PASSIVE-ACTIVE OSCILLATIONCONTROL FOR HIGH-RISE STRUCTURES

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The oscillationcontrol system for high-rise constructions presupposing structural rigidityadjustment is proposed. Passive elements – diagonal links with hydraulic dampers. They supplement an active part of a control system, increasing reliability of control with construction oscillations. In the active system the oscillation control is executed by electric hydraulic actuators. The active system comprises a subsystem of measurement and estimation of state variables and of identification of disturbing effects at incomplete information. Control subsystem providing optimal the control law. Mathematical modelsof the objectwithbuilt-incontrollinks and electro-hydraulic actuators (EHA) have been set up. For formation of the optimum control law the theory of variation calculus is used. Effectiveness ofthe proposed vibration control system under seismic impact on thestructureandat differentdesign conceptof passive-active communication has been studied.

Keywords: high-rise structures, oscillation control, seismic and wind loads, electric hydraulic actuators

For suppression of undesirable fluctuations of high-rise constructions we use a control system with additional links.

The oscillation control for high-rise structures is formed on the basis of requirements to the systems of extinguishing oscillations of civil engineering structures [1]

Passive elements add to the active system increasing the reliability of the total construction control system. In the active system the oscillation control is executed by electric hydraulic actuators. The active system comprises a subsystem of measurement and estimation of state variables and of identification of disturbing effects at incomplete information. Control subsystem providing optimal the control law.

Let's consider a high-rise structure, equipped with additional connections (Fig. 1). Stress-deformation state of the structure is described by means of the differential equation system in partial derivatives. By means of variation methods (eg. the finite element method)) the problem of researching the stress-deformation state is reduced to the system of ordinary differential equations. For a general disturbing effect case the structure's movement is described through the following equation [2]:

$$\begin{gathered}\mathbf{M}\ddot{\mathbf{q}}(t)+\mathbf{K}(t)\dot{\mathbf{q}}(t)+\mathbf{H}(t)\mathbf{q}(t)\\ =\mathbf{B}_F\mathbf{F}(t)+\mathbf{B}_R\mathbf{R}(t), \qquad (1)\\ \mathbf{q}(t_0)=\mathbf{q}_0,\end{gathered}$$

where **M, K, H** – are the inertial, dissipative and stiffness matrixes of the object; $\mathbf{q}(t)$ – vector of generalized coordinates of the structure; $\mathbf{F}(t)$, $\mathbf{R}(t)$ – determinate vector of disturbing and controlling effects respectively; $\mathbf{B}_F$, $\mathbf{B}_R$ – are distribution matrixes of disturbing and controlling efforts in the construction respectively.

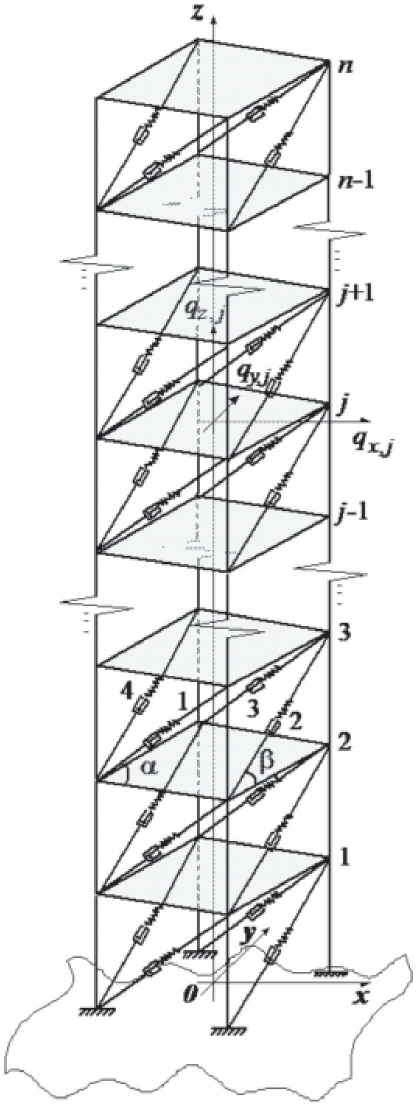

Fig. 1. Design of a high-rise structure equipped with passive-active connections located on all sectional views

A mathematical model of the electric-hydraulic actuator complex is described by the differential equation [2]

$$\mathbf{E}\ddot{\mathbf{R}}(t)+\mathbf{G}\dot{\mathbf{R}}(t)+\mathbf{DR}(t)=\mathbf{NU}(t), \quad (2)$$

where **E**, **G**, **D**, **N**are diagonal coefficient matrixes; $\mathbf{U}(t)$ a stress vector, given to the actuators inputs.

Combination of equations (1) and (2) allows to obtain a close system of differential equations of the controlled structure

$$\dot{\mathbf{X}}(t)=\mathbf{AX}(t)+\mathbf{B}_x^F\mathbf{F}(t)+\mathbf{B}_x^U\mathbf{U}(t). \quad (3)$$

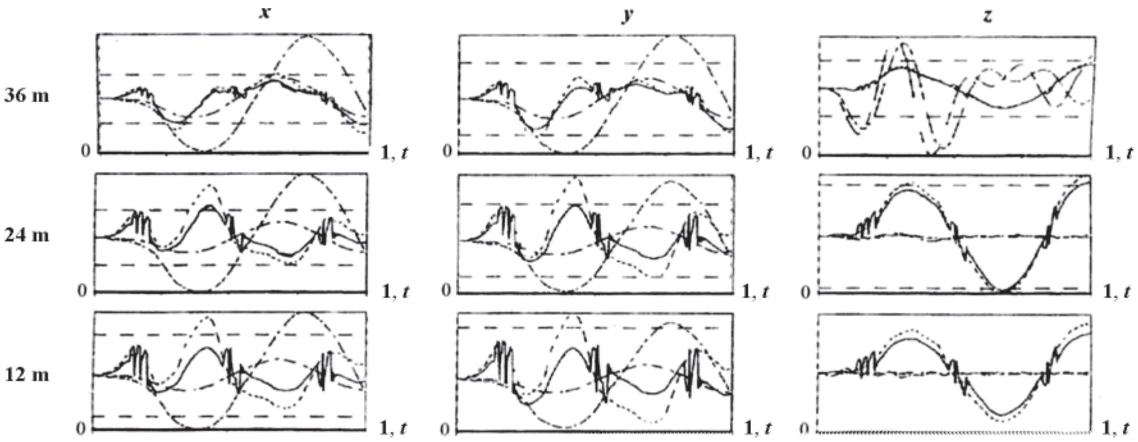

Fig. 2. The comparative analysis of passive and active damping of one period of fluctuations:
– – – – level of admissible fluctuations;
——— construction with system of rigid communications;
- · - · - · - construction with system of the rigid communications equipped «a hydraulic spring»;
— · — · — construction with system of the communications equipped hydraulic damper with a throttle;
——— construction with system of is passive-active communications

Vector of optimal control stresses $\mathbf{U}(t)$ is defined from quadratic functional minimum

$$2\Phi=\mathbf{X}^T\mathbf{V}_3\,\mathbf{X}\big|_{t_1}+\int_{t_1}^{t_1}\varphi\left(\mathbf{X},\,\dot{\mathbf{X}},\,\mathbf{U}\right)dt\rightarrow\min,$$

where

$$\varphi\left(\mathbf{X},\ \dot{\mathbf{X}},\mathbf{G}\right)=\mathbf{X}^T\mathbf{V}_1\mathbf{X}+\mathbf{U}^T\mathbf{V}_2\mathbf{U}+2\mathbf{L}^T\left(-\dot{\mathbf{X}}+\mathbf{AX}+\mathbf{B}_x^F\,\mathbf{F}+\mathbf{B}_x^U\mathbf{U}\right);$$

$V_1(t)$, $V_2(t)$ is a nonnegatively definite symmetric matrix, $V_4(t)$ – a positively definitely symmetric matrix.

The solution is obtained in the form

$$\mathbf{U}_{\text{опт}}=-\mathbf{V}_2^{-1}\left(\mathbf{B}_x^U\right)^T\mathbf{L};$$

$$\frac{d}{dt}\begin{bmatrix}\mathbf{X}\\ \mathbf{L}\end{bmatrix}=\begin{bmatrix}\mathbf{A} & -\mathbf{B}_x^U\mathbf{V}_2^{-1}\left(\mathbf{B}_x^U\right)^T\\ -\mathbf{V}_1 & -\mathrm{A}^T\end{bmatrix}\begin{bmatrix}\mathbf{X}\\ \mathbf{L}\end{bmatrix}+\begin{bmatrix}\mathbf{B}_x^F\mathbf{F}\\ 0\end{bmatrix}$$

using boundary conditions [5]

$$\left(\mathbf{L}+\mathbf{C}^T\,\mathbf{V}_3\left(\hat{\mathbf{z}}-\mathbf{CX}\right)\right)\Big|_{t_2}=0;$$

$$\mathbf{L}\left(t_2\right)=\mathbf{V}_3\left(t_2\right)\mathbf{X}\left(t_2\right).$$

Numerical experiment

Numerical study of control system is presented by the example of a high-rise structure – tower-type headgear. A mass reinforced concrete tower-type headgear erected in the sliding form 120 sm. high and plan sizes 21×21 m was subjected to seismic impact with oscillation strength of 7 grades with direction cosines $\cos x=35°$, $\cos y=55°$, $\cos z=45°$ elative to global coordinate system. Impact frequencyresonates with the structure's main vibration tone. Control system sensors and additional links are set on the marks 12, 24, 36 m, providing its observability and controllabilityrelative motion of the tower-type headgear on the mark 36 m by axes *x* exceeds allowance by 8 times, by axes *y* – 6 times, by axes *z* – by 1,5 times; on the mark 24 m by axes *x* – 7 times, by axes *y* – 6 times, by axes *z* – 1,3 times; on the mark 12 m by axes *x* – 6 times, by axes *y* – 5 times, by axes *z* – doesn't exceed.

Conclusions

Analysis of numerical modeling outcomes provides the following conclusions:

– using rigid links and links equipped with «hydraulic spring» alternates frequency characteristics of a building and allows to avoid resonance by reducing vibration amplitude but it does not protect the structure from failure;

– using passive links with hydraulic vibration absorber changes the frequency characteristic of the structure reducing vibration amplitude significantly, That being provided, the links maintain serviceable condition and the building does not collapse. As a result of reducing general link rigidness the required full vibration suppression of the multidimensional structure is not achieved;

– using active links reduces vibration amplitude of the structure down to allowance level and maintains the building's integrity vibration amplitude significantly.

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