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EXCITATION OF RAYLEIGH AND CONICAL WAVES BY SOURCES MOVING IN VICINITY OF DIVIDING BOUNDARY OF TWO CONTACTED MEDIA

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Results of theoretical analysis of conical and Rayleigh waves excited by oscillating force $F\exp - iwt$ that moves into one of two media contacted along plane boundary is presented in this report. Asymptotic expressions describing excitation efficiency and wave frequency shift are given and discussed. Possibility of ground profiling is considered on base of the reception of conical wave generated by moving source.

We consider a situation that corresponds to source motion with Mach number less than one, i.e we supposed that waves were excited by a source moving with velocity lower than minimal sound propagation speed. The direction of source motion is assumed as well normal as parallel to interface of horizontal boundary. Note that interface of two scalar (acoustical) media is assumed by conical wave generation and scalar (upper medium where placed source) with solid body (down medium) interface will be supposed at Rayleigh wave excitation. Besides by assumption the velocity of sound propagation in upper medium is lower than Rayleigh wave velocity at the body boundary. Asymptotic estimations of integral expressions which carried out in vicinity of a branch peculiarity point give the formulas described particle wave displacement. So z-component of conical wave displacement for the case of normal (vertical) motion is as follows [1]:

$$U_z = \frac{F_0}{pw'r_2 c_2 (1+(\frac{V}{c_1})\sqrt{1-\frac{c_1^{\ 2}}{c_2^{\ 2}}})\sqrt{rL^3}} \exp[-iw'\{t - \frac{L}{c_2} - \frac{|z+h|}{c_1\sqrt{1-\frac{c_1^{\ 2}}{c_2^{\ 2}}}}\}], \qquad (1)$$

where $w' = w(1+\frac{V}{c_1}\sqrt{1-\frac{c_1^{\ 2}}{c_2^{\ 2}}}), L = r - |z+h|\,tgi_1.$

Sketch of acoustical medium structure, displacement of source and receiver is presented on Fig. 1.

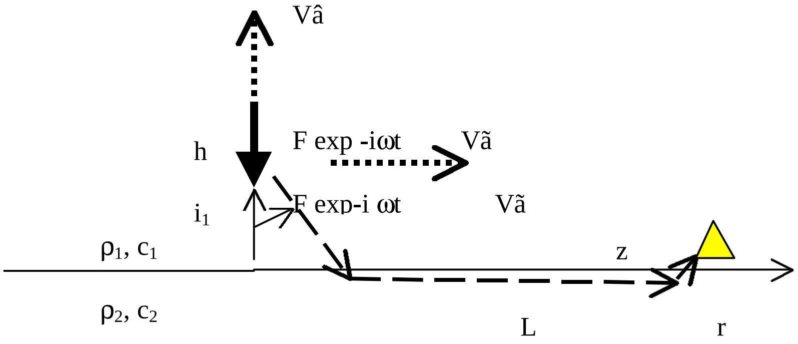

Fig.1.

Doppler frequency shift is positive by source moving away from a boundary and determined by the formula:

$$dw = w(\frac{V}{c_1})\sqrt{1-\frac{c_1^{\ 2}}{c_2^{\ 2}}}. \qquad (2)$$

With respect to amplitude dependence the formula (1) predicts the decrease of wave intensity at moving from the boundary.

In the case of parallel to plane boundary motion the observation to be conveniently performed in translation moving system that accompanied the source. Doppler shift in this observation system will be showed itself at wave number dependence. The formula describing the amplitude and frequency dependence from azimuth angle ψ at excitation of conical wave is the following [1]:

$$U_z = \frac{F_0\,(1-\frac{V\cos y}{c_2})}{p r_2 c_2 w\sqrt{rL^3}} \exp[-i\{wt - w\frac{\frac{L}{c_2}+\frac{|z+h|}{c_1\sqrt{1-\frac{c_1{}^2}{c_2{}^2}}}}{(1-\frac{V\cos y}{c_2})}\}] \tag{3}$$

Higher frequency and lower amplitude are distinguished by wave excitation for the source moving in direction of wave propagation. Frequency shift is resembled to that of Rayleigh wave excitation [2].

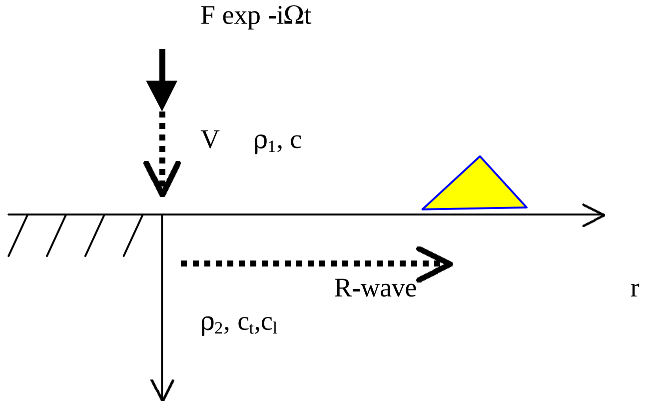

Fig.2.

Similar results of analysis by excitation of Rayleigh wave of source moving perpendicularly to boundary would be presented. The positive direction of source motion should be coincided with a vector of intrinsic normal to boundary and looking to solid body. Sketch of interface of acoustical medium with solid body, source and receiver is presented on Fig.2.

The following equation of frequency ϖ of surface R-wave that received in observation system connected with boundary is obtained:

$$(2\frac{v^2}{\tilde{n}_{\hat{E}}{}^2}-\frac{1}{\tilde{n}_t{}^2}(\Omega+V\sqrt{\frac{\Omega^2}{c^2}-\frac{v^2}{c_R{}^2}})^2)^2-4\frac{v^2}{c_R{}^2}\sqrt{\frac{v^2}{c_R{}^2}-\frac{1}{c_l{}^2}(\Omega+V\sqrt{\frac{\Omega^2}{c^2}-\frac{v^2}{c_R{}^2}})^2}\cdot \tag{4}$$

$$\sqrt{\frac{v^2}{c_R{}^2}-\frac{1}{c_t{}^2}(\Omega+V\sqrt{\frac{\Omega^2}{c^2}-\frac{v^2}{c_R{}^2}})^2}=0,$$

It can be seen from equation (4) that frequency of the wave registered in nonmoving observation system is to be itself into interval: $\frac{\tilde{n}_R}{c}>\frac{v}{\Omega}>\frac{c_R}{c_t}$, that defined by ralation of acoustical and elastic wave propagation velocities. The equation (4) is analyzed numerically and both cases of direction motion are considered (V>0,V<0). Calculations are performed by values of ratio $\frac{c}{c_R}=0.6,0.8,0.95.$ These results are plotted as graphics (ϖ,V) on Fig.3 by curves 1,2,3 correspondingly. Analysis shows that there is slow frequency increase for positive velocity directions and decrease otherwise. More fast increase corresponds to lower values c/c_R. The motion from the boundary causes the diminution of wave frequency. Besides by the exceeding of motion velocity of about 10%-15% with respect to sound velocity causes full wave silence. It is illustrated by onset of left hand side of curves 1,2 on Fig.3.

Resemble analysis of body wave generated by oscillating force placed in acoustical medium and moving normally to the boundary shows that P and S-waves would be registered far from origin in solid medium at frequency with Doppler shift that is constant for all directions. It equals to: $v=\Omega(1+\frac{V}{c})$. This circumstance is true when the distance between moving source and boundary is less than wave length. This result is like to usual acoustical Doppler effect but they are not identically due to boundary influence. However there is distinguishing between frequency shift of body waves, Rayleigh waves and conical waves which generated by moving sources. This peculiarities arise due to

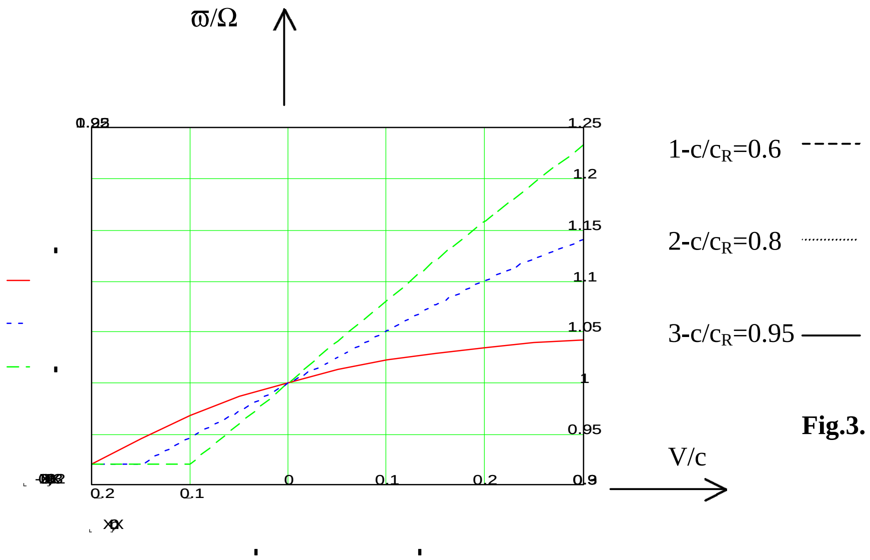

Fig.3.

medium inhomogeneities such as boundaries. Features of different wave type Doppler effect can be used for example in ground profiling. Paths of wave propagation are given on Fig.4. Under it the simplest formulas are presented and they help to get minimal elastic wave velocity jumps (that differ nearest layers) required for separated extraction of spectral component in multiple of received signal.

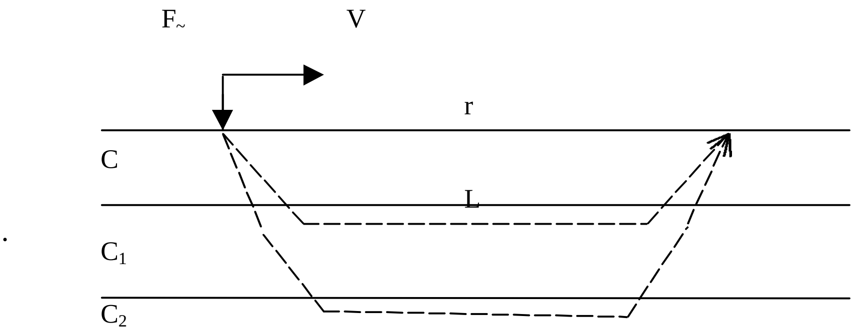

Fig.4

$$f_1 = \frac{f_0}{1 - \frac{V}{C_1}},\ f_2 = \frac{f_0}{1 - \frac{V}{C_2}},\ f_1 - f_2 = f_0 \frac{M_1 - M_2}{(1 - M_1)(1 - M_2)},\Delta f = \frac{1}{T_{\text{íàáë}}} << f_0 V \frac{\Delta C}{C^2},\Delta C >> \frac{C^2}{f_0 V T_{\text{íàáë}}}$$

Thus an estimation of ground profiling possibility could be accomplished on the base of reception of conical wave excited by moving source and signal frequency resolution and extraction of different spectral components which formed the multiple. The amplitudes of multiple components depend on wave excitation efficiency and on attenuation by wave propagation. However in addition to a requirement of an exceeding by signal over noise level it is necessary to provide of narrower natural band width than difference of Doppler frequency shift of conical waves propagating along the neighbour boundaries. Last condition permits to get the next relation connecting the frequency of sounding signal, source motion velocity, time of observation with seismic – acoustical parameters: average P-wave velocity and P-wave velocity jump of two nearest layers:

$\Delta f = \frac{1}{T_{íàáë}} << f_0 V \frac{\Delta c}{c^2}, \Delta c >> \frac{c^2}{f_0 V T_{íàáë}}$. The use of following values of listed above parameters: c=1000 m/s, f_0=100 Hz, T=10 s, V=20 m/s allows to obtain the minimal P-wave velocity jump that equals of about Δc=50 m/s. Real velocity jump that occur in near to surface geology structures exceed this estimation that demonstrates possibility of ground profiling by this method.

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