

Investigation Report

Identification

Type of Occurrence:	Serious incident
Date:	17 August 2007
Location:	Munich Airport
Aircraft:	Transport aircraft
Manufacturer / Model:	Airbus / A 330-200
Injuries to Persons:	None
Damage:	Minor damage to aircraft
Other Damage:	Taxiway surface
State File Number:	BFU EX007-0/07

Factual Information

While initiating a turn during taxiing to the runway the bogie beam of the right main landing gear fractured behind the shock absorber.

History of the Flight

At 1550 hrs¹ the airplane left parking position 113 at Terminal 1 and taxied across Apron West. The taxiways Oscar 1, Charly 4, and entrance Sierra 6 to runway 26L were used. At about 1600 hrs the airplane left entrance Sierra 6 and initiated a left-

¹ All times local, unless otherwise stated.

hand turn to taxiway Sierra. During the turning movement the bogie beam of the right main landing gear fractured behind the shock absorber.

The immediate braking action stopped the airplane right behind the bend. The 244 passengers and 15 crew members left the airplane on the taxiway uninjured via the provided stairs.



Image 1: Taxiway Sierra

Personnel Information

The Pilot in Command (PIC) held an Airline Transport Pilot's Licence (ATPL (A)) issued in accordance with ICAO. It was initially issued in 1994 by the General Civil Aviation Authority of United Arab Emirates (UAE). He held a class 1 medical certificate.

The co-pilot held a Commercial Pilot's Licence (CPL(A)) issued in accordance with ICAO. The licence was initially issued by the General Civil Aviation Authority of United Arab Emirates. The co-pilot held a class 1 medical certificate.

Aircraft Information

The aircraft type Airbus A330-200 is a transport aircraft equipped with two Rolls Royce Trent 772B-60 engines. The airplane was manufactured in 2000 and had the manufacturer's serial number 328 and was registered in the UAE.

Maximum take-off mass was 233,000 kg. At the time of the serious incident the aircraft had a take-off mass of 198,631 kg.

The airplane was equipped with a nose landing gear and two main landing gears underneath the wings. The fractured bogie beam had been manufactured in November 1999 and until the fracture had accumulated a total operating time of 32,616 flight hours at 8,682 cycles.

Meteorological Information

It was daylight with broken clouds. Wind velocity 170°, 4 kt. Ground visibility was more than 10 km.

Communication

There were radio transmissions with Munich roll control.

Aerodrome information

Munich Airport has two parallel concrete runways. Both runways with the designations 08L/26R and 08R/26L are 4,000 m long and 60 m wide. The three aprons and the taxiways also have concrete pavements.

Flight Recorder

The Flight Data Recorder (FDR) and Cockpit Voice Recorder (CVR) were seized by and read out at the BFU.

Wreckage and Impact Information

A spot of hydraulic fluid and an impact spot were found in the intersection of entrance Sierra to taxiway Sierra. Beginning at this impact site and all along the turn radius a deep groove was visible. This groove was 42.8 m long and up to 3 cm deep.

The airplane stood on taxiway Sierra behind the intersection Sierra 6 pointing in 082°. It had tilted right. The right engine and the right wing did not have ground contact. The bogie beam of the right main landing gear had fractured into two parts. The fracture had occurred approximately 90 mm behind the pivot pin, which connects the shock absorber with the bogie beam. Due to the fracture the aft part of the bogie beam including the aft axle and the aft wheels had been completely severed. Only two brake rod linkages connected the aft part of the fractured bogie beam, aft axle and aft wheels to the rest of the landing gear. The airplane had come to a halt with the right main landing gear shock absorber sliding tube clevis fork legs contacting the taxiway surface.

Because the fracture of the landing gear was the cause for the serious incident further examinations concentrated on the fracture of the bogie beam.

The bogie beam was cylindrical in shape. On its two ends were two sockets where the wheel axles were located. The bearing seat for the pivot pin was located in the middle of the bogie beam.

An initial on-site examination of the bogie beam's fracture revealed that the fracture had its origin in the 6-o'clock position of the bogie beam main bore. The paint on the inside of the bogie beam bore at the bottom was in places locally missing. The two fracture surfaces showed some damages due to dragging along the taxiway surface. The lower edge of the outer diameter was abraded on both sides of the fracture surface. The lower ends of the landing gear shock absorber sliding tube clevis fork legs and the brake linkage were also abraded. The brake hoses for the aft wheels had been torn off. Different substances such as lubricants and contaminants were found inside the bogie beam bore. Images 2 and 3 show the fracture surfaces.



Image 2: Front part of the bogie beam including pivot pin

Source: BFU



Image 3: Aft part of the bogie beam including aft wheels

Source: BFU

After this initial visual on-site examination, the two bogie beam parts were disassembled and the fracture surfaces sealed. Then they were sent to Great Britain, where further examinations were conducted under the supervision of the Air Accidents Investigation Branch (AAIB) at facilities of the landing gear manufacturer.

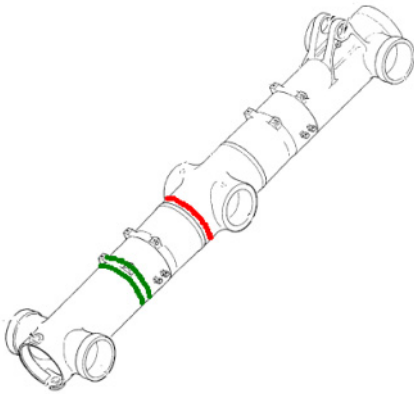


Image 4: Drawing of the bogie beam; red line indicates the fracture level

Source: Manufacturer

Samples of the contaminants at the inside of the bogie beam were taken. Then the bogie beam was cleaned around the fracture surfaces. This revealed that the paint had in places locally come off or was missing. In some places, the paint had a rough surface or had begun to blister. In locations where the paint was missing a galvanic coating was visible. This was cadmium plating. The surface of the material in the immediate vicinity of the crack origin, approximately 50 mm by 50 mm, was devoid of paint and cadmium plating and corroded.

Further samples of lubricants, paint, and contaminants from different places on the inside of the bogie beam bore were taken. It was easier to remove the paint in the corroded areas than in other areas farther away.

Non-destructive testing showed no indications of other crack formations. Examinations of the material showed that it had not been subject to over-stress during manufacture and had low internal stress. Material samples were taken in order to conduct tensile tests. The results met the material specifications.

The fracture surface was examined under an optical microscope (30-times magnified) and the fracture origin located on the surface at the bottom of the bogie beam bore. Image 6 shows the corrosion pit, which was the cause of the crack.



Image 5: Fracture with point of origin

Source: BFU

The corrosion pit had a total depth of 0.669 mm and at its surface a diameter of 1.534 mm. The fracture surface surrounding the pitting corrosion showed indications of intergranular fractures with the characteristic thumb nail shape. The length of the shear lips was 10.506 mm and fracture bands of a depth of up to 6.4 mm were found. Stress corrosion was the mode of crack propagation.

The surface of the rest of the fracture showed a ductile appearance. The wall thickness, as shown in the Images 5 and 7, was thinner than the original, because part of the outer radius had been abraded by dragging along the taxiway surface.

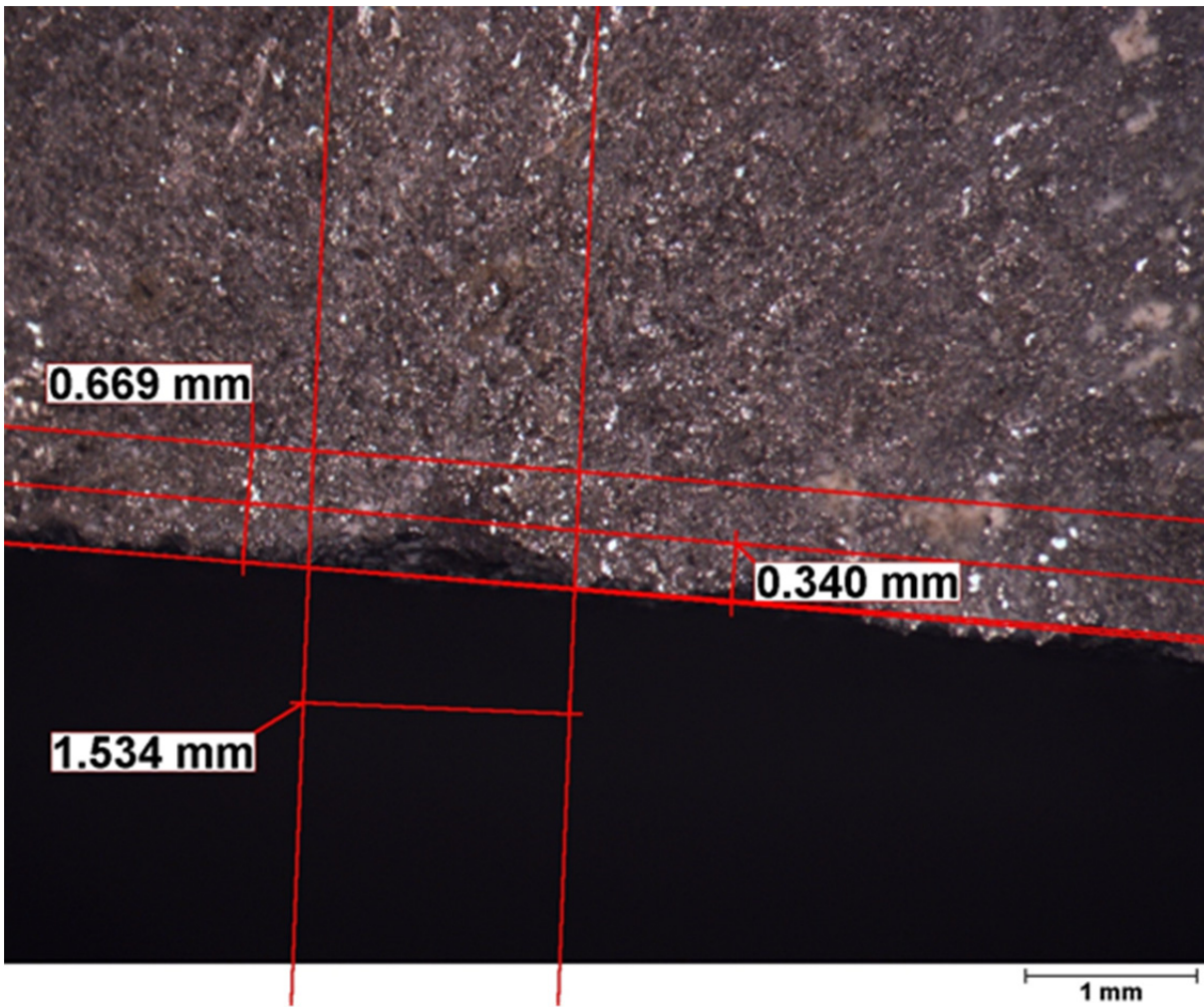


Image 6: Fracture origin at the bogie beam bore

Source: Manufacturer

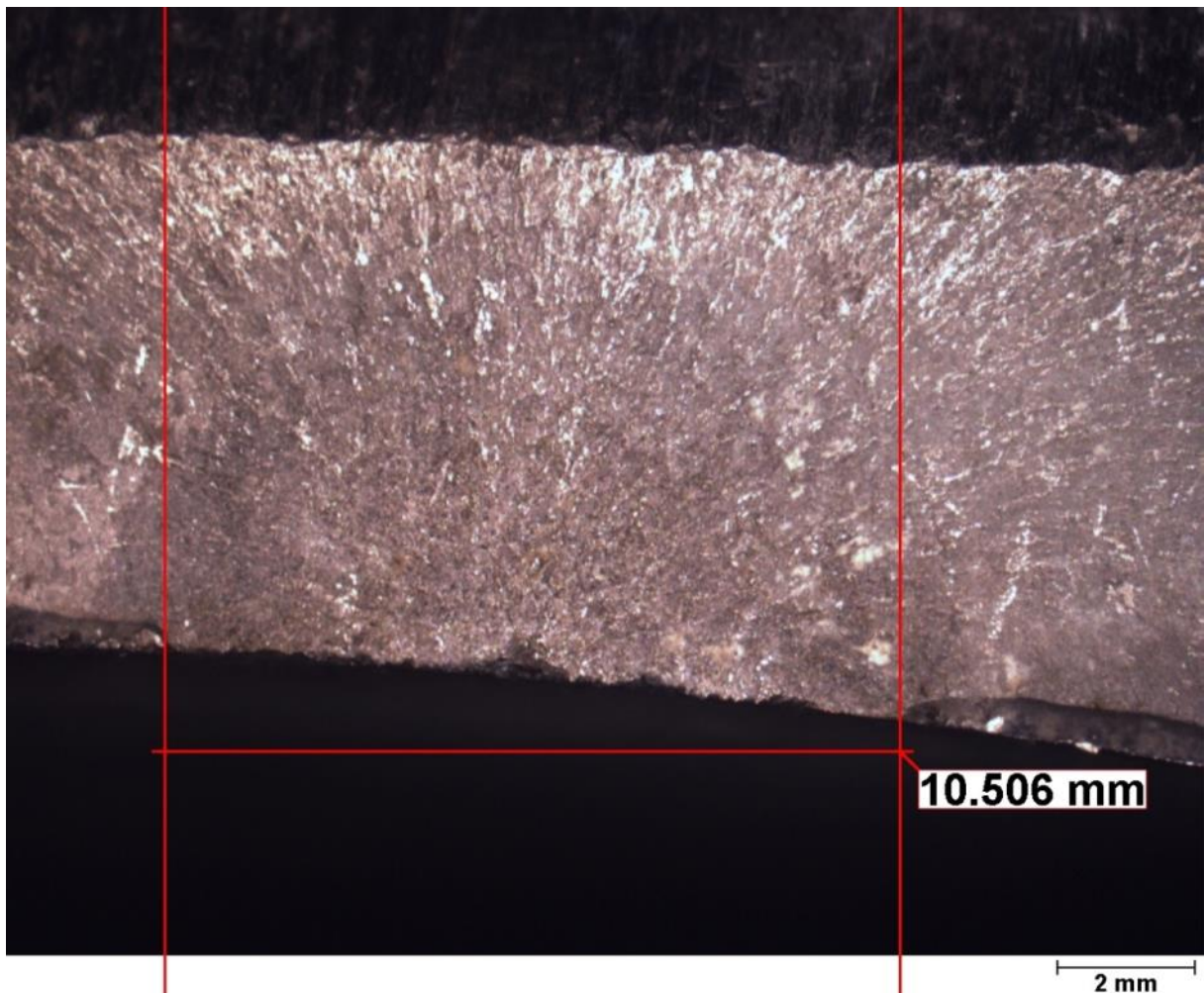


Image 7: Fracture point of origin with shear lips at the bogie beam bore

Source: Manufacturer

The images taken with the scanning electron microscope confirmed the results of the optical microscope.

After the investigation of the fracture revealed the above-mentioned facts, the focus of the investigation then changed to the corrosion protection of the bogie beam bore. The local area of the fracture origin did not have any remaining corrosion protection. In some places on the inside of the bogie beam bore the paint had locally begun to blister. Opening some of the blisters showed that at these places the paint had separated from the cadmium plating.

According to the design specifications the corrosion protection had several layers, see Chapter Additional Information. Measurements of the thicknesses of the paint layers at the edge of the local area of missing corrosion protection, around the fracture origin, revealed that all three layers were thinner than specified or in some places non-existent. This was also confirmed at measurement points at the front part

of the bogie beam. The measurements also revealed that the layer thicknesses in the 6-o'clock position were thinner than in the 12-o'clock position. The fracture area, i.e. the bogie beam bore adjacent to the pivot pin, showed the heaviest degradation of the corrosion protection.

During paint adhesion tests on the inside of the bogie beam bore, in the fracture area and the bore adjacent to the pivot pin, the paint came off very easily. All other areas had a good adhesion test result.

The analysis of the samples taken from the contaminants on the inside of the bogie beam showed that the lubricant used was Nyco 22 grease. The major part of the contamination consisted of the lubricant. In addition, traces of Skydrol (hydraulic fluid) were found, which could be traced to the brake hoses, which had ruptured. The contaminations also contained sand. Water content of the contaminants was below 1 %. The acidity of the lubricant was typical.

Fire

There was no fire.

Tests and Research

After the fracture mechanism and its cause, the corrosion, had been determined the corrosion protection was examined in detail. Three different test procedures were performed using corrodible steel panels. In the first test painted and oven-cured panels were semi-immersed in distilled water or contaminants such as de-icing fluid for 2 weeks at 70° C. This is a standard test procedure used by paint suppliers to verify product quality. The second test consisted of pressure cooker testing, where painted and oven-cured panels were subjected to 25 of 1-hour cycles exposed to distilled water at 117°C. This test has been defined as an accelerated test, trying to simulate similar paint degradation effects as those resulting from prolonged exposure to moisture over months/years in service. The third test consisted of salt spray testing; the objective was to determine whether any degradation of the paint would accelerate the onset of corrosion of the panel's base metal.

Tests were performed on the 3-coat paint scheme (wash primer, primer and top coat) as used on the incident bogie beam and on a 2-coat paint scheme (primer and top coat) as used in the current production bogie beam.

The tests regarding the degradation of the paint scheme showed the following results:

Prolonged exposure to moisture is associated with the formation of blisters in the paint scheme.

Rough cadmium plating resulted locally in thin paint layers.

Contamination of the cadmium plating prior to painting resulted in severe blistering of the paint.

The presence of lubricants did not degrade the paint scheme, but moisture trapped by lubricants resulted in staining and the creation of small blisters in the paint scheme.

Exposure to glycol-based de-icing fluids resulted in severe blisters in the paint scheme.

Exposure to formate-based de-icing fluids only resulted in staining of the paint scheme.

Exposure to the cleaning product Aeroclean CD1 used on the aircraft involved resulted in chemical attack of the paint.

The samples of lubricants and contaminants taken from the bogie beam, showed no evidence of the presence of either glycol-based de-icing fluids or cleaning products.

Additional Information

The type of main landing gear and its bogie beam which fractured was fitted to the aircraft types Airbus A330 and Airbus A340.

Corrosion Protection Scheme

The fractured bogie beam bore had a 3-coat layered paint scheme for corrosion protection, consisting of a wash primer paint, a primer paint and a top coat paint. Initially, in a galvanic bath the high strength steel was covered with a layer of cadmium plating. According to the technical drawing it should have a thickness of 10 to 20 μm . Then a 3-coat paint scheme was applied. According to the technical drawing the wash primer paint was 9 to 12 μm thick. Then the primer paint was applied in two coats with a thickness of 30 to 40 μm , according to the technical drawing. The final layer was top coat paint with a required thickness of 40 to 50 μm .

In addition, on the inside of the bogie beam bore Ardrox 3140 dewatering oil corrosion protection was applied.

At the time of the serious incident this paint scheme had already been modified for the current production to a 2-coat paint scheme. This paint scheme does not include a wash primer; the primer paint is applied directly on the cadmium layer followed by top coat paint. The primer is applied in -two coatings and had, according to the technical drawing, a required thickness of 40 to 50 μm . The top coat had a required thickness of 40 to 50 μm . In addition, on the inside of the bogie beam bore Ardrox AV100D wax oil corrosion protection is applied.

Initial Actions

During the initial examination, local places at the inside of the bogie beam bore were found, where the paint had come off and corrosion developed. Therefore, an inspection program was established for in-service bogie beams. The landing gears of the incident aircraft operator's Airbus A330/340 fleet, having the same 3-coat paint scheme as the fractured bogie beam, were inspected in accordance with their service time. The focal point of the inspection was the condition of the corrosion protection of their bogie beam bore. Depending on the condition of the corrosion protection local material repair actions or bogie replacements were required.

As an immediate action, in the production the thicknesses of the individual layers (cadmium and paint) of the protective treatment were measured.

Analysis

The investigation showed that intergranular stress corrosion cracking caused the fracture of the bogie beam. Pitting corrosion constituted the origin of the crack. The corrosion developed at the bottom of the bogie beam bore adjacent to the pivot pin in the centre of the bogie beam. In this area, there were local places, where corrosion protection was non-existent and corroded steel visible. Once the crack had developed it propagated and created arrest marks until the critical cross section had been reached and then fracture occurred by ductile rupture. The high stress during the taxi turn, which such a manoeuvre creates in a landing gear in double-tandem configuration, aided the fracture of the landing gear.

After the origin of the fracture and its cause had been determined, further investigation focused on the local degradation and detachment of the corrosion protection. The examination of other in-service main landing gear bogie beams showed that this was no isolated case.

In the fractured bogie beam mainly the inside bottom of the main bore fore and aft of the pivot pin was affected by local paint degradation and detachment. In this area blistering of the paint had occurred. The insides of the paint blisters showed an image of the cadmium layer from which they had detached. In some of these blisters cadmium residue was found, but not in all of them. The topography of the cadmium residue did not always mirror the topography of the steel surface. Therefore it has to be assumed that after plating in the galvanic cadmium bath the entire inner diameter was covered with cadmium. It is highly likely that parts of the cadmium, which were locally missing, had degraded in-service and then disappeared due to sacrificial corrosion depletion.

During the investigation the thicknesses of the corrosion protection layers were measured. Different places on the inside of the bogie beam bore were chosen for the measurements. It was determined that the layers at the measurement points at the bogie beam bore bottom (6-o'clock position) in the vicinity of the pivot pin and at the edges of the corroded areas were thinner than the specified thickness values. The specified values were met at measurement points 400 mm behind the fracture. The results of the measurement points of the inner diameter of the bogie beam allowed the conclusion that during the production process the specified thickness values were not always met. Further examinations and tests showed that in local places, where the wash primer was missing, corrosion protection was not fully provided.

The examination of the individual contaminants, taken from the inside of the bogie beam bore, and the tests with the de-icing and cleaning agents showed different effects on the corrosion protection.

The degradation of the corrosion protection was caused by a combination of several factors: environmental influences, use of agents necessary for the operation of the airplane, and the incomplete paint scheme in some areas. In some areas this resulted in local degradation and detachment of the paint scheme. As a result, the cadmium layer was exposed and in places had locally disappeared due to sacrificial corrosion depletion. Subsequently, the steel was locally unprotected against corrosion leading to corrosion pitting, stress corrosion cracking, which resulted in this fracture mode.

Conclusions

Pitting corrosion constituted the origin for the fracture. The crack propagated in an intergranular mode from there until the ductile rupture occurred. Crack initiation and propagation occurred through stress corrosion.

Cause for the corrosion in the fracture area was the local loss of the corrosion protection layers by degradation and detachment of the paint and sacrificial corrosion depletion of the cadmium plating.

Safety Recommendation

The BFU refrains from issuing safety recommendations, because right after the commencement of the investigation the landing gear manufacturer implemented a corresponding one time inspection program of in-service bogie beams. The landing gear manufacturer described the inspection checks in the Service Bulletins (SB) A33/34-32-271 and SB A33/34-32-272. The aircraft manufacturer used these for its SB A330-32-3212 (for the aircraft type A330) and SB A340-32-4268.

These SBs were then the basis for the Airworthiness Directive (AD) No. 2007-0314 of the European Aviation Safety Agency (EASA) and therefore became mandatory for the A330 and A340 fleets.

Subsequently, further EASA ADs were issued to extended the applicability of the one-time inspection to other A330 and A340 aircraft variants, introduce repetitive inspections and a terminating modification to improve paint application method,

introduce the two coat paint scheme and apply a wax oil corrosion protection to the bogie beam. The requirements of these Ads are now defined in, or superseded by, EASA AD No: 2013-0267R1.

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Braunschweig 31 July 2017

This investigation was conducted in accordance with the regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and the Federal German Law relating to the investigation of accidents and incidents associated with the operation of civil aircraft (*Flugunfall-Untersuchungs-Gesetz - FIUUG*) of 26 August 1998.

The sole objective of the investigation is to prevent future accidents and incidents. The investigation does not seek to ascertain blame or apportion legal liability for any claims that may arise.

This document is a translation of the German Investigation Report. Although every effort was made for the translation to be accurate, in the event of any discrepancies the original German document is the authentic version.

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