FINAL REPORT

CESSNA 350, REGISTRATION N1222G

WHEEL FIRE

8 DECEMBER 2016

AIB/AAI/CAS.131

Transport Safety Investigation Bureau
Ministry of Transport
Singapore

5 January 2018

The Transport Safety Investigation Bureau

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> *"The sole objective of the investigation of an accident or incident shall be the prevention of accidents and incidents. It is not the purpose of this activity to apportion blame or liability."*

Accordingly, it is inappropriate that TSIB reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

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GLOSSARY OF ABBREVIATIONS

A&P	:	Airframe and Powerplant
ARFF	:	Airport Rescue and Fire Fighting
ATC	:	Air Traffic Control
CCTV	:	Closed Circuit Television
FAA	:	U.S. Federal Aviation Administration
LT	:	Local Time
POH	:	Pilot's Operating Handbook

SYNOPSIS

On 8 December 2016, a Cessna 350 was returned to service after a major repair. A pilot, accompanied by a mechanic, did a high-speed brake test to bed in the new brake linings. After that, the pilot took off for a test flight but aborted the take-off at about 75 knots. During the taxiing back to the parking bay after the aborted take-off, the aircraft veered to the left of the taxiway centreline. The pilot shut down the engine in an attempt to slow down the aircraft. He managed to steer the aircraft to avoid a parked aircraft as well as an aircraft that was being towed into a parking bay. When his aircraft had eventually come to a stop, the pilot noticed a burning smell in the cockpit and ordered an evacuation. After the pilot and mechanic had evacuated from the aircraft, the main landing wheels caught fire. The fire was eventually extinguished. The aircraft's belly and main landing gears were damaged by the fire. The pilot and mechanic were not injured.

The occurrence was classified as an accident.

AIRCRAFT DETAILS

Aircraft type	:	Cessna 350 LC42-550FG
Manufacturer	:	Cessna Aircraft Company
Operator	:	Private owner
Registration	:	N1222G
Engine details	:	1 x Teledyne Continental I0-550N-37
Date and time of occurrence	:	8 December 2016, 1743LT
Location of occurrence	:	Seletar Airport, Singapore
Type of flight	:	Test flight
Persons on board	:	2

1 FACTUAL INFORMATION

All times used in this report are Singapore times. Singapore local time (LT) is eight hours ahead of Coordinated Universal Time (UTC).

1.1 History of the flight

1.1.1 After having been grounded for three years, a Cessna 350 aircraft was returned to service on 8 December 2016 by an Airframe & Powerplant (A&P) mechanic licensed by the U.S. Federal Aviation Administration (FAA).

1.1.2 The aircraft owner requested the A&P mechanic to arrange for a test flight on the same day. He also requested the previous owner[1] of the aircraft, who was a Cessna 350 pilot, to fly the test. The A&P mechanic asked the pilot to include a high-speed brake test for bedding in the linings of the aircraft's new brakes.

1.1.3 At about 1732LT on 8 December 2016, the pilot, accompanied by the A&P mechanic, conducted the high-speed brake test on the aircraft on Runway 21 in Seletar Airport. The test involved accelerating the aircraft to about 40-50 knots and applying brakes to bring the aircraft to a stop, but did not involve any taking off.

1.1.4 The pilot was satisfied with the high-speed brake test. He decided to proceed with the test flight. For this, he exited Runway 21 at Taxiway W3 and obtained clearance from the Air Traffic Control (ATC) to taxi back to the threshold of Runway 21 via Taxiways WP and W1 for take-off. During the taxiing to the runway threshold, the pilot checked the brakes and found them functioning normally.

1.1.5 At about 1738LT when the aircraft was approaching the threshold of Runway 21, the ATC gave the pilot the take-off clearance. The pilot proceeded with a rolling take-off[2].

1.1.6 According to the pilot, when the aircraft reached about 60-65 knots during the take-off run, the aircraft started to veer to the left. He applied full right rudder but this did not seem to bring the aircraft back to the centerline.

1.1.7 By then, the aircraft had reached about 75 knots. The pilot attempted to rotate the aircraft for the lift-off. However, he felt that the aircraft was not responding to his attempt. Therefore he decided to abort the take-off by putting the aircraft nose down and pulling back the throttle to reduce the engine power. The aircraft rolled down the runway and the pilot applied

[1] The aircraft was sold to the current owner on 26 September 2014.

[2] Typically a pilot would enter the runway, stop at the runway threshold, apply take-off thrust while still holding at the threshold, and start the take-off run only after the take-off thrust level has been reached. A rolling take-off means that the pilot would enter the runway without stopping and would increase the engine power to the take-off thrust level while rolling on the runway.

brakes when the aircraft had slowed to about 50 knots. However, he felt that the brakes were sluggish .The pilot thought that the sluggishness was due to the brakes' being hot, so he started to tap on the brakes intermittently to avoid stepping too hard on the brakes. The aircraft ended up going off the runway and stopping about 30 metres into the clearway (see **Figure 1**).

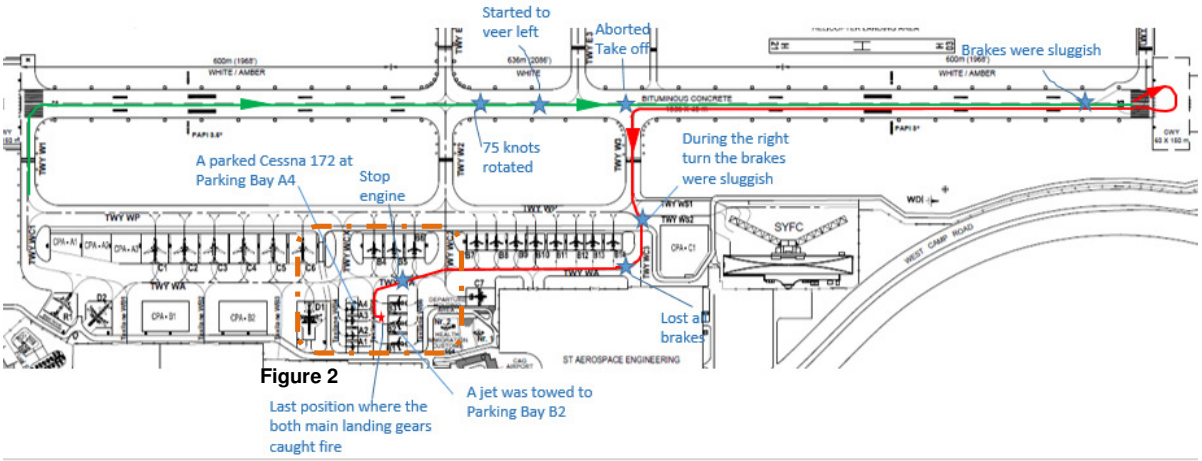

Figure 1. Cessna 350's taxi route during and after the aborted take-off

1.1.8 With ATC's permission, the aircraft backtracked on the runway and exited the runway at Taxiway W3 at 1739LT. The aircraft then taxied from W3 to Taxiway WC3. This involved making a slight left veer from W3 and then a slight right veer onto WC3. During the slight right veer onto WC3, the pilot again felt that the brakes were sluggish, although the left brake appeared to be less sluggish than the right brake.

1.1.9 Subsequently, the pilot turned right from WC3 onto Taxiway WA. After the turn, the pilot felt that he had lost all brakes and he told the A&P mechanic so. The aircraft coasted along on WA until the intersection with Taxiway WC2, at which point the aircraft began veering to the left.

1.1.10 Having veered off the WA centerline, the aircraft headed now towards a Cessna 172 aircraft that was parked at parking bay A4. The pilot resorted to shutting down the engine in an attempt to slow down the aircraft. As he had lost all brakes, the pilot could not steer the aircraft using differential braking, he applied left rudder to try to turn the aircraft towards the left, but his attempt was unsuccessful[3]. The pilot then tried applying left brake, knowing that it was more responsive than the right brake. He managed to get the aircraft turn almost 90° left to avoid the Cessna 172. However, the aircraft ended up moving towards a jet aircraft that was being towed into parking bay B2. In desperation, the pilot pressed hard on the brake pedals and the aircraft, running out of momentum, came to a stop at 1743LT in

[3] Using rudder to steer an aircraft is not effective at low speed.

the middle of Taxilane WB5 and facing parking bay B2 (see **Figure 2**), with the nose gear at 60° to the left.

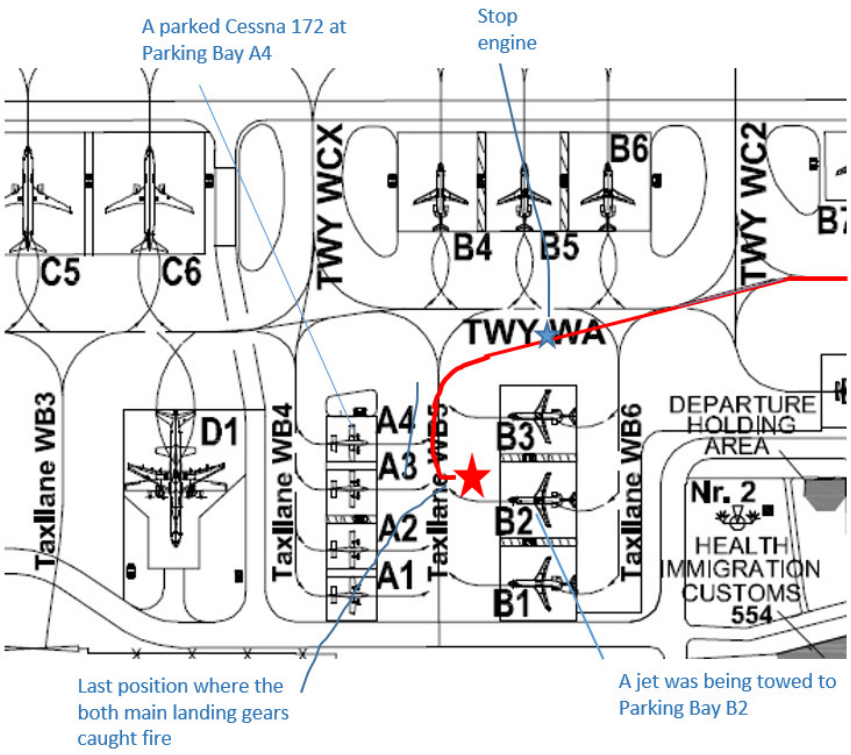

Figure 2: Final resting position of Cessna 350

1.1.11 After the aircraft had stopped, there was smoke from the main landing gears. The tow crew of the jet aircraft that was being towed into parking bay B2 saw a fire on the right main landing gear of the Cessna 350 and quickly brought a powder extinguisher over to the aircraft and discharged it at the main landing gears. The fire was not extinguished. At about the same time, the pilot noticed a burning smell in the cockpit and ordered an evacuation. After the pilot and the A&P mechanic had evacuated from the aircraft, both main landing gears caught fire, which generated black smoke (see **Figure 3**).

Figure 3: Fire at the main landing gears of the aircraft

1.1.12 The jet tow crew brought over another powder extinguisher but still did not manage to extinguish the fire. They then wheeled over a 45kg foam extinguisher and the A&P mechanic assisted to discharge the foam on both wheels. The fire was brought under control.

1.1.13 The Airport Rescue and Fire Fighting (ARFF) Service was activated at about 1744LT. The ARFF Service arrived at the aircraft at 1746LT and put out the fire completely.

1.2 Injuries to persons

1.2.1 The pilot and A&P mechanic were not injured.

1.3 Damage to aircraft

1.3.1 The damage to the aircraft included the following:

- Both landing gears sustained heat damage (see **Figure 4**).

Figure 4: Damage to the landing gears

- The right side of the lower fuselage sustained more heat damage than the left side, including some blistering of paint (see **Figure 5**).

Figure 5: Heat damage on the lower fuselage of aircraft

- The brake fluid reservoir in the engine compartment was found to be totally dry.
- The brake housing and discs had uneven wear and were charred from the fire.
- Brake debris was found in both brakes.
- Black fluid was found on the brake components.

1.3.2 According to the aircraft manufacturer, there were seven prior occurrences of wheel/brake fire within the aircraft family:

(a) In 2008, a wheel/brake fire occurred because of the failure of a worn-out tyre during take-off, resulting in the pilot's aborting the take-off.
(b) In 2009, a wheel/brake fire occurred after a pilot had aborted a take-off and immediately taxied for take-off.
(c) Three occurrences (in 2007, 2011 and 2012) of wheel/brake fires when the brakes were left engaged during towing operation.
(d) In 2010, a wheel/brake fire occurred during a towing operation as a result of an incorrectly assembled brake.
(e) In 2012, a wheel/brake fire occurred after the aircraft had carried out a series of four high-speed brake tests.

1.4 Personnel information

1.4.1 Pilot's information

Gender	Male
Age	45
Licence	Private Pilot Licence issued by FAA, Instrument, Multi-engine, Eclipse 500 Jet Type Rating
Total Flying Experience	650 hours
Total hours on Cessna 350	191
Flying in last 24 hours	0

Flying in last 28 days	0
Flying in last 90 days	16.4 hours

1.4.2 A&P mechanic's information

Gender	Male
Age	59
Licence	FAA A&P Licence with Inspection Authorisation privilege
Experience as mechanic	About 40 years, with experience on Cessna 350 and several other Cessna models

1.5 Aircraft information

1.5.1 Return to service on 8 December 2016

1.5.1.1 The aircraft had been grounded for over three years after it was damaged during an engine ground run on 27 June 2013 following replacement of engine components, e.g. spark plugs. The aircraft jumped chocks during the engine ground run and hit some steel barriers forming a safety barricade for the ground run, resulting in the following damage to the aircraft's wings and propeller.

(a) Damage to the lower and upper skin of the left and right wings
(b) Damage to the propeller blades and spinner

1.5.1.2 The wings were subsequently sent for repairs. The engine was also sent for propeller strike inspection and repair. The damaged propeller and spinner were scrapped and replaced with serviceable ones.

1.5.2 Aircraft weight and balance

1.5.2.1 The aircraft was weighed on 8 December 2016. The empty weight of the aircraft was determined to be 2,576 pounds. This was 8 pounds over the maximum empty weight of 2,568 pounds prescribed in the aircraft's Pilot's Operating Handbook (POH). The weight and balance record form in the POH was not updated accordingly.

1.5.2.2 Before the test flight, the aircraft's ground handling agent added 200 litres of fuel (52.8 US gallons, 303.1 pounds). Taken into account of the 33 US gallons of fuel (189.4 pounds) that was in the aircraft before the fuelling, the aircraft had a total of 85.8 US gallons or 492.5 pounds.

1.5.2.3 The total weight of the pilot and the mechanic was about 360 pounds. Thus, the aircraft's take-off weight was about 3,428.5 pounds. This exceeded the aircraft's maximum gross weight of 3,400 pounds.

1.5.2.4 On 8 December 2016 and prior to the aircraft's operation, the pilot asked the A&P mechanic about the amount of fuel in the aircraft and was informed that the aircraft was about half tank full, which the pilot deemed

would be adequate for the high-speed brake test and test flight. However, according to the A&P mechanic, he did not make any mention of the aircraft's fuel tank status to the pilot. According to the pilot, he had no reason to believe the aircraft would be overweight for take-off prior to the operation. The pilot also stated that he, having clocked 191 flying hours as a Cessna 350 pilot-in-command, was familiar with the aircraft type and had no reason to be concerned about the aircraft empty weight. Thus, the aircraft take-off weight was not checked against the aircraft's maximum gross weight.

1.5.2.5 A post-accident inspection of the aircraft found that the fuel indicator showed a remaining fuel quantity of 81.9 US gallons or 470.1 pounds. According to the POH, the aircraft had a full fuel tank capacity of 98 US gallons. This suggested that the aircraft's fuel tank could not have been about half full prior to the aircraft's operation on 8 December 2016.

1.5.3 Brake system

1.5.3.1 There was no technical logbook entry related to the aircraft's brake system since the aircraft's delivery in 2008.

1.5.3.2 The high-speed brake test was called for by the A&P mechanic as the aircraft had been installed with new brakes[4].

1.5.3.3 During a scheduled maintenance on 24 October 2016, the A&P mechanic inspected the brakes and assessed them as serviceable[5].

1.5.4 Brake cooling

1.5.4.1 The aircraft's Pilot's Operating Handbook (POH) contained the following statement:

> "After heavy braking, especially when the airplane is near gross weight, allow the brakes to cool for about 20 minutes before additional heavy braking. The brakes may overheat if there is repeated heavy braking without adequate cooling time[6]."

1.6 Meteorological information

1.6.1 At the time of the occurrence, the runway was dry. There was no precipitation. Runway visibility range was more than 10km. The wind was 5 knots from a direction of 260 degrees.

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[4] Date of purchase of the new brakes was 18 December 2014. The new brakes were installed by another mechanic.

[5] The aircraft had been grounded all this while.

[6] The heavier an aircraft is and the higher the speed at which the heavy braking is applied, the more brake heat will be generated.

1.7 Medical and pathological information

1.7.1 The pilot underwent a medical examination and toxicological tests following the occurrence. There was no evidence of any medical or toxicological factors that could affect the performance of the pilot.

1.8 Recorded data

1.8.1 The aircraft was not installed, nor was required to be installed, with cockpit voice recorder or flight data recorder.

1.8.2 The following sources were very useful for establishing the sequence of events and how the fire/smoke started:

(a) Video footage from the aerodrome operator's closed circuit television (CCTV) cameras facing the taxiway
(b) Eyewitnesses
(c) ATC audio recordings

1.9 Tests and research

1.9.1 After the occurrence, the following systems were tested/examined:

- Flight control systems (tested and examined)
- Engine (tested and examined)
- Hydraulic lines (examined)
- Wheel/brake assemblies (tested and examined)

1.9.2 Flight control systems

1.9.2.1 The rudder, aileron, and elevator control systems were examined. No anomaly was found.

1.9.3 Engine

1.9.3.1 There appears to have been no problem with the engine's running. Nevertheless, an engine cold compression check was carried out after the occurrence and no anomaly was found[7].

1.9.4 Hydraulic lines

1.9.4.1 Hydraulic continuity checks were carried out for the hydraulic lines upstream of the brakes. No anomaly was found.

[7] The pilot and mechanic did not feel that there was a problem with the engine's running during the high-speed brake test and, later, the attempted take-off.

1.9.5 Wheel/brake assemblies

The left and right wheel/brake assemblies were dismantled for a detailed examination. Apart from the fire damage, the components of these assemblies did not appear to have sustained mechanical damage. The brakes were able to function when hydraulic fluid was introduced, although it was observed that hydraulic fluid was leaking from the cylinder assembly of each brake assembly, suggesting some internal damage to the cylinder assembly.

2 DISCUSSION

2.1 Wheel fire

2.1.1 Post-accident examination of the aircraft did not reveal any anomaly of the brake system, engine and flight control surfaces. The cause of the wheel fire is most likely the overheating of the brakes.

2.1.2 The overheating probably compromised the integrity of the hydraulic lines associated with the left and right brakes. It could not be ascertained how exactly the hydraulic lines were compromised. One possibility is that the O-rings within the cylinder assemblies in the brakes could have failed because of the overheating, thus allowing hydraulic fluid to leak onto the overheated brake components, thereby igniting to develop into a fire.

2.2 Cooling requirement for aircraft brakes

2.2.1 The pilot did not allow a 20-minute cooling period after the high-speed brake test. Instead, he proceeded to a take-off within about six minutes. The taxiing to take-off involved making turns and differential braking. The thermal load on the brakes was exacerbated when this take-off was aborted after the aircraft had reached a speed of about 75 knots. This was aggravated by the pilot's application of brakes when the aircraft slowed to about 50 knots, after the aborted take-off, as it was moving towards the end of the runway. Thereafter, the aircraft still had to make a number of turns, which involved braking actions, when the pilot was taxiing the aircraft towards parking bay A2.

2.2.2 Thus, within a span of about 11 minutes (between the high-speed brake test and when the aircraft finally came to a stop facing Parking Bay B2), the brakes were not given much chance to cool down. The potential for wheel/brake fire, and thus the need for brake cooling, was even greater when the aircraft operated at, near or over its maximum gross weight.

3 CONCLUSION

From the information gathered, the following findings are made. These findings should not be read as apportioning blame or liability to any particular organisation or individual.

3.1 As mentioned in paragraph 1.3.2(b) and (e), there were similar wheel/brake fire incidents resulting from inadequate brake cooling. This incident again highlights the need to adhere to the aircraft manufacturer's advice regarding brake cooling.

3.2 The aircraft was over the maximum gross weight prior to its operation on 8 December 2016. The weight and balance record form in the POH was not updated following an aircraft weighing on 8 December 2016.

4 SAFETY RECOMMENDATIONS

A safety recommendation is for the purpose of preventive action and shall in no case create a presumption of blame or liability.

It is recommended that:

4.1 The owner of the aircraft ensure that aircraft weight and balance information is updated in the documentation system in respect of the aircraft. [TSIB Recommendation RA-2018-001]

4.2 The aircraft manufacturer remind owners/pilots of its aircraft of the need for an adequate aircraft brake cooling period after repeated heavy braking. [TSIB Recommendation RA-2018-002]

4.3 The FAA remind owners/pilots of Cessna 350 of the need to ensure that the maximum gross weight is to be observed. [TSIB Recommendation RA-2018-003]