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Across the modeling spectrum: Analytical and hybrid approaches to vibrations in mechanical drivetrains

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Abstract

Mechanical drivetrains – whether in rotorcraft or wind turbines – pose persistent challenges for dynamics modeling due to nonlinearities, multi-scale behavior, and evolving performance demands. This talk explores vibration modeling across two distinct but mechanically linked systems: a helicopter tail rotor driveline with friction-induced impacts, and a wind turbine blade-rotor system with complex aeroelastic dynamics. In the first part, we present a semi-analytical approach to model the nonlinear vibratory response of a tail rotor driveline incorporating a dry friction damper. Through this framework, parametric insights are obtained, enabling efficient optimization for vibration mitigation and robustness. The method balances analytical tractability with real-system complexity. In the contrast, the second part transitions to a hybrid modeling paradigm applied to wind turbine systems. Here, high-order structural dynamics are captured using a data-driven approach informed by physical priors, enabling refined predictions without sacrificing computational feasibility. Together, these case studies illustrate a continuum of modeling strategies – ranging from foundational analytical techniques to modern data-enhanced framework – each chosen to match system characterises and design objectives. I will end the presentation with our recent development on digital twins aiming for both predictability and adaptability across a system's lifecycle.