National Transportation Safety Board
Aviation Incident Final Report

Location:	Ugolny Airport, Unknown	**Incident Number:**	ENG13IA033
Date & Time:	07/02/2013, 1026	**Registration:**	HL8275
Aircraft:	BOEING 777	**Aircraft Damage:**	None
Defining Event:	Loss of engine power (total)	**Injuries:**	N/A
Flight Conducted Under:	Part 129: Foreign		

Analysis

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. The pilots diverted the airplane to Ugolny Airport (DYR), in Siberia, Russia where an uneventful single engine landing was made. The Korean ARAIB requested delegation of the investigation and the NTSB accepted responsibility for investigating this incident. Post landing examination of the No. 1 engine revealed that the radial gearshaft within the transfer gearbox housing was fractured. Metallurgical examination of the radial gearshaft found an 0.049-inch axial crack with striation features indicative of fatigue propagation and a morphology consistent with initial fatigue initiation occurring under a torsional and/or biaxial stress condition. This axial crack was considered the primary crack and the fracture origin area. Microhardness tests near the fracture origin revealed a reduction in near surface hardness (lower hardness values than required). GE concluded that the near surface low hardness was attributable to decarburization due to marginal (thin or detached) copper plating existing on the gearshaft surface during the hardening process. Through computer modeling and testing of the radial gearshaft, GE concluded that the initiation of the axial crack was likely the result of a combination of high residual tensile stresses produced by local decarburization coupled with the operating stresses experienced at the outer diameter surface. To address the manufacturing process deficiency, GE issued seven service bulletins to remove, inspect, and repair the suspect radial gearshafts. To expedite the removal of the suspect radial gearshafts, the Federal Aviation Administration issued three separate Airworthiness Directives (AD). According to GE, all affected radial gearshafts addressed by the various FAA ADs have been removed from service.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: The failure of the transfer gearbox resulting from the fracture and separation of the radial gearshaft from fatigue cracking as a result of a combination of high residual tensile stresses produced by local decarburization during the manufacturing process coupled with the normal

operating stresses.

Findings

Aircraft	Accessory drives - Failure (Cause)
	Accessory drives - Design (Factor)

Factual Information

HISTORY OF FLIGHT

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. The Korean ARAIB subsequently requested delegation of the investigation and the NTSB accepted responsibility for investigating this incident.

TRANSFER GEARBOX DAMAGE

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.

TEST AND RESEARCH

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 fracture 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 the outer diameter surface.

ADDITIONAL INFORMATION

Corrective Actions

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.

History of Flight

Enroute-cruise	Loss of engine power (total) (Defining event)
	Engine shutdown
	Powerplant sys/comp malf/fail

Aircraft and Owner/Operator Information

Aircraft Manufacturer:	BOEING	**Registration:**	HL8275
Model/Series:	777 300ER	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	No
Airworthiness Certificate:	Transport	**Serial Number:**	37651
Landing Gear Type:	Tricycle	**Seats:**	
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	2 Turbo Fan
Airframe Total Time:		**Engine Manufacturer:**	General Electric
ELT:		**Engine Model/Series:**	GE90-115B
Registered Owner:	KE Export Leasing (2013-B)	**Rated Power:**	
Operator:	KOREAN AIR LINES COMPANY LTD	**Operating Certificate(s) Held:**	Foreign Air Carrier (129)
Operator Does Business As:		**Operator Designator Code:**	KALF

Meteorological Information and Flight Plan

Conditions at Accident Site:	Unknown	**Condition of Light:**	Not Reported
Observation Facility, Elevation:		**Observation Time:**	
Distance from Accident Site:		**Direction from Accident Site:**	
Lowest Cloud Condition:		**Temperature/Dew Point:**	
Lowest Ceiling:		**Visibility**	
Wind Speed/Gusts, Direction:		**Visibility (RVR):**	
Altimeter Setting:		**Visibility (RVV):**	
Precipitation and Obscuration:			
Departure Point:	Chicago, IL (ORD)	**Type of Flight Plan Filed:**	IFR
Destination:	Seoul, FN (ICN)	**Type of Clearance:**	IFR
Departure Time:		**Type of Airspace:**	

Wreckage and Impact Information

Crew Injuries:	N/A	**Aircraft Damage:**	None
Passenger Injuries:	N/A	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	N/A	**Latitude, Longitude:**	60.071111, -178.676111

Administrative Information

Investigator In Charge (IIC):	Jean-Pierre M Scarfo	**Adopted Date:**	05/14/2014
Additional Participating Persons:			
Publish Date:	05/14/2014		
Investigation Docket:	http://dms.ntsb.gov/pubdms/search/dockList.cfm?mKey=87474		