Method of Coupling Linear Solutions for Large-Scale Vibration Systems with Clearances

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ABSTRACT

The behavior of vibration systems with clearances is essential from the viewpoint of dynamic design, and a noise and vibration control. Clearance type nonlinearities possess non-smooth force–deflection characteristics (usually modeled as piecewise linear) and generally require a special treatment compared with other types of nonlinearities [1]. There is no general analysis method applied to all nonlinear systems in all instances.

Numerous methods, such as standard time-domain numerical integrations, various harmonic balance methods, analog and digital simulation, piecewise linear techniques [2] and the time finite element method have been developed.

In this paper, a new method for calculating steady state responses of large-scale systems with clearances is presented. The method is a new developed semi-analytical procedure of explicit integration based on coupling series of linear solutions, associated with piecewise linear functions. The system with clearances starts from an initial position described with one of linear equations of motion. When any displacement changes the piecewise linear stiffness region, the motion is represented with the new linear equation. The transition point between equations can be determined only numerically.

The accuracy of the method does not significant depend on a magnitude of the integration step since the local linear equations of motion are being solved analytically. The time step has to be sufficiently small for reliable numerical determination of the switching points between sequential linear equations. Furthermore, the analytical solutions have the same precision at any point within time step. It is a remarkable advantage with respect to other explicit integration methods (Runge-Kutta, etc.).

The method is applied to obtain the frequency response of the three-degree-of-freedom semi-definite system with two clearances under periodic excitations. The numerical results are validated considering the describing function method, finite element in time method and MATLAB Simulink ODE113 solver. Close agreement is found between the frequency responses resulting from all employed approaches.

REFERENCES

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[2] J.M.T. Thompson and H.B. Stewart, *Nonlinear dynamics and chaos: Geometrical methods for engineers and scientists*, John Wiley & Sons, (1986).