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Journal of Sound and Vibration 271 (2004) 470–471
JOURNAL OF SOUND AND VIBRATION
www.elsevier.com/locate/jsvi

Author's reply ☆

K.-H. Jeong

Mechanical System Development Department, Korea Atomic Energy Research Institute, P. O. Box 105, Yuseong, Daejeon 305-600, South Korea

Received 19 May 2003; accepted 19 May 2003

The author thanks Professor Amabili for his comments [1]. Eq. (5) in Ref. [2] describes the fluid oscillation, and is known as the Laplace equation for the velocity potential. The equation implies the continuity equation for an ideal fluid flow. The equation can be solved with the cylindrical co-ordinates using the separation of variables technique,

$$\frac{\phi(r,\theta)_{,rr} + (1/r)\phi(r,\theta)_{,r} + (1/r^2)\phi(r,\theta)_{,\theta\theta}}{\phi(r,\theta)} = -\frac{f(x)_{,xx}}{f(x)} = -\beta_{ns}^2 \tag{1}$$

when the general velocity potential is written in the form

$$\Phi(x,r,\theta,t) = \mathrm{i}\omega\phi(r,\theta,x)\exp(\mathrm{i}\omega t) = \mathrm{i}\omega\phi(r,\theta)f(x)\exp(\mathrm{i}\omega t). \tag{2}$$

Since the first value of β_{ns} for the in-phase modes with $n=0$ is zero, the solution for $\beta_{ns}=0$ ($n=0$, $s=1$) will be

$$\phi(r,\theta,x) = (A_1 x + A_2)[B_1 \ln(r) + B_2], \tag{3}$$

where $A_1, A_2, B_1, \mathrm{and} B_2$ are the integral constants. As the velocity potential must be finite at $r=0$, the general velocity potential for the axisymmetric in-phase modes with $n=0$ will be given as described in Ref. [3]

$$\phi(r,\theta,x) = E_{oo}x + \sum_{s=2}^{\infty} E_{os}\mathrm{J}_o(\beta_{os}r)\sinh(\beta_{os}x). \tag{4}$$

Eq. (13a) of Ref. [2], or the compatibility condition gives

$$\sum_{m=1}^{M} q_m\left[\mathrm{J}_o(\lambda_{om}r) - \frac{\mathrm{J}_o(\lambda_{om}R)}{\mathrm{I}_o(\lambda_{om}R)}\mathrm{I}_o(\lambda_{om}r)\right] = -E_{oo} - \sum_{s=2}^{\infty} E_{os}\beta_{os}\cosh\left(\frac{\beta_{os}d}{2}\right)\mathrm{J}_o(\beta_{os}r) \tag{5}$$

for the in-phase modes with $n=0$.

☆ Reply to doi: 10.1016/S0022-460X(03)00626-6.

E-mail address: khjeong@kaeri.re.kr (K.-H. Jeong).

doi:10.1016/S0022-460X(03)00627-8

For $n=0$, expanding $J_o(\lambda_{om} r)$ and $I_o(\lambda_{om} r)$ of Eq. (5) into the Bessel–Fourier series [4] will be given as

$$a_{oms} = \frac{-2(\lambda_{om}R)J_1(\lambda_{om}R)}{[(\beta_{os}R)^2 - (\lambda_{om}R)^2]J_o(\beta_{os}R)}, \tag{6a}$$

$$b_{oms} = \frac{2(\lambda_{om}R)I_1(\lambda_{om}R)}{[(\beta_{os}R)^2 + (\lambda_{om}R)^2]J_o(\beta_{os}R)}. \tag{6b}$$

When Eqs. (6a) and (6b) are substituted into Eqs. (5) and (4) of Ref. [2] is used, the coefficient E_{oo} can be obtained for $\beta_{os}=0$:

$$E_{oo} = -4\sum_{m=1}^{M} \frac{q_m J_1(\lambda_{om}R)}{(\lambda_{om}R)}. \tag{7}$$

Therefore, the velocity potential of the fluid can be rewritten in terms of unknown constant q_m instead of unknown coefficients E_{oo} and E_{os}:

$$\phi(r,\theta,x) = \sum_{m=1}^{M} q_m \left\{ -4\frac{J_1(\lambda_{om}R)}{(\lambda_{om}R)} + \sum_{s=2}^{\infty} \Xi_{oms} J_o(\beta_{os} r)\sinh(\beta_{os} x) \right\} \tag{8}$$

for the in-phase modes with $n=0$, where Ξ_{oms} is a derived coefficient:

$$\Xi_{oms} = -\frac{[a_{oms} - b_{oms} J_o(\lambda_{om}R)/I_o(\lambda_{om}R)]}{\beta_{os}\cosh(\beta_{os} d/2)} \quad \text{for } s>1. \tag{9}$$

The reference kinetic energy owing to the first term of Eq. (8) can be calculated by the integration

$$\begin{aligned} T^*_{F1} &= -\frac{\rho_o}{2}\int_{-d/2}^{d/2}\int_0^R \sum_{k=1}^{M} q_k W_{ok}\phi_1(r,\theta,x)\, r\, \mathrm{d}r\, \mathrm{d}x \\ &= 2\rho_o \mathrm{d}\int_0^R \sum_{k=1}^{M} q_k \left[J_o(\lambda_{ok} r) - \frac{J_o(\lambda_{ok}R)}{I_o(\lambda_{ok}R)} I_o(\lambda_{ok} r)\right] \sum_{i=1}^{M} q_i \frac{J_1(\lambda_{oi}R)}{(\lambda_{oi}R)}\, r\, \mathrm{d}r \\ &= 4\rho_o\, \mathrm{d}R^2 \sum_{k=1}^{M} \frac{q_k J_1(\lambda_{ok}R)}{\lambda_{ok}R} \sum_{i=1}^{M} \frac{q_i J_1(\lambda_{oi}R)}{\lambda_{oi}R}. \end{aligned} \tag{10}$$

The first term of the AVMI matrix for the in-phase modes with $n=0$, will become

$$4\mathrm{d}R^2 \left(\frac{J_1(\lambda_{ok}R)}{\lambda_{ok}R}\right)\left(\frac{J_1(\lambda_{oi}R)}{\lambda_{oi}R}\right). \tag{11}$$

This result is identical to the description in the last sentence of p. 659 of Ref. [2].

References

[1] M. Amabili, Comments on "Free vibration of two identical circular plates coupled with bounded fluid", *Journal of Sound and Vibration* 271 (2004) 469, this issue.

[2] K.-H. Jeong, Free vibration of two identical circular plates coupled with bounded fluid, *Journal of Sound and Vibration* 260 (2003) 653–670.

[3] M. Amabili, Vibrations of fluid-filled hermetic cans, *Journal of Fluids and Structures* 14 (2000) 235–255.

[4] I.N. Sneddon, *Fourier Transforms*, McGraw-Hill, New York, 1951.