Saab-Scania SF340B, G-GNTH

AAIB Bulletin No: 3/99 Ref: EW/C98/2/2 Category: 1.1

Aircraft Type and Registration:	Saab-Scania SF340B, G-GNTH
No & Type of Engines:	2 General Electric CT7-9B turboprop engine
Year of Manufacture:	1989
Date & Time (UTC):	27 February 1998 at 0720 hrs
Location:	Leeds Bradford Airport
Type of Flight:	Public Transport
Persons on Board:	Crew - 3 - Passengers - 15
Injuries:	Crew - None - Passengers - None
Nature of Damage:	Minor damage to rudder stops, wheels and brakes
Commander's Licence:	Airline Transport Pilot's Licence
Commander's Age:	43 years
Commander's Flying Experience:	3,781 hours (of which 872 hours were on type)
	Last 90 days - 176 hours
	Last 28 days - 50 hours
Information Source:	AAIB Field Investigation

History of the flight

The crew were operating the first sector of the day as a flight to Glasgow. It was also a line training flight for the first officer; he had completed his first two line training flights on type the previous day with the same training captain. On this first sector, the commander in the left seat was designated as the handling pilot. Prior to flight, the crew had obtained the latest weather information which was printed at 0601 hrs. The actual weather showed a surface wind of 250°/24 kt gusting to 35 kt, visibility of 20 km and cloud broken at 2,000 feet agl; the forecast weather from 0700 hrs to 1600 hrs included a surface wind of 250°/23 kt gusting 40 kt with a

'Tempo' throughout the period of 270°/28 kt gusting to 50 kt. There were no significant entries in the aircraft technical log, and pre-departure checks and engine start were normal.

With Runway 32 in use, the commander taxied G-GNTH towards holding point 'Delta 1'. There, the aircraft was held in preparation for a backtrack along the runway once a preceding aircraft had departed. During this period, the Automatic Terminal Information Service (ATIS) was broadcasting information 'B'; this was timed at 0658 hrs and gave a surface wind of 240°/25 kt gusting 40 kt. While G-GNTH was holding at 'Delta 1', the preceding aircraft was cleared for take off with a surface wind of 250°/32 kt. Following this departure, the commander taxied G-GNTH onto the runway and backtracked to the end of the available hardstanding where there is a turning area on the north side of the runway. The final part of the aircraft line-up manoeuvre was to the right and the crew disconnected the control gust locks and completed a full and free check of all flight controls as the aircraft was head-on to the wind. The line-up checks were also completed and the crew were cleared to take off with a surface wind of 250°/29 kt; the normal take-off setting of Flap 15 was being used.

The commander commenced the take off by advancing the power levers; his feet were on the rudder pedals and he was operating the nosewheel steering with his left hand. The first officer was holding full left aileron into wind with his hands on the control wheel; his feet were clear of the rudder pedals. While take-off power was being set, the commander was maintaining the aircraft on the centreline using a combination of nosewheel steering and rudder. With take-off power set and equal on both engines, the first officer checked the airspeed and called "60 kt"; this is the normal speed to release the nosewheel steering control and the commander moved his left hand to the control wheel and called that he had control. The first officer acknowledged this call and took his hands off the control wheel; he did not touch any flight controls during the subsequent ground run.

Almost immediately, the commander was aware of the aircraft drifting to the right of the centreline and applied left rudder to stop this movement. However, although the commander was certain that he progressively applied left rudder as far as the pedal would move, G-GNTH continued to drift to the right. With no apparent change in direction, the commander moved his right hand to the control wheel and his left hand back to the nosewheel steering control. His input to the nosewheel steering made no apparent difference to the aircraft track and, with the indicated airspeed being too low for rotation, he closed both power levers, centralised the rudder pedals and applied braking with the aircraft headed for the grass at intersection 'Delta'. As G-GNTH left the runway, the commander pulled back on the control wheel because he thought that the gear might collapse. Thereafter, he used limited thrust reverse until the aircraft came to rest after turning through almost 180° to the right. Then, with the aircraft stopped, the commander called for the first officer to complete the evacuation drills which involved securing both engines and activating both engine fire extinguishers. The commander was aware that there was no indication of major damage or fire and he could see the AFS in close proximity. Therefore, because he considered that the windmilling propellers were a danger, he decided not to order a passenger evacuation. Once the propellers had been secured, the passengers deplaned normally and were taken to the terminal.

The ATC controller watched the aircraft start the take-off roll. Initially, it appeared normal but, after a short time, the aircraft seemed to change direction and was then pointing directly at the ATC Tower; the controller could clearly see three taxy/landing lights on the aircraft. One light is located at the nose gear and the others are positioned on the inboard of each wing leading edge. As the aircraft left the side of the runway, the controller activated the crash alarm. The AFS had been on weather standby because of the strong surface winds and this meant that all the fire vehicles were manned and had their engines started. The AFS crews also saw the aircraft leave the runway and reacted extremely quickly; having received clearance from ATC, they arrived at the aircraft just as it came to rest.

Subsequently, the crew commented that they had not seen any audio or visual warnings in the cockpit during the take-off roll and that both engines were operating correctly and symmetrically. Additionally, the aircraft was within normal weight and C of G limits.

Company procedures and instructions

The Company Operations Manual details the crosswind limit for both dry and wet runways as detailed as 35 kt based on mean calculated crosswind component. It contains the following advice for a crosswind take off:

'Crosswind take off capability is good. The up-wind wing will have a tendency to rise and aileron deflection must be applied towards the wind. If the wings are kept level during the take off, directional control is maintained as during normal take off. As the speed increases, the aileron deflection requirement will decrease. The main objective is to keep the wings level. Maintain a slight forward pressure on the control column until rotation.'

Prior to engine start, the first officer stated that he had set the yaw trim to $1\frac{1}{2}$ units right in accordance with company procedures.

Wind information

Wind information is derived from two anemometers, located one near each end of the main runway (32/14). The ATC controller can select the appropriate anemometer for wind information depending on the runway in use. Additionally, the wind information displayed in the ATC tower can be the actual at the time (instant) or can be a mean of the either the previous 2 or 10 minutes. The recorded extremes for both direction and strength of the 10 minute wind are maintained within

ATC. There is another recording system, called 'Vaisala', which continually records the actual wind at each anemometer. On the day of the incident, the 'Vaisala' recording system for Runway 32 anemometer was unserviceable. The recording system for Runway 14 anemometer was serviceable as was the ATC recording system for the 10 minute mean and extreme winds from each anemometer.

The surface wind, 250°/29 kt, passed to the crew of G-GNTH prior to take off was taken from the Runway 32 anemometer and, since an instant wind was not specifically requested, this was probably the 2 minute wind. Subsequent review of the 10 minute period up to 0720 hrs for the same anemometer shows a minimum wind of 16 kt and a maximum wind of 46 kt with the direction extremes being 216° and 272°. For the same period, the Runway 14 anemometer shows a minimum wind of 10 kt and a maximum wind of 36 kt with the direction extremes being 216° and 289°. This indicates a 10 kt variation of the maximum wind at different ends of the runway within the same time period. Review of the 10 minute period up to 0730 hrs shows a maximum wind for Runway 32 of 45 kt and a maximum wind for Runway 14 of 37 kt. Examination of the 'Vaisala' recordings for Runway 14, showed a maximum gust of 36 kt very close to the time that G-GNTH was accelerating for take off. The current UK AIP entry for the airport advises pilots "to expect windshear and turbulence when the surface wind is between 190° and 240° above 20 kt. Some variations to reported wind readings may also occur." This warning was submitted prior to the incident as an amendment but was not published until after the incident.

Aircraft information

G-GNTH carried the constructor's serial number 169 and was built in 1989. It was equipped with a nosewheel steering system designed by Parker Hannifin Corporation. Although the nosewheel is designed to be free to castor through 360 degrees, the landing light harness would be damaged in this case, and normally free castoring is limited by the steering brake to 20 degrees each way plus or minus 5 degrees. Steering, up to 50° each way, is also available when the tiller is depressed; if the pilot releases the tiller when the nosewheel is outside the normal free castoring limit, the nosewheel is locked at that angle. The nosewheel steering brake may be over-ridden by the commander by use of the tiller. A ground handling lockout switch in the nosegear bay can be operated by the ground crew to permit unrestrained free castoring for towing.

The aircraft is equipped with a spring-tab operated rudder. The FDR measures rudder deflection at the surface, but this angle is not necessarily directly related to rudder pedal position, as large rudder hinge moments cause a spring within the mechanism to compress. SAAB Aircraft AB supplied the following data relating maximum rudder angle, pedal force at maximum pedal deflection and Corrected Air Speed for a 25 kt crosswind from the left:

CAS	Pedal force lb	Rudder angle

100 kt	148	16.6°
80 kt	147	16.3°
60 kt	131	16.9°

To prevent overstressing of the aircraft structure at higher airspeeds, a rudder limiter system is installed which reduces the maximum available rudder angle to 15° each way above 150 kt and further restricts it to 5.7° each way above 200 kt. The rudder limiter stops are withdrawn automatically as the speed reduces allowing greater rudder travel.

Initial engineering investigation

The AAIB team examined the aircraft on the taxiway at Leeds-Bradford Airport where the aircraft appeared undamaged but the three landing gears were heavily contaminated with mud from the grassed area. The tyres were examined for scrubbing or other damage of the tyre surfaces but none was obvious; those scrub marks which were seen were found to be merely mud patterns on the tyres, related to the recovery rather than the incident. Later, it was found that some damage to the rudder system limit stops had occurred due to the aircraft being tail to wind for several hours in the very strong winds conditions.

Tyre marks from all three landing gears were visible on the runway from the 'piano keys' to where the aircraft left the side of the runway and through the grass until the aircraft came to rest. These showed that G-GNTH had initially deviated to the left of the centreline in the vicinity of the 'piano keys' but had then crossed the centreline and continued to drift to the right until it left the runway. It then travelled over the grass while turning progressively to the right, finally coming to rest after about 500 yards; at its final position the aircraft was on a heading of 100°M. While still on the runway, the nosewheel had left more or less continuous marks from both tyres; the displacement of the nosewheel marks between those left by the mainwheels indicated that the aircraft was yawed to the left of its track, ie aligned with the runway heading, as it went on to the grass.

With the evidence from the commander that he did not commence braking until shortly before the aircraft left the runway, the mainwheel tyre marks seen throughout the take-off roll must have resulted from scrubbing during a sideways movement of the aircraft. Additionally, the marks from the nosewheels show that they were not free to align with the direction of travel. This provided further confirmation that the aircraft was yawed left but tracking progressively right.

Examination of aircraft in hangar

The aircraft was recovered to a hangar and examined in detail. The engines, propellers and landing gear were inspected. All the wheels and two brakes were replaced. The anti-skid system and flight controls were checked and found satisfactory. The nosewheel steering system was functioned several times, and castoring was satisfactory with the ground handling lockout switch operated. With the ground handling lockout switch in the normal position the steering control was satisfactory.

The operation of the steering brake was checked as per the Aircraft Maintenance Manual (AMM) by turning the nosewheels until they were locked by the steering brake, and then measuring the angle of the nosewheels. This could not be done accurately at the time since the required protractor was not available, however it was observed in repeated tests that the steering brake permitted less castoring to the right than to the left. This was understood at the time to be due to the tolerance specified in the AMM, however the difference, while difficult to measure without proper tooling, was clearly observable without measurement. Some time later, when it became apparent that the nosewheel free castoring angle could be relevant, the aircraft was re-examined during scheduled maintenance at Glasgow. With an accurate protractor made up and fitted to the nosegear, exactly 20 degrees of movement each way was observed in repeated tests. Further examination of the system showed that, due to the design of the system, it was unlikely that the free castoring angle would have been affected by the events of the incident and subsequent recovery. The Technical Log did not show any recorded adjustment of the system following the incident.

Flight recorder information

Recorded data showed that the aircraft had taxied from the stand to the start of Runway 32 with the gustlocks engaged and Flap 15 selected. During the taxy to the holding point at 'Delta 1', indicated airspeeds ranging from 2 kt to 35 kt were recorded. As the aircraft, on a heading of 195°M, left the holding point to enter the runway, a 15 second period of increasing airspeed values was recorded which culminated in a reading of 45 kt.

At the beginning of the runway the aircraft initially turned left and then right, pausing on a heading of 238°M. At this point the gust locks were withdrawn and indications of a full and free check on the controls were recorded. During this check, airspeed readings of between 12 kt and 24 kt were noted.

The aircraft turned further right to line up on the runway heading of 323°M. Progressive symmetrical engine power, 10° of trailing edge down elevator, full into wind aileron (left aileron trailing edge 26° up) and 7° of left rudder were applied at the start of the take-off roll. As airspeed increased, the down elevator and into-wind aileron were slowly reduced. For the first three seconds of acceleration, the rudder was held at 6° left. Thereafter, as the heading changed slowly to the left by 5°, the rudder was moved, on average, progressively right. During this movement, large excursions in rudder angle of between 6° left and 22° right were recorded.

Eleven seconds after the application of power and with an airspeed of 49 kt, the readings from the lateral accelerometer started to indicate an increasing oscillatory motion; during these oscillations, of which there were 3 complete cycles, magnetic heading reduced with acceleration to the left and vice versa. Five seconds later, at an airspeed of 73 kt, the into-wind aileron was recorded as 13.5° up. Over the next three seconds, the aileron reduced to 6.5° up by which time the airspeed had increased to 85 kt. The aircraft heading changed from 314°M to 333°M and full into-wind aileron was re-applied together with a maximum recorded rudder deflection of 13° left. By now, the elevator had reduced to 4.7° trailing edge down.

Two and a half seconds later, at a peak airspeed of 96 kt, both power levers were closed and the oscillatory motion ceased; rudder and elevator were centralised and into-wind aileron was reduced to 20° up. Four seconds later, the aircraft ran onto the grass at an airspeed of 88 kt and on a heading of 329°M. It began to turn consistently to the right. Thrust reverser deployment on both engines was recorded for two seconds only. Right rudder and down elevator were recorded as the aircraft slowed. As the aircraft continued in the right turn through 060°M, the rudder deflection changed rapidly from 26° right to a full left position of 30°. The aircraft came to a halt on a heading of 099°M. At no stage during the take-off roll, was there any indication of asymmetric engine performance. Flight data recording stopped when both engines were shutdown.

Previous Technical Log entries

Prior to the incident, there had been several recent entries in the technical log regarding the rudder limiter indication caption. This is an indication on the flight deck that the rudder travel available has been reduced by the rudder limiter system (necessary during flight at higher indicated airspeeds). It was considered by engineering that this was generally a false indication problem and that the rudder limiter was functioning correctly. On 16 December 1997 a further case was reported on this aircraft when, during short finals the light came on. On touchdown the rudder could not be moved and this was reported to be due to icing within the tailcone.

Examination of the rudder limiter system after this incident showed no evidence of any technical deficiency, and the FDR data shows that the rudder movement achieved was outside the range available with the limiter engaged.

Manufacturer's analysis

A number of questions concerning the SAAB 340 dynamic behaviour were put to the manufacturer, who carried out a detailed analysis using a digital computer model and the known conditions. Their report stated that, from about 16 seconds from the start of the take-off roll, the simulation did not show the same principle directional behaviour as the incident and suggested that a large force input was required to match the simulation to the incident. Traces produced by the simulation assumed that the nosewheel was free to castor throughout the take-off roll. During discussions between the AAIB and the manufacturer, it was established that the nosewheel could have generated such a force if either the tiller was released with the nosewheel locked outside the normal castoring range, or if the castoring angle became large enough to activate the steering brake.

The manufacturer also commented that the rudder activity during the take-off roll was greater than expected. Furthermore, they considered that, for the reported conditions the initial rudder deflection was the wrong way from that which they would have expected; this would imply that a correspondingly larger than expected nosewheel steering angle to the right would have been required to maintain heading.

-

Additionally, the manufacturer confirmed that in the prevailing wind conditions, the rudder angle achieved by the commander, during the latter part of the take-off roll when he tried to apply full left rudder, was commensurate with almost full left pedal.

Discussion of behaviour of aircraft forces and moments

The SAAB simulation and the tyre marks on the runway both suggest that unusual forces were acting on the aircraft during the take-off roll after it passed the 'piano keys'. The ground marks alone show that while it was drifting right it was heading more or less down the runway, and the wheel marks suggest large lateral forces acting on the aircraft. Further, the marks left by the nosewheels show that they could not align with the direction of travel, either because the tiller had been released while they were outside the castoring range, or because the yaw angle became large enough to activate the steering lock. The natural directional stability of the aircraft and the rudder moment were both generating yawing moments to the left, thus there had to be a further large moment to the right opposing the required change of heading. This was not generated by power asymmetry, braking or aerodynamic forces**.** However, this moment could have been generated by the side force of the nosewheels if they had been locked pointing to the right.

Discussion of incident

The aircraft appeared fully serviceable to the crew prior to take off and they had configured it correctly. They were also confident that they had complied with the standard company procedures for a crosswind take off and that the wind was within limitations. The commander had experienced crosswinds before and was familiar with operations at Leeds Bradford Airport. He subsequently expressed surprise that G-GNTH drifted to the right and that he was unable to turn the aircraft to the left in the prevailing conditions. The investigation concentrated on three aspects which may have contributed to the incident; the surface wind, aircraft systems and pilot handling.

The forecast indicated that the surface wind was generally within the aircraft's crosswind limitation of 35 kt but that there may have been temporary occasions when gusts would have been outside this limitation. These conditions were acceptable for operations but the commander would have needed to monitor the wind prior to his take off. A preceding aircraft took off with a declared wind of 250°/32 kt, a crosswind component of 30 kt**.** Then, G-GNTH was cleared for take off with a surface wind of 250°/29 kt, a crosswind component of 27 kt**.** Both these reported winds were within the aircraft limits. However, it is possible that the aircraft was subjected to strong gusts during the take-off roll. The maximum gust recorded within 10 minutes of the time G-GNTH was taking off was 46 kt and, with the varying wind direction, this could have been directly across the runway giving a crosswind component of 46 kt. It is therefore possible that the aircraft was subjected to a wind gust some 11 kt outside the maximum crosswind permitted by the operator during take off. Although a strong wind from the left will generally weathercock the aircraft to the left, the extent of this movement depends on the strength and duration of gusts and the control positions being applied. The wind conditions at the time were therefore conducive to directional problems.

Evidence from the FDR shows that symmetrical power was being achieved from the two engines during take off. All other relevant aircraft systems appeared fully serviceable apart from one possible area. This concerned the nosewheel steering mechanism which may have resulted in the nosewheel being locked to the right, possibly at an angle smaller than the normal locking angle. With weight on the nosewheel, this would have caused the aircraft to track to the right.

The other aspect which could have had an influence on the incident was the control inputs from the crew. The FDR shows that the first officer was correctly holding full aileron into wind and forward pressure on the control wheel. The commander had control of the rudder and nosewheel steering and, with a strong wind causing a weathercock effect to the left, he would normally input right rudder and right nosewheel steering; as the aircraft accelerated, the rudder would become more effective and when the commander took his hand off the nosewheel steering, the rudder should have become the only directional control because of the castoring nosewheel. However, the FDR shows that initially the rudder was deflected 7° to the left; there was no recorded information on the position of the nosewheel but it must have been turned to the right to counter the wind and the inappropriate rudder. In fact, the FDR and the marks on the runway show that G-GNTH moved to the left of the centreline. Logically, this move to the left should have been countered by right rudder and possibly more right nosewheel; the right rudder input was confirmed by the FDR and the result was a change of direction to the right. Around this time, the aircraft speed passed 60 kt and the commander took control of the control wheel; this required him to release the nosewheel steering control which should then have allowed the nosewheel to castor. At the same time, the FDR showed that the into wind aileron control and the right rudder input were relaxed. These inputs were consistent with a desire to turn left. However, there then followed indications of lateral acceleration which could have been an indication of a strong wind gust together with countering rudder control inputs. With the aircraft now tracking right but heading left, the FDR showed a left rudder deflection of 13°; the commander remembered applying as much rudder as he could and the manufacturer subsequently confirmed that deflection as the maximum practicable in the wind conditions. At this stage, the commander recalled that he had tried to re-engage the nosewheel steering. However, the FDR shows that the time period between the application of 13° left rudder and closing of the power levers was 2 and a half seconds; this was a very short time for the commander to change his hands to the nosewheel control, try the nosewheel steering and then move his hands back to the power levers. Apparently unable to correct the drift to the right, the commander then concentrated his attention on keeping the aircraft straight while reducing speed before leaving the side of the runway.

Further incident

After this investigation was completed and just before publication of this report, on 19 January 1999, a similar incident occurred to G-GNTH. While taking off from East Midlands Airport, with a 20 kt crosswind from the left, as control was transferred from the nosewheel to the rudder the aircraft veered to the right and full left rudder deflection was required for several seconds to maintain control. The take-off was continued using some left rudder throughout and the nosewheel was heard to be "scrubbing"; the commander believed it was not castoring. Subsequently, significant engineering effort was required to rectify the problem, with assistance from SAAB. The cause was not positively identified, but as precautionary measures the nosewheel steering actuator was bled, the steering handle microswitch was replaced, the nosewheel steering gearbox, control cable, brake solenoid switch, rocking lever and leaf spring were all replaced and the aircraft taxi tested satisfactorily. It is thought that an intermittent fault in the steering handle microswitch or associated mechanism could have caused the steering brake to remain engaged when the tiller was released. The details of this incident are being analysed by SAAB. Such a defect could have accounted for the incident under investigation here, causing the nosewheel to lock at less than 20 degrees. It would also explain the observed asymmetry of nosewheel movement after the incident, and the subsequent correct rigging observed when the aircraft was later re-examined.

Summary

In summary, the tracking to the right seen in this incident could only have been caused by, a very strong gusty wind, inappropriate control inputs or some sort of misalignment of the nosewheels. In reality, it is most likely that it was caused by a combination of these factors. The wind was probably gusting above the maximum crosswind permitted by the operator during take off and, with an initial inappropriate rudder input, the commander would have require additional right nosewheel steering to try and maintain the runway centreline. This nosewheel angle may have been beyond the normal free castoring limit; it is also possible that with the post incident anomaly found in the nosewheel steering, the nosewheel may have locked at an angle within the normal free castoring limit. In either situation, the locked nosewheel would have produced a strong yawing moment to the right on the aircraft.

There was only some 30 seconds from brake release to the aircraft going off the runway. Once the aircraft had drifted off to the right, the commander had very limited time in which to recognise his problem and rectify it. Once he realised that he could not stop the aircraft going off the side of the runway, his decisions and actions to minimise the dangers to his passengers and aircraft were appropriate.