Test and Simulation Study for Magnetic Bearing's Backup Bearing Contact Forces during Rotor Drops

Xiao Kang and Dr. Alan Palazzolo
Texas A&M University, Dept. of Mechanical Engineering

The literature contains a number of papers that consider the vibration response of a rotating shaft assembly supported by magnetic bearings MBs during a MB power outage incident resulting in the sudden drop of the shaft onto the backup (catcher) bearings. Some of these papers compare predicted and measured vibration displacements of the shaft near to the catcher bearings, revealing repeated impact, whirl, orbiting and bouncing related motions, and heat-up of the bearing components. Their comparison of displacements provides a good means to improve the prediction of displacement motion, however catcher bearing life is more directly related to the contact forces exerted on it by the journal during a drop event. Only a very small number of papers have experimentally measured the impact and friction forces during a rotor drop event. Said Lahriri et al [1] measured the impact force between the rotor and two types of backup bearings. However, the rotor-bearing contacts in their tests resulted from large vibration under resonance conditions or from forced impact excitation, but not from a free drop onto the catcher bearings. Unlike a true rotor drop the rotor's drop behavior was influenced by the supporting bearings and motor coupling. Saket et al [2] installed a strain gauge type load measurement system in their catcher bearing system, however drop tests were not conducted and only load cell calibration results were provided. The present paper will discuss a new catcher bearing test rig wherein the rotor is spun at high speed as initially supported with a self aligning bearing and a tapered roller bearing. The drop test is initiated when the drive motor is mechanically pulled axially backwards separating it from the rotating assembly and in this process the gap in the magnetic coupling that connects the motor and rig rotor is suddenly thrust open. Next, the outer race of the tapered roller bearing is pushed forward by a solenoid - spring system opening a clearance in the bearing to let the rotor drop freely onto the catcher bearing. The complete separation of the shaft from the tapered roller bearing was experimentally confirmed. A 3 axes piezoelectric load cell is installed under the catcher bearing housing to measure the impact forces on the catcher bearing during rotor drops. The high stiffness of the load cell and its support, and the 10 kHz DAQ sampling rate yield highly accurate measurements in both the horizontal and vertical directions. Tachometers are installed to measure the spin speeds of both the rotor and the catcher bearing inner race. Parameters varied during the rotor drop tests include catcher bearing clearance, mass imbalances and rotational speed. Correlations of measured contact forces and vibrational motions, with predictions from a high fidelity model including individual ball motions shows good agreement.

[1] Said Lahriri, Ilmar F. Santos. Experimental quantification of dynamic forces and shaft motion in two different types of backup bearings under several contact conditions. Mechanical System and Signal Processing. 2013.

[2] Fawas Y. Saket, M. Necip Sahinkaya, Patrick S. Keogh. Touchdown Bearing Contact Forces in Magnetic Bearing Systems. Proceedings of ASME Turbo Expo 2013: Turbine Technical Conference and Exposition GT2013. June 3-7, 2013, San Antonio, Texas, USA