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Application of structural modification for beam vibration control

L. Rolník[a], M. Naď[a], L. Kolíková[a] , R. Ďuriš[a]

[a] *Faculty of Materials Science and Technology in Trnava, Slovak University of Technology in Bratislva, J. Bottu 25, 917 24 Trnava, Slovak Republic*

The beam as one of the fundamental structural elements is very often used in the engineering application - mechanical and civil engineering. During operation, these structures may be subjected to periodic dynamic loading forces, which in certain adverse cases may cause their resonance state. The possibility of reducing the level of undesirable vibrations or preventing their occurrence should be one of the important objectives in the design of the structure. The design and analysis of the beam structure that will allow its spatial properties (mass and stiffness) to be redistributed using the displaceable core inserted into the beam structure is investigated in this paper. The change in the deflection of a beam loaded by the force effect that causes its resonance state, depending on the redistribution of spatial properties (based on the position of the reinforcement core), is studied.

The structural model enabling continuous modification of dynamic properties of the beam structure by inserting the reinforcement core is shown in Fig.1. The basic shape of beam body has a length L_0 and a rectangular cross-section - width b_0 and height h_0. In the longitudinal direction, a hole with a radius r_c for insertion reinforcing the core is drilled into the beam body. The top surface of the beam structure is loaded with time-varying pressure $p_y(t)$. The different material properties are considered for beam body and movable core. The following assumptions are considered in the mathematical model of beam composite structure modified by the reinforcing core - beam cross section is planar before and during deformation, isotropic and homogeneous material properties of beam structural parts are assumed, mutual displacements of interacting points between beam body and core are the same, i.e. perfect adhesion is assumed for the corresponding points perfect adhesion at the interfaces of beam structural parts is supposed.

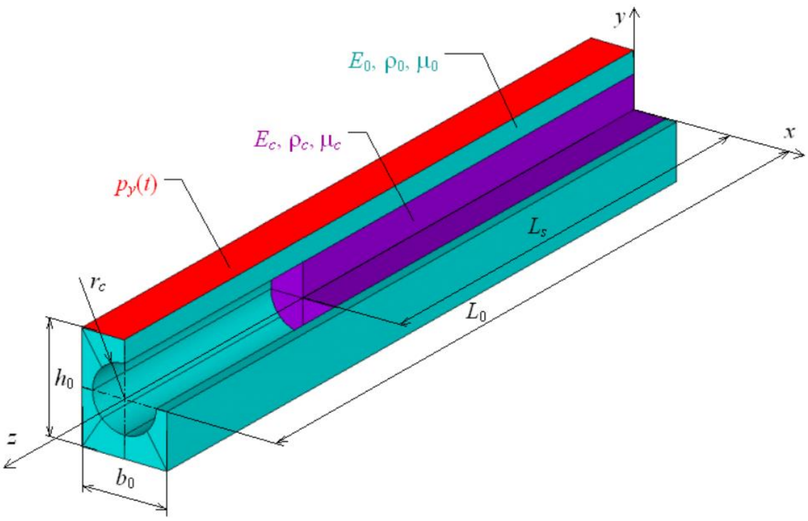

Fig. 1. Structural model of modified beam structure

The model of considered beam structure is divided into two segments with different cross-sections. The general equation of motion for forced bending vibration of *k*-th segment of considered beam structure [1,2] can be expressed in the following form

$$\frac{\partial^2}{\partial x_k^2}\left[(EJ)_k \frac{\partial^2 w_k(x_k,t)}{\partial x_k^2}\right] + (\rho S)_k \frac{\partial^2 w_k(x_k,t)}{\partial t^2} = p_y(t), \quad (k=1,2), \tag{1}$$

where $w_k(x_k,t)$ - beam displacement in *k*-th segment, $p_y(t)$ - uniform pressure acting on top surface of beam and cross-section parameters of *k*-th segment of beam structure are

- bending stiffness $\quad (EJ)_k = E_0 J_0 [(1-\kappa_J) + \delta_k \kappa_E \kappa_J]$, (2)
- unit mass $\quad (\rho J)_k = \rho_0 S_0 [(1-\kappa_S) + \delta_k \kappa_\rho \kappa_S]$. (3)

The dimensionless parameters applied in (2), (3) are defined by $\kappa_S = S_c / S_0$, $\kappa_J = J_c / J_0$, $\kappa_E = E_c / E_0$, $\kappa_\rho = \rho_c / \rho_0$. The following is applied for $\delta_{k=1\div 2}\langle \begin{smallmatrix} =1; & S_k = S_0 + S_c & \text{and} & J_k = J_0 + J_c \\ =0; & S_k = S_0 & \text{and} & J_k = J_0 \end{smallmatrix}$, where *S* is cross-section area and *J* is quadratic moment of cross-section for full beam cross-section (subscript 0) and core (subscript *c*).

After application $w_k(x_k,t) = W_k(x_k)T(t)$ into (1) (for $p_y(t) = 0$), the differential equation of the *k*-th segment for determination of mode shapes and natural angular frequency for complete beam structure [2] has the following form

$$\overline{W}_k^{IV}(\xi_k) - \beta_k^4 \overline{W}_k(\xi_k) = 0, \tag{4}$$

where $\beta_j^4 = \omega_{0,m}^2 \left(\frac{\rho_0 S_0}{E_0 J_0} L_0^4\right) f_m(\delta_k, \kappa_S, \kappa_E, \kappa_J, \kappa_\rho)$ is a frequency parameter, $\overline{W}_k(\xi_k) = W_k(x_k)/L_0$, $\xi_k = x_k / L_0$ and x_k is position of cross-section in *k*-th segment.

The states of resonant behavior of the beam structure, which is caused e.g. by the action of harmonic pressure $p_y(t) = p_0 \sin(\omega t)$, can be eliminated by the insertion of a reinforcing core. During the core insertion process, the stiffness and mass parameters are redistributed and this new structural state leads to a change in the resonant frequency [2] and and this also causes a change in the deflection of the beam structure.

Acknowledgements

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