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## OSCILLATION OF CURRENTCARRIER CYLINDRICAL ENVELOPE WITH FILTER

**Abstract**

*In the paper small axially symmetric oscillations of a thin cylindrical currentcarrier envelope of infinite length filled with elastic medium. The asymptotic formulas for determination of fundamental frequency of oscillations of analyzed system are obtained.*

Consider small axially symmetric oscillations of a thin cylindrical currentcarrier envelope of infinite length filled with elastic medium. Consider that the envelope is prepared from superconductive material and placed in magnetic field.

Let's write out the equations of small axially symmetric oscillations of infinity length envelopes in displacements [1].

$$\begin{gathered}\frac{\partial^2 u}{\partial x^2}+\frac{\nu}{R}\frac{\partial w}{\partial x}=-\frac{1-\nu^2}{Eh}P_x^*,\\ \frac{\nu}{R}\frac{\partial u}{\partial x}+\frac{h^2}{12}\frac{\partial^4 w}{\partial x^4}+\frac{w}{R^2}==\frac{1-\nu^2}{Eh}\left(P_r^*-\rho h\frac{\partial^2 w}{\partial t^2}\right).\end{gathered}\tag{1}$$

where $u,w$ are the components of displacement vectors; $R,h$ are the radius and thickness of envelope, respectively; $\nu,E$ are the Poisson's coefficients and Young module of material of envelope respectively; $\rho$ is the density of material of envelope; $t$ is time; $P_x^*$ and $P_2^*$ involve magnetic pressure and the force of reaction from filler side.

$$\begin{gathered}P_x^*=P_x+q_x,\\ P_r^*=P_r+q_r.\end{gathered}\tag{2}$$

where $P_x$ and $P_r$ are determined from the expressions [1]

$$P_x=ikP_0\omega;\quad P_r=-\frac{2w}{R}P_0,\tag{3}$$

where $k$ is a wave number, $P_0$ is a magnetic pressure. We represent the components $q_x$ and $q_r$ of pressure vector from filler side on envelope in the form of [2]

$$q_x=-k_x u;\quad q_r=-k_r w,\tag{4}$$

where $k_x$ and $k_r$ are subject to definition. We'll search the solution (1) in the form of

$$\begin{gathered}u=u_0\exp i(kx-\omega t),\\ w=w_0\exp i(kx-\omega t),\end{gathered}$$

where $k$ is a wave number, $\omega$ is a circular frequency, $u_0,w_0$ are displacement amplitudes. Substituting (4) in (1) with regard to (3) and (4) we arrive at the equations

$$\begin{gathered}\left(-\frac{(1-\nu^2)k_x}{Eh}-k^2\right)u_0+\left(\frac{\nu ik}{R}+\frac{1-\nu^2}{Eh}ikP_0\right)w_0=0,\\ \frac{\nu}{R}iku_0+\left(\frac{h^2k^4}{12}+\frac{1}{R^2}-\frac{2(1-\nu^2)}{Eh}\frac{P_0}{R}+\frac{(1-\nu^2)}{Eh}K_2-\frac{1-\nu^2}{E}\rho\omega^2\right)w_0=0.\end{gathered}\tag{5}$$

The system (5) is homogeneous, algebraic and linear with respect to $u_0, w_0$. For the existence of a non-trivial solution of the named system we equal the principal determinant to zero;

as a result we obtain the frequency equation

$$\det\|a_{ij}\| = 0 \quad (i, j = 1,2), \tag{6}$$

where

$$a_{11} = \frac{(1-\nu^2)k_x}{Eh} - k^2 \qquad a_{12} = \frac{\nu ik}{R} + \frac{1-\nu^2}{Eh} ikP_0 \qquad a_{21} = \frac{\nu}{R} ik$$

$$a_{22} = \frac{h^2k^4}{12} + \frac{1}{R^2} - \frac{2(1-\nu^2)}{Eh}\frac{P_0}{R} + \frac{(1-\nu^2)}{Eh}k_r - \frac{1-\nu^2}{E}\rho\omega^2$$

The frequency equation (6) is transcendental, since the modified Bessel's function of zero and first order, of the first and second genus $k_r$ and $k_x$ are contained in the expressions of $I_0, I_1, k_0$ and $k_1$.

Using the asymptotic formula for the Bessel's function the frequency equation (6) is reduced to algebraic one.

In the case when inertial actions of the filler in the oscillation process of the envelope are small, i.e. for $\omega << ka_e$ the expression for $k_x$ and $k_r$ admits the form [2]

$$k_x = \frac{\mu L_1}{RL_2}; \quad k_r = \frac{\mu N_1}{RN_2}$$

for $k^* >> 1$

$$L_1 = -k^{*2}(1 + 0{,}5q_1) + 2k^{*2}q_1 - 1{,}5k^*,$$

$$L_2 = -k^*(1 + q_1 + 2Hq_1) + 0{,}75(2 - 3q_1) + H(1 - 0{,}5q_1),$$

$$N_1 = (1 + b^2k^{*4})[-2k^* + 1{,}5 + q_1(-4k^* + 0{,}25)] + 2k^* + (2k^* + 2{,}25),$$

$$N_2 = -k^* + 0{,}5 - q_1(k^* + 0{,}75) + H[-2k^* + 1{,}5 + q_1(-4k^* + 0{,}25)]$$

for $k^* << 1$

$$L_1 = -2k^{*2}q_1; \qquad L_2 = -q_1 + (1 - 2q_1)H,$$

$$N_1 = \frac{\lambda}{\mu}(b^2k^{*4} + 1) - 2\left(1 + \frac{\lambda}{\mu}\right),$$

$$N_2 = -1 - H\frac{\lambda}{\mu},$$

where $k^* = kR$, $a_t, a_e$ are propagation velocities of longitudinal and transverse waves in the filler: $q_1 = \frac{a_t^2}{a_e^2}$, $H = \frac{(1-\nu^2)R\mu}{\nu Eh}$; $\lambda, \mu$ are the Liame coefficients for filler.

From the equation (6) for the square of the fundamental frequency we obtain

$$\omega^2 = \frac{E}{(1-\nu^2)R^2\rho}\frac{a_{11}a_{22}^* - a_{12}a_{21}}{a_{11}}, \tag{7}$$

where

$$a_{22}^* = \frac{h^2k^4}{12} + \frac{1}{R^2} - \frac{2(1-\nu^2)}{Eh}\frac{P_0}{R} + \frac{(1-\nu^2)k_r}{Eh}.$$

Taking into account that $\frac{(1-\nu^2)k_x}{Eh} << k^2$ from (7) it is easy to get

$$a_{22}^{*} = \frac{E}{(1-\nu^2)R^2\rho}\left[1-\nu^2+\frac{h_*^2k^4}{12}-\frac{2(1-\nu^2)P_0}{Eh_*}+\frac{(1-\nu^2)\mu}{Eh_*}\frac{N_1}{N_2}\right]. \qquad (8)$$

Note that the formula (8) for $\omega^2$ is $\mu \to 0$ passes to the formula for the fundamental frequency of oscillation of cylindrical envelope in magnetic field without filler [1]:

$$\omega^2 = \frac{E}{(1-\nu^2)R^2\rho}\left[1-\nu^2+\frac{h_*^2k^4}{12}-\frac{2(1-\nu^2)P_0}{Eh_*}\right].$$

From the formula (8) it is obvious that with increase of magnetic pressure the frequency oscillations of analyzed system decrease, with increase of rigidity it increases.

### References

[1]. Вольмир А.С. *Оболочка в потоке жидкости и газа.* Задачи аэроупругости. М.: Наука, 1976, с.415.

[2]. Латифов Ф.С. *Колебание оболочек с упругой и жидкой средой.* Баку, «Элм», 1999, 164 с.

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