Optical Measurements of Axial and Tangential Steady-State Blade Deflections Obtained Simultaneously

Case-mounted fiber-optic sensors have been used by aircraft engine manufacturers mainly to monitor blade vibration in fans and compressors. The simplest probe arrangement is a spot probe where, typically, a center fiber transmits laser light, and the outer fibers collect the reflected light from the blade tips and transmit it to a photodetector. Because the spot of incident light is fixed in space, whereas the blade deflects dynamically, the reflected light will originate from slightly different portions of the blade tip under different operating conditions. Unless corrections are developed to compensate for this effect, some error in vibratory tangential amplitude will occur. For monitoring vibrations, this error is usually not critical.

However, when steady-state blade deflections are being measured, it is very important to fix the spot on the blade tip at a particular location because the operating speed blade deflections are evaluated against a low-speed reference run. The change in speed usually implies a significant change in the blade orientation and possibly its shape brought about by the aerodynamic and centrifugal loading.

It is most convenient to select the blade's leading and trailing edges as the fixed points for which deflections will be evaluated. To capture the blade edges at various speeds, the light probe must be movable. This was achieved by mounting the probe in an eccentric hole in a bushing that fit the fan case in the region that overlapped the path of the blade edge. The probe was actuated to search for a blade edge while all the blades were viewed on an oscilloscope. The blade edge was considered to be captured when a pulse associated with a particular blade was significantly reduced in magnitude but was clearly distinguishable from the background noise level. By tracing the axial position of either blade edge, one could extend the deflection measurement to two dimensions: axial and tangential. These blade deflection measurements were obtained during a wind tunnel test of a fan prototype.

Probe-actuator/motor assembly.

As shown in this photograph of the servomotor-actuator assembly, the cylindrical enclosure that accommodates the eccentrically positioned optical probe was open on one side to provide an exit path for the fiber-optic cable. The 180° opening in the housing was oriented such that its base (along the diameter) was parallel to the fan rotor axis. Thus, when the motor was actuated, the probe moved over a semicircular path, maximizing the extent of the motion in the axial direction. The two noncontacting limit switches (not shown in the photograph) restricted the extent of rotation to 180°. The servomotor had a resolution of 4000 counts per revolution and was controlled remotely by a computer.

Bibliography

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