Stochastic resonances and antiresonances in rotating mechanisms

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Abstract. Within the framework of vibration mechanics, a general equation for the slow motion of a rotating mechanisms in the presence of high-frequency stochastic excitation is obtained. As an application, a centrifugal vibration absorber with a high-frequency stochastic component in the rotation speed is considered. It is shown that its behaviour differs significantly from that of a standard pendulum without stochastic excitation.

Introduction

The effect of high-frequency stochastic excitation of dynamic systems on their low-frequency behaviour is well-known. A special manifestation of this effect is so-called stochastic resonance – a resonance-like response of a system to the level of a random excitation [1]. This effect applied in many fields of natural sciences and engineering is relevant for a wide class of dynamical systems and can be effectively considered within the frame of the concept of vibrational mechanics. This concept was originally proposed by I. I. Blekhman [2] and developed later by many researchers.

In this study, the basic method of this concept - the method of direct separation of motion – is applied with some modifications to the obtaining averaged equations of a rotating mechanism in the presence of high-frequency stochastic excitation [3,4]. This problem is of interest for many engineering applications(for example in vibration absorbers and regulators), where the frequency characteristics of the mechanism are important and can be affected with stochastic excitation from impacts in gearboxes, processed material in vibration machines, etc

Results and Discussion

A rotating multi-body mechanism with one degree of freedom ψ is considered, consisting of n kinematically coupled solids performing a flat motion relative to the rotating disc. The disc rotates with an angular velocity $\Omega = \Omega_0(1+\xi(t))$, oscillating near its average value Ω_0 where $\xi(t)$ is some stochastic process [3,4]. The kinetic energy of the system $T = \frac{1}{2}A\dot{\psi}^2 + B\dot{\psi}\Omega + \frac{1}{2}C\Omega^2$ involves the inertial coefficients A, B, and C which are functions of ψ and depend on the concrete kinematics of the mechanism. Potential energy $\Pi(\psi)$ as a function of ψ and the dissipative function $\Phi(\dot{\psi})$ are assumed to be predetermined. With a modification of the method of direct separation of motion, the equation for the averaged generalised coordinate Ψ is obtained.

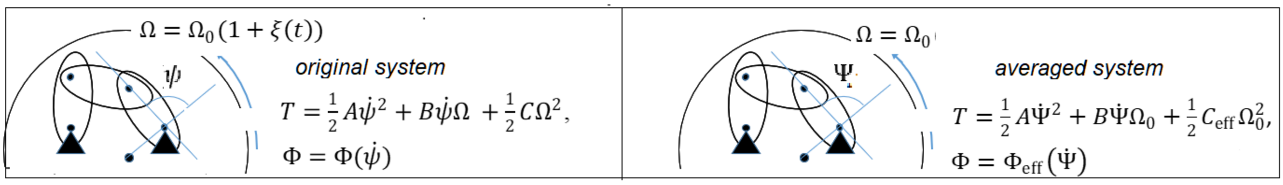

Figure 1: Vibrational mechanics transformation of the rotating mechanism with stochastic excitation.

This equation has the form of the Lagrange equation with the modified inertial coefficient C_{eff} and dissipative function Φ_{eff}, which depend on the spectral density S(k) of the random process ξ through a parameter $\kappa = \int_0^\infty S(\mathrm{k})\mathrm{k}^{-2}d\mathrm{k}$ and are calculated as $C_{eff} = C + \frac{\kappa(CA-B^2)}{A}$ and $\Phi_{eff} = \Phi + \kappa\Omega_0^2\frac{d^2\Phi}{d\Psi^2}B^2/(2A^2)$. It determines the dependence of equilibrium positions, eigenfrequency, and dissipation on the intensity of high-frequency excitation. This result is applied further for a centrifugal vibration absorber. It is shown that its behaviour differs significantly from that of a standard centrifugal pendulum without stochastic excitation.

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References

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