

Case History: Gear Tooth Failure Problem Resolution

MSI was contracted by the OEM to perform testing and analysis and determine the root cause of gear tooth failures on an aeroderivative gas turbine power generation drivetrain. The 37 MW gearbox had broken teeth on the pinion after several thousand hours of operation. The OEM was proceeding with a gear tooth profile re-design to make the gear more tolerant of the misalignment to which other consultants had attributed the tooth failures. The OEM was suspicious that the suspected level of gear mesh misalignment could not explain the tooth failures, but at the time there was no better explanation.

MSI's measurements at the bearing locations indicated imbalance in the radial loading of the pinion rotor from the turbine end to the alternator end. The pinion centerline (average location, not vibration) moved with increasing load as shown by the arrows in Figure 1. It is important to note that the two ends of the pinion behaved very differently, with the turbine end following a crescent shaped trajectory and the generator end gradually moving toward the centerline as the load was increased.

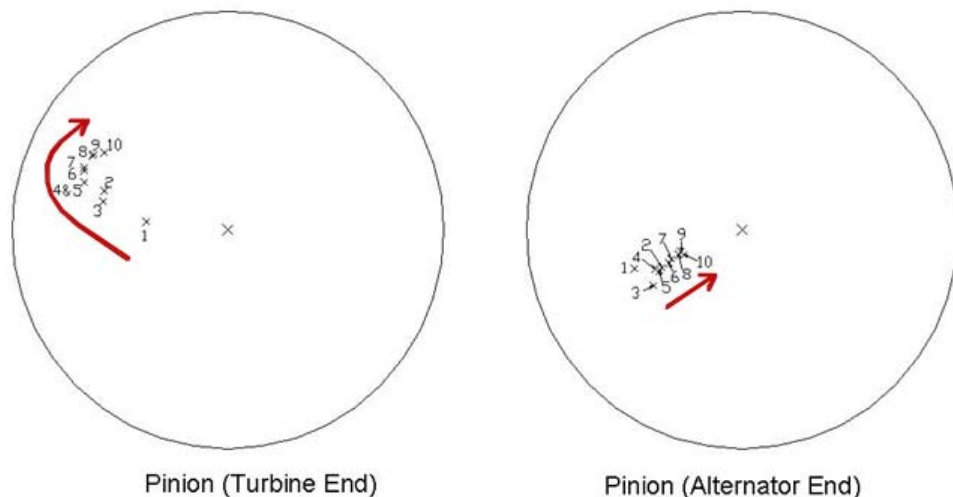


Figure 1: Shaft centerline position relative to the bearing centerline. The outer circle represents the bearing clearance. The arrows indicate the direction the rotor centerline moves with increasing load.

The bearing temperatures and eccentricity at the two ends of the rotor differed considerably and both indicated that the radial loading was skewed to the turbine end. In double helical gear sets, one of the elements, in this case the pinion should be free to move axially with respect to the other to equalize the tooth loads on each helix. Imbalance in the radial loading implied that there was external force acting on the pinion rotor which resulted in one of the helices carrying significantly more load. The source of this force was thermal growth of the high-speed rotor system (pinion and power turbine) exceeding the axial clearance in the coupling. The axial growth reacts at the thrust bearing of the bull gear rotor, transmitting unbalanced axial loads through the gear teeth.

The problem was corrected by increasing the axial travel of the coupling between the power turbine and the pinion. The route which the OEM was taking to redesign the gear tooth profile to account for a hypothetical gear mesh misalignment would not have solved the problem, and may have even resulted in higher tooth stress levels and more frequent failures.

The dynamic behavior of the gearbox while operating at no load and at reduced speed provided several other conditions, which could contribute to gear tooth failures. Large shifts in the axial position of the pinion as well as high amplitude axial vibrations were measured while operating at idle speed (3300 RPM). The axial vibration was strongly exacerbated by the excitation of an axial natural frequency of the pinion. Radial vibrations of the pinion increased from 0.5 to 2.5 mils (0.013 – 0.064 mm) peak-to-peak when the gearbox was operating at synchronous speed, but under no load. The primary component of this vibration was at 35 Hz (43% of running speed) and was the result of rotordynamic instability.

Gear mesh misalignment may have been a contributing factor to the gear tooth loading, but is not the sole or even the primary cause of the gear failures.

Mechanical Solutions, Inc.
11 Apollo Drive
Whippany, NJ 07981 USA
www.mechsol.com

Tel: (973) 326-9920
Fax: (973) 326-9919
msi@mechsol.com