



NATIONAL TRANSPORTATION SAFETY BOARD
Office of Aviation Safety
Washington, D.C. 20594

February 20, 2014

POWERPLANT GROUP CHAIRMAN'S FACTUAL REPORT

NTSB No: ENG13IA033

A. INCIDENT INFORMATION

Location: Bering Sea

Date: July 2, 2013

Time: 1026 local time

Aircraft: Korean Airlines Boeing B777-300ER, registration HL8275

B. POWERPLANTS GROUP MEMBERS

Safety Board Member:

Jean-Pierre Scarfo
Powerplant Lead Engineer
Washington D.C.

General Electric Member:

David C. Robbins
Commercial & BGA Flight Safety
Lead Engineer / Investigator
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C. SUMMARY

On July 2, 2013, a Korean Air Lines (KAL) Boeing 777-300ER, registration number HL8275, powered by two General Electric (GE) GE90-115B turbofan engines, experienced a No.1 engine (left) in-flight shutdown (IFSD) while crossing the Bering Sea (60°4'16.32"N/178°40'33.60"W) en route to Seoul, South Korea. The pilots diverted the airplane to Ugolny Airport (DYR), a mixed-used military and civil airport in Siberia, Russia. An uneventful single engine landing was made and no injuries were reported. The incident flight was a 14 *Code of Federal Regulation* Part 129 regularly schedule international flight from O'Hare International Airport (ORD), Chicago, Illinois, to Incheon International Airport (ICN), Seoul, South Korea. The Korean Aviation and Railway Accident Investigation Board (ARAIB) initially opened an investigation into this incident and provided the National Transportation Safety Board (NTSB) as the state of manufacturer of the engines and airplane an initial notification in accordance with International Civil Aviation Organization (ICAO) Annex 13 ([ATTACHMENT 1](#)). The Korean ARAIB subsequently requested delegation of the investigation and the NTSB accepted responsibility for investigating this incident ([ATTACHMENT 2](#)).

Post landing examination of the No. 1 engine revealed that the transfer gearbox (TGB) housing was fractured and the internal gears were damaged. The No. 1 engine was removed from the airplane and shipped to the GE-Wales facility in Cardiff Wales for removal of the TGB. Removal of the TGB revealed a separated radial bevel gearshaft (subsequently referred to as radial gearshaft) within the TGB. TGB hardware, included the separated radial bevel gearshaft were sent to GE-Aviation facility in Evendale, Ohio for metallurgical examination.

Visual examination of the radial gearshaft found three X-shaped cracks in the short shaft side outer diameter at the shaft-to-web transition radius, with one of the X-shaped cracks (associated with fractured and missing material) linked to a 0.049-inch axial crack. The axial crack was considered the primary crack and the origin area. Scanning Electron Microscope (SEM) examination of the axial fracture region revealed striation features indicative of fatigue propagation but did not exhibit morphology typical of axial-axial induced fatigue fracture surfaces, such as interpretable flow lines pointing back to a single origin location, but instead was more consistent with initial fatigue initiation occurring under a torsional and/or biaxial stress condition. Published literature for fatigue cracking under torsional and/or biaxial loading conditions was consistent with the X-shaped cracking observed on the fractured radial gearshaft. GE subjected several steel test bars made from the required material to various biaxial fatigue loading conditions in an attempt to reproduce fracture features observed within the axial fracture. The results of the testing indicated biaxial loading conditions could reproduce features observed in axial fracture.

Microhardness tests of the short shaft revealed a reduction in near surface hardness (lower hardness values than required) while the core hardness met the part drawing requirement. Other than the near surface hardness loss, the material was determined to be consistent with properly processed material in accordance with the part drawing requirement. No evidence of any obvious material inclusions or other discrepancies was observed within the initial axial fracture (origin region) or on the outer diameter surface adjacent to the initial axial fracture.

During the manufacturing of the radial gearshaft, the gear teeth and splines are case hardened using a process called 'carburization' which adds a layer of carbon to the outer surface of low carbon steels via a diffusion process by heating the steel in a carbon-rich environment. A carburized surface increases the surface hardness improving wear resistance and fatigue strength. Surfaces of the radial gearshaft not requiring carburization are copper plated prior to the carburization cycle. The area of

cracking in the shaft region is not case hardened and, thus, would have been copper plated. After the carburization process, the copper plating is stripped. The entire part is then re-copper plated prior to the hardening cycle (austenization heat treat) to prevent decarburization, a depletion of surface carbon, from occurring on all surfaces. GE concluded that the near surface low hardness values measured on the radial gearshaft were attributable to decarburization due to marginal (thin or detached) copper plating existing on the gearshaft surface and an hardening atmosphere which was prone to causing decarburization. Through computer modeling and various testing of the radial gearshaft, GE concluded that the axial crack was the initial crack and was likely the result of a combination of high residual tensile stresses produced by local decarburization coupled with the operating stresses experienced at by the outer diameter surface.

Having determined that the cause of the radial gearshaft cracking was due to a manufacturing process deficiency, GE issued four service bulletins (SBs) to remove suspected radial gearshafts from service, one SB to provide a specific crack detection inspection, and two SBs to repair and toughen the radial gearshafts. To expedite the removal of the suspect radial gearshafts, the Federal Aviation Administration issued three Airworthiness Directives (AD), two of which were emergency ADs requiring compliance within 5 days of receipt. According to GE, all effected radial gearshafts (186 in total) addressed by the various FAA ADs have been removed from service.

1.0 ENGINE INFORMATION

1.1 ENGINE HISTORY

The incident engine was a GE90-115B, engine serial number (ESN) 907-235; it had accumulated 239 hours time since new (TSN) and 38 cycles since new (CSN) at the time of the IFSD. Due to the short low accrued hours and cycles, no repairs or significant maintenance had occurred to the engine between its initial installation on the airplane and the IFSD.

1.2 ENGINE DESCRIPTION

The event airplane was powered by two GE90-115B turbofan engines. The GE90-115B turbofan is a high-bypass, variable-stator, dual rotor, axial flow turbofan engine with a 9-stage high pressure compressor (HPC) driven by a 2-stage high pressure turbine (HPT), an annular combustor, and an integrated fan booster assembly (also called the low pressure compressor (LPC)) comprised of a single-stage fan and a four-stage booster driven by a 6-stage low pressure turbine (LPT).

According to the engine's Federal Aviation Administration (FAA) Type Certificate Data Sheet E00049EN, Revision 17, dated January 24, 2011, the GE90-115B has a maximum takeoff thrust rating of 115,540 pounds, flat-rated¹ to 86°F (30°C) and a maximum continuous thrust rating of 110,000 pounds flat-rated to 77°F (25°C).

All directional references to front and rear, right and left, top and bottom, and clockwise and counterclockwise are made aft looking forward (ALF). The direction of rotation of the engine rotors is clockwise. All numbering starts with the No. 1 position at the 12:00 o'clock location and progresses sequentially clockwise ALF.

1.3 TRANSFER GEARBOX DESCRIPTION

The transfer gearbox (TGB) is part of the fan hub assembly which is the first static structure of the engine. The TGB is attached to the bottom of the fan hub assembly and directs/transfers torque from the inlet gearbox (IGB) to the accessory gearbox (AGB) (**FIGURE 1**). The TGB also acts as a separate sump and has its own oil scavenge outlet to the lube pump/oil system.

Within the TGB is a radial gearshaft (sometimes referred to as the radial pinion gearshaft but will be referred to simply as the radial gearshaft in this report), supported by a roller and a ball bearing, that transmits torque from the IGB to a horizontal gearshaft, which is also supported by a roller and ball bearing, and transmits the torque to a horizontal drive shaft that drives the AGB. The radial gearshaft is a one-piece design made from American Iron and Steel Institute (AISI) 9310 steel² comprised of primarily tempered martensite. Specific features of the radial gearshaft are shown in **PHOTO 2**.

¹ Flat-rated to a specific temperature indicates that the engine will be capable of attaining the rated thrust level up to the specified inlet temperature.

² AISI 9310 steel is a wrought alloy steel comprised of 0.1% Carbon, 1.2% Chromium, 3.25% Nickel, 0.12% Molybdenum, and 0.55% Magnesium with the remainder Iron.

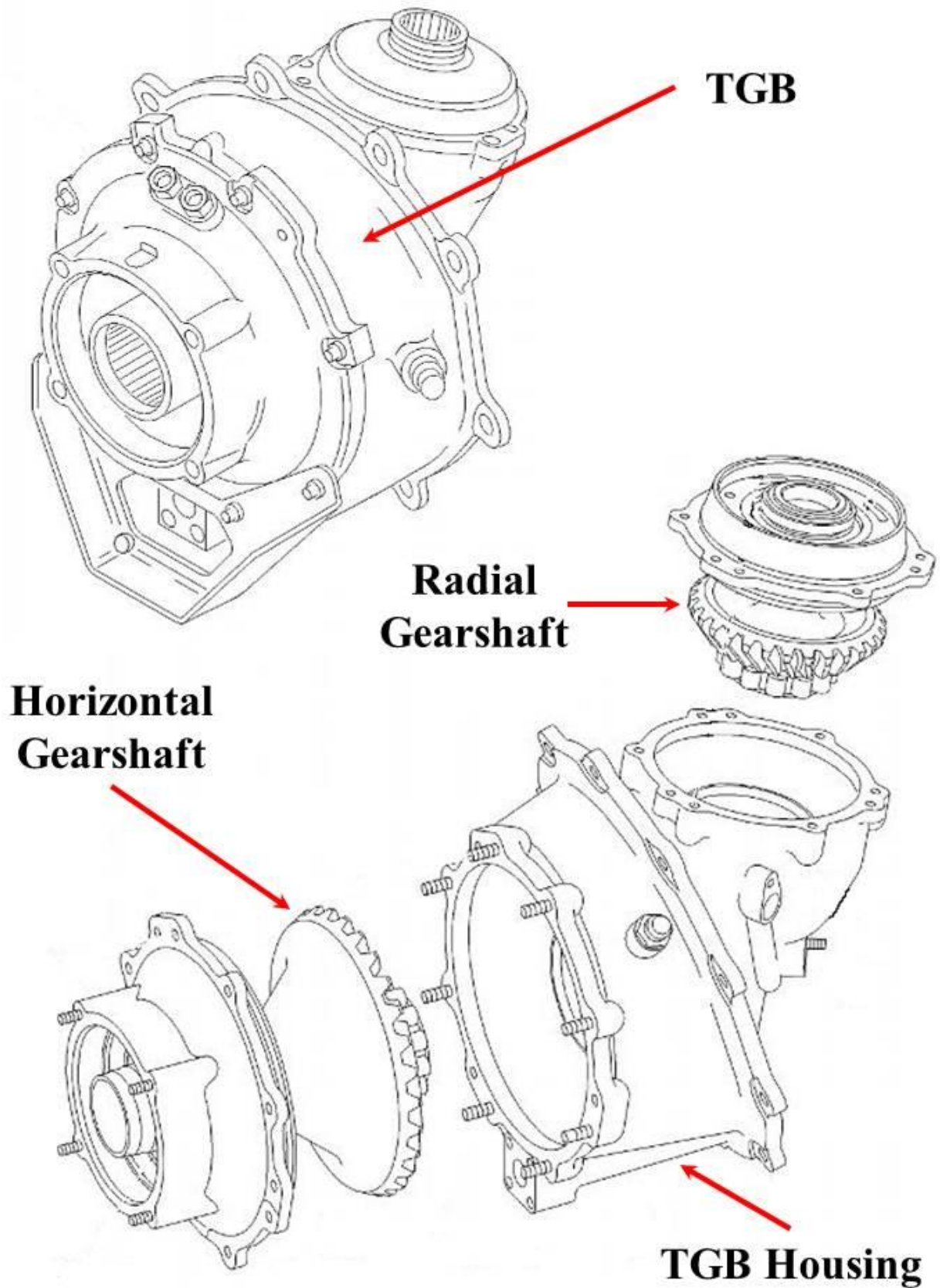


FIGURE 1: TRANSFER GEARBOX EXPLODED VIEW OF INTERNAL PARTS

2.0 RADIAL GEARSHAFT EXAMINATION RESULTS

The Safety Board staff did not travel to GE-Wales or GE-Aviation to oversee the examination of the TGB hardware. GE conducted all the work and provided periodic updates on the progress of the examination. GE produced a Metallurgical Investigation Report, FA 16356, dated February 3, 2014 that documents the findings from the disassembly and laboratory examination of the TGB and associated hardware ([ATTACHMENT 3](#)).

2.1 INITIAL EXAMINATION AT GE-WALES

With the TGB removed and disassembled, examination of the horizontal bevel gearshaft (subsequently referred to simply as the horizontal gearshaft in this report) revealed that it was intact, the gear teeth displayed damage, and both sets of bearings appeared intact and in good condition ([PHOTO 1](#)). Examination of the radial gearshaft revealed that: 1) a 12-tooth section of the spiral bevel gear teeth and web had separated, 2) all 27 gear teeth were accounted for, 3) gear teeth were damaged, 4) the shafts (long and short) exhibited cracks and missing material, 5) the roller bearing elements were loose, the cage damaged, and the outer race was fragmented into several pieces, and 6) the ball bearing appeared intact and in good condition ([PHOTO 2](#)). The radial gearshaft was part marked as follows: part number (PN) 1995M24P02, serial number (SN) FIA0K63L, MD 5.3346, BL.0047 ([PHOTO 3](#)).

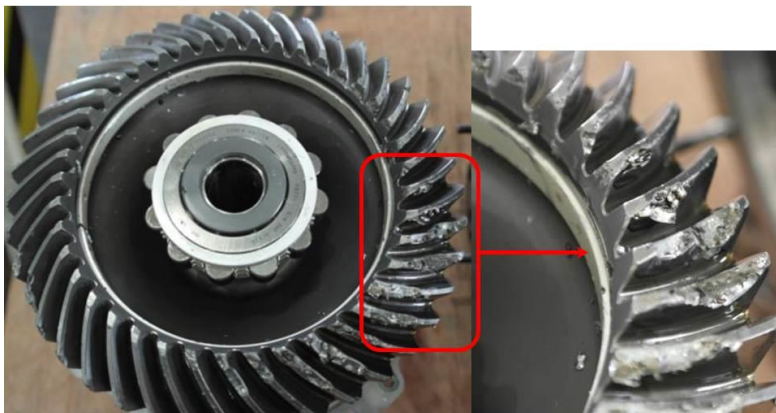


PHOTO 1: DAMAGED HORIZONTAL GEARSHAFT TEETH

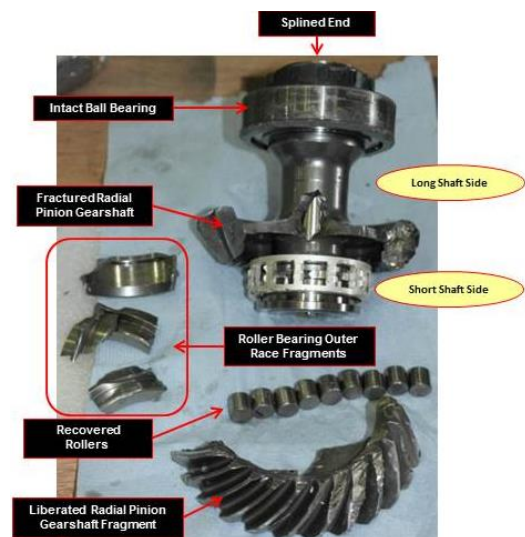


PHOTO 2: FRACTURED RADIAL GEARSHAFT

(Pictures Courtesy of GE-Aviation)



PHOTO 3: RADIAL GEARSHAFT MARKINGS (INNER DIAMETER – OUTER DIAMETER IS BEARING RACE)

(Pictures Courtesy of GE-Aviation)

2.2 Metallurgical Examination of the Radial Gearshaft at GE-Aviation

Initial visual examination revealed that the gear teeth contact surfaces revealed no evidence of fatigue spalling damage or unusual contact wear patterns. An X-shaped crack was observed in the short shaft side outer diameter at the shaft-to-web transition radius where part of the bevel gear and long shaft material was missing (**PHOTO 4**). In this area, an axial crack that measured about 0.049-inches (49 mils) in length was also noted. Fluorescent penetrant inspection (FPI) of the rest of the radial gearshaft revealed two additional X-shaped cracks in the short shaft side of the shaft-to-web transition radius region. According to GE, the X-shaped nature of cracking supported at least some torsional or biaxial stress influence during initial cracking. Published literature for fatigue cracking under torsional and/or biaxial loading conditions was consistent with the X-shaped cracking observed on the fractured radial gearshaft. GE subjected several AISI 9310 steel test bars to various biaxial fatigue loading conditions in an attempt to reproduce fracture features observed within the axial fracture. The results of the testing indicated biaxial loading conditions could reproduce features observed in the axial fracture.

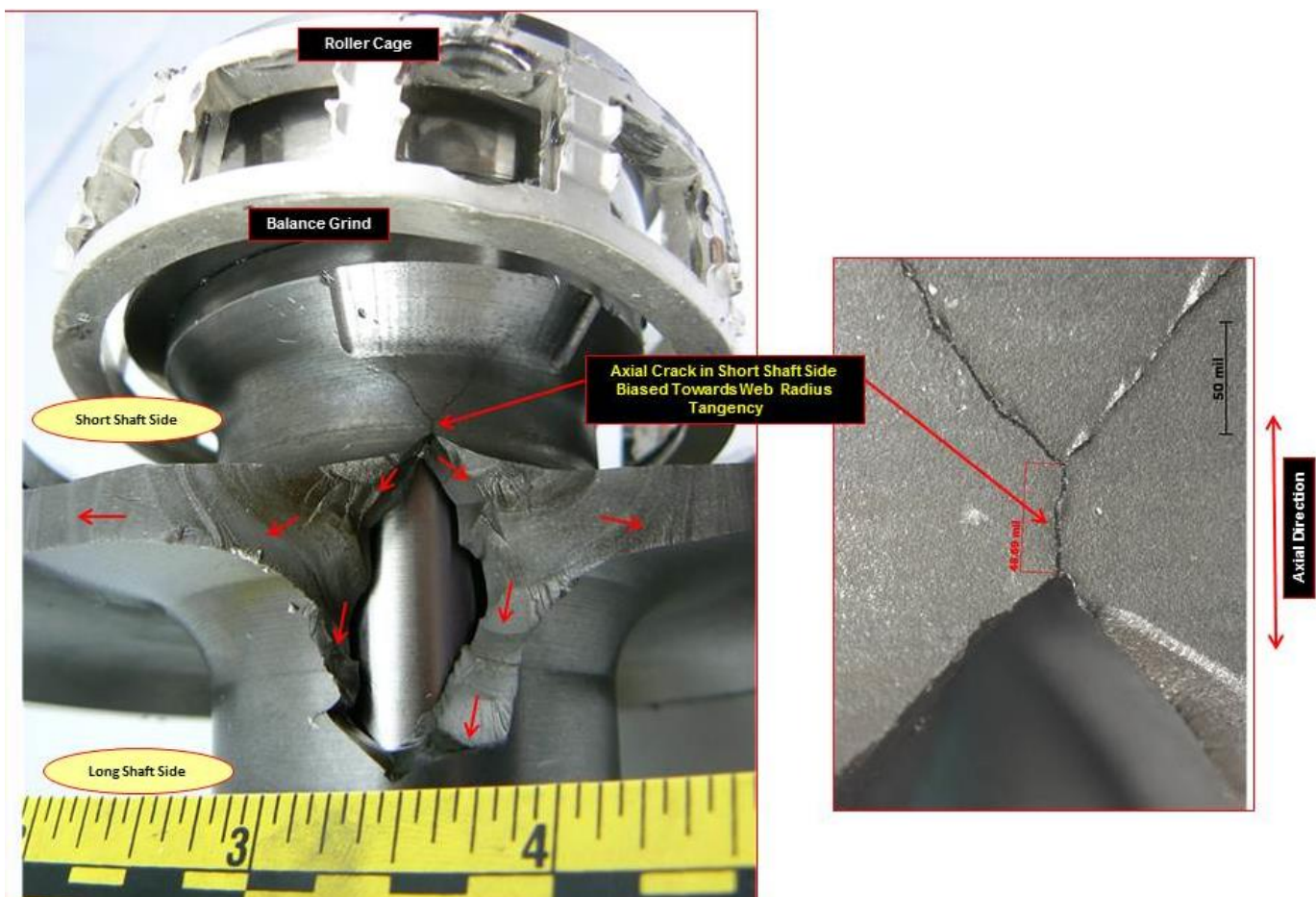


PHOTO 4: X-SHAPED AND AXIAL CRACK RADIAL GEARSHAFT SHORT SHAFT SIDE

(Pictures Courtesy of GE-Aviation)

Scanning Electron Microscope (SEM) inspection of the axial fracture region revealed: 1) striation features indicative of fatigue propagation, 2) no evidence of any unusual surface anomalies such as impact or heavy scoring was associated with the axial fracture, 3) no appreciable oxidation was observed on the axial fracture region indicating fracture was not exposed to elevated temperatures such as from forging or heat treatment, 4) did not exhibit morphology typical of axial-axial induced fatigue fracture surfaces, such as interpretable flow lines pointing back to a single origin location, but instead

was more consistent with initial fatigue initiation occurring under a torsional and/or biaxial stress condition, 5) fracture morphology exhibited features consistent with tensile shear dimples indicating exposure to high shear stresses, and 6) no additional secondary cracks were observed adjacent to the primary axial fracture (**PHOTO 5**). According to GE, the axial crack was considered the primary crack initiation site for the fractured radial gearshaft with the crack continuing to propagate leading to the X-shaped crack. The axial and X-shaped cracks were consistent with torsional and/or biaxial fatigue mechanism. The fracture morphology outside of the axial fracture region exhibiting a “feathery” appearance and according to GE is more consistent with axial-axial fatigue, typical of lower alternating stress fatigue (high cycle fatigue) mechanisms attributed to the gear meshing stresses experienced by the gearshaft during engine operation.

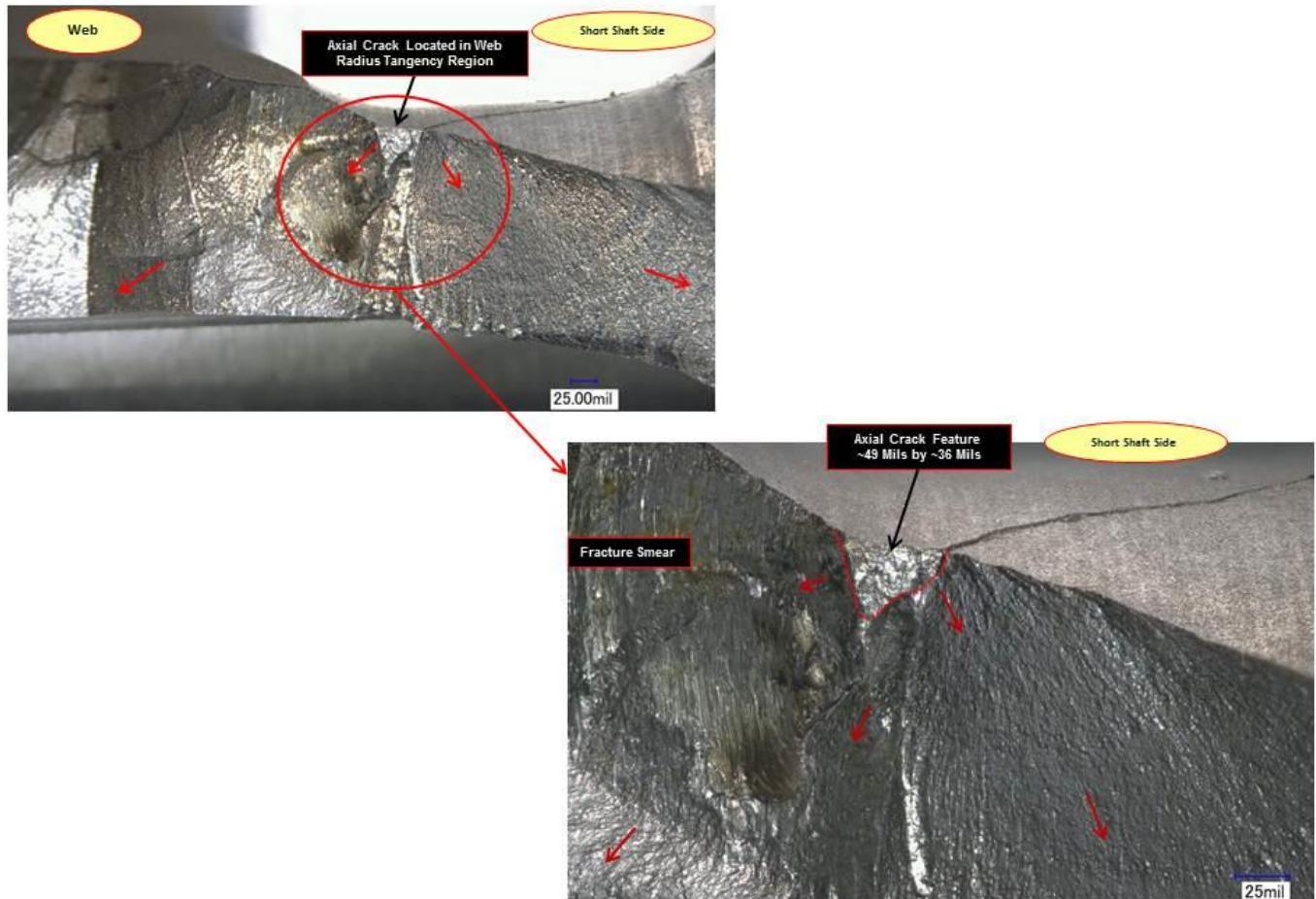


PHOTO 5: FATIGUE PROPAGATION FROM AXIAL CRACK

(Pictures Courtesy of GE-Aviation)

Etching³ of a cross-section through the short shaft side revealed a near surface etch affect (lighter shading) on the outer diameter surface both at and away from the axial fracture location (**PHOTO 6**). Microhardness tests were performed on the radial gearshaft and a corresponding reduction in near surface hardness was measured within the lighter etching region with near surface hardness loss beginning at about 4 mils (**FIGURE 2**)⁴. The core hardness averaged HRC 40.4 (Rockwell Hardness on the C Scale) which met the part drawing requirement of HRC 32-44.

³ Metallographic etching is the process of revealing microstructural details that would otherwise not be evident on the as-polished sample.

⁴ 1 mil = 0.001 inches = 25.4 micrometers(μm)

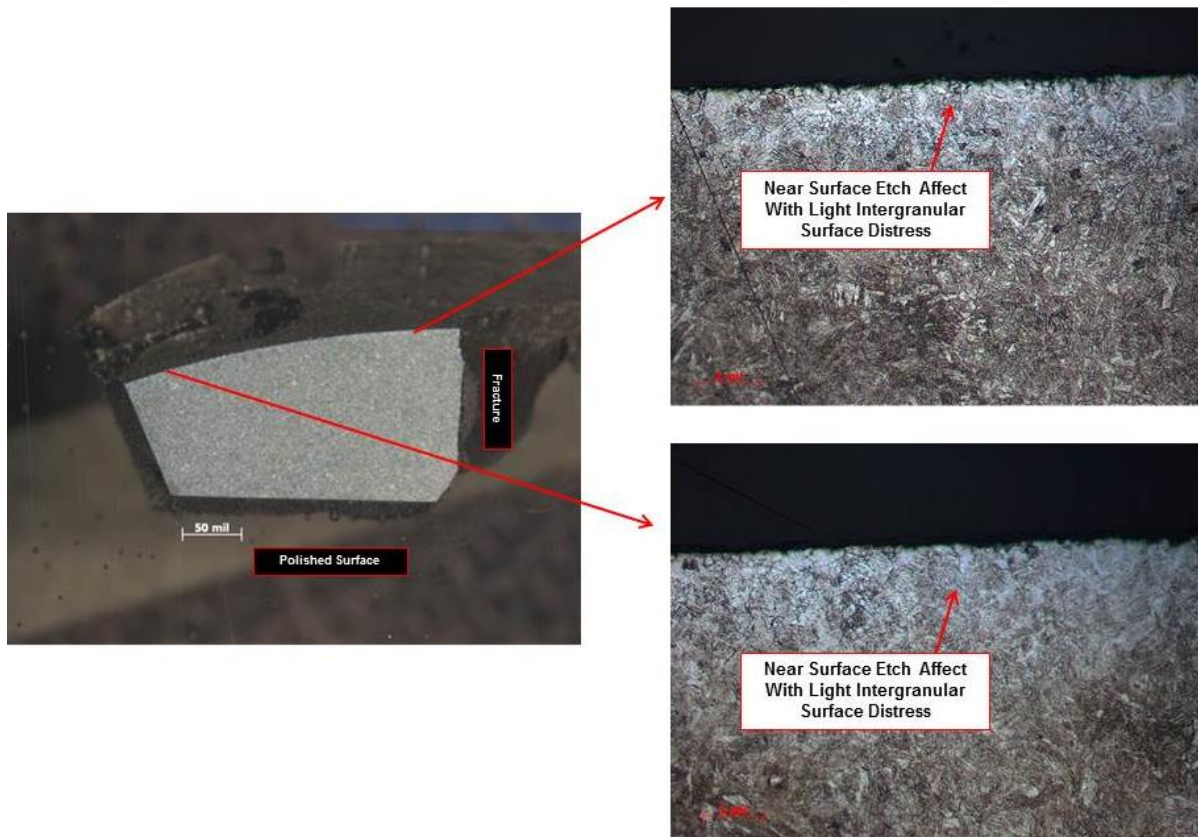


PHOTO 6: ETCHING OF SHORT SHAFT SHOWING NEAR SURFACE LIGHT INTERGRANULAR DISTRESS
 (Pictures Courtesy of GE-Aviation)

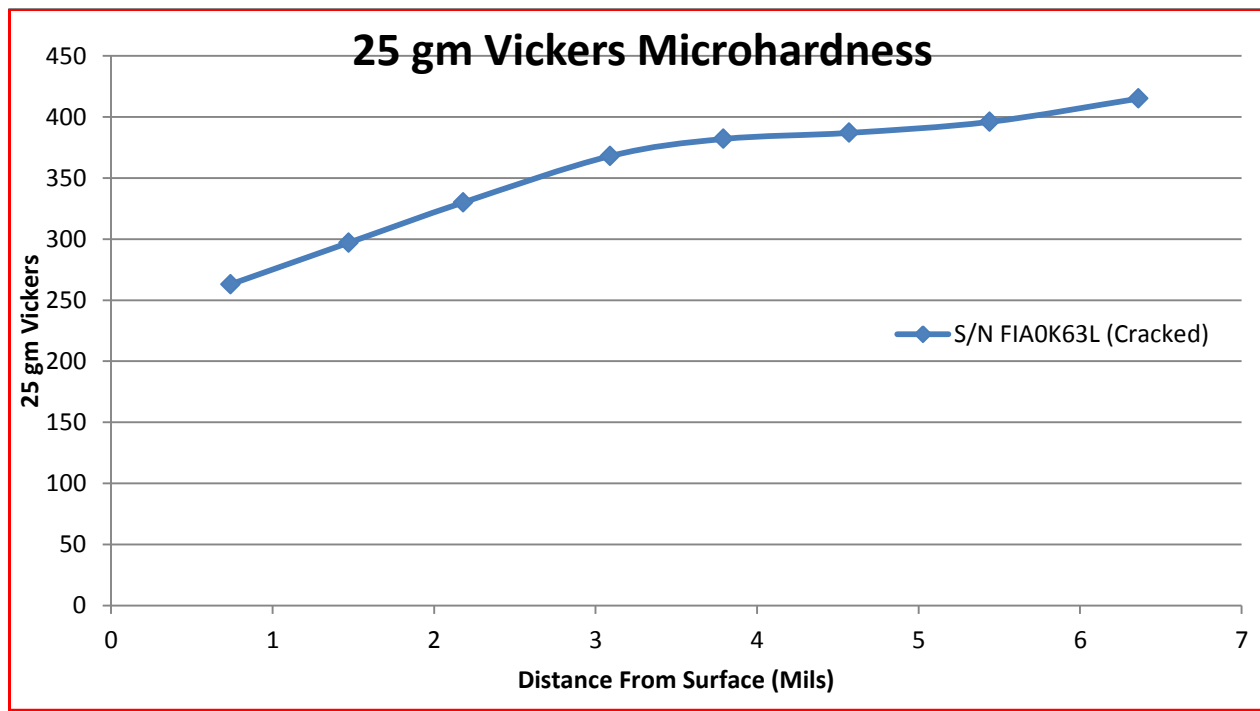


FIGURE 2: NEAR SURFACE MICROHARDNESS MEASUREMENTS NEAR AXIAL CRACK LOCATION
 (Graph Courtesy of GE-Aviation)

An Energy-dispersive X-ray Spectroscopy (EDS) spectrum of the radial gearshaft revealed the material to be a low alloy steel. General core microstructure was consistent with properly processed AISI 9310 steel. No evidence of any obvious material inclusions or other discrepancies was observed within the initial axial fracture (origin region) or on the outer diameter surface adjacent to the initial axial fracture. Thus far there have been seven cracked GE90-115 radial gearshafts (5 occurred prior to this event and one occurred after this event) and according to GE, the observed cracking morphology, surface condition, and crack location of the KAL radial gearshaft was similar to what was observed on the other cracked radial gearshafts.

GE performed a Barkhausen Noise (BN) inspection on the fractured radial gearshaft. This technology measures the part's response to a varying magnetic field to detect variations in microstructure, hardness, or residual stresses. This BN will be discussed further in Section 3 *GE Failure and Root Cause Analysis*; however, the results of the BN inspection of the fractured event radial gearshaft showed elevated BN noise levels and associated residual tensile stress.

3.0 GE FAILURE AND ROOT CAUSE ANALYSIS

As previously mentioned, there have been a total of seven cracked radial pinion gearshafts from various operators, all with low operating times (between 24 and 192 hours TSN). All the cracked radial gearshafts had hardening/quench dates ranging from September 2012 to April 2013 and these hardening/quench lots were identified as "Lot 1" to "Lot 26", respectively. The event gearshaft (SN FIA0K63L) was from "Lot 26", and had accumulated 38 CSN at the time of separation. According to GE none of the radial gearshafts prior to "Lot 1" have cracked.

GE conducted engine testing and found no significant vibratory response levels in the short shaft side of the radial gearshaft that would have contributed to the observed cracking. All attempts to crack the gearshaft in the short shaft region including severe distortion and severe oil flow restriction during the press quench operation were unsuccessful. GE also reviewed the manufacturing process for the radial gearshaft, with special emphasis on the hardening/quenching process, and to date has found no significant documented changes to the manufacturing process that would account for the reduction in near surface hardness observed on the fractured radial gearshaft.

The radial gearshaft is case hardened using a process called carburization. Carburizing is a process by which carbon is diffused into the surface of low carbon steels (case) at elevated temperatures to increase the surface hardness, wear resistance, and fatigue strength. When the part is cooled rapidly by quenching, the higher carbon content on the surface becomes hard, while the core remains softer and tough. The surface (case) will have a higher carbon content, thus higher hardness, than the parent material (core material); therefore the effective and total case layer depth can be determined by measuring hardness as a function of depth from the surface. Case surface hardness and depth are dependent on carburization process time, temperature, and carbon concentration level. Decarburization is the process opposite to carburization, namely the reduction of the surface carbon content as the metal reacts during heating commonly with oxygen containing atmospheres starting at about 700°C, or in the case of the GE90 radial gearshafts, during the hardening (austenization) heat treatment cycle which occurs at 815°C. Decarburization can lead to a reduction in surface hardness with a significant increase in residual tensile stresses following quenching. To prevent decarburization, a minimum of about 0.8 mil (20µm) of copper plating is applied to the radial gearshaft prior to the hardening heat treatment cycle. GE suspected that local decarburization of the radial gearshaft outer diameter surface occurred as the result of thinner than expected or detachment of copper plating. The most likely cause for

premature cracking was based in part by the near surface etch effect and associated reduction in hardness found near the surface of all the cracked or fractured radial gearshafts. To confirm their suspicion, GE conducted a series of tests and observations of all the cracked and fractured radial gearshafts.

Metallography performed on all previously cracked/fractured radial gearshafts revealed some degree of near surface etch effect similar to what was observed on the event radial gearshaft. According to GE, no evidence of similar near surface etch effect was observed on any older non-cracked radial gearshafts. Microhardness readings taken on all previously cracked/fractured gearshafts revealed a loss of near surface hardness. Again, older non-cracked gearshafts exhibited no such loss of near surface hardness.

Computer modeling of the radial gearshaft predicted the highest residual tensile stress to be located in the shaft transition radius region which is where the actual cracked radial gearshaft origin regions were located. Furthermore, the model predicted significant near surface residual tensile stresses due to local decarburization. To confirm this GE subjected cracked and non-cracked radial gearshaft to BN inspections and found that areas of decarburization had higher levels of BN response while properly copper plated surfaces exhibited a lower BN response. Through these trials GE was able to correlate BN response with residual stress levels (high BN response indicates high tensile residual stress) and is now using this inspection technique on new and overhauled gearshafts.

Tensile residual stress on older gearshafts was measured and showed high levels near the surface of the gears between roller bearing journal and web. GE believes these elevated residual stresses can drive the mean stresses outside of the material fatigue capability, and along with the biaxial loads/alternating stresses experienced during typical engine operation, can initiate and propagate a fatigue crack. This situation is made worse when decarburization exists since it can lead to a significant increase in tensile residual stresses. Therefore, GE finally concluded that crack initiation was likely the result of a combination of high residual tensile stresses attributed to surface decarburization coupled with gearshaft operating stresses.

To address the high residual stresses found in the radial gearshaft short shaft, GE shot peened (transforms tensile residual stresses to compressive near surface) test gearshafts and found that decarburization areas that had been shot peened had significantly reduced BN response whereas areas not shot peened still had relatively high BN responses. The above mentioned results indicated that shot peening removed the residual near surface tensile stresses, leaving a residual compressive stress and improved the fatigue capability over similarly processed non-shot peened specimens. Previously the radial gearshaft was not shot peened, but now all radial gearshafts will be subjected to this process. The shot peened radial gearshafts are introduced by service bulletins (SB) 72-0563 and 72-0570 which are terminating action for FAA Airworthiness Directive 2013-15-20. See Section 4.0 *Previous Transfer Gearbox Failures and Corrective Actions* for more details.

4.0 PREVIOUS TRANSFER GEARBOX FAILURES AND CORRECTIVE ACTIONS

On February 11, 2013, an operator of a Boeing 777-300ER, powered by two General Electric GE90-115B turbofan engines, experienced a uncommanded IFSD of the No. 2 engine (right) during cruise flight. The flight crew heard a loud bang from the right hand side and observed the No. 2 engine N1 (low pressure rotor speed) and N2 (high pressure rotor speed) drop down below flight idle. A successful single engine landing was made and a post event inspection found that the radial section of the TGB housing, as well as the radial gearshaft, were fractured. GE conducted a metallurgical examination of the radial gearshaft and found a manufacturing defect. Through manufacturing records, GE was able to identify all the radial gearshafts from the production lot in which the event radial gearshaft was manufactured along with other potential suspect lots. This initial suspect population was identified as coming from hardening/quenching “Lot 1”. On February 27, 2013, GE issued GE90-100 Alert Service Bulletin (ASB) 72-A0544 (compliance category 2)⁵ to identify those engines with suspect TGBs that had radial gearshafts that were produced within “Lot 1” and to require operators to “de-twin” their fleet; this is to say that if any single airplane has two engines with a TGB that has a radial gearshaft from “Lot 1” installed, one of the engines or TGBs was to be removed as soon as possible without effecting revenue service but within seven days from the issuance of the ASB. The removed TGBs were returned to the manufacture (Avio S.p.A) for disassembly and further inspection. Inspection of the returned TGBs, found two additional cracked radial gearshafts. Since these cracked radial gearshafts were from “Lot 1”, no additional action was taken at that time. “Lot 1” was comprised of 16 radial gearshafts.

On May 9, 2013, another Boeing 777-300ER operator experienced an IFSD as a result of a fractured TGB radial gearshaft. Based on the findings from this event, the suspect population of radial gearshafts expanded and GE issued two ASB, 72-A0558 (compliance category 1) and 72-A0559 (compliance category 2) on May 13 and May 14, 2013, respectively, to de-twin the airplane; essentially requiring the removal of an engine or TGB to ensure that no two suspect radial gearshafts are installed on the same airplane. The fractured radial gearshaft from the May 9th event was not part of the suspect population from “Lot 1”. This fractured radial gearshaft came from hardening/quench “Lot 4”. On May 16, 2013, the FAA sent to owners and operators of GE90-110B1 and GE90-115B turbofan engines emergency AD 2013-10-52 with an effectively upon receipt that prohibits operation of an airplane with affected TGBs installed on both engines five days after receipt of the emergency AD. Along with the ASB for the removal of the suspect radial gearshaft, GE issued two additional SBs to provide instructions for eddy current inspection of the radial gearshaft at the piece part level (SB 72-0560) and at the module level (SB 72-0561). Both SBs were issued on May 22, 2013 with a compliance category 7.⁶

⁵ GE Compliance Category Definition is as follows:

Category 1: GE recommends that you do this Service Bulletin before subsequent flight or before **xx** hours, **yy** cycles, or a specific end date or specified interval. Compliance is mandatory, generally as a result of FAA, DGAC, JAA, or other Aviation Authority action, i.e. airworthiness directive (AD), notice of proposed rulemaking (NPRM), or pending AD etc. Will cause customer action

Category 2: GE recommends that you do this Service Bulletin as soon as possible without effect on revenue service but before **xx** hours, **yy** cycles, or a specific end date or specified interval. Used when GE technical reasons make the compliance necessary and when an aircraft can stay for suitable time at a line station or maintenance base with the capability to do the procedure. The justification for hour, cycle and end date requirements will be based on technical considerations only (i.e. safety, risk analysis, etc.). Can cause non-routine customer action

⁶ Category 7: GE recommends that you do this Service Bulletin at customer convenience/option. Do at customer convenience after the old parts are all used. Do at customer option if the old parts will be supplied (date supported) for engines that have not been changed.

On June 7, 2013, a cracked radial gearshaft was discovered during a shop inspection and it was determined from manufacturing records that it came from hardening/quench “Lot 6”. No modifications to the existing published SBs or AD were made to expand the population size to include this finding. On July 2, 2013, the KAL radial gearshaft failure occurred. Maintenance records indicated that this particular radial gearshaft came from hardening/quench “Lot 26”. Similar to GE ASBs 72-0558 and 72-0559, GE issued ASB 72-0568 (compliance category 1) on July 10, 2013 to expand the suspect population and to de-twin airplanes to ensure that no two suspect radial gearshafts are installed on the same airplane. Using the same process and procedure as AD 2013-10-52, the FAA sent to owners and operators of GE90-110B1 and GE90-115B turbofan engines emergency AD 2013-14-51 on July 12, 2013 with an effectively upon receipt that prohibits operation of an airplane with affected TGBs installed on both engines five days after receipt of the emergency AD. This emergency AD superseded emergency AD 2013-10-52 that was issued in May 2013. As a follow up to ASB 72-0568, GE issued three additional standard SBs; SB 72-0563 (compliance category 6) issued July 10, 2013 for shot peen repair of the radial gearshaft, SB 72-0569 (compliance category 2) issued July 19, 2013 to remove the remaining suspect population, and SB 72-0570 (compliance category 3) issued July 29, 2013 to re-identify those radial gearshafts that had not been re-identified while at the manufacturer.⁷

The FAA issued AD 2013-15-20 with an effective date of August 21, 2013 to supersede emergency AD 2013-14-51 that was issued in July 2013. Emergency AD 2013-14-51 was sent previously to all known U.S. owners and operators of GE90-110B1 and GE90-115B turbofan engines and prohibited operation of an airplane if more than one installed engine had an affected TGB radial gearshaft. AD 2013-15-20 contains the same prohibition as AD 2013-14-51 and also prohibits operation of any airplane 60 days after the effective date if any installed engine has an affected TGB radial gearshaft. AD 2013-15-20 also revised the applicability by adding GE90-76B, GE90-77B, GE90-85B, GE90-90B, GE90-94B, and GE90-113B turbofan engine models and adds a mandatory terminating action – installation of shot peened radial gearshafts. According to GE, all effected radial gearshafts (186 in total) addressed by the various FAA ADs have been removed from service.

⁷ Category 3: GE recommends that you do this Service Bulletin at next shop visit of engine or module. Compliance is necessary regardless of the reason for the shop visit. Disassembly that was not planned can be necessary. Category 6: GE recommends that you do this Service Bulletin when the part is routed for repair. Do when the affected part is exposed and a repair is planned.

ATTACHMENTS

1. Korean ARAIB initial notification
2. Korean ARAIB request for delegation of the investigation to the NTSB
3. GE Metallurgical Investigation Report, FA 16356, dated February 3, 2014