Theoretical Analysis, Numerical Computation, and Experimental Measurement of the Transient Wave Propagation and Inverse Problem in Multi-Span Plate

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This paper combines theoretical analysis, experimental measurements, and finite element analysis to investigate the dynamic behavior of multi-span plates. In theoretical analysis, the superposition method is employed to determine the resonance frequencies, mode shapes, and full-field strains of multi-span plates, providing an analysis of free vibration characteristics. Subsequently, based on the free vibration characteristics and the orthogonality of mode shapes, the normal mode method is used to analyze the transient wave propagation problem when the structure is subjected to dynamic external forces. In the experimental measurement, frequencies and mode shapes of multi-span plates with different spans are conducted using Electronic Speckle Pattern Interferometry (ESPI). For transient wave propagation analysis, the impact response of the multi-span plates is excited at different span locations using steel ball impacts. The duration and transient strain signals resulting from the impact are measured using piezoelectric film sensors (PVDF). The results from theoretical analysis, experimental measurements, and finite element analysis are then compared to validate the accuracy of the theoretical analysis. Furthermore, theoretical analytical solutions are applied to inverse problems. The material parameters of the structure are determined using a simplified inverse method; the position of impact points is calculated by combining the results from free vibration and transient wave propagation, and a method for inversely estimating the history of external forces using theoretical analytical solutions is proposed. The inverse results are validated and compared with experimental measurements, showing good correspondence.