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Investigation into operation dynamics of a downhole eccentric-type vibration source

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Abstract. Wave-type oscillations generated by a downhole unbalanced seismic source are studied on the laboratory test stand. The mode of source operation with an inner chamber filled with a fluid is investigated at shaft rotation frequency ranged from 3 to 8 Hz. The difference of rotation frequencies of vibration source and magnetic field of asynchronous motor stator is determined. The amplitude-frequency characteristic of the vibration source in the low-frequency range is obtained.

1. Introduction

The vibration– and wave-type processes are used to rectify and to enhance oil yield from production active reservoirs [1–9]. Surface-mounted vibration sources with controllable frequency and effect embracing a whole oil reservoir are efficiently applied to generate elastic oscillations [1–5]. Generated seismic oscillations passing through a rock mass thickness are recorded by downhole geophysical devices mounted at the active reservoir level. When processing a seismic signal, the carrying frequency of a vibrosorce and a response of a rock mass to its effect are singled out. After tuning in terms of resonance frequency of an active reservoir the vibration source generates a continuous flow of seismic energy for a long term, up to three months in some cases [1–2]. Deviation from the resonance frequency of the active reservoir aggravates the wave effect efficiency with no notable increase in oil production [5, 6]. Tuning of the vibrosorce in terms of resonance frequency of the reservoir takes much time and is considered an expensive prior operation, as it implies demounting and pulling out equipment from a number of bore wells.

The downhole immerse vibration sources are used to increase density of the seismic energy flow supplied to the active reservoir. Tuning of carrier frequency of an emitted signal in terms of resonance frequency of the oil bed is not practiced for impulse generators [7–9].

The eccentric-type sources are capable to adjust carrier frequency of an emitted signal and allow its compliance with resonance frequency of the production reservoir by increasing an oil yield flow to the productive well. A The tuning of emitted signal of the source is performed by adjusting frequency of rotation of electrodrive shaft which actuates an accentric mass executes. Downhole vibration sources work in a fluid occurring in a hole; such fluids in different deposits can differ in density and viscosity. In high-viscosity oil deposits the downhole accentric vibrosorce is subjected to substantial drag force, acting on rotating eccentric mass. Tuning of a vibrosorce relative to resonance frequency of an oil bed is realized by a generator drive being an asynchronous electric drive. Increase in load on drive shaft should result in reduction in rotation frequency. In other words, instead of operation at expectant resonance frequency of oil reservoir the vibration source would operate at lower frequency and this fact can negatively affect the oil production rate per this oil well. The present paper aims at



determination of discrepancy between rotation frequency of eccentric vibrosource operation in a fluid and the prescribed frequency of a magnetic field of the starter of the asynchronous electric drive. To gain these objective requires to study dynamics of low-frequency operation of the vibrosource.

2. Description of the test stand and experimental procedure

The test stand to study dynamics of a downhole vibration source consists of a metallic case with an eccentric mass mounted on it and actuated by asynchronous electric drive, the water supply and drain system, seismic oscillation recorder (Figure 1).

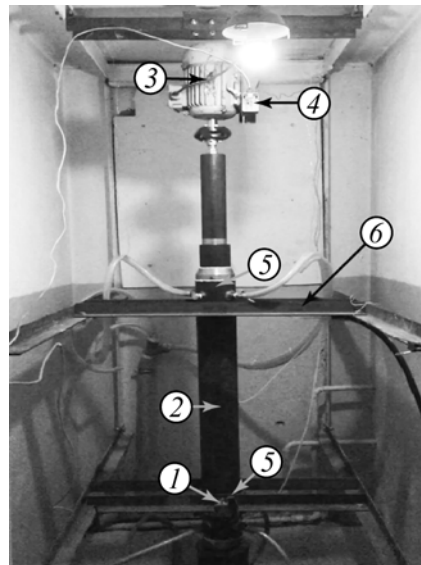


Figure 1. Scheme of eccentric mass location in the test stand: 1—seismic sensor; 2—external case of the vibration source; 3—asynchronous electric drive; 4—digital temperature gauge; 5—bearing units; 6—metallic case of the stand.

The eccentric vibrosource is mounted vertically on the test stand. The rotation moment is transmitted from asynchronous electric drive 3 through shaft and flexible coupling. Seismic sensor GMT-12.5 1 mounted at the level of bearing units 5 records frequency of magnetic field generated by source 2 under GOST ISO 10816-1-97 [10]. The analogue seismic signal is received by measurement transmitter HANDYSCOPE HS4 DIFF and then its digital form passes to a personal computer. The heating of electric drive and bearing blocks is controlled by the monitoring system consisting of digital temperature sensors, microcontrollers and a computer. Before the test the internal chamber of the vibration source is filled with water. A series of measurements is fulfilled at frequencies of magnetic field of electrodrive starter: 3, 4, 5.1, 6.2, 7.2, 8.2 Hz.

3. Procedure for processing of experimental vibrovelocity signal data

Vibrovelocity signal transmitted from analogue-digital converter to a personal computer was digitally processed to single out main harmonics with respective carrier frequency at which an eccentric device operates. Chebyshev's narrow-band filter with the final impulse characteristic was used [11–13]. In Figure 2 the amplitude-frequency spectra of the initial and filtered signals for 5 Hz carrier frequency are reported.

Fields of electric-drive starter are preset by frequency converter ABB IP20 / UL Open type.

After preliminary filtration of signals obtained at different frequencies their amplitude- frequency spectra were plotted on cumulative graph in view to determine a frequency difference Δf_i , corresponding to i -th carrier frequency of the vibration source (Figure 3).

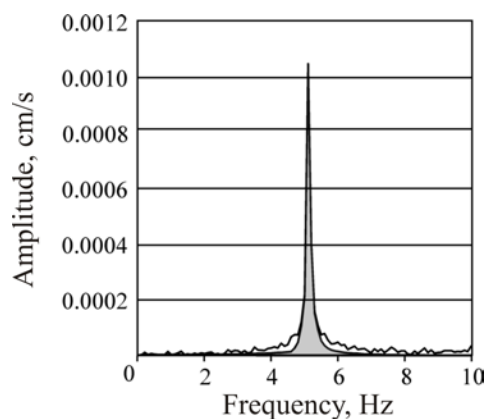


Figure 2. Amplitude and frequency distribution in initial signal of vibrovelocity (unshaded) and after application of narrow-band filter (shaded).

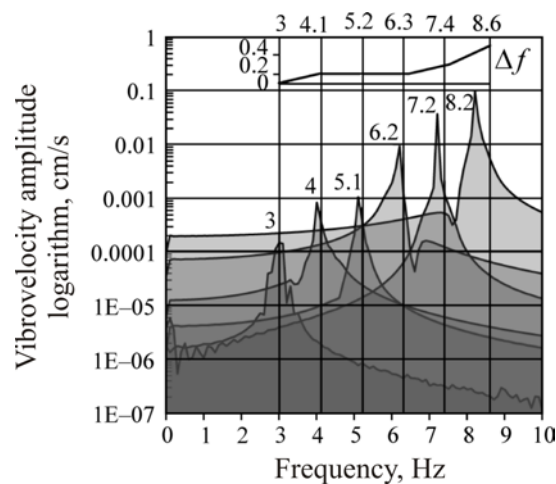


Figure 3. Summary graph of amplitude-frequency spectra of seismic signals (solid lines with filling) and respective rotation frequencies of the magnetic field starter (vertical straight lines).

The wave shape of a filtered signal was used to evaluate average amplitude of vibrovelocity at the preset frequency. In the tests the frequency range was selected within 3–8 Hz with step of 1 Hz. The wave form of the filtered vibrovelocity signal with carrier frequency of 5.1 Hz is shown in Figure 4. The measurement data and follow-on processing of the signals were used to obtain amplitude-frequency characteristics of the eccentric source in the low-frequency range (Figure 5).

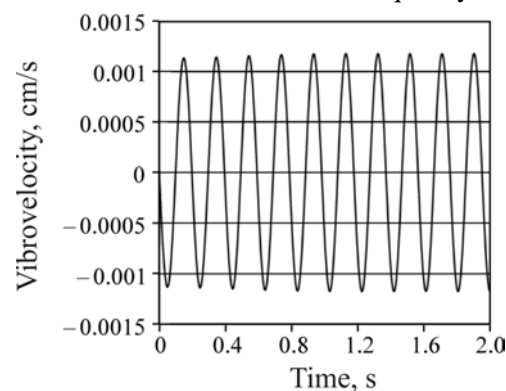


Figure 4. Wave form of vibrovelocity signal after filtration through narrow-band filter.

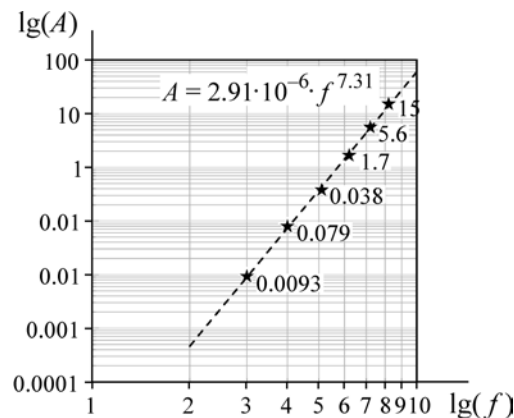


Figure 5. Amplitude-frequency characteristic of the eccentric source in the low-frequency range.

Discrete values of amplitudes at preset frequencies are approximated by power dependence of $A = kf^b$, where A is amplitude of vibrovelocity oscillations, cm/s; f is frequency, Hz; k, b are constants, equal to $2.91 \cdot 10^{-6}$ and 7.31, respectively.

Sliding of asynchronous electric drive at i -th carrier frequency of the source is determined as a ratio of frequency difference Δf_i to frequency of rotation of magnetic field starter f_{st_i} , expressed in [14–16]:

$$s_i = \frac{\Delta f_i}{f_{st_i}} 100 \% .$$

The sliding is increasing with growth of eccentric source rotation frequency. The maximum value of sliding amounts to 4.7 % and corresponds to frequency of 8.2 Hz. The instrumental determination of sliding could not be made at frequency lower than 3 Hz

4. Conclusions

With growth of rotation frequency of a downhole vibration source the drag force of the fluid acting on an eccentric source and load on the drive tend to increase and, as a consequence, difference of frequencies of magnetic field of the starter and rotor of the asynchronous electric driver is increasing.

Calibration curve is plotted for frequency difference allowing tuning of vibrosource operation in a well filled with a fluid in terms of the resonance frequency of the oil reservoir; analytical dependence of the amplitude-frequency specification was used to compute amplitude of vibrovelocity, generated by the source.

It is established experimentally that in the frequency range within 3–8 Hz the maximum sliding of the electric drive of the generator equals less than 4.7 %, thus providing the reliable operation of the generator drive.

Acknowledgements

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