Aviation Investigation Final Report

Location:	Busan, Other Foreign	**Incident Number:**	ENG19IA008
Date & Time:	December 26, 2018, Local	**Registration:**	HL8314
Aircraft:	Airbus A220	**Aircraft Damage:**	None
Defining Event:	Powerplant sys/comp malf/fail	**Injuries:**	N/A
Flight Conducted Under:	Non-U.S., commercial		

Analysis

On December 26, 2018, KoreanAir flight 0753, an Airbus A220-300, registration HL8314, experienced a commanded inflight shutdown of the left (No. 1) engine, a Pratt & Whitney (P&W) PW1521G-3, while climbing through 29,000 feet on a flight from Busan, Korea (PUS) to Nagoya, Japan. The flight crew reported hearing a loud bang that was followed by vibrations and an engine fire warning. The flight crew shut down the engine and the airplane returned to PUS without further incident. The engine was removed from the airplane and shipped to P&W's Columbus Engine Center, Columbus, Georgia for disassembly and examination.

The examination of the engine revealed one low pressure turbine (LPT) stage 3 blade, No. 52, that had a flat, planar, elliptical-shaped fracture surface at the rear half of the blade. The metallurgical examination of blade No. 52 showed that the grain size and hardness conformed to the requirements for the specified IN-100 nickel alloy. The energy dispersive spectroscopy (EDS) of blade No. 52 away from the origin of the fatigue crack produced a spectra that was consistent with the requirements for IN-100. However, the EDS of blade No. 52 at the preexisting intergranular crack and the origin of the fatigue crack produced a spectra that was consistent with IN-100, but also had peaks of zirconium and hafnium.

Arconic suggested the elevated level of zirconium that was noted in the EDS could be from the zirconia crucible in which the nickel alloy was melted. Since all of the blades from this engine and many others were cast from nickel alloy melted in a zirconia crucible and the Korean Air event was the only IN-100 LPT stage 3 blade fracture, that would suggest the elevated level of zirconium noted in the EDS of LPT stage 3 blade No. 52 was probably not a major factor in the failure of the blade. Hafnium is not one of the alloying elements in IN-100. It is however, one of the alloying elements of MAR-M-247, which according to Arconic's records was the alloy that had been melted in the crucible just prior to it being used to melt the IN-100 nickel alloy to cast the blades that included the LPT stage 3 blade that would become No. 52. Arconic also suggested that the presence of the hafnium could be from the incomplete cleaning of the

crucible from the previous melt that was of MAR-M-247 that has hafnium as an alloying element.

The presence of the hafnium in the intergranular crack would suggest the formation of a localized brittle structure that cracked very early in the life of the blade that progressed into the fatigue crack leading to the fracture of the blade and the subsequent loss of power. As previously noted, Arconic stated the crucible that was used to pour the IN-100 alloy into the molds for the LPT stage 3 blades including the blade that fractured had been used to pour MAR-M-247 nickel alloy. Although there are some common elements in both IN-100 and MAR-M-247, hafnium is unique to the MAR-M. Arconic asserted that the crucibles are cleaned between casting pours. However, the presence of the hafnium in the fractured blade would suggest that the cleaning of the crucible was inadequate.

According to Arconic, the blades undergo several post-casting inspections including visual, fluorescent penetrant inspection (FPI), and x-ray. The metallurgical examination of the fractured blade showed that the fatigue crack originated from a subsurface intergranular crack. Since the origin of the fatigue crack was a subsurface intergranular crack, presuming it was even cracked at the time of the post-casting visual inspections, it would not have been detectable since the visual and FPI inspections require a defect to be surface breaking to be detectable. Additionally, even if the defect was surface breaking, it is unlikely that the defect would be detectable. The initial intergranular crack probably only involved a few crystals that would be far smaller than 0.020-inch sized defect that would result in a 90 percent probability of detection. The blades also undergo an X-ray inspection. Although a subsequent review of the X-ray inspection records that was focused on the area where the fatigue crack originated detected a casting anomaly, the manufacturer stated that the casting anomaly lacked contrast to be detectable by the typical production level of inspection.

Probable Cause and Findings

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

The manufacturer's inadequate cleaning of the crucible before melting the nickel alloy used in casting the low pressure turbine stage 3 blades that resulted in a casting anomaly from where an intergranular crack occurred became the origin of a fatigue crack that led to the fracture of a low pressure turbine stage 3 blade.

Findings

Aircraft	Turbine section - Fatigue/wear/corrosion
Aircraft	Turbine section - Failure
Organizational issues	(general) - Manufacturer
Organizational issues	Equipment manufacture - Manufacturer

Factual Information

History of Flight

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

On December 26, 2018, KoreanAir flight 0753, an Airbus A220-300, registration HL8314, experienced a commanded inflight shutdown of the left (No. 1) engine, a Pratt & Whitney (P&W) PW1521G-3, while climbing through 29,000 feet on a flight from Busan, Korea (PUS) to Nagoya, Japan. The flight crew reported hearing a loud bang that was followed by vibrations and an engine fire warning. The flight crew shut down the engine and the airplane returned to PUS without further incident. The examination of the engine revealed damage to the turbines and several holes in the low pressure turbine (LPT) case. Although there was a fire warning, the examination of the engine did not reveal any fire damage. There were no reported injuries to the passengers and crew that were on board the airplane. At the time of the event, the engine had accumulated only 417 hours and 529 cycles since new.

The engine was removed from the airplane and shipped to P&W's Columbus Engine Center, Columbus, Georgia for disassembly and examination. The examination of the engine revealed there was a sector of six adjacent LPT stage 3 blades, Nos. 52 to 57, that were fractured between about 0.25- and 1-inch above the blade root platform. There was one LPT stage 3 blade, No. 52, that had a flat, planar, elliptical-shaped fracture surface at the rear half of the blade. In comparison, the fracture surfaces on the forward half of blade No. 52 as on the other five blades in that cluster of blades, Nos. 53 to 57, were coarse and grainy.

LPT stage 3 blade No. 52 along with all of the other LPT stage 3 blades were sent to P&W's Materials and Process Engineering laboratory for a metallurgical examination. The metallurgical examination showed that blade No. 52 separated from a fatigue crack that had originated from a preexisting intergranular crack near the trailing edge. The fatigue had progressed to the trailing edge and forward to the mid chord area of the blade before the remainder of the blade fractured in overload. The examination of blades Nos. 53 to 57 showed those blades had separated in overload. The metallurgical examination of blade No. 52 showed that the grain size and hardness conformed to the requirements for the specified IN-100 nickel alloy. The energy dispersive spectroscopy (EDS) of blade No. 52 away from the origin of the fatigue crack produced a spectra that was consistent with the requirements for IN-100. However, the EDS of blade No. 52 at the preexisting intergranular crack and the origin of the fatigue crack produced a spectra that was consistent with IN-100, but also had peaks of zirconium and hafnium.

Within the PW1000 engine series, there are engines that have LPT stage 3 blades that are made of beta Ti [titanium] and engines that have LPT stage 3 blades made of IN-100. Although those engines with the beta Ti LPT stage 3 blades have had numerous blade fractures and those

blades are in the process of being replaced with the IN-100 blades, this Korean Air LPT event is the only reported IN-100 LPT stage 3 blade fracture.

The LPT stage 3 blade is made of cast IN-100 nickel alloy. According to the manufacturer, Arconic, the nickel alloy is melted in a zirconia crucible and then poured into molds. Each mold contains several blade castings. According to Arconic's records, the mold that contained the casting of the fractured blade was the first one cast. Furthermore, the Arconic's records revealed that MAR-M-247 alloy had been melted in the crucible just prior to it being used to melt the IN-100 nickel alloy to cast the blades that included the LPT stage 3 blade that would become No. 52. Hafnium is however, one of the alloying elements of MAR-M-247. Arconic performed several post-casting inspections of the blades including visual, fluorescent penetrant inspection (FPI), and x-ray; no anomalies were detected. The metallurgical examination of the fractured blade showed that the fatigue crack originated from a subsurface intergranular crack. Since the origin of the fatigue crack was a subsurface intergranular crack, presuming it was even cracked at the time of the post-casting visual inspections, it would not have been detectable since the visual and FPI inspections require a defect to be surface breaking to be detectable. The blades also undergo an X-ray inspection. Although a subsequent review of the X-ray inspection records that was focused on the area where the fatigue crack originated detected a casting anomaly, the manufacturer stated that the casting anomaly lacked contrast to be detectable by the typical production level of inspection.

Information

Certificate:	**Age:**
Airplane Rating(s):	**Seat Occupied:**
Other Aircraft Rating(s):	**Restraint Used:**
Instrument Rating(s):	**Second Pilot Present:**
Instructor Rating(s):	**Toxicology Performed:**
Medical Certification:	**Last FAA Medical Exam:**
Occupational Pilot:	**Last Flight Review or Equivalent:**
Flight Time:	

Aircraft and Owner/Operator Information

Aircraft Make:	Airbus	**Registration:**	HL8314
Model/Series:	A220 300 (CS300)	**Aircraft Category:**	Airplane
Year of Manufacture:	2018	**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	55035
Landing Gear Type:	Retractable - Tricycle	**Seats:**	
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	2 Geared turbofan
Airframe Total Time:		**Engine Manufacturer:**	Pratt & Whitney
ELT:		**Engine Model/Series:**	PW1521G-3 (No. 1)
Registered Owner:		**Rated Power:**	
Operator:		**Operating Certificate(s) Held:**	Foreign air carrier (129)
Operator Does Business As:	KoreanAir	**Operator Designator Code:**	

Meteorological Information and Flight Plan

Conditions at Accident Site:	Unknown	**Condition of Light:**	Not reported
Observation Facility, Elevation:		**Distance from Accident Site:**	
Observation Time:		**Direction from Accident Site:**	
Lowest Cloud Condition:		**Visibility**	
Lowest Ceiling:		**Visibility (RVR):**	
Wind Speed/Gusts:	/	**Turbulence Type Forecast/Actual:**	/
Wind Direction:		**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:		**Temperature/Dew Point:**	
Precipitation and Obscuration:			
Departure Point:	Busan, OF (PUS)	**Type of Flight Plan Filed:**	IFR
Destination:	Nagoya, OF	**Type of Clearance:**	Unknown
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:		**Aircraft Explosion:**	None
Total Injuries:	N/A	**Latitude, Longitude:**	35.15406,131.133565(est)

Administrative Information

Investigator In Charge (IIC):	Hookey, Gordon
Additional Participating Persons:	Hyoo Choi; Korean Ministry of Land, Infrastructure, and Transport; Seoul Helen Tsai; Transportation Safety Board of Canada; Gatineau, Quebec Hyo-min Park; Korean Air; Seoul Jae Hong Choi; Korean Air; Seoul Robert Farinas; Transport Canada Civil Aviation; Ottawa Jimmy Avgoustis; Airbus A220; Mirabel, Quebec Liviu Badita; Airbus A220; Mirabel, Quebec Stephen Yee; Pratt & Whitney; East Hartford, CT James Chrisikos; Pratt & Whitney; East Hartford, CT Robert Peters; Pratt & Whitney; East Hartford, CT Vincent Simms; Pratt & Whitney; East Hartford, CT
Original Publish Date:	March 2, 2022 **Investigation Class:** 3
Note:	The NTSB did not travel to the scene of this incident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=98808