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Investigation of Self-Excited Vibrations in Turbine Blades: The Role of Under-Platform Damper Geometry and Centrifugal Force in Stability Envelopes

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ABSTRACT

Self-excited vibrations in turbine blades, arising from the interaction between aerodynamic and structural forces, represent a critical challenge in turbomachinery design due to their potential to cause high-cycle fatigue. Underplatform dampers (UPDs) are widely employed to mitigate these vibrations through passive frictional energy dissipation. In such systems, the centrifugal force acts as the primary loading mechanism, generating the normal contact pressure between the damper and the blade platforms required to activate frictional damping.

The nonlinear contact behavior of the damper leads to non-unique equilibrium states, resulting in multiple periodic responses characterized by distinct limit cycle oscillation (LCO) and stability limit (SL) amplitudes. This study investigates the existence of multiple periodic solutions and the associated vibration amplitude boundaries, with particular emphasis on the effects of centrifugal force magnitude and UPD geometry, considering both symmetric and asymmetric configurations. The governing equations are solved in the frequency domain using a coupled Harmonic Balance Method (HBM), in which static and dynamic equilibrium equations are addressed simultaneously.

An optimization-based procedure is employed to determine the amplitude boundaries by maximizing the dissipated frictional energy, providing a systematic identification of admissible LCO and SL envelopes. The results are validated through time-domain simulations using the Runge–Kutta method. The findings demonstrate that damper geometry strongly influences the amplitude boundaries and stability characteristics. The centrifugal force significantly effects the vibration levels in both LCO and SL amplitudes. This research offers valuable design insights for robust friction-damped turbomachinery systems.

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