Aviation Investigation Final Report

Location:	PALM SPRINGS, California	**Incident Number:**	LAX98IA158
Date & Time:	May 10, 1998, 12:20 Local	**Registration:**	N651MK
Aircraft:	North American NA265-65	**Aircraft Damage:**	Minor
Defining Event:		**Injuries:**	8 None
Flight Conducted Under:	Part 91: General aviation - Executive/Corporate		

Analysis

An uncontained engine failure occurred during the takeoff roll. The high pressure centrifugal impeller disk had burst, with one chunk exiting through the engine cowling. The melt and forging records for the disk were reviewed and met the required specifications, including alloy chemistry. Metallurgical examination of the disk revealed subsurface primary and secondary fatigue cracks near an area that had been reworked to remove LCF stresses in accordance with a Service Bulletin. The cracks were located opposite of each other in the seal relief undercut area. The primary fatigue origin was below the shot-peened surface near a high stress area and the secondary fatigue origin remained subsurface, with the propagation of both cracks running parallel to the surface until overload separation. The primary fracture surface could not be definitively analyzed due to plasticity and the presence of an oxide layer. No melt, forging-related or heat-treating defects were found in the vicinity of the fatigue origins; however, subsurface LCF was present. No significant hardness difference was found either in or away from the fatigue origins. There was no evidence of a subsurface occlusion. A physical resemblance between the fatigue origin and the zones of crystallographically aligned phase (texture zones) was observed in the microstructure. The shape and orientation of the origin macrostructure and/or texture may have been a contributing factor to crack initiation; however, no precipitating event or cause for the fatigue initiation was identified. Analysis reverified the Service Bulletin rework specifications, confirming that residual stress was negligible at the depth of crack initiation.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: the fatigue failure and uncontained separation of the high pressure impeller in the No. 2 engine during the takeoff roll. While the impeller showed evidence of a subsurface fatigue origin, the

percipient cause of the separation was not definitively determined.

Findings

Occurrence #1: LOSS OF ENGINE POWER(PARTIAL) - MECH FAILURE/MALF
Phase of Operation: TAKEOFF - ROLL/RUN

Findings
1. 1 ENGINE
2. (C) COMPRESSOR ASSEMBLY,IMPELLER - FATIGUE
3. (C) REASON FOR OCCURRENCE UNDETERMINED

Factual Information

On May 10, 1998, at 1220 hours Pacific daylight time, a Rockwell International Sabreliner NA265-65, N651MK, experienced an uncontained engine failure during takeoff roll at Palm Springs, California. The aircraft sustained minor damage; however, neither the pilot, copilot, nor any of the six passengers on board were injured. The aircraft was being operated as a corporate transportation flight by the Mallinckrodt Group, Inc., under 14 CFR Part 91 at the time of the incident. The flight was originating from the Palm Springs Regional Airport at the time with a destination of St. Louis, Missouri. Visual meteorological conditions prevailed at the time and an IFR flight plan had been filed.

The aircraft was accelerating through 70 knots on runway 31L during the takeoff roll when a loud bang was heard and the aircraft lost power. The pilot immediately performed a rejected takeoff and brought the aircraft to a stop on the runway.

A postaccident inspection conducted by Federal Aviation Administration airworthiness inspectors revealed evidence of an uncontained failure of the No. 2 engine. The high-pressure centrifugal impeller disk (P/N 307 3394-1) (S/N 7-23365-1482) had burst, with a chunk exiting through the engine cowling at the 1:30 away from fuselage (ALF) position. Evidence of flying debris was also visible on the aft fuselage and the horizontal stabilizer.

The disk had fractured into three pieces with one piece (3.4 pounds) being thrown from the aircraft. This piece was recovered during a runway sweep conducted by the engine manufacturer on May 16, 1998. The remaining two pieces (7.2 and 5.7 pounds) were found in the engine. The engine and all three pieces were shipped by certified carrier to the manufacturer's facility in Phoenix, Arizona, for examination under the supervision of the Safety Board investigator.

During the investigation, manufacturing records from the firms involved in processing the impeller were examined. The 8-inch diameter forging stock from which the impeller came was produced by Timet in Henderson, Nevada, in December 1977. The double (VAR) melt process was used and identified as heat code P2842. The impeller was then forged by Wyman Gordon in Harvey, Massachusetts, in December 1977 (forging S/N 7-23365-1482). It was 1 of 46 pieces from the forging lot (heat code P2842). A type II stringer (an aluminum Alpha defect) was found in the top of the billet, and the top 24 inches was removed. The forging chemistry met the titanium (Ti-6242) alloy specification requirements.

After manufacture, the disk, P/N 3072639-1, accumulated 3,038.12 hours and 3,251 cycles prior to being reworked in 1982 due to the identification of a life limiting region in a double radius located at the No. 5 seal relief outside the diameter bore area. The work was done in accordance with Service Bulletin TFE 731-72-3239RWK that directed the rework of the seal

relief surface to reduce low cycle fatigue (LCF) stresses. At that time, the disk was zero-timed (TSN=0), reidentified as P/N 3073394-1, and given a life of 10,000 cycles.

The disk was reinstalled in November 1982, and accumulated another 3,408.5 hours and 3,537 cycles before it was removed in December 1988. It was installed in the accident engine (S/N 83252) and accumulated an additional 3,294.7 hours and 2,292 cycles at the time of the failure. The time on the impeller at separation was 6,703.2 hours and 5,829 cycles. The cumulative totals on the life of the disk were 9,741.32 hours and 9,080 cycles.

The engine manufacturer estimated that about 7,310 disks have gone into service since manufacturing began in 1972. Of these disks, 3,500 are of new design and do not require rework. There are 2,010 disks that have been subject to rework since September 18, 1982, and have had their P/N's changed to 3073393 and 3073394. The remaining 1,800 disks have not been reworked. The engine manufacturer recomputed the disk design and the rework specifications and made an overlay comparison of the old design on the rework design. This was done in order to evaluate the actual amount of material removed, and to aid in confirmation of the original stress analysis. Residual stress measurements in the seal relief area indicated that the shot peening had been done properly and that residual stress was negligible at the depth of crack initiation. The manufacturer concluded that the rework dimensions were within intended limits and had not been a factor in the failure.

A metallurgical examination conducted by the engine manufacturer, and under the supervision of a Safety Board investigator, revealed subsurface primary and secondary fatigue cracks near the rework area. The cracks were located about 180 degrees in opposition to each other in the seal relief undercut area. The primary fatigue origin measured 0.020 by 0.067 inches, had propagated to the surface, and was oil soaked. The origin was about 0.025 inches below the shot-peened surface near a high stress area. The final fatigue thumbnail had propagated to 0.90 by 1.50 inches before ultimate failure. A striation count was performed which indicated a total of 3,500 resolvable striations on the fracture surface. The secondary fatigue origin measured 0.030 by 0.060 inches and was followed by an overload separation. No striations were resolvable on the secondary fracture. In both origins, crack propagation was found to run parallel to the surface.

The alloy chemistry, the hardness, and the grain structure (Alpha/Beta) were verified and no cold dwell effects (hydrogen embrittlement) basal plane texturing were observed at either fatigue origin, although minor prism texturing was present in the vicinity of the secondary fracture. The bulk of the interstitial element content was within specified limits. There was no significant difference in hardness in, or away from, the fatigue origins. The primary fracture surface could not be definitively analyzed due to plasticity and the presence of an oxide layer. There was no evidence of a subsurface occlusion.

The microstructure indicated that no melt, heat treating, or forging-related defects existed in the vicinity of the fatigue origins. There was noted a physical resemblance between the fatigue origin and the zones of crystallographically aligned phase (texture zones) in the

microstructure.

After removal of the fracture surfaces, three impeller pieces were blue etch anodized and fluorescent penetrant inspected. No additional cracks or anomalies were found.

Southwest Research Institute in San Antonio, Texas, conducted scanning electronic microscope (SEM) and transmission electron microscope (TEM) examinations. The examinations revealed LCF initiating approximately 0.015 to 0.027 inches subsurface. The manufacturer stated that the shape and orientation of the origin suggest macrostructure and/or texture may have contributed to crack initiation. The appearance of the fracture was not typical of previously observed titanium fractures.

Pilot Information

Certificate:	Airline transport; Commercial; Flight instructor	**Age:**	36,Male
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	Airplane single-engine; Instrument airplane	**Toxicology Performed:**	No
Medical Certification:	Class 1 Valid Medical--no waivers/lim.	**Last FAA Medical Exam:**	December 30, 1997
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	
Flight Time:	8494 hours (Total, all aircraft), 2316 hours (Total, this make and model), 6110 hours (Pilot In Command, all aircraft), 115 hours (Last 90 days, all aircraft), 75 hours (Last 30 days, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	North American	**Registration:**	N651MK
Model/Series:	NA265-65 NA265-65	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	465-73
Landing Gear Type:	Retractable - Tricycle	**Seats:**	10
Date/Type of Last Inspection:	March 29, 1998 Continuous airworthiness	**Certified Max Gross Wt.:**	24000 lbs
Time Since Last Inspection:	68 Hrs	**Engines:**	2 Turbo fan
Airframe Total Time:	7183 Hrs	**Engine Manufacturer:**	Garrett
ELT:	Not installed	**Engine Model/Series:**	TFE 731-3R-1D
Registered Owner:	MALLINCKRODT GROUP INC.	**Rated Power:**	3700 Lbs thrust
Operator:		**Operating Certificate(s) Held:**	None
Operator Does Business As:		**Operator Designator Code:**	

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	PSP ,462 ft msl	**Distance from Accident Site:**	
Observation Time:	11:53 Local	**Direction from Accident Site:**	
Lowest Cloud Condition:	Clear	**Visibility**	10 miles
Lowest Ceiling:	None	**Visibility (RVR):**	
Wind Speed/Gusts:	13 knots / 20 knots	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	320°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	29 inches Hg	**Temperature/Dew Point:**	23°C / 6°C
Precipitation and Obscuration:	No Obscuration; No Precipitation		
Departure Point:	, CA (PSP)	**Type of Flight Plan Filed:**	IFR
Destination:	ST LOUIS , MO (STL)	**Type of Clearance:**	IFR
Departure Time:	12:20 Local	**Type of Airspace:**	Class D

Airport Information

Airport:	PALM SPRINGS REGIONAL PSP	**Runway Surface Type:**	Asphalt
Airport Elevation:	462 ft msl	**Runway Surface Condition:**	Dry
Runway Used:	31L	**IFR Approach:**	None
Runway Length/Width:	8500 ft / 150 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	2 None	**Aircraft Damage:**	Minor
Passenger Injuries:	6 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	8 None	**Latitude, Longitude:**	33.849178,-116.560363(est)

Administrative Information

Investigator In Charge (IIC):	Crispin, Robert
Additional Participating Persons:	ERIC JACKSON; RIVERSIDE , CA MIKE A CUMMINS; PHOENIX , AZ JOHN J MECALO; ST LOUIS , MO
Original Publish Date:	November 29, 2000
Last Revision Date:	
Investigation Class:	Class
Note:	
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=29968