STFT-Based Time–Frequency Analysis of Rotor–Stator Interaction in Multistage Turbines

This study presents a detailed post-analysis of time-resolved experimental data obtained from a four-stage axial flow turbine equipped with high-pressure steam turbine blading. The investigation focuses on unsteady rotor–stator interaction (RSI) effects observed on a stator vane in stage 3. Fast-response pressure transducers mounted at mid-span of the vane surface capture transient pressure signals under both design and off-design conditions. By correlating the spectral content of these signals with the blade-passing frequencies of individual blade rows, the origins of dominant unsteady fluctuations are identified. This frequency matching serves as the foundation for interpreting inter-row interactions and their propagation mechanisms. To further resolve the temporal behavior of these interactions, Short-Time Fourier Transform (STFT) is applied, enabling a joint time–frequency analysis. The phase information extracted from STFT reveal that the RSI effects propagate through the turbine stages as frequency-modulated (FM) waveforms. Moreover, temporal amplitude envelopes of individual harmonic components are extracted via STFT to evaluate envelope similarity and enable separation of overlapping contributions at identical blade-passing frequencies. This allows decomposition of composite pressure signals into constituent sources based on envelope shape coherence, following methodologies similar to partial separation techniques in multichannel mixtures. The phase and amplitude characterization form the basis for a modulation-based model that captures the spatial and temporal evolution of RSI effects. The resulting framework advances understanding of multistage aerodynamic coupling and provides a pathway toward improved prediction of blade loading and forced response under realistic operating conditions.

Keywords: Rotor–Stator Interaction (RSI), Multistage Axial Turbine, Short-Time Fourier Transform (STFT)