AUTOPARAMETRIC STABILIZER OF OSCILLATION AMPLITUDE

Abramian A.K., Litvin S.S.

Institute for Problems in Mechanical Engineering RAS, St.Petersburg,
E-Mail: abramian@math.ipme.ru

The idea of stabilization of oscillation amplitudes based on the properties of multi-degree of freedom system to have amplitude – frequency dependence.

The resonance peaks and the corresponding frequencies could be changed with changing of the system parameters. Let us consider two extreme regimes: with minimum $F_{0\min}$ and maximum $F_{0\max}$ amplitudes of exciting force F_0. For these two cases the amplitude of system vibration must be practically constant.

At the first moment the system tunes to the frequency ω_0, which corresponds to the first maximum of resonance response. At this moment we have a desired value x_{0H} of mass M (equipment) oscillation amplitude. It is necessary to note, that because of large viscous friction to the load of the pendulum movement this part of stabilizer has non-periodic character and a response of the 3-degree of freedom system has only two well marked maximum and one minimum.

The increasing of F_0 to $F_{0\max}$ leads to changes in the system response in that way that the frequency ω_0 corresponds minimum of amplitude x_0, which could be equal to x_{0H}. At this moment, when $F_0 = F_{0\max}$, the values of amplitude angle of the pendulum φ_0 will be bigger than for case $F_0 = F_{0\min}$. This fact could be proved if we consider the case, when the pendulum has the constant length and if we take into account the nonlinear relation between x_0 and φ_0. The qualitative character of $x_0(\omega_0)$ and $\varphi_0(\omega_0)$ dependence does not depend on the pendulum length. This fact leads to increasing of a centrifugal force, which is acting on the load m, when F_0 increases. Also it leads to new equilibrium state of the load on the pendulum arm with larger deformation of spring. When the length of the pendulum increases the response shifts to the low-frequency band.

The dynamic equations of the system has the form:

$$\begin{cases} (M+m)\ddot{x} + c_x x + n_x \dot{x} + m(l+q)\ddot{\varphi}\cos\varphi + 2\dot{q}\dot{\varphi}\cos\varphi + \ddot{q}\sin\varphi - (l+q)\dot{\varphi}^2\sin\varphi = F_0 \sin\omega t \\ m(l+q)^2\ddot{\varphi} + c_\varphi \varphi + n_\varphi \dot{\varphi} + m(l+q)(\ddot{x}\cos\varphi + 2\dot{q}\dot{\varphi}) = 0 \\ m\ddot{q} + c_q q + n_q \dot{q} + \ddot{x}\sin\varphi - (l+q)\dot{\varphi}^2 = 0 \end{cases}$$

The properties of this nonlinear system with three degrees of freedom have been studied by the Runge-Kutta method of 6th order. The results are as follows:

1. To increase the possible region of amplitude of exciting force change we have to increase the gap between the first resonance peak $x_0(\omega_0)$ and the next minimum of amplitude. It is possible if the viscous friction along x and φ coordinates decreases. A nonlinear constraint of mass m displacement

along x axis and angle φ is a limitation in this case. The acceptable maximum values of φ_0 lies in the region $\frac{\pi}{4} \div \frac{\pi}{3}$.

2. The main factor which influence on the stabilization phenomenon is the rigidity c_q. This rigidity defines the connection between the pendulum length and centrifugal force acting on mass m.
3. The specific investigation shows that autoparametric stabilizer could be applied for vibro-equipment with electromagnetic drive or kinematical drive with elastic transmission.
4. Note, that the stabilization occurs with 10% accuracy and when $F_0 > F_{0\max}$ the fast increasing of the oscillation amplitude take place. At the same time, if we want to make value x_0 equal to x_{0H} we have to decrease the rigidity c_q when q is small.

   If q is large and it is necessary to increase the value x_0 to x_{0H} we have to increase rigidity c_q. To preserve the fast jump of x_0 when $F_0 > F_{0\max}$ a specific limitator of load m displacement along an arm is necessary.