Frequency selection in vibro-stimulation for the model of the large scale stress redistributon in a productivity formation

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Abstract. Possible approach to vibrorelaxation mechanisms of the high order stress ununiformities between the homogenous blocks near deposite is proposed. It is based on a well-known simple model In that way the conditions for oscillations occurrence and stability are obtained. Despite the simplifications, this approach reflects principal properties of presently used vibrostimulation technologies, and offers to obtain the qualitative criteria for vibration frequency checking. Vibration frequencies will manifest resonance properties. The changes of stressed state in deposit occurs when neighbour blocks displace, the vibration will be more effective near the borders of blocks.
Some experimental manifestations of near-surface and deep bedded (regional) block displacements are considered. Obtained data let us to compare the effect of regional and surface blocks and define the near-surface block sizes.

INTRODUCTION

Some technologies of secondary oil recovering by seismic vibration are found and developing at recent time [1-4]. Their description in publications are not full due to “know-how” contenting. In addition to that, there are not clear concept of weak vibrational wave’s influence on processes in porous saturated media [5]. One of models for describing mentioned effect is the model of the high order stress ununiformities redistribution in the oil deposite. Stimulation technology [2,4], based on that model, is now adopted to use in West Siberia by a/s Khantymansiuskgeophysics.

It is known, what ununiformities in compressible layer are the cause of not fully compression on some parts of it, us a result of stress redistribution on uncompressible parts of that layer and it’s encirclement. Such a redistribution may go on at the natural and mining processes [6].

If we initialize the relief of that uncompressible (bearing) regions, the additional compression on whole layer and pore pressure increase occur. In [6] is noted, what one of the methods of that relief is the vibration, which leads to the microdeformations accumulation, fatigue of the rock and the slipping between layer's large order parts (blocks).

The purpose of this report is to call attention on possibility of qualitative description of such mechanism's frequency dependence.

SIMPLE MODEL

It is a model of certain mass, located between two vibrating walls and elastically connected with them. Schematically it is a cub (body A) which is attached to the walls by springs on the right and on the left of it [7].

In such a picture, the cub with springs represents weaken zones between large-scale blocks, and the walls represent the borders of those blocks.

Equation of motion for body A is:

$$\ddot{x}+\omega^2 x=0 \qquad (1)$$

We assume what the body is deflected from equilibrium state at the time moment t_0 , when it's coordinate is $x(t_0)=-\frac{1}{2}X$ and it come in motion with the velocity $\dot{x}(t_0)=v_0(1+\varepsilon\sin(\Omega t_o)$, directed to equilibrium position. Equation (1) with this initial conditions define the motion during $t=t_1$, when, at $x(t_1)=\frac{1}{2}X$ body take the velocity $\dot{x}(t_1)=v_0(1+\varepsilon\sin(\Omega t_1)$. After all, this scheme repeated.

Integration of (1) with noted initial conditions give:

$$\begin{aligned} x(t) &= \left[X^2\omega^2+4v_0^2(1+\varepsilon\sin(\Omega t_0))^2\right]^{\frac{1}{2}}\times \\ &\times(2\omega)^{-1}\sin\left\{\omega(t-t_0)-\operatorname{arctg}\left[\frac{1}{2}X\omega v_0^{-1}\left(1+\varepsilon\sin(\Omega t_0)\right)^{-1}\right]\right\} \end{aligned} \qquad (2)$$

Equation (2) leads to condition

$$\Delta T=t_1-t_0=\frac{2}{\omega}\operatorname{arctg}\frac{1}{2}X\omega v_0^{-1}(1+\varepsilon\sin\Omega t_0)^{-1}+\frac{\pi}{\omega} \qquad (3)$$

where Δt is time interval during which the body return to the equilibrium position

Using (3) one can obtain the condition of periodical motion for body, which is moved from x=-X/2 at $t=t_0$:

$$\sin(\Omega t_0)=-\varepsilon^{-1}(1+z\,\mathrm{tg}\pi y)\,, \qquad (4)$$

where $z = \frac{1}{2} X\omega v_0^{-1}$ and $y = m\omega\Omega^{-1}$ (y is the ratio of springs-body natural frequency ω to Ω/m, where Ω is frequency of external excitation and m is integer number). So expression (4) can be written in form:

$$1 - \varepsilon < -z\,tg\pi y < 1 + \varepsilon \qquad (5)$$

The condition of stability for considering periodical regime is obtained in [7].

$$\varepsilon^2 - (1 + z\,tg\pi y)^2 < \left(\frac{zy}{m\cos^2(\pi y)} \right)^2 \qquad (6)$$

We can see what process is stabile at any small excitation amplitude ε if ω/Ω is close to n-1/4, where n is positive integer.

As can be obtained $y_n = -\frac{1}{\pi} \mathrm{arctg} \frac{1}{z} + n$ (n=1,2,…) and consequently the system will be in stabile periodic regime with frequency Ω/m at any small ε when

$$\omega = \omega_n^* = \frac{\Omega}{m} \left(\frac{1}{\pi} \mathrm{arctg} \frac{1}{z} + n \right). \qquad (7)$$

For small natural frequency ω and initial amplitude of velocity v_0 , ω^* can be approximated by (n-1/2) Ω/m .

Equation (2) let to hold what oscillation's amplitude is in weak dependence on ω when v_0 is not very large than Xω. Approximations show, what for typical vibrostimulation frequencies (near 10 Hertz), this conditions are true.

The affect of vibration's frequency at small amplitudes seems to be determined by oscillation's stability, because rock's fatigue is in direct dependence on periodical regime's duration. Stimulation will be more effective at that frequencies and amplitudes, the stability region for which (in ε ,y plane, see (6)) is maximally wide.

Some components of deposit seismic background may be close to mentioned "stabile" frequencies Ω, and external vibration at those may have resonance response.

We can use above treated to make conclusion what vibrosensitiv places on ground surface over the deposit will show increase of background seismicity at the vibration's and it's multiple frequencies. In that case the resonance curves will be more sharp in more sensitive points. Seems obvious what the changes in that frequency's values indicate the beginning of blocks moving and system's redistribution.

SOME EXPERIMENTAL OBSERVATIONS

Some information of small (~10 km) blocks gives us the observation of the corrosion density on pipeline Urengoy-Surgut-Cheliyabinsk. We dealed with the 140km length section, which was explored above 20 years. Defect's distribution was compared with magnetic field along the pipeline. Results are presented on fig.1.

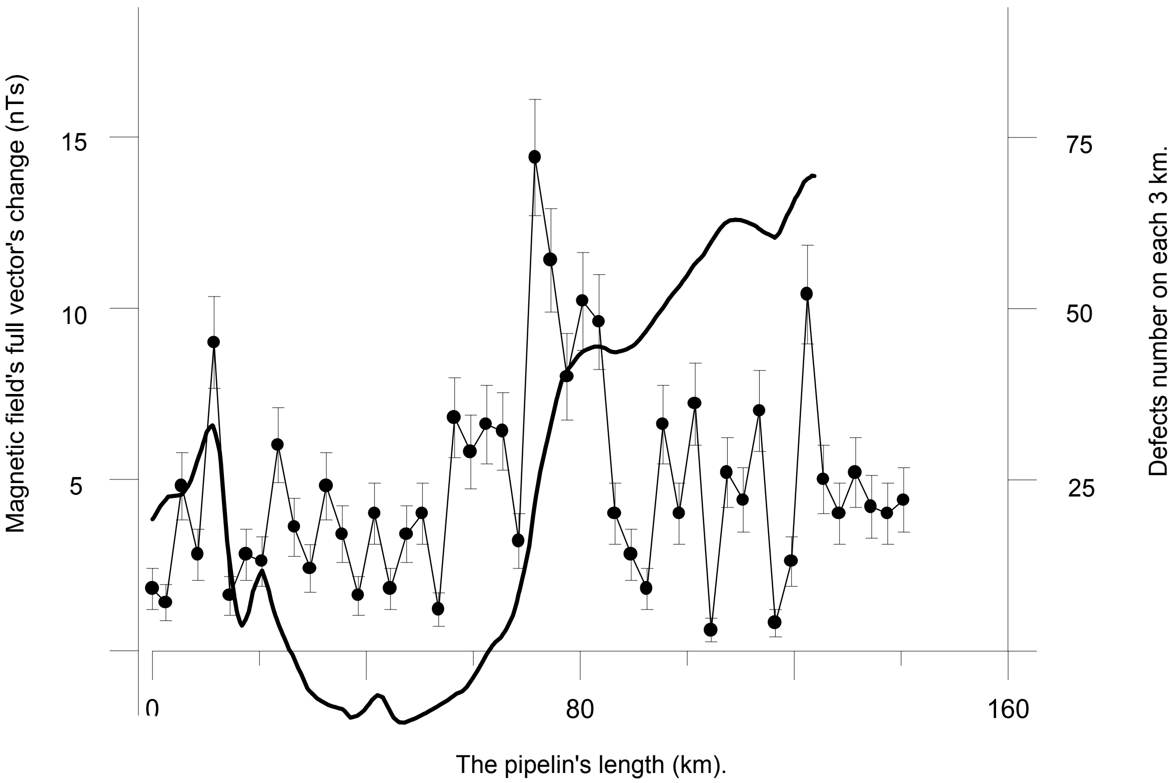

Figure 1

One can see, what corresponding two curves are not independent, and be sure in correctness of this conclusion on 0.999 probability level.

Our magnetic field maps make possible to separate the borders of large (regional) deep located (2km) blocks, by coupling them with field's changes in passing from one block to other, each with it's own, uniform magnetization.

We see what together with large crust breaks (block's borders), fig.1 show more frequently small breaks. Corresponding small block's length is ~10km, and that is in order of value comparable with typical deposit's sizes.

Large crust's breaks was filling by sedimentary rocks and erosion products in long time. The stiffness of medium in such a zones becomes less, than in paternal rock. Gravitational influence of moon and sun leads to relatively big deformations and to rock fatigue and corrosion in that zones.

Analogous mechanism formed the multiple secondary breaks, based on large break in lithosphere. They are less differ in magnetization and our methodic is not the best for separation them.

But we can conclude, that there are a tree of breaks, going from the border of deep laying blocks to the surface. In our point of view, vibration energy reaches deep layed blocks due to high conductivity, which is inherent to "branches" of that tree at noted stability conditions. The borders of blocks are most weakened and well deforming parts of the crust, and the vibration can provocate the blocks slipping with each other.

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