REPORT IN-031/2012

DATA SUMMARY

LOCATION

Date and time	**Saturday, 11 August 2012; 19:47 h**[1]
Site	**Almeria Airport (Spain)**

AIRCRAFT

Registration	**D-EEDM**
Type and model	**CESSNA 177RG**
Operator	**Private**

Engines

Type and model	**LYCOMING IO-360-A1B6D**
Number	**1**

CREW

Pilot in command

Age	**49 years old**
Licence	**PPL(A)**
Total flight hours	**663 h**
Flight hours on the type	**250 h**

INJURIES	Fatal	Serious	Minor/None
Crew			**1**
Passengers			**3**
Third persons			

DAMAGE

Aircraft	**Minor**
Third parties	**N/A**

FLIGHT DATA

Operation	**General aviation – Private**
Phase of flight	**Landing**

REPORT

Date of approval	**27 January 2014**

[1] All times in this report are local. To obtain UTC, subtract 2 hours from local time.

1. FACTUAL INFORMATION

1.1. History of the flight

Summary of the incident

On Saturday, 11 August 2012, a Cessna 177RG, registration D-EEDM, made an emergency landing with the main gear not locked in the down position at the Almeria Airport. Onboard the private flight were the pilot and three passengers.

There were no injuries. The aircraft sustained damage to its underside.

Conduct of the flight

The aircraft, owned by the pilot flying, had made a local flight in Catania (island of Sicily, Italy) early in the morning that had lasted 15 minutes, after which, at 08:20[2], the aircraft's four occupants proceeded to fly to Almeria, with a scheduled stopover at the Cagliari Airport (island of Sardinia, Italy) to take on enough fuel to fly directly to Almeria over the Mediterranean Sea.

After the stopover, the aircraft took off from Cagliari at 13:00 for Almeria (Spain). The alternate airport listed in the flight plan was Murcia – San Javier (Spain). Four hours into the flight, the pilot decided to stop over at the Murcia – San Javier airport to take on more fuel. The stopover was uneventful and at 18:00 the pilot was cleared to take off en route to Almeria.

After being cleared to land on runway 25 at the destination airport (Almeria), the pilot tried to lower the landing gear but did not receive confirmation in the cockpit that the main gear was locked. After being cleared to do a fly-by of the Almeria Airport tower, tower personnel confirmed that the gear was down but they could not be sure if it was locked. The pilot tried to deploy and lock the landing gear using the emergency procedure, but this also failed to give the gear down and locked indication in the cockpit, so the pilot decided to make an emergency landing at 19:47.

When the airplane landed, the main gear legs, which were not locked, gave way under the weight of the airplane, causing it to land on the front gear leg (which was properly locked) and the aft lower part of the fuselage. The airplane eventually departed the runway to the right and came to a stop on the dirt and gravel runway strip.

The aircraft's occupants were uninjured and exited the aircraft under their own power. The aircraft sustained minor damage. There was no damage to any airport facilities.

[2] Since Spain and Italy are in the same time zone, the local times in the two countries are the same.

Figure 1. Aircraft on runway strip after emergency landing

1.2. Damage to aircraft

The aircraft exhibited damage to the:

- Bottom surface of the horizontal stabilizer.
- Lower aft part of the fuselage.

1.3. Personnel information

The aircraft's pilot, an Italian national, had a private pilot license (PPL(A)) for the aircraft type. It had been issued by the Italian aviation authority and was valid and in force until 22/07/2013. He also had a valid class 2 medical certificate that expired on 15/03/2013.

The pilot had a total of 663 flight hours, of which 250 had been on the type.

The aircraft belonged to the pilot, who was its usual pilot.

1.4. Aircraft information

Manufacturer:	Cessna
Model:	177RG (Cardinal)
Serial number:	177RG1054
Year of manufacture:	1976

Maximum weight:	1,220 kg
Maximum capacity:	4 people
Engine:	• Number: 1 • Manufacturer: Lycoming • Model: IO-360-A1B6D • Serial number: L-16301-51A
Propeller:	• Manufacturer: McCauley • Model: C3D36C415/82NGA-8 • Serial number: 061256

The aircraft was registered in Germany's Aircraft Registration Registry in November 2008.

Its airworthiness certificate was issued by the German authority in September 2005, and revised by the Italian authority in June 2012, which renewed the certificate until 8 June 2013.

The last time the aircraft's weight and balance were certified was on 24/05/2011, with the aircraft equipped as per the flight manual, with no fuel and with engine oil. A study of the aircraft's weight and balance reveals that its operation during the incident flight was within limits at all times.

The most recent maintenance activities[3] had been:

Date	Total flight hours	Inspection
25/05/2010	3,795:05 h	50-h, 100-h and 200-h/annual
11/12/2010	3,843:25 h	50-h
25/05/2011	3,857:15 h	50-h, 100-h and 200-h/annual
09/06/2012	3,901:25 h	50-h, 100-h, 200-h/annual and airworthiness

No abnormalities were detected in the documentation of the scheduled maintenance, which was verified to have been carried out in keeping with the Maintenance Program.

1.5. Meteorological information

According to the weather information supplied by the Meteorological Office at the Almeria Airport (part of Spain's National Weather Agency), the conditions at the time of the incident were:

[3] These activities were carried out at the Max Aviation srl. maintenance center, an EASA-approved organization with number IT.145.0295.

- Visibility: in excess of 10 km.
- Wind: variable between calm and 3 kt, shifting between 140° (southeast) and 220° (southwest).
- Temperature: 26 °C.

1.6. Aerodrome information

The Almeria Airport is located 9 km west of the city. Its reference point is at an elevation of 21 m (70 ft).

It has one 3,200-m long by 45-m wide asphalt runway in a 07/25 orientation. There is one 23-m wide taxiway that connects the apron to the runway thresholds.

1.7. Survival aspects

The pilot carried out the emergency landing maneuver at the minimum speed possible so as to cushion the impact with the runway. Also, during the final approach phase, once he was committed to landing, he stopped the engine, shut off the fuel valve and unlatched the doors.

During the landing, after the main landing gear collapsed, the aircraft skidded along the runway on its lower aft fuselage and horizontal stabilizer before departing the runway and coming to a stop between the runway and the taxiway. The passenger compartment was not compromised and there was no fire. All four occupants onboard were uninjured and exited the aircraft without any problem.

1.8. Tests and research

1.8.1. *Pilot's statement*

The pilot flying was interviewed and stated that upon arriving at the Almeria Airport, he contacted the control tower to request clearance to land. He was cleared to land on runway 25, at which time he lowered the landing gear lever. The mechanism sounded normal, but the green light[4] on the control panel did not turn on. From the pilot's seat on this aircraft the left main gear wheel is visible, and its position indicated that it was not locked. He could not see the nose wheel.

He went around and asked the tower for permission to do a fly-by at low speed so tower personnel could report the condition of the landing gear. The tower informed him that the gear was down but maybe not locked.

[4] This aircraft has a single green light to indicate when the gear is fully extended and locked.

He then decided to continue flying an additional 25 or 30 minutes to burn off fuel and try to recycle the gear. He had the aircraft manufacturer's Pilot's Operating Handbook[5] onboard and he performed the *Landing gear fails to extend* procedure from Section 3 of the Emergency Procedures in an attempt to lower and lock the landing gear manually.

He then asked the tower to once again check the condition of the gear, the response being the same as the first time. The pilot thus decided to make an emergency landing assuming the main gear was not locked in the down position and not knowing the condition of the nose gear.

He tried to make the landing as smooth and as slow as possible. On final approach, once he was committed to landing, he stopped the engine, closed the fuel shut-off valves and unlatched the doors.

When the unlocked main gear wheels touched down, they were unable to support any weight and the aircraft settled on the lower aft part of the fuselage. The front leg was locked and withstood its corresponding portion of the aircraft's weight.

The aircraft skidded on the runway and departed it to the right. When it came to a stop, the four people onboard exited the aircraft under their own power. All were uninjured.

As the aircraft was being lifted from the strip using a crane and slings, the main gear fell under its own weight into an almost locked position. The pilot himself pulled one of the legs and both locked, so it was decided to lower the aircraft to the ground (with the gear supporting its weight normally) and tow it to a parking stand on the apron.

1.8.2. *Field investigation*

The examination of the aircraft wreckage revealed that:

- The hydraulic fluid level was correct and there were no leaks.
- The hydraulic pump showed no signs of having failed.
- The aircraft's frame was almost completely intact, with the external damage limited to the underside of the horizontal stabilizer and the aft center section of the fuselage.

In order to access the mechanical assembly that raises and lowers the main gear when actuated by a hydraulic piston, the seats and the floor plates were removed from the cabin.

[5] Pilot´s Operating Handbook, Cessna model 177RG (Cardinal). 1976.

It was noted that the assembly seemed to be in good overall condition and was properly greased.

The actuator rod end, however, was broken.

The function of this piece is to transmit the force generated by the hydraulic piston to an arm that transforms the rod's translational motion into the motion of the pinion gear, which raises and lowers the main landing gear.

The hydraulic piston was actuated, it worked properly in both directions, but since there was no mechanical continuity at the rod end, it was impossible to transfer forces to the rest of the system.

Figure 2 shows the components mentioned above and their relative positions. For a more detailed explanation of the system's operation as a whole, see Section 1.9.2 *Operation of the main landing gear extension and retraction system*.

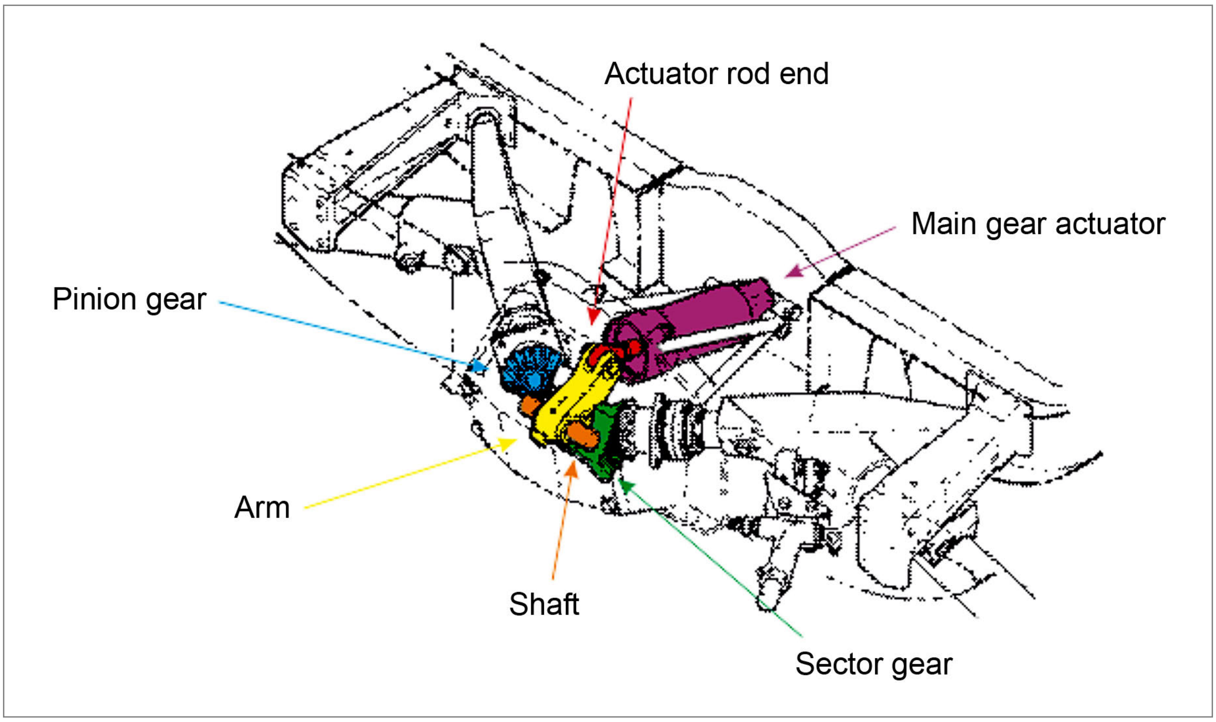


Figure 2. Main landing gear extension/retraction system

1.8.3. *Analysis of the broken part*

The part of the actuator rod end that was loose in the hydraulic piston (henceforth referred to as "rod end") was sent to the Materials Testing Laboratory of the

Universidad Politécnica de Madrid's Department of Aeronautical Engineering for an analysis of the fracture.

The summary provided below is taken from the report issued by the laboratory. Appendix I, at the end of this report, provides more detailed information on the metallurgical analysis of the fracture surfaces.

Figures 3 and 4 show the two sides of the rod end fragment analyzed. They clearly show that the rod end's original circular shape was substantially altered, especially toward the narrower end of the fragment. This means that during the failure process, the rod end underwent a considerable amount of plastic deformation before the component completely detached.

Figure 5 shows the central through-hole at the thicker end of the rod end, which is used to grease the interior of the rod end. Figure 6 shows the inner surface on the rod end

Figure 3. Side view of rod end fragment

Figure 4. View from opposite side

Figure 5. Front view

Figure 6. Inner surface

Figures 7 and 8. Fragments from the rest of the broken rod end

fragment and the presence of a projecting rib, at either side of which there are yellowish bands produced by residue from the rod end's internal brass bearing.

The brass bearing explains the presence of Cu and Zn on the corrosion products found on the fracture surfaces. Also detected was Cd, possibly produced by a cadmium plating on the surface of the piece.

The failure process of the rod end began in area A (see Figure 6), which was the first to break. The fracture occurred in the section with the greasing hole.

Part of the fracture surface is completely covered in corrosion products. The rest of the fracture exhibits features consistent with a ductile failure.

The failure of the rod end in area A took place either as a result of a single overload that instantaneously broke the rod end at area A, or of a series of overloads that led to progressive cracking.

There were no signs indicating the presence of a conventional fatigue failure process.

Once area A broke completely, area B fractured instantly.

1.9. Additional information

1.9.1. *Emergency procedure performed*

The pilot carried out the *Landing gear fails to extend* emergency procedure contained in the Section 3, Emergency Procedures, of the aircraft manufacturer's Pilot's Operating Handbook (see Figure 9). This procedure relies on a hand pump to supply pressure manually to the hydraulic landing gear extension system.

LANDING GEAR FAILS TO EXTEND

(1) Landing Gear Circuit Breaker -- PULL OUT.
(2) Landing Gear Lever -- DOWN.
(3) Emergency Hand Pump -- LIFT COVER, EXTEND HANDLE, and PUMP (until resistance becomes heavy -- about 40 strokes).
(4) Gear Down Light -- ON.
(5) Pump Handle -- STOW.
(6) Landing Gear Circuit Breakers -- IN.

Figure 9. Emergency procedure used

1.9.2. *Operation of the main landing gear extension and retraction system*[6]

Each of the two main landing gear ends in a pinion gear (located at the end opposite the wheel).

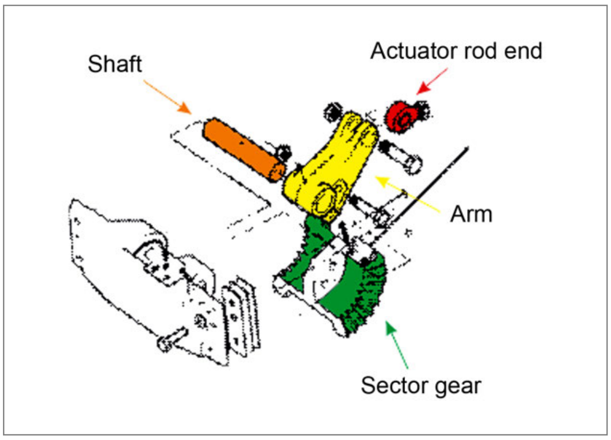
When the stem on the hydraulic piston extends or retracts, the actuator rod end transmits this motion to a hinged arm located at one end of a fixed shaft, which makes it rotate. Since the arm is attached to the two sector gears where the ends of the main gear legs mesh, when the arm moves, this motion is transmitted to the main gear legs simultaneously.

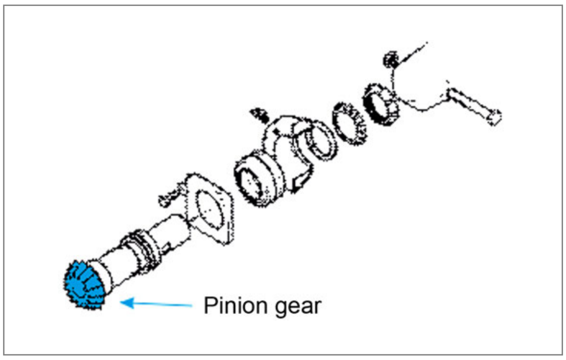
If the hydraulic piston loses pressure, the aircraft is equipped with an emergency hand pump that can be used to build up pressure in the system. If the piston stem breaks, however, no motion can be transmitted to the sector gears, meaning the main landing gear cannot be extended or retracted. In the absence of hydraulic pressure in the piston, the gear can be allowed to fall by gravity, but this is not sufficient to lock it in place.

Figures 10 and 11 show an exploded view of the main landing gear extension and retraction system components contained in Figure 2.

As a result of the simultaneous movement of both main landing gear legs in this type of aircraft (interlocked with the sector gears), the legs cannot be locked independently through the application of inertial forces in high-g turns.

[6] The nose gear leg extends and retracts by means of a hydraulic actuator independent from that for the main gear, though both are commanded from the cockpit using a single control.





Figures 10 and 11. Close-ups of the main landing gear extension/retraction system

1.9.3. *Information on the broken part*

The rod end hinges with the arm to transmit to it the motion of the main gear actuator rod end.

Internally the rod end has a bearing to reduce friction. The rod end also has a central through-hole that can be used to inject lubricant, which is distributed internally by a rib that protrudes from the inner central part of the rod end.

On 6 August 1979, Cessna, the aircraft manufacturer, issued Service Information Letter (SIL) SE79-37 specifically concerning this component. The SIL was applicable to the incident aircraft since its serial number, 177RG1054, was listed among the SIL's addressees[7]. This SIL was subsequently revised on 15 December 1980 (attached as Appendix II).

This SIL recommended replacing the existing rod end (which was the one installed on the incident aircraft with P/N S2049-6FG) with another without a greasing hole and without an internal brass bearing prior to (or at the latest during) the aircraft's next annual inspection. The new rod end (with P/N S2426-6) had a higher strength and an internal Teflon bearing to minimize friction with the shaft on the sector arm.

Compliance with the contents of SIL SE79-37 was recommended, not obligatory.

FAA Advisory Circular 43-16A[8] reveals that Cessna issued a second revision to SIL SE79-37 in which the new recommended rod end now had P/N S3469-1, very similar to P/N S2426-6, but that also had to be inspected prior to leaving the manufacturing center.

[7] Serial numbers of affected aircraft: 177RG0001 to 177RG1366 and F177RG0001 to F177RG0177.
[8] Alert number 271, february 2001.

The aforementioned Advisory Circular also indicated that if the rod end installed had P/N S2426-6, it was not necessary to replace it but it did have to be carefully checked during annual inspections.

1.9.4. *History of similar failures*

An incident of almost identical characteristics took place in the United Kingdom[9] on 5 September 2003 involving a Cessna F177RG Cardinal, registration G-BFIV and S/N F177RG0161.

In this incident, the pilot was unable to get the landing gear to lower and lock down and had to make an emergency landing. Neither of aircraft's occupants was injured.

The cause of the improper operation of the main landing gear of aircraft G-BFIV was the fracture of the same rod end (the one originally installed on the aircraft, with the through-hole and the internal brass bearing) as the one involved in this report. The nature of the fracture of the rod end on G-BFIV was practically identical to that determined for the broken rod end on D-EEDM by the Universidad Politécnica de Madrid's School of Aeronautical Engineering.

In addition, according to data published in 2001 by the FAA's Aircraft Certification Office in Wichita, Kansas, a total of 13 Service Difficulty Reports (SDR) were reported from 1979 to 1998 involving problems with rod end P/N S2049-6FG, and five accident/incidents were analyzed from 1979 to 1989 in which the rod end P/N S2426-6 had broken.

From 1977 to 2001, 30 SDRs reported the fracture of rod end P/N S2049-6FG. From 1978 to 1987, the FAA recorded 10 accidents/incidents involving the fracture of rod end P/N S2049-6FG. No problems were reported, however, with the rod end P/N 3469-1.

The FAA issued one safety recommendation (FAA Safety Recommendation 00.284), which recommended replacing rod end P/N S2049-6FG with P/N S3469-1 as soon as possible.

2. ANALYSIS

2.1. General considerations

The pilot of the aircraft had the necessary licenses, valid and in force, to make the flight and the aircraft had been maintained in accordance with the manufacturer's maintenance manual and was properly licensed and certified.

[9] The United Kingdom's accident investigation commission issued the relevant report (AAIB Bulletin N° 4/2004, Ref: EW/G2003/09/06).

The aircraft's weight and balance during the incident flight were likewise within limits at all times.

The weather conditions were suitable for the approach and landing.

2.2. Failure of main landing gear to extend and lock down

The failure of the rod end made it impossible for the main landing gear to extend and lock down. This was not the case with the nose gear, which has a separate actuator.

With the main gear actuator rod end broken, it was impossible to transmit the movement of the hydraulic piston to the rest of the mechanical system used to extend and retract the main landing system.

Thus, even though the hydraulic piston worked properly and extended and retracted the internal rod, the arm was not receiving any force to be transmitted to the pinions responsible for moving the main landing gear since the mechanical connection was completely decoupled.

2.3. Alternate maneuver

Even though the noise heard in the cockpit was the usual one for when the hydraulic system that extends or retracts the landing gear actuates, the pilot tried to pump pressure into the system manually by following the proper emergency procedure. But the result continued to be the lack of a green light indicating the gear was down and locked.

In light of the situation, and since inertial forces in turns are insufficient to fully extend (and lock) the main landing gear on this type of airplane, the pilot made the right decision and burned off fuel before making an emergency landing at the lowest speed possible in anticipation of having (at least) the main landing gear collapse when it touched down on the runway.

2.4. Broken part

The part fractured instantaneously and with no prior warning that it was working improperly. In fact, the incident landing was the fourth that day, with the aircraft's landing gear having worked perfectly on the three previous landings made hours earlier.

The original design of the rod end with the greasing through-hole had previously been responsible for nearly identical failures. In fact, SE79-37, dated August 1979 and modified in December 1980, recommended that this part be replaced with another with the same operational characteristics but without the through-hole and with a higher strength.

The rod end installed on the aircraft bore the original design and had not been replaced as recommended in either SE79-37 or in FAA Safety Recommendation 00.284.

3. CONCLUSIONS

3.1. Findings

- The four flights made by the aircraft on the day of the incident were uneventful until the pilot started the landing approach for the last flight into the Almeria Airport.
- The aircraft's pilot had a valid and in force flight license and medical certificate.
- The aircraft was properly licensed and certified for the operation.
- An analysis of the aircraft's weight and balance revealed that the incident flight operated within these limits at all times.
- No abnormalities were detected in the scheduled maintenance documentation, which showed that the Maintenance Program had been complied with.
- The approach and landing were made under suitable weather conditions.
- The field investigation of the aircraft revealed that the landing gear extension and retraction system was in good condition except for the presence of a failed rod end in the mechanical assembly that extends and retracts the main landing gear.
- This failure of the rod end happened instantaneously in flight without prior warning of any malfunction.
- The failure of the rod end interrupts the mechanical continuity of the main landing gear extension and retraction system, rendering it inoperative.
- The fractured rod end had been the subject of a service letter (SIL SE79-37) issued by the aircraft manufacturer in 1979 that recommended it be replaced with a stronger part without the greasing hole.
- The rod end installed in the aircraft was of the original design. It had not been replaced as recommended in SIL SE79-37.
- There are records indicating that the failure of the rod end in question has occurred on other occasions on aircraft of the same type where the original rod end had not been replaced, as recommended in SIL SE79-37 and in FAA Safety Recommendation 00.284.
- There is no emergency procedure for extending and locking down both main landing gear legs in flight on this type of aircraft following a failure of the rod end.
- The pilot made the emergency landing after taking the proper precautions.
- The aircraft's passenger compartment retained its integrity and its occupants were able to exit the aircraft under their own power and without sustaining any injuries.

3.2. Causes

The incident was caused by the instantaneous fracture in flight of the main gear actuator rod end, which interrupted the mechanical continuity in the main gear extension and retraction mechanism, thereby rendering it inoperative by failing to transmit the motion of the hydraulic piston to the rest of the system.

Contributing to this incident is the fact that the rod end that was installed on the aircraft was of the original design and had not been replaced with a stronger part without a greasing hole, as per the recommendation in Cessna's SIL SE-79-37.

4. RECOMMENDATIONS

REC 07/14. It is recommended that the FAA require the replacement of the rod end with the original design by the one recommended in Cessna Service Information Letter SE79-37.

APPENDICES

APPENDIX I
Analysis of the fracture surfaces

So as to determine the microfractographic features associated with the fracture process, the two fracture surfaces located at either end of the fragment, labeled as A and B in Figure 6, were analyzed using a scanning electron microscope and an X-ray microanalyzer.

Fracture A

Figure 12 shows a full image of this fracture, which extends to both sides of the central through-hole. At low magnifications there are two regions with a different appearance. These regions are separated as shown by the dashed line.

There is an area near the outer surface of the rod end at either end of the hole with an apparent uniform and non-directional roughness. The rest of the fracture surface, in contrast, exhibits a high directionality along the plane of the rod end and parallel to the through-hole.

Various areas from both fracture regions and on either side of the through hole, numbered in Figure 12, were selected for determination of their microfractographic features.

At high magnifications, area 1, near the hole and very close to the rod end's outer surface, shows a microrelief that cannot be associated with any specific fracture mechanism, but rather with the presence of corrosion products on the surface that prevent a proper observation of the original fracture relief in this area.

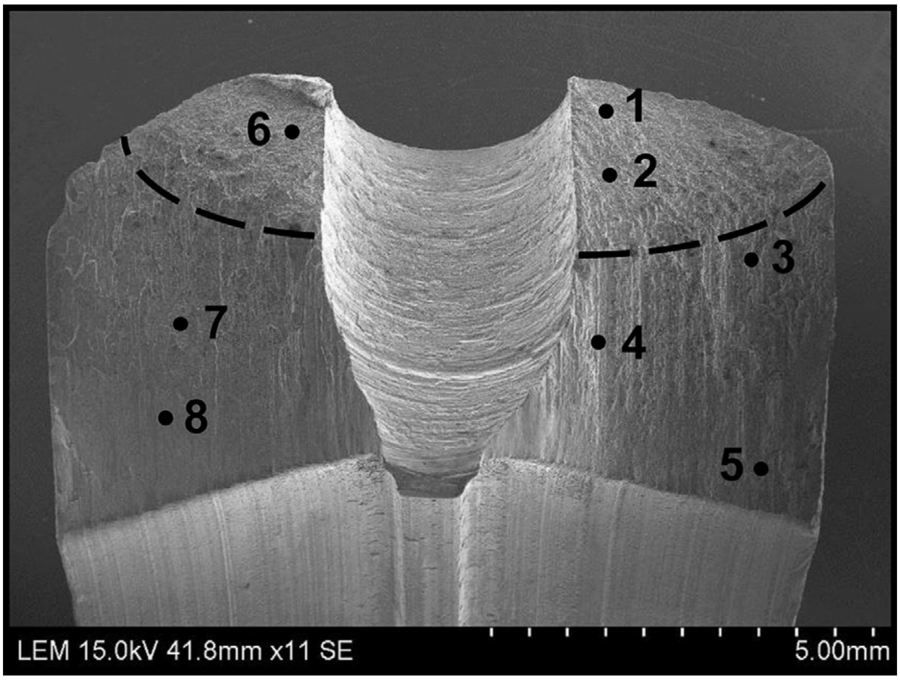


Figure 12. General view of fracture A

The X-ray spectrum emitted by this area revealed the presence of various elements. The Fe (the most abundant element) and probably the Cr are due to the steel used to manufacture the part.

The fracture surface also revealed the presence of significant amounts of C, O, Cu, Zn, Al, Si, S and Cd, explained by the presence of the corrosion products that cover the fracture.

In area 2, situated in the same region as 1 but deeper inside the rod end, shows a prominent microrelief that has also been deteriorated by the subsequent corrosion of the surface. Some points show marks resembling elongated ridges facing from the rod end’s outer surface to its inner surface.

The X-ray spectrum for area 2 was similar to that for area 1, though with lower amounts of Cu, Zn, Al, Si, S and Cd.

Area 3, located at the other end of the dashed line but close to it, shows a relief that is similar to that of 2 but with less deterioration due to corrosion, which revealed at some points signs of the plastic deformation that occurred during the failure process.

Area 4 is in the region where the microrelief is directional. At low magnifications, the relief is not that dissimilar from the one found in area 3, though at high magnifications it exhibits evidence of plastic deformation and dome formation with underdeveloped vertical walls.

Area 5 is very close to the rod end’s inner surface. Its microrelief consists of clearly developed domes of different sizes. There are also elongated ridges, some parts of which exhibit the presence of a phase, probably a steel inclusion. There are no corrosion products on the surface.

Area 6 is on the other side of the through-hole, near the rod end’s outer surface in a position equivalent to area 1’s. Its microrelief is identical to that of area 1, with the presence of corrosion products that hamper the observation of the original relief. The X-ray spectrum from this field is completely analogous to that of area 1, with the presence of the same surface contaminants.

Area 7 is in a region where the relief shows a directional elongation. At high magnifications, the microrelief is similar to that of area 4 with signs of plastic deformation and the presence of underdeveloped domes. The X-ray spectrum for this area is similar to that of area 6, but with lower levels of surface contaminants.

Area 8 is near the rod end’s inner surface. Its microrelief consists of small domes that are slightly elongated in the direction of the prevailing microrelief present in that region. There are no corrosion products on the fracture surface. The spectrum for this area does not indicate the presence of unexpected elements, which is consistent with the absence of corrosion products.

Fracture B

Figure 13 shows a general view of fracture B, which is at the other end of the rod end fragment that was analyzed.

At low magnifications, its relief is uniform throughout the surface and slightly oriented from the outer surface to the inner.

Area 9 typifies this fracture. At high magnifications we can see a microrelief consisting of domes and elongated ridges that are similar to and in the same direction as those noted for fracture A. There are also sections of the fracture surface that are covered in corrosion products, while other sections appear unaffected.

An X-ray microanalysis was conducted for one of the areas with corrosion products. This spectrum revealed the presence of the same contaminants seen in the spectra for the other corroded regions. This is in contrast to the spectra for the unaffected areas, which do not show the presence of Cu, Zn, S or Cd.

Finally, area 10 is near the rod end’s inner surface. Its microrelief consists of clearly developed domes. There are also some elongated ridges with inclusions in their interiors. There are no regions with corrosion products.

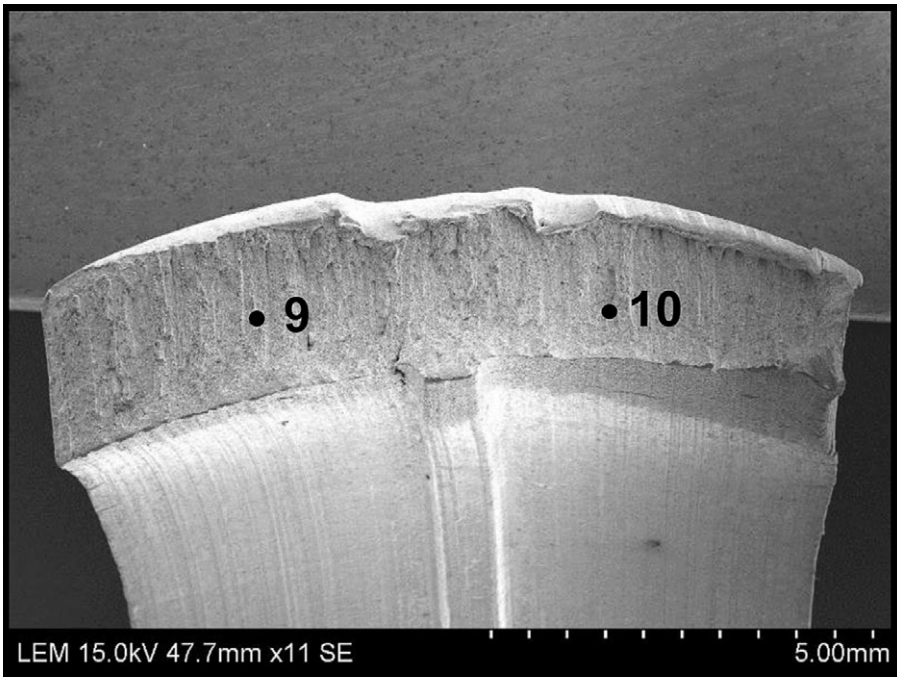


Figure 13. General view of fracture B

The X-ray spectrum of this area did, however, reveal the presence of small quantities of surface contaminants (Cu, Na, Al, Si, S, Cl and Cd).

Fracture growth

The rod end fragment analyzed exhibits significant plastic deformation. This resulted in the inner surface losing the circular shape it must have had originally.

This deformation is much more pronounced in the thinnest area of the fragment, next to fracture B (see Figure 6).

This indicates that fracture A was the first area to break. The fracture in this area was helped by the presence of the through-hole present there.

Once fracture A occurred, the force exerted on the rod end at that moment resulted in a significant plastic deformation that caused the rod end to open and then to fracture along area B.

Fracture A most likely started on the outer surface of the rod end at either side of the through-hole. Since the microrelief of the fracture could not be observed in these areas given that it was covered in corrosion products, it was not possible to accurately determine the fracture mechanism at work in this area.

As the fracture progressed toward the inner surface of the rod end, the appearance of the relief at low magnifications undergoes a change as it takes on a certain directionality.

In the central part of fracture A, on either side of the through-hole, we start to see signs of plastic deformation and the presence of underdeveloped domes, both features typically associated with instantaneous fracture processes of a ductile nature. The surface contamination in these central areas is much lower than that on the outer surface of the rod end.

Near the inner surface of the rod end the microrelief reveals the abundant presence of domes with no surface deterioration or significant amounts of contaminants.

The presence of a fracture area near the outer surface of the rod end and on both sides of the through-hole, along with a microrelief different from that found in the rest of the fracture, as well as the fact that this entire area is completely covered in corrosion products, could indicate that this area fractured before the rest of the rod end.

In the central part of fracture A, however, in the region with the more directional relief, the microrelief does not appear very different from that of the region discussed above. It also exhibits surface corrosion, though to a lesser extent.

Near the rod end's inner surface the fracture surface is populated by domes, indicating a ductile failure that occurred instantaneously.

The ridge-shaped reliefs that appear in various areas of fracture A could be associated with the presence of elongated inclusions in the steel used to manufacture the part.

This might indicate the development of a classical fatigue crack on the outer surface of the rod end and on either side of the through-hole. The subsequent corrosion of the fracture surface in this area prevents seeing the microfractographic features, and thus categorically confirming or denying the initial presence of a classic fatigue process.

There is, however, one radical difference in the relief of this potential fatigue area and the central fracture area and its directional relief. This potential fatigue area also features the presence of ridge-shaped reliefs, which typically suggests a failure process enhanced by the presence of inclusions, something that is more likely is the fracture process results from an overload than if the growth is driven by fatigue.

As a result, and without being able to rule out the presence of a conventional fatigue failure, it seems more likely that the fracture of the outer surface of the rod end was caused by an overload.

The complete fracture of area A of the rod end could have occurred due to a single static overload, which originated the entire fracture surface all at once, or due to the application of successive overloads, which would have made the crack grow in stages until the eventual fracture, which could be regarded as a fatigue process with a very low number of cycles.

The presence of areas fully covered in corrosion products (next to the rod end's outer surface) and of areas practically free from corrosion (next to the inner surface) could confirm the hypothesis that the fracture progressed in several stages, with the first areas to crack corroding more.

The fracture of area B clearly corresponds to a single instantaneous fracture process of a ductile nature that occurred after the fracture of area A. This fracture surface was the last to form, and it also exhibits regions that underwent a corrosive attack very similar to that seen in fracture A.

As a result, the possibility remains that all of the corrosion on the surface area was produced after a full and instantaneous fracture of area A, followed by area B, with some areas being more corroded than others for unknown reasons.

APPENDIX II

"TAKE YOUR CESSNA HOME FOR SERVICE AT THE SIGN OF THE CESSNA SHIELD"

SINGLE ENGINE CUSTOMER CARE SERVICE INFORMATION LETTER

MARKETING DIVISION / CESSNA AIRCRAFT COMPANY / WICHITA, KANSAS 67201 / CABLE ADDRESS - CESSCO WICHITA

REVISION NOTICE: This revised Service Letter supersedes the original issue of SE79-37 dated 8-6-79. Areas of change are marked (▌) in the left hand margin. If the previous letter has been complied with, review changes to determine additional requirements.

December 15, 1980

SE79-37
Revision #1

SUBJECT: MAIN GEAR ACTUATOR ROD END

AIRCRAFT APPLICABILITY: 1971 thru 1978 Model 177RG

Serial Numbers . . . . . .
177RG0001 thru 177RG1366
F177RG0001 thru F177RG0177

A new high strength main landing gear actuator rod end (Part Number S2426-6) is now available for the 177RG aircraft.

It is recommended that the present main landing gear actuator rod end be replaced with the new part, prior to or at the next annual inspection.

Instructions for installing this rod end are provided on the opposite side.

Parts required for this improvement are listed below and are available through the Cessna Dealer Organization. The suggested list prices are also indicated.

Part Number	Description	Suggested List Price
S2426-6	Rod End	$ 76.00 (S) each
AN316-7R	Lock Nut	$ .57 (S) each

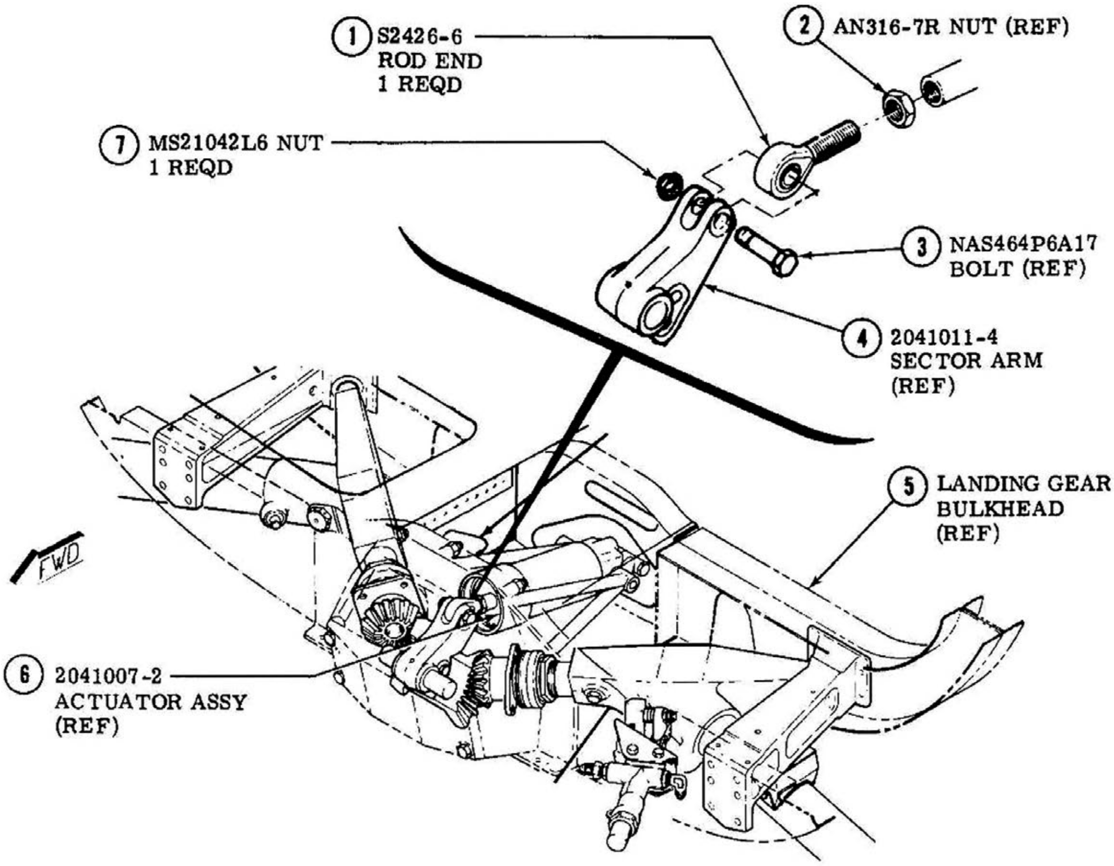
* * * * * *

(Owner Notification System - No. 1)

ALL PRICES SUBJECT TO CHANGE WITHOUT NOTICE

CESSNA AIRCRAFT COMPANY

TO OBTAIN SATISFACTORY RESULTS, PROCEDURES SPECIFIED IN THIS SERVICE INFORMATION LETTER MUST BE ACCOMPLISHED IN ACCORDANCE WITH ACCEPTED METHODS AND PREVAILING GOVERNMENT REGULATIONS. CESSNA AIRCRAFT COMPANY CANNOT BE RESPONSIBLE FOR THE QUALITY OF THE WORK PERFORMED IN ACCOMPLISHING THIS SERVICE INFORMATION LETTER.



MAIN LANDING GEAR ACTUATOR ROD END REPLACEMENT.

1. Put aircraft on jacks in accordance with the appropriate Service/Manual.
2. Remove seats and carpet as required for access to the access plate above main landing gear actuator and remove access plate.
3. Put landing gear in the unlocked position, allowing the main gear to rotate freely.
4. Remove bolt (3) and nut (7) attaching actuator rod end (1) to sector arm (4).
5. Retain bolt (3) and discard nut (7).
6. Loosen locknut (2) and remove rod end (1) from piston rod. Remove locknut from rod end.
7. Install locknut (2) on new rod end (1) and install rod end into piston rod.
8. Adjust rod end and attach to sector gear arm (4) using existing bolt (3) and new nut (7).
9. Use the appropriate Service Manual for main landing gear rigging procedures.
10. Replace all parts previously removed for this replacement.
11. Remove aircraft from jacks.