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ALTERNATIVE SOURCE OF ENERGY FOR ACTIVE VIBRATION CONTROL OF ELEVATED WATER TANK

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1. Introduction :

The real bottleneck for active vibration control of civil engineering structure is the large amount of energy needed to suppress the vibration. In this paper, the use of potential energy of the water, contained in the elevated tank is proposed for active vibration control. In adaptive structures, the changes in the nominal values of one or more important response component are monitored continuously by means of appropriate sensors. These changes are evaluated by a microprocessor. If and when they are found excessive, counterbalancing modifications are introduced in the structure by the strategically positioned actuators in order to eliminate the excesses in real time.

2. Theoretical Background :

In order to identify the options one may have in controlling one or more response in a discrete structure, one needs its linear excitation -response relations in their original form as restated below:

$$\begin{bmatrix} 0 & B & 0 \\ B^T & 0 & -I \\ 0 & -I & \mathrm{diag}(K^m) \end{bmatrix} \begin{bmatrix} \xi \\ s \\ v \end{bmatrix} = \begin{bmatrix} p - M\ddot{\xi} - C\dot{\xi} \\ -v_0 \\ 0 \end{bmatrix} \qquad (1)$$

Where s, v and ξ are the response quantities representing, respectively the element force, corresponding element deformations and nodal defl -ections, p and v_0 are the excitation quantities representing, respect -ively, the prescribed nodal forces and the element deformations, B is the sparse coefficient matrix of element forces in the nodal equilibrium equations, $\mathrm{diag}(K^m)$ is the block diagonal matrix of element stiffnesses, I is the identity matrix, 0,0 are zero matrices, M is the mass matrix and C is the damping matrix. In order to keep some of the response quantities (i.e. the controlled response quantities) at their nominal values, provided that these changes we introduce do not cause the remaining response quantities(i.e. the uncontrolled response quantities) to exceed their allowable limits. The mechanisms that create the the required modifications are the actuators. In the adaptive structures technology, usually the axial length change component of v_0 are used to control the response, therefore the actuators are of length adjusting type. They function like turn-buckles. The energy requirment to suppress the earthquake-induced vibrations in civil engg. structure is large and on the other hand at the time of earthquake power supplies are cut-off to reduces fire hazards. Therefore the control devices should be provided with large size power standby unit which are quite costly and cannot be a reliable solution.

3. Alternative Energy Source :
The energy of the earthquake itself can be used in three different ways; Tuned mass driver, active stiffness driver and active mass driver. These are low power schemes that work only when the structure acquire high kinetic energy. Other potential method can be, to latch and unlatch the reserved structural element, under the control scheme, either they have no strain energy or when the monitored response exceed the threshold value. These schemes renders the structure stiffer thus the motion is suppressed faster since the natural damping is high for high-freqency modes.

4. Active Control of Vibration :
By eliminating v and s by substitution, and using v_0 as the actuation, one may rewrite equation(1) as

$$M\ddot{\xi} + C\dot{\xi} + K\xi = p - B\,\mathrm{diag}(K^m)v_o \qquad (2)$$

suppose v represents the element elongations created by the actuators and the effect of all the prescribed element elongations are included in p. Suppose that there are also q number of actuators collocated with q number of sensors, measuring the associated actual element deformation v_t and deformation rate $\dot{v}_t$, properly placed in some elements of the structure. consider a velocity and displacement feedback law

$$v_0 = F_d\, v_t + F_v \dot{v}_t \qquad (3)$$

where v_0 is the q-tuple representing the non zero entries of v_0 caused by the actuators, F_d and F_v are the displacement and velocity feedback matrices that can be determined to satisfy any reasonable criteria for suppression of the vibrations.

5. Energy and Power :
Let M_b denote the total mass, g the acceleration due to gravity and Vmax the estimate of the magnitude of maximum velocity at mass center of the structure. Then the maximum energy input to the structure is its Kinetic energy i.e. $M_b\ v^2/2$. Since the control energy E, suppressing lower modes, cannot be larger than this, one may write

$$E < M_b v_{max}^2 /2 \qquad (4)$$

We may estimate the decrease in the potential energy of water tank due to lowering of its mass centre by an amount of h in order to suppress the kinetic energy of the water tank with the mass M_b, to the kinetic energy shown in equation (4), we obtain

$$h = v^2 /(2g)$$

6. Conclusion :
To suppress actively the undesireable modes of vibration in buildings due to earthquakes, the use of alternative source of energy,(which is potential energy of water stored in the tank) is proposed.

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