Airbus A321-211, EI-CPE

AAIB Bulletin No: Ref: EW/C2000/6/8 Category: 1.1

Aircraft Type and Registration:	Airbus A321-211, EI-CPE
No & Type of Engines:	2 CFM56-5B3/P turbofan engines
Year of Manufacture:	1998
Date & Time (UTC):	21 June 2000 at 1200 hours
Location:	London Heathrow Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 9 - Passengers - 180
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Aft fuselage damaged between frames 63 and 67
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	51 years
Commander's Flying Experience:	13,190 hours (of which 700 were on type)
	Last 90 days - 130 hours
	Last 28 days - 58 hours
First Officer's Flying Experience:	274 hours (of which 82 were on type)
	Last 90 days - 82 hours
	Last 28 days - 58 hours
Information Source:	AAIB Field Investigation

The aircraft was operating a scheduled service flight from Dublin Airport, Ireland, to London Heathrow Airport. The crew had operated one round trip earlier in the morning, this flight was thus their third sector of the day. The 1050 hrs ATIS report received by them was as follows: Surface wind 210°/16 kt, visibility 40 km, scattered cloud at 3,000 and 4,500 feet, temperature 17°C, dewpoint 9°C, QNH 1009. The ATIS also included information regarding windshear on the approach to Runway 27R, of plus or minus 10 kt at 400 feet agl. The last reported surface wind, 20 seconds before the aircraft landed, was 220°/18 kt.

The aircraft received radar vectors to an ILS approach on Runway 27R with the first officer (FO) as the pilot flying (PF). When established on the ILS approach, and in visual contact with the runway, he disconnected the autothrottle and the autopilot. The remainder of the approach was flown manually with reference to managed speed and using the flight director. From 300 feet agl until landing the aircraft became destabilised in pitch. At around 200 feet agl the rate of descent reduced significantly and the aircraft began to deviate above the ILS glideslope. The FO attempted to correct and in so doing a rate of descent of 800 to 900 feet per minute developed. He then started to apply aft sidestick at a height of 60 feet agl and continued the input until touchdown but the rate of descent was not fully arrested and the aircraft landed firmly.

The main wheels contacted the runway and then the aircraft rebounded into the air with both wheels lifting off again. Ground spoilers deployed at the initial touchdown and the pitch attitude continued to increase. The aft fuselage made contact with the runway at the same time as the second mainwheel touchdown occurred. The remainder of the landing was carried out uneventfully

with the crew being unaware of the tailstrike until advised by ATC on vacating the runway. The cabin crew also reported to the commander that there had been an unusual noise at touchdown.

Damage to the aircraft

The rear fuselage lower skins were heavily abraded between the aft potable water and toilet service panels over an area extending some 2.5 metres longitudinally and 0.4 metres laterally, and the lower segment of the aft galley drain mast was bent and partly ground away by contact with the runway. A scrape mark approximately 0.4 metres wide and 8 metres long was found on the surface of Runway 27R in Block 18, slightly to the left of the centre line, consistent with the damage observed on EI-CPE.

The lower skin damage was bounded approximately by frames 63 to 67 and stringers 43L to 42R respectively, implying a small amount of right bank at the instant the tail contacted the ground, and comprised localised penetrations through the full thickness of the skins where these were supported by frames and stringers, together with minor damage to underlying structure including localised bending of butt-straps and frame flanges. The fuselage skins immediately surrounding the penetrated regions, which were not directly supported by underlying structure and consequently had been able to deflect partially away from the runway surface, suffered less severe abrasion damage together with inwards buckling at the centres of some skin panels.

Whilst any penetration of the pressure hull has potentially serious implications, in this case the structural integrity of the fuselage had not been compromised.

The aircraft

The aircraft landed at a weight of 70.7 tonnes, the maximum allowable being 75.5 tonnes. A landing wind of 240°/15kt had been entered on the performance page of the Multipurpose Control and Display Unit (MCDU). The aircraft was flown with reference to managed speed displaying to the pilot a computed variable speed target according to the actual wind, with a minimum target of 141 kt (V_{APP}). The A321 pitch attitude when on a stable approach at V_{REF} (136 kt in this case) is 4°.

Ground spoilers deploy when both main landing gears touchdown, and remain extended during a bounce unless either thrust lever is advanced. Automatic braking commences either 2 or 4 seconds after ground spoiler deployment, dependant upon the level pre-selected.

The manufacturer produced a Flight Crew Operators Manual Bulletin No 22/2 dated April 1999 in which the issue of tailstrike avoidance was addressed. Deviations from normal landing techniques were cited as being the most common cause. The bulletin included a note: "it is imperative to reach the flare height at the appropriate speed and flight path angle (-3°)".

The two sidestick controls on the aircraft have an equal priority during normal operations. There is no physical movement or any other mechanism by which the pilot non-flying (PNF) can know what the PF demanded input is at any particular moment. When the PNF operates his sidestick in the same or opposite direction as the PF, both pilots inputs are algebraically added. Thus, the procedure for the commander to take over control was to press the takeover pushbutton on his sidestick, to establish priority, and to announce "I have control".

Pilot experience

The aircraft commander had been flying this type of aircraft for approximately one year. The nature of the scheduled service operation ensured that he had carried out a large number of sectors in this time. He had no previous experience of a bounced landing in this type of aircraft, it being difficult to reproduce in an aircraft simulator for a pilot to practice. The FO had recently completed his line training on the type.

Flight recorders

The Cockpit Voice Recorder (CVR), an Allied Signal Solid State A200S was removed and replayed by the AAIB. The two hour recording began prior to the previous approach into Dublin, and covered the entire incident flight, including the approach and landing at Heathrow. The Flight Data Recorder (FDR), an Allied Signal Solid State Recorder was also replayed and parameters from the entire incident flight and 12 previous flights were obtained.

Figure 1 shows some of the recorded parameters from 300 feet agl to touchdown. The aircraft was on the ILS glidepath with a rate of descent of 700 ft/min. At around 200 feet and an airspeed of 142 kt CAS, there was an increase in engine power from 53% N1 to around 67%N1 for 4 seconds. The rate of descent reduced to 450 ft/min and the aircraft began to deviate slightly above the glidepath. There was a forward movement of the FO's sidestick and the aircraft pitched down to 0°; airspeed increased to 148 kt CAS and the rate of descent increased to 800-900 feet/min. The aircraft returned towards the glidepath and pitch was increased to 4.5° nose-up. At 90 feet agl the FO made two brief nose-down demands on the sidestick which caused the aircraft to pitch down and reach an attitude of 0.5° nose-up at 50 feet agl. The rate of descent increased and at 60 feet agl the FO's sidestick began to be moved aft to demand a nose-up elevator position for the flare. Two seconds later the pitch attitude had reached 2° nose-up and continued to increase but the rate of descent reduced only slightly. From 90 feet agl thrust was gradually reduced and the thrust levers were closed by 20 feet.

The aircraft touched down at an airspeed of 130 kt CAS, with a pitch attitude of 7.4° nose-up and a normal acceleration of 2.0g. The FO's sidestick position was 92.5% nose-up demand with an up-elevator angle of 12.3°. The FO's sidestick demand then reduced, towards 46.8% nose-up demand. The ground spoilers deployed automatically; this is designed to occur when both the main landing gear oleo switches are compressed. The FDR showed that these switches then 'unmade' indicating that the aircraft had rebounded into the air. The pitch attitude continued to increase to a maximum of 9.8° nose-up, which was reached just as the aircraft mainwheels touched the ground again. The tailscrape occurred at this point. The second touchdown recorded a normal acceleration of 1.6g at which time the commander's sidestick moved forward to a 56.3% nose-down demand.

Simulation

Tests were conducted in a simulator by the aircraft manufacturer using recorded data from the flight. It was found that to match the aircraft performance to the achieved flight path a corrective wind input was required. The magnitude of this could then be measured. A significant vertical turbulence was observed at 300 feet agl. Coincident with this the angle of attack changed and the aircraft pitched up to 4° nose up for about 4 seconds. Below 100 feet agl there was a sustained loss of headwind of 10 kt which was considered to be the principle cause of the limited change of flight path with the increasing pitch attitude during the flare.

Previous incidents

The manufacturer had details of 9 tailstrikes on the A321 aircraft before this event, all of which occurred during the landing phase. Two of these events have been reported on previously by the AAIB. In the incidents for which data was available to the AAIB it could be seen that, after an initial touchdown, the aircraft all continued to pitch up, resulting in the tailstrikes after touchdown or during the resultant bounce. Subsequent to this event there have been two further instances, one of which (D-AIRE) is also reported on in this bulletin.

Aft fuselage contact will occur on the A321 at a pitch attitude of 9.7° with the main landing gear oleos compressed, as compared with 11.7° for the A320. The rate of tailstrike incidents per aircraft landing for the A321 is 4 times greater than that for the A320 probably as a result of the smaller margin from the normal flare attitude. Damage to the structural integrity of the fuselage should not pose a significant flight risk to the aircraft provided the tailstrike is detected during or after landing. In this case although it was not detected by the flight deck crew, both ATC and the cabin crew reported it to the commander.

Analysis

This incident is similar to others reported on previously in that a combination of three effects result in the tailstrike. These were: the pitch up effect of the automatic ground spoiler deployment; the elevator position, which, although the sidestick moved forward, would still produce some nose up demand; and the pitch inertia which had developed during the landing flare.

A comparison was performed using data from the previous incidents investigated by the AAIB and 12 other landings on EI-CPE which were recorded on the FDR. The data showed that in the normal landing a flare would be initiated at a height of around 60 feet, the sidestick position would then be checked to maintain a sidestick position between 25% and 37.5% nose up demand below 40 feet. The average sidestick position at touchdown was 37.5% nose up demand. All the recorded landings showed a similar flare initiation height and rate of application of aft sidestick input. However, in the tailstrike incidents the sidestick continued to move aft and achieved a stick position of between 75% and 100% nose up demand at touchdown. This additional aft sidestick movement produced higher pitch attitudes at initial touchdown, between 5° and 7°, as compared with an average of 3.5° nose-up for the normal landings. It would seem that the tailstrike becomes very likely with such an aft sidestick position at the initial touchdown, due to the three effects discussed earlier.

All four tailstrike incidents examined showed a greater variation of rate of descent through the approach, suggesting a less stable approach. The average rate of descent at the flare initiation was 700 ft/min, reducing to around 300 ft/min at touchdown. In the tailstrikes the rate of descent did not reduce as much during the flare, leading to a rate of descent at touchdown between 700 and 800 ft/min.

In the case of the incident involving EI-CPE there were some quite large variations in rate of descent. The destabilisation of the approach during the later stages was probably as a result of local turbulence arising from the gusty crosswind conditions. The approach however was not sufficiently destabilised for the commander to have had concerns about the eventual outcome of the landing.

Below 100 feet the aircraft experienced a loss of headwind and by 70 feet the airspeed had reduced to 136 kt, which was 5 kt below VAPP. The margin between the more positive pitch attitude required to maintain the flight path and the 9.7° at which tailstrike would occur was therefore reduced. As a result of destabilisation resulting from turbulence and sidestick inputs the aircraft pitch attitude was 1.5° decreasing to 0.5° nose-up at the beginning of the flare. Inertia from an

increased rate of descent and the low pitch attitude would have delayed the change of flight path angle at the flare.

After touchdown, the pitch inertia from a late and large aft stick input, the continued presence of a nose up elevator demand, and the pitch up effect of spoiler deployment all contributed towards the aircraft continuing to pitch up. It is also worth noting that in the event of a bounced landing the aircraft would not experience the normal pitch down effect as a result of braking action. The pitch up effect at touchdown would have made it difficult for the pilots to determine whether or not a bounce had occurred.

The commander did not anticipate a problem until after the aircraft's initial touchdown. He could not have been aware of the control inputs applied by the FO, in particular the continued aft sidestick input late in the landing, because his own sidestick showed no movement. It is unlikely that he had sufficient information available to be able to evaluate and carry out any corrective action at this stage. When he applied an input after the second touchdown any effect would have been reduced because he did not use the takeover pushbutton.

A review of previous events showed that a significant proportion of tailstrike incidents occurred when co-pilots recently qualified on type were handling the aircraft. There are several possible explanations for this. When a deviation above the glideslope occurs at low level a choice arises as to whether it is preferable to maintain a stable approach and accept a greater landing distance, or to destabilise the approach. A greater level of experience may be required to make this judgement. It is also possible that some less experienced pilots may follow the ILS glideslope too closely below 100 feet thereby diverting their attention from the visual landing phase leading to a late recognition of a low pitch attitude and high rate of descent. Once the high rate of descent has been detected, this then leads to an input of aft stick being sustained until after touchdown has occurred.

The sidestick control authority logic requires a different method of intervention by commanders from that which they may have experienced on other aircraft types. Because of the difficulty of detecting the inputs made by the other pilot early takeover of control based on flight characteristics is required. On a number of tailstrike incidents commanders have made control inputs without using the takeover pushbutton and have thereby limited the effectiveness of those inputs. There is therefore a need for commanders to be well practised in a strategy for taking over control when necessary during the landing phase.

It is considered that pilots need more guidance towards detecting the flight characteristics which may lead to a tailstrike to enable them to take effective preventative action. Flight path destabilisation with increased rates of descent below 150 feet are an indication and particular attention needs to be given to abnormally low pitch attitudes at a late stage of the approach. Airbus Industrie have indicated that they are reviewing the Operator's Manual Bulletin dealing with the subject of tailstrikes. It is therefore recommended that Airbus Industrie should include this information in a revised Bulletin.

Summary

This incident occurred when a first officer who had recently qualified on type was flying the approach. In its latter stages the approach became destabilised, probably because of local turbulence arising from the gusty crosswind conditions and sidestick inputs which resulted in some quite large variations in rate of descent. Inertia from the increased rate of descent and the low pitch attitude of 0.5° at the beginning of the flare delayed the response of the aircraft to the aft stick input

at the flare and resulted in a heavy touchdown. After touchdown, the pitch inertia from a late and large aft stick input, the continued presence of a nose up elevator demand, the pitch up effect of spoiler deployment, and the lack of the normal pitch down effect as a result of braking action all contributed towards the aircraft continuing to pitch up and bounce. The aft fuselage made contact with the runway at the same time as the second mainwheel touchdown occurred.

Safety recommendation

Recommendation 2001-46

It is recommended that Airbus Industrie should reissue the Operator's Manual Bulletin dealing with the subject of tailstrikes. This should include further guidance regarding flight path destabilisation with increased rates of descent and abnormally low pitch attitudes at a late stage of the approach. It should also re-emphasise the need to use the takeover pushbutton to achieve effective intervention.