Technical report

A-003/2022

Accident on 10 January 2022, involving a PS-28 Cruiser aircraft operated by Flyschool Air Academy, registration EC-NKP, at Casarrubios del Monte Aerodrome (Toledo, Spain)

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MINISTRY OF TRANSPORT, MOBILITY AND URBAN AGENDA

UNDERSECRETARIAT

CIVIL AVIATION
ACCIDENT AND INCIDENT
INVESTIGATION COMMISSION

NOTICE

This report is a technical document that reflects the point of view of the Civil Aviation Accident and Incident Investigation Commission (CIAIAC) regarding the circumstances of the accident and its causes and consequences.

In accordance with the provisions in Article 5.4.1 of Annex 13 of the International Civil Aviation Convention; and with articles 5.6 of Regulation (UE) nº 996/2010, of the European Parliament and the Council, of 20 October 2010; Article 15 of Law 21/2003 on Air Safety and articles 1 and 21.2 of Regulation 389/1998, this investigation is exclusively of a technical nature, and its objective is the prevention of future civil aviation accidents and incidents by issuing, if necessary, safety recommendations to prevent from their reoccurrence. The investigation is not pointed to establish blame or liability whatsoever, and it's not prejudging the possible decision taken by the judicial authorities. Therefore, and according to above norms and regulations, the investigation was carried out using procedures not necessarily subject to the guarantees and rights usually used for the evidences in a judicial process.

Consequently, any use of this report for purposes other than that of preventing future accidents may lead to erroneous conclusions or interpretations.

This report was originally issued in Spanish. This English translation is provided for information purposes only.

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ABBREVIATIONS

AESA ..... Spain's National Aviation Safety Agency

ARO ..... Air traffic service reporting office

ATO ..... Approved training organisation

ATPL(A) ..... Airline transport pilot license (aircraft)

CPL(A) ..... Commercial pilot license (aircraft)

FAA ..... Federal Aviation Administration

Inch-lb ..... Pound per inch

IR ..... Instructor rating

kt ..... Knots

LECU ..... ICAO callsign for Cuatro Vientos Airport (Madrid)

m ..... Metres

METAR ..... Aviation routine weather report

Nm ..... Newton-metres

p/n ..... Part number

s/n ..... Serial number

VFR ..... Visual flight rules

Technical Report A-003/2022

Owner and operator:	Flyschool Air Academy
Aircraft:	Czech Aircraft Group PS-28 Cruiser, EC-NKP (Spain)
Date and time of accident:	Monday, 10 January 2022; 11:30 local time[1]
Site of accident:	Casarrubios del Monte Aerodrome (Toledo)
Persons on board:	2 (crew, uninjured)
Type of flight:	General aviation - instruction – dual command
Phase of flight:	Take off - take-off run
Flight rules:	VFR
Date of approval:	28 September 2022

Synopsis

Summary:

On Monday, 10 January 2022, the PS28 Cruiser aircraft operated by Flyschool, registration EC-NKP, was carrying out a dual-command instruction flight with two people on board when it suffered a separation of the right main landing gear wheel at the start of its take-off run. The aircraft travelled approximately 70 metres along the runway supported on the right main landing gear's brake disc before stopping. The two people on board were uninjured.

The investigation has identified the cause of the accident as the deterioration, due to loss of tightening torque, of the threaded joint between the hub and inner and outer wheel rim after three tyre changes (procedure 8.5.1 Tire Change in the Maintenance Manual). The deterioration of the assembly produced fatigue in two of the three bolts of the threaded joint, which eventually ruptured, causing the right-hand wheel to detach from the main landing gear.

The failure to explicitly stipulate the non-reuse of self-locking nuts in the instructions for fitting and removing this threaded assembly in procedure 8.5.1 Tire Change of the Maintenance Manual is considered to be a contributing factor.

The report contains three safety recommendations addressed to the manufacturer, Czech Aircraft Group, in relation to the Maintenance Manual for PS28 Cruiser aircraft. The report also lists the safety actions implemented by the operator during the course of the investigation.

[1] 11:30 UTC. All times referenced in this report are local time.

1. THE FACTS OF THE INCIDENT

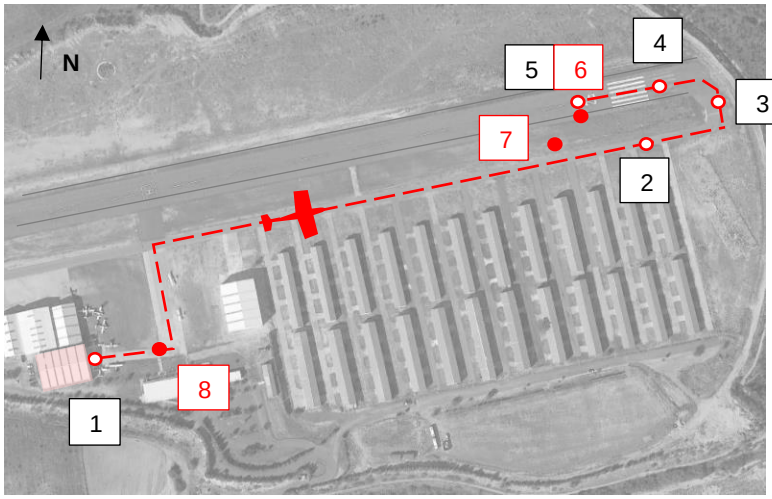
1.1. Overview of the accident

On Monday, 10 January 2022, the Flyschool Air Academy[2] PS28 Cruiser aircraft, registration EC-NKP, flight number FSM697, took off at 10:48 hours from its base at Cuatro Vientos Airport (Madrid) for a two-hour[3] local dual-command instruction flight.

It was the aircraft's second flight of the day, and because the previous student had reported problems with the left brake[4], they headed to the school's maintenance centre at Casarrubios del Monte (Toledo) to have the aircraft checked before starting the actual training flight.

The aircraft approached Casarrubios to land on runway 26, with the student seated on the left as the pilot flying. Their first attempt to land had to be aborted due to the wind. On the second attempt, with the instructor as the pilot flying, they landed without incident. They taxied to the maintenance hangar and ran checks on the brake assembly (pressure, hydraulic fluid level and functional test) for approximately 10 minutes without finding anything abnormal.

At around 11:30 hours, the crew reboarded the aircraft and checked the brakes with satisfactory results. The aircraft began taxiing from the Flyschool maintenance hangar to the head of runway 26.



1 Start of taxi
2 Momentary vibration of the aircraft
3 Engine test at holding point
4 Start of take-off run
5 Final position of the aircraft
6 Bolt fragment
7 Separated right wheel
8 Bolt fragment

Figure 1. Take-off run (described by the crew)

The instructor and student described the following sequence of events (figure 1):

1. They initiated the taxi from the maintenance hangar.
2. During the taxi to the holding point for runway 26, they noticed the aircraft vibrate momentarily and attributed it to the crosswind. The student also described a metallic sound. The vibration stopped, and the remainder of the taxi passed without incident.

[2]An EASA-approved training organisation operating under the name Airpilot Escuela de Vuelo, with ATO reference E-207.
[3] The flight plan was filed at the LECU ARO office at 09:57 local time and approved at 10:07 local time. It specified that the flight would be conducted under VFR rules with an estimated duration of 2 hours.
[4] According to the pupil's description, he had to "push the brake all the way down" to get the aircraft to brake.

3. They arrived at the holding point for runway 26, performed the engine test and, after radio notification, entered and lined up on the runway. There was no traffic.
4. They configured the aircraft with flaps in the take-off position (one flap point, 12°) and applied full power.
5. A few seconds into the run (4-5 seconds and at 15-20 kt, according to the student), they noticed the right wing dropping and saw a wheel overtaking them, crossing to the left. They immediately interrupted the take-off by pulling back on the throttle.

After stopping at the runway 26 designator numbers and securing the aircraft they called the aerodrome and maintenance to report the incident and were immediately assisted. The instructor and student were uninjured and evacuated the aircraft without assistance. Within approximately 15 minutes, the aircraft was removed from the runway.

At 11:43, the ARO office at Cuatro Vientos was notified of the flight plan closure.

The detached wheel, belonging to the right main gear, was recovered about 30 m from the aircraft. Two bolt fragments from the right wheel, with their washers and nuts in place, were also found. The location of these parts and the ground trajectory followed by the aircraft are shown in figure 1. Based on the sketch made by the instructor, it's estimated the aircraft travelled 70 m on the runway.

1.2. Injuries to persons

Injuries	Crew	Passengers	Total in the aircraft	Others
Fatalities				
Serious				
Minor				
Unharmed	2		2	---
TOTAL	2		2	---

1.3. Damage to the aircraft

The damage was limited to the right main gear wheel and brake assembly.

1.4. Other damage

None.

1.5. Information about the personnel

Instructor:

The 40-year-old instructor held a CPL(A) and, among others, a valid instructor rating (IR). His medical certificate was also valid. His total experience was 1,300 hours, of which 780 hours were on the PS28. He had accumulated 939 hours as an instructor.

The accident occurred during the second flight he had made that day. The previous flight was on the same aircraft and had a duration of 50 minutes, ending at 09:45 hours. Prior to that, his last flight had been the day before, and he had had a rest period of 21 hours.

Student:

The 18-year-old student had been enrolled on an ATPL(A) Integrated course[5] since September 2021. He held a valid medical certificate. At the time of the event, his flight experience was 18:05 hours, 91% of which had been with the instructor he was flying with that day and all of which were on the PS28 aircraft.

The accident flight was his first flight that day, having most recently flown 2 days before.

1.6. Information about the aircraft

The EC-NKP Czeck Aircraft Group model PS-28 Cruiser, s/n C0661, was purchased by Flyschool[6] in 2020. It had a restricted certificate of airworthiness issued by AESA. It was maintained by Flyschool, which was also a Combined Airworthiness Organisation (CAO)[7] based at Casarrubios del Monte Aerodrome, authorised by AESA with reference ES.CAO.017.

Figure 2. Aircraft EC-NKP

The flight was conducted with the tanks 50% full. The maximum take-off weight was 576 kg, 24 kg below the maximum permitted (600 kg) for this aircraft. A review of the weight and balance

[5] The Integrated ATPL(A) Course is one of 26 courses approved by AESA for this training organisation.
[6] At the time of the accident, the school was operating 6 aircraft of this type.
[7] Approved to maintain and manage the continuing airworthiness of aircraft and their components not classified as complex engine-powered aircraft and not listed in the AOC of an air carrier licensed under Regulation (EC) No 1008/2008.

calculations showed that they were within the limits defined by the Flight Manual. With regard to the wind (section 1.7), on runway 26, there was a 7 kt crosswind and a 12 kt headwind, below the maximum permitted speeds (12 kt and 24 kt, respectively).

As the aircraft was a training aircraft, it always operated without the landing gear fairing. At the time of the accident, it had accumulated 622 hours 25 minutes of flight in 1,626 cycles. The last scheduled maintenance prior to the incident had been carried out 3 weeks earlier on 21/12/2021 (599:20 aircraft hours), consisting of, among other actions, a 100-hour inspection. A review of the aircraft's maintenance history showed that the aircraft's maintenance complied with the specified maintenance schedule.

1.6.1 Information on the fractured bolts

The fractured bolts (p/n MSC.31-18X1.25SHCS) were part of the main wheel and brake assembly, which was the original factory-fitted assembly. The bolts, washers (p/n MSCAN960-516L) and nuts (p/n MSC.31-18NYLOCK) were also the original factory-fitted parts and had, therefore, accumulated the same number of flight hours as the aircraft: 622 hours 25 minutes.

1.6.2 Location of the bolts on the MATCO MHE51CZ wheel and brake assembly

The aircraft was fitted with a main wheel and brake assembly made by MATCO, model MHE51CZ. The parts described below are relevant to the investigation:

- The 3 fractured bolts connect the hub to the wheel rim.
- The fractured bolts are inserted through a threaded hole in the hub and then pass through two non-threaded through-holes in the wheel rims. In other words, the head of the bolt sits on the hub and it passes through three parts.
- The hub, which supports the wheel rims, is not only screwed but also fitted into the two rims.
- The fractured bolts were secured with a washer and a self-locking nut on the outer rim.
- The hub is also connected to the brake disc with three bolts.
- In addition, the two rims are joined by three bolts that are similar to the ones that fractured but shorter.
- Therefore, on the outer rim, you can see the ends of 6 bolts with their washers and self-locking nuts: the 3 bolts connecting the inner and outer rims and the 3 bolts that secure the hub to the rims.

The MATCO Technical Service Bulletin (Chapter O. Wheel assy. Torque values) states that the torque applied to all the bolts and nuts on the wheel and brake assembly should be 11.3 Nm (100 inch-lb). The aircraft's Maintenance Manual did not specify this for the fractured bolts and their nuts, although it was indicated for other wheel bolts, such as the three that join the inner and outer rims (see section 1.16.4).

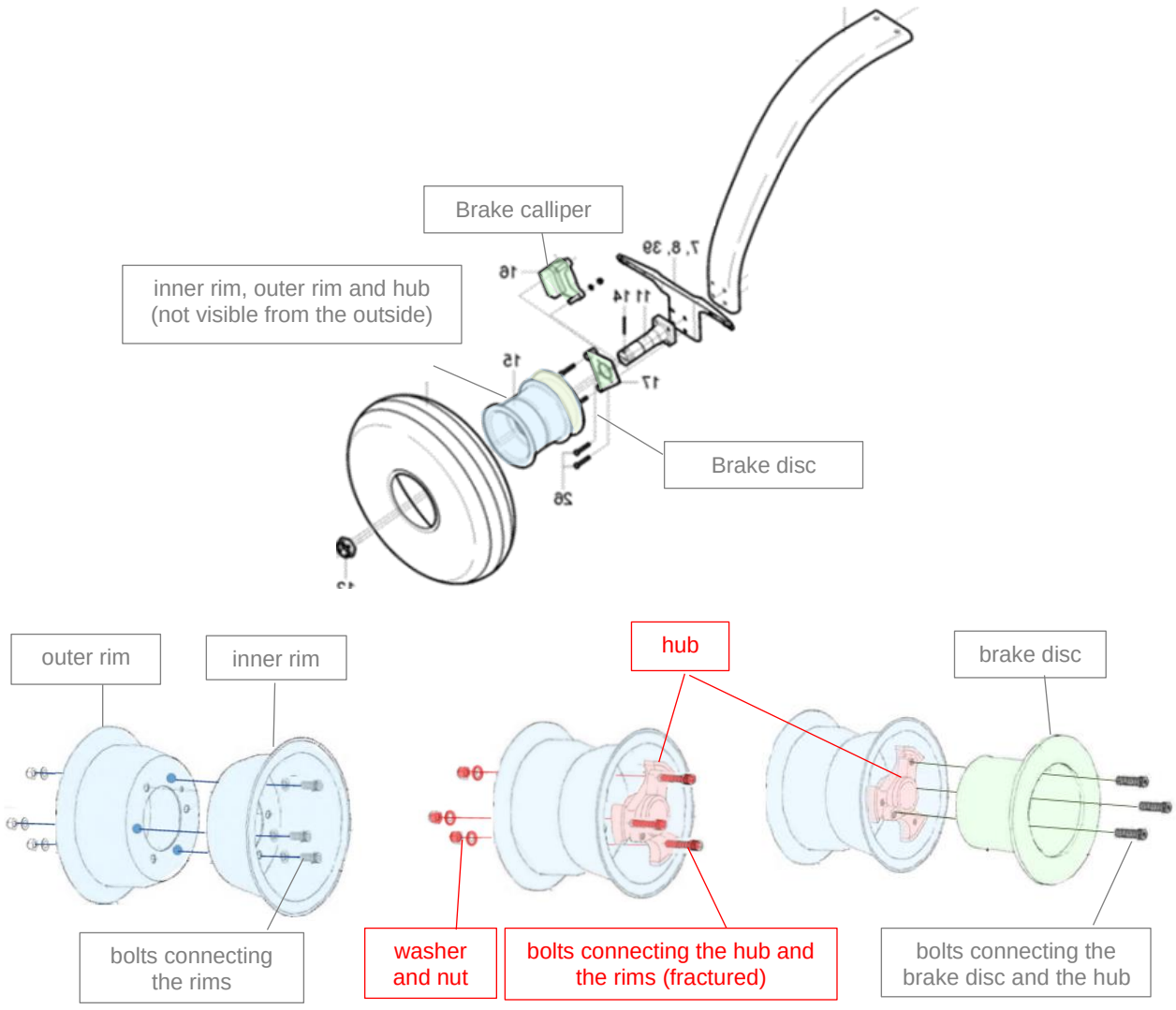


Figure 3. Fractured bolts on the MATCO MEH51CZ wheel and brake assembly

1.6.3 Maintenance tasks involving the fractured bolts

The only maintenance task involving the fractured bolts is the tyre replacement task identified in the Maintenance Manual as CR-MM 8.5.1 Tire Change. This procedure consists of 12 steps, listed from (a) to (l) but does not include the specific task dealing with the fractured bolts (see section 1.16.4).

The execution of this procedure was tested with the operator on a total of 7 wheels, confirming the following sequence (only the actions involving the fractured bolts are included):

To separate the hub from the two wheel rims during disassembly:

1. The self-locking nuts and washers securing the bolts are removed.
2. As the hub is fixed into position between the two wheel rims, a rubber mallet is used to separate the wheel rims from the hub.
3. The bolt, therefore, is never unscrewed from the hub.

To connect the hub to the two wheel rims during assembly:

1. The hub is centred on the inner rim, using the bolts as a guide.
2. The hub is then knocked into position with a rubber mallet, using the bolts as a guide.
3. Finally, the washers and self-locking nuts are fitted, using 11.3 Nm of torque.

The torque applied by Flyschool was correct (11.3 Nm), and the technicians used a Stahlwille brand torque spanner, p/n 730N/2 and s/n 608079008, with a range of 2 to 20 Nm, which had been calibrated on 28/09/2021 by a certified company.

1.6.4 Reuse of bolts, nuts and washers

Chapter 8 of the Maintenance Manual, which deals with the landing gear and specifically procedure CR-MM 8.5.1 Tire Change (see section 1.16.4), does not specify that the nuts and/or washers must be replaced every time the wheel is disassembled. Therefore, anyone reading this procedure in isolation may assume that the nuts, washers and bolts can be reused.

However, chapter 15 of the Maintenance Manual, which deals with *General Repairs*, specifies that, in the absence of criteria defined in the specific chapters for each system, all repairs to the aircraft must be carried out in accordance with FAA Advisory Circular AC 43.13-1B[8], which says[9] that the self-locking nuts on the PS28 landing gear cannot be reused. This information was confirmed with the manufacturer.

1.6.5 Reuse of the fractured bolts, nuts and washers on the EC-NKP aircraft

The history of the EC-NKP aircraft showed that, since its manufacture in 2020, the right tyre had been changed 3 times due to wear and punctures. This means it had been disassembled and reassembled three times, using the same bolts, washers and nuts.

1.7. Meteorological information

The meteorological information for Casarrubios Aerodrome was obtained from the METARs for the nearest aerodromes (Cuatro Vientos and Getafe, located 25 km northeast of Casarrubios). The expected conditions were CAVOK visibility, wind 290°-300°, 10-14 kt and gusty.

1.8. Aids to navigation

N/A.

1.9. Communications

Any relevant communications are included in section 1.1.

[8] AC 43.13-1B: *Acceptable methods, techniques, and practices-aircraft inspection and repair*.

[9] *Section 7-64.f, self-locking nuts- nylon* states the following: "*after the nut has been tightened, make sure the bolt or stud has at least one thread showing past the nut. DO NOT reuse a fiber or nylon locknut if the nut cannot meet the minimum prevailing torque values* (table 7.2)". This table does not apply to the nut, in question, which is why the manufacturer concluded that they could not be reused.

1.10. Information about the aerodrome

Casarrubios del Monte Aerodrome (LEMT) is a restricted aerodrome at an elevation of 625 m with a 900 m long asphalt runway, orientation 08/26. Although the airfield is equipped with perimeter surveillance cameras, neither the taxi nor take-off of the aircraft was recorded.

The taxiway used by the aircraft to travel from the maintenance hangar to runway 26 is paved and in good condition. The route was inspected during the investigation in an attempt to recover the fragment of bolt 2.

1.11. Flight recorders

The aircraft was not equipped with a flight data or cockpit voice recorder because they are not a regulatory requirement for this type of aircraft.

1.12. Aircraft wreckage and impact information

The aircraft came to a halt on the runway, resting on the right wheel's brake disc, the nose wheel and the left wheel. Neither the wings, propeller nor fuselage came into contact with the asphalt, so the damage was limited to the right main gear wheel.

The right wheel assembly was separated into two parts:

- Detached components:
  a) The rims and tyre, which the crew reported seeing rolling ahead of them during the incident, were recovered 30 m from the aircraft's final position.
  b) The fractured ends of the three bolts connecting the wheel rims to the wheel hub, of which only two were recovered. These fragments had retained their nut and washer. The results of the fractographic analysis of the fractured bolts are shown in section 1.16.1.
- Components attached to the aircraft:
  a) The hub, where the three fractured bolts connecting the rims to the hub were embedded.
  b) The brake disc, which had been dragged along the runway, and the brake calliper.

All the recovered components were examined, and the findings and conclusions most relevant to the investigation are detailed below:

- Rims and hub:
  a) The three bolts connecting the wheel rims remained correctly installed.
  b) The three empty holes (randomly numbered 1, 2 and 3) for the fractured bolts were identified. These holes (particularly hole 2) had a high degree of ovalisation produced during the rupture process.
  c) Despite their ordinarily smooth surface, the sections of all three holes revealed irregular thread marks, indicating that the bolt had been moving inside the holes.
  d) The surface of the inner rim had notably deteriorated. Abrasive wear had given it a rough, shiny texture with circular and concentric linear marks. These marks and signs of wear were also identified on the hub, suggesting that the hub was moving inside the rim during the breakage process.

e) The outer rim had a more uniform overall appearance, but the bearing surface of the washers was deteriorated, with superficial pitting and a rough, matt texture. Circular marks made by the torque spanner when tightening the nut were visible around the contour of the washer because the rims are made from a softer material than the nuts.

- Brake disc:
  a) The entire perimeter showed signs of abrasion but it was particularly noticeable in one area where material loss had produced a flat spot. This abrasion suggests that the disc was in direct contact with the asphalt as it dragged along the runway.

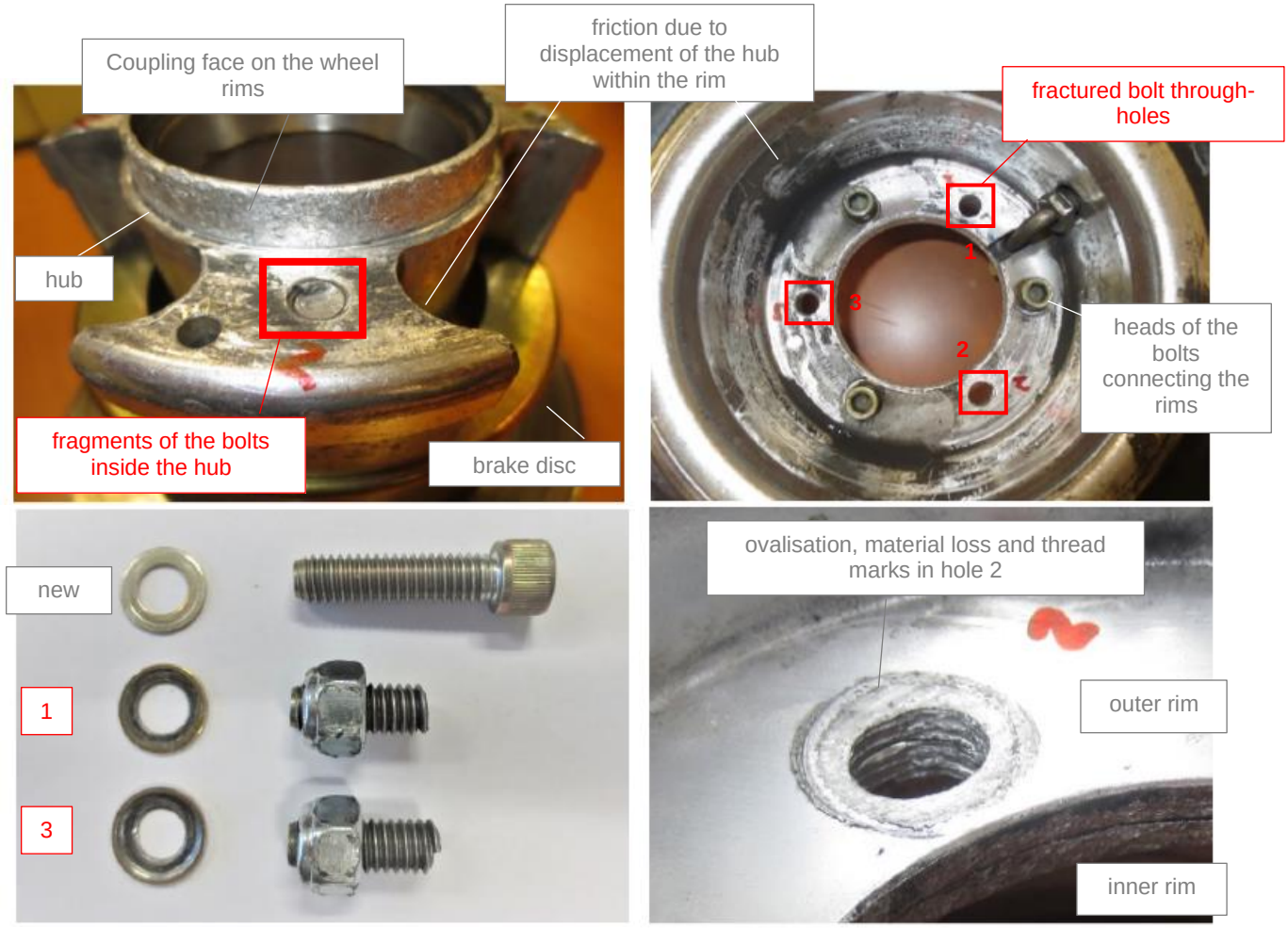


Figure 4. Wheel rims, hub and bolts

1.13. Medical and pathological information

Neither of the two people on board required medical assistance.

1.14. Fire

There was no evidence of fire during the flight or after the impact.

1.15. Survival aspects

The harnesses and restraint systems worked adequately, and the cabin interior maintained its structural integrity.

1.16. Tests and research

1.16.1 Analysis of the fractured bolts

The 6 bolts installed in the rims were inspected in the laboratory. With regard to the 3 bolts connecting the wheel rims, which had remained installed in their correct position, no significant heterogeneities were observed that could have been related to the breakage of the 3 bolts connecting the hub to the wheel rims. In relation to the material specifications, any anomaly that could have contributed to the failure of the bolts was ruled out.

Threads and nuts

The threads of the two fragments of bolts 1 and 3 did not have any significant marks or heterogeneities. The nuts remained attached to the bolts and displayed some marks, in all likelihood made by the tightening tool. The washers had abrasion marks consistent with the marks observed on the outer rim.

Bolt 1

Both pieces of this bolt were recovered: the fragment in the hub and the fragment that had detached. It had ruptured close to where the hub meets the inner rim and displayed two distinctly affected zones:

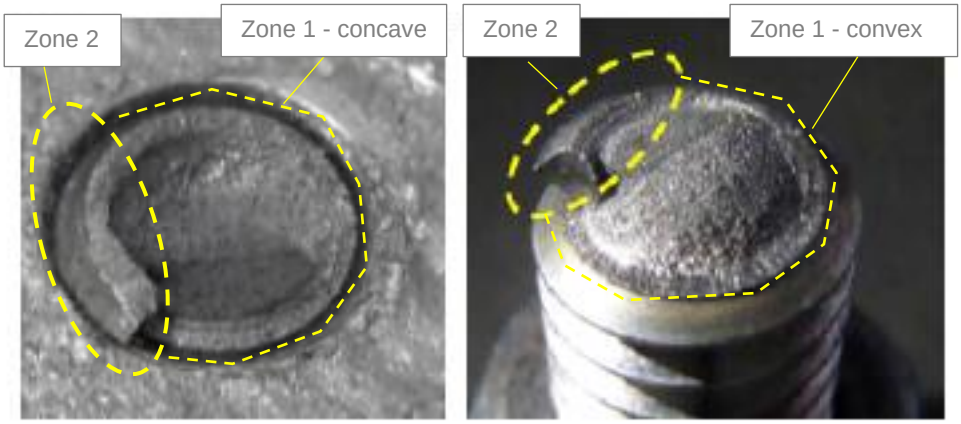


Figure 5. Bolt 1

- Zone 1: comprised most of the surface and had a rough, wood-like texture, typical of a semi-fragile tear. In the fragment from the hub, the fracture surface was concave, while the fracture surface of the detached fragment was convex and cone-shaped, as is typical of tensile breakages.
- Zone 2: the last area to rupture, located on the outer surface of the bolt close to the thread. This zone showed a change of plane in a helical direction which had even resulted in a small tear in the form of a crack in the valley of the thread.

Bolt 2

For bolt 2, only the piece embedded in the hub was recovered; the detached fragment was never found. The fracture surface had developed perpendicular to the axis of the bolt and the maximum tensile stresses, with three distinct distinguishable zones:

Figure 6. Bolt 2

- Zone 1: the surface was smooth, even and matt, and fine, straight lines running almost parallel to each other were discernible, showing the sequential progress of the breakage, commonly known as beach marks. Radial striations were visible around the perimeter where the beach marks were located, indicating numerous breakage origin points. Therefore, in this bolt, the breakage had originated in the peripheral zone, specifically the thread valley, due to a concentration of elevated stresses that generated several fatigue initiations (striations), which then rapidly joined together to create a single fatigue crack that advanced over approximately 70% of the surface.
- Zone 2: had a rough, wood-like texture typical of a semi-fragile tear, with some orientation towards the direction of the breakage.
- Zone 3: was the last area to rupture and showed a change of plane with some degree of plastic deformation. Zone 3 is diametrically opposed to the origin of the break.

Bolt 3

Both fragments of this bolt were recovered, and, as with bolt 2, the fracture surface had developed perpendicular to the bolt's axis and the maximum tensile stresses. Two zones were identified on the fracture surface:

- Zone 1: comprised 90% of the surface and had a matt, even and smooth morphology in which thin, straight and parallel lines were identified (beach marks), indicating the advance of the fracture. Radial striations were also identified around the perimeter of the breakage, suggesting the fracture mechanism originated in multiple places and then merged into a single advancing fatigue crack, similar to zone 1 on bolt 2.
- Zone 2: had a wood-like texture and was the area diametrically opposite the origin of the break. It was, therefore, identified as the final point of rupture.

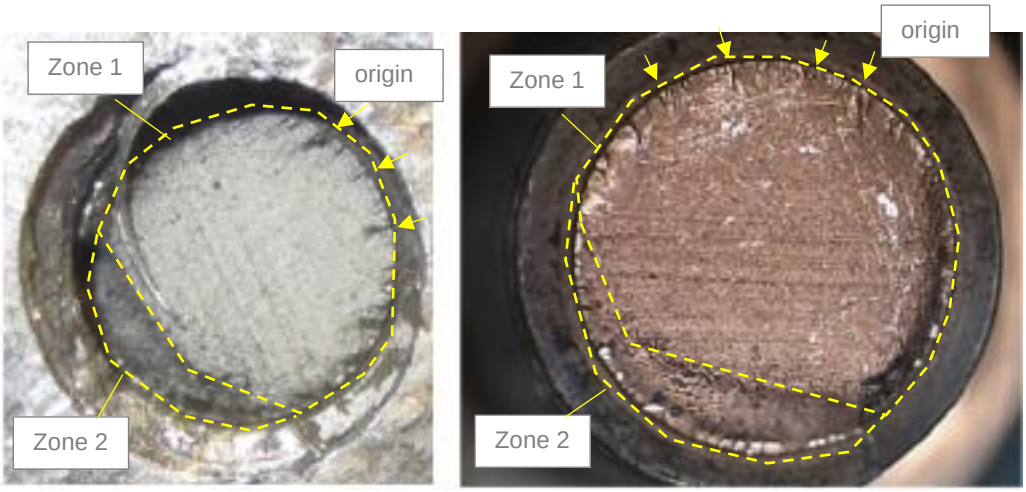


Figure 7. Bolt 3

1.16.2 Inspection of the operator's other aircraft

A total of 7 main landing gear wheels were dismantled and inspected: six[10] from in-service PS28 aircraft and one new wheel and brake assembly. The disassembly process led to several conclusions in relation to:

- The presence of thread marks in the rim through-holes.
- The position of the nuts relative to the end of the bolts.

Thread marks in the wheel rims

The purpose of removing additional operational wheels that had previously had their tyre changed was to identify whether the thread marks observed in the bolt housings of the EC-NKP aircraft were a consequence solely of the incident under investigation. The investigation found that the thread marks were present on all the wheels inspected, although to a lesser degree than on the accident aircraft. This indicated that they had all been subjected to the relative movement of the bolts inside the rims, the effect of which was further compounded by the fact the rims are made from aluminium, which is much softer than the steel used for the bolts. There were no similar marks on the new assembly. The possibility that a machining error in the diameter of the bolt through-holes could have led to excessive stresses being placed on the bolts was ruled out.

Position of the nuts

Compared with the new assembly, the nuts on the bolts connecting the hub to the wheel rims had been displaced, with fewer free bolt threads showing past the nut:

- On the new assembly, all the bolts had 2 threads showing past the nut.
- On all the wheels in operation, the bolts had fewer than 2 threads showing past the nut. The fractured bolts had 1 and 0 free threads showing past the nut.

[10] The left wheel of the EC-NKP accident aircraft, the right wheel of the EC-NKP accident aircraft after 50 hours of operation following the accident, and 4 wheels installed on two other aircraft (EC-NKO and EC-NKN) operated by the same operator.

- This was only the case for the 3 bolts connecting the hub to the rims. By contrast, the nuts on the 3 bolts joining the rims were in the same position as those on the new assembly, with 2-3 threads showing.

Figures 8 and 9 show photographs of the two types of bolts on a new wheel, on the wheel that detached from the EC-NKP aircraft and on two other operational aircraft (one from the same operator and one from a different operator).

Figure 8. Nuts and bolts connecting the hub and the rims

Figure 9. Nuts and bolts connecting the rims

1.16.3 Consultation with another operator

For further comparison, it was consulted another operator with ten PS28 aircraft. It confirmed the same findings: on their operational aircraft, the nuts on the bolts connecting the hub to the rims were not in the same position as on the new assembly, leaving fewer (or even no) threads showing past the bolt.

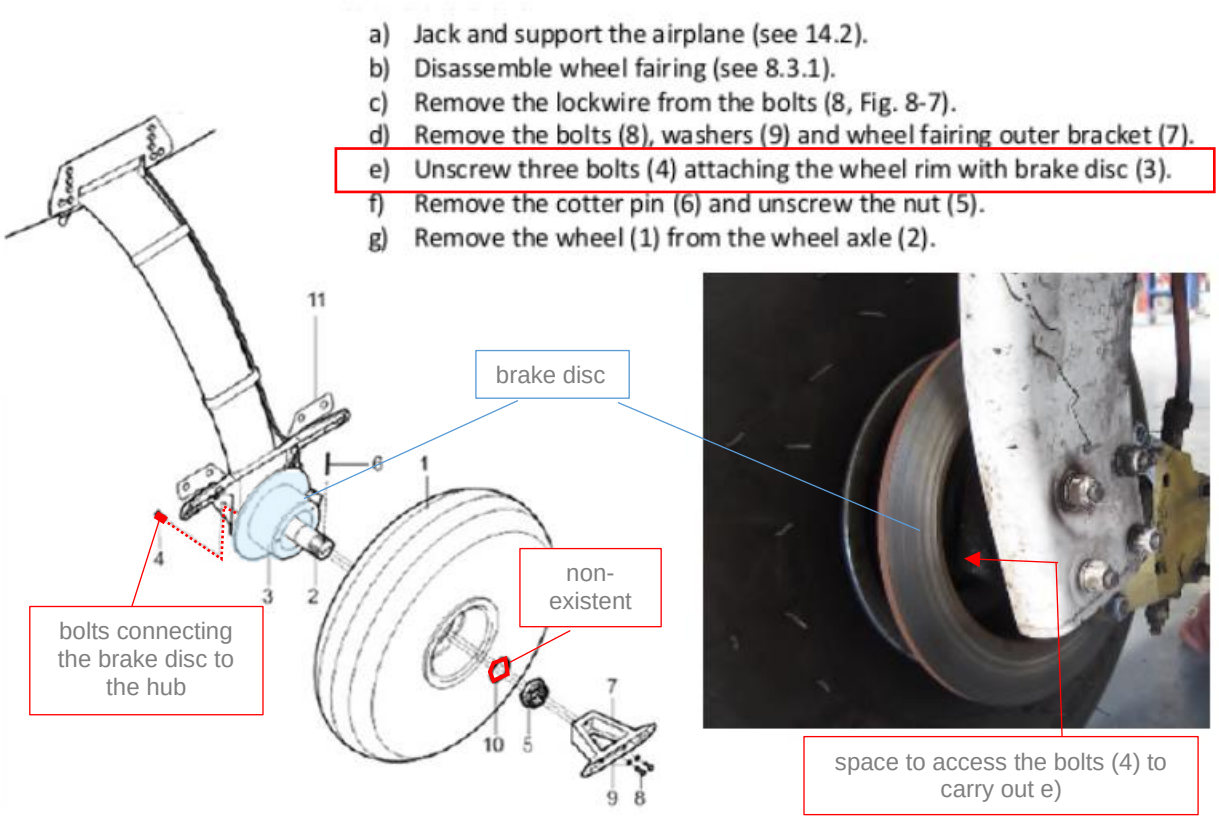
1.16.4 Maintenance procedures

The only maintenance procedure in which action is taken on the threaded joint that failed in the EC-NKP aircraft accident is the tyre change, which is described in the Maintenance Manual in procedure 8.5.1 Tire Change[11]. To change the tyre, the wheel must first be removed from the aircraft, the instructions for which are set out in procedure 8.3.3, Removal of Main Landing Gear Wheel. Procedure 8.3.3 is carried out in step c) of procedure 8.5.1.

During the investigation, a total of 6 wheels were removed from operational aircraft to check the execution of these two procedures, with the following being detected:

[11] Revision number 26 issued on 23/06/2021.

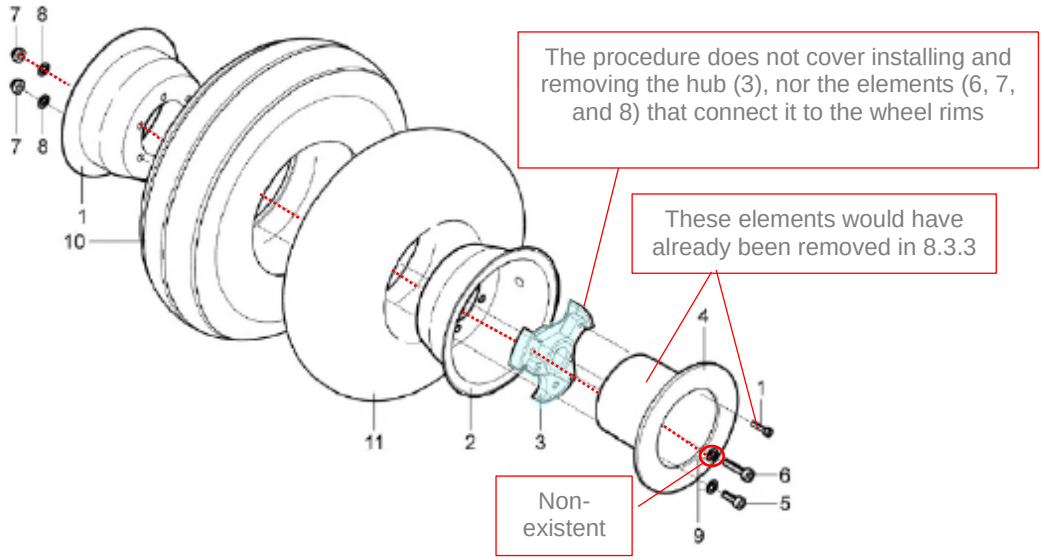
From procedure 8.3.3 *Removal of Main Landing Gear Wheel (figure 8-7) in the CR-MM*.



- Step (e) contains an error, as the bolts (4) shown attach the brake disc to the hub, not to the wheel rim.
- The washer (10) in figure 8-7 of the Maintenance Manual does not exist.
- If the disassembly were carried out according to the published procedure, the wheel would be removed without the brake disc, which would have been separated from the hub in step e). This step conflicts with section e) of procedure 8.5.1.

From procedure 8.5.1 *Tire Change (figure 8-16) of the CR-MM*.

a) Jack and support the airplane (see 14.2).
b) Remove the wheel fairing (see 8.3.1 / 8.3.5).
c) Remove the main landing gear wheel (see 8.3.3) or the nose landing gear wheel (see 8.3.7).
d) Deflate the tire.
e) Unscrew the bolts (1, Fig. 8-16).
f) Set apart both halves of the rim (1, 2) and remove the tire (10) with the air tube (11).
g) Exchange the air tube or the tire, if necessary.
h) Put the air tube (11) into the tire (10) and inflate it slightly.
i) Put the inner tube on that half of the rim, which has the hole for the valve.
j) Put the other half of the rim on this unit. Join both halves of the rim with bolts – torque value 11,3 Nm *(8,3 lbf/ft)*.
k) Inflate tires to the prescribed pressure:
- nose wheel 1,2 + 0,1 bar *(17,4 + 1,5 psi)*
- main wheel 1,8 + 0,2 bar *(26,1 + 2,9 psi)*
l) Mark position of the rim and the tire by redline overreaching about 10 mm *(3/8 in)* to the rim and the tire (serves for checking the tire slewing against the wheel rim in operation).



- Step e) instructs technicians to unscrew the bolts connecting the brake disc to the hub, a task that has already been completed in procedure 8.3.3 step e).
- To carry out step f), the hub must first be removed from the two wheel rims,
- The step to remove the hub from the rims is omitted. It should be carried out prior to step f). This new step should specify that the removed nuts and washers are to be discarded.
- Step j) instructs technicians to join both rims with the 3 bolts, specifying the correct tightening torque.
- However, the step describing how to couple the hub with the rims is omitted. It should come after step j) with the following content:
  - Instructions on how to fit the hub into the wheel rims, ensuring that it is correctly aligned and fits perfectly to prevent separations in the joint.
  - The measures necessary to ensure correct contact between the bolt head and the hub when tightening the nuts, to prevent bolt displacement.
  - The tightening torque to be applied to the bolts and nuts.
  - The requirement to use new nuts and washers.
- The washers (9) on the bolts (6) do not exist.

1.17. Organisational and management information

N/A.

1.18. Additional information

During the investigation, Flyschool took two immediate actions:

- It incorporated the obligation to replace the installed nuts and washers with new ones at every tyre change in Maintenance Manual procedure 8.5.1 Tire change.
- It issued an operational safety communication (CSO 2022-01, dated 20/02/2022, called "Visual inspection PS28") to all crews specifying that before each flight, they should check that the main gear wheel bolts show 2 threads past the nut.

This pre-flight pre-inspection measure was also adopted by the other operator consulted.

1.19. Special investigation techniques

N/A.

2. ANALYSIS

On Monday, 10 January 2022, the PS28 Cruiser aircraft operated by Flyschool, registration EC-NKP, lost its right main landing gear wheel at the start of a take-off run due to the fracture of the three bolts connecting the wheel rims to the rest of the aircraft via the hub. The analysis of this incident contains 5 sections related to two areas:

- The root causes of the fracturing of the bolts in the threaded hub-rim joint. This part comprises sections 2.1, 2.2 and 2.3 and concludes with the justification for issuing safety recommendations to the aircraft manufacturer (Czech Aircraft Group) in relation to the maintenance instructions.
- The sequence of breakages on both the wheel and the aircraft during the event. This part comprises sections 2.4 and 2.5.

2.1. Fracture of the bolts due to fatigue

The investigation has established that the breakage of the bolts (p/n MSC.31-18X1.25SHCS) connecting the two wheel rims to the hub occurred in this order: 3-2-1.

- Bolt number 3 was the first to fracture due to flex fatigue, with an elevated and highly concentrated stress level evident in the fracture zone. The fatigue process started on the surface of the bolt, in the zone where the hub ends and the inner rim halve begins. The extent of the fatigue zone indicates that almost the entire section of the bolt withstood the fatigue progression until, finally, the minimal remaining section ruptured under the static load. The sizes of these distinct zones allowed to identify this bolt as the first to break.
- The next bolt to fail was number 2 due to a unilateral flex fatigue process with several origins, indicating an elevated and highly concentrated stress level in the fracture zone. In this instance, the surface area of the bolt that withstood the fatigue was smaller than that observed on bolt 3, leading to a semi-fragile tearing that ended with the rapid breakage of the remaining section of the bolt. The reduced fatigue surface, together with the extensive ovalisation in this bolt's housing, confirms an uneven stress distribution after the loss of bolt 3, which accelerated the rupture of bolt 2.
- Finally, the failure of bolt number 1 was caused by a pure traction mechanism when the loads on the only remaining bolt increased, following the loss of the other two bolts (2 and 3).

The analysis of the fracture surfaces confirmed the presence of elevated stresses in the fracture zone, which was precisely where the hub and the inner rim come into contact.

2.2. Cause of the bolt fatigue

The evidence obtained during the investigation (perimeter cracks indicative of concentrated stress on the bolts, vibration marks on the surfaces of the hub and wheel rims, thread marks in the through-holes in the wheel rims and the displacement of the self-locking nuts with respect to their original position) has confirmed that the main gear wheels on the PS28 aircraft experienced relative movement between the rims and the hub.

In other words, the threaded joint that holds the hub and the two rim halves together was deteriorating, losing its tightening torque and compromising the overall integrity of the assembly.

This generated tensile loads, which were further compounded by bending loads when the wheel was in operation. The combination of these stresses, which the wheel is not designed to withstand, resulted in material fatigue.

To understand why the threaded joint had begun to deteriorate, it is necessary to have to look at its design and maintenance:

- In terms of design, it is a "hybrid" joint which, on the hub side where the bolt head sits, functions as a threaded bolt, but on the rim side, where the washer and nut sit, functions as a through-bolt.
- With regard to maintenance: to join the parts together correctly, technicians must both use the bolt-washer-nut assembly and fit the hub into the rims; the bolt is never unscrewed from the hub. However, there are no specific and clear instructions for the process to ensure that the joint is solid.

Based on the above, it is concluded that the origin of the threaded joint's loss of torque and the consequent bolt fatigue can be attributed to the following three factors:

- The reuse of the self-locking nuts, which lost their self-locking capability. This loss of friction between the threads on the nut and those on the bolt caused the nut to work its way loose whenever the assembly was subjected to the vibrations of the undercarriage.
- The displacement of the bolt when tightening the nut.
- The incomplete or non-symmetrical fitting of the hub inside the rim halves. During the assembly process, a rubber mallet and the bolts themselves are used as guides to centre the two parts longitudinally. If this fit were incomplete or misaligned at any point, there would be a shorter length of bolt remaining after it had passed through the rims, and the assembly would be operating under differing torque conditions than those envisaged. Although this factor is considered less likely than those previously mentioned, it has been included as a mode of joint failure.

All these factors, either in combination or individually, would result in a loss of torque and the failure of the threaded joint to hold together, generating relative movements between the different parts of the assembly and unforeseen loads (bending and tensile) on the bolt.

2.3. Contribution of maintenance procedures

All the factors identified as potentially responsible for the threaded joint's loss of tightening torque are directly related to maintenance. Maintenance interventions on the hub-rim threaded joint only take place during a tyre change, for which the following procedures in the manufacturer's Maintenance Manual are used: 8.5.1 (Tire Change) and, indirectly, 8.3.3 (Removal of Main Landing Gear Wheel).

The content of these procedures is related to the factors responsible for the bolt fatigue:

- With regard to the reduced self-locking capability of the nuts, the procedure does not prohibit the reuse of the self-locking nuts because it doesn't even mention them. However, Chapter 15 of the Maintenance Manual does not support the conclusion that the bolts may not be reused, either directly or intuitively. In the specific case of the EC-NKP aircraft, the nuts had

been reused three times. The need to discard these nuts during every maintenance intervention should be clearly specified, just as it is for the nuts used in other landing gear parts, although best practice in aeronautical maintenance advises against the reuse of self-locking nuts. Furthermore, the tightening torque for this nut is not specified in the procedure.

- In relation to the displacement of the bolt during the nut tightening processes, the procedure omits the instruction to fit the hub into the rims. Therefore, no specific instruction is included with regard to ensuring the head of the bolt is correctly seated on the hub and the appropriate tightening torque to be applied to the bolt.
- The procedure also fails to provide any instructions for fitting the hub into the wheel rims, and, as with the previous points, there are no guidelines to ensure the parts are correctly joined together.

In addition to the aforementioned absence of instructions on how to fit the hub and rims together, a documentary and practical review of the procedures identified several minor errors or inconsistencies, as described in section 1.16.4. Accordingly, three recommendations are issuing to Czech Aircraft Group, which focus on modifying and disseminating the maintenance instructions.

2.4. Sequence of breakages after the bolts fractured

Following the sequence of fractures described in section 2.1, when bolt number 3 fractured completely, the hub remained anchored to the rims by bolts 2 and 1 only. This allowed some relative circular movement around the wheel axis between the hub and the inner rim surfaces, evidenced by circular, linear friction marks. Similarly, the extensive ovalisation seen in through-hole 2 is associated with the secondary damage inflicted during the later stages of the failure process.

Lastly, when bolt 2 fractured completely, only bolt 1 remained to keep the hub attached to the rims. The damage identified on the inner surface of the inner rim is thought to have occurred in this last stage when the hub separated from the rim and knocked against it until the wheel completely detached with the fracture of the last remaining bolt.

Once all the bolts had fractured at the start of the take-off run, the wheel rolled off without further damage. As a result, the right gear leg was resting on the brake disc, which is consistent with the crew's feeling that the right wing was "falling". The damage to the brake disc confirms that the aircraft only continued to move forward for a relatively short time and distance because the loss of material was minor compared to other events where the drag has been sustained over time[12]. This evidence is consistent with the crew's description of the course of the accident.

In conclusion:

- The damage identified on the hub and inner rim is consistent with the bolt breakage sequence.
- The damage to the aircraft occurred as a consequence of the event.
- The damage is consistent with the crew's description.

[12] CIAIAC Technical Report A-022/2021.

2.5. Time references for the bolt fractures

The bolt breakage sequence (3-2-1) and the fact that bolt fragments 1 and 3 were recovered along the aircraft's taxi trajectory confirm that the complete fracture of the three bolts during the accident flight, ruling out the possibility that the aircraft had made previous flights having already lost one or more of the three bolts.

Thus, the rupture of bolt 3 occurred at the start of the taxi. The wheel, now operating with two bolts, held up throughout the entire taxi, helped by its low rotational speed, until the start of the take-off run. Once on the runway, the increase in speed after applying power accelerated the rupture process of the other two bolts, resulting in the complete separation of the wheel.

Although the threaded joint working with one less bolt would generate vibrations, those vibrations would be continuous and not disappear. Therefore, it is ruled out the possibility that the wheel produced the momentary vibration noticed by the crew before reaching the holding point.

3. CONCLUSION

3.1. Findings

With regard to the event:

- The right wheel of the EC-NKP aircraft detached during the take-off run.
- The detachment occurred because the three bolts (p/n MSC.31-18X1.25SHCS) that attach the hub to the rims fractured.
- The weather conditions, characteristics of the operation, taxi before the event and the experience and condition of the crew did not influence the incident.
- All the damage is consistent with and occurred as a consequence of the event.

With regard to the fracture of the bolts:

- The bolt-nut-washer assemblies were reused on three occasions.
- The event began with the rupture of two of the three bolts due to a unilateral flex fatigue mechanism. The third ruptured due to the tensile stress it was subjected to following the fracture of the previous two.
- A high degree of stress was concentrated in the zone where the hub meets the inner rim.
- The threaded hub-rim joint displayed marks characteristic of relative movement between its parts and incorrectly configured nuts, both on the EC-NKP aircraft and the other aircraft inspected.
- Maintenance interventions on the threaded hub-rim joint are only required during a tyre change (procedure 8.5.1 Tire Change).
- The right wheel of the EC-NKP aircraft had had three tyre changes prior to the event.
- All three bolts ruptured during the accident flight.

With regard to the Maintenance Manual:

- The Maintenance Manual (procedure 8.5.1 Tire Change) did not include instructions for the assembly and disassembly of the threaded joint between the wheel hub and inner and outer wheel rims.
- The Maintenance Manual (procedure 8.5.1 Tire Change) did not specifically prohibit the reuse the self-locking nuts or specify the tightening torque to be applied to the threaded joint.

3.2. Causes/contributing factors

The accident suffered by the EC-NKP aircraft was caused by the deterioration, due to loss of torque, of the threaded joint between the wheel hub and inner and outer wheel rims after three tyre change operations (procedure 8.5.1 Tire Change in the Maintenance Manual). The degradation of the assembly generated fatigue in two of the three bolts, which eventually fractured, causing the right main landing gear wheel to detach.

A failure to explicitly state that the self-locking nuts can not be reused in the maintenance instructions for the assembly and disassembly of this threaded joint provided in procedure 8.5.1 Tire Change of the Maintenance Manual is considered to be a contributing factor.

4. RECOMMENDATIONS

The investigation has determined that the insufficient instructions provided in procedures 8.5.1 and 8.3.3 of the Czech Aircraft Group manufacturer's Maintenance Manual caused the threaded hub-rim joint to deteriorate and eventually fail due to bolt fatigue. The issue has been detected in the EC-NKP aircraft and other aircraft from both the same operator and a different operator, suggesting that the problem affects all PS28 Cruiser models.

In order to ensure these procedures include the instructions necessary to maintain the threaded joint in its original condition with the correct torque, the following recommendations are issued to the manufacturer.

REC25/22. It is recommended that the manufacturer, Czech Aircraft Group, modify procedure CR-MM 8.5.1 Tire Change and figure 8-16 in the Maintenance Manual for the PS28 Cruiser aircraft in line with the observations detailed in section 1.16.4 of this report to ensure that the three factors responsible for the loss of tightening torque in the threaded hub-rim joint are eliminated:

1. Specify in the procedure that self-locking nuts and washers may not be reused.
2. Specify the actions necessary to ensure the bolt head sits correctly on the hub when tightening the nuts to prevent bolt displacement.
3. Specify the actions necessary to install the hub into the wheel rims correctly, ensuring that it is aligned and fits perfectly to avoid separations in the joint.

REC26/22. It is recommended that Czech Aircraft Group, as the manufacturer, modify procedure CR-MM 8.3.3 Removal of Main Landing Gear Wheel and figure 8-7 in the Maintenance Manual of the PS28 Cruiser aircraft, considering the observations included in section 1.16.4 of this report.

The deterioration of the threaded hub-rim joint due to any or all of the three factors described in the analysis (nut, bolt or coupling) can be easily detected by visually checking the number of threads showing past the self-locking nut. Pending the implementation of the above recommendations and intending to ensure users of PS28 Cruiser aircraft are aware and able to detect this type of threaded joint failure, the following safety recommendation is issued to the manufacturer.

REC27/22. It is recommended that Czech Aircraft Group, as the manufacturer of the PS28 Cruiser aircraft, disseminate information to users, by whatever means it deems appropriate, on the following:

1. Detecting any anomalies in the condition of the threaded hub-rim joint by checking the position of the self-locking nut (p/n MSC.31-18NYLOCK) with respect to the bolt (p/n MSC.31-18X1.25SHCS), taking into account that, if correctly installed, there should be at least 2 threads showing past the nut.
2. The prohibition on reusing the self-locking nuts (p/n MSC.31-18NYLOCK) in the MATCO MHE51CZ main wheel and brake assembly.

Safety measures already adopted

The operator, Flyschool, having been informed of the findings during the course of the investigation, immediately took measures to detect and prevent the failure of the threaded hub-rim joint:

- It incorporated the obligation to replace the installed nuts and washers with new ones at every tyre change in Maintenance Manual procedure 8.5.1 Tire change.
- It issued an operational safety communication (CSO 2022-01, dated 20/02/2022, called "Visual inspection PS28") to all crews specifying that before each flight, they should check that the main gear wheel bolts show 2 threads past the nut.

The additional operator consulted also took identical measures in regard to checking the condition of the threaded joint by counting the number of free threads showing past the nut.

ANNEX

COMMENTS FROM CZECH AIRCRAFT GRUP (CAG)

Review and comments of accident final report A-003-2022

Dear

thank you for the opportunity to comment draft of the accident final report A-003-2022 involving PS - 28, registration EC-NKP, SN C0661.

First of all, please be aware that continued airworthiness support was transferred from Czech Sport Aircraft to Czech Aircraft Group as per the NOT-CR-011.
(https://cruiseraircraft.cz/wp-content/uploads/2020/12/NOT-CR-011.pdf)

In general:
The Czech Aircraft Group (CAG) in not convinced that the insufficient instructions provided in procedures 8.5.1 and 8.3.3 of the CR-MM-1-0-00 PS-28 Maintenance Manual is direct cause of deterioration of the nut and bolt fatigue.
The CAG company has not registered a question or complaint about this chapter of the MM from Flyschool Air Academy, the maintenance center at Casarrubios del Monte (Toledo), or any other customers nor question or complaint about zero shown threat above the nut.

Chapter 1.1
Assumes , that brakes were checked with satisfactory results. According to provided measurement in the document title: Medidas de espesor.pdf the disk was worn below limit 4,25mm in most of measured points.

1	2	3	A	B	C	D	E
4,14	4,18	4,22	4,78	4,17	4,40	5,42	5,43

Notwithstanding that condition of brake disk is not the direct cause of the incident, if chapter 1.1 is dealing with brake system, it would be appropriate to provide all information obtained.

Chapter 1.6.3
Specifies the **correct** tightening torque was used by the Flyschool technicians. Nerveless the chapter 1.16.4 of A-003-2022 defines that the value of correct torque is not specified in Maintenance Manual.

Chapter 1.6.5
Summarizes that aircraft right tire got changed 3 times and still same Bolts, Nuts and Washers were used. That is directly in contradiction with chapter 15 of the MM. Chapter 15 specifies that all repairs to the aircraft must be carried out in accordance with FAA Advisory Circular AC 43.13-1B therefore all self-locking nuts have to be used only once.

Chapter 1.16.2

The description in Figure 8 indicates that the EC-NKP has 0 threats shown above the nut. In spite of this claim Figure 4 shows the same bolts in perpendicular view and the 1 thread above a nut is clearly visible.

Nonetheless, the difference in shown threads is not causing the bolt's fatigue, but by the design change made by the wheel manufacturer the Matco company. CAG questioned a manufacturer Matco company and it was confirmed that in March 2019 the hub was redesigned. The countersink on the hub was increased by 0.060 in. **The only difference on the MHE51CZ is the extra threads past the end of the nut**. Therefore, the concept of checking one or two shown threads above is false.

2018

2021

Chapter 1.16.4
The CAG company has not registered a question or complaint about this chapter of the MM from Flyschool Air Academy, the maintenance center at Casarrubios del Monte (Toledo), or any other customers nor question or complaint about zero shown threat above the nut.
However, the section of CR-MM-1-0-00 PS-28 Maintenance Manual has space for improvement and it will be updated.

Chapter 2.1
Deals with the sequence of bolt failure. Sequence based on beach marks is a logical way. On the other hand, sequences #3 - #2 - #1 do not correspond with large elongation only in hole #2 in the disk (rim). Large elongation only in hole #2 suggests that the last holding bolt was #2. Moreover, the report miss the information witch bolt fragment was found in point 8 of Figure 1 and which bolt fragment was found in point 6 of Figure 1.

Chapter 2.2
As described in the comment for chapter 1.16.2 the amount of shown threads is caused by the design change of the manufacture Matco company made in 03/2019.

There is specified that bolts were further compounded by bending loads. According to the provided technical drawings, there is a flange contact between the hub and outer wheel disc preventing this possible bend loading of the bolts, even in case of loosen nuts.

In chapter 2.2, pg. 19 states, that thread joint between bolt and hub is “solid”. The joint is not solid therefore the common practice to secure bolts against rotation during nut lossing. Also, it is common sense if zero threat is shown above a nut, the mechanic closely observes the joint, and if the bolt's head is tightened all the way down to the bottom of the pocket hole in the hub.

Has been received MATCO manufacturer's statement on the matter of EC-NKP, SN C0661 incident?