NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

April 16, 2013

MATERIALS LABORATORY FACTUAL REPORT Report No. 13-023

A. ACCIDENT

Place	:	Phoenix, Arizona
Date	:	May 2, 2012
Vehicle	:	Hughes 269C, N380TL
NTSB No.	:	WPR12FA191
Investigator	:	Thomas Little, AS-WPR(SEA)

B. COMPONENTS EXAMINED

Main Transmission Pinion, aft pinion nut, section of tail rotor drive shaft, driving spline, phenolic plug, and forward bump stop.

C. DOCUMENTS REVIEWED

- Sikorsky Aircraft Preliminary Field Notes, WPR12FA191
- Boeing Field Investigation Notes, Accident Case File # 120502/269C/0694C
- NTSB Materials Laboratory Factual Report 05-072

D. DETAILS OF THE EXAMINATION

A Hughes 269C (S/N 68-0694) that crashed into a residential home was recovered and inspected at Mesa, AZ at a facility owned by Canyon State Aero, the aircraft operator. The initial teardown identified several components in the main transmission with evidence of pre-existing damage prior to the incident. These components were removed and sent to the NTSB materials laboratory for examination. Figure 1 illustrates these components, as received. The aircraft purportedly had undergone 1584.4 total flight hours since new. A similar incident, NTSB Investigation # IAD05LA046, occurred involving a Schweizer 269C in 2005.

1. Driving Spline and Section of Tail Rotor Drive Shaft

Figure 2 illustrates the driving sleeve (P/N 269A5430-1, S/N 0646) of the aft transmission assembly. Fretting wear scars and material removal were observed on the outer teeth of the driving spline (Figure 3), along with chatter and circumferential gouging on the outer forward surface (Figure 4). The chatter marks in Figure 4 are located where a roller bearing is normally in contact with the driving spline. As shown in Figure 3, the damage was located on the forward faces. The smearing pattern is consistent with contact in rotation. While all the splines exhibited some loss of material, the amount varied from negligible to almost 50% of the cross-sectional area, with the largest difference in loss 180° apart. In contrast, the interior splines of the part were relatively undamaged, exhibiting no appreciable loss of material. Some rubbing was observed on the forward interior of the part mirroring the exterior shape of the pinion.

The angle of material removed on the drive spline outer splines mirrored that of the wear and material loss on the mating interior splines of the forward section of the tail rotor drive shaft (P/N 269A6040-7, S/N 3425). Figure 5 displays this damage on the interior splines. The damage is rotational in nature, but is not as severe as on the driving spline—the material loss is confined to an approximately 90° area. The forward faces of the splines also exhibited some smearing and material loss in a counterclockwise direction, forward looking aft (FLA).

2. Main Transmission Pinion and Aft Pinion Nut

The section of the main transmission pinion (P/N 269A5103-9, S/N 1174915) submitted to the Materials Laboratory is shown in Figure 6. Approximately 0.3 inches of the aftmost portion of the pinion fractured transversely while still fastened inside the aft pinion nut (P/N 269A5449-5) with the cotter pin still in place.

The exterior of the pinion possesses a series of splines that contact the interior splines of the drive spline. The aft 2 inches of the exterior faces of the splines exhibited a shiny luster indicative of the outer surface having been worn off. As shown in Figure 7, the drive faces on the exterior pinion splines showed fretting wear scars and material loss. Upwards of 0.015 inches of material had been removed on the aftmost 0.5 inches of the splines on the contact surfaces. Chatter marks were visible on the pinion exterior just forward of where the splines taper off.

The mating fracture surfaces of the pinion are shown in Figure 8. A small jog was present on the fracture, indicative of torsional failure. The fracture surface was flat, relatively smooth, and perpendicular to the long axis of the part. The surface exhibited fine crack arrest and ratchet marks indicative of progressive cracking. Closer examination using a scanning electron microscope (SEM) revealed an oxidized surface with a pattern consistent with underlying fatigue striations (see Figure 9). Cleaning solutions were able to remove some of the oxide layer, better exposing the striations.

The pinion fracture surface displayed a variety of ratchet marks, indicative of multiple fatigue crack initiation. However, examination of the fatigue striations revealed a primary crack initiation site, shown in Figure 11. This initiation site corresponds to the location shown in Figure 8a, counterclockwise aft looking forward (ALF) from the jog on the fracture surface. The fatigue crack initiated at a thread root, consistent with the area of highest stress concentration on the part. No material deficiencies such as inclusions, pits, or voids were found at the crack initiation site.

The features on the fracture surface suggest that after initiation, the fatigue crack progressed rotationally, while other cracks initiated ahead of the crack on the outer surface of the pinion in the thread root. Once the crack grew to sufficient size, the remaining cross-section succumbed to overstress. Approximately 0.25 inches of the fracture surface exhibited dimple rupture, indicative of overstress, located on jog (projecting outward in Figure 8a). No indications of other failure mechanisms, such as intergranular cracking, were observed.

The forward faces of the pinion threads were relatively undamaged and showed no indications of contact wear with the adjacent nut. However, the aft faces of the threads displayed rotational wear to approximately half of the depth of the thread root. The aft thread tips showed indication of fretting wear and minor material loss. No indication of mechanical damage or contact was found in the valleys of the pinion threads.

A portion of the pinion was sectioned, mounted, polished, and etched for metallographic examination. A typical area of the pinion microstructure is shown in Figure 12. The microstructure was consistent with that of tempered martensite, expected for the given material composition and heat treatment. The surface areas of the part revealed no indications of decarburization or similar material deficiencies.

The chemical composition of the pinion was inspected using energy dispersive X-ray spectroscopy (EDS). The composition was consistent with AMS 6260, alloy steel comparable to SAE 9310. The hardness[1] of the pinion was inspected per ASTM E384. The core hardness of the part averaged 40 HRC (404 HK_{500}). The part exhibited a case hardness of 61 HRC (726 HK_{200}) at a depth up to approximately 0.010 inches. These data are within the prescribed specification limits supplied by the manufacturer.

Erik Mueller
Materials Research Engineer

[1] The hardness was inspected using a microhardness tester with a Knoop indentor (HK) and converted to Rockwell C (HRC) per ASTM E140.

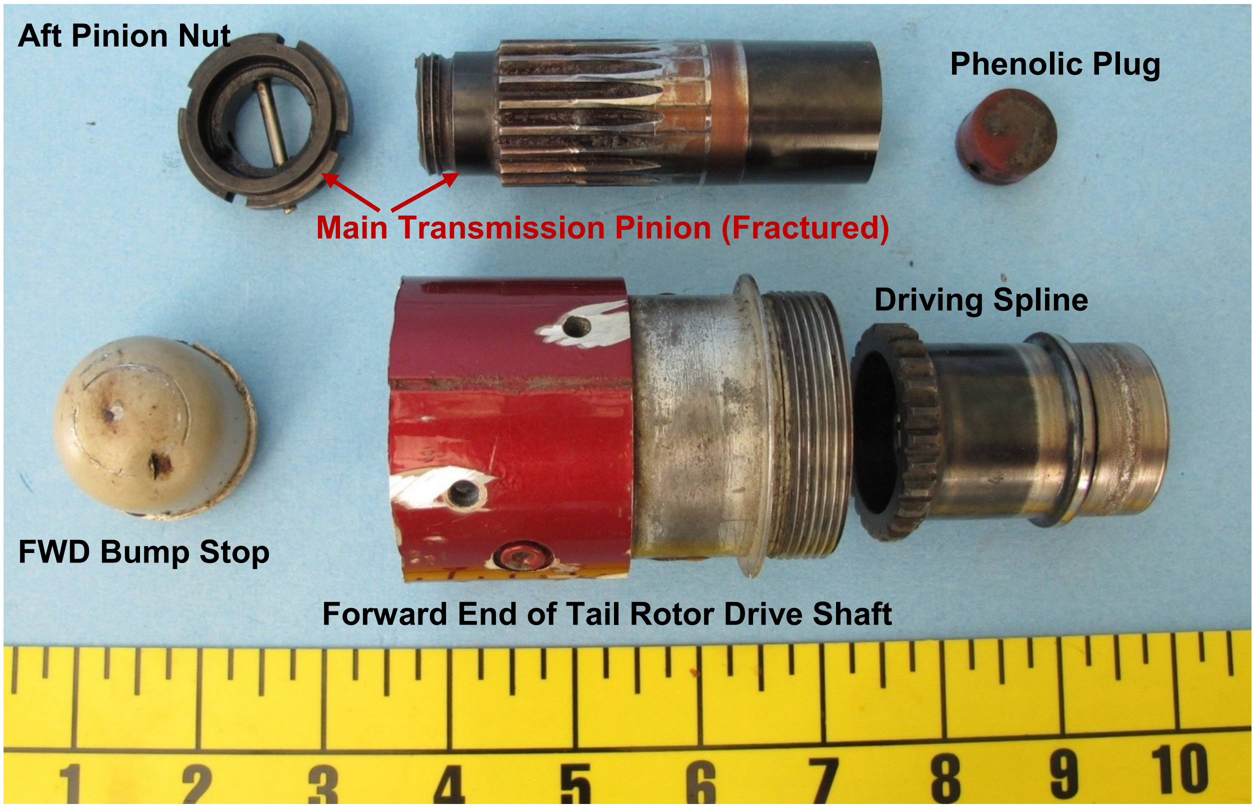

Figure 1 – The components of the transmission as received.

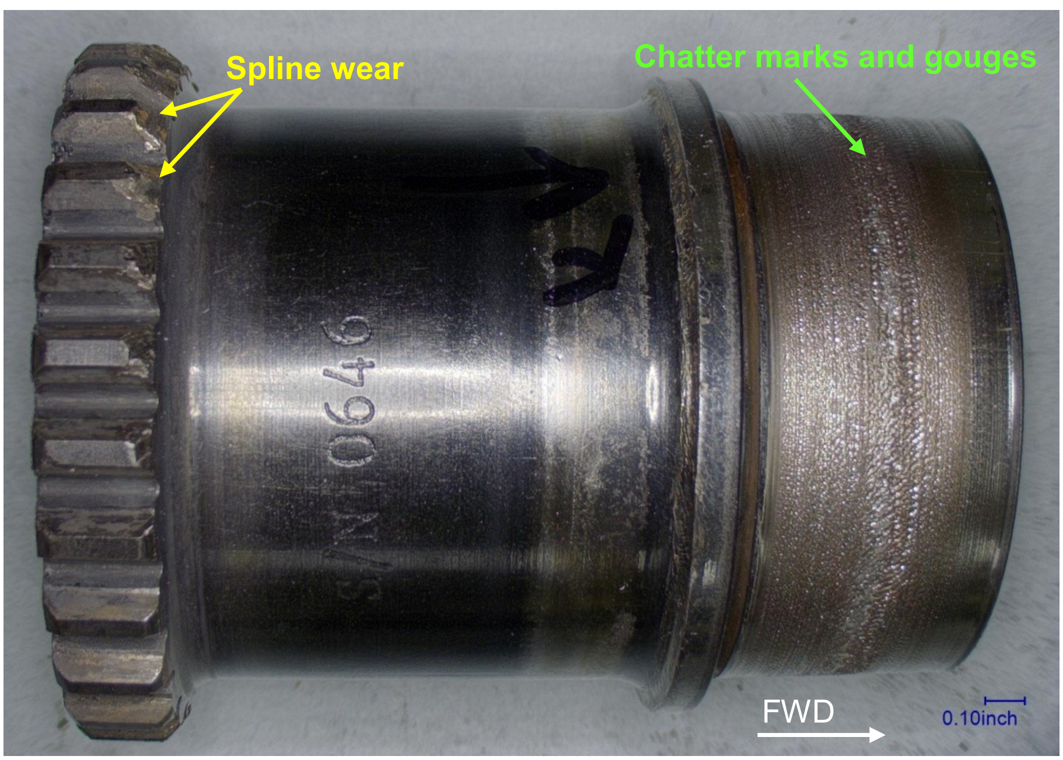

Figure 2 – The driving sleeve, after cleaning with acetone. Spline wear and shaft chatter are readily visible.

Figure 3 – The most damaged splines from the driving spline showing material removal, viewed forward looking aft (FLA).

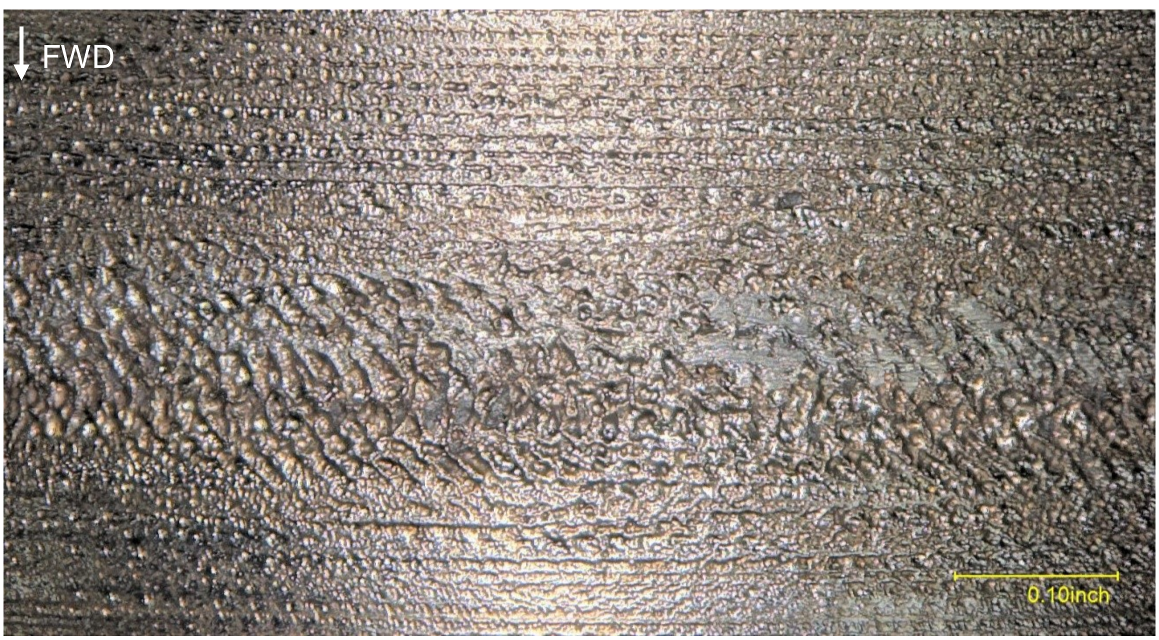

Figure 4 – Closer view of the chatter marks and gouges on the forward outer surface of the driving sleeve illustrated in Figure 2.

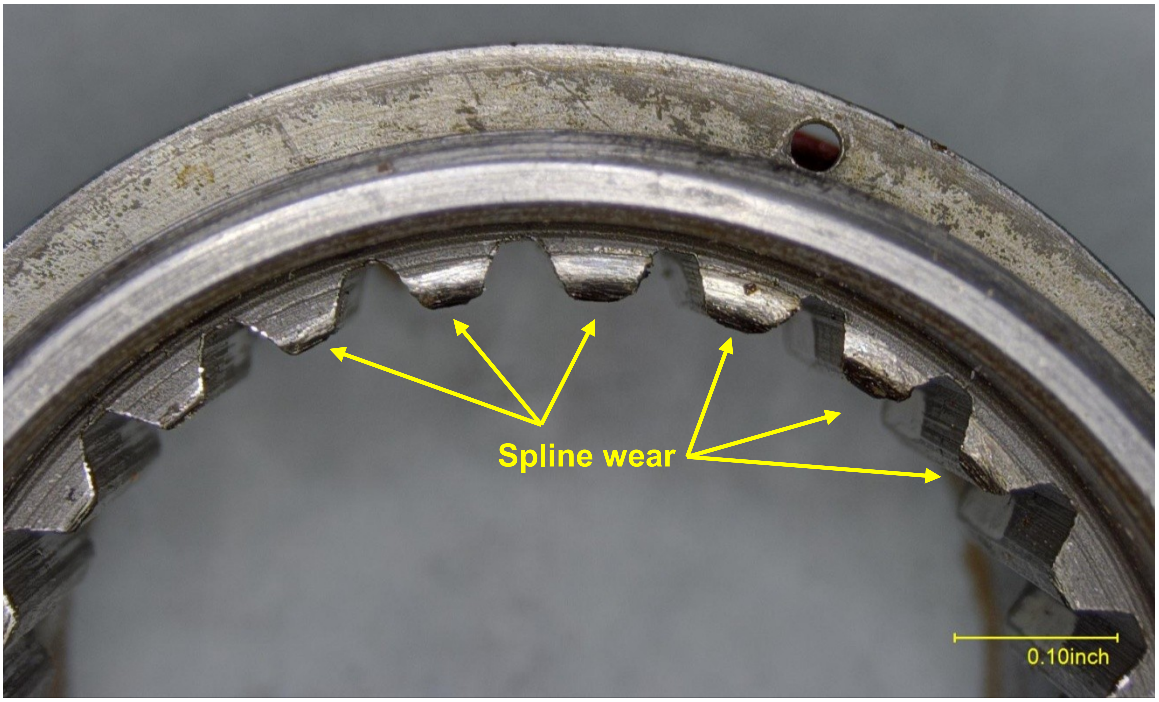

Figure 5 – The interior splines of the tail rotor drive shaft, aft looking forward (ALF). Several of the splines exhibited moderate to severe damage missing material.

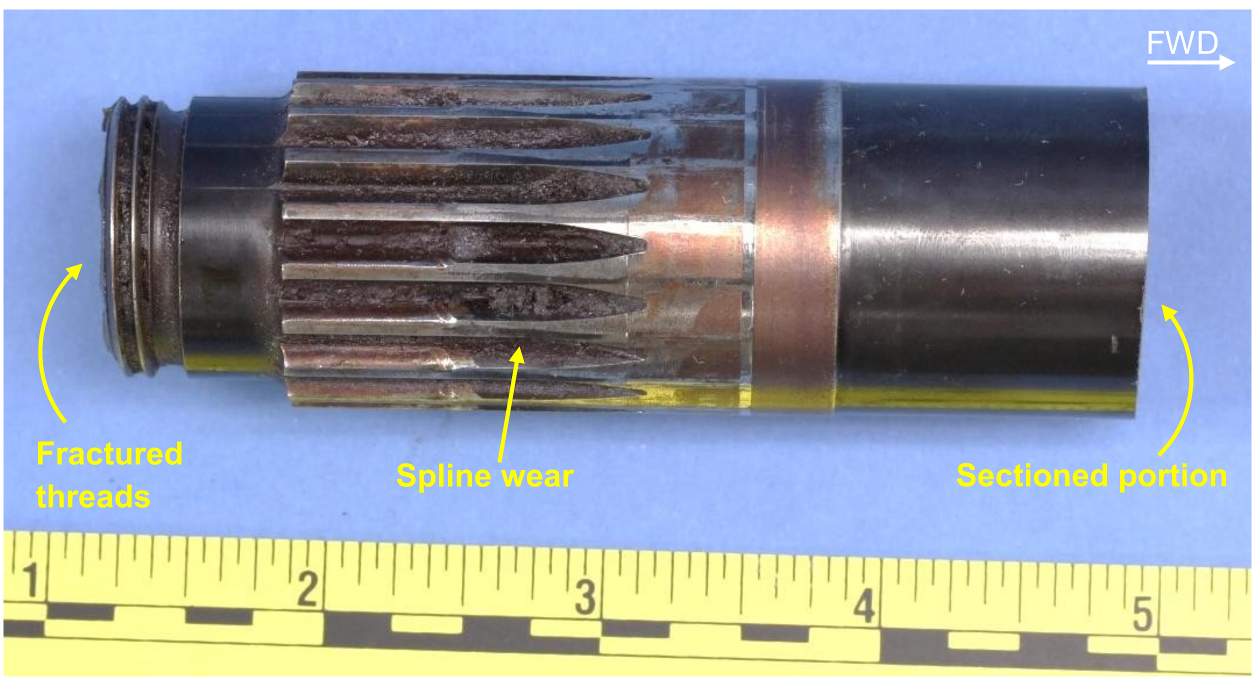

Figure 6 – The forward portion of the main transmission pinion section, as received.

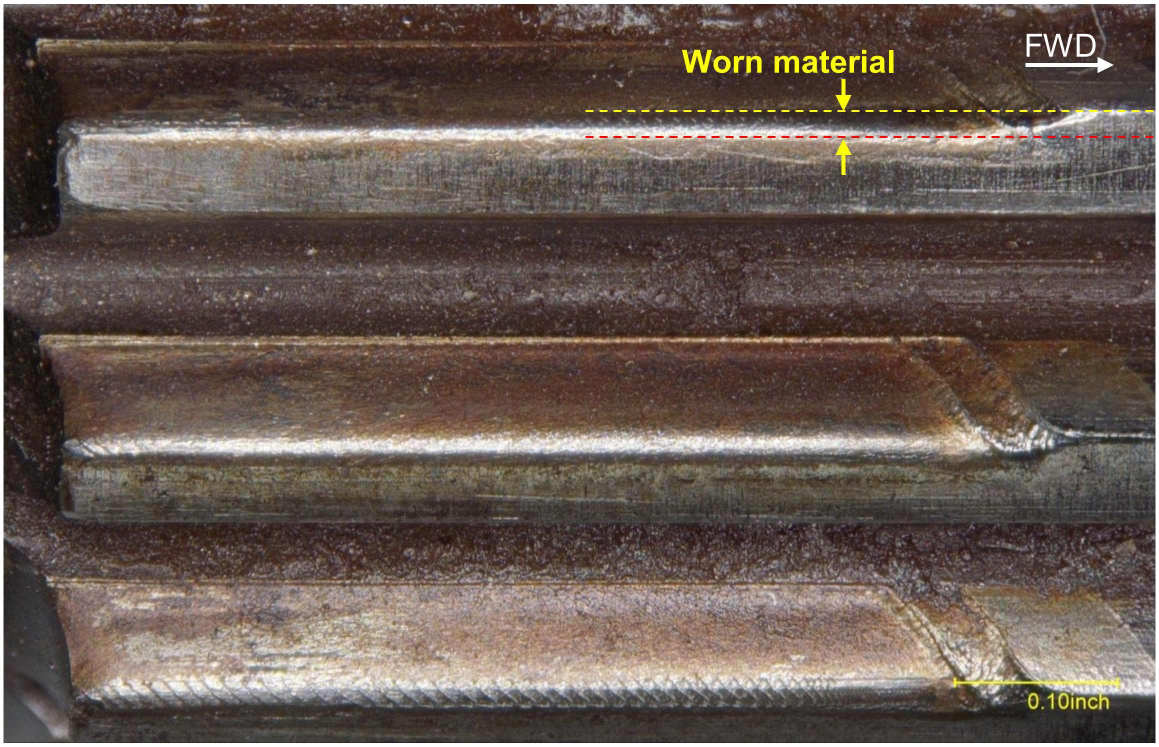

Figure 7 – Contact faces on the splines of the pinion, showing fretting wear scars and loss of material over approximately 0.5 inches.

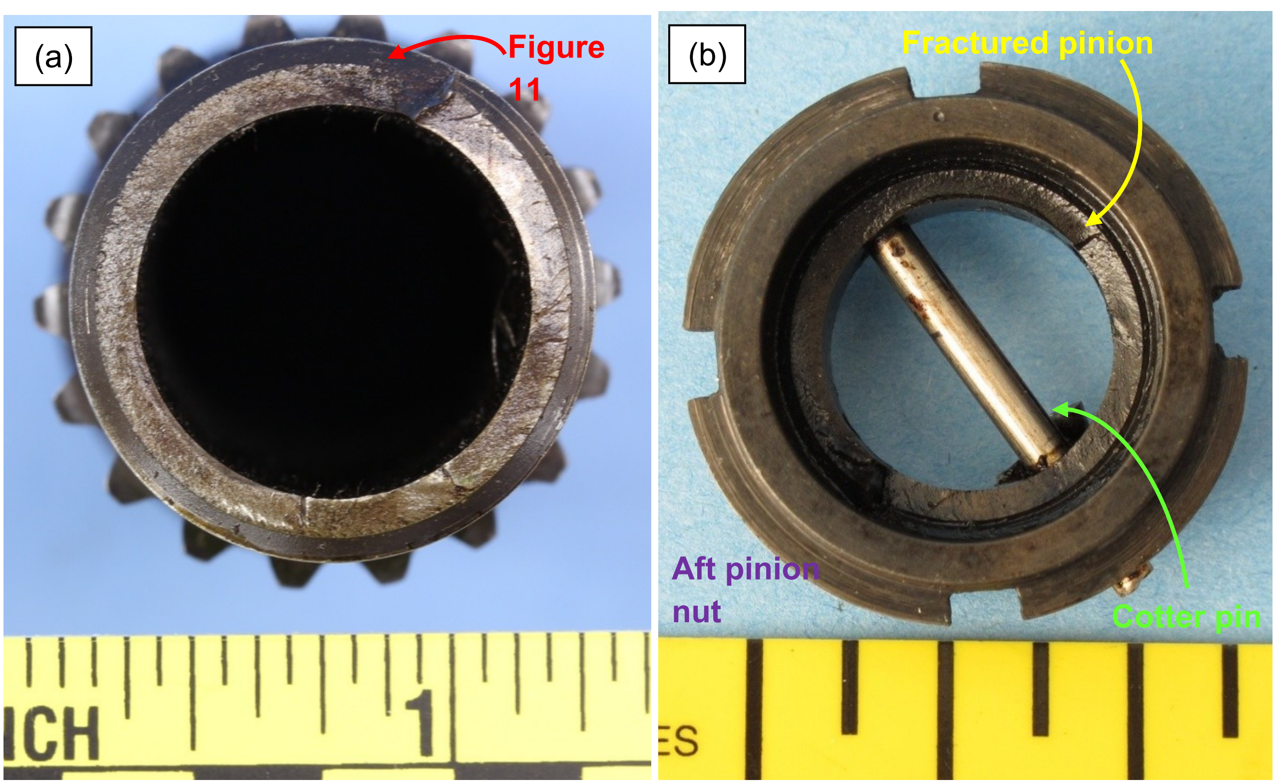

Figure 8 – The (a) forward and (b) aft faces of the pinion fracture, as received. The aft side fracture was still threaded in the aft nut with the cotter pin in place. The area labeled in (a) is highlighted in Figure 11.

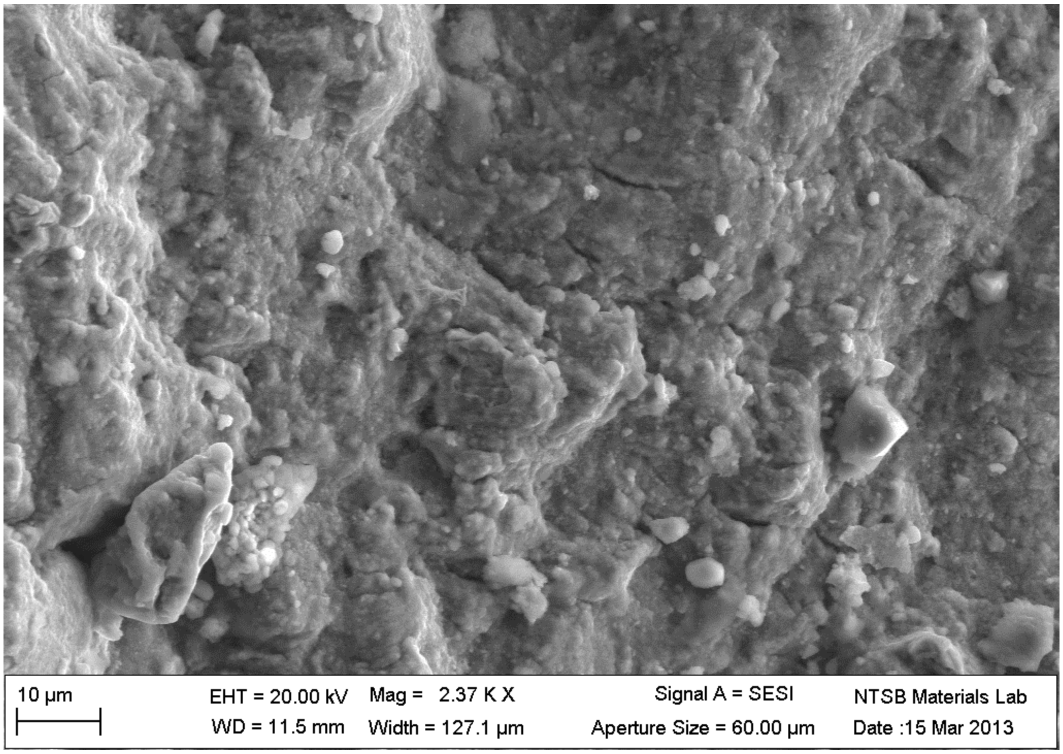

Figure 9 – Secondary electron (SE) micrograph of the pinion fracture surface, showing oxidized fatigue striations.

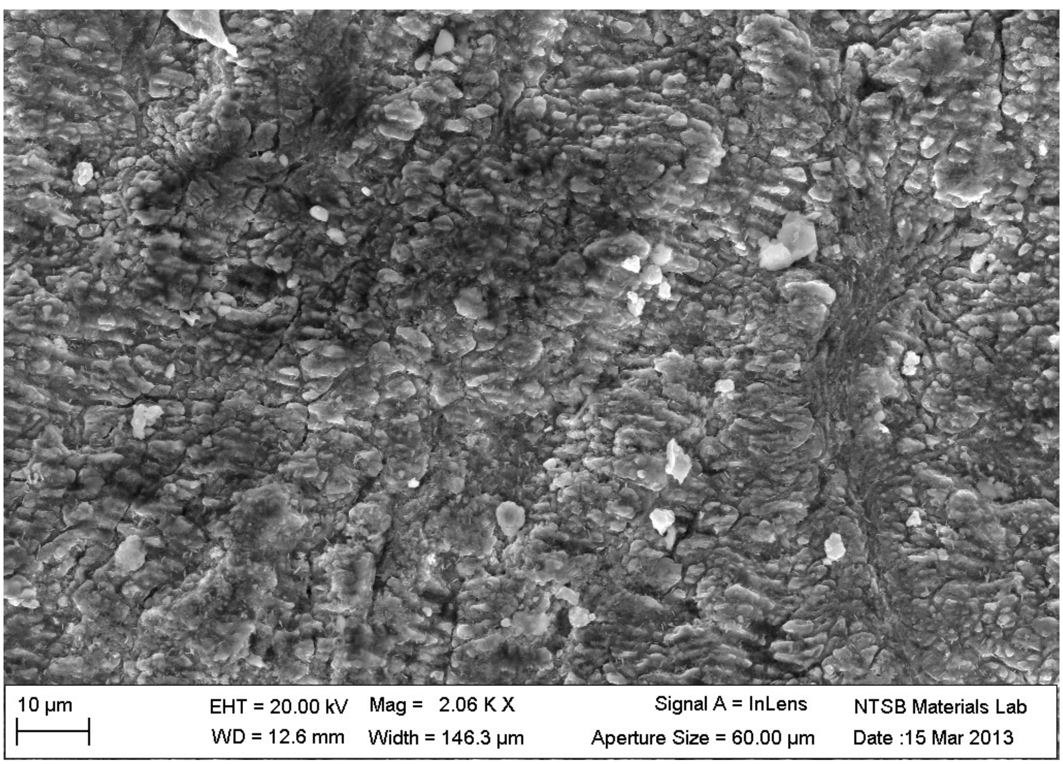

Figure 10 – SE micrograph of the pinion fracture surface, after cleaning, shows oxidized fatigue striations.

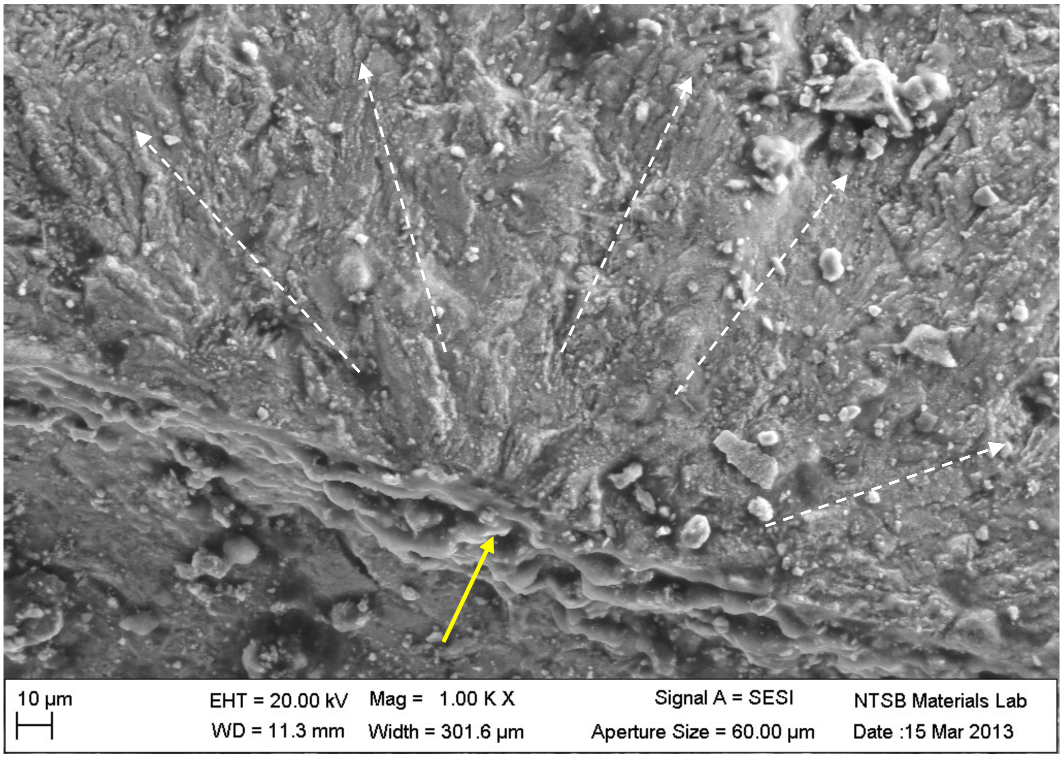

Figure 11 – SE micrograph of the pinion fracture surface, showing the primary fatigue crack initiation site (yellow arrow).

Figure 12 – Metallographic cross-section of the pinion core (~500X, etched with 2% Nital).