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Letter to the Editor

Comments on "Vibration suppression for high-speed railway bridges using tuned mass dampers" [J.F. Wang, C.C. Lin, B.L. Chen, 2003. Int. J. Solids Struct. 40(2) 465–491]

Abstract

In this comment, the discusser makes some remarks on the paper "Vibration suppression for high-speed railway bridges using tuned mass dampers" by Wang, J.F., Lin, C.C., Chen, B.L., published in the International Journal of Solids and Structures, 2003, Vol. 40, No. 2, pp. 465–491. First, the formulation of $H(t, t_k)$ on p. 470 is questionable. Second, for a moving suspension mass model, the interaction force between moving mass and bridge is incorrectly given. Third, for a moving mass model for the train and without the installation of PTMD (passive tuned mass damper), the equation of motion of the bridge is incorrect. Lastly, for the train load model, which consists of one-half of a train car, one bogie, two wheel sets, spring and dashpot between bogie and half of a train car, and spring and dashpot between bogie and each wheel set, the authors did not put forward the formulation of interaction force between wheel set and bridge, but the discusser does.

Keywords: Train model; Moving train; Interaction force; Equation of motion

In a recent paper, Wang et al. (2003) studied the applicability of passive tuned mass dampers to suppress train-induced vibration on bridges. In their paper, a railway bridge is modeled as an Euler–Bernoulli beam and a train is simulated as series of moving forces, moving masses or moving suspension masses to investigate the influence of various vehicle models on the bridge features with or without PTMD (passive tuned mass damper). While the development is interesting, some statements are questionable. In this comment, the discusser would like to make some remarks on their paper.

1. This discusser notes that there are errors in the formulation of $H(t, t_k)$ in the third line on p. 470. The formulation of $H(t, t_k)$ should read as follows:

$$H(t, t_k) = U(t - t_k) - U[t - (t_k + L/v)] \tag{1}$$

2. For a moving suspension mass model (Fig. 1(c)), Eq. (5c) on p. 470 is incorrectly given. Eq. (5c) neglected the inertia force and gravity force of unsuspension mass. Eq. (5c) should be

$$p_k = m_{v_k} \cdot [g + \ddot{z}_v(t)] + m_{w_k} \cdot [g + \ddot{z}_w(t)] \tag{2}$$

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where g is the acceleration of gravity, m_{v_k} and m_{w_k} are the suspension mass and unsuspension mass (i.e., wheel set mass) of the kth mass–spring–dashpot system, respectively; $\ddot{z}_v(t)$ and $\ddot{z}_w(t)$ are the vertical acceleration of the suspension mass and unsuspension mass of the kth mass–spring–dashpot system, respectively.

If the unsuspension mass m_{w_k} of the kth mass–spring–dashpot system is neglected, Eq. (2) will be written as

$$p_k = m_{v_k} \cdot [g + \ddot{z}_v(t)] \tag{3}$$

Eq. (3) is same as Eq. (5c) on p. 470.

3. For a moving mass model for the train and without the installation of PTMD, the equation of motion of the bridge, Eq. (7) on p. 474, is incorrectly given. As shown in Eq. (7a), the term $m_v \mathbf{\Phi}^{\mathrm{T}}[v(t-t_k)]\ddot{\boldsymbol{\eta}}(t)$ only partially describes the dynamic effect of the kth moving mass. Since the mass is moving along a vibrating path, the vertical velocity of the kth moving mass is

$$\dot{y}[(vt - vt_k), t] = v\mathbf{\Phi}'^{\mathrm{T}}(x)\big|_{x=v(t-t_k)}\boldsymbol{\eta}(t) + \mathbf{\Phi}^{\mathrm{T}}(x)\big|_{x=v(t-t_k)}\dot{\boldsymbol{\eta}}(t) \tag{4}$$

and the vertical acceleration of the kth moving mass can be expressed as

$$\ddot{y}[(vt - vt_k), t] = v^2\mathbf{\Phi}''^{\mathrm{T}}(x)\big|_{x=v(t-t_k)}\boldsymbol{\eta}(t) + 2v\mathbf{\Phi}'^{T}(x)\big|_{x=v(t-t_k)}\dot{\boldsymbol{\eta}}(t) + \mathbf{\Phi}^{\mathrm{T}}(x)\big|_{x=v(t-t_k)}\ddot{\boldsymbol{\eta}}(t) \tag{5}$$

where dots and primes denote differentiation with respect to time t and coordinate x, respectively. The physical meanings for the terms of right hand side in Eq. (5) can be given as follows (Frýba, 1996): the first term expresses the influence of beam curvature, the second term the influence of Coriolis acceleration, and the third term the influence of the support beam acceleration at the point of contact with the moving mass. All terms are absent in their paper (Wang et al., 2003) except the last one. The interaction force p_k between the kth moving mass and beam, including the static load due to moving mass weight, must be described as following

$$p_k = m_v\left\{g + v^2\mathbf{\Phi}''^{\mathrm{T}}(x)\big|_{x=v(t-t_k)}\boldsymbol{\eta}(t) + 2v\mathbf{\Phi}'^{T}(x)\big|_{x=v(t-t_k)}\dot{\boldsymbol{\eta}}(t) + \mathbf{\Phi}^{\mathrm{T}}[v(t-t_k)]\ddot{\boldsymbol{\eta}}(t)\right\} \tag{6}$$

Therefore, Eq. (17a) should read

$$\begin{aligned}\mathbf{M}_{\mathrm{b}}\ddot{\boldsymbol{\eta}}(t)+\mathbf{C}_{\mathrm{b}}\dot{\boldsymbol{\eta}}(t)+\mathbf{K}_{\mathrm{b}}\boldsymbol{\eta}(t) = -\sum_{k=1}^{N_v} m_v\left\{g+v^2\mathbf{\Phi}''^{\mathrm{T}}(x)\big|_{x=v(t-t_k)}\boldsymbol{\eta}(t)+2v\mathbf{\Phi}'^{\mathrm{T}}(x)\big|_{x=v(t-t_k)}\dot{\boldsymbol{\eta}}(t)+\mathbf{\Phi}^{\mathrm{T}}[v(t-t_k)]\ddot{\boldsymbol{\eta}}(t)\right\} \\ \times\mathbf{\Phi}[v(t-t_k)]H(t,t_k)\end{aligned} \tag{7}$$

and Eq. (17b) should read

$$[\mathbf{M}_{\mathrm{b}} + \mathbf{M}_{11}(t)]\ddot{\boldsymbol{\eta}}(t) + [\mathbf{C}_{\mathrm{b}} + \mathbf{C}_{11}(t)]\dot{\boldsymbol{\eta}}(t) + [\mathbf{K}_{\mathrm{b}} + \mathbf{K}_{11}(t)]\boldsymbol{\eta}(t) = -\sum_{k=1}^{N_v} m_v g\mathbf{\Phi}[v(t-t_k)]H(t,t_k) \tag{8}$$

where

$$\mathbf{M}_{11}(t) = \sum_{k=1}^{N_v} m_v\mathbf{\Phi}^{\mathrm{T}}[v(t-t_k)]\mathbf{\Phi}[v(t-t_k)]H(t,t_k)$$

$$\mathbf{C}_{11}(t) = \sum_{k=1}^{N_v} m_v 2v\mathbf{\Phi}'^{\mathrm{T}}(x)\big|_{x=v(t-t_k)}\mathbf{\Phi}[v(t-t_k)]H(t,t_k)$$

$$\mathbf{K}_{11}(t) = \sum_{k=1}^{N_v} m_v v^2\mathbf{\Phi}''^{\mathrm{T}}(x)\big|_{x=v(t-t_k)}\mathbf{\Phi}[v(t-t_k)]H(t,t_k)$$

4. The train load model in Fig. 10 (p. 481), which consists of a mass–spring–dashpot system (m_v, k_v, c_v) to represent one-half of a train car, one bogie system with two degrees of freedom (z_b, θ_b), and two wheel sets (m_w), is different from moving force model (Fig. 1 (a), p. 469), moving mass model (Fig. 1 (b), p. 469), and moving suspension mass model (Fig. 1 (c), p. 469). Therefore, Eqs. (5a), (5b) and (5c) on p. 470 cannot be applied to calculate the dynamic responses of bridge-PTMD system and French T.G.V., German I.C.E., and Japanese S.K.S. trains. The authors, however, did not put forward the formulation of interaction force between wheel set and bridge. Now, the discusser derives the formulation of interaction force between wheel set and bridge as follows. First of all, it is assumed that the vertical displacements and rotation θ_b of the train load model in Fig. 10 (p. 481) are measured with respect to their equilibrium positions before coming onto the bridge. Second, the interaction force p_k between wheel set and bridge can be expressed in terms of the static interaction force p_{kw} and the dynamic interaction force Δp_k as

$$p_k = p_{kw} + \Delta p_k \tag{9}$$

Third, half of a train car, one bogie and two wheel sets are isolated as free bodies, respectively. Fourth, the dynamic interaction force Δp_{kl} between wheel set of left side and bridge can be expressed as by means of d'Alembert's principle

$$\Delta p_{kl} = m_w \ddot{z}_{wl} - c_b \dot{z}_b + c_b l_w \dot{\theta}_b + c_b \dot{z}_{wl} - k_b z_b + k_b l_w \theta_b + k_b z_{wl} \tag{10}$$

where, all symbols are defined in Fig. 10 (p. 481).

Lastly, considering the static interaction force p_{kwl} due to weight of quarter of a train car, half of one bogie, and wheel set of left side in Fig. 10 (p. 481)

$$p_{kwl} = \frac{1}{2} m_v g + \frac{1}{2} m_b g + m_w g \tag{11}$$

in which, m_v denotes half mass of a train car and m_b denotes mass of one bogie. Therefore, the interaction force p_{kl} between wheel set of left side and bridge can be written as

$$p_{kl} = \frac{1}{2} m_v g + \frac{1}{2} m_b g + m_w g + m_w \ddot{z}_{wl} - c_b \dot{z}_b + c_b l_w \dot{\theta}_b + c_b \dot{z}_{wl} - k_b z_b + k_b l_w \theta_b + k_b z_{wl} \tag{12}$$

Similarly, the interaction force p_{kr} between wheel set of right side and bridge can be expressed as

$$p_{kr} = \frac{1}{2} m_v g + \frac{1}{2} m_b g + m_w g + m_w \ddot{z}_{wr} - c_b \dot{z}_b - c_b l_w \dot{\theta}_b + c_b \dot{z}_{wr} - k_b z_b - k_b l_w \theta_b + k_b z_{wr} \tag{13}$$

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Ping Lou
School of Civil Engineering and Architecture
Railway Campus, Central South University
22 Shao-shan-nan Road, Changsha
Hunan Province 410075, People's Republic of China
E-mail address: pinglou@mail.csu.edu.cn

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