AAIB Bulletin No: 2/2005 **Ref: EW/C2003/08/11** **Category: 1.1**

INCIDENT

Aircraft Type and Registration:	Airbus A320-200, C-FTDF
No & Type of Engines:	2 IAE V2500-A1 turbofan engines
Year of Manufacture:	1993
Date & Time (UTC):	3 August 2003 at 2325 hrs
Location:	Cardiff International Airport, South Glamorgan
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 7 Passengers - 162
Injuries:	Crew - None Passengers - None
Nature of Damage:	Rupture of three main landing gear tyres and damage to a landing gear light
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	28 years
Commander's Flying Experience:	7,500 hours (of which 1,700 were on type) Last 90 days - 140 hours Last 28 days - 50 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot plus additional inquiries and data analysis by the AAIB and the aircraft operator

Synopsis

The aircraft was landing on Cardiff's Runway 30. On finals, the Electronic Centralized Aircraft Monitoring (ECAM) display showed a STEERING caption and the crew cycled the A/SKID & N/W STRNG switch in an attempt to reset the Brake and Steering Control Unit (BSCU). The indications were that it was successfully reset but after touchdown the aircraft did not decelerate normally. The commander pressed the brake pedals to full deflection without effect. He then selected maximum reverse thrust and the co-pilot cycled the A/SKID & N/W STRNG switch. The commander again attempted pedal braking, without effect, and the crew selected the A/SKID & N/W STRNG switch to OFF. The commander then braked to bring the aircraft to a halt about 40 metres from the end of the runway, bursting three mainwheel tyres. There was no fire and the passengers were deplaned on the runway through the normal exit doors.

Analysis showed that it took 10 to 13 seconds for the commander to recognise the lack of pedal braking and there was no overt warning from the ECAM of the malfunction of the BSCU. Two safety recommendations were made to the aircraft manufacturer regarding improved warnings and crew procedures.

History of the flight

The aircraft was returning to Cardiff from Tenerife. The winds at Cardiff Airport were light, there was no cloud and the visibility was good. The air temperature was 15°C and the runway was dry. At the time of the occurrence the crew had been on duty for approximately 10 hours.

Before the descent, the commander had briefed for an ILS approach to Runway 30 and, to comply with local noise abatement procedures, to use only idle reverse thrust after landing. The published landing distance available for this runway is 2,201 metres and the crew selected LOW autobrake. The descent and initial approach were uneventful and, after interception of the localiser and the glideslope at 2,000 feet, the expected 'CAT III DUAL' caption illuminated and the landing gear was selected DOWN at approximately 1,700 feet.

At about 1,000 feet on the final approach to Runway 30, the aircraft's approach status changed to the downgraded 'CAT III SINGLE' (where a single system failure will terminate the automatic approach) and the crew noted that the WHEEL page on the ECAM (Electronic Centralized Aircraft Monitoring) display showed the 'STEERING' caption in amber. The crew cycled the 'anti-skid & nosewheel steering' switch (A/SKID & N/W STRNG) whereupon the WHEEL page indications returned to normal, with the approach status returning to 'CAT III DUAL'. The commander could not later recall whether or not the crew reselected autobrake after the cycling the switch.

The aircraft landed normally and idle reverse thrust was selected. However, the aircraft did not appear to be decelerating normally and the first officer announced "Manual Braking" because the autobrake panel showed that autobrake was not functioning. The commander pressed the brake pedals progressively "all the way to the floor" but sensed no braking response and so he then selected maximum reverse thrust. Next he instructed the co-pilot to cycle the A/SKID & N/W STRNG switch. Once this had been done, the commander tried the brake pedals again and, with no retardation response, he ordered the co-pilot to turn the A/SKID & N/W STRNG switch to OFF, in order "to get alternate braking pressure from the hydraulic accumulator". He then applied sufficient wheel braking to stop the aircraft on the paved surface, coming to a halt about 40 metres from the end of the runway. In achieving this braking, however, three tyres of the main landing gear burst and the fourth was badly scuffed.

After the aircraft stopped the commander advised the cabin crew to remain seated and contacted the control tower for the emergency crews to check for smoke around the main wheels. The emergency personnel confirmed that there was no need for an emergency evacuation and the crew and passengers left the aircraft 15 minutes later, without further incident. The aircraft remained on the runway for about 3 hours after the incident as wheels and tyres needed replacement before the aircraft could be safely moved.

Systems description

In the A320 the wheel brakes operate on two separate and independent systems. The 'normal' system uses 'green' hydraulic pressure and the 'alternate' system uses 'yellow' hydraulic pressure, backed by a hydraulic accumulator.

Anti-skid and autobrake functions are controlled by a two-channel Brake and Steering Control Unit (BSCU), a computer which transmits brake commands either from the pilots' brake pedal positions or from the autobrake system. Autobrake is armed by the crew through a push-button panel on the flight deck and operated in MAX (maximum, for rejected takeoffs), MED and LOW (medium and low, for landings). In LOW setting, autobrake applies brake pressure four seconds after spoiler deployment on landing and has a target deceleration rate of 5.6 ft/sec/sec (0.17g).

There is an 'anti-skid & nosewheel steering' switch (A/SKID & N/W STRNG) with simple 'ON' and 'OFF' selections. With this switch OFF there is no anti-skid protection to the brakes and pilots should refer to the triple pressure indicator (showing left, right and accumulator), keeping brake pressures at the wheels to below 1,000 psi to prevent the tyres from skidding and bursting.

The wheel braking system can operate in four modes:

1) Normal braking - with autobrake available and anti-skid operating (Green hydraulic system).

2) Alternate braking with anti-skid - pedal braking by crew with anti-skid operating (Yellow hydraulic system).

3) Alternate braking without anti-skid - pedal braking by crew with no anti-skid, either due to BSCU failure and/or A/SKID & N/W STRNG switch OFF. Crew maintain brake pressures below 1,000 psi to avoid locking a wheel.

4) Parking brake - primarily used for aircraft parking but this may be used as an emergency brake in short and successive applications.

Note: The triple brake pressure gauge does not indicate wheel brake pressure when the brakes are operating in 'normal' mode, hence the operation of the wheel brakes cannot always be determined by inspecting the gauge.

Technical examination

After the incident at Cardiff the BSCU from C-FTDF was returned to the manufacturer of the brake system and subjected to an extensive investigation, including tests to reproduce the fault codes triggered during this event. The investigation included repetitive flight cycle simulations, hot and cold soaking and the application of a range of conditions designed to induce BSCU faults. In spite of this testing, the manufacturer was unable to repeat the fault conditions which were recorded in flight by the BSCU built-in test equipment (BITE), the Central Fault and Display System (CFDS) and the Flight Data Recorder (FDR). However, a 'micro-cut' test of the BSCU (a power interruption test where electrical power is removed for very short periods) did reveal a problem in the separate power supplies for both BSCU channels and it is likely that this was related to the faults recorded.

Flight recorders

The CVR was recovered from the aircraft but had overrun and the recording did not include either the approach or the landing.

Data from the FDR was analysed by the aircraft manufacturer and the analysis agreed with the sequence of events reported by the pilots. On the approach, data was lost from the BSCU (as indicated by the brake pedal position transducers and 'autobrake fault' parameter) for a period starting 53 seconds before touchdown, corresponding to the airborne cycling of the A/SKID & N/W STRNG switch at about 1,000 feet. The changes at about this time in the discrete autobrake parameters indicate that the cycling of the switch resulted in a change of active channel in the BSCU and the loss of autobrake arming.

The FDR traces showed that, after the touchdown, the spoilers extended in about two seconds and reverse thrust was initiated at the same time. The deceleration rose to 0.18g in the six seconds after touchdown, due to the spoilers and idle reverse thrust, but, by the time the pilot brake pedal inputs started (eight seconds after touchdown), the rate of deceleration was reducing. The brake pedals were progressively applied over a period of 10 seconds to maximum and back to zero deflection over the next three seconds. This confirms that pedal braking was not effective, even at large deflections. The decline in deceleration rate was arrested 19 seconds after touchdown with the application of maximum reverse thrust by the crew, which alone resulted in the deceleration rate reaching 0.19g. Evidence of pedal braking was apparent 28 seconds after touchdown, with a rapid rise in longitudinal

deceleration to about 0.4g, punctuated by three sharp 'spikes', probably corresponding to the rupture of the three mainwheel tyres. The aircraft came to rest 50 seconds after touchdown.

Data was again lost from the BSCU for a period starting 23 seconds after touchdown (at about 78 kt ground speed), consistent with the crew's reported cycling, and then turning off, the A/SKID & N/W STRNG switch. Effective pedal braking was apparent at 28 seconds after touchdown, five seconds later.

A simple analysis of the available FDR traces by the AAIB indicated that the runway distance covered during the 10 seconds of the gradual initial application of pedal braking was some 590 metres. The analysis also showed that this would have been reduced if full reverse thrust had been selected with the initial application of pedal braking. By comparison, the cycling of the A/SKID & N/W STRNG switch covered about 120 metres of runway, as it occurred over a much shorter period and at a lower ground speed.

Procedure

For a loss of braking action, the following actions are detailed in the operator's FCOM (flight crew operating manual) as memory items:

LOSS OF BRAKING

- **IF AUTOBRAKE IS SELECTED**:
  - BRAKE PEDALS ..... PRESS
    (this will override the autobrake)

- **IF NO BRAKING AVAILABLE**:
  - REV ..... MAX
  - BRAKE PEDALS ..... RELEASE
  - A/SKID & N/W STRG .....OFF
    (braking system reverts to alternate mode)
  - BRAKE PEDALS ..... PRESS
  - MAX BRK PR .....1000 PSI

- **IF STILL NO BRAKING**:
  - PARKING BRK ..... SHORT AND SUCCESSIVE APPLICATIONS

Commander's comments

The commander had filed the appropriate safety reports following the incident. He was contacted by the AAIB later for additional comments, following the analysis of the technical information.

Concerning the cycling of the A/SKID & N/W STRNG switch at about 1,000 feet, the commander commented that, had the action not been effective in removing the amber STEERING caption on the ECAM display, he would have performed a missed approach. He was uncertain as to whether the crew had then re-armed the autobrake for the landing.

The first officer's "Manual braking" call had surprised the commander. Concerning his initial response, he commented that, in an aircraft which provides a wide range of visual and aural warnings, the lack of a compelling ECAM warning suggested to him at the time that any autobrake discrepancy would be a problem with the selector switch rather than with the braking system. Regarding the 10 seconds from initial application of brake pedals to full deflection, he commented that this was partly due to concern for passenger comfort and the sensitivity of the A320 pedal brakes, partly his sense that this was just a switch discrepancy, and partly that this was happening at the end of a long duty day. It was only during the last stages of pedal deflection that he realised that he had a serious braking problem.

On his decision to order the cycling of the A/SKID & N/W STRNG switch, before selecting it OFF, the commander agreed that it did not match the memory drill but, after successfully cycling the switch on approach, he had been reluctant to lose the steering function on the runway. He also confirmed that this had added only about two seconds before the switch was selected OFF and braking became available through the pedals.

Analysis

The evidence recorded by the Brake and Steering Control Unit (BSCU) built-in test equipment (BITE), and other onboard systems, showed that the initiating factor in this incident was the behaviour of the BSCU. It has not been possible fully to explain this behaviour. But it is important to consider how, in good weather conditions and on an adequate runway, an overrun nearly occurred despite a 'memory item' drill designed to prevent it. One consequence of the lack of wheel braking during the major portion of the aircraft's ground roll was that the crew then applied pedal braking sharply and quickly burst three of the four tyres on the main landing gear. With the A/SKID & N/W STRNG switch at OFF, as the aircraft slowed, the commander's ability to maintain directional control was reduced and there was a potential for a runway excursion.

Following the cycling of the A/SKID & N/W STRNG switch in the air, permitted in the procedures, it appeared from the DFDR trace that the LOW autobrake arming was lost. This is consistent with the change of BSCU channel that would occur with this cycling.

In ordering the cycling of the A/SKID & N/W STRNG switch on the runway, when it became apparent that pedal braking was having no effect, the commander delayed the onset of substantial pedal

braking. This braking became available when the A/SKID & N/W STRNG switch was then selected OFF. The cycling of the switch while in motion on the ground is not recommended in the FCOM and the 'Loss of Braking' procedure requires that, if no braking is available, this switch should be selected OFF. However, the FDR data showed that only five seconds elapsed between what appears to have been the start of the switch cycling and the achievement of substantial pedal braking. As the brakes should be applied gently in 'alternate mode without anti-skid', the time spent in cycling this switch was less than five seconds and likely to have been close to the two seconds estimated by the commander. The simple analysis of the FDR data indicated that only about 120 metres of runway were covered during this cycling of the switch.

A greater distance along the runway (some 600 metres) was traversed without wheel braking during the 10 to 13 seconds of the commander's initial pedal application, both because of the greater elapsed time and the higher ground speed. The commander's later comments indicate that factors in this relatively slow response were the lack of ECAM warning, concern for passenger comfort with sensitive pedal brakes and the effects of a long duty day. An additional factor in recognising the lack of pedal effect may have been that the aircraft was already decelerating from the effect of idle reverse thrust and the initial level of this deceleration (about 0.18g) was close to the target level (0.17g) automatically set for the LOW autobrake setting.

Analysis of the time and distance performance of C-FTDF in its landing roll therefore shows that a major factor in the near overrun was the low deceleration level (at idle reverse thrust) during the initial period the commander was attempting to apply pedal braking. The deceleration rate would have been significantly enhanced by earlier application of maximum reverse thrust. Crews may at times encounter a conflict between local airfield noise abatement procedures and the need to use greater than idle reverse thrust. The implications of delaying the selection of full reverse thrust when wheel braking appears to be less effective than anticipated can be punitive.

Conclusions

A number of factors were present in the crew's delayed recognition of the failure of the braking system, including its occurrence at the end of a long duty day. A major contributory factor was the lack of warning of the BSCU system problem to the crew because the Flight Warning Computer (FWC) does not provide active monitoring of the BSCU.

The records of typical UK operators of A319/320/321 aircraft indicate that 'loss of braking' events immediately following touchdown are infrequent. However, over a three-year period one UK operator of A320 aircraft reported a total of five ASRs (Air Safety Reports) featuring apparent failure of the braking system during landings. These incidents are potentially very hazardous, as shown in the report into the accident to a UK-registered Airbus A320-212, G-UKLL, at Ibiza Airport

on 21 May 1998. This accident, where the aircraft substantially overran the runway and was steered into an earth embankment to avoid the sea, was investigated by the Spanish authorities with significant technical contribution by the AAIB.

Safety Recommendations

Incidents and accidents such as those to C-FTDF and G-UKLL highlight the need for early recognition of braking problems during a landing roll and early action to reduce the kinetic energy of the aircraft. Therefore, the AAIB makes the following Safety Recommendations:

Safety Recommendation 2004-82

It is recommended that Airbus improve the automated warnings to flight crews concerning the loss of braking system effectiveness following touchdown or a rejected takeoff.

Safety Recommendation 2004-83

It is recommended that Airbus amend the Flight Crew Operating Manuals, and related material, to advise application of maximum reverse thrust as soon as a loss of braking performance is suspected following touchdown, rather than delay the application whilst awaiting confirmation that no braking is available.