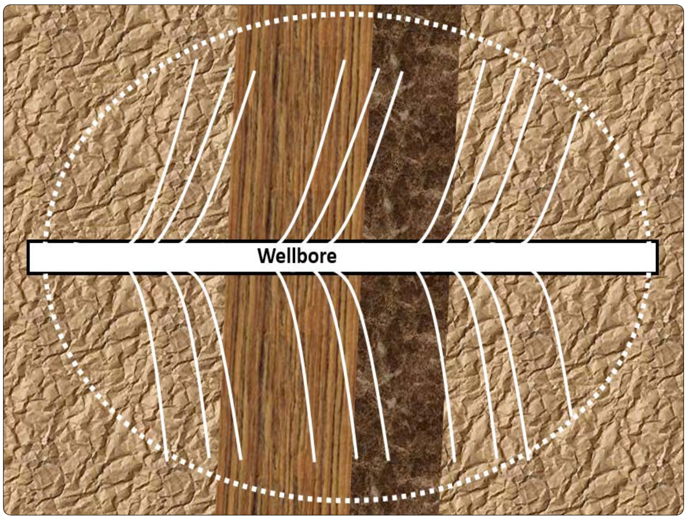

Figure 2. Fishbone well.

Zonal Isolation (Completion)

There are many challenges when completing a new drilled well, especially in unconventional reservoirs. One of most famous challenges is trying to prevent early water or gas breakthrough, especially in the heel section of a horizontal well. Another known challenge is the excessive/unwanted water/gas production from unwanted features/zones, which is well-known in the oil and gas industry. More challenges like cross flow between the zones, non-uniform flow from production zones and sand control issues are well-known challenges in many oil and gas fields. A smart way to overcome those challenges is by applying zonal isolation technologies. They deliver an increase in the productivity of the wells, which leads eventually to an increase in the recovery factor of the field. The isolation technologies maintain good performance for the well by delaying the water/gas breakthrough/conning effects. They can be also used in injection wells to ensure a good conformance in the reservoir by directing the injected fluid to the matrix and desired zones, instead of losing the injection to thief zones and high permeability features. As a result, the adjacent producer would suffer from an increase in the water production because of that. Therefore, zonal isolation is essential to be applied when needed in injection wells.

Zonal isolation generally falls under two main categories; annular isolation and reservoir/feature isolation. Annular isolation aims to isolate specific intervals within the wellbore and optimize the productivity of the well by cutting the communication within the wellbore from the unwanted zones. Reservoir isolation aims to seal off the unwanted zones/intervals within the reservoir and ensure producing from target zones only. Both types of isolations can be achieved using many smart methods and tools. For examples, plugs and packers can be used as physical barriers. Inflow control valves ICVs, inflow control devices ICDs and autonomous inflow control valves AICDs are system that can be used to control the fluid to the wellbore. Formation/reservoir isolation methods can be achieved by injecting polymers, gels or cement to seal the unwanted zones. They typically have higher cost and risk, but potentially deliver better results. Annular isolation methods are faster, cheaper and have the potential to be controlled from the surface in a smart way. This paper is going to focus on the smart annular isolation methods and tools.

Plugs and Packers

Packers are considered as one of most well-known methods to complete wells in a smart way especially for isolation operations and water-shutoff methods inside the wellbore. The practice of using the zonal isolation tools in early stages of the well life, especially in the completion stages after drilling, is very common and beneficial. Inflatable packers are usually successful in optimizing the productivity of the well by eliminating the production from unwanted zones and achieving isolation from unwanted features. Oil operators depend on these kinds of systems to improve the performance of the wells and reduce unwanted production [6].

Inflatable packers are mainly consisting of rubber element, which expand in the wellbore from a smaller to a larger diameter in order to isolate and seal the wellbore from unwanted formations/features [7]. Inflatable or swellable packers are available in different types and various properties depending on the wellbore conditions and properties to accommodate different environments and situations. Therefore, choosing the suitable elements and packers has to be done accurately and with cautions to avoid any kind of failures. Their setting techniques also vary from type to another. For example; swellable packers inflates when they make a contact with a certain fluid, either oil, water or hybrid. Those elements depend also on down hole properties such as temperature, pressure and salinity of water formation. Therefore, the down hole properties must be taken into consideration while designing the packers to avoid failures in setting the elements. If the element does not inflate, the wellbore would produce from unwanted formations/features, which is going to increase the water cut, gas production and an early breakthrough would occur. The other types of packers and plugs are mechanically deployed. They inflate by either sending steel balls or darts down hole or by pumping fluids. That helps in applying pressure on the packer, expand, and increase its diameter. In order to make it more clear, assuming that the unwanted formation or zones are identified using logs; the completion can be designed to place the inflatable in a way to isolate those features from the wellbore (Figure 3).

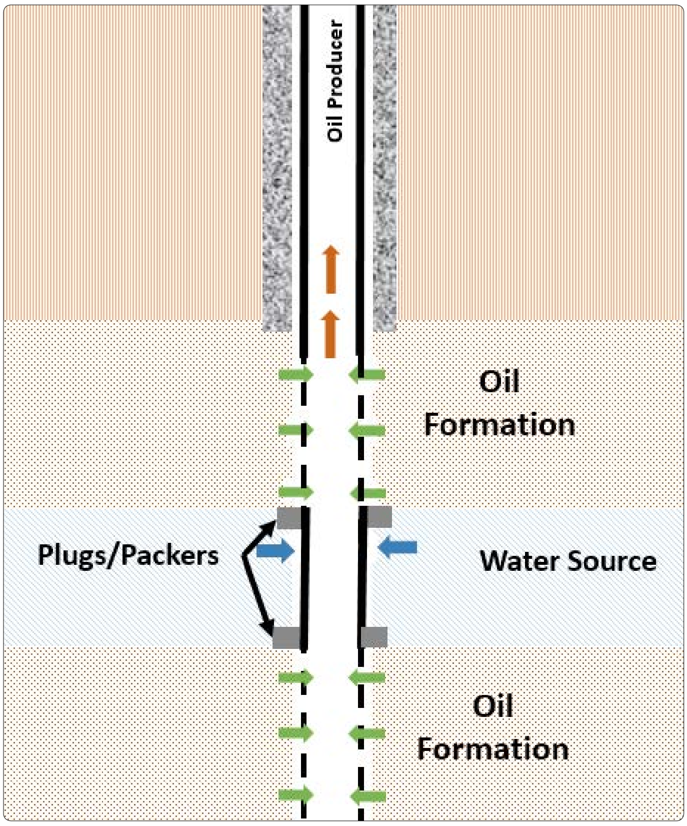

Figure 3. Using inflatables to shut-off the production unwanted zones.

It requires a reasonably decent knowledge of the expected features and layers of the operated reservoir. Also logging while drilling tools are needed and can asset in placing the elements by identifying the unwanted features, which might be the future reason for unwanted production. Usually, the elements are placed on pre-perforated liners after collecting the data from drilling and logging operations. Same technique can be applied for water injection wells to provide better conformance in the reservoir. Plugs and packer can be used in this matter to direct the injected water into the matrix instead of injecting in open/high permeability features and thief zones. That would reflect on production wells and eliminate producing excessive water. For examples, assuming that the unwanted formation or thief zones are known and identified using logs; the completion can be designed to place the inflatable in a way to isolate the injected water from going to those features and direct it to the matrix instead (Figure 4).

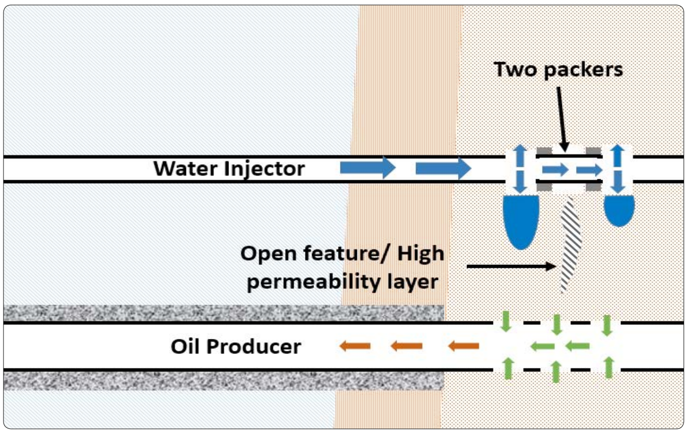

Figure 4. Two packers pre-installed to avoid injecting the water into open features or high permeability layers.

Mechanical External Casing Packers MECP

One of the most effective zonal isolations systems is the mechanical external casing packers (MECP) (Figure 5). It is an upgrade of the external casing packer (ECP) added to it the properties of normal packer used in a cased-hole with a different way of deploying it down hole. It is energized mechanically by applying force on the elastomeric elements, which push to expand and create the seal. This system is mainly applied to provide an effective zonal isolation in the open-hole completions as well as controlling the unwanted production from zone/features [8].

Figure 5. Mechanical External Casing Packer [8].

Inflow Control Valves ICV

Inflow control valves or interval control valves are used to actively control the flow from the different zones of the reservoir to the wellbore remotely. They are working as sets of chokes pre-installed down hole with the completion to control the amount of flow from each zone or to control which zone to be produced. Similarly, they can be used to in directing the injected water in case of injection wells to the targeted zones, instead of injecting into open/high permeability features and thief zones. ICVs can be operated hydraulically through hydraulic control lines using the hydraulic force, which open or close the valves (actuators). They also can be controlled electrically through a telemetry system from the surface that sends the signals through an electrical control lines to operate the valves. These systems are rewarding when applied especially in the reservoir with compartmentalization issues. They are mainly used with other isolation methods such as swellable packers or mechanical external casing packers to deliver a constant flow from the near wellbore area to the wellbore [8] (Figure 6).

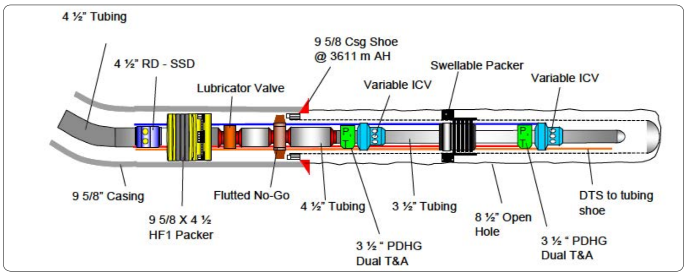

Figure 6. Example of ICV completion with swellable packers [9].

Inflow Control Devices ICD

The main aim from this passive system is to delay the conning effect in the wellbore by delivering an overall stability to the wellbore [10]. The stability is achieved by balancing the drawdown of the production from the different zones. The ICD systems deliver stability to the production profile by creating a drop in the pressure [11]. This pressure drop occurs due to the pre designed orifices and nozzles systems based on the properties of the reservoir (Figure 7). They create an extra obstruction to delay the gas/water conning, especially when the high permeability features/zones exist in the heal section of a horizontal well. The system has to be pre-designed carefully based on the properties of the reservoir to achieve optimal pressure drop and friction. ICDs are mainly used with other isolation methods such as swellable packers or mechanical external casing packers to deliver a constant flow from the near wellbore area to the wellbore [8] (Figure 8). The disadvantage of this system is that when the gas/water conning occurs, the oil production is going to be effected depending on the mobility of the gas or water.

Figure 7. Inflow Control Device ICD [8].

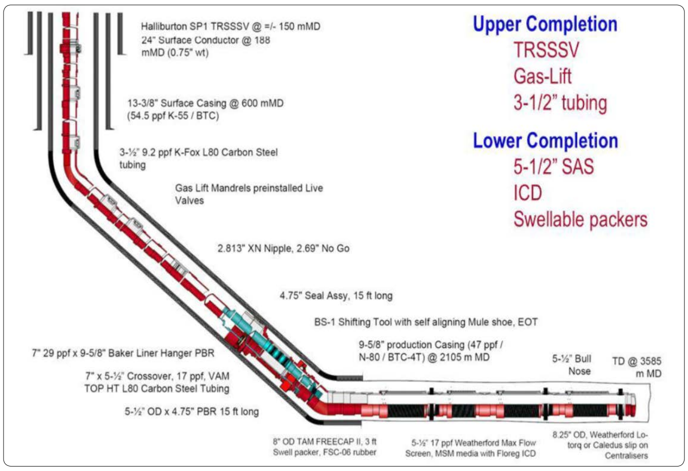

Figure 8. Example of ICD completion with Swellable packers [2].

Autonomous Inflow Control Valves AICD

When it comes to self-controlling the gas production, water and high Gas Oil Ratio (GOR) issues, Autonomous Inflow Control Valves (AICD) are the smart solution to be used. It is an effective system to control the early breakthrough of the gas as well as water. The system creates a smart restriction on the produced fluid based on it is properties, without any kind of control from the operators. It is considered as a self-control device that restricts the production of certain fluid based on pre-designed rate, viscosity or density. In another word, it prevents gas or water from passing to the wellbore while allowing oil to be produced. The system is very beneficial with high GOR wells and has the ability to optimize the production in the reservoir. If AICD systems are installed in the wellbore, there is no need to shut-in well due to high GOR and lose the production from those wells. It can also work with the conning effect or after the breakthrough unlike the conventional inflow control valves. It has a similar design/concept like the electrical submersible pumps ESP. The device consist of plates, floating disks and outlet ports pre-designed to actively control or allow the fluid to pass through based on its properties or rate [11] (Figure 9). Autonomous Inflow Control Valves can be also used as a key element to improve the performance of enhanced oil recovery operations EOR in unconventional reservoirs [12].

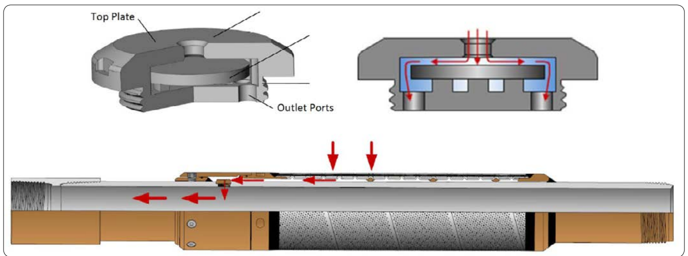

Figure 9. Autonomous Inflow Control Valves (ACID) [8].

Down hole Gauges (Monitoring)

Down hole gauges are typically essential in all wells since they monitor the conditions and transfer a live broadcast from the wellbore to the surface. Any change in the fluid properties or wellbore conditions can be noticed in real time, up to seconds, nowadays. These down hole gauges are very useful and beneficial to keep an eye on the performance of the well and keep a closer eye on critical wells such as wells with integrity issue, not stable performance and many other conditions. Down hole gauges are capable of providing the operators with valuable information such as; reservoir pressure at static and flowing conditions and tubing head pressure. They also can provide many other properties of the produced fluid such as; temperature, rates and composition. The gauges can be installed at any point of the well based on the operators' objective, desire; the area of the wellbore needed to be monitored and to collect a data of interest. Usually the gauges are installed above the reservoir section and at the well head. In the oil and gas service market, generally, there are many different available types of gauges. Two types are going to be clarified briefly in this research study; electrical and optical [13].

Electrical sensors generate electrical charges with every change happens to the pressure or temperature values in the wellbore. These changes are captured and received by the telemetry system installed on the surface. The changes are transferred from the electrical sensor to the telemetry system through the electrical lines. Within the electrical sensors, there are different types for different environments and properties. Some types of electrical sensors operate in high temperature and high pressure reservoirs but cost more. Other types of electrical sensors would be, fairly, cheaper and can be installed in relativity low pressure and low temperature reservoir.

Optical sensors capture the changes in the pressure or temperature values by using the signals generated from the lights and received by special types of detectors. This type of sensors is capable of measuring the pressure and temperature values without the need of electrical source. They generally perform fine with rough down hole conditions such as high temperature and high pressure [14].

Applying Smart Methods

After discussing several ways of achieving a smart well, many more smart methods and systems are available in the oil and gas services market that can deliver optimization and improve the productivity. However, it does not necessarily mean that the above-mentioned methods would be suitable for any well and deliver decent results. For example, operators need to be extra cautious when using fishbone method while drilling in highly fractured reservoirs and make sure to have sufficient and enough data to place the fishbone ribs in the right place. Wrong placement would lead to connect the wellbore with unwanted features and zones, which would lead to excessive water or gas production. Similarly, zonal isolation method has to be chosen based on knowledge of reservoir's properties. Choosing the wrong type of swellable packer would result in unsuccessful isolation, hence production from unwanted zones. Moreover, economics has to be taken into consideration before applying any type of smart methods. Having many gauges at the wellbore is doable but does not always have an economical return to the operator. Smart well's true definition is a well that delivers the highest rate of return with the lowest expense in a safe way.

Conclusion

"Smart Wells" technologies are needed to enhance the profitability of unconventional reservoirs. Smart wells drive the development projects to be cost effective and increase their Net Present Value. That can be achieving by reducing the number of drilled wells, work overs and intervention operations. Fishbone technology helps in connecting far points of the formation directly to the wellbore and achieving a larger drainage area. The ribs help in achieving more exposure, which leads to increase the production from a single well and reduce the well count. Those kind of drilling technologies can be used in re-developing the fields and increase their Net Present Value. Smart technologies can optimize the overall productivity of the well by controlling the production and injection zones and delay the breakthrough of gas and water. They can also avoid water and gas coning and sand production, which lead to an increase in the productivity of the well. In addition to that, collecting data while the well is on production without the need to shut-in for intervention or data collecting campaign is a great advantage for smart technologies. The aim behind this study was to provide an introductory overview of the "Smart Wells" technologies, starting from the drilling to the daily monitor.

References

1. Orlov D, Enikeev R, Nazipov D, et al. Well Placement Application to Drill Fishbone Well on Russkoe Field. Moscow, MC; Society of Petroleum Engineers; 2007.
2. Chan KS, Masoudi R, Karkooti H, Shaedin R, Othman MB. Production Integrated Smart Completion Benchmark for Field Re-Development. Qatar QT: International Petroleum Technology Conference; 2014.
3. Xiance Y, Guo B. A Comparison between Multi-Fractured Horizontal and Fishbone Wells for Development of Low-Permeability Fields. Indonesia, IN: Society of Petroleum Engineers; 2009.
4. Hassan A, Abdulraheem A, Elkatatny S, Ahmed M. New Approach to Quantify Productivity of Fishbone Multilateral Well. Texas, TX: Society of Petroleum Engineers; 2017.
5. Xing G, Guo F, Song C, Sun Y, Yu J, Wang G. Fishbone Well Drilling and Completion Technology in Ultra-thin Reservoir. Tianjin, TJ: Society of Petroleum Engineers; 2012.
6. Offenbacher M, Gadiyar B, Messler D, Krishnamoorthy SR, Abasher D. Swellable Packer Fluids Designed for Zonal Isolation in Openhole Completions. Budapest, BP: Society of Petroleum Engineers; 2015.
7. Wilson P, Hoffman CE. Zonal Isolation in Stimulation Treatments and Gas/Water Shutoff Using Thermally Compensated Inflatable Packers and Plugs. Kuala Lumpur, KLMP: Society of Petroleum Engineers; 2000.
8. Armenta M, Al-Ghamdi A, Al-Hajji A. Applications of Mechanical External Casing Packers. Manama, MN: Society of Petroleum Engineers; 2007.
9. Obendrauf W, Schrader K, Al-Farsi N, White A. Smart Snake Wells in Champion West-Expected and Unexpected Benefits From Smart Completions. Adelaide, AL: Society of Petroleum Engineers; 2006.
10. Voll BA, Ismail IM, Oguche I. Sustaining Production by Limiting Water Cut And Gas Break Through with Autonomous Inflow Control Technology. Moscow, MC; Society of Petroleum Engineers; 2014.
11. Ahmad F, Al-Neaimi A, Saif O, et al. Rejuvenating a High GOR, Light Oil Reservoir Using ACID Completion Technology for Gas Control. Abu Dhabi, AD: Society of Petroleum Engineers; 2016.
12. Konopczynski M, Dowlatabad MM. Improving the performance of EOR in Unconventional Oil Reservoirs Using Advanced Completion Technology. Moscow, MC; Society of Petroleum Engineers; 2015.
13. Bazitov MV, Golovko SI, Konosov DA, et al. First Fishbone Well Drilling at Vankorskoe Field. Moscow, MC; Society of Petroleum Engineers; 2015.
14. Abdullayev A, Kedia R, Urakov A Temizel C. Optimization of Recovery Using Intelligent Completions in Intelligent Fields. Baku, BK: Society of Petroleum Engineers; 2017.