BULETINUL Universităţii Petrol – Gaze din Ploieşti	Vol. LXII No. 3B/2010	65 - 72	Seria Tehnică

Trends in the Well Completion

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Abstract

Well completion is the interface between the reservoir and surface production systems and is critical factor of the performance of the well. This can be varies from the simple to complex configuration depending by several factors like well construction, well depth lifting method of the fluids from the well, number of the perforated intervals produced separately or commingled, completion option at the formation level, flow rate of the well, available technology, location of the well etc.
In this paper we present the trends in the well completion in accord with the complexity of the wells construction and the influence of the well completion to the well performance.

Key words: *smart well, well completion, sensors, production, conventional completion*

Introduction

Well completion is the interface between the reservoir and surface production facilities. This is a very important stage during the well life because it influences the productivity of the production well or the injectivity of the injection well. Then we can say that the well completion is a critical factor of the well performance.

To design a well completion must take account of a lot of factors which depends by the reservoirs characteristics, geographical zone and type of the well and production system. The petroleum companies offer many variants for a well completion taking account of the factors mentioned above.

In last ten years have appeared the intelligent or smart well completion systems like a result of the efforts to enhance the reservoirs production, and real-time production monitoring. Therefore, the well completion systems can be divided in two categories like:

- Conventional completion;
- Smart or intelligent completion.

The trends in the well completion are related on the trends in the drilling wells and on the requirements of reservoirs production optimization, controlling and monitoring in order to increase the recovery factor.

Evolution of Well Profiles

Well profiles have advanced from the vertical profile to very complex multi-branch profiles. Now the vertical and slightly deviated wells are named “conventional wells”, and the highly deviated wells, horizontal wells and multi-laterals or multi-branch wells are named “advanced wells” or unconventional wells.

The first goal of unconventional wells is to improve the oil and gas recovery through an increasing of the contact area with the reservoir. Also, these wells have proved good performances in the reduction of the conning effect and in combination with enhanced oil recovery methods they lead to the increasing oil production at reduced costs.

In the figure 1 we show the different types of the wells profiles from the simply vertical profile to a 3D wells profiles.

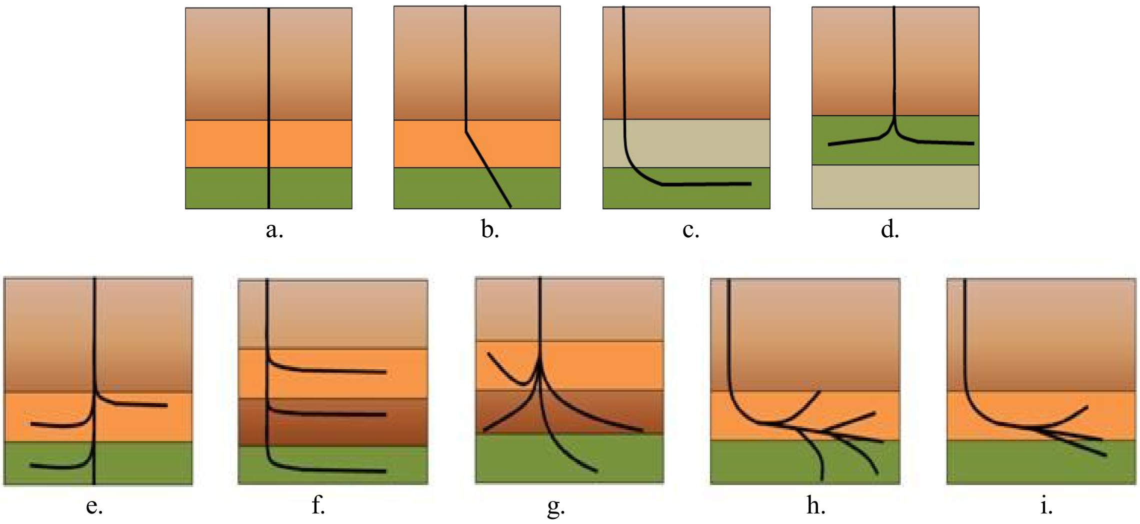

Fig. 1. Profiles of the wells. a. vertical well, b. deviated well, c. horizontal well, d.dual-opposing laterals, e.laterals into vertical hole, f. stacked multi-branch well; g. cluster multi-branch; h. horizontal well with laterals; i. forked well.

The vertical wells were used mainly in the petroleum industry up to the ‘80 years (fig. 1.a) Deviated wells have been drilled frequently in the ’70 years to intercept the reservoirs located in difficult zones or to develop the offshore reservoirs using the multi-wells offshore platforms. The main problem of the vertical wells is their small contact area with the reservoir and then necessity to drill a large number of the wells in order to increase the production rate of the reservoir and to enhance recovery. The deviated wells permit an increase of contact area with the reservoir and then an improvement of the reservoir production.

At the end of the ’80 years the drilling of the horizontal wells was technically possible and starts to be wide used (fig. 1.c). They have a larger contact area with the reservoir, and then a higher production rates can be obtained.

The development of multilateral wells (fig. 1.d-i) lead to further increase in the contact area between wells and reservoir because from a single main wellbore multiple wells can be drilled. In this way it is eliminating supplementary costs with drilling of a number of individual wells. In the case of the offshore wells, where the risks and the costs of the deepwater installation are huge, the multilateral wells represent o solution to reduce the number of the well and then the costs and the risks with drilling and completion of individual wells.

Conventional Well Completion Systems

In consonance with the evolution of well profiles, the well completion systems have presented a similar trend toward complex systems. Actually, there are many variants for well completions; to choose one or another is based by some factors such as: the number of the productive zones, the reservoirs fluids characteristics (corrosive, abrasive), well profile, the rate and pressure of the reservoir fluids, reservoir drive mechanism, well location, the operating company philosophy etc.

The well completion can be treated at three levels as: sand face level, well level and surface level.

Completion at the well level means in fact that the equipment run in the well to lift the reservoir fluids up to the surface. This equipment varies from the simple tubing string without any additional devices and packers to a complex tubing strings which include many devices as: the tubing string for fluids flow (reservoir fluids flow up to the surface, and other fluids injected into the well in different cases), packers for sealing the annular space between the production casing and the tubing string in order to protect the casing from the well and injected fluids; device for compensation of the expansion or contraction of the tubing, circulation device (sliding sleeve valve) for killing well or bringing in production, devices for the flow control, pressure and temperature measurements (nipples locators for landing with wireline chokes, plugs, downhole gauges etc), safety valve for closing the well in emergency case.

Completion of the conventional wells is generally composed by a single or dual tubing string depending of the number of the layers that are perforated and the company completion philosophy.

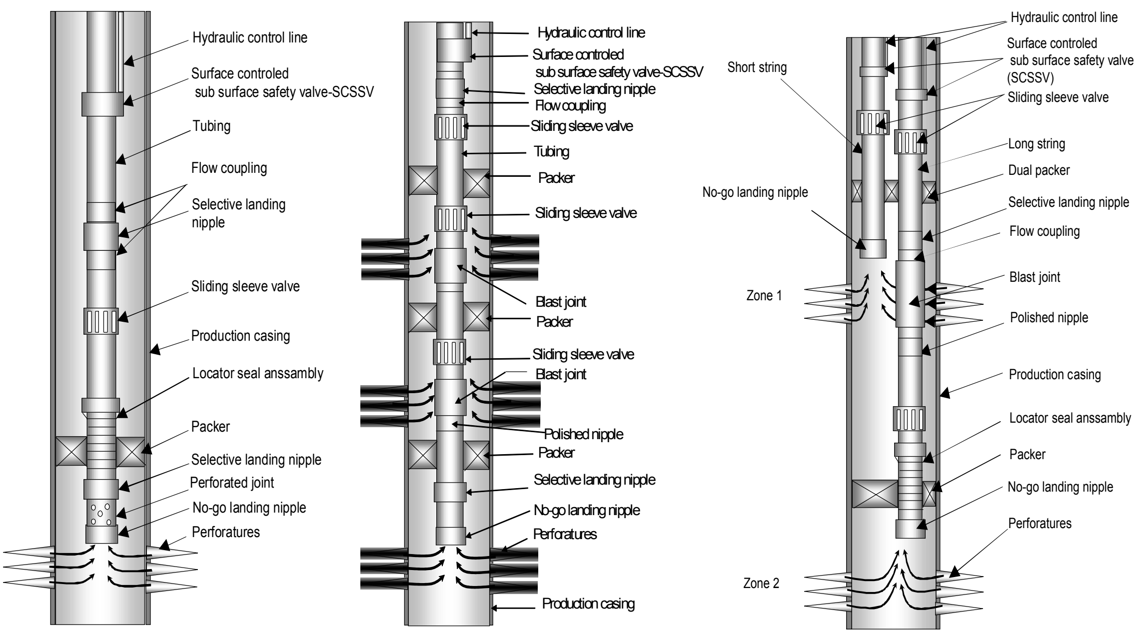

Fig.2. Types of completion systems for conventional wells. a. Single zone and single string completion., b. Multiple zone completion and single string completion. c. Multiple zone completion and dual string completion.

In the figure 2 we present three schemes for conventional well completion function of the number of the production zones (single zone and multiple zones completion).These schemes include the devices listed above that are in generally mechanically actuated(only the subsurface safety valve is hydraulically actuated from the surface). In these cases, to measure the pressure and temperature in the well, or to actuate any device in the wellbore (beside the subsurface safety valve) it is necessary to make a workover in the wellbore in generally with wireline. That supposes to interrupt the well production in order to make the workover.

Smart Well Completion

Smart well completion is different from a conventional well completion because has additional equipment to monitoring the flow parameters (down-hole sensors), to remotely control and modify the pay zones production parameters (interval flow control devices), to transmit the data and the power (power cables, optical fiber), to isolate the pay zones (feed –through isolation packers) and to analyze the data. Then this type of completion is able to collect, transmit in real-time and analyses the wellbore production data continuous without any intervention.

In figure 3 is presented a smart well completion schema.

Even if this completion system has the properties mentioned above, in this stage it hasn't the automated capability for self control or optimization; the completion control command being initiated from a manual interface [5].

This completion system is suitable for advanced wells as highly deviated, horizontal and multilateral wells. Also the smart wells are relevant for marginal fields, remote fields, harsh environment conditions (desert, deep- water, swamps etc.) and high rate wells.

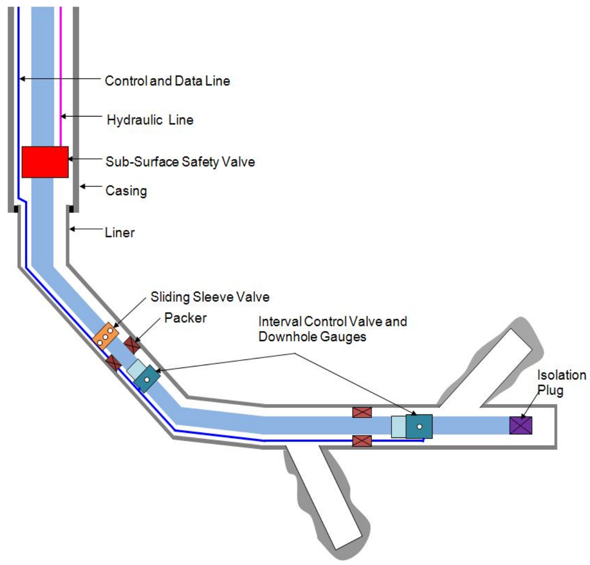

Fig. 3. Smart well completion schema.

There are many benefits of smart well completion which are proven in practical operations. Among these we mention: very flexible in multilateral and monobore wells operation with commingled production from multiple reservoirs because has the ability to monitor and control each interval independently; increase the recovery factor; decrease and control water production and coning phenomenon; reduce the operating expenses (workover operations), improve water and /or gas injection efficiency for injection wells and manage uncertainties better.

From the smart well completion component mentioned above, the interval flow control devices are very important because are directly implied in the adjustment process of the interval production and further in well and reservoir production optimization process. These devices are usually valves that in early smart completion systems were the conventional wireline-operated sliding sleeves valves with two operation position on/off. To avoid the workover of the well in order to actuate the valves, it was necessary to transform these mechanical valves in the devices actuated hydraulically, electrically or electro-hydraulically. Also, to improve the flexibility and reliability of the system it was necessary to reconfigure these valves to provide on/off and variable position choking and to resist at corrosion and high differential pressure [5]. These types of valves are used for reactive control because these are actuated as a reaction to the data monitored from the downhole sensors (for example to avoid the increase of water cut in accord with the predictions of the reservoir performances).

Another available type of the interval flow control devices is proactive, that prevents the water cut increase phenomenon to happen. These devices are designed on the basis of a predictive reservoir model and installed in the well without any possibility to remote change their parameters. Practically the reactive control is more efficiently in real application [7].

The first smart completion system SCRAMS (Surface Controlled Reservoir Analysis and Management) was installed at Saga's Snorre Tension Leg Platform in North Sea[3]. This system control the flow control devices (Infinitely Variable Interval Control Valves), and monitoring the pressure and temperature from each zone.

After this another smart completion systems have developed as: Direct Hydraulics, Mini Hydraulics, InForce(hydraulic powered), InCharge(electric powered), each system having different features which determine their applications range. All this systems use the hydraulic or electric power to actuate the downhole equipment. Also contain many electronic components that are sensible to downhole pressure and temperature conditions. To increase the monitoring and control reliability, the fiber optic sensing technology is developed. This technology can be deployed in a wide conditions range(from the arctic conditions to desert, high depth(6706 m), high temperature(150 ^{0}C), high pressure(1034 bar)) [3].

Influence of the well completion to the well performance

To illustrate the difference between a conventional well completion and smart well completion we consider an offshore well that produce from three pay zones. Schema for the entire production system is shown in figure 4.

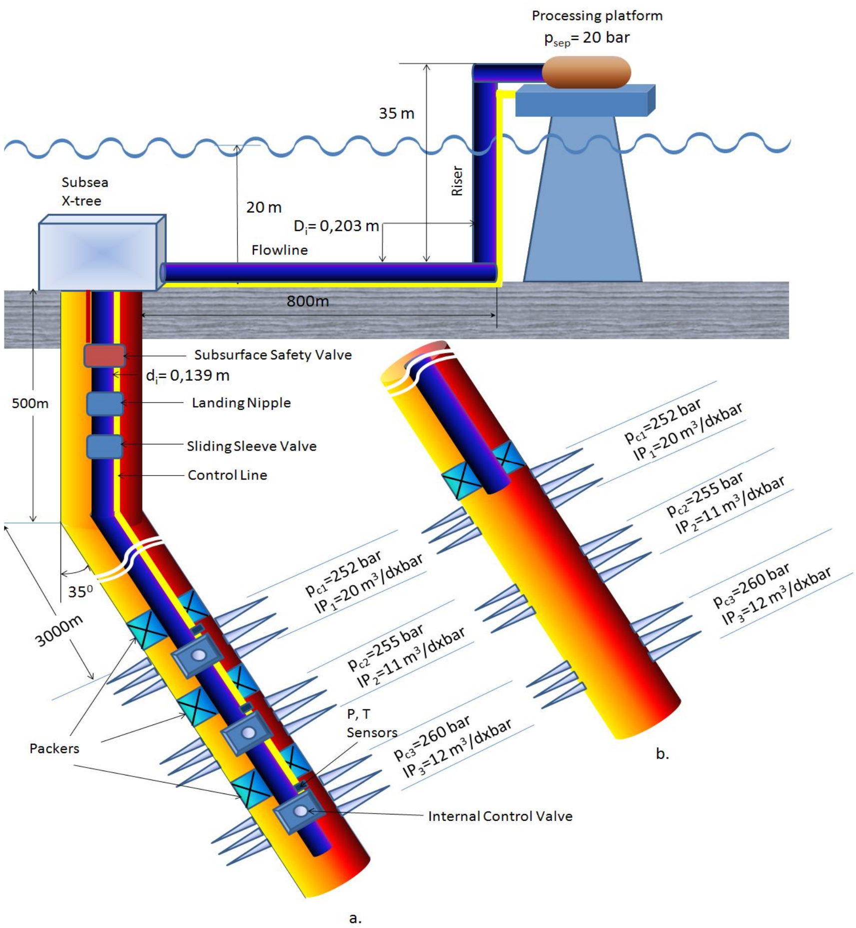

Fig.4. Production system schema. a. Smart well completion; b. Conventional well completion without separation devices between the layers.

We have considered the follows scenarios:

- The three layers produce commingled without water cut- the well having a conventional completion (fig.4b);
- The layer 3 begun to produce with water cut that increase from 0 to 80%- the well having a conventional completion(fig 4.b);
- The layer three is isolated by closing the interval control valve (considering the smart well completion of the well)(fig.4a) .

For each scenario we make a simulation of the nodal analysis with Pipesim. The results are shown in figure 5(a, b, c, d,e).

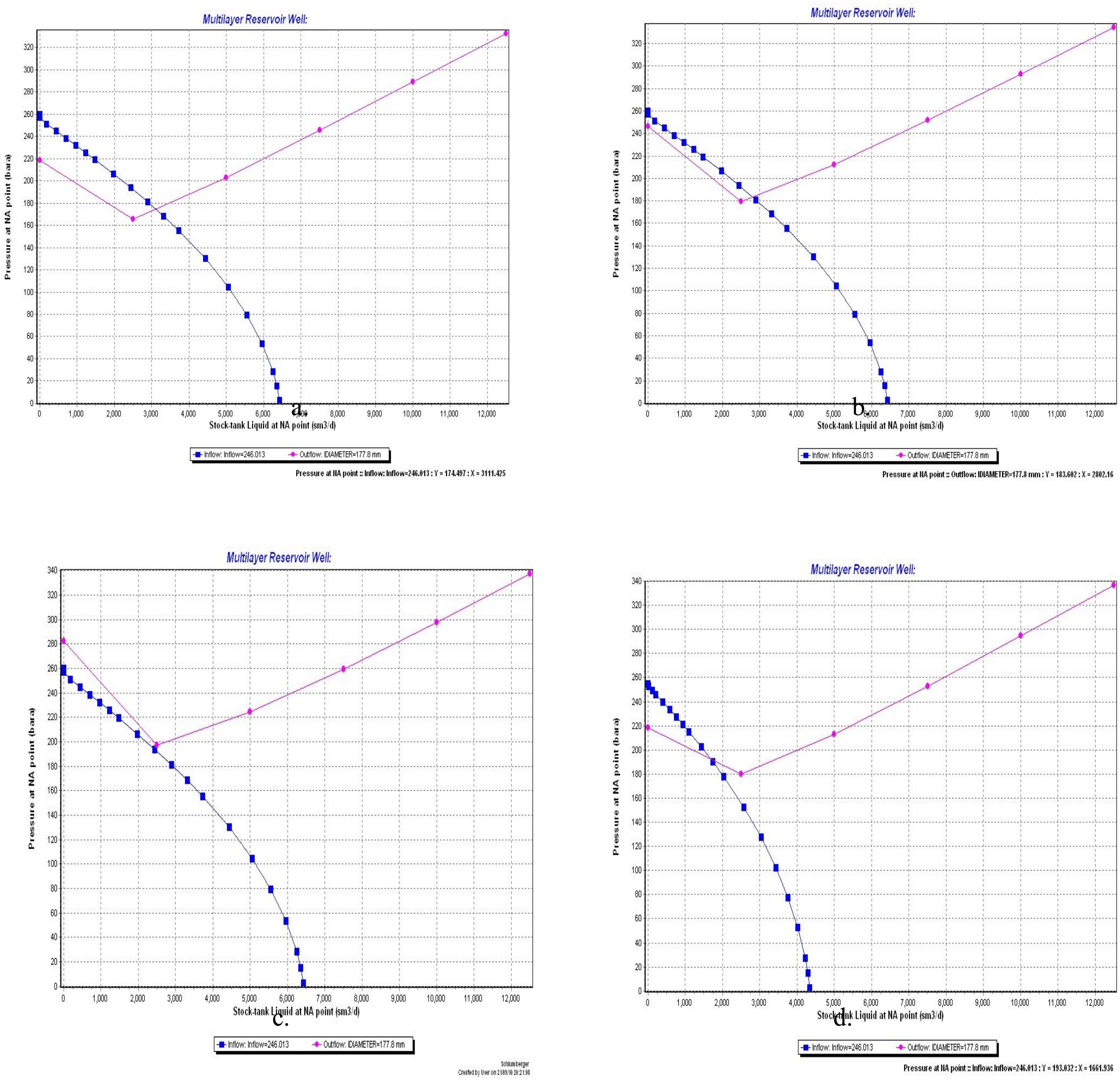

Fig.5. Nodal analysis for the considered scenarios: a. conventional completion –water cut=0%; b. conventional completion –water cut=40%; c. conventional completion –water cut=80%; d. smart completion – third layer isolated.

From the figure 5 results that in the case of the conventional completion without any separation devices between layers and the commingled production if water cut increase at some value the well can stop to produce (fig.5c).

In the case of the smart completion we can block or choked the layer that produce with high water cut, and also we can monitor the flow parameters. In the figure 5d is shown the nodal analysis in the case of the smart completion with one layer closed (third layer). In this case the well produce without any interruption for intervention on the well equipment or on the layer (to plug).

In the case of conventional completion to have the similar effect will must do workover in well to plug by cement the third layer where the water production has a high level.

Conclusions

Well profiles have advanced from the vertical profile to very complex multi-branch profiles in order to increase the contact area with the reservoir and then to enhance the oil and gas recovery. Then it was necessary that well completion to advance too from the conventional completion to advanced completion such as smart completion.

Smart well completion systems are developed in last ten years and are suitable for marginal fields development, remote fields, harsh environment conditions and high rate wells.

Even these systems have many advantages, their costs are high. Hence, before to choose a smart well completion it is necessary to analyze also different completion variants and to simulate the well performance in these cases. Sometimes, in some conditions, conventional completion variants have better performances than a smart well completion.

In the case of the commingled production and high rate, the smart well completion is suitable because it permit to monitor the flow parameters and to block or choke the layer that produce with high water cut without any workover of the well.

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Tendinţe în completarea sondelor

Rezumat

Completarea sondelor reprezintă interfaţa dintre zăcământ şi sistemele de producţie de la suprafaţă şi din acest motiv este un factor critic al comportării sondei. Aceasta poate varia de la o configuraţie simplă la una complexă depinzând de o serie de factori cum ar fi: comstrucţia sondei, adâncimea sondei, metoda de liftare a fluidelor din sondă, numarul intervalelor perforate care produc separat sau impreună, opţiunea de completare a sondei la nivelul formaţiei, debitul sondei, tehnologia disponibilă, locaţia sondei, etc.

În acest articol se prezentintă tendinţele în completarea sondei ţinând seama de complexitatea construcţiei sondelor şi influenţa completării asupra performanţelor sondei.