Repetitive Impact in Continuous Structures

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Impact in structures can occur due to clearances and manufacturing tolerances, or through intermittent contact between rotating or translating machine elements. Excessive clearance between an engine's piston and the cylinder wall, for instance, enables the piston to move laterally and impact the cylinder with each stroke [1]. Turbomachinery blades are likewise sensitive to imbalance, and their vibration leads to high cycle fatigue problems [2]. Aside from machine dynamics, nuclear power plants are one class of structures for which impact-driven contact can occur between two beam-like structures. Both steam generator tubes and reactor control rods can impact their supporting structures, causing damage and wear that can introduce contaminants into the reactor's fluids systems [3].

Since impact is a highly nonlinear phenomenon, the prediction of dynamic response after an impact event can be complicated. The constraint and modal mapping method has been developed that couples modal analysis with state-space extended operator formulations. The analysis algorithm is first applied to a beam-rigid body structure impacting a comparatively compliant base structure subjected to a sinusoidal base excitation. A modal analysis based upon extended operators for the (continuous) beam and (discrete) rigid body establishes a piecewise linear state-to-state mapping for transition between the in-contact and not-in-contact conditions. The resulting steady-state dynamic responses exhibit complex characteristics as a function of excitation frequency. The period-doubling bifurcations, grazing impacts, sub-harmonic regions, fractional harmonic resonances, and apparently chaotic responses have also been experimentally verified.

The next phase investigates the repetitive impact dynamics of two orthogonal pinned-pinned beams subjected to a sinusoidal base excitation. The orthogonal beam configuration restricts the contact to a single point, and the contact interface between the beams is modeled by a spring. This analysis for the impact of two beams is an extension of the single beam impacting a compliant support. The contact impulse is used to describe the repetitive impact frequency response functions and their additional complexity.

Future plans involve the investigation of impact between two parallel beams. Additional modeling challenges include balancing the determination of the contact location(s) and the associated mode shapes with computational efficiency.

[1] S.-H. Cho, S.-T. Ahn, and Y.-H. Kim. "A simple model to estimate the impact force induced by piston slap," Journal of Sound and Vibration, vol. 252, pp. 229-242, 2002.

[2] K. P. Duffy, R. L. Bagley, and O. Mehmed. "On a self-tuning impact vibration damper for rotating turbomachinery," AIAA Joint Propulsion Conference, AIAA-2000-3100, NASA TM-2000-210215, 2000.

[3] P.L. Ko, M.-C. Taponat, and M. Zbinden. "Wear studies of materials for tubes and anti-vibration bars in nuclear steam generators," Journal of Pressure Vessel Technology, vol. 118, pp. 287-300, 1997.