Laboratory study of terrigenous core samples strength after chemical consolidation

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Abstract. This paper presents an overview of currently available technologies and different ways of sand consolidation. The results of laboratory studies show the increase in the strength of core samples compression up to 3,5 times, which testifies of high cementing ability of chemical compositions. The developed chemical method for consolidation of the bottom hole formation zone of producing wells is described.

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Introduction

There are a lot of reservoirs which formations are composed of loose, unconsolidated formations in Russia. The most important technological issues in such hydrocarbon production from these fields are to implement sand control and prevention bridging [1].

Sand production from the formation is the result of unconsolidated or disintegrated sand grains around the wellbore or perforations. Usually that are formations of low or intermediate strength with little or no cementing/bonding material between grains; but in fact sand production is possible also from the higher strength formations with good grain bonding. In both cases sand production can start immediately or can result later in well life cycle [2, 3].

Therefore, it is crucial to know whether and when the sand production would occur and how severe it will be, so corresponding measures could be taken to guarantee the oil production and maximize the project economics.

The sand is taken from the reservoir at destruction of the natural cementing material (gypsum, hydrate of iron oxide, clay) as a result of swelling in the period of the irrigation wells, and also because of mechanical disturbances due to the influence of pressure drop or deformation of formation skeleton under the impact of formation pressure. The destruction of formations that form the reservoir, and the sand and the well is due to the simultaneous action of complex reasons. However during various periods of well performance of those or other reasons may prevail and have the greatest impact on the process of sand production. So, in the production of many wells during their water-free operation almost no mechanical impurities (sand), in flooding observed a sharp increase in sand content [4].

The main part

Washing-out of weakly cemented formation under the impact of liquids filtrating for certain values of the gradient of pressure or velocity. Significant sand production in the well may start at differential pressure of 0,025 MPa.

The possible sand production depends on the interaction of the grains, their inter-granular friction and in-situ stresses, capillary forces and in some cases by the viscosity of the fluids in place.

The classification of sand production is considered as an essential part of sand prediction as it defines the situation assessed. There are three types of sand production in the literature [5]: transient sand production, continuous sand production and catastrophic sand production. Transient sand refers to a sand concentration declining with time under constant well production conditions. Continuous sand production means stable sanding continues for a long time with an acceptable sand concentration. Catastrophic sand production refers to events where a high rate sand influx causes the well to suddenly choke or die. Studying the effects of cumulative injection volume on sanding helps to understand how the sanding may change with production history and determine the sanding type.

Caverns form in the bottom hole formation zone as a result of sand production from the reservoir, the size and shape of which is currently impossible to describe in detail. There are cases when a set of these caverns under the influence of overlying beds fall. This fact leads to a dynamic effect on the production casing, causing it to break, crush and offset.

The best up today example for catastrophic sand production compaction of Wilmington field resulted with surface subsidence of up to 10 m. Several earth-quakes have been registered and about 300 producing oil wells have been damaged with complete loss of 120 more [3]. Usually the compaction of the reservoir increases axial loading and shortening of casing or slotted liner. If loads exceed elastic limit of the steel pipe it can be plastically deformed or slots can be bulged or distorted. The amount of possible formation compaction can be estimated by using Eq. 1.1.:

$$\Delta H = \left(\frac{\Delta e}{1 + e_0}\right) \cdot H, \qquad (1)$$

Vertical compaction ΔH is determined by the thickness of the zone , change in void ratio Δe (ratio between the volume of voids and volume of solids) and original void ratio e_0.

Criterion selection of compression strength

Most of the latest energy theories fit into the framework proposed by R. Mizer and F. Schleicher conditions, according to which in the ultimate state of material octahedral shear stress is:

$$\tau_{av} = \frac{1}{3} \cdot \sqrt{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}, \qquad (2)$$

a specific feature of octahedral normal voltage. Moreover, for a total limit curve in the coordinates as the points corresponding brittle fracture of formations at low values of all-round compression, and the points corresponding to the beginning of plastic deformation at higher values of all-round compression. However, when tested weakly cemented soft sandstone different porosity and permeability was found that the impact of all-round compression leads to an increase shearing octahedral tangent voltage is linear.

With increase of the depth of the reservoir the comprehensive compression grows so that to a certain depth L_y layer under certain conditions will deteriorate fragile, and when $L>L_y$ instead of destruction will be loading conditions of the field of elastic deformations in the area of plastic [2].

In the past decades, a number of approaches have been developed to predict the sand production. In general, these approaches can be categorized into three basic groups: 1) empirical methods; 2) laboratory evaluation; 3) theoretical modeling including analytical and numerical methods. Empirical methods are quite simple and usually based on the field observations. Laboratory experiments are carried out to disclose the possible sanding mechanism and understand the influence of the field and operational parameters. Theoretical modeling is based on the perforation stability analysis and requires the mathematical formulation of the sand failure mechanism such as compressive failure, tensile failure and erosion [6].

During chemical consolidation of unconsolidated sandstones by chemical composition an important factor is to evaluate cementing material and measure its strength. Compression strength - the property of a material to resist destruction under the influence of internal stresses caused by external forces or by other factors. The main strength characteristic is the tensile strength at compression, which is the maximum pressure that the material can withstand without changes (reduction) of the volume [7].

This paper assesses the strength of terrigenous weakly cemented core samples, composed of quartz sandstone, before and after treatment with chemical composition.

If the structure of the bottom hole formation zone has been modified and, as a consequence, there is sand production, we recommend using a chemical method of consolidation of slightly cemented reservoir.

To bond the bottom hole formation zone, experiments were carried out by injecting into the formation chemical agents. Through a sand packed tube an aqueous calcium chloride, and, as plugging composition, an aqueous caustic soda (sodium bicarbonate) was injected. As a result of the reaction calcium ions formed water insoluble compound, i.e. there is sedimentation in the form of fine suspended solid particles in the pore space, and on the walls of the pore channels in the form of solid microcrystals. Injection each of these solutions into the formation was produced by equal portions. It is assumed that the sedimentation in the bottom hole formation zone will also prevent the formation water invasion by water shutoff by means of insoluble compound. In summary we suppose to bring into development stagnant zones [8].

The optimum ratio of dry chemical compound in the solution was determined by stoichiometric calculations of the reaction with the calculation of mass fractions and with laboratory research.

According to this method we applied the Patent Office for a patent № 2475622 «Consolidation technology of the bottom hole formation zone of gas wells." [9, 10].

Laboratory experiments of compression strength are carried out on the unit 65-L11G2/C.

Next type of the core samples were selected for the experiment: 10 core samples of natural saturated without treatment; 10 core samples saturated with oil and treated with a chemical composition and 10 core samples saturated with water and treated with a chemical composition. The results of the experiments are presented in table 1.

Fig.1. Semi-automatic unit for testing the compression/bend 65-L11G2/C

When formation is producing oil, it is possible that there will be no sand production. But when water begins to flow through the matrix it will raise the drag resistance among the water phase and the water-wetted sand grains and cause the well to start producing sand. Water production always reduces a formation's strength due to the dispersion of amorphous bonding materials. The magnitude of the fluid drag is dependent on velocity (and therefore a function of both permeability and flow rate) as well as fluid viscosity, interfacial tension and fluid phase [6].

Table 1.The results of the laboratory experiments of the terrigenous core samples compression

Number of core samples	Processing type of core samples treatment	Legth, sm	Diameter, sm	Average compression, MPa
1	**Core sample is saturated with water and treated with chemical composition**	4,2-4,7	2,86-3,02	8,61
2	**Core sample is saturated with oil and treated with chemical composition**	3,9-4,1	2,93-3,01	9,99
3	**Natural core sample and it is not processed**	4,1-4,5	2,64-3,01	2,82

Conclusion

The compression strength of the terrigenous core samples increased up to 3,5 times as a result of chemical consolidation, which testifies of the high consolidation capacity. It should be noted that the compressive strength of water saturated samples is less than oil saturated that indicates the negative impact of water on the strength characteristics of weakly cemented sandstones.

The decision of implement or does not implement any kind of sand control can be done based on the integrated geomechanical and passive sand-control approach proposed by [7]. It presents a general rock-failure criterion as a function of stresses in the formation, rock strength, reservoir pressure and its changes and wellbore trajectory and perforations spacing and direction.

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