

Performance of Nitrided Gears in High Speed Epicyclic Gearbox Used in Gas Turbogenerators - A Case Study

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American Gear Manufacturers Association



TECHNICAL PAPER

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[The statements and opinions contained herein are those of the author and should not be construed as an official action or opinion of the American Gear Manufacturers Association.]

Abstract

High speed epicyclic gearboxes used in gas turbogenerators are typically designed with either carburized and hardened or nitrided gears. Each of these types of gear has its own merits and limitations. While carburized and hardened gears offer optimum design, nitrided gears are sometimes preferred because of their low heat-treat distortion. In terms of load capacity, carburized and hardened gears perform satisfactorily not only under steady load but also heavy shock load. Nitrided gears, on the other hand, are known to operate successfully only under steady state load. The fatigue life of these gears reduces significantly under heavy shock load. That there is also a considerable reduction of nitrided gears life under rated load with wide fluctuations is unknown. A recent failure of an epicyclic gearbox with nitrided gears that was operating under such loading confirms this fact. In this case, the gearbox was used to reduce the speed of a gas turbine rated 10.4 mW. During the engine wash cycle, the load at the generator end varied from 0 to 10 mW at 1.5 cycles per second for about 25 seconds duration, with the peak occasionally reaching to 12 mW. No such failure is reported in similar gearboxes that are operating at various installations that did not experience this type of load fluctuations.

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PERFORMANCE OF NITRIDED GEARS IN HIGH SPEED EPICYCLIC GEARBOX USED IN GAS TURBOGENERATORS — A CASE STUDY

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Introduction

Case carburized and hardened gears are known to operate satisfactorily both under steady and overload conditions. Nitrided gears, on the other hand, seem to perform well only under steady load [1]. Shock loads detrimentally affect nitrided gears life [2]. Thus, nitrided gears are rarely used in applications that experience occasional shock loads. However, that the life of nitrided gears may also deteriorate when subjected to a rated load that varies widely in a very short time period is relatively unknown. Although, such load spectrums are not very common, sometimes these are observed in gas turbogenerator applications. An analysis of a gas turbogenerator load during start-up shows load fluctuations to occur whenever the fuel control system malfunctions. In this paper, a case-study on the failure of nitrided gears used in a gearbox subjected to a load with wide fluctuations is presented.

Failed Gearbox

The gearbox is of star epicyclic configuration and is used as a speed reducer in between a 10.5 mW gas turbine and an electric generator. The general characteristics of the gearbox are:

Horsepower rating (hp)	:	16,500
Input speed (rpm)	:	8625
Output speed (rpm)	:	1,500

The sun pinion and planet gears are nitrided whereas the ring gear is just through-hardened. The design life of the gears is 100,000 hours minimum.

Failure Incident

According to a field representative, gearbox failure occurred after three hours of operation following a scheduled on-line turbine water wash cycle. In general, all turbines go through a water wash cycle after a few thousand hours of operation. During such a cycle for this turbine, the generator load is brought down to about the 80 percent level and then water is injected through the compressor section of the turbine. Following wash, the load is raised to the maximum continuous level. After the last wash cycle, high vibration levels of the gearbox were reported just before the gearbox failed. Unfortunately, no data were taken. The gearbox had a total of about 16,000 hours of service before the failure.

Following this incident, to ensure the failure was not caused by misalignment of equipment or any malfunction of components such as bearings, couplings, shaft, a thorough inspection was conducted. The equipment alignment of the package was found to be within the allowable tolerance. Also, no visible damage of any component was noticed. This led the inspection toward the gearbox internal components.

Visual inspection of the disassembled gearbox revealed severe mechanical damage to all gears. The failure was so catastrophic that one complete tooth fell off from one of the planet gears and was found at the bottom of the housing. Figure 1 shows the damaged planet gear and Figure 2 the severed tooth. Tooth debris was noticed in various gear meshes. No abnormal distress was found on planet sleeve bearings, although the thrust faces of output shaft sleeve bearings were completely wiped out. Also, sealing surfaces of output shaft and labyrinth seal were found to be burnt.