P097 IS THERE PERSPECTIVES TO FIND OUT FLUIDS IN CRACKS DUE TO SEISMIC WAVES ATTENUATION?

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Abstract. There are a lot of papers, which dedicate to attenuation of seismic waves due to viscous fluid in pores and cracks. Beginning from famous papers of Biot, the attenuation of seismic waves was related with internal friction between matrix and fluid. But this theoretical model ignores the structure of pore space, in particularly, a specific surface of the pore space. But just this internal surface produces a friction effect itself. No wonder, the main effect was the more viscosity, the more attenuation of seismic waves. If it would be truth, the mentioned problem would be solved immediately, because the differences of viscosity of fluids reach up to several orders. Obviously, the real pore space gives some not simple effects, which don't us a possibility to have a success in all real geological situations. In this paper author decide that the attenuation depends not on viscosity itself, but on the ratio between average thickness of crack and so called viscous length of fluid. Besides of it, there is no monotonous increasing of attenuation by increasing of frequency. This relation has some maximum, and there is a small attenuation both by very high frequency and by very low one.

Key words. Specific surface, viscous length, attenuation, internal friction, dissipate forces.

Introduction. The cracked media have very special structure of pore space. The main feature of it is following. These media may have very small porosity, but not small, even very large a specific surface. There is a relation [1] between specific surface σ_0 , an average distance between one crack to another l_0 and porosity f in the form:

$$\sigma_0 l_0 = 4(1-f) \qquad (1)$$

The special feature of small porosity cracked medium is small one dimension compared to two others. On the other words, the thickness of crack is very small value, compared to the average straight linear segment of it, or square root of one section area. It gives a possibility, as a first step, to use the test problem about of fluid, which is moving through volume, bounded by infinite parallel planes divided fluid (within of them) and solid matrix (outside of them) (Fig.1). This classical problem about moving of fluid through narrow slot was solved Landau and Lifschitz [2].

Test problem of Landau and Lifschitz.

Let's put that two planes oriented parallel axes x. Vertical coordinates of them are $-h/2$ and $h/2$. Let's put too, that the volume force, which causes a flow of fluid, oriented along axes x too. Besides of it authors supposed that mentioned volume force is a periodic function of time, kind of $ae^{-i\omega t}$, where a-is amplitude and ω is a frequency of vibration. On the other words there is a relation

$$-\frac{\partial p}{\rho \partial x} = ae^{-i\omega t} \qquad (2)$$

In the equation (2) p is a pressure in liquid and ρ is a density of it. The Navier-Stokes equation takes a form:

$$\frac{\partial V}{\partial t} = \nu \frac{\partial^2 V}{\partial y^2} + ae^{-i\omega t}, \qquad (3)$$

where V means the particle velocity, $\nu=\eta/\rho$ is the kinematics viscosity and η is an usual dynamics viscosity. After Fourier transformation with respect to time arises the ordinary differential equation in the form:

$$V_{yy} + ik_0^2 V = \frac{a}{\nu}. \qquad (4)$$

In equation (4) $i = \sqrt{-1}$, while $k_0 = \sqrt{\frac{\omega}{\nu}}$, and $\frac{1}{k_0} = \sqrt{\frac{\nu}{\omega}} = \lambda_s$ is the viscous length. As to boundary conditions there are usual hydrodynamics conditions of adhesion, i.e.

$$V(h/2)=V(-h/2)=0. \qquad (5)$$

A strong solution of equation (4) by boundary conditions (5) is giving by expression

$$V = \frac{ia}{\omega}\left(1 - \frac{Cosky}{Coskh/2}\right) \qquad (6)$$

k means an expression $k = k_o\sqrt{i}$, i.e. k is a complex value.

The average relative velocity between boundary and liquid $<V>$ may be calculated as:

$$<V> = \frac{ia}{\omega}\left(1 - \frac{2}{kh} tg\frac{kh}{2}\right). \qquad (7)$$

In the case of very thin slot, i.e. $kh \to 0$ there is more simple relation

$$<V> = a\frac{h^2}{12\nu} \qquad (8)$$

It means that the value $<V>$ is a pure real value in this passage to the limit. In the opposite case by $kh \to \infty$, the analogous value is a pure imaginary one, according to expression

$$<V> = i\frac{a}{\omega}. \qquad (9)$$

Equation of motion and attenuation of seismic waves.

Lets try to calculate the volume friction force F due to gradient of particle velocity, namely:

$$F = \sigma_0 \eta \frac{\partial V}{\partial y} = -\rho a \sigma_0 \frac{h}{2} tg\frac{kh}{2}\frac{2}{kh} = -\rho a f \frac{2}{kh} tg\frac{kh}{2}. \qquad (10)$$

The specific surface σ_0 remakes a surface force $\eta\frac{\partial V}{\partial y}$ into volume force F, which corresponds to the mentioned surface force. A dimensionless product of a specific surface σ_0 to the average thickness h is equal to the double porosity $2f$. A volume force F in (10) is a complex value, because k is a complex value too. In order to write the equation, of motion it is necessary to generalize the effects on the arbitrary positions of forces or arbitrary normal vectors of planes. As to volume forces ρa, which is acting to fluids bounded by any couple of plane, this value is equal to the common volume force in microinhomogeneous medium, i.e. $\frac{\partial \sigma_{ik}}{\partial x_k}$, or to the equal value $\rho\omega^2 u_i$. The friction volume force is acting against inertial force, and thy have the opposite signs. Hence in inertial term there are two summands, namely usual inertial force and friction force with opposite Sign. The equation of motion takes a form:

$$\frac{\partial \sigma_{ik}}{\partial x_k} + \rho \omega^2 u_i (1 - f \frac{2}{kh} tg \frac{kh}{2}) = 0. \qquad (11)$$

The real value in brackets means some change of frequency due to internal friction, while an imaginary part $fg(kh)=Im\, f \frac{2}{kh} tg \frac{kh}{2}$ gives us an attenuation of seismic wave due to internal friction. This dimensionless function $g(kh)$ can be expressed by the real variable $x=k_0h/2\sqrt{2}$ or $x=h/2\sqrt{2}\lambda_s$, where λ_s is the viscous length. The formula, which describes an attenuation takes the form:

$$g(x) = \frac{ShxChx - SinxCosx}{x(Cos^2 x + Sh^2 x)} \qquad (12)$$

The relationship (12) is shown on the Fig2. The curve, which shows an attenuation have a maximum near $x=3/2$. It means, that the attenuation depends on a ratio between average thickness of crack and viscous length of fluid. There is no possibility to divide the effects of viscosity and thickness of crack separately. There is a possibility to estimate a ratio of them only. Besides of it, the attenuation doesn't depend on specific surface. It is an interesting case that the structure of pore space represented by porosity only. On the table 1 is shown different attenuation for average thickness of crack which is equal to one mm. The numbers of vertical lines on the Fig. 2 correspond to numbers on the table 1. The gases have very small usual dynamics viscosity η. But the kinematics viscosity $\nu=\eta/\rho$ is not small

TABLE 1.

h=0,1 cm	$x=h/2\sqrt{2}\lambda_s$
1. Gas *50 Hz , pressure 10 Mpa*	*x=1.414*
2. Water *50 Hz*	*x=2,5*
3. Oil *1 KHz*	$x=1{,}12.10^{---2}$
4. Gas *1 KHz pressure 10 Mpa*	*x=6,324.*
5. Gas *1KHz pressure 1 Mpa*	*x=2*
Other situations with very small attenuation due to viscous fluid in cracks	
6. Oil *50 Hz*	*x=25*
7. Gas *50 Hz pressure o,1 Mpa*	*x=14,1*
8. Water *1KHz*	*x=11,2*

The maximum of attenuation for frequency *50 Hz* and average thickness *0,1 cm* corresponds to gas in cracks by pressure about *10 Mpa.* But by pressure about *0,1Mpa* the attenuation is negligible small. The same not simple situations there are for other practical examples. There is no wonder, that in practice there are a lot of positive examples of detection expressly of gas in cracks and pores, in spite of the viscosity of it is very small. Besides of it, the attenuation is not increase with growing of frequency, unlike on simple media without pore space. In structured media, in particularly, in cracked media there is both effects, namely, increasing and decreasing of attenuation with frequency, depends on the ratio between average thickness of crack and viscous length of it.

Conclusion.

The attenuation of seismic waves in cracked media due to viscous fluid in cracks doesn't depend on viscosity itself. It depends on the ratio between average thickness of crack and viscous length of fluid. This mentioned value (viscous length) for gas is changing very fast by

different pressure in it. This phenomenon explains some successful experiments about detection of productive layers, containing gas with high pressure.
There is no a monotonous increasing of attenuation by increasing of frequency. This relationship has some maximum. Thus there is small attenuation both for very high frequency and for very low one.

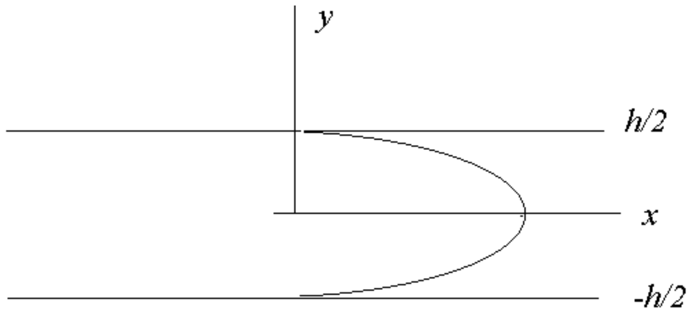

Fig.1

On the Fig.1 is shown the profile of fluid particle velocity. The fluid bounded by two planes *y=-h/2* and *y=h/2.*

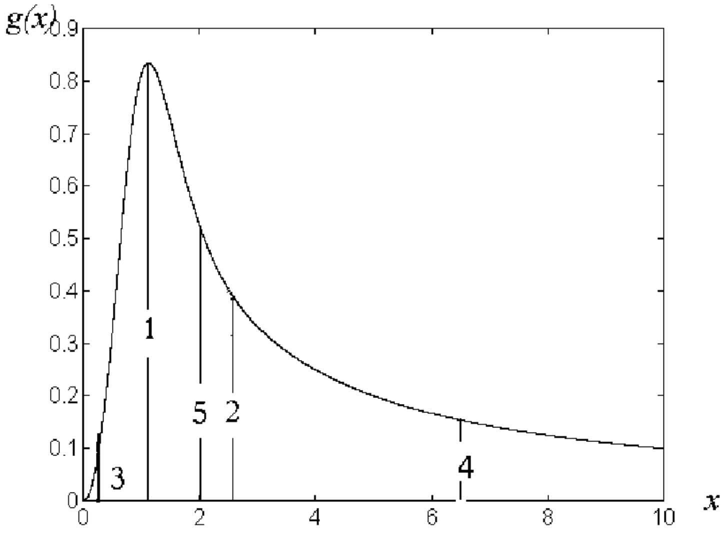

Fig.2

On the Fig. 2 is shown a relationship between dimensionless function of attenuation *g(x)* and dimensionless ratio between average thickness of crack and viscous length of fluid $x=h/\lambda_s 2\sqrt{2}$. This relation has a maximum, and there is a small attenuation both for very high frequency and very low one. The numbers correspond to data on the table 1.

References.

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