Statens haverikommission
Swedish Accident Investigation Authority

Final report RL 2021:06e

Accident at Linköping/Saab Airport, Östergötland County on 26 September 2020 involving SE-CXN, an aeroplane of the model Cessna-180D, operated by a private individual.

File no. L-83/20

10 June 2021

SHK investigates accidents and incidents from a safety perspective. Its investigations are aimed at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigations do not deal with issues of guilt, blame or liability for damages.

The report is also available on SHK´s web site: www.havkom.se

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This document is a translation of the original Swedish report. In case of discrepancies between this translation and the Swedish original text, the Swedish text shall prevail in the interpretation of the report.

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Content

General observations

The Swedish Accident Investigation Authority (Statens haverikommission – SHK) is a state authority with the task of investigating accidents and incidents with the aim of improving safety. SHK accident investigations are intended to clarify, as far as possible, the sequence of events and their causes, as well as damages and other consequences. The results of an investigation shall provide the basis for decisions aiming at preventing a similar event from occurring in the future, or limiting the effects of such an event. The investigation shall also provide a basis for assessment of the performance of rescue services and, when appropriate, for improvements to these rescue services.

SHK accident investigations thus aim at answering three questions: *What happened? Why did it happen? How can a similar event be avoided in the future?*

SHK does not have any supervisory role and its investigations do not deal with issues of guilt, blame or liability for damages. Therefore, accidents and incidents are neither investigated nor described in the report from any such perspective. These issues are, when appropriate, dealt with by judicial authorities or e.g. by insurance companies.

The task of SHK also does not include investigating how persons affected by an accident or incident have been cared for by hospital services, once an emergency operation has been concluded. Measures in support of such individuals by the social services, for example in the form of post crisis management, also are not the subject of the investigation.

Investigations of aviation incidents are governed mainly by Regulation (EU) No 996/2010 on the investigation and prevention of accidents and incidents in civil aviation and by the Accident Investigation Act (1990:712). The investigation is carried out in accordance with Annex 13 of the Chicago Convention.

The investigation

SHK was informed on 26 September 2020 that an accident involving an aeroplane with the registration SE-CXN had occurred at Linköping/Saab Airport, Östergötland County, on 26 September at 15:05 hrs.

The accident has been investigated by SHK represented by John Ahlberk, Chairperson, Gideon Singer, Investigator in Charge, and Ola Olsson, Technical Investigator.

Magnus Axelsson and Johan Nordström have participated as advisers for the Swedish Transport Agency and Alessandro Cometa has participated as an adviser for the European Union Aviation Safety Agency (EASA).

SHK has been assisted by Magnic AB as an expert in audio and visual analysis and by Element Materials Technology AB for materials analysis.

The EASA, European Commission, the National Transportation Safety Board (NTSB) in the US and the Swedish Transport Agency have been notified about the investigation.

Investigation material

Interviews have been conducted with the pilot, the passenger, the air traffic controller, the head of the rescue operation and the head of the airport. The aeroplane and the crash site have been examined. A video recording of the occurrence from the remotely operated air traffic control Remote Tower Services (RTS) has been analysed. The strength of the bolted joint and metal remains from the nut have been examined and analysed.

A fact-finding presentation meeting with the interested parties was held on 1 December 2020. At the meeting, SHK presented the facts which were available at that time.

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Aircraft:	
Registration, type	SE-CXN, Cessna 180
Model	180D
Class, airworthiness	Normal, Certificate of Airworthiness and valid Airworthiness Review Certificate (ARC)[1]
Serial number	18050969
Owner	Private
Time of occurrence	26 September 2020 at 15:05 in daylight Note: All times are given in Swedish daylight saving time (UTC[2] + 2 hours)
Place	Runway 11, Linköping/Saab Airport, Östergötland County. (position 5840N 1567E, 50 metres above mean sea level)
Type of flight	Private
Weather	According to SMHI's analysis: Northeasterly wind 5–10 knots, visibility > 10 km, cloud 5–8/8 at 1,000–1,500 feet, temperature/dew point +17/+15°C, QNH[3] 1002 hPa
Persons on board:	2
crew members including cabin crew	1
passengers	1
Injuries to persons	None
Damage to the aircraft	Substantially damaged
Other damage	None
The pilot in command:	
Age, licence	54 years, PPL[4]
Eligibility	SEP[5](land)
Total flying hours	440 hours*, of which 1.6 hours on type
Flying hours previous 90 days	1.6 hours, all on type
Number of landings previous 90 days	5
	* With tail-wheel aeroplanes 348 hours and 506 landings. Differences training for tail-wheel aeroplanes performed September 2002.

[1] ARC – Airworthiness Review Certificate.
[2] UTC – Coordinated Universal Time.
[3] QNH – barometric pressure at mean sea level.
[4] PPL – Private Pilot Licence.
[5] SEP(land) – Single-Engine Piston Land.

SUMMARY

The occurrence took place in conjunction with a short local flight from Linköping/Saab Airport (ESSL), where it was also planned that the landing would take place. The pilot and one passenger were on board.

The approach to runway 11 proceeded along a normal glide path and the touchdown point was approximately 300 metres down the runway. After a short roll on the runway, the aeroplane began to yaw to the left and roll to the right. As a result, the aeroplane ended up in an uncontrolled yaw, known as a ground loop, and exited the runway resulting in broken landing gear and damage to the right wing.

The instantaneous wind on runway 11 at the time of the accident was from the north-east at 5–8 knots and there were no gusts that differed markedly from the average wind speed.

During the accident, the right landing gear was broken at its attachments to the structure of the aeroplane and folded under the fuselage. The bolt for the inboard attachment of the landing gear was bent and parts of the threads were damaged. The nut for the bolt was missing and has not been found. The overall picture of the sequence of events indicates that the threads on the nut have sheared off as a result of an instantaneous overload in the longitudinal direction of the bolt. Potential defects in the bolted joint with regard to tightening torque or worn threads on the nut may have weakened the joint.

The accident was caused by continuing the attempt to land despite several bounces having occurred.

Contributing factors to the accident were the pilot’s limited experience of the aircraft type and the fact that touchdown unintentionally took place on the main landing gear rather than the planned three-point landing.

The damage was caused by the substantial lateral forces on the wheel, which led to the inboard bolted joint of the right landing gear being overloaded, the landing gear folded and broke off, after which the right wing hit the ground and suffered structural damage.

It cannot be ruled out that there were deficiencies in the bolted joint caused by insufficient tightening torque or wear of the nut.

Safety recommendations

None.

1. FACTUAL INFORMATION

1.1 History of the flight

1.1.1 Circumstances

The flight was a short local flight from Linköping/Saab Airport (ESSL) under visual flight rules. The pilot had good knowledge of the flying area and had experience of flying tail-wheel aeroplanes[6]. The pilot had 1.6 flying hours on type.

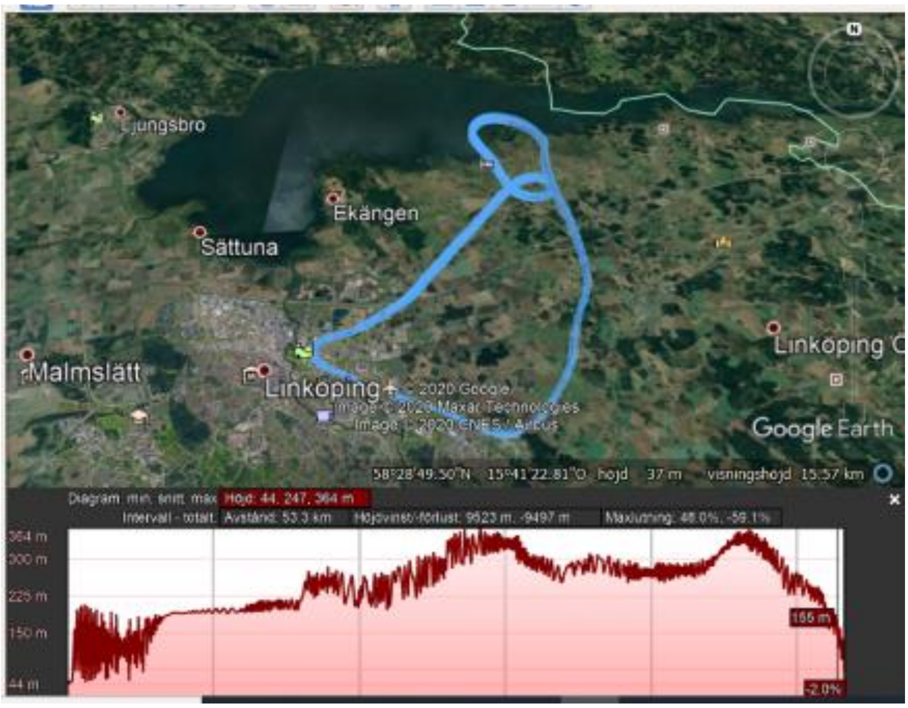

Figure 1. The track of the flight from take-off to landing according to the recording on the passenger's tablet.

1.1.2 Sequence of events

The video material from the remote-controlled traffic control (Remote Tower Services, RTS) indicates that the approach to runway 11 proceeded along a normal glide path and the touchdown point was approximately 300 metres down the runway. After a short roll on the runway, the aeroplane began to yaw to the left and roll to the right (the left wing was lifted up), after which the aeroplane exited the paved surface of the runway on the left side.

According to the pilot, the landing was planned as a three-point landing, i.e. that all three wheels make contact with the ground simultaneously, which is the recommendation in the aircraft flight manual. According to the pilot, however, the main wheels touched down first and at a slightly higher speed than planned, which led to some bounces on the runway. The aeroplane began to yaw to the left and the pilot was not

[6] Tail-wheel aeroplane – an aeroplane that has its main wheels at the front and a small, steerable wheel at the rear. This landing gear configuration requires a special technique for taxiing, take-off and landing.

able to stop the yaw motion using rudder or brakes. As a result, the aeroplane ended up in an uncontrolled yaw, known as a ground loop[7], and exited the runway resulting in a broken right landing gear and damage to the right wing.

The aeroplane was transported to a hanger and the runway was swept clear in order to allow an incoming scheduled flight to land. On the runway there were clear traces of tyre and metal that ended with tracks in the grass.

The accident occurred in daylight at position 5840N 1567E, 50 metres above mean sea level.

1.2 Injuries to persons

None.

1.3 Damage to the aircraft

Substantially damaged. More detail is provided in section 1.12.2.

1.4 Other damage

None.

1.5 Personnel information

1.5.1 Qualifications and duty time of the pilot

The commander

The pilot in command was 54 years old and had a valid Private Pilot Licence, PPL with flight operational and medical eligibility.

Flying hours				
Latest	24 hours	7 days	90 days	Total
All types	0.2	1.0	1.6	440
Actual type	0.2	1.0	1.6	1.6

Number of landings actual type previous 90 days: 5.
Familiarisation training on type concluded on 13 July 2020.
Latest PC[8] on class SEP(land) conducted on 29 October 2019.

The pilot underwent differences training for tail-wheel aircraft at Linköping Flying Club in 2002. The course included theory and practical exercises on a Piper PA-18 (Super-Cub).

[7] See section 1.18.1 for a description of a ground loop.
[8] PC – Proficiency Check.

1.6 Aircraft information

The Cessna 180D is a four-seater, single-engine, high-wing aeroplane (see Figure 2). The aeroplane in question was configured in a tail-wheel configuration, but can also be used as a seaplane by attaching floats instead of the landing gear.

Figure 2. The aeroplane SE-CXN. Photo: Private.

1.6.1 Aeroplane

TC-holder	Textron Aviation Inc.
Model	Cessna C-180D
Serial number	18050969
Year of manufacture	1960
Gross mass (kg)	Max. take-off mass 1,200 current 1020
Centre of gravity	Within limits
Total operating time, hours	5592
Operating time since latest periodic inspection, hours	7
Number of cycles	N/A
Type of fuel uplifted before the occurrence	91/96
Engine	
TC-holder	Continental Aerospace Technologies, Inc
Type	O-470-L
Number of engines	1
Serial number	82262-6-L4
Total operating time, hours	1479
Operating time since latest overhaul, hours	7

Propeller	
TC-holder	McCauley Propeller Systems
Type	2A34C203
Serial number	061411
Total operating time, hours	314
Operating time since overhaul, hours	6
Deferred remarks	
None	

The aircraft had a Certificate of Airworthiness and a valid ARC.

1.6.2 Aircraft flight manual

According to the aircraft flight manual (*Owner's Manual*), a normal landing may take place using any flap position, but flap positions 3 and 4 are indicated specifically for landing. The aircraft flight manual's checklist specifically emphasises the importance of being in a trimmed state (stabiliser trim) ahead of a three-point landing. In other respects, the landing technique is described as conventional for all flap positions.

According to the aircraft flight manual, the recommended speed ahead of landing with flaps is 70–80 mph (61–70 knots).

By estimating the conditions at the time of the landing using information obtained, SHK has calculated the gross mass and centre of gravity. Figure 3 shows the permitted mass and balance states as per the aircraft flight manual.

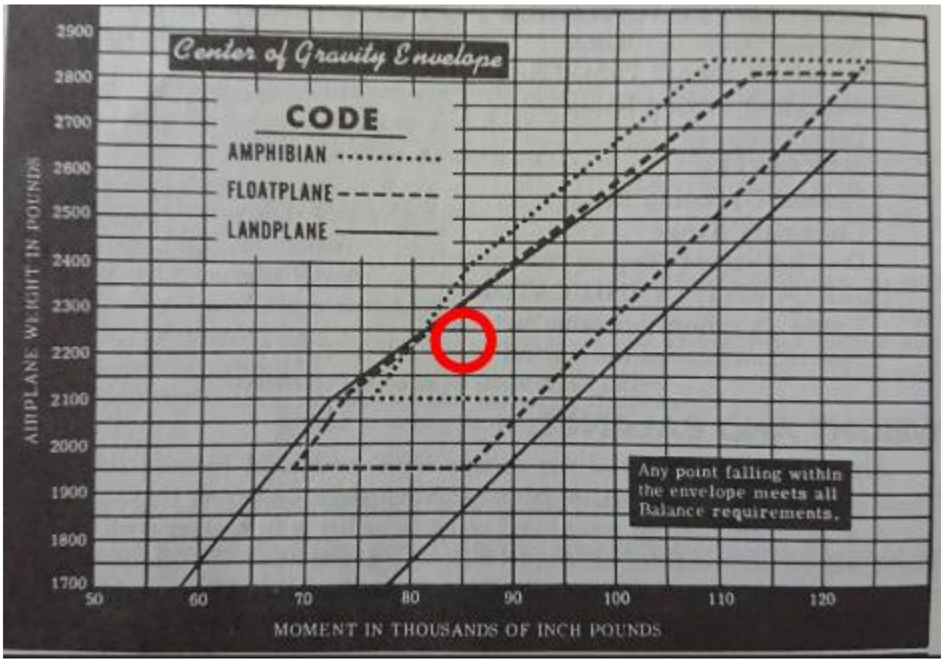

Figure 3. Mass and balance state at the time of the accident (red ring indicates the calculation by SHK).

1.6.3 Main landing gear

This model of aeroplane is equipped with main landing gear at the front and a tail wheel at the back. This model is not equipped with tail-wheel locking.

The main landing gear consists of a steel leaf spring that is both attached to the fuselage outboard structure with shims and wedges and also to the inboard structure with a bolted joint which passes through a hole in the end of the leaf spring. The aeroplane’s wheel is mounted on the lower part of the leaf spring and consists of a rim made of alloy and a tubeless tyre (see Figure 4).

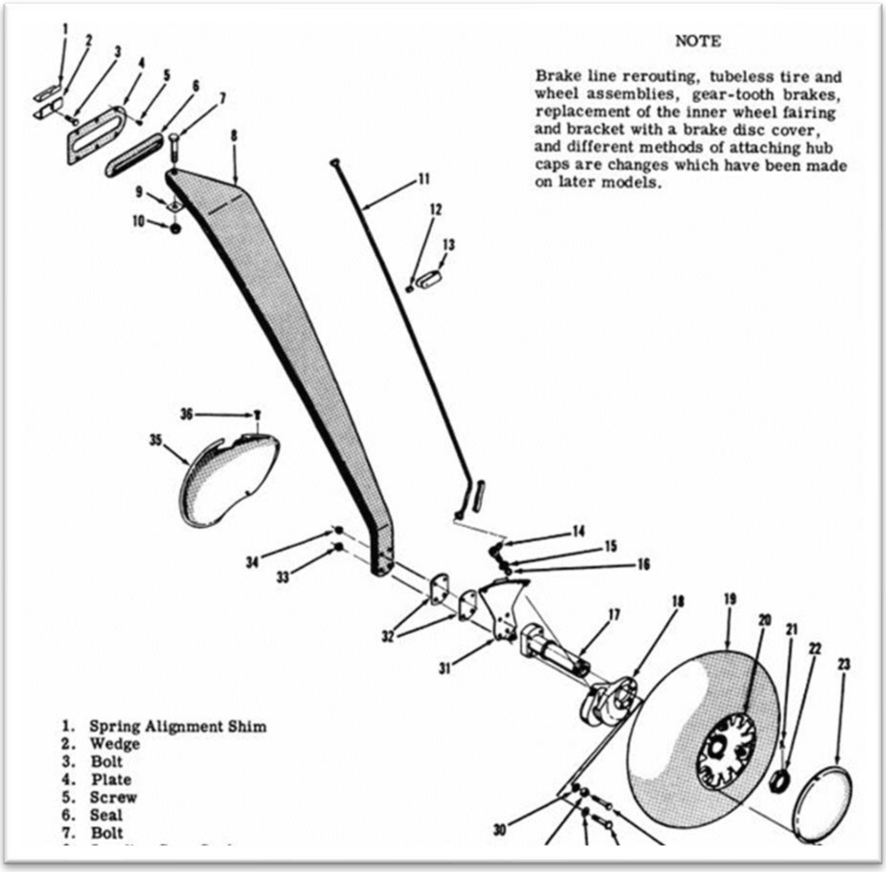

Figure 4. Schematic showing the components in the main landing gear. Source: Textron IPC.

Under normal circumstances, there are no large tensile loads on the bolted joint during take-off and landing. However, in a ground loop, a lateral load on the landing gear arises, which causes a tensile force in the bolted joint, i.e. in an opposite direction to that to which the construction is intended to be exposed in normal use (see Figure 5). Also refer to section 1.16.4 for calculations of the forces in a ground loop.

According to the type certificate holder, a ground loop that is intensive or takes place at high speed or on an uneven surface can cause the landing gear to collapse due to the lateral load.

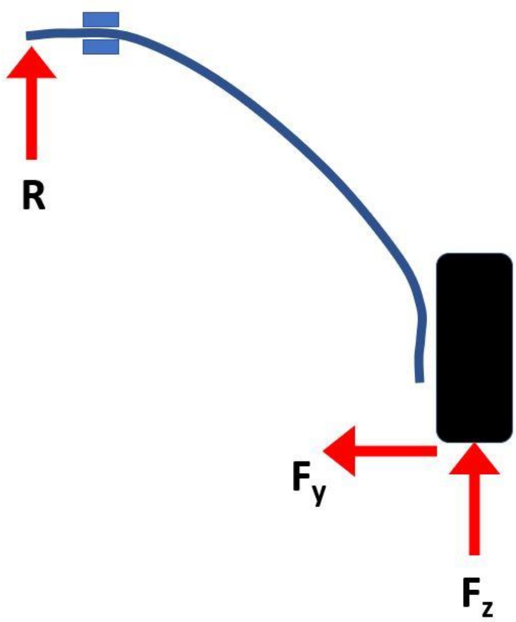

Figure 5. Diagram showing the forces exerted on the landing gear in a ground loop.

1.6.4 *Maintenance of the aeroplane*

According to the aeroplane's technical log, the latest periodic inspection was performed on 7 May 2019 at a flight time of 5,585 hours. The inspection included maintenance tasks as set out in the Cessna SID (*Supplemental Inspection Document*) including inspections of the main landing gear and its attachments for corrosion, cracks and structural integrity. The inspections did not include a check of the tightening torque of the bolted joint for the landing gear. No remarks or deficiencies in respect of the landing gear emerged during the inspections.

According to the aeroplane's maintenance programme, which contains maintenance tasks and intervals based on the type certificate holder's instructions, the periodic inspection is to be performed each year or every 100th flying hour, depending on which occurs first. Consequently, the inspection should have been conducted no later than May 2020. The period for performing the inspection had therefore been exceeded.

During its life, the aeroplane has alternated between being equipped with wheels and with floats for use as a seaplane.

SHK has not found any certificate of release to service from the latest change from floats to landing gear configuration.

Nevertheless, with the help of the aeroplane's journey log, it can be estimated that the latest change from floats to landing gear took place in August 2018 at 5,581 flying hours.

1.7 Meteorological information

According to SMHI's analysis:

North-easterly wind 5–10 knots, visibility > 10 km, cloud 5–8/8 at 1,000–1,500 feet, temperature/dew point +17/+15°C and QNH 1002 hPa.

The weather at the time of the occurrence was clear under the cloud layer and the runway was dry. The mean wind direction and speed ahead of the landing were 060 degrees and 7 knots.

Instantaneous wind registration (one-minute wind speed) at runway 11 indicates that in the period 12:45–13:10 UTC, the wind was 040–080 degrees 5–8 knots and without any gusts that differ markedly from the average wind speed (see Figure 6).

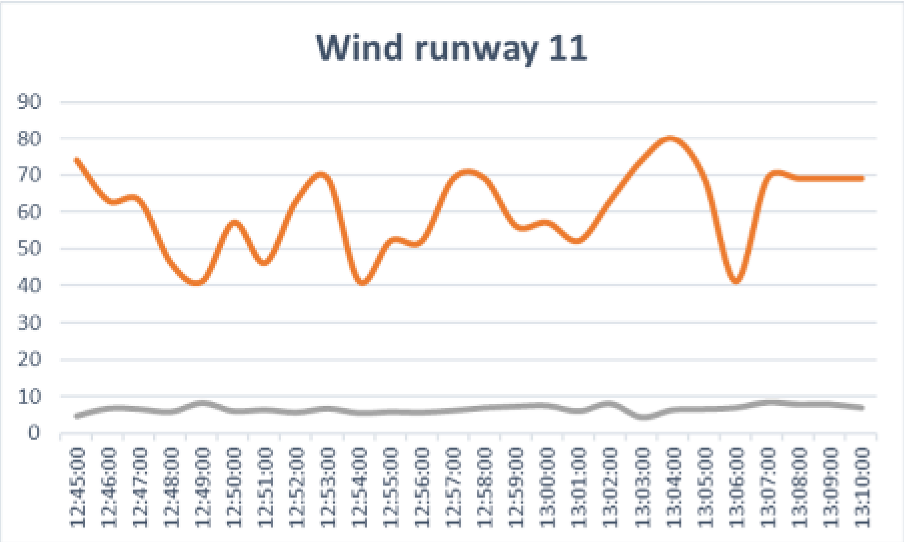

Figure 6. Registration of the instantaneous wind (one-minute wind) at the start of the runway. The upper curve represents the wind direction in degrees and the lower curve the wind speed in knots. SHK graphic.

1.8 Aids to navigation

No aids to navigation were used during the flight. The flight was performed under visual flight rules (VFR) and only visual orientation was pertinent.

1.9 Communications

Air traffic Control was operating and permission to land was requested and obtained. Radio communication between the air traffic controller and the ground units was recorded and this communication has been analysed by SHK.

1.10 Aerodrome information

Linköping/Saab Airport (ESSL) had status in accordance with AIP[9] Sweden.

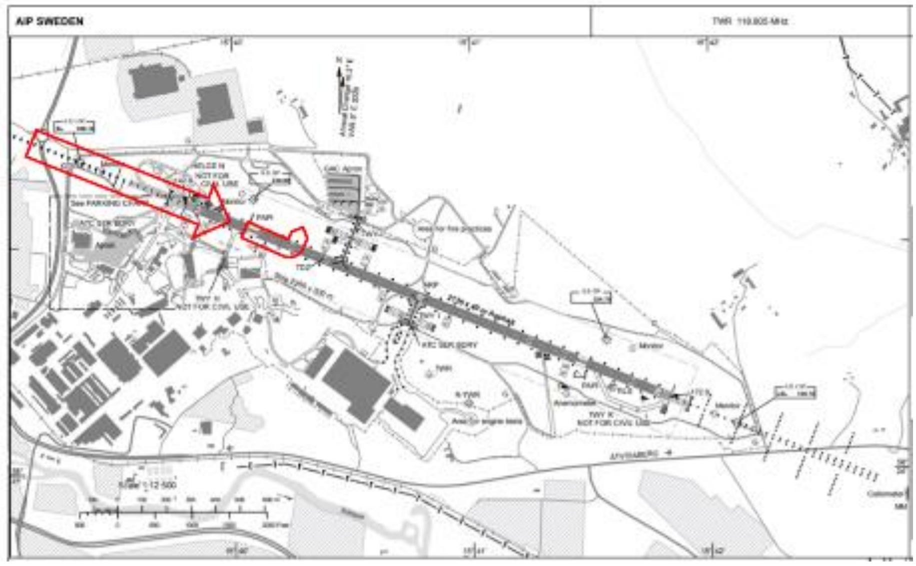

Figure 7. The map taken from AIP with red arrows added by SHK to show the landing direction. Source: AIP Sweden.

Air Traffic Service (ATS) and weather observation service at the airport was managed from a centre in Sundsvall (*RTC*[10]). Traditional visual observations from the tower is replaced by 14 cameras that cover a visual field of 360 degrees around the mast. In addition, the air traffic controller is able to use a zoom function to enlarge specific parts of the visual field.

Figure 8. The air traffic controller's position at a Remote Tower Centre in Sundsvall (conceptual image). Source: Saab AB.

[9] AIP – Aeronautical Information Publication.
[10] RTC – Remote Tower Centre.

Figure 9. The camera tower at Linköping/Saab Airport.

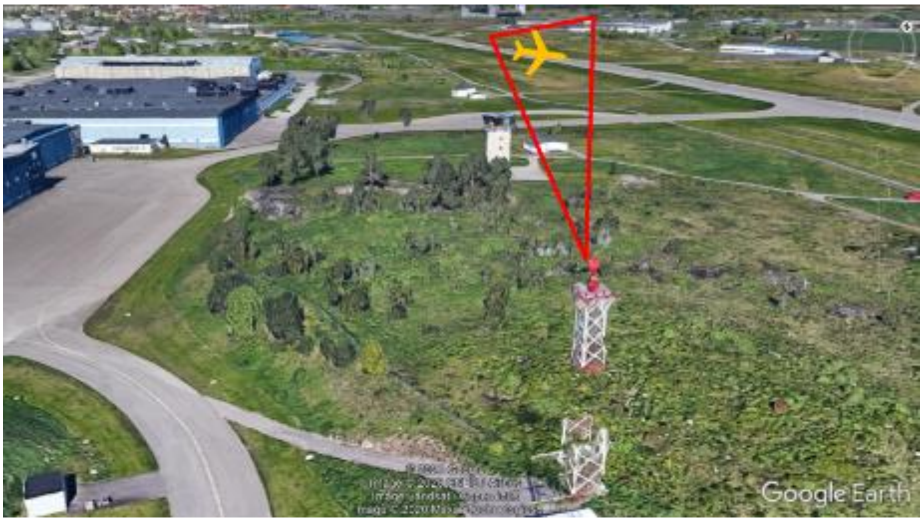

Figure 10. Camera angle at the time of the occurrence. Source: Google Earth (with SHK added graphics).

1.11 Flight recorders

Flight recorders were not required for this type of aircraft and nor were there any installed.

1.11.1 Recording from a tablet

The flight (GPS positions) was recorded on the passenger's tablet. The recorded data only covers up to the point at which the threshold is passed before landing.

1.11.2 Video recording from air traffic control

The air and ground radio traffic from before and after the occurrence has been analysed and shows no discrepancies or lack of clarity in the communication that took place.

Video footage from the landing show that the aeroplane touched down at the beginning of the runway with the main wheels first, bounced two or three times and then started to roll to the right (the left wing lifts up). Just after this, the aeroplane started to yaw sharply to the left and passed the edge of the runway with its left wing raised. When the main wheels approached the edge of the runway, the aeroplane sank clearly in two steps before coming to a stop.

The photographs below are of low resolution due to the large zoom-in. The aeroplane's position and movements tough are visible and some important sequences are presented below (see Figure 11–14).

Figure 11. The aeroplane's estimated initial touch-down point. The centre line and circle have been added by SHK. Source: Sundsvall RTC.


Figure 12. The left wing is raised and the ground loop sequence begins. Source: Sundsvall RTC.


Figure 13. The aeroplane leaves the paved surface. Source: Sundsvall RTC.

Figure 14. The aeroplane comes to a stop with the main wheels outside of the paved surface and the right wing is in contact with the ground. Source: Sundsvall RTC.

1.12 Accident site and aircraft wreckage

1.12.1 Accident site

SHK visited the accident site on 29 September 2020 and examined the marks left by the aeroplane on the runway and on the grass strip alongside it. At the time of SHK's visit, the aeroplane was being stored in a nearby hanger.

On the runway there were clear marks of tyre and metal that ended with tracks in the grass (see Figures 15, 16 and 17). The marks were of a rubber and metallic nature and were a total of 50 metres long.

Figure 15. Clear white marks of metal and marks of rubber up to the excursion point.

Figure 16. Marks on the runway from rubber and metal.

Figure 17. Marks on the runway from the first mark to the final position north of the runway (tyre and metal). SHK's measurements overlaid on a picture of the runway from Google Earth.

1.12.2 Aircraft wreckage

During the accident, the right landing gear was broken from its attachments to the structure of the aeroplane and folded under the fuselage (see Figure 18).

Figure 18. Right landing gear folded under the fuselage. Photo: Saab fire and rescue service.

As a result of this, damage occurred to the right wing, right aileron and propeller (see Figures 18 and 19).

Figure 19. Damage to the right wing and aileron. Photo: Saab fire and rescue service.

There was extensive structural damage to the fuselage area at the landing gear outboard attachment and to parts of the cockpit floor (see Figure 20). The outboard attachment, which i.e. consists of a bracket, was structurally broken.

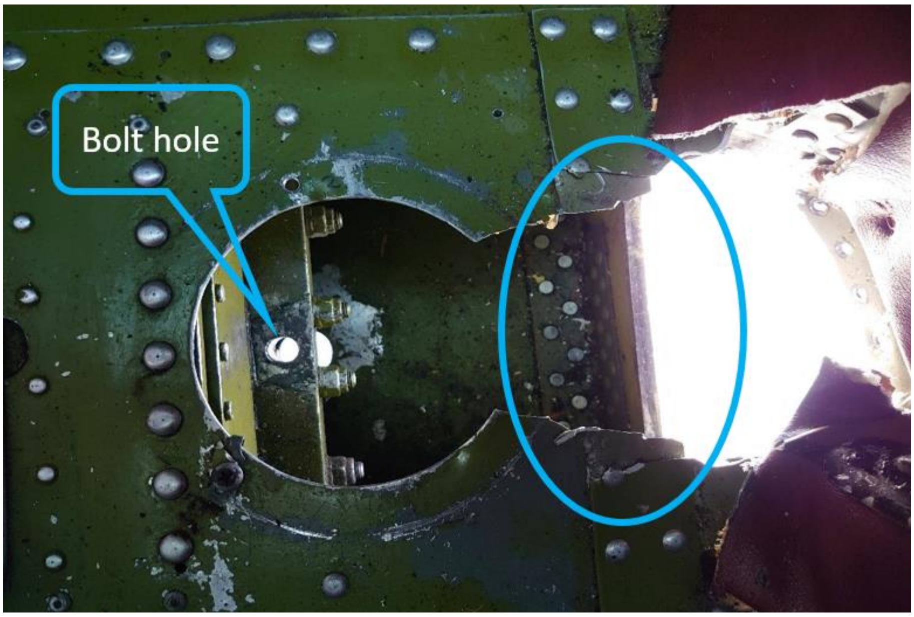

Figure 20. Damage to the fuselage in the area of the attachment of the right landing gear. The bolt hole for the inboard attachment and damage at the outboard attachment are indicated.

The bolt for the inboard attachment of the landing gear was bent and parts of the threads were damaged. The nut for the bolt was missing and has not been found.

Figure 21. Landing gear strut with bolt for attachment.

The upper side of the right landing gear had significant scrape marks that were deemed to correspond to the white marks on the runway (see Figure 22).

Figure 22. The upper side of the right landing gear.

The right wheel suffered extensive damage and parts of the outer part of the rim were broken off.

Figure 23. Damaged right wheel.

1.13 Medical and pathological information

There is nothing to indicate that the mental and physical condition of the pilot was impaired before or during the flight.

1.14 Fire

No fire broke out.

1.15 Survival aspects

1.15.1 Rescue operation

When the aeroplane exited the runway, the air traffic controller activated the accident alarm and the airport's fire and rescue service were thus called out. An ambulance, SAR helicopter and the municipal fire and rescue service were also called out. The airport's fire and rescue service were on site within around a minute (see Figure 24). No rescue operation was necessary and the other emergency services were recalled. The people in the aeroplane had got out themselves and no fire or leak of hazardous substances had occurred.

Figure 24. The airport fire and rescue service at the crash site. Photo: Saab fire and rescue service.

The rescue operation was concluded at 15:35.

The emergency locator transmitter (ELT[11]) of the type EBC-102A was not activated at the time of the occurrence.

1.15.2 Position of crew and passengers and the use of seat belts

The pilot and the passenger were uninjured and were able to get out of the aeroplane themselves. They were seated on the first row of seats and were using the available three-point seatbelts.

[11] ELT – Emergency Locator Transmitter.

1.16 Tests and research

1.16.1 Examination of the bolt for the landing gear

According to the aeroplane's parts catalogue (IPC – *Illustrated Parts Catalog*), the bolted joint for the inboard attachment of the landing gear consists of a bolt with the specification AN7-20A and a nut in accordance with MS20365-720C. The marking and measurements of the bolt are consistent with this. The nut was missing following the accident, which is why it is not possible to confirm its specifications.

An examination of the bolt has been conducted in order to establish the type of failure that occurred to the bolted joint. The examination has involved a visual examination, low-power stereo microscopy and scanning electron microscopy (SEM) with energy-dispersive x-ray spectroscopy (EDS). The material was deemed to be tempered carbon-manganese steel with a small amount of chromium, which is a typical composition for a bolt of this strength class.

The entire bolt is bent, which means that its yield strength has been exceeded (see Figure 25).

Figure 25. The bolt for attachment of the landing gear.

The threads on the bolt are heavily deformed along a section approximately 7 millimetres in length and, in this area, the threads are filled with metallic material (see Figure 26).

Figure 26. Enlargement of the bolt with deformed threads and metallic material in the threads.

Higher magnification of the deformed threads reveals clear signs of powerful shearing between two metallic materials, with high-temperature oxides[12] and marks in the longitudinal direction of the bolt (see Figure 27). These damages indicate a high instantaneous tensile overload of the bolt.

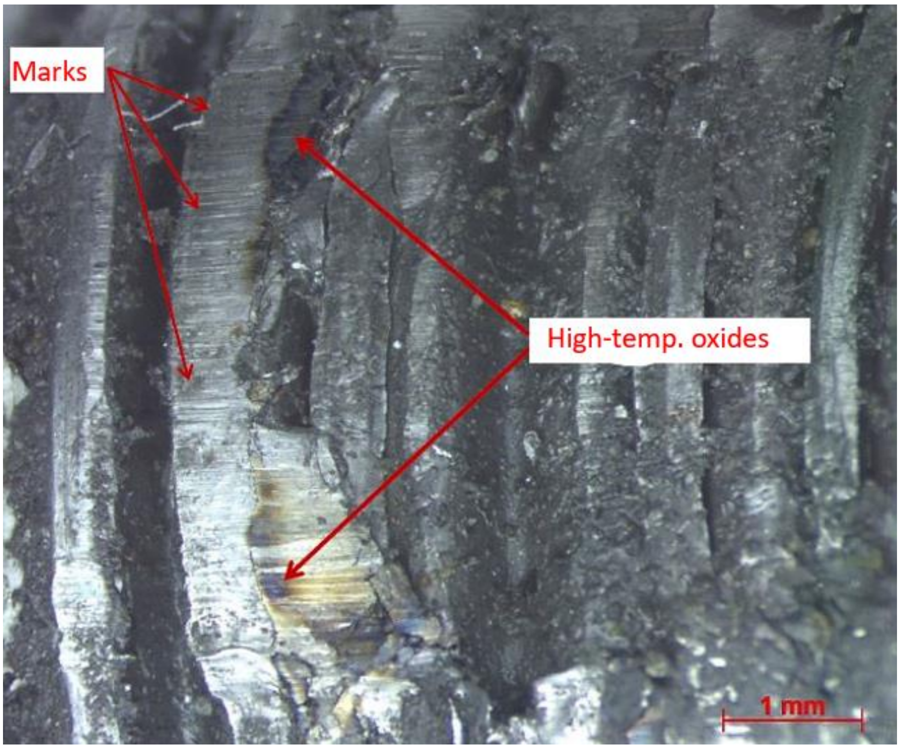

Figure 27. Enlarged image of the threads.

[12] High-temperature oxides can form when two metallic materials under high pressure move relative to one another.

The bolt was examined using EDS in order to establish the composition of the material that is filling the threads. The result of the examination showed that the material in the threads was a carbon-manganese steel and most probably material from a mounted nut, the threads of which has sheared off and has been left in the threads on the bolt.

A visual examination shows that the length of the section of the bolt with very deformed thread corresponds relatively well to the number of turns on the thread up to the locking point of a nut with the specification MS20365-720C.

The overall picture of the sequence of events in which the bolted joint was damaged suggests that the threads on the nut has broken as a result of a high instantaneous tensile overload of the bolt. The damage that occurred to the threads of the bolt indicates that the dimensions of the nut were consistent with the specifications in the aeroplane's IPC.

1.16.2 Examination of the bolted joint on the left landing gear

In order to give an indication of whether the correct type of bolt and nut were mounted on the damaged right landing gear, a comparative examination of the bolted joint on the left landing gear has been conducted.

The markings on and dimensions of the bolt for the left landing gear were consistent with an AN7-20A bolt in accordance with the specifications in the aeroplane's IPC. The nut was removed for examination. It was tightened, but with a torque that was estimated to be lower than the tightening torque specified in the aeroplane's maintenance manual. A washer under the nut was missing. The self-locking action of the nut was largely lacking in function and it was easy to loosen the nut by hand. The appearance of the nut indicates that it was well used; loosened and tightened many times. The dimensions of the nut indicate that it was of the correct type, MS20365-720C, in accordance with the specifications in the aeroplane's IPC.

1.16.3 Reference testing of bolt and nut

Element Materials Technology AB was commissioned by SHK to conduct reference testing on the type of bolt and nut specified in the aeroplane's IPC.

A destructive over-torque test of the nut and the bolt was performed. The testing also included a nut with a lower height (MS20364-720[13]) in order to assess whether an incorrect type of nut could potentially have been installed.

According to Cessna's service manual, the tightening torque for the bolted joint is 51–56 Nm and during the test, this was exceeded with a good margin without succeeding in destructively over-tightening/tearing the threads, even when mounting a nut with a lower height. This

[13] Nut with a lower height for use in bolted joints that are only subject to shear load.

demonstrates that it is unlikely to exceed the tightening torque so much that the threads are sheared off during assembly.

Tensile testing of the bolted joint in the tensile testing machine was performed in order to obtain the ultimate tensile strength. The testing showed that the forces exceed the specification values by a good margin.

1.16.4 Calculation of forces exerted on the landing gear in a ground loop

Calculations have been performed in order to obtain an estimate of the forces that are exerted on the landing gear in a ground loop that takes place on a surface made of dry asphalt (see Figure 28).

The factors used in the calculations were the aeroplane's mass, the dimensions of the landing gear, the coefficient of friction for dry asphalt and the angle at which the aeroplane was banking during the sequence of events. The calculations show that the resulting tensile force in a ground loop is around half the breaking load of the bolted joint according to the specifications.

It should be emphasised that these calculations are theoretical. The dynamic effects during the sequence of events are difficult to determine. Nor have the calculations taken into account deficiencies in the joint related to tightening torque or if the threads have been worn.

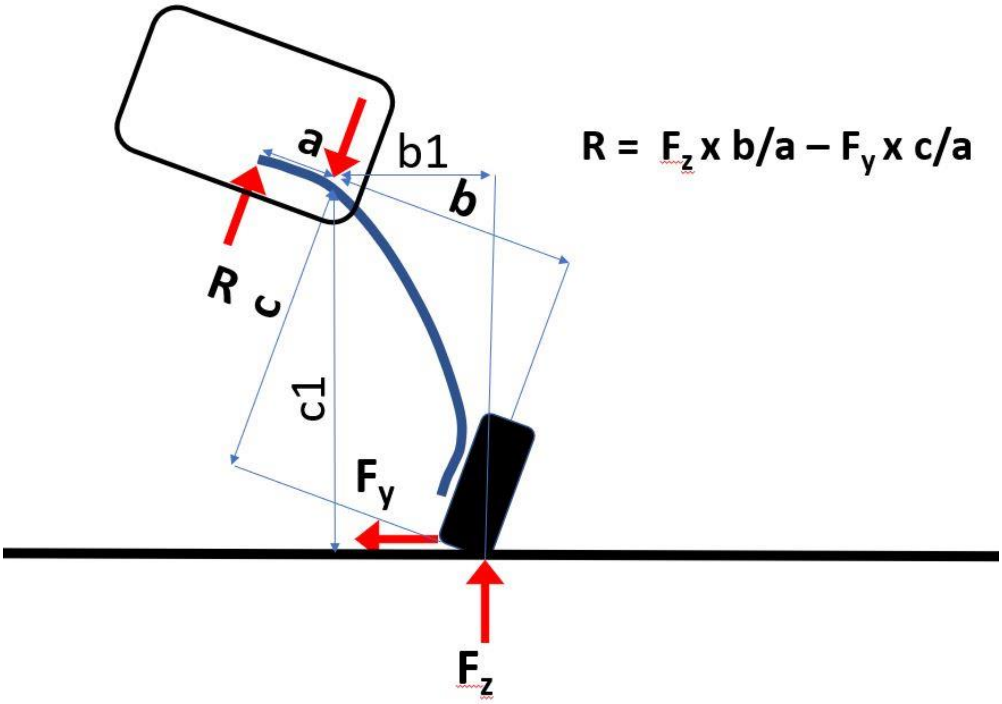

Figure 28. Theoretical calculation of forces exerted on the landing gear in a ground loop. F_Z is normal force, F_Y is the side force generated in a ground loop, a, b and c are the dimensions of the landing gear. R is the resultant force in the bolted joint.

1.16.5 Calculation of the aeroplane's speed over the threshold

The speed during the landing phase has been estimated using still images from various points in the video recording from the camera tower and with the help of the consultancy firm Magnic AB (see Figure 29).

The calculations are based on two fixed points in the images – the left edge of the start of the runway and the light in the PAPI (*Precision Approach Path Indicator*) that was closest to the runway. The distance in millimetres in the image from the aeroplane to a vertical line from the start of the runway and the PAPI light, respectively, was measured in order to work out how much of the visual field from the camera tower was taken up at each distance.

Figure 29. Lines drawn on image to calculate the aeroplane's ground speed. Source: Google Maps with SHK added graphics.

The first touchdown was deemed to have taken place just after the runway threshold 13.03.22. The table (see Figure 30) shows the distance and time between various measured points above. When the time between the seconds 13.07 and 19.3 (rows marked in green), i.e. before touchdown, is calculated, the average speed is 75.5 mph (33.9 m/s) and the average speed from just before touchdown 19.3 to 28.9 (rows marked in blue) is 61 mph (27 m/s).

Tid [s]	Tid diff [s]	Avstånd THR [m]	Avstånd diff [m]	Fart [m/s]	Fart [kt]	Fart [mph]
13,07		-203,00				
	1,36		47,00	34,6	67,2	77,3
14,43		-156,00				
	1,24		42,00	33,9	65,8	75,8
15,67		-114,00				
	3,63		122,00	33,6	65,3	75,2
19,30		8,00				
	2,90		86,00	29,7	57,6	66,3
22,20		94,00				
	1,83		48,00	26,2	51,0	58,7
24,03		142,00				
	4,87		127,00	26,1	50,7	58,3
28,90		269,00				
	2,20		50,00	22,7	44,2	50,8
31,10		319,00				

Figure 30. Time and distance on the runway calculated as ground speed.

The accuracy of the calculations using this method is limited and is estimated at 5–10 mph (2–4 m/s). The reasons for this include the fact that the angle between the runway and the line from the camera tower to the start of the runway is only 13 degrees. The greater the angle, the higher the accuracy. Another factor is the low resolution that results in the aeroplane appearing as a small, blurred spot. One further factor that has an impact is if the aeroplane is not heading in a straight line directly above the runway centre line.

1.17 Organisational and management information

Not pertinent.

1.18 Additional information

1.18.1 What is a ground loop?

A ground loop is an uncontrolled yaw on the ground following landing or during take-off in which the pilot loses control of the aeroplane's movements in the horizontal plane. This phenomenon is particularly prevalent when flying tail-wheel aeroplanes where the centre of gravity is behind the main landing gear during the ground roll. When a yaw into the wind is not countered in time using opposite rudder, the rate of turn rapidly increases to a point at which it is no longer possible to correct the motion. The yaw usually becomes a roll in which the inner wing is lifted, the inner wheel is lifts and the outer wheel begins to bend inwards (see Figures 31 and 32).

Figure 31. An example of a ground loop involving a Cessna 180 during an occurrence in the USA in 2017. Source: YouTube. Santa Monica Airport Cessna crosswind ground loop – Birddog Austria.

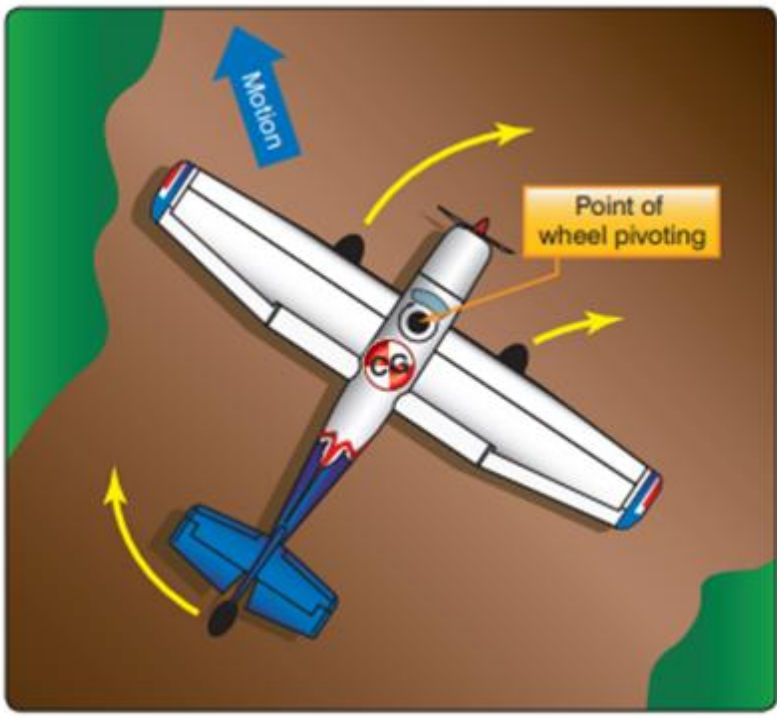

Figure 32. The centre of gravity effect on the tendency to yaw that can increase the risk of a ground loop. Source: FAA Airplane Flying Handbook (FAA-H-8083-3B) Chapter 13.

A ground loop most frequently occurs when landing in cross winds (see Figure 33) and in combination with the pilot having limited experience of tail-wheel aeroplanes. The Cessna 180 is known to be particularly sensitive to landing in cross winds and is over-represented in the statistics concerning damage in this type of occurrence.

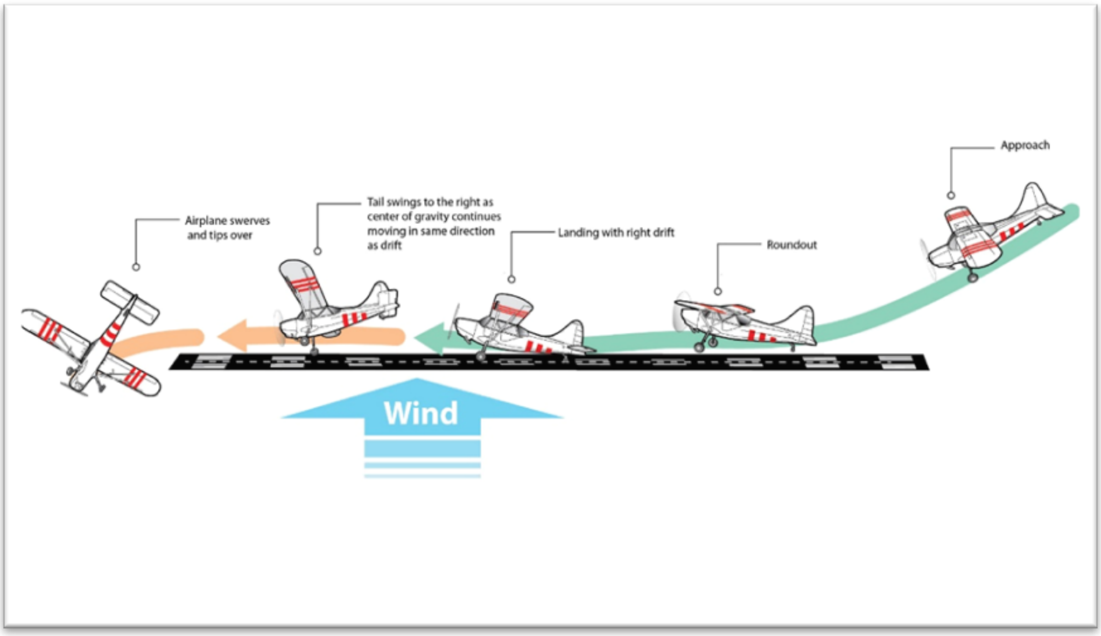

Figure 33. Development of a ground loop when landing in cross winds. This sequence shows the development of a yaw followed by roll and finally the tipping forward. Source: www.aopa.org/news-and-media/all-news/2019.

1.18.2 Previous occurrences with the aircraft type

The same aeroplane (SE-CXN) was involved in an accident at Sveg Airport on 15 May 1986. The accident was reported to the Swedish Civil Aviation Authority, which at that time was Luftfartsinspektionen. The accident report and the subsequent technical examination describe a ground loop sequence of events following touchdown with damaged wheels, landing gear, wing and elevator. According to the report, the threads in the bolt for the main landing gear were sheared off and the nut cracked, which led to the landing gear breaking off the aeroplane.

SHK has studied the American National Transportation Safety Board's (NTSB) accident reports concerning the Cessna 180 aircraft type over a ten-year period. This resulted in the identification of more than 20 cases in which the landing gear strut (and sometimes also the wing) were damaged as a result of an uncontrolled ground loop during landing. The NTSB was not able to find any technical faults with the landing gear in any of these cases.

According to the Aviation Safety Network's database for 2019–2020, an uncontrolled yaw on the ground during take-off or landing (ground loop) is a common cause of accidents for the Cessna 180, resulting in damage to the wing and landing gear. The same trend is seen in the database for previous years. Of the 37 Cessna 180-related accidents between January 2019 and October 2020 in the database, 19 involve a ground loop as a factor during the landing or take-off phase.

A similar occurrence from September 2015 involving a Cessna 180C, with the registration VH-FDH, in which the landing gear and the wing were broken off during a yaw on the runway, was investigated by the Australian Transport Safety Bureau (ATSB).

1.18.3 Actions taken

None.

1.19 Special methods of investigation

Not pertinent.

2. ANALYSIS

2.1.1 Circumstances

The investigation indicates that until 90 days before the accident, the pilot had no experience of the aircraft type in question. The pilot's total experience on the aircraft type was only 1.6 hours and 5 landings. However, the pilot's logbook showed that the pilot had a great deal of experience of flying other types of tail-wheel aeroplane. The pilot had completed differences training for tail-wheel aeroplanes in 2002, which is a formal training programme.

According to the NTSB and the ASN accident database (see 1.18.2) a ground loop is frequently a factor in accidents during landing involving this aircraft type. The accident statistics show that the aircraft type is sensitive to the development of a ground loop during landing.

The investigation indicates that the pilot was aware of the risk of a ground loop when landing in a tail-wheel aeroplane, but had limited experience of the Cessna 180. The pilot planned to land using a three-point landing.

The flight took off from Linköping/Saab Airport and lasted approximately 10 minutes, which means that the pilot was well aware of the wind conditions over the runway. In conjunction with the approach, the pilot received information about the weather and was cleared to land on runway 11 by air traffic control.

2.1.2 Sequence of events

The video sequence from air traffic control shows that the landing took place on the intended part of the runway and at a normal approach angle.

The information about the instantaneous wind (one-minute wind at 12:45–13:10 hrs) for runway 11 at the time of the accident indicates that the wind speed was never higher than 10 knots and that the cross-wind component was not more than 4 knots and had small variations.

According to the aircraft flight manual, the recommended speed before landing with flaps is 70–80 mph (61–70 knots). Given that the cross-wind component above the threshold was 4–6 knots, the ground speed should have been between 55 and 66 knots. Using the video material, SHK has estimated the ground speed above the threshold at 65 knots (75 mph), which is consistent with the recommendations in the aircraft flight manual.

The interview with the pilot and the video sequence indicate that the aeroplane bounced a few times before finally touching down on the runway. The aeroplane can be clearly seen yawing to the left with a roll attitude to the right. The pilot has stated that the movement became uncontrollable before the aeroplane stopped outside of the runway.

Based on an analysis of the video sequence and the marks on the runway, it appears most likely that, during the sequence of events, the aeroplane slid to the right with almost its entire mass resting on the right wheel. The damage to the tyre shows clear signs that demonstrate that the outer tyre surface was scraped against the runway and that the large lateral forces led to the right landing gear leg collapsing and the aeroplane sliding further on the upper part of the strut and the outer part of the wheel.

It is SHK's assessment that a combination of a cross-wind component and a bounce, following the landing having taken place unintentionally on only one main wheel resulted in the occurrence of a ground loop.

2.2 Survival aspects

2.2.1 Rescue operation

SHK has established that rescue resources were on site quickly and that the combined rescue operation appears to have worked well.

2.3 Technical examinations

According to the type certificate holder, a ground loop can cause a landing gear to collapse due to the lateral load that arises. Other accidents involving this type of aeroplane show that the landing gear can collapse in a ground loop as a result of lateral forces on the landing gear.

SHK makes the assessment that this has also been the case in this occurrence. The examination of materials shows that the bolted joint for the inboard attachment of the landing gear has failed due to the threads on the nut being sheared off by an instantaneous overload. As a result of this, the outboard attachment has failed, resulting in the right landing gear folding under the fuselage.

The fact that the nut was missing can probably be explained that it fell out through the damaged fuselage structure in the area of the landing gear attachment, and then cleared when the runway was swept following the removal of the aeroplane.

The examination showed that the nut for the left landing gear did not have a self-locking function (worn out) and that a washer under the nut was missing, which may indicate that there was a similar fault with the nut for the right landing gear. A lack of self-locking function and missing washer may result in the bolted joint having lost its tightening torque, which may in turn have led to a free play and a weakened attachment in the event of large tensile loads.

According to the examination of the materials, it is unlikely that the bolted joint's tightening torque has been exceeded so much during assembly that the threads have sheared off.

Tensile testing of the bolted joint has shown that the necessary forces exceed the specification values by some margin and that the static forces on the joint during a ground loop do not normally lead to a tension failure. However, the forces that arise from dynamic effects during the sequence of events are difficult to calculate. Any faults in the bolted joint with regard to tightening torque or worn threads in the nut may have weakened the joint.

The calendar time interval for the annual periodic inspection had been exceeded at the time of the occurrence. However, as this inspection does not involve any detailed inspection of the attachments for the main landing gear, SHK makes the assessment that the fact that the interval has been exceeded has not been a contributing factor in the accident.

The latest change from floats to landing gear is estimated to have taken place in August 2018 at a flying time of 5,581 hours, however there was no certificate of release to service for this action. Following the change, the aeroplane has been operated for 11 flying hours without any remarks of relevance to the occurrence.

3. CONCLUSIONS

3.1 Findings

a) The pilot had flight operational and medical eligibility to perform the flight.
b) The pilot was qualified to fly tail-wheel aeroplanes of the class in question.
c) The aeroplane had no known technical deficiencies that prevented the flight.
d) The aeroplane had a Certificate of Airworthiness and valid ARC.
e) The calendar time interval for the periodic inspection had been exceeded.
f) The latest reconfiguration between floats and landing gear was not documented in the aeroplane's technical documentation.
g) The airport was EASA certified and approved as an instrument aerodrome.
h) Air traffic control at the airport was open and run from Sundsvall RTC.
i) The aeroplane was operating under visual flight rules and was to land on runway 11 in accordance with the clearance from air traffic control.
j) Touchdown took place on the main wheels and was followed by a couple of bounces before the aeroplane rolled along the runway.
k) During the ground roll, the aeroplane's left wing lifted and a yaw to the left developed. This led to an uncontrolled ground loop.
l) The right landing gear folded under the fuselage.
m) The aeroplane came to a stop with the main wheels off the runway and with extensive damage to the landing gear and wing.
n) The air traffic controller noticed that the aeroplane was yawing and ended up off the runway and led to the controller raising the alarm.
o) The pilot and passenger were uninjured.
p) The airport's fire and rescue service were on site one minute after the occurrence.
q) The accident occurred in daylight with visual meteorological conditions and good visibility.
r) The overall picture of the sequence of events in which the bolted joint of the right landing gear was damaged suggests that the threads on the nut has broken as a result of an instantaneous tensile overload of the bolt.

3.2 Causes/contributing factors

The accident was caused by continuing the attempt to land despite several bounces having occurred.

Contributing factors to the accident were the pilot's limited experience of the aircraft type and the fact that touchdown unintentionally took place on the main landing gear rather than the planned three-point landing.

The damage was caused by the substantial lateral forces on the wheel, which led to the inboard bolted joint of the right landing gear being overloaded, the landing gear folded and broke off, after which the right wing hit the ground and suffered structural damage.

It cannot be ruled out that there were deficiencies in the bolted joint caused by insufficient tightening torque or wear of the nut.

4. SAFETY RECOMMENDATIONS

None.

On behalf of the Swedish Accident Investigation Authority,

John Ahlberk   Gideon Singer