AVIATION OCCURRENCE REPORT
A97H0008

LOSS OF CENTERLINE LANDING GEAR

AIR CANADA

AIRBUS A-340-313 C-FYLD

FRANKFURT, GERMANY

01 SEPTEMBER 1997

The Transportation Safety Board of Canada (TSB) investigated this occurrence for the purpose of advancing transportation safety. It is not the function of the Board to assign fault or determine civil or criminal liability.

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Summary

The Air Canada Airbus A340-313 was on a flight from Frankfurt, Germany, to Vancouver, British Columbia. During rotation for lift-off in Frankfurt, a loud bang was heard in the cabin. Several passengers reported feeling the floor of the cabin rise with the bang. When the flight crew selected the landing gear up after take-off, it did not retract. On a subsequent recycling, the landing gear retracted but there was an indication of a disagreement in gear position. Departure control informed the flight crew that landing gear pieces, later identified to the flight crew as being from the centerline landing gear, had separated from the aircraft. The captain advised the cabin crew to prepare for an emergency landing. The flight crew lowered the landing gear using manual gear extension procedures. The aircraft landed at Frankfurt without further incident after having circled for two hours burning off and jettisoning fuel. There was no injury and no additional damage to the aircraft.

Ce rapport est également disponible en français.

Other Factual Information

The rotation speed at take-off was about 153 knots. At 90 feet above ground level the ram piston, lower torque link, axle, wheels, and tires of the centerline landing gear separated from the aircraft. The separated landing gear, which weighed about 630 kilograms, travelled several thousand feet across airport property but did not cause any damage.

The aircraft was equipped with this centerline landing gear to permit operation with an increased maximum certified operating weight of 271 000 kilograms. For the occurrence flight, the take-off weight was about 224 900 kilograms.

The centerline landing gear is a dual-wheel, forward-retracting gear that incorporates a mechanical downlock and an airframe-mounted uplock. It is positioned under the centre of the fuselage and directly in line with the rear wheels on the left and right main landing gear bogies. The centerline landing gear's primary purpose is to carry a share of the aircraft weight on the ground so as to not overload the main landing gear. Three major assemblies make up the centerline gear: a shock strut, a drag stay with a downlock, and a retraction actuator. The shock strut has a transverse axle on which the two centerline wheels and tires are mounted. One purpose of the shock strut is to decelerate the downward motion of the aircraft without applying damaging loads to the gear attachment points.

The shock strut is a two-stage, oleo/pneumatic shock absorber that takes energy from the in-stroke, such as on landing, by utilizing a dual-diameter, ram-like piston to compress gas and displace hydraulic fluid. As the ram piston moves into the cylinder of the shock strut under the tire compression forces, it displaces hydraulic oil into the upper chamber which is designed to gradually increase resistance as the piston strokes inwards. The upper chamber is called the stage 1 low-pressure chamber and is statically charged with a hydraulic oil/nitrogen mixture to about 700 pounds per square inch gauge (psig). The lower chamber is called the stage
2 high-pressure chamber and is statically charged with nitrogen gas to about 2 000 psig.

Two damping rings act as valves to restrict the flow of hydraulic fluid in one direction but not in the other. The in-stroke damping ring restricts the rate at which fluid can be pushed past it into the upper chamber on the in-stroke but allows relatively unrestricted flow in the opposite direction. The rebound damping ring works in the opposite sense. Together they serve to control the rate of in-stroking and the rate of rebound of the gear.

The seal between the low-pressure chamber and the high-pressure chamber is a floating piston which is free to move downwards inside the ram piston and further compress the high-pressure charge once the low-pressure chamber exceeds 2 000 psig on the in-stroke. This increases the energy-absorbing volume of gas under compression and slows the build-up of pressure in the stage 1 chamber.

The charges in the two chambers are replenished by a servicing technician through separate fill valves designated as Valve "A" for the low-pressure chamber and Valve "B" for the high-pressure chamber. Corresponding "A" and "B" gauges are mounted on the gear leg for reading the static chamber pressures.

The order in which the chambers are ground-serviced is critical to ensuring that the system is charged properly. The proper procedure calls for the high-pressure, 2 000 psig chamber to be charged first. If the low-pressure,

700 psig chamber were to be charged first, the subsequent filling of the high-pressure, 2 000 psig chamber would cause both chambers to be charged to 2 000 psig. Such a condition would cause the oleo to become very stiff and lose much of its ability to function as a shock absorber.

On 22 August 1997, nine days prior to the incident in Frankfurt, the aircraft had a hydraulic failure which necessitated an emergency gear extension for landing. An emergency extension does not extend the centerline gear. As a consequence, a servicing crew had to discharge both chambers in the centerline gear on the ground in order to extend it for resetting. The chambers then had to be recharged. The recharging was completed according to the guidance provided by instructions on a plate attached to the gear leg, Inflation Chart placard P/N 15272-103. The example on this plate reads as follows:

> EXAMPLE:-
> GEAR FULLY EXTENDED (H = 18.9 INCHES) AND AT 20°C
> INFLATE PORT "A" TO 700 PSIG (48.3 BAR)
> INFLATE PORT "B" TO 1 993 PSIG (137.4 BAR)

While the placarded instructions above it are correct, the example has its steps in the wrong order. If the example were followed in the order presented, then the procedure would be completed in reverse order, resulting in a Stage 1 low-pressure chamber charge of nearly
2 000 psig, that is, about 1 300 psig too much. An over-charged centerline gear strut was found on a Gulf Air A340 during a routine check for leaks in March 1999.

A review of the aircraft maintenance manual (AMM) instructions on the servicing of the centerline gear revealed that they would benefit from clarification. In the aircraft maintenance manual, AMM 32-15-00-401, on page 8 at E., there is a series of steps leading to TASK
12-14-32-614-806 for recharging the centerline landing gear. If this task is carried out exactly as given in 12-14-32 on page 394, dated Jul 01/97, the strut pressures will be correct. There is a danger, however, of the servicing technicians departing from the correct procedure, on noting low Stage 1 pressure. When the Stage 2 pressure is released in this servicing process, the
Stage 1 pressure falls to less than half of its usual static value of 700 psig. This is due to the expansion of the Stage 1 volume by the floating piston moving downwards. This is normal; the Stage 1 pressure will return to its nominal static value when the Stage 2 chamber is re-inflated to
2 000 psig. The servicing technicians need to be aware of this. As well, they need to have a clear understanding of what is occurring inside the gear.

Required monitoring of the centerline landing gear's pressure gauges was being completed by the operator's servicing technicians according to the procedures supplied by the manufacturer. The Daily Gas Pressure Monitoring check, gear leg placard P/N 15716-101, was written in such a way as to suggest that there was a minimum acceptable pressure reading but no unacceptable maximum for each of the centerline gear gauges, and that any pressure above the minimum, short of the gauge's red line, would pass. Gauge "A", the gauge for the low-pressure chamber, is readable to a maximum of 3 000 psig. Gauge "B", the gauge for the high-pressure chamber, is

readable to 2 500 psig. This situation could be misleading in that the gauge with the higher scale reads the lower pressure, and a 2 000 psig reading on a gauge calibrated to 3 000 psig does not appear excessive.

Information from the aircraft's digital flight data recorder, on the two flights prior to the incident flight, indicates that the centerline gear strut did not compress enough on landing. The dial face of the gear's low-pressure gauge was marked by its pointer at 1 700 psig during a shock load such as occurred when the landing gear was lost. The acceleration reaction of the aircraft to the landing gear's expulsion resulted in a calculated Stage 1 chamber pressure in excess of
2 000 psig. Stress analysis determined that the nominal pressure of 700 psig was insufficient to fail the weakened gland nut, yet the gland nut failed. These facts are consistent with an overcharging of the Stage 1 low-pressure chamber to about 2 000 psig. This is the pressure that would exist on reverse order charging of the gear chambers which the servicing instructions fail to caution against and provide a placarded example on the landing gear leg with the recharging steps in reverse order.

A gland nut retains a seal carrier in place and thereby keeps elastomeric ring seals positioned to prevent leakage of the strut's compressed gas and hydraulic oil from where the piston emerges out of the cylinder. On take-off from Frankfurt, the initiating event that led to the gear departing the aircraft was a failure of the gland nut. The failed gland nut displayed a defective thread profile that had been present from the time of manufacture. This defect was the result of improper lathe thread cutting technique, in that the cutting tool of the lathe was not backed out sufficiently to clear the thread when the lathe was reversed. An extra groove was cut in the flank of the thread by the same tool that made the original thread, thereby weakening it. This resulted in the gland nut having less retention strength than it was designed to have.

Analysis

The separation of the centerline gear on take-off was the result of a combination of an over-pressure condition in the strut and a gland nut that was weakened by a manufacturing defect.

When the aircraft was serviced in Vancouver, nine days prior to the accident, the maintenance crew followed the procedures depicted on the instruction plate on the gear leg. The information on the plate was exemplified in such a way as to invite a reversal in the order of charging for the system. Reversing the order results in an overcharged gear strut. Once the initial charging procedures were completed, there was little possibility that an overcharge would be discovered during routine monitoring inspections as the Daily Gas Pressure Monitoring check only insured that the gear strut pressures were above minimum values. There was nothing in the check to alert ground maintenance workers to an overcharged condition that was still well below the red line on the gauge.

The following Engineering Branch reports were completed:

LP 136/97 FDR/CVR Analysis
LP 141/97 Gland Nut Examination
LP 142/97 Centerline Landing Gear

Findings

1. The shock strut assembly of the centerline landing gear had a Stage 1 static pressure that

was considerably higher than it should have been.

2. The placarded instructions for servicing the gear's shock strut were exemplified in such a way as to invite a reversal in the order of charging of its low-and high-pressure stages.

3. A reversal in the order of charging of the shock strut stages results in a very stiff, overcharged condition for the gear.

4. Instructions for recharging of the centerline gear in the aircraft maintenance manual (AMM) at TASK 12-14-32-614-806 dated Jul 01/97 need clarification.

5. The Daily Gas Pressure Monitoring check was unlikely to alert service technicians to an overcharged condition.

6. The strength of the gland nut was reduced as a result of a manufacturing defect.

Causes and Contributing Factors

The centerline gear separated from the aircraft on take-off when the weakened gland nut was forced out by excessive gas pressure.

Contributing factors to the occurrence were as follows: the placarded servicing instructions for the shock strut contained an error in the example, which led to overcharging of the strut system; the existing Daily Gas Pressure Monitoring check was inadequate to alert service technicians to the overcharging of the strut; the scaling of the low-pressure gauge was such that its red line and its needle position would not arouse suspicion when the strut was overcharged; and the gland nut was weakened by a manufacturing defect.

Safety Action

All stocks of centerline landing gear gland nuts were checked by Messier-Dowty for correctness of thread profile. All 59 gland nuts installed on aircraft were inspected. One more mis-machined nut was found with the same incorrect thread profile as that of C-FYLD.

The thread profiles of all gland nuts are now being 100 percent inspected at Messier-Dowty and at the manufacturing subcontractor by additional methods that will expose any faulty thread profile.

All Aircraft Maintenance Manual procedures on CLG servicing have been revised to improve their clarity; they are available in the 01 July 1998 AMM revision.

The Daily Gas Pressure Monitoring Check procedure was modified in order to add a check for over-pressure and to make it clearer; the TR was available 15 June 1998.
Modifications to the gauges and placards have been produced and were incorporated in Messier-Dowty production units as of February 1999.

A modification to make the gland nut of steel instead of aluminium has been produced and incorporated in

Messier-Dowty's April 1999 production.

This report concludes the Transportation Safety Board's investigation into this occurrence. Consequently, the Board, consisting of Chairperson Benoît Bouchard, and members Maurice Harquail, Charles Simpson and W.A. Tadros, authorized the release of this report on 23 June 1999.