AAIB Bulletin No: 2/2005 **Ref: EW/C2003/08/05** **Category: 1.1**

Aircraft Type and Registration:	Avro 146-RJ100, G-CFAD
No & Type of Engines:	4 Lycoming LF507-1F turbofans
Year of Manufacture:	2000
Date & Time (UTC):	26 August 2003 at 0656 hrs
Location:	London City Airport, London
Type of Flight:	Public Transport (Passenger)
Persons on Board:	Crew - 6 Passengers - 110
Injuries:	Crew - None Passengers - None
Nature of Damage:	Lower rear fuselage scraped, tail bumper strip removed, skin, stringer and frame damage
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	35 years
Commander's Flying Experience:	3,283 hours (of which 110 were on type) Last 90 days - 96 hours Last 28 days - 38 hours
Information Source:	AAIB Field Investigation

Synopsis

After an uneventful flight the aircraft was positioned onto the ILS approach to Runway 10 which has a 5.5° glidepath. During the manually flown final stages of the approach the aircraft descended slightly below the glidepath. In regaining the glidepath insufficient power was used to correct for the resultant decay in airspeed and the thrust levers were closed early during the landing flare. These factors led to the aircraft being 8 kt below the correct speed at touchdown. In an attempt to arrest the rate of descent in the flare, an abnormally high pitch attitude was reached resulting in the aircraft striking its tail on the runway.

History of flight

The crew were operating the first sector of their duty and had taken off from Glasgow Airport at 0530 hrs for London City Airport with the co-pilot acting as handling pilot. The takeoff and cruise

went without incident and shortly before descent, the commander briefed for an ILS approach and landing to Runway 10, with the co-pilot flying the approach and the commander taking control for the landing. The co-pilot had been seconded to the RJ Fleet from another part of the parent company; he had more than 8,000 hours flying experience with 413 hours on type.

ATC cleared the aircraft to descend to an altitude of 2,000 feet and provided radar vectors to establish it on the ILS localiser for Runway 10. This runway has a 'steep' approach with a 5.5° glideslope. In accordance with company Standard Operating Procedures (SOPs) the pilots configured the aircraft with full flaps and landing gear down prior to intercepting the glideslope and reducing the speed to the final approach speed (VAPP) of 127 kt. This equated to the reference speed ($V_{REF}33$) of 122 kt for the aircraft's landing weight of 39,179 kg with an additional 5 kt added, as per the SOPs. The surface wind was light so the crew did not need to increase the approach speed to protect against gusts.

When the aircraft was fully established on the ILS approach, the speed brake was extended. Visibility was good and with the runway in sight, the commander took control at about 800 feet agl for the landing. He disengaged both the autopilot and autothrust and at 500 feet agl the co-pilot confirmed to the commander that the aircraft was stable on the approach.

At between 100-200 feet agl the commander stated that he increased the aircraft's pitch slightly as the PAPIs were indicating three red lights. The radar altimeter 'autocall' then announced that the aircraft was passing 100 feet agl, at which point the commander slowly brought the power levers back to idle. Both pilots commented that they noticed the aircraft seem to sink slightly, and the commander stated that he again increased the aircraft's pitch to compensate for the sink. At this point the co-pilot noticed the airspeed was about 120 kt, which appeared normal to him in relation to the expected threshold speed of 122 kt ($V_{REF}33$).

The aircraft's touchdown was described as normal by both pilots, although the co-pilot stated that the pitch was slightly higher than usual and the commander described the handling as being "a little spongy". At the time he attributed his perception to the aircraft being at a relatively heavy landing weight. During the subsequent landing rollout the co-pilot resumed control and the pilots heard ATC transmit a request for a runway inspection. On enquiring whether something had been seen falling from the aircraft, ATC advised that they suspected the aircraft had struck its tail on landing. The pilots were then instructed to backtrack the runway and taxi to stand where, after a normal shutdown, evidence of a tailscrape was confirmed.

Weather conditions

At the time of the accident a light wind was reported of 030°/06 kt, visibility was 10 km and the cloudbase was broken at 4,500 feet. There were no reports of any turbulence or windshear on the approach.

Company SOPs

Within the 'Approach-General' section of the operator's SOPs is the statement:

> *"On all approaches the P2 must continue to monitor the flight instruments until nosewheel touchdown, calling attention to any discrepancies and making standard callouts."*

Instructions within the company Operations Manual for airspeed control during a 'steep' ILS approach' are to maintain $V_{REF}33 + 5$ kt + gust factor[1] for the glideslope descent with landing gear, 33° flap and the airbrake extended. When approaching the runway, speed should be reduced to cross the threshold at $V_{REF}33$ + gust factor.

Operator's tail strike information

The operator published a Flight Operations Bulletin (Number R03/06) as a result of previous tail strikes suffered by its RJ fleet. In it, when discussing the causes of tail strikes, it states:

> *"The second most likely cause is an approach where because of higher than expected ground closure rate – (as in a Steep Approach) – the pilot flares too early (causing subsequent 'sink' in the flare) or again prolongs the flare with a similar eventual effect. This 'sink' or rapid ground closure can provoke or tempt a further flare or over-rotation, again causing a heavy landing with a likely Tail Strike."*

It further states:

> *"There is no fixed advice on pitch angles for a correct landing, indeed, the pilot should clearly be looking out at this point rather than at the PFD. For guidance, it is rather unusual to require more than four degrees pitch up in a correctly executed flare-to-land manoeuvre, and usually less."*

[1] The gust factor is defined as half the gust, irrespective of gust direction, up to a maximum of 15 kt

Engineering Investigation

Damage to the aircraft comprised a region of severe scuffing and abrasion over a region extending from frame 36 (approximately in line with the centre of the rear cargo hold access door) to frame 36Y, a total longitudinal distance of approximately 1.7 metres. The tail bumper - an inverted top hat channel section forming, in effect, a lightweight longitudinal keel member fixed externally on the underside of the rear fuselage - had been largely ground away over this region. The damage became progressively more severe towards the forward end of the affected region, where the abrasion spread increasingly to involve the adjoining fuselage skins up to a maximum spread of approximately 27 centimetres about the centre line. Examination of the internal fuselage structure revealed that the principal frames over the affected region (36, 37, 38 and 39) were buckled locally in the area of the lower chord consistent with the observed external damage. The intermediate frames over this same region, which have a lighter form of construction, displayed characteristic bowing of the web elements; again, consistent with the observed external damage. Overall, the extent of damage did not appear to pose any immediate threat to structural integrity.

A distinctive scrape mark was found on the runway, consistent with the external damage to the rear fuselage of G-CFAD, at a location approximately one metre to the right of the centre-line and 200 metres beyond the start of the 'piano key' markings at the threshold of Runway 10. This mark, which began as a single point-contact, progressively broadened to approximately 20 centimetres after a distance of 5.3 metres at which stage it ran across the raised casing of a runway light. Thereafter, it extended a further 1.7 metres, and broadened to a maximum width of 27 centimetres, before fading out and becoming indistinguishable. No other evidence of structural contact was apparent on the runway and it was evident that the damage to G-CFAD had been produced by a single strike occurring at, or very close to, initial wheels touch and that the touch down itself took place within the normal area for aircraft landing on Runway 10.

Flight recorders

The aircraft was installed with a 25 hour duration Flight Data Recorder (FDR) and a 2 hour duration Cockpit Voice Recorder (CVR). The CVR and FDR recordings contained the time history of the entire flight from Glasgow to London City.

The CVR audio from the cockpit area microphone could not be utilised in this investigation. This was due to a 400-hertz signal being recorded which rendered the background audio unintelligible. Audio was successfully recovered from the remaining CVR audio channels.

Flight data indicates the autopilot and autothrust were disconnected at about 800 feet agl by which point Flap 33 had already been selected and the landing gear extended. The airspeed at that time was 125 KIAS and the aircraft was maintaining both the ILS localiser and glideslope.

At 500 feet agl an automatic altitude callout was recorded on the CVR and the aircraft was still established on the localiser and glideslope, maintaining 125 KIAS with a thrust of 53% N1. Engine power remained stable at 53% N1 from the point the autothrust had been de-selected, however at 420 feet agl the power was reduced slightly to 50% N1. No significant change to thrust was made subsequently until thrust was reduced during the landing flare.

At about 280 feet agl the aircraft began to descend below the glideslope. At 190 feet agl the aircraft was 0.58 dots below the glideslope and at 175 feet agl the aircraft was 0.72 dots below the glideslope. Deviation below the glideslope continued to increase to a maximum value of 0.92 dots when the aircraft was descending through 128 feet agl, at which point a small increase in engine thrust of about 1% N1 was made.

After the aircraft had begun to descend below the glideslope the pitch had been gradually increased from 3.0° nose-down to a maximum value of 0.8° nose-up. The pitch had then decreased again and at 75 feet radio altitude the aircraft momentarily regained the glideslope at a pitch of 1.75° nose-down and an airspeed of 119 KIAS. The pitch then immediately started to increase again as the aircraft began its transition into the flare.

The time interval between flare transition and weight on wheels activation was 5 seconds with an average rate of change of radio altitude (derived descent rate) over this time of 636 feet per minute. Half a second prior to weight on wheels activation the derived descent rate had reduced to 480 feet per minute.

The transition of the weight on wheels parameters occurred at an indicated airspeed of 107 kt, this was coincident with a pitch up attitude of 7.82 degrees and a normal acceleration value of 1.775g, both were the maximum recorded values for each parameter during the landing. Deployment of the yellow hydraulic system ground spoilers occurred one-quarter second later, followed two seconds later by the green hydraulic system ground spoilers.

Seven seconds after weight on wheels the co-pilot took control. During the landing rollout ATC requested that the runway be inspected at the western end. Some 77 seconds after touchdown, the co-pilot asked ATC "DID WE DROP SOMETHING". ATC responded with "I THINK YOU JUST TOUCHED THE TAIL ON LANDING, YOU SCRAPED IT A BIT ABOUT FIVE TO TEN METRES ALONG THE RUNWAY".

Analysis

There had been an adequate period of rest for the flight crew prior to the flight and despite the early start of the duty period, neither pilot complained of feeling fatigued.

The aircraft had been correctly configured for the approach and had the correct approach speed of 127 kt selected for the landing weight. At 500 feet agl the FDR trace and co-pilot's statement both confirm that the aircraft was stable on the approach. This is defined in the company's operations manual as aircraft in the landing configuration, established on the glideslope with the approach power set and an indicated airspeed no more than V_{REF} + 20 kt.

When the aircraft had begun descending below the glideslope at 280 feet agl, the commander had attempted to regain the correct profile by increasing the pitch, however he had failed to compensate for the resulting increase in drag (and consequent loss in airspeed) with an adequate increase in engine thrust. As a result, although he managed to regain the glideslope (momentarily and late in the approach), the airspeed had decayed 8 kt below the correct approach speed.

The aircraft normally loses about 7 kt speed during the flare and so the ideal touchdown speed should be V_{REF}33 + gust factor – 7 kt; that equates to an ideal touchdown speed of 115 kt for this flight whereas the aircraft touched down at 107 kt. The aircraft lost too much airspeed in the final stages of the approach because the commander closed the thrust levers as the aircraft entered the flare instead of adding thrust to counteract the trend towards becoming both low and slow. In order to arrest the rate of descent for touchdown at this low speed, a higher than normal pitch attitude, 7.82 degrees, was required. Information provided by the manufacturer indicates a tail strike will occur at pitch attitudes on touchdown in excess of 6.9 degrees.

No reference to airspeed was made by either pilot once the aircraft had descended below 500 feet agl. At this point the handling pilot's attention would have been drawn increasingly outside the cockpit, rather than looking in at his flight instruments. The role of the non-handling pilot in monitoring the aircraft parameters below this point is, therefore, very important. Whilst the co-pilot noticed the speed was low when passing 100 feet agl, he made the incorrect assumption that in relation to their target threshold speed, it was acceptable at this late stage of the approach.

Conclusion

The weather report and additional evidence gathered gave no indication that a shift in either wind strength or wind direction occurred. Consequently, a late change in wind conditions can be discounted as a causal factor. It was the lack of sufficient thrust during the latter stages of the approach that allowed the aircraft's speed to decay and it touched down at 107 kt (V_{REF}33-15 kt)

which was some 8 kt too slow. The loss in airspeed late in the approach was aggravated by an early thrust reduction during the landing flare and the pitch attitude required to arrest the sink rate just prior to touchdown was such that on landing, the aircraft struck its tail on the runway. The commander's inattention to the loss of airspeed was compounded by the co-pilot's lack of warning about the significant deviation below the correct approach speed. In view of their overall flying experience (commander 3,283 hours and co-pilot 8,000 hours) although neither pilot was paying sufficient attention to airspeed control, the relatively low experience on type for each pilot (commander 110 and co-pilot 413) were not considered to be causal factors by the investigators. The commander acknowledged that his lack of speed awareness was the main contributory factor. However, he also stated that he believed his inexperience on type and on aircraft of this weight category were contributory factors. He had never before flown an aircraft in the 20 tonne category that had a tail strike risk and he believed he was following company advice to retard the throttles at 100 feet agl for a steep approach.

The steep approach and restricted runway length (1,508 metres) presented by London City Airport provide challenges to flight crews landing there. In particular, there is a natural tendency to avoid getting high or fast on the approach profile; however, as this accident demonstrates, there are also dangers present in allowing the aircraft to become too slow and/or too low. Moreover the role of the non-handling pilot in monitoring the aircraft parameters may occasionally be made more difficult by the steep approach in that the external view presented is both attractive and distracting.

Safety actions taken

As a result of this accident the operator reviewed its RJ100 pilot conversion training to ensure that it imparted a thorough understanding of the principles of thrust management once past the stabilised approach gate at 500 feet, including the relationship between aircraft weight and inertia. Training was also revised to ensure pilots are not unduly influenced in their management of thrust by the automated call out of radio heights when approaching the landing flare.

In order to reinforce the information contained in Flight Operations Bulletin Number R03/06 a letter on the topic of avoiding tail scrapes prepared by an experienced test pilot flying for the company was sent to all its RJ100 pilots. In addition, existing written guidance on the avoidance of landing tail strikes issued to RJ100 pilots already current on type was to be reviewed to improve its effectiveness.