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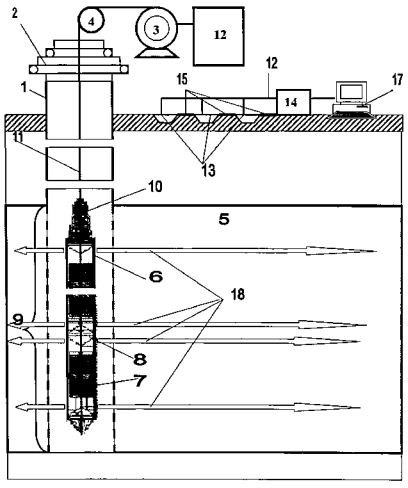

Fig. 1

(57) Abstract: Invention relates to the gas and oil producing industry and could be used in the wells with the different geological structure types, including a depleted field and well with the reserve difficult to recover. The technical solution results in the seismic survey output accuracy and oil recovery factor increase. The seismic research during the crude oil production consists of generation of elastic vibrations by the sound-emitting device in the form of horizontally directed to the reservoir cylindrical wave. The longitudinal and lateral waves penetrating the reservoir formed by the deformed layers due to exposure to the elastic vibration of sound-emitting device are registered by the seismic sensors, which are located on the ground surface and measure their amplitude frequency response. Simultaneously with the seismic survey, the sound-emitting device elastic vibration provides the pressure oil feeding gradient and crude oil production.

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Acoustic Measurement Method for the Crude Oil Production

Engineering Area

Invention relates to the gas and oil producing industry and could be used for acoustic measurement operations during the crude oil production in the wells with the different geological structure types, including a depleted field and well with the reserve difficult to recover.

In order to increase a production rate of depleted and wet reservoirs with the petroleum reserves difficult to recover the new effective technologies are required.

An increase of oil recovery efficiency is possible due to reservoir data collecting in the process of production, that is the essential factor for production control optimization without the well decommissioning.

Reservoir data collection in the process of production is allowed by the combination of the field development activity and the lead geophysical research method – a seismic survey. The seismic survey features by its reliability, high resolution capacity, production effectiveness and huge volume of collected data, which may serve as a reliable criterion of production log interpretation aiming for the accurate geophysical reservoir model creation to plan the further well operations.

A new direction of seismic survey is a seismic monitoring. With help of the seismic monitoring they are tracking changes in the reservoir during the well operation and such basic elements as an oil-water contact repositioning. An advantage of seismic monitoring is that it can be performed in real time. This allows the artificial conditions to be controlled by a specialist on the basis of monitored changes in the reservoir model. The next advantage is the analysis and interpretation of outputs after the activity completion. A seismic event data can be processed and interpreted for better understanding of current reservoir structure condition. A specialist may use the present information in order to plan the additional artificial conditions for the well stimulation and possible infill drilling aiming to enhance the production.

The main purpose of seismic monitoring in the process of hydrocarbon production is the enhanced oil recovery and oil recovery factor.

The continuous seismic monitoring suggests the availability of permanent seismic data monitoring system in the well and represents the passive seismic observations in real time to monitor, for example, the reservoir fracturing directions.

However, it is possible to create an updated proved geophysical reservoir model after the active phase of seismic observations and seismic data collection during the acoustic well-logging measurement.

The seismic monitoring process could be too expensive, if the production time-out, pulling of field equipment out of the well, and installation of additional equipment is required in order to pursue the research.

Since the acoustic well-logging measurement is a basis for the seismic survey methods, it is proposed to use the field equipment as a technical elastic vibration source. In the Patent RF № 2318223 on the reservoir fracturing seismic monitoring the reservoir fracturing pump is used. In the Patents RF № 1035549 and RF № 2265235 the drill tool is used for the borehole seismology. In the Patent RF № 2291955 the injection well electric-centrifugal pump and the exploitation well sucker-rod pump are operated to produce the elastic vibrations for the geophysical research and the fracture distribution survey.

The Proceeding Level of Engineering

In the Patent RF № 2144684 the Vertical Profile Method Used During Well Boring is described; the seismic prospecting technology with use of boring tool as a seismic source is proposed. The method is based on the detection time of elastic energy pulses generated by the boring tool after their reflection from the formation boundary on the different depth. The reflected elastic vibration pulses penetrate the reservoir and recorded by the sensors in the form of geophones, which are located at such distance from the drilling site to provide a possibility of seismic data collection. The system contains the devices of processing and interpretation of reflected waves registered by the sensors.

In the present method the geological research is combined with the continuous drilling process in order to provide the well sound logging.

Using the data collected by this method they may predetermine the availability or lack of oil and gas only. The research resolving capacity is limited. This method does not

provide the precise reservoir depth definition, for this purpose it is required to increase a seismic event timing accuracy and a pressure wave velocity. Provided information regards to the well formation ambient only. This is due to the scatter of boring tool spheric-shaped seismic waves in the formation. The present seismic monitoring method can not determine the oil-and-gas-bearing formation geologic structure, for such research the additional adjacent well is required.

The Patent RF № 2439621 provides the Method and System of Cross-Borehole Exploration, which uses a seismic energy source and a seismic event generation time scaler in the first well; use of seismic sensor for registering of seismic event and the seismic event record time scaler for the second well – the monitored well; use of independent ground reference system for each well, which receives the signal from the Global Positioning System (GPS) satellite. Thus, the seismic energy source and seismic sensor operation is synchronized with the common time reference system.

During the announced invention realization the seismic stimulations are mapped. As compared with the previous analogue, the obtained result will consist in the time reference point exact indication for each seismic event and achievement of adequate exact velocity model of interwell space as opposed to the previous monitoring method with the single well.

The present research method can be realized with the purpose of reservoir fracturing monitoring and for crude oil production. Method increases the horizontal sweep, but at the expense of additional well, which location is confided by the elastic wave attenuation. Research accuracy is increased due to the command and data monitoring during the well operation with help of the additional equipment and additional well.

The method Seismic Analysis with Use of Electric Submersible Pump as a Seismic Signal Source (Patent RF № 2386985) is currently in use.

The seismic productive strata monitoring is proposed, in which the equipment being currently in the well without production interruption is used. The present invention uses the electric submersible pump powered by the adjustable speed drive as a seismic signal source. By means of drive frequency oscillating change (sweeping) the main frequency and harmonics family, which could be recorded and processed, may be produced. Sensor packages placed in the other well are registered the seismic waves. While the crosswell

earth formation changes, for instance, a water blockage, the seismic signal is changed and an operator can analyse the consequences of the performed stimulation.

The present method provides the seismic survey with the insignificant intervention in the well operation. Research may be performed in the specified time intervals, in this case the data are registered and compared with the previous research data in order to analyse the production activity results during the elapsed time.

Electric submersible pump elastic vibrations have the same nature as in the previous analogues and have the spherical shape. Such wave is quickly dissipated, moreover, the wave propagation along the whole well bore leads to the wave power loss. The penetrated residual signal with the specific frequency and wavelength based on the oil-and-gas reservoir nonuniformity will attenuate due to the wave dissispation at 50 m from the seismic source, therefore they perform the frequency sweep, and the waves with the different frequencies penetrate the earth formation in the form of seismic waves with the variable frequencies, and some of them are registered by the sensor in the adjacent well.

Using this method the data may be collected as in the previous analogue on the crosswell area. Data collection is impossible for the entire reservoir geological model creation, otherwise the replication of this method for the reservoir will be economically inadvisable.

Summary of the invention

The proposed method allows reducing a number of wells to single one for the acoustic measurements during crude oil production.

The proposed invention is intended to create a low-cost acoustic measurement method with use of a single well with the productive strata seismic monitoring without the crude oil production interruption, by which during the hydrocarbon extraction they collect the reliable data on the geological structure and productive strata condition in real time in order to select the optimum drilling practices with the possibility of use of this method for the reservoirs with different structure and for the depleted and hard-to-recover petroleum reserves.

The technical solution results in the increased seismic survey output accuracy on the reservoir area, production optimization, cost saving due to rejection from the additional equipment to be operated and monitored, and increase of oil recovery factor.

The objective and the said technical solution are achieved by the seismic survey during the crude oil production using a sound-emitting device located in the injection well on the gun perforation level, seismic sensors located on the ground surface on the profile. The sound-emitting device generates the elastic vibrations in the form of cylinder-shaped wave horizontally directed to the reservoir, which generated by the piezoceramic radiator vertically directed plane wave reflection from the external cone surface with the taper angle of 90 grad. The reservoir penetrating longitudinal and lateral wave amplitude-frequency response native to the deformation of reservoir exposed to the sound-emitting device elastic vibrations is registered by the seismic sensors located on the ground surface. Upon the registered data interpretation the reservoir geologic structure image is created in 3D indicating the gas-oil and water-oil stratums.

Simultaneously with the seismic survey they make oil providing the whisper of pressure providing the pressure oil feeding gradient by the elastic vibration with use of sound-emitting device. As far as the reservoir geological structure changing the sound-emitting device operational mode or its location relative to the reservoir is controlled in order to provide the calculated open flow.

The elastic vibration source to monitor the reservoir represents the same sound-emitting device, which produces the reservoir superpressure to displace oil. The sound-emitting device includes a set of piezoelectric converters to generate the elastic vibration in the form of sine wave, in which the vertically directed plane elastic waves are converted into the horizontally directed ones by reflection and 90 grad. turn from the external cone surface with the taper angle of 90 grad., and transformed into the cylindrical waves with the effective power equal to the sound-emitting device length. As a result of the sound-emitting device location on the perforation level the cylindrical wave moves in the horizontal direction right and left the reservoir and unconstrained penetrates the reservoir bed forming the wavefield and extends over the whole reservoir area as on the waveguide in the form of longitudinal and lateral deformations contributing to the reservoir coverage increase. The cylindrical wave is also could be generated with use of the cylindrical-form radiator.

The arisen reservoir deformation propagates in the form of medium vibration at each effected point through time and space forming the longitudinal and lateral waves, which penetrates the whole reservoir area crossing the oil and gas net pay and water-

saturated formation at the rate appropriate to each formation-physical properties, which are registered by the seismic sensors on the ground surface. Meanwhile, the elastic wave dynamic behavior and velocity characteristics are used, the amplitude-frequency response and velocity and time parameters are measured. The longitudinal and lateral wave measurement allows not only studying the composition and type of well fluids saturating the formation pore space, but also increasing the accuracy and precision of study and enhancing the resolving capacity. The accurate traveltime and dynamic parameter estimate is the background to create the true heterogenous geological environment model.

The method novelty consists in the increased reliability and accurate output interpretation achieved by the whole reservoir coverage by elastic waves penetrating the reservoir and generating the appropriate dynamic deformation at each formation point. Replacement of sweepout thruster type in the formation-water fluid matrix system with the whisper of pressure and increase of exposure power at the initial point leads to the entire exploitation well external boundary reaming to nominal size.

During crude oil production the reservoir is monitored simultaneously or in real time, as required. The seismic sensor profiles are relocated, if required, according to the research plan, or a few profiles are located simultaneously. The simultaneous use of large number of measurement points makes the crude oil production cheaper and more effective. As far as the oil displacement and well stimulation, the reservoir geological structure is changed, the signals registered by the ground seismic sensor are changed, and an operator visually controls these changes depending to the geological structure image and adjusts the sound-emitting device operational mode. Thus, the seismic research is performed in the dynamic mode with the stimulation monitoring in real time and without oil production interruption, this increases the output accuracy. As far as the proposed method is used, the seismic survey output precision and accuracy enable to maximal correctly select the quantitative index of operational mode change and sound-emitting device effect, reduce the unreasonable expenses incurred by the invalid data and therefore to maximize the oil conservation control. The method accuracy and obvious efficiency allow the thin bed of a few meters to be detected and treated, thereby increasing its oil recovery factor up to 100%. The proposed seismic survey can be performed both continuously and at any time intervals.

Brief Description of the Dravings

The method is illustrated with the referenced seismic survey diagram for the crude oil production as follows:

injection well operational frame 1

drive head 2

eductor 3

wellhead control equipment 4

gas and oil deposit 5

sound-emitting device 6

with

piezoelectric converter 7

and

cone surface with taper angle of 90 grad. 8

located on the level of

perforation zone 9

cable head 10

conducting rope 11 to power the sound-emitting device

control unit ground power generator 12

interconnected seismic sensors 13

acoustic signal analog-digital converter 14

piezocable 15

seismic sensor connecting link 16

portable computer 17

elastic vibration 18.

The Best Option of the Invention Implementation

During the method application the sound-emitting device (6) located in the injection well (1) on the perforation level (9) regulated on the specific frequency and power generates an acoustic pressure on the reservoir and the oil is produced. On the ground surface the seismic sensors (13) are located on the profile. Acoustic injection well operational frame

(1) generates the elastic vibration (18) by the horizontally directed cylindrical wave to the gas and oil deposit (5), which formed by reflection of vertically directed plane waves (not shown) of piezoelectric converter (7) from the external cone surface with taper angle of 90 grad. (8). Penetrated the formation longitudinal and lateral waves (not shown) are registered by the seismic sensors (13) on the ground surface. For instance, a number of profile seismic sensors can register the waves penetrating the water bed, at the same time, the other seismic sensors register the waves penetrating the oil-bearing bed, which are differed by their dynamic behaviour. The analyzed signals are transmitted by the seismic sensors (13) to the acoustic signal analog-digital converter (14). The converted digitized data are transmitted to the portable computer (17), in which they are interpreted, and the reservoir geological structure is imaged in 3D in time with shown delimitation (gas, oil, water) with the delay of 4-6 seconds by means of the dedicated software. Simultaneously with the reservoir monitoring in real time the crude oil is produced on the estimated flow. As far as the gas and oil deposit (5) geological structure change, the sound-emitting device (6) operational mode is adjusted by changing of control unit ground power generator (12) frequency to provide the calculated open flow.

The equipment set may be resupplied with the piezocable – vibration remote sensor (15), layed along the whole profile of seismic sensors with the purpose to collect the additional data regarding the elastic vibration propagation limits in the tested reservoir and the low-permeability matrix vibration power.

Industrial Use

As can be seen, the method is cost effective and do not require the additional equipment to perform the seismic research. On the occasion, the wave acted on the wellbottom zone scavenges the pore and fracture space, extricates the capillary oil, levels up the water-oil front, this involves into production a low-permeability matrix and increases a production rate.

Due to the effective power equal to the sound-emitting device length and an increase of reservoir area coverage by the wave radiator, the resolving capacity and accuracy are increased, the reservoir internal structure projection reliability is ensured, and the oil recovery factor is increased.

As a result of alterations in the reservoir, the optimal crude oil production process control in real time is reached without any "guesswork". Research may be conducted continuously or in any time without the crude oil production interruption.

The method precision and obvious efficiency allows differing and treating the gas and oil deposit in the entire area and between the remote wells, so, increasing the surface efficiency and displacement efficiency setting them to 1.0., and therefore, the oil recovery efficiency will also go to 1.0. In this case the oil-pool development will be totally monitored and controlled due to collection of operating data on the reservoir processes and possibility of changing of modes of exposure and sound-emitting device location relative to the reservoir. The method usage possibility to quarry the residual oil is increased in the wells with the depleted deposit and reserves difficult to recover, as well as during the new field development.

Claim of Invention

Seismic research during the crude oil production includes the location of sound-emitting device in the injection well on the perforation level.

The seismic sensors are located on the profile on the ground surface.

The sound-emitting device generates the elastic vibration in the form of horizontally directed to the reservoir cylindrical waves which are formed in the sound-emitting device by reflection of the piezo radiator vertically directed plane waves from the external cone surface with the taper angle of 90 grad.

The longitudinal and lateral waves penetrating the reservoir formed by the deformed layers due to exposure to the elastic vibration of sound-emitting device are registered by the seismic sensors, which are located on the ground surface and measure their amplitude frequency response.

According to the registered data interpretation, the reservoir geological structure image in 3D is created indicating the gas-oil and water-oil stratums.

Simultaneously with the seismic survey they make oil providing the whisper of pressure providing the pressure oil feeding gradient by the elastic vibration with use of sound-emitting device.

As far as the reservoir geological structure changing the sound-emitting device operational mode or its location relative to the reservoir is controlled in order to provide the calculated open flow.

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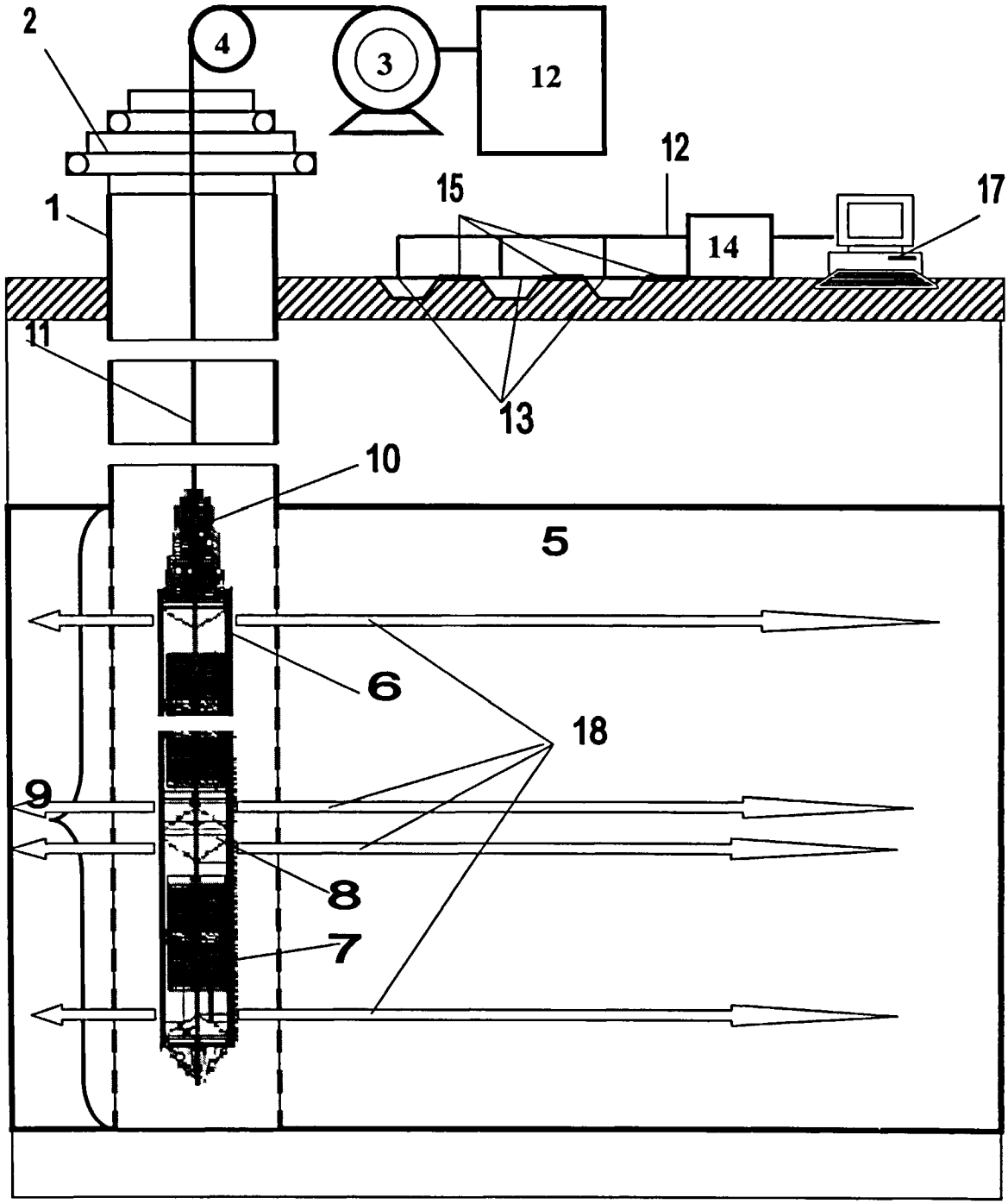

Fig. 1