AGH DRILLING, OIL, GAS • Vol. 31 • No. 2 • 2014

http://dx.doi.org/10.7494/drill.2014.31.2.307

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STIMULATION OF UNCONVENTIONAL HYDROCARBON RESERVOIRS

1. INTRODUCTION

Hydrocarbons like natural gas, crude oil as well are mostly trapped in subsurface formations called reservoir rock. Pores of various sizes between the grains create the rock matrix.

The quality of a reservoir rock is determined by its porosity and its permeability. Porosity is the void space between the particles, and represents the rock's capacity to contain liquid or gaseous form of hydrocarbons (or both of them simultaneously). A highly porous reservoir rock therefore can contain a large volume of hydrocarbons. Only the high porosity alone will not fulfil the criteria's for reservoir rock.

Fluid, gas must be able to flow through the reservoir rock, it means that the pores must be interconnected. This characteristic, called permeability is the measurement of the rock's ability to transmit or flow the oil or gas to the well.

The unit of permeability measured in Darcy. Permeability is one of the parameters by which conventional gas reservoirs can be distinguished from unconventional formations. An average or good quality conventional hydrocarbon reservoir has a permeability at least of 1 Darcy or more.

2. UNCONVENTIONAL GAS RESERVOIRS

Many of the developed reservoirs in the past decades were sandstone, low permeability carbonates, shale's and coal seams which contains dry natural gas. A common feature

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of unconventional gas reservoir: hydrocarbons are trapped in very low-permeability rock – ultra-compact structures that prevent or sharply limit the migration of the gas.

Tight gas is trapped in ultra-compact reservoirs characterized by very low porosity and permeability that produce mainly dry natural gas. The rock pores that contain the gas are minuscule, and the interconnections between them are so limited that the gas can only migrate through it with great difficulty. Tight gas reservoirs, are more compact than brick, may have permeability of only a few dozen micro Darcy.

Shale gas is extracted from a geological layer known as the "source rock" rather than from a conventional petroleum reservoir structure. The gas it contains is either adsorbed the organic matter or in a free state. This clay-rich sedimentary rock has naturally low permeability. The permeability values of shale gas layers are around one thousandth of the permeability of tight gas formations. The unit here is the Nano Darcy.

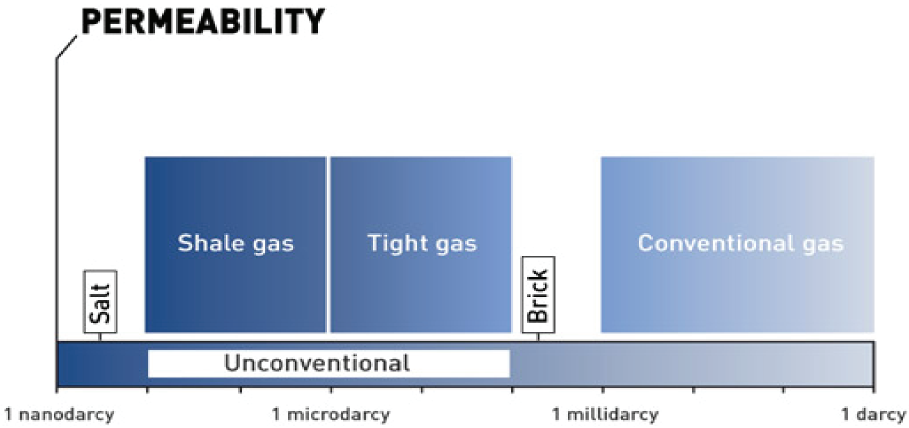

Fig. 1. Shale gas and tight gas permeability [1]

3. STIMULATION PROCESS

Oilfield household expression "hydraulic fracturing" becomes into focus in the branch called unconventional energy resources. Hydraulic fracturing techniques becomes the most common method used today for stimulating the unconventional bearings of hydrocarbons called shale gas, tight sand and coal bed methane reservoirs. The aggressive research and development opened also a new path for experiments to improve well economics. Case studies and positive enhancing of well productivity on the North American shale and other unconventional reservoirs could confirm hydraulic fracturing is far and away the most efficient stimulation technique on the shale and tight sand reservoirs.

Must be emphasised fracturing methods that works on one isolated field and may not guarantee the success in another. Application of hydraulic fracturing techniques allows for drilling fewer wells and can more effectively influence the recovery factor of the given reservoir. Reservoirs of unconventional hydrocarbon resources could not be economically and successfully produced without stimulation works called hydraulic fracturing.

Increasing tendencies for exploration and production of unconventional resources in the last 30 years helps to improve the arsenal of tools.

Not even the drilling and well completion tools were improved during the evolution of the past few decades. Very important auxiliary and support systems were introduced and successfully tested in the fields in various well conditions.

Micro seismic exploration of the shale reservoirs helps understand the different geological properties such as pore structure and rock hardness and permeability around the well bore. Behaviour of the well bore structure helps choose the right design and fracturing treatment.

TABLE 1—TABLE 1—DISTRIBUTION OF WORLDWIDE UNCONVENTIONAL-GAS RESOURCES (AFTER ROGNER 1996, TAKEN FROM KAWATA AND FUJITA 2001)

Region	Coalbed Methane (Tcf)	Shale Gas (Tcf)	Tight-Sand Gas (Tcf)	Total (Tcf)
North America	3,017	3,840	1,371	8,228
Latin America	39	2,116	1,293	3,448
Western Europe	157	509	353	1,019
Central and Eastern Europe	118	39	78	235
Former Soviet Union	3,957	627	901	5,485
Middle East and North Africa	0	2,547	823	3,370
Sub-Saharan Africa	39	274	784	1,097
Centrally planned Asia and China	1,215	3,526	353	5,094
Pacific (Organization for Economic Cooperation and Development)	470	2,312	705	3,487
Other Asia Pacific	0	313	549	862
South Asia	39	0	196	235
World	9,051	16,103	7,406	32,560

Fig. 2. Unconventional gas resources worldwide [5]

4. PROCESS OF HYDRAULIC FRACTURING

Gas shale and tight sand reservoirs differs in his structure. Shale gas and oil reservoirs typically contains in high percentage of mudstone rocks and various percentage of clay, clay stone and bentonite. Tight sand reservoir structure consists of highly consolidated sand and sandstone rocks, carbonates with average permeability of 0,1mD. The key parameters of the fracturing are based on the analysis of the recovered core samples which helps to define the fracture height and the propant size. Fracture height in the horizontal well bore could connect separated numerous lenses of natural gas or crude oil which is trapped in a separated reservoir near the well bore but isolated by a thin shale layer. Fractures in the well bore usually are in longitudinal direction from the well bore. The hydraulic fracturing techniques could differ between offset well in same basin located few hundred meters. Hydraulic fracturing stages and fluid composition are always based on behaviours of the formation, closure stress, pressure depletion around the well bore, effective wellbore radius.

5. GENERAL DESCRIPTION OF WATERFRAC PROCESS

Acid stage: pumping stage of a mixture of water with diluted acid such as hydrochloric acid. Pumped down to the well bore to remove dirt and clean the path to the formation. Technique also utilize to dissolve rock and to initiate cavitation in over pressured chalk.

Pressure stage: carrying fluid is pumped to open paths in the target formation. Main goal is the natural fracture network reactivation through tensile and shear processes

Fig. 4. Frac head including BOP´S and coiled tubing [4]

Proppant stage: During this stage a selected facture treatment mixture of water and proppant (low gel guar borate widely applied in coal bed seams) is pumped down under extremely high pressure to continue the fracking procedure. The high viscosity carrying fluid with the propants such as multi coated grains of sand or bauxite, lightweight ceramic grains (non API proppants) non compressible materials are delivered to the open fracture network to prevent closing after the pressure is bleed of.

Flush stage: Coiled tubing is commonly used to clean out any excess of proppant and to access the next stage of fracturing.

Fig. 5. Interconnected pumping units [4]

6. MICROSEISMIC MONITORING

„Industrial microseismic monitoring is the passive observation of very small-scale earthquakes which occur in the ground as a result of human activities or industrial processes such as mining, hydraulic fracturing, enhanced oil recovery, geothermal operations or underground gas storage" [7].

On the pioneer prospects or multistage fracturing well bores the reservoir mechanics is closely monitored. The micro seismic analysis and monitoring was first developed for monitoring the rock mechanics in deep mines. In the pre drilled pilot holes geophones are lowered inside to monitor the seismic activity and the rock mechanics. Each stage of the fracturing procedures is recorded for further evaluation. The emission amplitudes, timing of the sequence and direction of the motion generated by the growing fractures helps understand the complexity of fracturing.

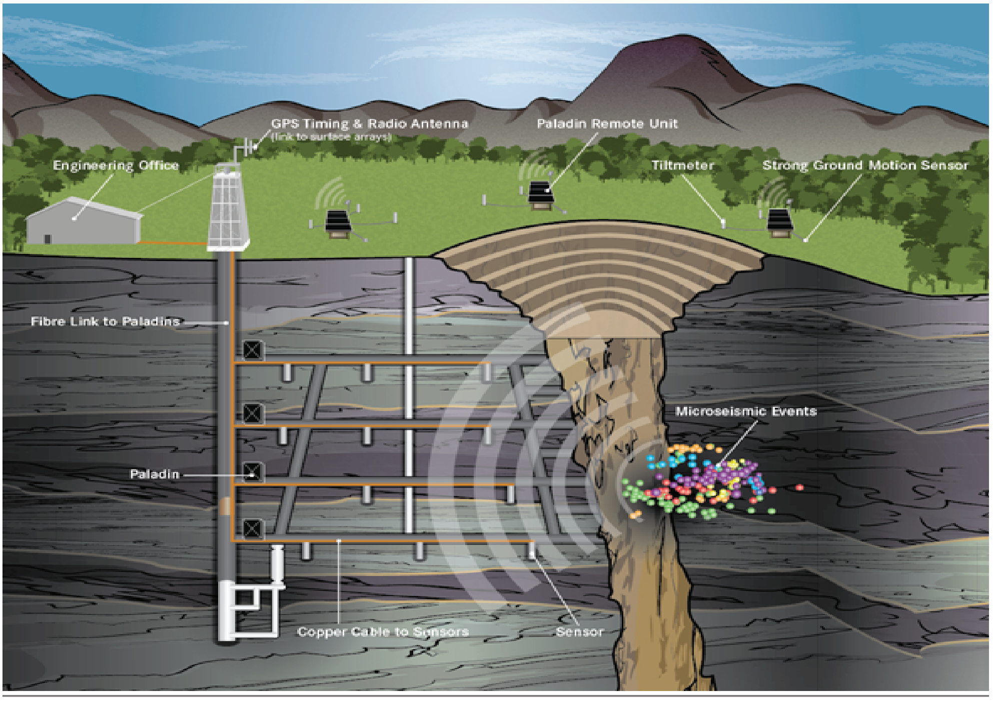

Fig. 6. Real time micro seismic monitoring [7]

7. CONCLUSION

Since hydraulic fracturing was introduced in the USA in the late 40´s more than 2 millions of fracturing and intensification treatments were performed. Nowadays approximately more than 50% of new drilled well are at least stimulated or hydraulically fractured. Fracturing treatments opens a new horizon of hydrocarbon production from the unconventional reservoirs. The newest and more sophisticated methods of stimulation treatments used on land and offshore wells helps to drill fewer wells and simultaneously increase the productivity. The evolution of the completion techniques in the newly discovered unconventional reservoirs allows numerous fracturing stages dependable on the length of the lateral section.

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