Aviation Investigation Final Report

Location:	Greenville, Texas	**Incident Number:**	ENG14IA001
Date & Time:	October 15, 2013, 14:51 Local	**Registration:**	N516NK
Aircraft:	Airbus A319 132	**Aircraft Damage:**	Minor
Defining Event:	Powerplant sys/comp malf/fail	**Injuries:**	150 None
Flight Conducted Under:	Part 121: Air carrier - Scheduled		

Analysis

Based on metallurgical analysis, a No. 1 engine high pressure turbine (HPT) 2nd stage blade separated below the blade platform due to stress corrosion cracking in the blade J-channel cooling air cavity. The liberated blade entered the gas path and caused extensive damage to the HPT and low pressure turbine (LPT) hardware and cases. The damaged engine was left at a high power setting for about four minutes until the crew received a No. 1 engine fire warning. During this time the turbine was exposed to temperatures that exceeded the material annealing temperature and resulted in failure and separation of multiple components including the LPT 3rd and 4th stage disks, turbine exhaust case center body, and the No. 5 bearing housing. The engine nacelle was not breached and all separated engine components traveled out the back of the engine.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be:

A high pressure turbine 2nd stage blade separation due to stress corrosion cracking in the J channel cooling cavity. The failed blade entered the gas path and caused substantial damage to the low pressure turbine. The engine was subsequently left at a high power setting for approximately four minutes, exposing the turbine hardware to temperatures that exceeded the material annealing temperature and resulted in in failure and separation of multiple engine components.

Findings

Aircraft	Turbine section - Fatigue/wear/corrosion

Factual Information

History of Flight

Enroute-climb to cruise	Powerplant sys/comp malf/fail (Defining event)

HISTORY OF FLIGHT

On October 15, 2013 at about 1451 CDT, a Spirit Airlines (NKS) Airbus A319, registration number N516NK, experienced a No. 1 (left) engine failure during climb out from Dallas-Fort Worth International Airport (DFW), Dallas, Texas. The airplane was equipped with two International Aero Engines (IAE) V2524-A5 turbofan engines. The flight crew reported that about ten minutes after takeoff, at FL190, the electronic centralized aircraft monitor (ECAM) displayed a No. 1 engine pressure ratio (EPR) mode fault, N2 over limit warning, and an exhaust gas temperature (EGT) over limit warning. The ECAM notifications coincided with heavy vibrations that could be felt throughout the cockpit and cabin. Both engines were advanced to the take-off/go around (TO/GA) power setting until a No. 1 engine fire warning registered about four minutes later at which time the flight crew shutdown the No. 1 engine and discharged one fire suppression bottle. During the event sequence smoke began entering the cockpit and the crew donned oxygen masks. The airplane returned to DFW and executed an uneventful single engine landing. Aircraft Rescue and Fire Fighting (ARFF) personnel met the aircraft on the runway and determined the fire had been extinguished. The flight was being operated in accordance with 14 *Code of Federal Regulations* Part 121 as a regularly scheduled flight from DFW to Atlanta Hartsfield International Airport (ATL), Atlanta, Georgia.

INJURIES

No injuries were reported to passengers or crew.

DAMAGE TO AIRPLANE

An on scene evaluation of the aircraft and No. 1 engine was conducted at DFW with members from IAE, NKS, the Air Line Pilots Association (ALPA), the Federal Aviation Administration (FAA) and the National Transportation Safety Board (NTSB). During a visual examination of the airplane minor impact damage was observed on the aft engine fairing, left wing fairing (canoe) and the leading edge of the left horizontal stabilizer. The impacts did not penetrate the outer panel or affect the underlying structure.

The No. 1 engine low pressure turbine (LPT) 3rd and 4th stage disks, turbine exhaust case center body, and the No. 5 bearing housing were jettisoned from the engine. The LPT 5th stage disk had separated from the 6th stage disk and was hanging on the LPT shaft. There was extensive damage to all remaining high pressure turbine (HPT) and LPT hardware. Large sections of the LPT and exhaust cases were breached and not recovered. The engine cowlings were in good condition without indications of radial uncontainment.

After removal of the engine, the No. 1 engine pylon was examined and exhibited sooting and substantial metal splatter in areas above the LPT plane of rotation. The pylon structure was deemed to be beyond repair limits by Airbus and was removed and replaced.

TEST AND RESEARCH

The engine was shipped to the Pratt & Whitney (P&W) Columbus Engine Center in Columbus, Georgia. The LPT shaft exhibited bending and heavy circumferential scoring. The LPT 6th and 7th stage disks remained intact but had substantial impact damage. All the LPT 6th stage blades were missing and all the LPT 7th stage blades were fractured at the root. The HPT 2nd stage disk had three blades separated below the platform with blade attachments secure in the hub slots and two blades were missing completely. All the remaining blades exhibited hard body impact damage on both the leading and trailing edge surfaces.

Components from the LPT, HPT and No. 4 bearing compartment were shipped to the P&W Materials Lab for analysis. The three HPT 2nd stage blades found fractured below the platform exhibited stress corrosion cracking (SCC) originating in the internal blade J-channel cooling air cavity. The remaining blades were sectioned for examination and a total of 41 of the 67 intact blades had varying levels of SCC. Probe spectrometry identified elemental sulfur at the corrosion front of each cracked blade that was examined. The presence of sulfur is not normal and is corrosive to blade material.

Hardness testing was done on all recovered HPT and LPT hardware to identify maximum gas path temperature exposure and map the temperature gradient at multiple points radially along each disk. The hardness values of the HPT disks were at levels consistent with exposure to temperatures in excess of 1950F (1066C). Hardness values increased by stage the further aft measurements were taken in the engine. Hardness levels were lowest along the outer rim of each disk and were progressively higher toward the center bore.

The No. 4 bearing compartment component fracture surfaces were examined and features were consistent with overload without indications of fatigue. None of the bearing compartment components exhibited signs of fire exposure or thermal distress.

ADDITIONAL INFORMATION

Crew Response

At the time the event occurred the airplane was climbing out from DFW and the crew was navigating between two cells of thunderstorms. The initial indication of a No. 1 engine failure was a heavy audible vibration through the airframe and an ECAM EPR mode fault indication. The crew began performing the EPR mode fault emergency procedures and realized that autopilot and autothrust had disengaged. The captain began to fly the airplane manually and advanced the throttles for both engines to the TO/GA power setting. The NKS Crew Operating Manual (COM) does not instruct the crew to advance the throttles in the applicable abnormal/emergency procedures. During the interview the captain did not have recollection of advancing the throttles but stated that he wanted to get the airplane to a position where the crew could better troubleshoot the failure. Advancing the throttle to TO/GA on the No. 1 engine did not further

increase N2 speed because the engine was already N2 limited by the full authority digital engine control (FADEC), but did continue to subject the HPT and LPT components to excessive gas path temperatures and vibration levels.

The NKS COM EPR mode fault, EGT Overlimit, and N2 Overlimit abnormal/emergency procedures available to the crew at the time of the incident were reviewed. During the event sequence the maximum N1 and N2 speeds that require engine shutdown were not reached. When the EGT limit is exceeded the COM states that the crew may continue operation until next landing but maximum temperature and duration at temperatures above the limit should be recorded. The COM then states, "if unable to maintain engine within limits, affected engine should be shut down. If conditions do not permit engine shutdown, land ASAP using the minimum thrust required to sustain safe flight." During the event the ECAM displayed an EGT warning but the actual temperature indication displayed amber X's due to gas path temperature exceeding the probe sensing capability.

The high engine vibration abnormal/emergency procedure does not have an associated ECAM warning. The NKS COM procedure states, "the VIB advisory on ECAM (N1 $\geq$ 5 units, N2 $\geq$ 5 units) is mainly a guideline to induce the crew to monitor engine parameters more closely." and "VIB detection alone does not require engine shut down.".

Electronic Centralized Aircraft Monitor Warnings

The ECAM warning sequence was evaluated by Airbus to better understand what was displayed in the cockpit during the event sequence. Airbus logic places priority on ECAM action items based on the level of urgency needed to maintain safe flight. During the event the initial item displayed at the top of the ECAM list was EPR mode fault and shortly after was replaced by N2 over limit and then EGT over limit. Based on Airbus logic, a N2 over limit warning is given higher priority than an EGT over limit warning due to the risk of N2 over speed causing a disk burst. The FADEC was attempting to bring the N1 speed back to nominal levels while simultaneously keeping the N2 speed below the upper limit. As the FADEC controlled the N2 speed, hysteresis in the control loop allowed the N2 speed to slightly overshoot the upper limit which tripped the ECAM N2 over limit warning. After the FADEC corrected the N2 speed to bring it back below the upper threshold, the N2 over limit warning was replaced by the EGT over limit warning. The two warnings continued to flip in priority as the FADEC attempted to control the engine. The EGT value remained above the warning levels throughout the event until the engine was shutdown.

Exhaust Gas Temperature Indication

According to IAE, the EGT probes installed on the V2524-A5 are temperature rated to 1238F (670C). The maximum EGT temperature demonstrated during the certification program was 1328F (720C) for a duration of 5 minutes. According to design specification, the probe is capable of functioning at temperatures up to 1400F (760C). According to Airbus, the engine electronic control (EEC) is capable of receiving an EGT signal up to 1830F (999C), temperatures exceeding that value are rejected as out of range. When the EGT probes are exposed to temperatures above 1830F (999C), the cockpit indication will display amber X's. The EGT probe range used on the V2524-A5 engine is consistent with other engines across the IAE and P&W product line.

Source of Corrosive Products

The source of the sulfur detected at the corrosion front of the cracked HPT 2nd stage blades could not be identified however, the investigative team looked at cleaning procedures and environmental factors for the introduction of the sulfur. All 44 blades that exhibited cracking were last repaired at Turbine Overhaul Services (TOS) in Singapore. As part of the investigation, IAE provided blade cleaning procedures and confirmed that all cleaning solutions have been verified not to be corrosive to blade materials. There is no way to confirm if the incident set of blades were repaired with a process that deviated from the manual.

The investigative team also considered sulfur introduction from environmental sources. The J-channel cooling air cavity provides circulates cooling airflow through the blade and in polluted air there is a possibility that sulfur byproducts can accumulate in the blades. The incident airplane flew routes over the continental United States which is not typically considered a problem area for environmental related SCC, but according to IAE, sulfur related accumulation has been an increasingly common event for all engines due to pollutants in the air.

Corrective Actions

Following the event, IAE revised their HPT 2nd stage blade inspection criteria in an effort to better detect internal cracks during blade repair/overhaul. Blades are x-rayed and then the internal cavities are borescoped to inspect for evidence of surface defects. IAE/P&W also developed an aluminide coating for the internal cavities of HPT 2nd stage blades to protect against corrosive deposits and has started installing the new blades on production V2500 SelectOne engines. A service bulletin to retrofit in service engines with the new HPT 2nd stage blades with the aluminide coating is expected to be released in the first quarter of 2015.

Pilot Information

Certificate:	Commercial	**Age:**	52
Airplane Rating(s):	Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	Unknown
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	May 20, 2013
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	15717 hours (Total, all aircraft), 5829 hours (Total, this make and model), 8341 hours (Pilot In Command, all aircraft), 156 hours (Last 90 days, all aircraft), 71 hours (Last 30 days, all aircraft), 7 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	26
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):	None	**Restraint Used:**	Unknown
Instrument Rating(s):		**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane multi-engine; Airplane single-engine	**Toxicology Performed:**	No
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	March 12, 2013
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	2001 hours (Total, all aircraft), 267 hours (Total, this make and model), 1562 hours (Pilot In Command, all aircraft), 115 hours (Last 90 days, all aircraft), 48 hours (Last 30 days, all aircraft), 7 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	Airbus	**Registration:**	N516NK
Model/Series:	A319 132 132	**Aircraft Category:**	Airplane
Year of Manufacture:	2006	**Amateur Built:**	
Airworthiness Certificate:	Normal; Transport	**Serial Number:**	2704
Landing Gear Type:	Tricycle	**Seats:**	
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	166449 lbs
Time Since Last Inspection:		**Engines:**	2 Turbo fan
Airframe Total Time:		**Engine Manufacturer:**	IAE
ELT:	Installed, not activated	**Engine Model/Series:**	V2500SERIES
Registered Owner:	WILMINGTON TRUST CO TRUSTEE	**Rated Power:**	24480 Lbs thrust
Operator:	Spirit Airlines	**Operating Certificate(s) Held:**	Flag carrier (121)
Operator Does Business As:	Spirit Airlines	**Operator Designator Code:**	NKS

Meteorological Information and Flight Plan

Conditions at Accident Site:	Unknown	**Condition of Light:**	Day
Observation Facility, Elevation:		**Distance from Accident Site:**	
Observation Time:		**Direction from Accident Site:**	
Lowest Cloud Condition:	Unknown	**Visibility**	
Lowest Ceiling:	Unknown	**Visibility (RVR):**	
Wind Speed/Gusts:	0 knots /	**Turbulence Type Forecast/Actual:**	/ Unknown
Wind Direction:	0°	**Turbulence Severity Forecast/Actual:**	/ Unknown
Altimeter Setting:		**Temperature/Dew Point:**	
Precipitation and Obscuration:	Moderate - Thunderstorm - Unknown obscuration		
Departure Point:	Dallas, TX (DFW)	**Type of Flight Plan Filed:**	IFR
Destination:	Atlanta, GA (ATL)	**Type of Clearance:**	Unknown
Departure Time:	13:21 Local	**Type of Airspace:**	Unknown

Airport Information

Airport:	DALLAS/FORT WORTH INTL DFW	**Runway Surface Type:**	
Airport Elevation:	607 ft msl	**Runway Surface Condition:**	Unknown
Runway Used:		**IFR Approach:**	Unknown
Runway Length/Width:		**VFR Approach/Landing:**	Unknown

Wreckage and Impact Information

Crew Injuries:	5 None	**Aircraft Damage:**	Minor
Passenger Injuries:	145 None	**Aircraft Fire:**	In-flight
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	150 None	**Latitude, Longitude:**	33.20111,-96.20111(est)

Administrative Information

Investigator In Charge (IIC):	Hunsberger, Robert
Additional Participating Persons:	
Original Publish Date:	February 5, 2015
Last Revision Date:	
Investigation Class:	Class
Note:	
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=88222