National Institute of Technology Rourkela

Defence Seminar

Seminar Title	: STUDY OF MISALIGNED SHAFT AND ITS VARIOUS MALFUNCTIONS
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Venue	: Seminar Hall Department of Mechanical Engineering
Date and Time	: 19 May 2025 (5:00 pm)

Abstract : Rotordynamics, a field within applied mechanics, focuses on understanding and mitigating vibrations in rotating machinery, where shafts or rotors are primary vibration sources. Excessive vibration jeopardizes system integrity and efficiency, making effective control crucial for reliable operation. When multiple flexible shafts are connected via couplings and experience misalignment&mdasha common issue where driving and driven shafts are non-collinear&mdashthe machinery faces substantial imbalance forces and vibrational instabilities. Failures stemming from these misalignment-induced instabilities, particularly the coupled torsional-flexural effects on the rotor-bearing system, are a leading cause of rotor failures and subsequent industrial downtime.

Misalignment, categorized as parallel, angular, or a combination, generates excitation forces and amplifies vibration amplitudes, posing a critical problem for shafts. Couplings, essential for long transmission shafts, can partially alleviate misalignment effects. While both rigid and flexible couplings exist, flexible types are favored for high-speed machinery. Acting as flexible elements, couplings introduce mass, damping, and stiffness to the system's dynamics, making them influential in defining dynamic properties. A new approach using a viscoelastic disc coupling to connect multiple misaligned flexible shafts is proposed. The disc is modeled as interconnected viscoelastic elements capable of energy absorption and release. An operator-based method incorporates the coupling material's inherent damping. The rotating coupling stiffness and damping influence overall system dynamics, including modal characteristics and vibration response. The study examines flexible shaft coupling behavior by integrating stiffness and damping properties into the shaft's mathematical model. Two modeling approaches of flexible shaft are used: a simplified lumped-mass model and a more detailed finite element model. Equations of motion for the viscoelastic shaft are derived using Euler-Bernoulli beam theory and an operator-based material constitutive relation. A spring-mass analogy incorporates coupling effects into the shaft model. A comparison between analytical and finite element methods considers critical speed, Campbell diagrams, and frequency/time response.

The connection of multiple shafts via couplings creates long, slender structures prone to non-linear behavior due to large deformations. Therefore, the theoretical study extends to geometrically non-linear rotor dynamics, incorporating various malfunctions, i.e. a loose rotating disc and non-linear imbalance rub pedestal looseness. The research validates these models separately using computer simulations to investigate linear and non-linear vibration responses across various rotational speeds, providing accurate and efficient insights into system dynamics. Simulations show stable responses for the linear system across the observed frequency range. In contrast, the non-linear system exhibits "jump phenomena" within specific frequency bands, a hallmark of non-linear behavior. This research provides mathematical models applicable to diverse rotor shaft systems for analyzing misalignment-induced malfunctions, long coupled shafts, and geometric non-linearities.