ACCIDENT

Aircraft Type and Registration:	Cessna Citation CJ1+, N646VP
No & Type of Engines:	2 Williams FJ44 turbofan engines
Year of Manufacture:	2007
Date & Time (UTC):	7 June 2010 at 1650 hrs
Location:	Leeds Bradford Airport, West Yorkshire
Type of Flight:	Private
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Significant damage to the wings and nose, detached nose landing gear, and collapsed right main landing gear
Commander's Licence:	Air Transport Pilot's Licence
Commander's Age:	44 years
Commander's Flying Experience:	3,078 hours (of which 690 were on type) Last 90 days - 72 hours Last 28 days - 27 hours
Information Source:	AAIB Field Investigation

Synopsis

During the takeoff run, the pilot judged that the aircraft would not accelerate to V_1 and decided to reject the takeoff. As he tried to stop the aircraft, both brakes failed, the right brake caught fire and the aircraft ran off the end of the runway. The brakes were probably on, at least partially, during the takeoff run.

History of the flight

N646VP was planned to undertake a private flight from Leeds Bradford Airport to Cannes Mandelieu Airport in France. The pilot arrived at the handling agent's office at 1445 hrs to prepare for a 1630 hrs departure and decided to load the aircraft with 3,320 lb of fuel, which corresponded to full fuel tanks. The flight was to be operated using single pilot procedures but the owner of the aircraft, a licensed helicopter pilot, joined the pilot in the cockpit just before departure and at 1634 hrs they were given taxi clearance. The wind was from the north at 5 kt, varying from between 320° and 070°. There was 30 km visibility, few clouds at 700 ft aal and scattered clouds at 3,000 ft aal. The temperature was 15°C and the QNH was 1008 milibars.

At 1641 hrs the Aerodrome Controller (ADC) cleared the aircraft to line up on Runway 14 and, after stopping on the runway, the pilot applied the parking brake. At 1644 hrs the ADC cleared the aircraft for takeoff. The pilot moved the throttles to the takeoff detent and

confirmed that the FADEC[1] Mode Indicator showed that takeoff thrust had been commanded. He checked on the centre multi-function display (MFD) that the two engine N_1 indications increased to the command bug, confirming that takeoff thrust had been achieved. He checked that the airspeed was increasing on the two airspeed indicators and, at 80 kt, confirmed that the two airspeed indications agreed.

The pilot reported later that, as the indicated airspeed increased towards V_1, he sensed that the acceleration was less than expected and he said "something's not quite right" to the owner in the right seat. The indicated airspeed seemed to the pilot to "hang" and, because he assessed that the aircraft would not achieve V_1, he decided to reject the takeoff. He stated later that he closed the throttles, applied maximum braking, extended the speed brakes and transmitted "ABORT; ABORT; ABORT" on the radio. The ADC asked him whether he needed any assistance, to which he replied "STAND BY".

After the throttles were closed, and with maximum pressure applied to the brake pedals, the aircraft "pulled to the left". At 1645:39 hrs, the ADC transmitted "YOU'VE GOT A FIRE ON THE RIGHT HAND SIDE". The aircraft drifted to the left edge of the runway and responded slowly to the application of full right rudder. Subsequently, the aircraft corrected towards, and then through, the runway centreline, but the pilot reported that by that stage the brakes were totally ineffective. As the aircraft approached the end of the paved surface, the pilot attempted to pull the emergency brake handle, but he accidentally pulled the auxiliary gear control handle instead, which was immediately to its right. When he managed to pull the emergency brake handle, it had no effect and the aircraft ran off the end of the runway to the right of the centreline and down the sloping ground beyond. As the aircraft left the hard surface, the owner moved the throttles to the OFF position to shut down the engines. At the bottom of the slope, the aircraft crossed the perimeter road and hit a fence. During the impact sequence, the right Main Landing Gear (MLG) collapsed and the nose landing gear detached before the aircraft came to a halt. Both occupants were unhurt and were able to exit the aircraft through the main access door on the left side of the fuselage behind the cockpit. The pilot stated that he returned to the cockpit briefly to ensure that the electrics had been turned off.

Footnote

[1] Full Authority Digital Engine Control.

Witness information

The pilot reported later that the aircraft's acceleration appeared normal up until 80 kt. At the point at which he decided to reject the takeoff, he judged that there was more than sufficient runway remaining in which to stop.

The owner reported that he did not notice anything unusual during the takeoff run until the pilot said that something did not feel right and rejected the takeoff. The owner judged that there was sufficient runway ahead to stop safely. He stated that the brakes did not seem to be effective and, when it became clear that the aircraft would run off the end of the runway, he moved the throttle levers from IDLE to OFF.

The ADC watched the aircraft begin its takeoff run and thought that it seemed "slightly slow". He stated that the aircraft had just passed Taxiway 'L' (Figure 1) when the pilot transmitted his intention to abort the takeoff. After a "short pause" the ADC saw flames "burst" out from the right side of the aircraft but he could not see their source. He did not think that the aircraft was travelling particularly fast when the takeoff was

Figure 1

Aerodrome Chart from the UK AIP entry for Leeds Bradford Airport

rejected and was surprised that it ran to the end of the runway and down the slope beyond.

An airport Airside Safety Co-ordinator was in his vehicle, which was stationary at 'VH1' (Figure 1). He reported that following the "ABORT" transmission the aircraft seemed to slow down initially. However, about two seconds after the transmission, flames began to emerge from the right MLG. The aircraft was just approaching Taxiway 'D' (Figure 1) when he first saw the flames.

Description of the braking system

The CJ1+ uses a hydraulically-powered braking system which incorporates an electrically-signalled anti-skid system. The power for the hydraulics is provided by an electric pump which activates to pressurise the brake accumulator to more than 1,300 psi and reactivates if pressure falls below 900 psi. The pump is active whenever DC power is applied to the aircraft and the landing gear handle is in the DOWN position.

Pressure at the brakes is modulated by master cylinders on each of the pilot's rudder pedals. Fluid from the

brake reservoir is received by the master cylinders on the right side of the cockpit, and pressure from either or both brake pedals is ported to the corresponding master cylinders on the left side of the cockpit. The left cylinders receive an analogue input of the foot pressure applied by the pilot on the right and that applied by the pilot on the left, converting whichever is greater into a pressure input to the Brake Metering Valve (BMV). The BMV converts left or right brake pedal commands into power-boosted pressures at the brake cylinders.

The anti-skid system uses electrical transducers on each wheel to feed rotational speed information to an electrical anti-skid Control Box. As a skid or impending locked wheel condition is sensed, a signal is sent to the BMV to release the pressure in the affected brake. The anti-skid system only releases a brake pressure demand; it does not apply any pressure itself.

The parking brake is set by applying and holding footbrake pressure from either seat position and then pulling a parking brake handle underneath the left instrument panel. This action traps the applied pressure in the brake lines such that, when the footbrake is released, the pressure at the brakes remains. If the parking brake handle is pulled with no footbrake pressure applied, no pressure will be present in the brakes. However, any subsequent footbrake pressure will be trapped and maintained, regardless of whether it is a full or partial demand, until the parking brake lever is returned to OFF. It is understood that the performance of the parking brake with full pressure applied is such that the wheels will remain locked even against a full power application on both engines.

The brakes are conventional multi-disc steel assemblies.

Emergency landing gear extension and emergency brakes

Both the emergency landing gear extension and emergency brakes are powered by a single high-pressure nitrogen bottle. Actuation of the emergency lowering handle supplies gas to the hydraulic extension/retraction actuators to 'blow down' the landing gear. If this is followed by a requirement to operate the emergency brakes, sufficient gas pressure should remain to allow several brake applications using gas pressure instead of hydraulic pressure. A handle underneath the instrument panel is used to apply emergency brakes: neither asymmetric braking nor anti-skid protection is available in this situation.

Examination of the aircraft and accident site

The overrun area on Runway 14 at Leeds-Bradford Airport comprises a grass area sloping downwards at about 10 degrees to the perimeter road and fence. The first tyre marks visible from the aircraft occurred as it left the end of the paved surface at the extreme right and carried on down the slope, missing the Instrument Landing System array and approach lights. The spacing of the three tyre marks in the grass showed that the aircraft was not appreciably yawed and there was no sign of braking action, since the grass appeared to have been rolled flat rather than torn up.

After some 83 metres, the aircraft encountered the perimeter road at the bottom of the slope. Whilst the left wheel seemed to have ridden up the lip of the tarmac road, the right wheel hit more firmly and metallic scrapes across the road suggested that damage to the right wheel or landing gear occurred at this point. The aircraft slewed to the right and struck the perimeter fence traveling almost sideways. The fence comprised an inner and outer row of concrete posts supporting chainlink wire fencing with barbed wire on top; the

aircraft demolished a section of the fence and came to rest against some small trees.

A considerable amount of debris was collected from the runway, by the airport authority, and its approximate location plotted. From this it would appear that the first pieces, which were all from the right brake, were sections of friction pad material found roughly in the middle of the runway adjacent to Taxiway 'D'. Further friction material and parts of the brake operating system, including wear indicators, were recovered almost to the point where the aircraft left the paved surface. All showed signs of gross overheating and, where pieces had fallen on joints in the concrete surface, melting of the mastic sealant could be seen. A video taken shortly after the accident by the airport authority traced a visible line of hydraulic fluid starting approximately on the runway centreline adjacent to Taxiway 'D' and curving to the left almost to the edge of the runway, before curving back to cross the centerline and leaving the paved surface at the extreme far right of the end of the runway.

The aircraft suffered significant (but later judged repairable) damage. Both wing leading edges were crushed in several places and the right wingtip had detached. There was a puncture in the top surface of the right wing above the MLG and damage to both flaps, which were in the takeoff setting of 15º. The composite nose radome was also badly damaged and the nose landing gear had detached. Both trailing-link MLGs had remained attached but the right oleo strut had detached at the top, effectively collapsing the MLG, and this had caused the puncture of the wing skin. The speed brakes were retracted.

The hydraulic/pneumatic pressure and contents gauges, visible within the nose baggage compartment, showed that the emergency gear and brake pneumatic pressure had fallen to 200 psi (normally about 2,000 psi) and the power brake accumulator charge had fallen to just above zero psi. The sight glasses for the power brake hydraulic reservoir showed that it was nearly empty.

Airport staff took photographs of the aircraft cockpit following the accident. The images showed that both throttles were in the OFF detent (engines shut down); the flap selector was in the 15° detent (takeoff/approach setting) and the parking brake handle was stowed (parking brake OFF). The auxiliary gear control handle had been pulled and rotated 45° clockwise, which would have released the MLG uplocks. The three-position speed brake switch was found in the centre position between EXTEND and RETRACT.

The cockpit floor on the left side was lifted to expose the parking brake control valve and the cable which connects it to the handle. There were no disconnections and the mechanism worked smoothly.

The Electronic Engine Control (EEC) units from both engines were interrogated for their fault history; no faults had been recorded.

Examination of the mainwheel brakes

After the aircraft had been recovered and placed on jacks in the hangar, the brakes were removed for examination.

The right brake had almost completely disintegrated (Figure 2) and loose pieces, mainly of friction material, were found in the wheel. The whole assembly showed signs of massive overheating and most elastomeric seals had disintegrated. The left brake had not broken up, but similar evidence of overheating had caused some melting and distortion of friction pads and stators (Figure 3).

Figure 2
Right brake

Figure 3
Left brake

Conclusions from engineering examination

Both brakes had suffered exposure to very high temperatures, causing melting and deterioration. The right brake had almost completely disintegrated but the left was also on the verge of disruption. It was evident that the right brake was losing fluid and that, in these circumstances, emergency pneumatic braking would also have been ineffective. The trail of hydraulic fluid and the fire reported by witnesses was consistent with hydraulic fluid coming into contact with very hot components of the right brake.

It is considered that both brakes overheated due to their being on, at least partially, during the takeoff roll and also possibly during taxi to the runway. No faults within the braking system could account for such brake application.

Previous incidents

On 22 September 2008, a Cessna Citation CJ1 rejected its takeoff at Jersey after the crew sensed slow acceleration and smoke was seen coming from the right brake. The crew reported later that the aircraft also seemed sluggish while taxiing before takeoff. The incident was not investigated by the AAIB at the time, but the Air Safety Report (Engineering) showed that no fault was found with the brake system and that the suspected cause of the problem was binding of the right brake. The report stated:

> *'There is a known problem with binding brakes on the CJ series whereby if the parking brake is applied when the brakes are hot the brake discs can sometimes bind.'*

A number of other reports were reviewed of brake-related incidents in Cessna Citation CJ1 aircraft. It was not possible to conclude from the evidence available whether or not binding brakes was a common problem with the aircraft type, but the manufacturer reported that their records did not suggest it was.

Certification basis

The Cessna Citation CJ1+ was certified as a Normal Category[2] aircraft in accordance with Federal

Footnote

[2] Aircraft with nine or less seats (excluding pilot seats); a maximum certified takeoff mass of 5,670 kg (12,500 lbs); and intended for non-aerobatic operation.

Aviation Administration (FAA) Part 23 Airworthiness Standards. For this category of aircraft there is no requirement for a takeoff warning system that provides an aural warning should the aircraft be in a configuration that would not allow a safe takeoff. The EASA accepted the certification because it took place before 28 September 2003 and issued Type Certificate Data Sheet (TCDS) IM A.078.

In December 2008 Cessna issued the following reminder to operators in their 'Direct Approach' magazine:

> *'Make Sure to Disengage Parking Brake*
>
> *There is no parking brake indicator to alert the flight crew that the park brake handle is engaged. Flight crews should follow the procedures in the Airplane Flight Manual (AFM) and the Pilots' Abbreviated Check-list regarding the brake system operation. The pilot in command is the last set of eyes to make certain the brake system switch, circuit breaker, and park brake handle are all in the correct positions before taxi or takeoff.'*

A modification is currently being proposed in the UK which, if approved and fitted, will illuminate a warning light when the parking brake is applied. Cessna have also advised that they are considering fitting a 'parking brake applied' warning on future models of the Citation.

Takeoff and stopping performance

The manufacturer calculated the expected acceleration and stopping performance of the aircraft in the circumstances using a wind of 320°/5 kt, which was a 5 kt tailwind, and a takeoff weight of 10,500 lb[3]. The aircraft should have taken 537 m to accelerate to V_1 and should have stopped in 464 m from V_1 (had it achieved V_1). Applying this stopping distance to the approximate point at which the pilot rejected the takeoff gave a total distance of 1,676 m from the start of the takeoff run. The Accelerate Stop Distance Available (ASDA) for the runway was 2,113 m.

Brake performance

The manufacturer stated that the ability of the brakes to stop the aircraft depended on the work being done by the brakes over an extended period. If the brakes were dragging while the aircraft was moving, even while taxiing at low speed, they would have been absorbing energy and increasing in temperature. If the brakes were dragging during the takeoff run, they may have been quite hot at the beginning of the rejected takeoff (RTO) and would not have been expected to survive the RTO.

Citation CJ1+ Flight Manual

The actions to be taken in the event of a rejected takeoff below V_1 are:

> 1. *'Brakes – AS REQUIRED'*
> 2. *'Throttles – IDLE'*
> 3. *'Speed Brakes – EXTEND'*

Analysis

The aircraft should have accelerated to V_1 in a distance of 537 m in the conditions that existed at the start of the takeoff. In the event, the aircraft was still on the ground after approximately 1,195 m when it had

Footnote

[3] 6,829 lb for the aircraft basic empty weight; 3,220 lb of fuel; 380 lb for the occupants; and 71 lb of miscellaneous cabin items (estimated).

just passed taxiway 'L' and the pilot decided to reject the takeoff. It was clear from this evidence that the aircraft's acceleration was less than expected. Given that the aircraft did not reach V_1, there was more than sufficient runway remaining after closing the throttles for a serviceable brake system to stop the aircraft.

The engine parameters were checked by the pilot at the start of the takeoff run and he stated that they indicated that the desired thrust was achieved. No fault messages were recorded on the EECs and the pilot did not report experiencing asymmetric thrust. It is probable, therefore, that the engines were performing normally during the attempted takeoff.

If the engines delivered the required thrust during the takeoff run, the reduction in performance would have been caused by the brakes being on, at least partially, while the aircraft accelerated. Furthermore, since the pilot did not report directional control problems in the early part of the takeoff run, there was probably equal brake pressure at the left and right brake assemblies. There were no faults found in the braking system that could have led to the brakes being on during the takeoff run and so the possible causes remaining for the reduced performance were that the parking brake had been left on, some toe braking was being applied, or that the brakes were binding. The investigation could not determine the actual pressure applied to the brake assemblies, but it had to be low enough to be overcome by takeoff thrust, and high enough to generate sufficient heat in the brake assemblies for them to be severely damaged.

It was possible that one or both of the occupants in the cockpit applied some toe braking during the takeoff run. Both occupants were familiar with the aircraft and this possibility seemed unlikely, especially as equal pressure would have to have been applied to both brake pedals, but the possibility could not be discounted. There was anecdotal evidence that the brakes in this aircraft type can bind, in some circumstances, and, although the evidence reviewed during this investigation could not corroborate it, this possibility also could not be discounted.

The pilot recalled applying the parking brake when holding on the runway awaiting clearance to takeoff and this would have trapped in the brake assemblies the hydraulic pressure present at the time. The brakes were designed to hold the aircraft against full power and, if maximum toe braking had been applied before the parking brake was selected, and the parking brake was not subsequently released, the aircraft would probably have remained stationary following the application of takeoff thrust. However, if the aircraft had been stopped using just enough toe braking to overcome the idle thrust of the engines, the pressure trapped in the brake assemblies would have been relatively low. In this case, takeoff thrust might have been sufficient to overcome the brakes although the subsequent acceleration would have been reduced and there would have been heating of the brake assemblies. The pilot did not recall whether or not he released the parking brake before beginning the takeoff run, but photographic evidence showed that it was released when the airport authorities reached the aircraft following the accident. It could not be determined if the parking brake had been released immediately prior to the takeoff run, but the possibility that it remained on could not be discounted.

Therefore, there was insufficient evidence to support or discount conclusively any of the three possibilities.

The actions to be taken in the event of an RTO include extending the speed brakes but the aircraft was found

with the speed brakes retracted. The investigation did not determine whether extending the speed brakes would have altered the outcome, but it seemed unlikely. When the pilot pulled the emergency brake handle it had no effect because the brake system had already been damaged to the extent that it was no longer effective.