OEMs recommend periodic inspection of pinned finger turbine blade attachments for detection of service-induced damage as part of ongoing rotor maintenance activity.

This article provides an example where ultrasonic inspection detected cracking in several pins of finger attachments and outlines an engineering assessment to support continued operation and identify a re-inspection interval. This approach can be applied to other pinned finger blade attachments to determine suitability for service.

Finger pin attachment designs are most common in the L-1 and L-0 stages of LP rotors where the largest blades are located. The finger pin design is capable of supporting long blades (> 40") with weights in excess of 100 lbs. Figure 1 is a photo showing the disk side component of finger pin connections at L-1 and L-0 stages. The blade side components of the connection have a mating set of fingers that are secured to the wheel with 3 pins per blade at the inner, middle and outer radial locations.

Finger pin inspections are performed using ultrasonic (UT) transducers from the admission and discharge ends of the pins. UT pin inspection is often part of a scheduled magnetic particle inspection of the LP rotor periphery and is part of ongoing maintenance activity. Inspections of disk and blade side fingers on the other hand are usually performed to address known issues (OEM TIL) or as a follow up to...
evidence of stress corrosion cracking (SCC) in the attachment. Finger inspections are more involved requiring blade removal and therefore are more resource intensive to perform.

In this article, the evaluation of finger pin inspection data is discussed. Pin data is reviewed to identify the affected pin shear planes and unable to transmit shear loading. Supporting finite element (FE) analysis is described that focuses on evaluating the redistribution of finger stresses to determine potential stress overload failures in the fingers (both disk and blade sides) as well as the pins. Disk and blade side finger inspection data, used to evaluate cracking in the attachment fingers, is discussed in a News and View article published by Structural Integrity (SI) in 2015 [1].

Stresses in the pins and fingers are obtained from a 3D FE analysis of a fully bladed finger pin attachment. As shown in Figure 2, symmetry boundary conditions are used with a one-half blade arc disk segment to effectively simulate the full disk geometry. Note that one plane of the model cuts through the center of the pins and blade (front surface) with the opposing boundary located at the blade outer surfaces (back surface). A pie shaped wedge of the stage disk defined by these bounding surfaces is included in the model. Contact elements are used at the pin/disk, pin/blade and disk/blade finger interfaces.

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Contour plots of radial stress distributions across the front and back surfaces of the FE Model are shown in Figure 3. Note that blade and disk finger stresses are uniform across all fingers. Figure 4 shows a plot of the through thickness (from back to front surfaces) distribution of radial stress at a typical disk side finger location. The stresses at the back-surface are of primary interest as these stress levels determine when attachment failure will occur. Corresponding plots for blade side finger radial stresses are similar to the disk side plots. Table 1 is a comparison of the disk side and blade side finger stresses on the back side of the model for the as-designed condition.

Cracked pin inspection data is recorded for each blade and pin location. UT measured distances from the end of the pin to defect locations from both the admission and discharge ends of the pin are recorded. A sample of data collected is shown in Table 2. Note that when the sum of the admission and discharge side UT measured distances equals the disk thickness (6.09”), a single defect is identified. When that sum is less than the disk thickness then two or more defects may be present. The data is tabulated to determine how many defects are collectively present at each shear plane for all blade locations.

Figure 5 is the schematic drawing of the finger pin attachment showing the locations of shear planes that have 1 or more recorded defects.
To evaluate the effect of pin defects on finger pin attachment stresses, two bounding assumptions are made. First, the locations of pin defects plotted in Figure 5 are assumed to prevent any transfer of shear loading, effectively modeling broken pins at those locations. Second, the defect locations shown in Figures 5 are assumed broken at all blade locations. Both assumptions are most limiting adding considerable conservatism to the analysis results.

The model discussed earlier is modified to include the broken shear planes identified in Figure 5. A contour plot of the resulting radial stress distribution on the back surface of the model is shown in Figure 6. Broken shear pin locations and maximum radial stress locations are identified in the plot. Note that when viewing the back-side surface of the model the broken shear pin locations are on the left side of the model. The locations of maximum radial stress are observed to be in the blade and disk fingers adjacent to the broken shear pin locations. This trend is also evident on the front-surface blade side radial stresses (not shown).

Table 3 is a summary of the maximum radial stresses in the finger pin attachment with broken pins. Table 3 includes maximum stresses for the five-disk side and six blade side fingers. Stresses from the as-designed attachment FE analysis are included to serve as a reference for comparison of the redistributed stresses from broken pins. Inspection of Table 3 shows that the highest radial stresses are in the blade and disk fingers adjacent to the broken shear pin locations (fingers B4 and D4 in Figure 6) with stress levels attenuating to lower values in fingers further removed from B4 and D4 locations. Radial stress levels in all blade side and disk side fingers, are well below yield levels indicating that the effects of pin defects are not compromising rotor integrity or preventing continued rotor operation.

References / Footnotes