INCIDENT

Aircraft Type and Registration:	Airbus A320-A1, EC-GRF
No & Type of Engines:	2 CFM 56-5A1 turbofan engines
Year of Manufacture:	1991
Date & Time (UTC):	4 April 2006 at 0802 hrs
Location:	Stand 203, Terminal 2, London Heathrow Airport
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 110
Injuries:	Crew - None Passengers - None
Nature of Damage:	Damage to left engine inlet cowl and airbridge protective railings
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	50 years
Commander's Flying Experience:	13,256 hours (of which 3,875 were on type) Last 90 days - 157 hours Last 28 days - 49 hours
Information Source:	Aircraft Accident Report Forms submitted by pilot and subsequent enquires by the AAIB

Synopsis

Shortly after commencing the taxi for takeoff, a hydraulic union in the braking system fractured, causing fluid to leak from the Yellow hydraulic system. The departure was cancelled and the aircraft returned to the terminal. After stopping on the allocated stand, the parking brake was selected ON, but the brakes failed to apply as the parking brake is operated by the Yellow hydraulic system. The aircraft then began to move forward under idle engine power. Attempts by the crew to stop using the brake pedals proved unsuccessful, as the other modes of braking are deactivated when the parking brake is selected ON. The aircraft collided with the airbridge, damaging the left engine inlet cowl, before coming to a stop.

History of the flight

The aircraft was pushed back from Stand 209R at Terminal 2, London Heathrow, for a scheduled passenger flight to Madrid. As the aircraft began to taxi away from the stand, the Yellow hydraulic system low fluid level message (HYD Y RSVR LO LVL) appeared on the ECAM[1]. The commander, who was the handling pilot, stopped the aircraft to assess the problem. On looking out of his side window, the co-pilot observed a large pool of liquid

Footnote

[1] Electronic Centralised Aircraft Monitor. This system comprises two electronic displays, located centrally on the main instrument panel, which provide information to the crew on the status of the aircraft systems, including systems that may be inoperative following specific failures. Faults in the aircraft systems are highlighted by warning, caution or memo messages, and checklists of actions to be taken by the crew are displayed automatically following a system failure.

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on the taxiway on the right side of the aircraft. The crew performed the ECAM checklist actions and consulted the appropriate procedure in the Flight Crew Operating Manual (FCOM). The departure was cancelled and ATC clearance was obtained to return to the terminal to park on Stand 203.

The commander reportedly checked the Yellow hydraulic system accumulator pressure on the cockpit gauge and noted that it was indicating that pressure was available. During the taxi back to the terminal, the aircraft had to stop a number of times and no problems were experienced with the use of the brake pedals. On arriving at the stand, the aircraft was brought to a halt again whilst the automated parking guidance system was being switched on. The commander then taxied the aircraft onto the stand, stopped on the appropriate mark on the stand centreline and applied the parking brake. However, on looking out of the cockpit again, he noticed that the aircraft was moving forward. Both he and the co-pilot attempted to stop it using the brake pedals, but this proved ineffective, and the engines were quickly shut down in order to minimise any damage. The aircraft continued rolling forward until brought to a halt as its left engine struck the airbridge.

Accident scene information

The airbridge, which is believed to have been unoccupied at the time, was in the parked position when it was struck by the aircraft. The top and bottom lips of the left engine inlet cowl were dented from contact with the upper attachment of one of the hydraulic operating rams and the protective steel railings at the base of the airbridge. The railings were heavily deformed by the impact, but there was no visible damage to the airbridge itself.

Examination of the centreline markings on Stand 203 showed that the stop markers for the different aircraft types were clearly identified. Assuming that the aircraft had initially stopped on the correct stop mark, as reported, measurements showed that it had then moved forward a distance of approximately four metres before the left engine struck the railings.

Inspection of the aircraft revealed that a hydraulic reducer union on the brake dual distribution valve (BDDV) had fractured, Figure 1, allowing fluid to leak from the Yellow hydraulic system.

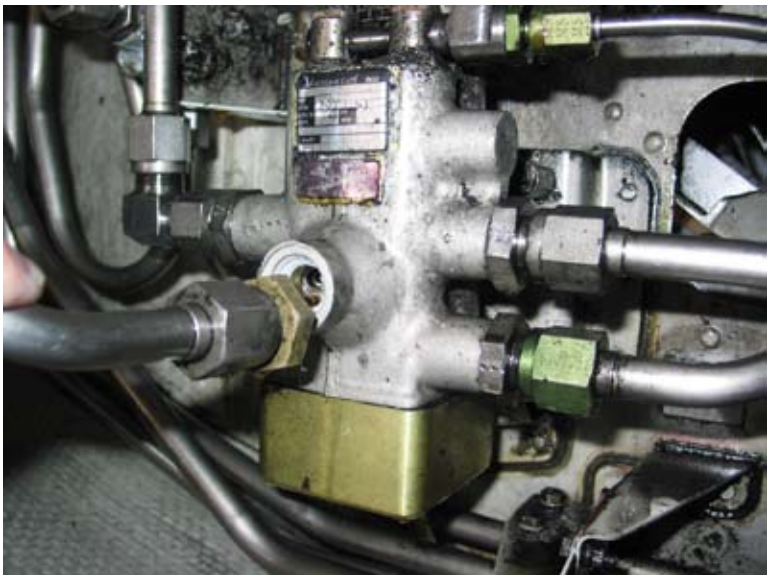

Figure 1

Fractured hydraulic union on the BDDV

A320 hydraulic systems description

The A320 has three independent hydraulic systems, designated Blue, Green and Yellow, operating nominally at a pressure of 3,000 psi. The Green and Yellow systems are normally pressurised by pumps driven by the left and right engines respectively, and the Blue system is pressurised by an electrically driven pump. The Yellow system is also equipped with an electrically driven pump, which allows the system to be pressurised on the ground when the engines are shut down. An accumulator in the

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Yellow system provides pressure for the parking brake system when the hydraulic pumps are not operating.

Should the pressures in the Green and Yellow systems differ by more than 500 psi (35 bar), the power transfer unit (PTU) automatically engages, boosting the pressure in the system experiencing the pressure drop. The PTU comprises a pair of mechanically connected dual action hydraulic motor/pump units; there is no transfer of fluid between the two hydraulic systems.

A320 parking brake system operation

The handle for the parking brake is located on the centre pedestal in the cockpit; the brake is applied by lifting the handle and rotating it 90° clockwise, from the OFF to the ON position. This operates the parking brake control switch, which signals the motors in the parking brake control valve to move the valve to the ON position. This causes Yellow system hydraulic pressure (from either pump, if running, or the accumulator) to be supplied to the alternate brake pistons on the brake units. The pressure in the parking brake system is maintained through the closure of the hydraulic return lines. When the parking brake control valve is in the ON position, ie when the parking brake handle is set to ON, the normal[2] and alternate braking systems are electrically and hydraulically deactivated.

The accumulator pressure and the parking brake system pressure are displayed on a combined triple pressure gauge mounted in the main instrument panel. When the parking brake is selected to ON, a green 'PARKING BRAKE ON' memo is displayed on the ECAM. However, this message only indicates the position of the parking brake control valve and appears whenever the valve is in the ON position, irrespective of whether or not Yellow hydraulic pressure is available to apply the brakes.

Brake Dual Distribution Valve (BDDV)

The BDDV is located on the rear bulkhead of the right main landing gear bay. Its function is to supply the alternate braking system with Yellow hydraulic system pressure. During alternate braking, the BDDV modulates the hydraulic pressure to the brakes in accordance with the level of braking demanded by the flight crew through the brake pedals. The alternate braking system automatically becomes available if the normal braking system should fail.

The BDDV is pressurised by the Yellow hydraulic system, except during normal braking and when the parking brake is applied. This is to ensure that hydraulic pressure is immediately available to operate the alternate braking system if the normal braking system fails. During normal braking, an automatic selector valve (ASV) located upstream of the BDDV cuts off the Yellow hydraulic system supply to the BDDV and supplies Green hydraulic system pressure to the normal braking system. When the brake pedals are released, the ASV restores the Yellow hydraulic supply to the BDDV. When the parking brake is applied, Yellow hydraulic system pressure is supplied to the parking brake circuit and the BDDV is by-passed.

The BDDV is therefore exposed to pressure variations during normal braking and parking brake operation.

Relevant flight recorder data

A copy of the relevant Quick Access Recorder (QAR) data was provided by the operator, which showed that full Yellow hydraulic system pressure was available after

Footnote

[2] The normal braking system is operated by the Green hydraulic system, which operates one group of pistons on each brake unit. The alternate braking system and parking brake are supplied by the Yellow hydraulic system and operate a different group of pistons on the brake units.

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engine start. However, shortly after the aircraft began to taxi, there was a drop in the Yellow system pressure to just below 2,000 psi followed, about 40 seconds later, by another drop to just below 500 psi. The second, larger, pressure drop triggered the Yellow hydraulic system low pressure warning and, following this, the ground speed parameter showed that the aircraft was stationary for about 75 seconds. The pressure drops were of short duration and, on both occasions, the pressure returned to normal. Approximately 30 seconds after the second pressure drop, whilst the aircraft remained stationary, the Yellow system pressure then fell to zero and did not recover. The aircraft then commenced the taxi to return to the terminal. The data show that the Green hydraulic system pressure dropped coincidentally with the pressure drops in the Yellow system, but to a lesser degree. The Green system pressure otherwise remained nominally at 3,000 psi.

Mandatory Service Bulletin 32-1201

In May 2001, following a previous A320 ground collision incident, the aircraft manufacturer issued Service Bulletin (SB) 32-1201, which modifies the parking brake system so that normal braking is automatically restored in case of low Yellow hydraulic system pressure. This configuration was subsequently adopted as the production standard on new-build aircraft. The SB was made mandatory by the European Aviation Safety Agency (EASA), and must be accomplished on all affected aircraft by 31 March 2009.

On aircraft of pre-service bulletin SB 32-1201 configuration, which includes EC-GRF, in the event of a parking brake failure, the parking brake handle must be moved to the OFF position in order to restore the normal braking system.

On aircraft of post-SB 32-1201 configuration, if the hydraulic pressure in the parking brake system decreases to less than 35 bar (approximately 500 psi), the parking brake control valve will be automatically commanded to the OFF position, irrespective of the parking brake handle position, thus reactivating the normal braking system.

The operator's fleet comprised a mix of pre- and post-SB 32-1201 configuration aircraft.

ECAM abnormal procedures

In the event of low hydraulic fluid quantity in the Yellow hydraulic system, the following ECAM messages and actions appear, which must be reviewed and actioned by the crew:

'HYD Y RSVR LO LVL

- PTU……OFF
- YELLOW ENG 2 PUMP…….....OFF
- YELLOW ELEC 2 PUMP……..OFF
- BRK Y ACCU PR .. MONITOR'

The ECAM does not indicate whether the parking brake is operative or not; the pilot must first check the triple pressure gauge to verify that accumulator pressure is available and then check that pressure has been applied to the brakes after setting the parking brake. Even though the Yellow hydraulic system may be unavailable, the 'PARKING BRAKE ON' memo will remain displayed on the ECAM when the parking brake is selected on.

Aircraft manufacturer's operational instructions

Following the previous incident, Airbus issued Operator Information Telex (OIT)/Flight Operations Telex (FOT) SE 999.0079/01/BB, in June 2001, proposing two changes to the A319/A320/A321 Flight Crew Operating Manual (FCOM):

Firstly, the 'PARKING' chapter of the Standard Operating Procedures in the FCOM was to be

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amended to include a check of the parking brake accumulator pressure prior to setting the parking brake. The purpose of this was to detect accumulator low pressure which could result in parking brake failure. (The existing FCOM procedures already stated that, in the event of a parking brake failure or unexpected movement of the aircraft occurring with the parking brake selected to ON, the parking brake handle must be selected to OFF to restore the normal braking system.)

Secondly, a note was to be added to the FCOM procedure for a Yellow hydraulic system failure to highlight that the parking brake may be inoperative due to low Yellow system accumulator pressure.

These changes were incorporated by Airbus in the July 2001 general revision (Revision 33) of the FCOM.

Operational procedures

The operator's A319/A320/A321 FCOM, which is based on the Airbus FCOM, reflected the changes introduced by Revision 33.

The parking procedure is contained in section 2.01.72 of the operator's FCOM and it states that the triple pressure gauge must be checked prior to selecting ON the parking brake, to verify that Yellow hydraulic system accumulator pressure is available. It also requires a check of the brake pressures on the triple pressure gauge after selecting the parking brake to ON. The procedure also contains the following:

> *'CAUTION*
>
> *If the aircraft begins to move after applying the parking brake, the PARK BRK handle should be immediately selected to off and the brake pedals applied.'*

The operator's FCOM includes the following note in the Yellow hydraulic system failure abnormal procedure:

> *BRK Y ACCU PR MONITOR*
>
> *This check is recommended to cover the case of a pipe, rupture, which could lead to the simultaneous loss of the hydraulic system and the accumulator fluid. If this occurs, the loss of the accumulator should be observed on the indicator within 10 minutes. In that case: the only remaining braking means is normal braking, using green pressure. The parking brake should not be used, since it is not available. And, the chocks should be put in place before Engine 1 shutdown.'*

Prior to the incident, the operator had not provided any specific training to flight crews on parking procedures following a Yellow hydraulic system failure.

Hydraulic reducer union

The failed union, which is of an aluminium alloy material, was located in the Yellow hydraulic system supply port to the BDDV. The part number of the union is MS21902D8 and it is identified as item 070 of Figure 2D in Chapter 32-43-03 of the A319/320/321 Illustrated Parts Catalogue.

The BDDV had completed a total of 29,665 flying hours and 23,871 flight cycles since new, and had not been previously overhauled.

The aircraft manufacturer, Airbus, was aware of two previous failures of hydraulic unions on the BDDV, but there was insufficient information to determine whether these were the same as that which failed in this incident. This union is installed on approximately 2,400 A319/A320/A321 aircraft; these have accumulated a total of more than 40 million

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flying hours and 20 million flight cycles, with the fleet leaders having attained, at the time of this incident, 55,000 flying hours and 38,000 flight cycles.

Metallurgical examination

The hydraulic union had fractured in the region of the last full thread before the run-out, on the threaded end to which the hydraulic pipe attaches. The fracture was the result of a fatigue crack initiation at the thread root, which propagated to a relatively small crack under low magnitude cyclic stress. Given the small crack advance, the large area of overload was possibly due to the presence of a high static load on the fitting, over which the cyclic loading was superimposed. This was possibly due to separate periods of vibration, or other excitation, as indicated by the presence of wider beach marks between the closely spaced striations. Crack initiation had occurred at multiple sites around the thread root, precluding a defect induced failure. There was no evidence of corrosion on the fitting. The final separation was essentially axial, and therefore unlikely to have been due to an attempt to over-tighten the fitting, which might be expected to produce a torsional separation. The results of the metallographic examination, hardness determinations and chemical analysis, indicated that the fitting had been correctly manufactured from an Al 2024 alloy in the fully heat treated condition.

Discussion

The QAR data show that full Yellow hydraulic system pressure was available after engine start and up to the point the aircraft began to taxi. The first indication of a problem was the initial drop in the Yellow system pressure, to just under 2,000 psi, shortly after taxiing, which probably signified the point at which the hydraulic leak started. The second, larger pressure drop triggered the Yellow system low pressure warning, prompting the crew to stop the aircraft and assess the problem. In both cases, the hydraulic pressure recovered, probably coincident with the automatic engagement of the PTU, which would have restored the Yellow system pressure, if sufficient fluid had remained in the system. The coincidental pressure drops in the Green system pressure were probably indicative of PTU operation.

Application of the parking brake, after stopping to investigate the problem, would have cut off the Yellow hydraulic system supply to the BDDV and reduced the rate of fluid leakage. The data shows however, that by the time the aircraft had commenced the taxi to return to the terminal, the Yellow hydraulic system pressure had fallen to zero and did not recover. The ECAM actions required the crew to turn off the Yellow system pumps and the PTU, after which the Yellow system would have no longer been pressurised.

The aircraft parking procedures require the crew to verify that pressure has been applied to brakes after selecting the parking brake to ON. Given that the aircraft began to move forward immediately after setting the parking brake, it is likely that there was little or no Yellow system hydraulic pressure available to apply the brakes, and this should have been indicated on the brake pressure gauges.

Once the aircraft began moving forward on the stand, the crew could have stopped it by selecting the parking brake to OFF, thus re-activating the normal braking system, before operating the brake pedals. The normal braking system would have been available as, with the engines still running, the Green hydraulic system was pressurised, as indicated by the QAR data. However, this action is not intuitive and the fact that the crew had not practised this particular failure scenario may have been a significant contributory factor.

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Although the ECAM action list included an action item to monitor the Yellow hydraulic system accumulator pressure, it gave no specific information that the parking brake might be inoperative. This information was, however, contained within the FCOM, which was consulted by the flight crew. It is possible that the crew, having seen an indication of accumulator pressure on the gauge at some point, assumed that the parking brake was serviceable.

The cause of the fatigue cracking in the failed hydraulic union was not established; however, no evidence was found of pre-existing defects, corrosion, or of an incorrect material specification.

Actions taken by the operator, post-incident

The operator has conducted its own investigation into the incident and took a number of safety actions intended to prevent recurrence. These actions include:

Additional flight simulator training on hydraulic failures for the crew involved in the incident.

The development of an appropriate flight simulator training scenario for all A320 crew members.

The issue of a safety recommendation to its A320 crews, stating that aircraft should be towed to the parking position in the event of a hydraulic system problem.

The operator has requested that the aircraft manufacturer provide the appropriate abnormal procedure for dealing with such a hydraulic system failure on A320-A1 aircraft.

Actions taken by the manufacturer, post incident.

The manufacturer also conducted an investigation into this incident, and has made a number of safety recommendations. These included:

- *'On affected aircraft, operators should embody SB 32-1201*[3]
- *Operators should specifically bring to the attention of flight crews the following:-*

  The condition and response of the parking brake system should be checked on the triple gauge at every ON or OFF selection (FCOM 3.02.25)

  The parking brake should be selected OFF in case of loss of efficiency in order to recover normal braking system (FCOM 3.02.25)

  When arriving at the gate [stand] with Yellow hydraulic system inoperative, use of chocks should be anticipated and demanded prior to release of normal braking system (FCOM 3.02.29)'

Airbus informed its operators of this incident at a Flight Safety Conference held on 17 October 2006.

In view of the above safety actions taken by the operator and manufacturer, it is thought not necessary to make any formal Safety Recommendations.

Footnote

[3] Although the manufacturer originally made the recommendation to embody to SB 32-1201 (up to a/c MSN 1380) in May 2001, and this was mandated by EASA (to be accomplished by 31 March 2009), they have re-iterated it following this incident.

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