INVESTIGATION OF ELASTIC CHARACTERISTICS OF BITUMEN CORE

Assist. of Prof. Ekaterina Yachmeneva[1]

Assist. of Prof. Alexander Starovoytov[1]

Sr. Lecturer Victor Kosarev[1]

[1] Kazan Federal University **- Russia**

ABSTRACT

There are rich heavy oil resources in Russia. The paper deals with bituminous sandstones in the southeast of the Republic of Tatarstan (central Russia). The shallow depth and high reservoir thickness of these deposits are very favorable factors for the heavy viscous oil development. Due to this, heavy viscous oil deposits of this territory are of great interest.

The conventional approaches for reservoir characterization and development monitoring are complicated for such bituminous deposits.

Currently, in the frame of Complex project for heavy oil shallow deposits development the development process monitoring is carried out by surface geophysics methods, including electrical prospecting and shallow seismic survey. The work presented is focused on the study of acoustic characteristics of bitumen-saturated sandstones in order to estimate the change in these parameters under the influence of hot steam used in SAGD technology. The core analysis results obtained can serve as the basis for the interpretation of the shallow seismic data and for the seismic modeling.

The reservoir characterization was conducted basing on well logging data, geological core description and lithological features. The influence of the lithological anisotropy of the reservoir layer on the change in acoustic parameters in the reservoir is discussed.

Keywords: rock physics, shallow seismic, elastic properties, core study.

INTRODUCTION

In this paper, the authors considered samples of bitumen-saturated sandstone of the Perm oil deposit located in the central part of Russia. The sandy pack is composed of loosely cemented, fine and medium-grained sands and sandstones of varying degrees of cementation, in which clastic grains are mostly fastened with high-viscosity oil.

The feature of natural bitumen is their high viscosity and density at low temperature in reservoir conditions. The temperature in the investigate reservoir is 7-8°C. Under such conditions, the movement of oil in the reservoir along the capillary will begin only after reaching the ultimate shear stress. With an increase in temperature from the reservoir to 150 ° C, the bitumen structure is destroyed due to an improvement in the solubility of asphaltenes and paraffins in the oil and the transition of their molecularly dispersed state. Under such conditions, the viscosity and dynamic shear stress for Perm bitumens are reduced by 2-3 orders of magnitude, approaching conventional oil [3]. Therefore, the deposit is developed by an underground method, in which high-viscosity oil is extracted with the help of wells with preliminary heating of the formation.

The method of steam gravity drainage (SAGD) is widely used for the development of bitumen deposits. The essence of this method for the development of high-viscosity oil is to drill a pair of horizontal wells located in a layer one above the other [7]. The upper horizontal well is inject steam into the formation. As a result of heating, the bitumen is liquefied and flows down to the lower horizontal well.

Examples of deposits developed by the SAGD method are the Athabasca deposit in Canada [2], the Ashalchinskoye [8] and the Karmalinskoye fields in central Russia. Thus, there is an increasing interest in studying the properties of the reservoir in conditions of warming up the reservoir.

In this paper, the authors studied the velocity characteristics of reservoir rocks before and after the temperature effect. The obtained results are important for the well logging interpretation [9], seismic data processing and monitoring of the field development.

METHOD AND THEORY

Nowadays laboratory experiment is the main source of reliable information about the properties of rocks. Changes in the properties of bitumen under the effect of temperature are described in the works of the University of Houston researchers [5]. It was found that the speeds of P and S waves of bitumen have a relationship with the change in density, temperature and pressure. The results presented in their papers show that the velocity of compressional and shear waves decrease under heated in the core samples with heavy oil saturation.

In a number of works on the study of the Athabasca deposit show the change in the acoustic characteristics with a change in the temperature of carbonate core samples [6,10]. Bitumen-saturated samples and samples extracted are examined in this works. Based on the results of these studies, it was concluded that the change in the velocity of compression and shear waves in rock samples depends on temperature, saturation, and pressure.

In this paper, the core material is represented by a collection of samples from a producing well, the development of which is conducted by the method of SAGD. Sandstone samples of bitumen saturated were selected for the study. The core data collection consists of 25 core samples.

The thickness of the reservoir in the selected well is 18 m. The depth of the layer is 151-169 m. According to the lithological description of core samples and geophysical data the reservoir has heterogeneous of saturation and lithological inclusions.

The laboratory study of the speed characteristics of the samples was carried out with a gradual heating from 20°C to 90°C in steps of 10°C. The value of the distance travel time of the compression and shear waves was fixed at each heating point.

LABORATORY DATA PROCESSING

In the course of the measurements, the presence of a systematic displacement of the compression and shear wave readings the time scale was established along with increasing temperature . To estimate the magnitude of the shift, the method described in the paper [4] was used. Figure 1 shows the wave patterns of one of the samples under study. In blue is a wave pattern at a temperature of 20 ° C, red - 60 ° C, green - 90 ° C. The magnitude of the shift was determined from the minimum of the objective residual function:

$$E(\Delta t) = \int_{T_w} \left(S_2(t+\Delta t) - S_1(t)\right)^2 dt\,, \qquad (1)$$

where E (Δt) is the residual function. In this case, the difference in the Tw window between the wave patterns is calculated, where S1 is the wave at 20 ° C; S2 - waves obtained during measurements with temperature increase and shifted relative to S1 by the discrepancy value Δt (in microseconds). This approach avoids the errors associated with discreteness of the quantization step in time and the incorrect choice of the time of the first wave piking.

The curves were pre-processed using wavelet filtration. As the motherboard wavelet, the Mexican Hat (MHAT) wavelet was selected. The filtering was carried out at a frequency of 850 kHz (Fig. 1, a). After filtering, for each sample, the search window for the first wave arrival was empirically selected. The objective function was calculated in the Tw = 2 μs window in 0.01 μs increments, the value of Δt was varied within ± 1 μs. The graph in Fig. 1, b shows that the magnitude of the shift between the curves for the measurement at 60°C relative to the initial measurement at 20°C was 0.13 μs, and for the measurement at 90°C it was 0.33 μs. Thus, the value of the shear time at each measurement point was obtained under conditions of temperature increase. After determining the magnitude of the shift, the values of the velocities of the elastic waves were calculated. In further analysis, the velocity value for each temperature point was normalized to the value obtained at a temperature of 20°C.

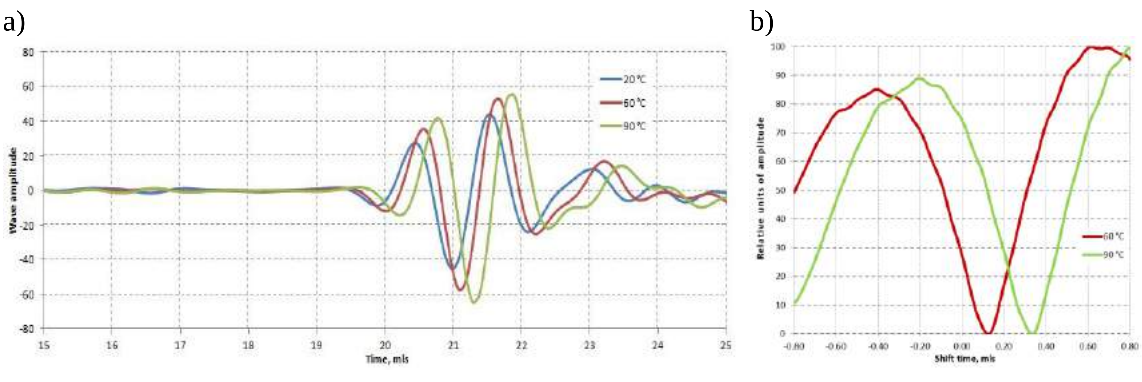


Figure 1 *Example of determining the velocity a) a fragment of the measured compression wave velocities after filtration b) a shift of the minimum of the objective residual function.*

RESULTS AND DISCUSSION

Figure 2 shows the results of the change in the compression and shear wave velocities obtained after processing the laboratory measurement data.

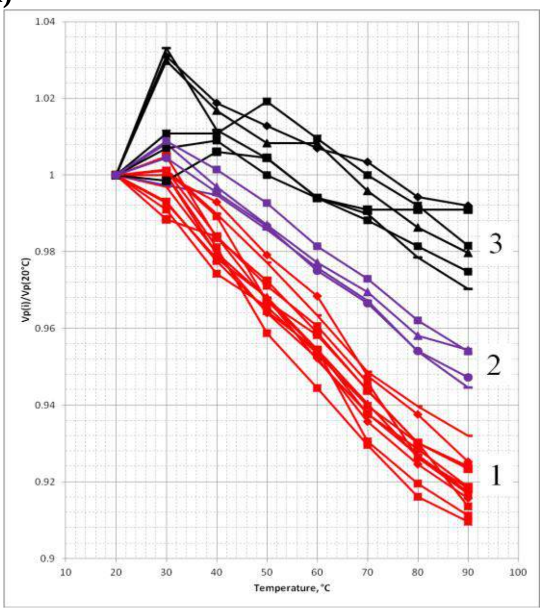
From the rate of change in the velocity of the compression wave, the samples were clearly divided into three groups. The first group represents samples of fine-grained sandstone of uniform bitumen-saturation (Fig. 2, c). The samples of this group are characterized by a drop in the value of the speed in the range from 6.8 to 9.2%. After heating on some samples, droplets of the bitumen emerging from the sample were observed. This group of samples is represented in red in Figure 2.

The second group is represented by samples of medium-grained sandstone, calcareous, having uneven spotted bitumen-saturation. The change in the velocity of a compression wave upon heating to 90°C in this case leads to a drop from 3.6 to 5.6%. This group of samples is shown in blue in Figure 2.

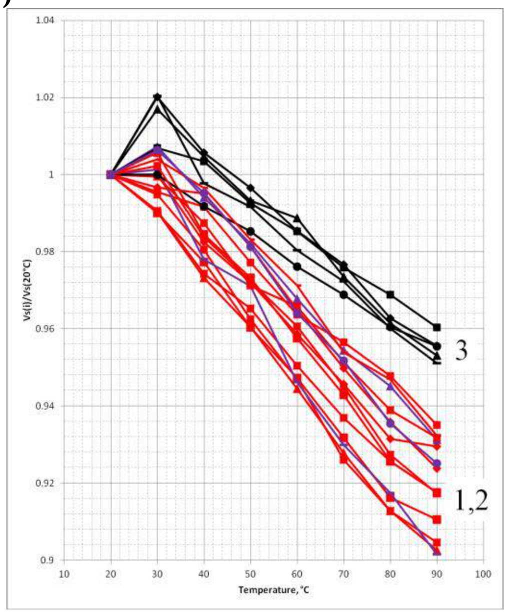
The third group is represented by samples of solid calcareous sandstone of low bitumen saturation. For this group of samples, the drop in the velocity of the longitudinal wave is fixed from 0.8 to 2.8%. This group of samples is represented in black in Figure 2.

According to the results of the study of the velocities of the shear wave, two groups of samples were singled out. All the samples of the second group (blue) went to the first group. The limits of the decrease in shear wave velocity in these groups are the following: from 5.6 to 9.8% and from 3.6 to 4.8% (Figure 2). This is due to the large bitumen saturation and significant reaction of the shear wave to the shear of bitumen from the solid state to the more liquid one.

a)



b)



c)

Figure 2 *The magnitude of the change in the velocity of the compressional wave (a) and the shear wave (b) with relative to the velocity obtained at a temperature of 20°C; c) core samples: the left sample core of the first group, in the center - the second group, on the right - the third group.*

In the temperature range from 20 to 50 ° C in the compression wave and from 20 to 30 ° C in the shear wave, the value of the velocity increases with increasing temperature. Studies carried out by Avchyan [1] on samples without bituminous saturation explain this behavior with increasing pore pressure in the samples.

CONCLUSION

In laboratory conditions, an experiment was conducted to measure the velocity of the compression and shear waves of core samples when they were heated from 20 to 90 ° C. All samples were selected in one well from the bitumen-saturated sand layer of the Karmalinskoye deposit of the Republic of Tatarstan. The results of the study are compared with the lithological description of the core samples.

As a result of the research, the velocity of the compression and shear waves in the core samples decreased. Such a change in speed is associated with a change in the properties of bitumen in the conditions of heating. At a temperature effect, the bitumen passes from a solid state to a more liquid one, its viscosity changes. This leads to a decrease in the total solid phase in the sample, an increase in its plasticity.

The different behavior of the velocity of the compression and shear waves as a result of the thermal action requires a special relation to the acoustic parameters used in the well logging interpretation and seismic modeling. In some cases, curves of changes in the velocity of the compression wave observed a flattening of the graph at high temperatures and a departure from the linear dependence. Studies are required with greater heating to refine the results obtained.

ACKNOWLEDGEMENTS

We would like to thank the Dr. Khasanov D., and Mrs Khamidullina G. for their practical advice in the research.

The work was supported by the Ministry of Education and Science of the Russian Federation (project No. 02.G25.31.0170) and by the subsidy allocated to Kazan Federal University as part of the state program for increasing its competitiveness among the world's leading centers of science and education.

REFERENCES

[1] Avchyan, H. M., Matveenko, A.A., Stefankevich, Z.B. Petrophysics of sedimentary rocks under deep conditions. Nedra, Moscow, 1979.

[2] Han, D., Liu, J., Batzle, M. Acoustic property of heavy oil - measured data. New Orlean : SEG/Annual Meeting, pp 1903-1907, 2006.

[3] Khisamov, R. S., Musin, M. M., Musin, K. M., Faizullin, I. N., Zaripov, A. T. Generalization of the results of laboratory and experimental-industrial works on the extraction of extra-viscous oil from the reservoir, Russia, Tatarstan Academy of Sciences, 2013.

[4] Kosarev, V.E., Gorgun, V.A., Gorbachev, V.N., Mikheev, M.L. Accounting for the influence of logging tool decentering in acoustic logging data processing. Geomodel 2016 - 18th Science and Applied Research Conference on Oil and Gas Geological Exploration and Development, 2016.

[5] Mochinaga, H., Onozuka, S., Kono, F., Ogawa, T., Takahashi, A., Torigoe, T. Properties of Oil sands and Bitumen in Athabasca. CSEG: CWLS Convention, pp 39-44, 2006.

[6] Rabbani, A., Ong, O., Chen, X., Schmitt, D., Nyez, J., Gray, K. Rock Physics Laboratory Experriments on Bitumen Saturated Carbonates from the Grosmont Formation, Alberta. SEG International Exposition and 86th Annual Meeting, 2016, pp 3464- 3467.

[7] Sudakov, V., Nurgaliev, D., Khasanov, D. Technology of Integrated Monitoring of Steam Chamber Evolution During the Oil Production from the Shallow Deposits of Super-Viscous Oil (Russian).*:* SPE Russian Petroleum Technology Conference and Exhibition, Russia, 2016, pp 220-243.

[8] Stepanov A.V., Sitdikov R.N., Golovtsov A.V. 2D shallow seismic study of heated by steam flooding heavy oil reservoir of Ashalchinskoye field, Neftyanoe khozyaystvo=Oil Industry,2015, no.9, pp.82-85.

[9] Yachmeneva, E. and Kosarev, V. Replenishment of the disadvantages of the prior information for the construction of the detail seismic section of the Permian system (Case study of the bitumen deposit of the republic of Tatarstan). International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management, SGEM 17(14), 2017, pp 343-350.

[10] Yuan, H., Han, D., Zhang, W. The Effect of Pressure and Temperature on Bitumen Saturated Carbonate. New Orleans: SEG Annual Meeting, pp 3151-3155, 2015.