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SOUND RADIATION OF PLATE EXCITED BY A FORCE OF AN ARBITRARY ANGLE DIRECTION

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ABSTRACT

This paper presents the far-field high-frequency acoustic radiation from periodic rib stiffened plate of infinite extent.

The plate is excited by line force oriented at arbitrary angle direction to the plate plane. For frequencies above the coincidence frequency it is shown the greatest values of sound pressure are generated by bending oscillations of the plate, exited by force reaction of ribs.

INTRODUCTION

Sound radiation from fluid-loaded point force excited plate assuming Timoshenko-Mindlin plate theory has been investigated by Feit [1], Stuart [2], etc. Evseev, Ivanov, Kirpichnikov [3] have investigated sound radiation from longitudinal force excited plate.

This paper, which extends earlier work by Evseev [4], considers a rib-stiffened plate line excitation by an arbitrary inclined force, which contains a cross plate component and a longitudinal component.

1. THEORETICAL FORMULATION

The plate is time-harmonic excited by a line force F oriented at angle φ to the plate plane at $x = x_0$.

The plate bending vibration theory accounts for shear and rotary inertia of the plate with thickness H [1]. H_1 and H_2 are rib thickness and height; L is ribs spacing.

The longitudinal vibration of the plate formulated as [3]. Integral equations for sound pressure in acoustic fluid $(\rho_0 c_0)$ are derived via a Fourier transform by analogy with [4]. The far-field pressure is defined as the stationary phase asymptotic expansion for distances $r = \sqrt{x^2 + z^2}$.

Sound pressure radiated by the plate bending vibration $P_{\Sigma b}$ includes four parts which caused by:

- the cross plate exciting force component

$$P_1 = -\frac{F\cos(\varphi) Ab\beta^3 k_0 \cos(\theta)}{G\sqrt{2\pi k_0 r}} e^{ik_0(x_0\sin(\theta)-r)+i\pi/4}; \tag{1}$$

- the cross plate force reaction of ribs longitudinal vibration

$$P_2 = -\frac{EH_1 Az_{33}S_1 b\beta^3 k_0 \cos\theta k_{LR}}{LG\sqrt{k_0 r}} e^{-ik_0 r+i\pi/4}; \tag{2}$$

- the moment reaction of ribs bending vibration

$$P_3 = -\frac{D_R k_{bR} z_{22} S_2 b\beta^3 k_0{}^2 \cos(\theta)\sin(\theta)}{LG\sqrt{k_0 r}} e^{-ik_0 r+i\pi/4}; \tag{3}$$

- the longitudinal to bending vibration transforming

$$P_4 = -\frac{iD_R k_{bR}{}^2 Az_{21}S_3 b\beta^3 k_0{}^2 \cos(\theta)\sin(\theta)}{LG\sqrt{k_0 r}} e^{-ik_0 r+i\pi/4}. \tag{4}$$

Sound pressure radiated by the plate longitudinal vibration $P_{\Sigma l}$ consists of four parts which caused by:

- the longitudinal exciting force component

$$P_5 = -\frac{iF\sin(\varphi)\sigma_2\cos(\theta)\sin(\theta)}{HMQ\sqrt{2\pi k_0 r}} e^{ik_0(x_0\sin(\theta)-r)+i\pi/4}; \tag{5}$$

- the cross plate exciting force component

$$P_6 = \frac{F\cos(\varphi)\sigma_2\sigma k_0\cos(\theta)\sin^2(\theta)}{(1-\sigma)MQ\sqrt{2\pi k_0 r}} e^{ik_0(x_0\sin(\theta)-r)+i\pi/4}; \tag{6}$$

- the longitudinal force reaction of ribs bending vibration

$$P_7 = -\frac{iD_R k_{bR}{}^3 \sigma_2 z_{11} S_3 \sin(\theta)\cos(\theta)}{MLHQ\sqrt{k_0 r}} e^{-ik_0 r+i\pi/4}; \tag{7}$$

- the bending to the longitudinal vibration transforming

$$P_8 = \frac{D_R k_{bR}^2 \sigma_2 z_{12} S_2 \sin(\theta)\cos(\theta)}{MLHQ\,\sqrt{k_0 r}} e^{-ik_0 r + i\pi/4}; \qquad (8)$$

where:

$$b = \rho_0 c_L / (2\sqrt{3}\rho c_0); \quad c_L = \frac{\omega}{k_L}; \quad \delta_1 = h\rho_0\omega^2 / [2k_0(\lambda + 2\mu)]; \qquad (9)$$

$$\beta^2 = \frac{k_e^4}{k_0^4}; \quad A = 1 + ak_o^2\sin^2(\theta) - ak_o^2\chi_L^2; \qquad (10)$$

$$\chi_L = \frac{k_L}{k_0}; \quad \chi_s = \frac{k_s}{k_0}; \qquad (11)$$

$$a = H^2 / \sigma v^2(1-\sigma); \quad \sigma_1 = \lambda\sigma(1+\sigma)/E; \quad \sigma_2 = \lambda(1-\sigma^2)/E; \qquad (12)$$

$$G = [\sin^4(\theta) - \sin^2(\theta)(\chi_L^2 + \chi_S^2) + \chi_L^2\chi_s^2 - \beta^2]\cos(\theta) - 2b\beta^3 A; \qquad (13)$$

$$Q = \chi_L^2 - \sin^2(\theta)(1 + \sigma_1 / M); \qquad (14)$$

$$M = 1 - i\cos\theta/\delta_1; \quad \theta = arctg\,(x/z); \qquad (15)$$

$$z_{11} = (iD_R k_{bR}^3/\omega)\frac{\sin(\psi) + \cos(\psi)th(\psi)}{1/ch(\psi) + \cos(\psi)}; \qquad (16)$$

$$z_{12} = z_{21} = (iD_R k_{bR}^2/\omega)\frac{\sin(\psi)th(\psi)}{1/ch(\psi) + \cos(\psi)}; \qquad (17)$$

$$z_{22} = (iD_R k_{bR}/\omega)\frac{\sin(\psi) - \cos(\psi)th(\psi)}{1/ch(\psi) + \cos(\psi)}; \qquad (18)$$

$$z_{33} = iEH_1 k_{LR} tg(k_{LR}H_2)/\omega; \qquad (19)$$

$$\psi = k_{bR}H_2. \qquad (20)$$

S_1, S_2, S_3, - are infinite sums which defining forces and moments of the plate-ribs interaction assuming construction wave dimensions.

2. RESULTS AND DISCUSSION

For numerical calculations the periodically stiffened plate was steel, the fluid was water: $b = 0.13$; $H_1/H_2 = 30$; $H/H_1 = 0.1$; $x_0 = 0.5L$; the internal loss factor η=0.004 .

The calculation results show the frequency dependencies of sound radiation above the coincidence frequency are similar to [4] and are formed by resonances of ribs and ribs spacing.

The calculated angular dependencies of sound pressure and it parts have multy-lobs interference diagrams.

For examples Fig. 1 shows angular dependencies of the sound pressure parts radiated by the plate bending vibration when φ =45° at twice coincidence frequency (β =0.5).

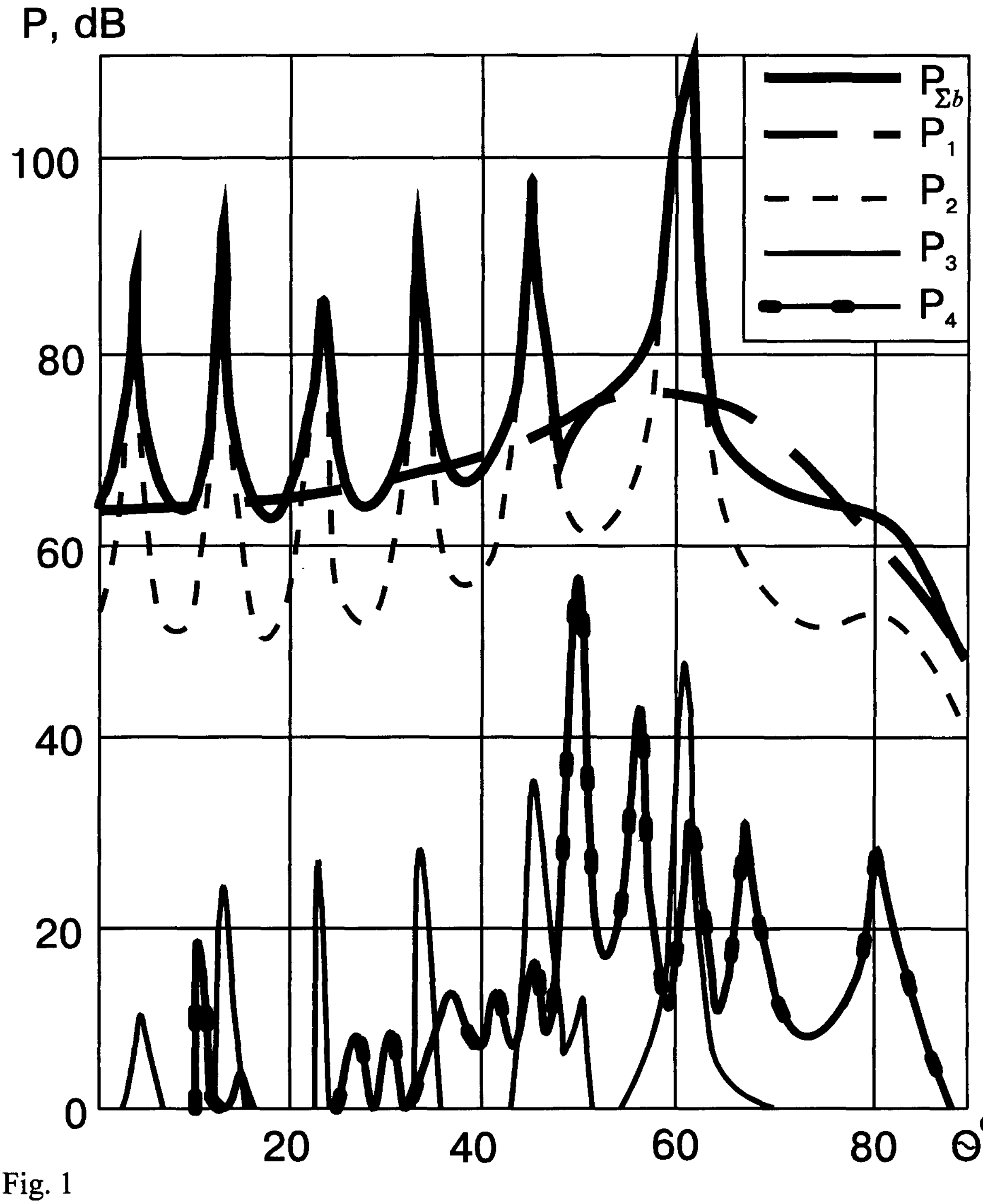

Fig. 1

The peaks in the radiated pressure diagram occur at directions which correlate with interferension of plate sections radiation. The stiffened ribs rise the plate origin sound radiation. The pressure highest levels are caused by the cross plate force reaction of ribs longitudinal vibration (P_2).

The cross-plate exciting force pressure component displays at some directions only. The moment reaction of ribs bending vibration and the longitudinal to bending vibration transforming are negligible in the plate sound radiation.

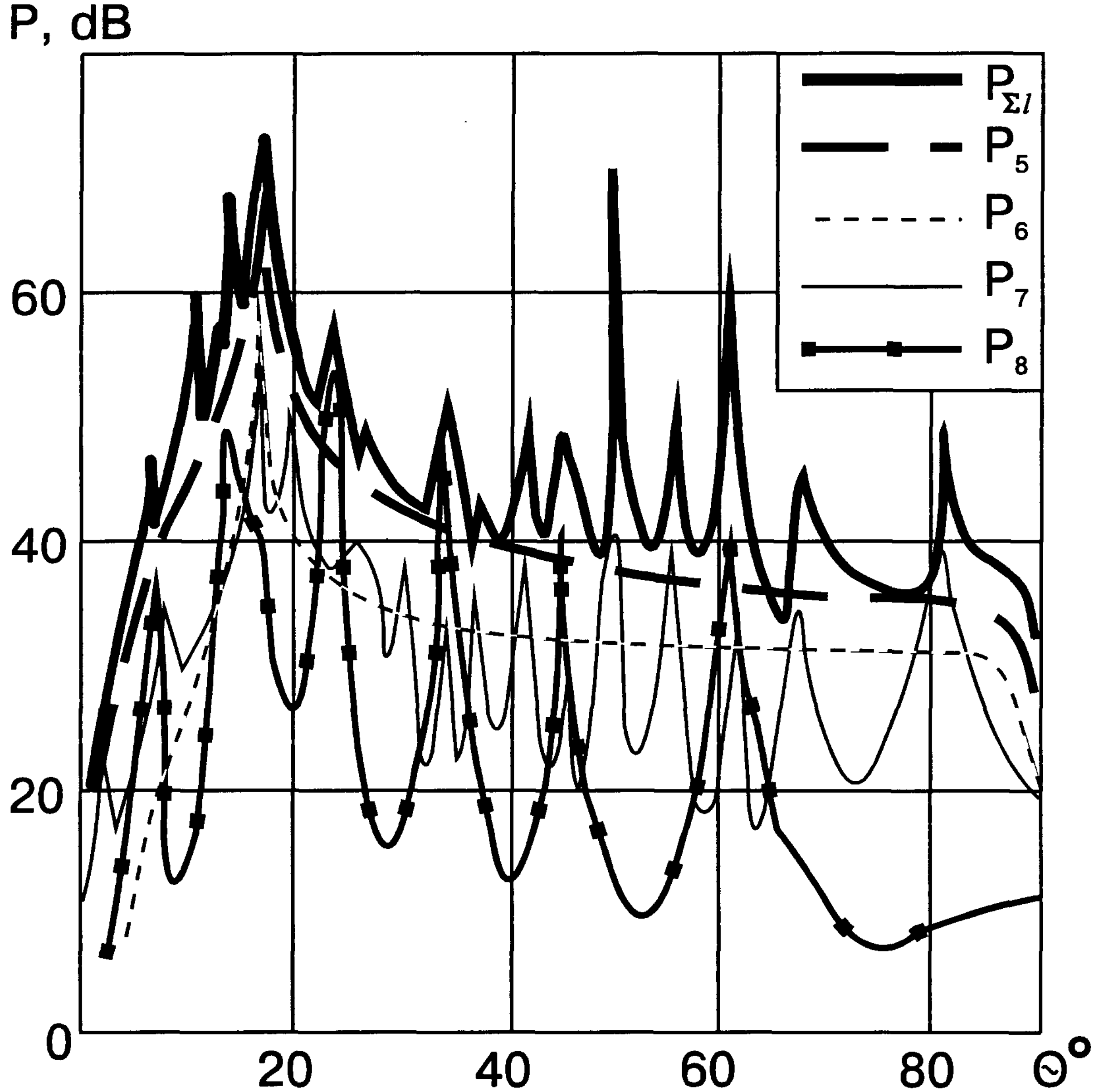

Fig. 2

Fig.2 shows the same dependencies of sound pressure parts radiated by the plate longitudinal vibration. The pressure levels are lower then at the Fig.1. The main role in the plate sound radiation have the longitudinal exciting force component and the longitudinal force reaction of ribs bending vibration.

CONCLUSION

The far-field high-frequency radiation from a rib-stiffened plate has been examined.

It was shown that stiffeners rise a plate sound radiation at high frequencies, above the coincidence frequency especially. A homogeneous plate radiation singularities are masked by interference peaks. The highest values of sound radiation are caused by the plate bending vibration which is excited by ribs force reaction.

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