DATA SUMMARY

LOCATION

Date and time	**5 August 2008; 18:40 h[1]**
Site	**Madrid-Cuatro Vientos Airport**

AIRCRAFT

Registration	**EC-HHX**
Type and model	**CESSNA 172 RG**
Operator	**Centro de Formación Aeronáutico Aerofan**

Engines

Type and model	**LYCOMING O-360-F1A6**
Serial Number	**RL-15404-36**

CREW

	Instructor pilot	Student flying
Age	**38 years old**	**37 years old**
Licence	**CPL(A)**	**Student pilot permit**
Total flight hours	**6,500 h**	**11:17 h**
Flight hours on the type	**4,000 h**	**11:17 h (3:25 h in the 172 RG)**

INJURIES

	Fatal	Serious	Minor/None
Crew			**2**
Passengers			**1**
Third persons			

DAMAGE

Aircraft	**Minor**
Third parties	**None**

FLIGHT DATA

Operation	**General Aviation – Flight Training – Dual**
Phase of flight	**Landing Pattern – Tailwind**

REPORT

Date of approval	**25 January 2012**

[1] All times in this report are local unless otherwise specified.

1. FACTUAL INFORMATION

1.1. History of the flight

On 5 August 2008, a CESSNA 172 RG, registration EC-HHX, was being used for an instruction flight consisting of a routing trip departing from and arriving at the Madrid-Cuatro Vientos Airport with stops at the aerodromes of Marugán (Segovia) and Robledillo de Mohernando (Guadalajara). Onboard were a pilot and two students.

One of the students flew the initial leg between the Madrid-Cuatro Vientos Airport and the aerodrome of Marugán, with the other student flying the rest, including two landings at the Robledillo de Mohernando aerodrome and returning to the Madrid Cuartro-Vientos Airport via point N (November).

As they were joining the downwind leg of the aerodrome's circuit, they lowered the landing gear. The aural and visual alarms indicating the gear was not down and locked immediately activated. On looking outside, they verified that the right main landing gear leg was halfway down. The other two were properly positioned.

The instructor took the controls and reported the problem to the airport control tower, which cleared them to remain in the circuit at 4,000 ft. Once in the circuit and in contact with the controller and with the aircraft operator's mechanics on the ground, they cycled the landing gear several times using both the normal and emergency procedures. The left and nose legs operated correctly during every cycle and locked in the down position, while the right leg only went down halfway.

The aircraft remained in the circuit for at least 40 minutes to burn fuel before eventually landing on the airport runway with the gear down. During the landing run, the right leg folded up completely, causing the aircraft to come to a stop on its right side, resting on the right wing tip, the right horizontal stabilizer and the aft fuselage. The aircraft's occupants were uninjured and left the aircraft under their own power. The aircraft was recovered by the airport's emergency services and taken to one of its operator's hangars.

1.2. Damage to aircraft

The aircraft suffered slight damage to its right wing tip and tail cone. The aft of the rear portion of the fuselage was scratched, with the right horizontal stabilizer suffering most extensive damage when it was bent slightly upward as it bore part of the aircraft's weight during the landing. Figure 1 shows the damage to this stabilizer.

Figure 1. Damage to right stabilizer

In addition, when the actuating mechanism on the right main landing gear leg was inspected, its rotational axis was broken some 3 mm from the actuator housing. The diagram in Figure 2 shows the location of the fractured section.

1.3. Aircraft information

The CESSNA 172 RG aircraft, registration EC-HHX and serial number 172RG-0006, had been manufactured in 1980. On the date of the accident it had accumulated a total of 7,618 flight hours and 1,855 engine hours, almost all on training flights. It had Airworthiness Certificate no. 4573, valid until 20 December 2008.

On 16-07-2008, with 7,550:05 h on the aircraft and 1797:46 on the engine, the 200-hr inspection was carried out, over the course of which the landing gear components were checked. The last 50-hr inspection had been performed on 28-06-2008, with 7,598:02 h on the aircraft and 1,845:43 on the engine.

The aircraft had incorporated Service Bulletin SIB01-02R2, which requires inspecting the main landing gear actuators for cracks using fluorescent penetrant dye. The bulletin requires initial actions followed by an inspection every 500 h. The last such check of the actuators had been on 12-06-2008, with 7,410 h on the aircraft. As a result, the service time remaining on the actuator pursuant to the Service Bulletin was 360 h on the date of the incident.

1.3.1. *Operation of the aircraft's main landing gear*

On the CESSNA 172 RG, the landing gear is retractable and operates when hydraulic pressure, generated by the hydraulic pump on the aircraft, is applied to the single actuators mounted on each leg. The pump is electrically driven and, when energized, maintains a pressure in the 1,000 to 1,500 psi range. The pump is engaged when the actuating lever of the landing gear is operated. If the hydraulic pump fails to run, the crew can lower the landing gear by building up pressure in the system through a manual actuator (emergency procedure).

The main landing gear moves differently from the nose gear. In the latter, the actuator is linear and its stem moves the leg structure directly. In the former, the actuator is rotary and works as shown in the diagram in Figure 2. This diagram, taken from the figures contained in the aircraft's Service Manual, shows the operation of one main landing gear leg. The operation of the other is fully symmetrical.

As Figure 2 shows, teeth are machined into the actuator stem that mesh with outer teeth on the wheel that is integrated into the actuator (see inset). When the gear is operated, hydraulic pressure is applied and the actuator stem moves. This causes the toothed wheel to turn in one direction or the other, depending on the stem's motion.

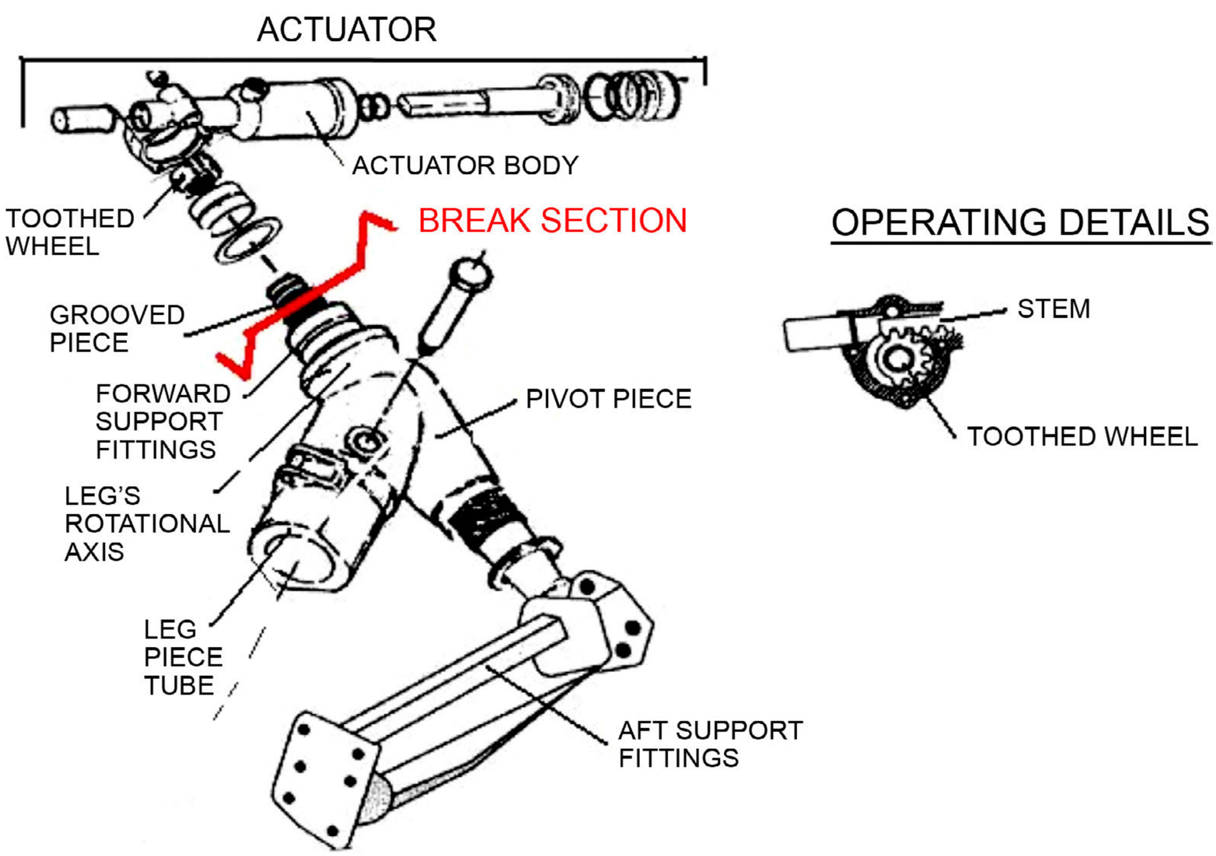

Figure 2. Functional diagram of the right gear leg

The inner crown on the toothed wheel is grooved such that one end of the grooved piece couples to it. The other end of this piece is coupled to the leg's rotational axis. This axis is part of the pivot piece, the ends of which are supported in resistant fittings attached to the aircraft structure and in which it can rotate with certain ease.

The pivot piece contains, in addition to this rotational axis, a tube for the leg piece, which is in the same direction as said piece and which is therefore tilted with respect to the rotational axis. In this tube enters the piece, the other end of which rests on the support for the brake-wheel assembly, and which comprises the leg itself. This tube also has, near its beginning, a nip for the gear down locked support.

The angle of the tube for the leg piece with respect to the rotational axis means that, when the axis turns, dragged by the toothed wheel on the actuator, the leg swings between the full up and down positions such that, when fully up, the wheel is situated in its housing in the fuselage.

The gear down locked support is joined to the structure and, in addition to locking the leg, it also offsets the torsional forces transmitted by the wheel when the aircraft is moving on the ground.

Figure 2 shows, in red, the position that fractured. As we can see, the break is in the area of the nip where the rotational axis joins the actuator. The break, thus, is in the grooved piece.

1.3.2. *Maintenance of the main gear actuator assembly*

The applicable Maintenance Manual contains the checks and adjustments necessary for the proper operation of the main gear, distributed in the periodic 50-, 100- and 200-hour checks.

As regards the actuator and actuator axis, these are subject to a special inspection every 500 h as part of which their components are disassembled, cleaned and inspected, with any damaged components being replaced. The service lives of these components are not limited by fatigue.

1.4. Inspection of right main landing gear actuating system

The actuator was removed and bench tested. The result of this functional test was satisfactory.

The actuator was subsequently disassembled. The toothed wheel and the broken part of the grooved piece were detached so that the break could be examined in detail.

Figure 3 shows the actuator disassembled into its main components. The most significant damage observed was: the break in the grooved section, the lower part of which started at the nip with the toothed wheel, and the top part of which was within 3 mm of said wheel; the deformation of the axis of the toothed wheel with respect to its cover; and, on the flat surface of the stem, some marks perpendicular to its axis.

The deformation of the toothed wheel's axis seems to have occurred as a result of the axis tilting as the break developed. The marks on the stem are believed to correspond to the different positions in which the stem contacted the roller on the actuator during the

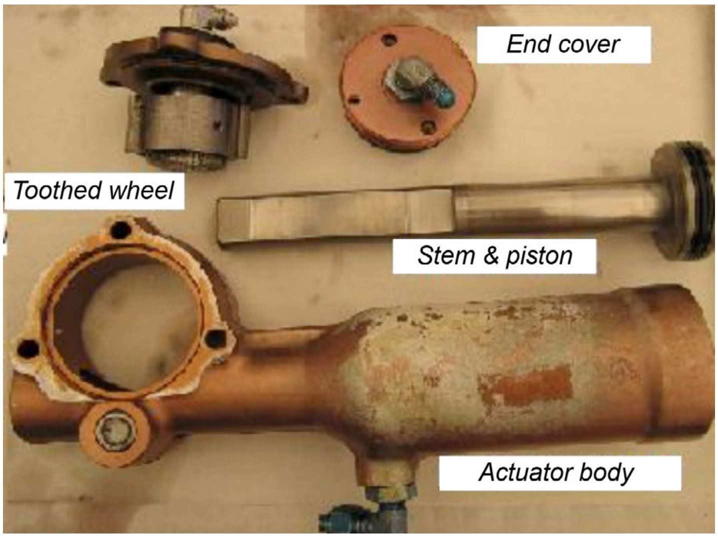

Figure 3. Disassembled gear actuator

various efforts to actuate the gear in flight in the circuit at 4,000 ft with the axis of rotation already broken.

The fracture in the section of the rotational axis indicated is basically perpendicular to the grooves, and therefore to the right leg's axis of rotation. Figure 4 shows a front view of the break in the axis of rotation as seen from the side with the toothed wheel.

Figure 4. Cross-section of fracture

1.4.1. *Laboratory analysis of fracture*

The components of the right main gear leg actuating system were sent to a laboratory for an analysis that consisted of a visual inspection of the assembly, the characterization of the material of the axis of rotation and the fracture it exhibited, and a determination of the operating conditions that could have resulted in the fracture of the piece.

The results of this analysis are presented below.

1.4.1.1. Visual inspection

As shown in Figure 5, the broken part on the shaft joining the actuator to the rotating element (pivot) exhibited a practically circumferential fracture located in the area of the transmission radius with the part that had become embedded in the pivot.

The grooved area exhibited parallel longitudinal cracks in the fillet area adjacent to the fracture (see top part of image in Figure 5). These cracks penetrated into the material in the toothed area.

The filleted area where the longitudinal cracks were exhibited a plastic deformation that was at an angle with respect to the generatrix.

Figure 5. Grooved area

1.4.1.2. Material composition

The material was made of an Al-Zn aluminum alloy, categorized as EN AW-7175. The hardness exhibited by this alloy was approximately 450 MPa and its microstructure indicated that it had been subjected to a tempering and aging treatment.

1.4.1.3. Characterization of the fracture

The fracture surface evidenced macrofractographic and microfractographic features typical of progressive fatigue failure.

The longitudinal cracks found on the grooved axis started outside the grooves, both in the valleys, sides and crests of the grooves. A cross-section of a metallographic specimen did not reveal any type of metallurgical defect or signs of corrosion (see Figure 6).

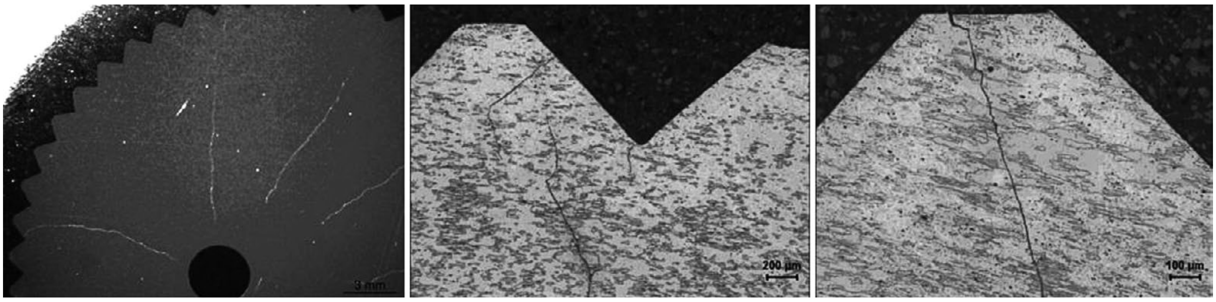

Figure 6. Cross section near the fracture zone. Close-up of cracks

1.4.1.4. Operating conditions

Friction marks and indentations were found on the inner actual actuator walls and on its cover that indicated that the pivot axis had moved parallel to the actuator's longitudinal axis, as well as circumferentially with respect to the ring's inner wall. These motions are believed to have been caused by a misalignment during the operation of the pivot.

In addition, there were longitudinal marks on the inner cylindrical wall at the end of the pivot opposite the fracture. These indicate that the pivot had moved along its longitudinal axis, a motion that is believed to have occurred as a consequence of a maladjustment during assembly.

1.4.1.5. Conclusions of analysis

All of the above yields the following conclusions:

a) The material with which the piece was manufactured complied with design specifications and did not exhibit any significant defects that would justify the lower strength of the material in the grooved axis under the conditions in which the fracture occurred.

b) The fracture was caused by fatigue due to the action of torsional forces.

c) No metallurgical defects of any kind or signs of corrosion at the origin of the longitudinal fatigue cracks were noted. The transmission radius of the grooved area is considered acceptable.

d) As a result of the various marks and indications found on the pieces analyzed, it may be concluded that the fatigue, which resulted in the fracture of the shaft, resulted from purely mechanical causes and was probably due to a slight misalignment of the pivot axis with respect to its axis of rotation.

1.5. History of fractures in main landing gear actuating systems

The manufacturer and the NTSB were asked about in-service failures of the main landing gear system in this type of aircraft.

The NTSB reported that its database showed 11 cases, occurring between November 1997 and June 2011, distributed as follows:

- Failure of actuating system – 3 cases.
- Failure of actuating assembly – 8 cases, of which:

  — Failure by overload: 6 cases.
  — Failure by fatigue: 2 cases.

In the two fatigue failure cases, the failure occurred in the ring of the actuator body inside which the toothed wheel turns. There were no cases involving a fracture of the toothed wheel axis.

2. ANALYSIS AND CONCLUSIONS

First, it should be noted that the fracture found on the axis of rotation of the right main landing gear leg left this leg without a connection to its actuating mechanism. The fracture of this axis, thus, prevented the leg from being lowered or retracted. Since the system for lowering the gear using the emergency procedure relies on manually pressurizing the hydraulic loop, the fracture of the axis also prevented the gear from being lowered using this procedure.

As regards the fracture, it has been determined that it showed evidence of having resulted from a fatigue mechanism due to the action of torsional loads. Due to the assembly's geometry, this type of oscillating load on the rotational axis of the landing gear legs is produced while the aircraft is taxiing on the ground as a consequence of the actions and reactions between the legs and the ground.

As noted in the next to last paragraph in 1.3.1, the gear down locked support, in addition to keeping the leg in place, also bears the torsional loads transmitted by the legs as the aircraft taxies on the ground. It also dampens the vibrations caused by the oscillating loads that are produced, as mentioned in the preceding paragraph. For this reason, the leg's axis of rotation is subjected directly to oscillating torsional loads produced when the aircraft taxies on the ground.

The laboratory analysis revealed a slight misalignment of the pivot axis with respect to its rotational axis. This could have been the purely mechanical trigger for the torsional fatigue fracture of the grooved area on the aircraft's right main landing gear rotational axis. The as-found condition of the assembly after the fracture did not reveal whether this misalignment resulted from improper assembly or from excessive clearances in the assembly.

Finally, as indicated in 1.5, no other cases involving an in-service failure with characteristics similar to those in this incident were found. This is thus considered to be an isolated case, and the failure occurring as a result of the design of the piece can be ruled out. It is more likely that the failure involved the assembly and/or maintenance of the piece.