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08FTM05

AGMA Technical Paper

Gear Failure Analysis Involving Grinding Burn

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Gear Failure Analysis Involving Grinding Burn

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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

When gears are case-hardened it is known that some growth and redistribution of stresses will occur which result in geometric distortion. Aerospace gears require post case-hardening grinding of the gear teeth to achieve necessary accuracy. Tempering of the case hardened surface, commonly known as grinding burn, occurs in the manufacturing process when control of the heat generation at the surface is lost. Excessive heat generated at the surface can induce surface tempering and / or re-austenitize the surface in a localized area. The localized area will have reduced or altered mechanical properties in addition to an unfavorable residual stress state [1].

A gearbox with minimal service time was removed from an aircraft, disassembled, and visually inspected. Linear cracks along the dedendum of the working gear tooth face were found during visual inspection in three adjacent teeth. No teeth had been liberated. A detailed inspection of the incident gearbox found no other components with distress.

Metallurgical evaluation determined that the cracks initiated in service at the boundary of a localized grinding burn, which had re-austenitized. The cracks propagated inward from the tooth surface in fatigue to a depth greater than the depth of case.

The metallurgical evaluation could not conclude if the crack trajectory would propagate across the tooth cross-section or radial into the gear rim. The cross-section trajectory results in the liberation of teeth. Linear elastic fracture mechanics (LEFM) was then used to predict the cracks' future propagation path based on assumptions from the one incident gear.

AGMA 2007-C00 [2] provides details of the temper etch process and specifically requires the use of a nitric acid etch process, which is typically used in production quality inspections. The incident gear was processed for grinding burn using an ammonium persulfate etch solution. Quality records documented variation in chemical concentration levels during the time the failed gear was manufactured. A design of experiments was conducted to understand the effects of the factors and interactions that impact the capability of the ammonium persulfate process used in production to detect grinding burn.

Presented are the metallurgical findings, load distribution analysis of actual geometry, crack propagation analysis, and design of experiment results of the ammonium persulfate etch process.

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American Gear Manufacturers Association
500 Montgomery Street, Suite 350
Alexandria, Virginia, 22314

October, 2008

ISBN: 978-1-55589-935-6

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Overview of gear system

The incident gearbox had accumulated 1,650 hours of use at the time of event. The design life of the engine is 20,000 hours with field demonstrated life in excess of 20,000 hours. An event this early in life is rare for this gearbox.

The failed gear was one of many gears in a reduction gearbox that is integrated with a Rolls-Royce gas turbine engine. The engine is used in a multi engine fixed wing application.

A partial illustration of the gear train and the incident gear is shown in Figure 1. The failed gear and mating pinion are carburized, ground, and shot peened AMS6265. The engine torque path is also shown in Figure 1.

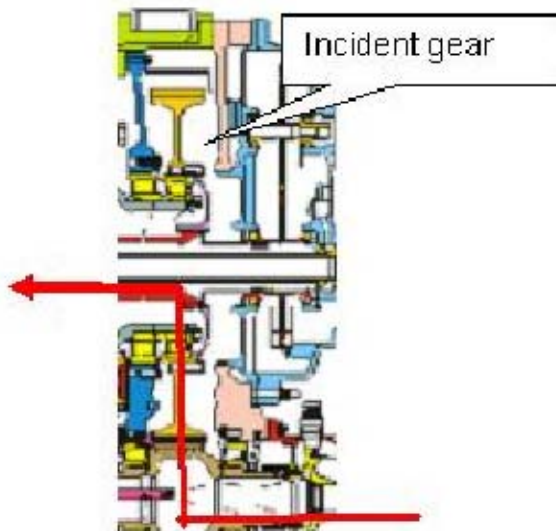


Figure 1. Partial illustration of gear train showing torque path

The incident gear is part of the first stage reduction in a legacy aerospace gearbox that has demonstrated high field reliability.

Background of failure

The gearbox has a chip detector in the scavenge oil passage. During flight, a chip light warning was acti-

vated by the system for one of the four engines. The aircraft safely landed without issue and ground crews began investigation to determine the source of the chip light indication.

The ground crew first removed the chip detector and found a large sliver of material clinging to the end. The size of the sliver is shown in Figure 2. Typically, wearing or pitting components will generate very fine particles, that when mixed with oil create a paste. The paste is what most technicians expect to find when investigating a chip light indication. The size of the debris found on the plug was cause for removal of the gearbox.

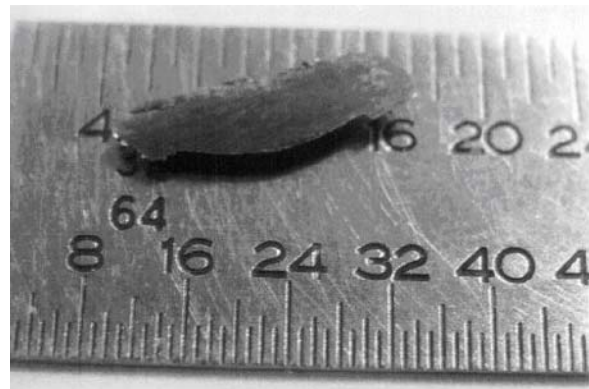


Figure 2. Debris found on chip detector

Tear down inspection

The gearbox was removed and sent to a maintenance facility for tear down inspection. The tear down was overseen by Rolls Royce Engineering as part of standard practice.

Cracks were found in the first stage spur gear as shown in Figure 3. Tooth number eight shown in Figure 3 was found to have a divot close in size to the metallic sliver found on the chip detector. The cracks were located in three adjacent teeth on the driven side. The cracks stretched across the central 75% of the face width within the active tooth profile. The cracks were arc shaped, higher on the active tooth profile at the ends than in the center.