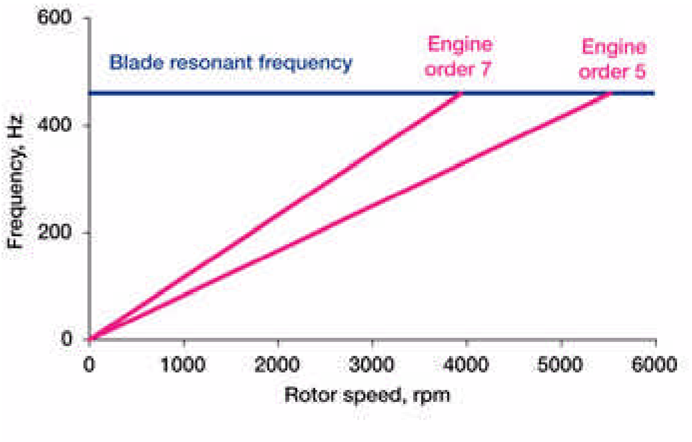
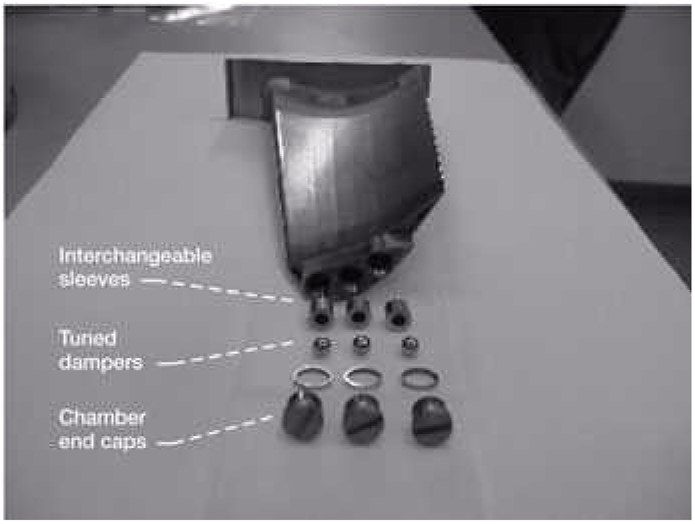
# Self-Tuning Impact Dampers Designed for Turbomachinery Blade Vibration Suppression




*Top: Campbell diagram showing engine order lines and blade resonance frequency. Bottom: Pratt & Whitney turbine blade with three self-tuning impact dampers added to the blade tip--exploded view.*

Turbomachinery blades are subject to aerodynamic forces that can lead to high-cycle-fatigue (HCF) failures. These failures will only increase as engineers begin to design blades without shrouds or as integrally bladed disks (blisks). These new designs will decrease blade damping significantly because the mechanical damping from shroud and blade joints will be eliminated. Also, it is difficult to design dampers for the engine environment with its extremely high centrifugal loads and high temperatures. The self-tuning impact damper has been designed to provide the additional damping required to avoid HCF while withstanding the harsh engine environment. In addition, the damper is placed within the engine blade itself rather than external to it.

The self-tuning impact damper combines two damping methods--the tuned mass damper and the impact damper. It consists of a ball located within a cavity in the blade. This ball rolls back and forth on a spherical trough under a centrifugal load (tuned mass damper) and can strike the walls of the cavity (impact damper). The ball's rolling natural frequency is proportional to the rotor speed and can be designed to follow an engine order line (integer multiple of rotor speed). Aerodynamic forcing frequencies typically follow these engine order lines, and a damper tuned to the engine order will most effectively reduce blade vibrations when the resonant frequency equals the engine order forcing frequency.

This damper has been tested in flat plates and turbine blades in the Dynamic Spin Facility at the NASA Glenn Research Center. During testing, a pair of plates or blades rotates in vacuum at up to 8000 rpm. Excitation is provided by one of three methods--electromechanical shakers, magnetic bearing excitation, and eddy current engine-order excitation. The first two methods apply excitation at any frequency to the shaft itself.

The eddy current system, manufactured by Hood Technologies and installed in fiscal year 2001, consists of magnets located circumferentially around the rotor. As a blade passes a magnet, a force is imparted on the blade. The number of magnets used equals the engine order of excitation. These magnets are remotely raised or lowered to change the magnitude of the forcing on the blades. Blade response is monitored with strain gauges and laser displacement probes.

Early tests in flat plates show that the damper is effective in reducing resonant blade response at and below the speed line crossing. Damping increased from 0.2 percent critical to about 1.0 percent critical. In fiscal year 2001, tests were performed on a pair of Pratt & Whitney low-pressure turbine blades. Preliminary results show peak resonance decreasing by 50 percent with the impact damper. In addition, very small dampers were designed such that a number of them could fit within the very thin profile of a fan blade.

# Bibliography

Duffy, Kirsten P.; Mehmed, Oral; and Johnson, Dexter: Self-Tuning Impact Dampers for Fan and Turbine Blades. 6th National Turbine Engine High Cycle Fatigue (HCF) Conference Proceedings, AFRL/PRT, Wright-Patterson AFB, OH, March 5-8, 2001.

**Glenn contact:** Oral Mehmed, 216-433-6036, Oral.Mehmed@grc.nasa.gov
**University of Toledo contact:** Dr. Kirsten P. Duffy, 216-433-3880, Kirsten.P.Duffy@grc.nasa.gov
**Authors:** Dr. Kirsten P. Duffy and Oral Mehmed
**Headquarters program office:** OAT
**Programs/Projects:** SEC