National Transportation Safety Board
Aviation Incident Final Report

Location:	Jeddah, Saudi Arabia	**Incident Number:**	ENG08IA030
Date & Time:	07/05/2008,	**Registration:**	HS-VAC
Aircraft:	BOEING B747	**Aircraft Damage:**	Minor
Defining Event:	Uncontained engine failure	**Injuries:**	N/A
Flight Conducted Under:	Part 129: Foreign		

Analysis

The airplane made an air turnback and successful landing following an uncontained No. 1 engine failure during initial climb after takeoff. There was minor impact damage to the airplane's left wing and flaps. The No. 1 engine low pressure turbine (LPT) case had separated circumferentially in plane with the stage 3 (S3) LPT turbine, and the engine components aft of the separation were liberated. A high pressure turbine (HPT) borescope inspection found localized airfoil damage sufficient to result in HPT rotor unbalance. HPT rotor unbalance-induced synchronous vibration forces interacted with the engine LPT rotor system through a common bearing support and excited a bladed-disk mode response in the LPT S3 disk. The resonant amplitude of the alternating stress experienced by the disk resulted in bending loads exceeding the material endurance limit, and high cycle/high amplitude fatigue cracks initiated along the LPT S3 disk forward spacer arm rim diameter. Once initiated, the cracks propagated rapidly through the spacer arm thickness and the individual cracks joined to form a single circumferential crack, resulting in the separation of the disk at the forward spacer arm. The freed aft portion of the LPT rotor accelerated and penetrated the engine case, releasing high-energy debris as disk fragments and all of the engine components aft of the LPT S3 nozzles were liberated.

NTSB Safety Recommendations A-10-98 and A-10-99 (Urgent); A-10-100, and A-10-101 were published in connection with this investigation. For further information about these recommendations, see NTSB case number ENG09IA004.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: Failure of the low pressure turbine stage 3 disk due to a design that is vulnerable to high pressure turbine unbalance-induced synchronous vibration that cannot be detected in flight, and the subsequent uncontained engine failure.

Findings

Aircraft	Turbine section - Design (Cause)

Factual Information

On July 4, 2008 a Saudi Arabian Airlines Boeing 747-300 experienced a No. 1 General Electric (GE) CF6-50 engine uncontained failure during initial climb after takeoff from the King Abdul-Aziz International Airport (JED), Jeddah, Kingdom of Saudi Arabia. The non-commercial flight was undertaken to reposition the airplane from JED to Jakarta, Indonesia for maintenance, including maintenance to the No. 1 engine due to degraded power. The flight crew reported that they reduced the No. 1 engine thrust following takeoff after noticing fluctuations in its exhaust gas temperature and fan speed (N1) indications. According to the captain, the fluctuations continued during the initial climb, and about one minute later, at about 1,100 feet above ground level (AGL), the engine's low oil pressure warning illuminated and the oil quantity indicator read zero. The flight crew shut down the engine, dumped fuel, and returned to the airport, where an uneventful landing was accomplished. No injuries were reported. Post-flight inspection of the airplane found that the aft end of the No. 1 engine was missing, and that the airplane's left wing and flaps were damaged from impact penetrations.

The liberated engine components were recovered about 2½ miles from the departure end of the runway. Photographs of the engine and the recovered parts provided to the National Transportation Safety Board (NTSB) by the Kingdom of Saudi Arabia's General Authority of Civil Aviation (GACA) indicated that the engine's low pressure turbine (LPT) stage 3 (S3) disk had separated at the forward spacer arm, and that all components aft of the separation had been liberated.

The GACA elected to send the liberated components to GE for metallurgical evaluation. Following the initial evaluation of these components, the forward spacer arm section (forward fracture surface) was removed from the engine at Jeddah and sent to GE for metallurgical evaluation.

MATERIALS ANALYSIS

The LPT S3 disk fracture surfaces were examined by GE at their Evandale, Ohio facility, with oversight from the NTSB. The examination found that the S3 LPT disk had separated circumferentially near the fillet between the spacer arm and the disk rim. This fracture surface was damaged by post-fracture smearing, however interpretable areas showed damage consistent with high amplitude/high cycle fatigue (HAF) from multiple initiation sites, primarily on the inner diameter. The features indicated that, once initiated, the cracks propagated rapidly through the spacer arm thickness and joined to form a single circumferential crack, resulting in disk separation. The material met all specifications except for a small deviation in the as-large-as grain size requirement, which likely played no role in the fatigue fracture.

TESTS AND RESEARCH

According to GE, when a high level of high pressure turbine (HPT)rotor unbalance occurs in the CF6-50 engine, the resulting synchronous vibration forces can interact with the engine's LPT through a common bearing support and excite a bladed-disk vibration mode within the engine operating range.

A post-incident video borescope inspection (BSI) of the engine's HPT found that three HPT stage one blades over a nine-blade sector were missing airfoil material, equivalent to the loss of about 1.8 blade airfoils. According to GE, a localized HPT blade airfoil loss equivalent to 1.8

blade airfoils will result in HPT rotor unbalance large enough to excite the bladed-disk vibration mode in the LPT S3 disk.

ADDITIONAL INFORMATION

The investigation of this incident was initially conducted by the GACA, Kingdom of Saudi Arabia. The investigation was delegated to the United States on April 11, 2009.

History of Flight

Initial climb	Engine shutdown
	Loss of engine power (partial)
	Part(s) separation from AC
	Uncontained engine failure (Defining event)

Aircraft and Owner/Operator Information

Aircraft Manufacturer:	BOEING	**Registration:**	HS-VAC
Model/Series:	B747 306	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	No
Airworthiness Certificate:		**Serial Number:**	
Landing Gear Type:		**Seats:**	
Date/Type of Last Inspection:		**Certified Max Gross Wt.:**	
Time Since Last Inspection:		**Engines:**	Turbo Fan
Airframe Total Time:		**Engine Manufacturer:**	General Electric
ELT:		**Engine Model/Series:**	CF5-50
Registered Owner:	Phuket	**Rated Power:**	lbs
Operator:	Saudi Arabian Airlines	**Operating Certificate(s) Held:**	None
Operator Does Business As:		**Operator Designator Code:**	SV

Meteorological Information and Flight Plan

Conditions at Accident Site:		**Condition of Light:**	
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:	Jeddah	**Type of Flight Plan Filed:**	Unknown
Destination:	Jakarta	**Type of Clearance:**	
Departure Time:		**Type of Airspace:**	

Airport Information

Airport:		**Runway Surface Type:**	
Airport Elevation:		**Runway Surface Condition:**	
Runway Used:		**IFR Approach:**	
Runway Length/Width:		**VFR Approach/Landing:**	

Wreckage and Impact Information

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

Administrative Information

Investigator In Charge (IIC):	Carol M Horgan	**Adopted Date:**	12/19/2012
Additional Participating Persons:	Les McVey; General Electric; Evandale, OH Robert Crispin; Jeddah,		
Publish Date:	12/19/2012		
Investigation Docket:	NTSB accident and incident dockets serve as permanent archival information for the NTSB's investigations. Dockets released prior to June 1, 2009 are publicly available from the NTSB's Record Management Division at pubinq@ntsb.gov, or at 800-877-6799. Dockets released after this date are available at http://dms.ntsb.gov/pubdms/.		

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