National Transportation Safety Board
Aviation Incident Final Report

Location:	Chicago, IL	**Incident Number:**	ENG08IA042
Date & Time:	10/01/2008, 1055 CST	**Registration:**	N551WN
Aircraft:	BOEING 737	**Aircraft Damage:**	Minor
Defining Event:	Landing gear collapse	**Injuries:**	133 None
Flight Conducted Under:	Part 121: Air Carrier - Scheduled		

Analysis

The airplane experienced separation of the right nose landing gear (NLG)wheel assembly as it exited runway after landing. Metallurgical examination revealed that the NLG axle fractured in a transverse plane, and that the failure of the axle was due to intergranular cracking that acted as stress concentrators from which fatigue cracks emanated. The fracture of the right side inboard journal on the NLG inner cylinder assembly was most likely due to the failure of a prior tapered roller bearing. Eventually the size of the fatigue crack and the forces generated during landing were sufficient to drive the crack in overstress, leading to fracture of the inboard journal. The change in ownership of the plane and the monthly swapping of bearings and wheels make it difficult to determine when the bearing failure occurred or why.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this incident to be: The right nose landing gear axle's failure from intergranular and fatigue cracking due to an earlier bearing failure.

Findings

Aircraft	Nose/tail landing gear - Failure (Cause)
	Nose/tail landing gear - Fatigue/wear/corrosion (Cause)

Factual Information

On October 1, 2008 at about about 1055 cdt a Southwest Airlines B-737 experienced separation of the right nose landing gear wheel assembly as it exited runway 31C after landing at the Midway Airport, Chicago, IL. The captain reported he felt a bump, but then everything seemed fine and he taxied to the gate. Another pilot reported FOD near the runway, which turned out to be the wheel assembly. There were no injuries to the 128 passengers or 5 crew. A FAA-FSDO inspector was on-scene. He reported that the axle appeared to have failed. There was no other damage to the airplane. The nose gear was installed in 2001, and was scheduled to be removed in 2010. It had accumulated 13,719 cycles at the time of the event. Preliminary visual examinations indicated the presence of a fatigue crack emanating from the exterior/chromed portion of the axle.

The fractured nose landing gear inner cylinder assembly, inboard roller bearing, and wheel were received by the NTSB Materials Laboratory. The axle fractured in a transverse plane through the right side inboard journal. The cage on the roller bearing was deformed. There was no visible damage to the inner race or the rollers and the rollers could be spun by hand. There were no visible signs of damage to the outer races on either side of the wheel. Deformation was observed along the edge where a c-clip retains a rubber seal. The edge was deformed radially outward and the edge had a scalloped appearance similar to the size and spacing of the tapered bearing rollers.

The inboard section of the fractured axle was cut from the rest of the inner cylinder. The spacer flange was removed, revealing accumulated dirt and grease.

The fracture surface was consistent with formation of a fatigue crack followed by fast fracture. A fatigue crack was observed at the bottom of the axle. Chevron marks consistent with crack propagation under loading were observed traversing around the forward and aft sections of the axle meeting at the top. Crack arrest marks were visible consistent with multiple intermittent loading cycles. Ratchet marks consistent with multiple crack initiation sites were observed. A brown/blue subsurface layer was visible on the fracture surface just below the chrome plating. This subsurface layer was observed around the entire perimeter of the axle.

The morphology of the subsurface layer was consistent with intergranular fracture when viewed by scanning electron microscopy (SEM). A micrograph of the fracture surface in the vicinity of the fatigue region shown that underneath the chrome layer was a region with a faceted fracture surface that extended approximately 0.3 mm into the axle cross section. The appearance of the surface was consistent with intergranular fracture. Beneath the intergranular zone, the fracture surface transitioned into the fatigue region at the bottom of the axle. The intergranular zone was observed along the forward, aft, and top regions of the axle.

The chrome plated journal showed signs of burnishing around the entire circumference of the journal and was most pronounced at the bottom of the axle. Burnishing marks could be seen running circumferentially around the journal. Cracks through the chrome layer were visible by the unaided eye in the burnished regions.

A longitudinal section was excised from the journal and a metallurgical cross section was prepared. In the vicinity of the fracture surface, cracks were observed in the chrome that extended between 0.2 mm and 0.8 mm into the low alloy steel substrate. The nital etch also

revealed a thin white layer just below the chrome that was 0.02 mm deep.

The extent of untempered martensite formation on the inboard journal was revealed by removal of the chrome followed by macroetching of the exposed low alloy steel surfaces. The chrome was electrochemically removed and the exposed low alloy steel surfaces were etched.

A 0.5 inch wide white etched band was observed on the outboard end of the journal on the aft section. The white etched band was consistent with the appearance of untempered martensite in macroetched low alloy steels. Dark gray etched bands were observed on either side of the white etched band consistent with the appearance of overtempered martensite in low alloy steels. The region furthest inboard on the journal covered by the bearing spacer had a medium gray appearance consistent with tempered martensite. Circumferential wear marks were observed in the chrome layer as indicated. The boundaries of the wear marks did not correlate with the boundaries of the etched layers. The white band observed on the aft section of the journal extended to the top section of the journal and the width increased to 0.67 inch as shown in figure 11. It then gave way to a dark gray etched region as the band extended around to the forward section of the journal as shown.

Discussion

The fracture of the right side inboard journal on the nose landing gear inner cylinder assembly was most likely due to the failure of a prior tapered roller bearing. This failure set into motion a series of processes that ultimately led to fatigue fracture of the inboard journal. The change in ownership of the plane and the monthly swapping of bearings and wheels make it difficult to determine when the bearing failure occurred or why. The cracks in this instance were visible to the unaided eye with adequate illumination.

Based on the results of the examination, the sequence of events leading to the fatigue fracture is: When the bearing failed, the inner race would have started spinning on the chrome plated journal. The heat generated by this friction would have been sufficient to heat the chrome and a shallow depth of the underlying low alloy steel substrate. Some regions were heated above the temperature at which a phase transformation from tempered martensite to austenite occurred . Subsequent rapid cooling promoted the formation of untempered martensite which etched white. Other regions were heated only to temperatures above approximately 600 °F, resulting in overtempered martensite which etched to a darker shade of gray.

The rapid heating and cooling, phase changes, and mechanical stresses induced a network of cracks that telegraphed through the chrome layer. It is possible that moisture subsequently worked its way into the cracks resulting in stress corrosion/hydrogen cracking, which produced the 0.2 mm to 0.8 mm deep intergranular fracture regions observed in the longitudinal cross section and scanning electron microscope (SEM).

The intergranular cracks acted as stress concentrators from which fatigue cracks emanated and ultimately combined to form the single thumbnail-shaped fatigue crack. Eventually the size of the fatigue crack and the forces generated during landing were sufficient to drive the crack in overstress leading to fracture of the inboard journal.

There was no evidence of manufacturing defects contributing to the fracture. The inboard and outboard journal diameters were within the specified tolerance band. If grinding burns had occurred during manufacturing, the burn would have appeared over the entire width of the journal. However the burn mark was localized to the portion of the journal underneath

the bearing.

History of Flight

Taxi-from runway	Aircraft structural failure Landing gear collapse (Defining event)

Aircraft and Owner/Operator Information

Aircraft Manufacturer:	BOEING	**Registration:**	N551WN
Model/Series:	737 -76Q	**Aircraft Category:**	Airplane
Year of Manufacture:		**Amateur Built:**	
Airworthiness Certificate:	Transport	**Serial Number:**	30280
Landing Gear Type:	Retractable - Tricycle	**Seats:**	145
Date/Type of Last Inspection:	Continuous Airworthiness	**Certified Max Gross Wt.:**	154000 lbs
Time Since Last Inspection:	3 Hours	**Engines:**	2 Turbo Fan
Airframe Total Time:	21206 Hours	**Engine Manufacturer:**	CFM
ELT:	Not installed	**Engine Model/Series:**	CFM56-7B22
Registered Owner:	Wells Fargo	**Rated Power:**	
Operator:	Southwest Airlines, Co.	**Air Carrier Operating Certificate:**	Flag carrier (121)
Operator Does Business As:	Southwest Airlines	**Operator Designator Code:**	SWAA

Meteorological Information and Flight Plan

Observation Facility, Elevation:		**Observation Time:**	
Distance from Accident Site:		**Condition of Light:**	
Direction from Accident Site:		**Conditions at 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:	Kansas City, MO (MCI)	**Type of Flight Plan Filed:**	IFR
Destination:	Chicago, IL (MDW)	**Type of Clearance:**	IFR
Departure Time:	0943 CDT	**Type of Airspace:**	

Airport Information

Airport:	Chicago Midway (MDW)	**Runway Surface Type:**	Concrete
Airport Elevation:	620 ft	**Runway Surface Condition:**	Dry
Runway Used:	31C	**IFR Approach:**	Unknown
Runway Length/Width:	6522 ft / 150 ft	**VFR Approach/Landing:**	Unknown

Wreckage and Impact Information

Crew Injuries:	5 None	**Aircraft Damage:**	Minor
Passenger Injuries:	128 None	**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	133 None		

Administrative Information

Investigator In Charge (IIC):	Deepak Joshi	**Adopted Date:**	03/23/2010
Additional Participating Persons:			
Publish Date:	03/23/2010		
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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