FINAL REPORT

ACCIDENT 2021/1048

State Commission on Aircraft Accidents Investigation (PKBWL)

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FINAL REPORT

on investigation of an accident of an aircraft with MTOW below 2250 kg

ACCIDENT

OCCURRENCE NO – 2021/1048

AIRCRAFT – Gyrocopter TERCEL, SP-XERO

DATE AND PLACE OF OCCURRENCE – 9 May 2021, Toruń

The Report is a document presenting the position of the State Commission on Aircraft Accidents Investigation concerning circumstances of the air occurrence, its causes and safety recommendations. The Report was drawn up on the basis of information available on the date of its completion.

The investigation may be reopened if new information becomes available or new investigation techniques are applied, which may affect the wording related to the causes, circumstances and safety recommendations contained in the Report.

Investigation into air the occurrence was carried out in accordance with the applicable international, European Union and domestic legal provisions for prevention purposes only. The investigation was carried out without application of the legal evidential procedure, applicable for proceedings of other authorities required to take action in connection with an air occurrence.

The Commission does not apportion blame or liability.

In accordance with Article 5 paragraph 6 of the Regulation (EU) No 996/2010 of the European Parliament and of the Council on the investigation and prevention of accidents and incidents in civil aviation […] and Article 134 of the Act – Aviation Law, the wording used in this Report may not be considered as an indication of the guilty or responsible for the occurrence. For the above reasons, any use of this Report for any purpose other than air accidents and incidents prevention can lead to wrong conclusions and interpretations.

This Report was drawn up in the Polish language. Other language versions may be drawn up for information purposes only.

WARSAW 2023

Occurrence reference number:	**2021/1048**			
Type of occurrence:	ACCIDENT			
Date of occurrence:	9 May 2021			
Place of occurrence:	Toruń			
Type and model of aircraft:	Gyrocopter TERCEL			
Aircraft registration marks:	SP-XERO			
Aircraft user/operator:	natural person			
Aircraft commander:	Professional ultralight gyrocopter pilot, UAGP			
Number of victims / injuries:	Fatal	Serious	Minor	None
	-	-	-	1
Domestic and international authorities informed about the occurrence:	Polish Civil Aviation Authority, Air Accidents Investigation Institute of the Czech Republic, EASA			
Investigator-in-Charge:	Krzysztof Błasiak			
Investigating Authority:	State Commission on Aircraft Accidents Investigation (PKBWL)			
Accredited Representatives and their advisers:	Not appointed			
Investigation team:	Not appointed			
Document containing results:	Final Report			
Safety recommendations:	Yes			
Addressees of the recommendations:	Propeller manufacturer - Kašpar a synové - strojírna Kalmar s.r.o			
Date of completion of the Investigation:	5.03.2023			

1. Type of occurrence

Accident.

2. Investigation conducted by

State Commission on Aircraft Accidents Investigation (PKBWL).

3. Date and time of the occurrence

9 May 2021, around 09:15 hrs UTC.

4. Take-off and planned landing location

Pomeranian Aeroclub's aerodrome in Toruń – EPTO.

Tab. 1. EPTO Aerodrome basic information [source: https://lotniska.dlapilota.pl/torun]

ICAO code	EPTO
Status	Aerodrome
Coordinates	N53°01'44.5" E18°32'48.8"
Radio frequency	Toruń-Radio 120.660
Elevation	164 ft
RWY	1) 105/285 (10/28), 1269 x 57 m (concrete), 2) 014/194 (01/19), 970 x 57 m (concrete), 3) 105/285 (13/31), 1091 x 152 m (grass),
Comments	Pomeranian Aeroclub's aerodrome. On 10/28 RWY the Calvert Cross Lighting System is available in direction 28.

5. Place of occurrence

Forest area near the railway line connecting Toruń and Unisław.

6. Operation type

Recreational flight.

7. Flight phase

En-route.

8. Flight conditions

Daylight, VFR.

9. Meteorological information

VMC - the weather had no effect on the course of the occurrence.

10. Aircraft user/operator

Natural Person.

11. Personnel information (crew data)

Pilot:

- male, aged 64, holder of the:
- UAGP (ultralight gyrocopter, mass bellow 560 kg), issued on 18 January, 2018, with ratings for ultralight gyrocopters – UAG(L), (valid until 18 January, 2023);
- valid aero-medical certificate.

12. Injuries to persons

The pilot involved in the accident was not injured.

13. Damage to aircraft

The accident aircraft was significantly damaged. The three-blade rear propeller was damaged, and one of the blades were found detached from it. The main rotor along with the blades and rotor mast were damaged. As a result of an emergency landing, the landing gear, empennage and elements of the cabin skin were damaged.

Fig. 1. Gyrocopter after the emergency landing [source: PKBWL][1]

[1] Unless otherwise stated, source: PKBWL.

Fig. 2. Gyrocopter after emergency landing

Fig. 3. Damaged propeller hub of the gyrocopter

14. Course and analysis of occurrence

14.1. History of the flight

On May 9, 2021, the pilot (and owner) of the TERCEL gyrocopter arrived at EPTO – Pomeranian Aeroclub's aerodrome to perform a recreational flight. The pilot performed a preflight check in accordance to the Flight Manual. No technical irregularities were found at that time.

At about 9:53 hrs UTC the pilot took off and then made a flight in the EPTO zone at an altitude of about 2400 ft. During the return flight to EPTO, when the gyrocopter was above a dense, high forest, the pilot noticed vibrations of the fuselage. According to the pilot's assessment, the vibrations gradually increased, therefore, he reduced the engine speed to the minimum in order to relieve the gyrocopter structure. At the same time, he began descending to 1400 ft , and chose the shortest way to the aerodrome. The pilot informed the Aerodrome service by radio about the emergency and asked for priority to land with any course, and immediately received clearance to land and was informed about the current wind direction. After reaching the altitude of 1400 ft , the pilot increased the engine speed to a value that guaranteed a level flight. After another 30 seconds, there was a sudden shock and a very strong increase in vibration of the entire gyrocopter. The pilot immediately shut down the engine and the vibrations stopped. Then the pilot turned off the main electric power switch, closed the main fuel valve and informed the aerodrome about the emergency landing in the forest.

The gyrocopter with the engine turned off abruptly lost speed, so the pilot performed a dive to gain speed and chose to land near the railway line crossing the forest. According to the pilot, it was the only place in this area that allowed for an emergency landing. Despite the limited manoeuvrability of the diving gyrocopter, the pilot managed to fly over the treetops. Before the touchdown, the tips of the main rotor blades collided with tree trunks and the power line located in the area of the landing site. Then, the gyrocopter touched down on the main landing gear on the north-west side of the railway track. During the touchdown, the left wheel of the main landing gear hit the granite post. As a result the landing gear was torn out and the fuselage turned to the left and the gyrocopter overturned to the right side. The rotating rotor hit the ground, causing blades, mast and rear tail destruction.

After the occurrence, the pilot left the wreckage unaided through the right door, without injuries, and then informed (via phone) the Pomeranian Aero Club, emergency services and PKBWL about the accident. The ambulance service arrived at the site and examined the pilot, and the fire brigade extinguished a forest litter fire, initiated by the broken power line.

14.2. Findings

During the investigation the State Commission for Aircraft Accidents Investigation determined that the accident gyrocopter had been maintained and operated properly from the very beginning of its operation. During the investigated accident, strong vibrations of the structure occurred, which were caused by inflight separation of one of

the three blades of the pushing propeller. Therefore, SCAAI paid special attention to the design of the Kašpar propeller installed in TERCEL gyrocopters.

The table below shows occurrences that involved inflight damage to this type of propellers.

Table 2. Occurrences that involved damaged Kašpar propellers.

Date of occcurrence	Occurrence numer	Propeller type	Occurrence description
August, 2015	Not applicable	Kašpar Ka-2/3-LT	During a flight, small vibrations began to build up. The pilot decided to return to the aerodrome. After landing, one of the propeller blades was found to be deflected by about 1.5 cm in a plane perpendicular to the propeller rotation axis. While disassembling the propeller at the company's premises, the mechanic noticed a circumferential fracture of the threaded sleeve of the propeller blade in the area of the first thread when viewed from the tip of the blade. The intact part of the sleeve circumference was about 2 cm.
7 June, 2020	2020/1368	Kašpar Ka-4 (dual blade)	The Tecnam P92 ECHO plane took off from the Elbląg aerodrome (EPEL). At an altitude of about 2,200 ft, the pilot felt a strong jerk of the aircraft, heard a rumble and the engine stopped. The pilot made an emergency off-field landing. During an investigation, it was found that one of the propeller blades broke off inflight because itsts mounting broke in the area of the thread securing the blade to the hub.
9 May, 2021	2021/1048	Kašpar Ka–2/3–LT	Accident described in this report.

Due to the above occurrences, the PKBWL commissioned a detailed expertise of the Kašpar propeller which failed during the accident of the TERCEL gyrocopter. The expertise was carried out by researchers from the Warsaw University of Technology.

The scope of tests and research included:

1) Cleaning and visual inspection, along with photographic documentation and a description of the external condition of the blade prior to invasive testing, assessment and description of external damage;
2) Disassembly of the remaining part of the torn off propeller blade from the hub and technical expertise of this fragment, including determination of the nature of the breakthrough;
3) Disassembly of one of the remaining blades from the propeller hub and its technical expertise, including visual assessment of the blade fragment mounted

in the hub, establishing the condition of the internal structure of this part by non-destructive testing (looking for cracks, discontinuities, signs of material fatigue).

The following activities were performed:

1) Visual examinations captured in photos;
2) Examination with a stereoscopic microscope, recorded in photos;
3) Non-destructive testing by colour penetration method;
4) Searching for cracks with an ultrasonic flaw detector and X-rays;
5) Hardness measurement with a Viskers micro hardness tester;
6) Metallographic examination;
7) Research on the basic mechanical properties of the material on a micro-sample.

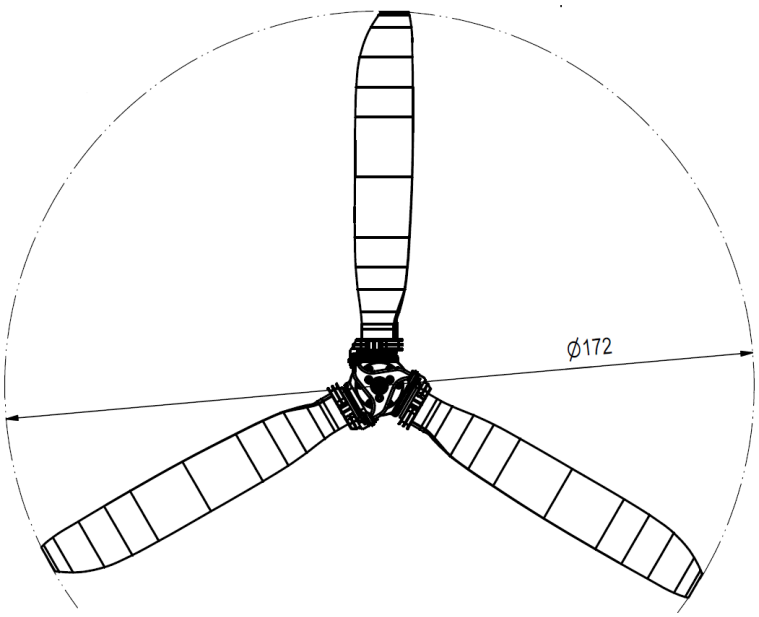

Fig. 4. Kašpar propeller KA – 2/3-LT [source: Kašpar a synové - strojírna Kalmar s.r.o.]

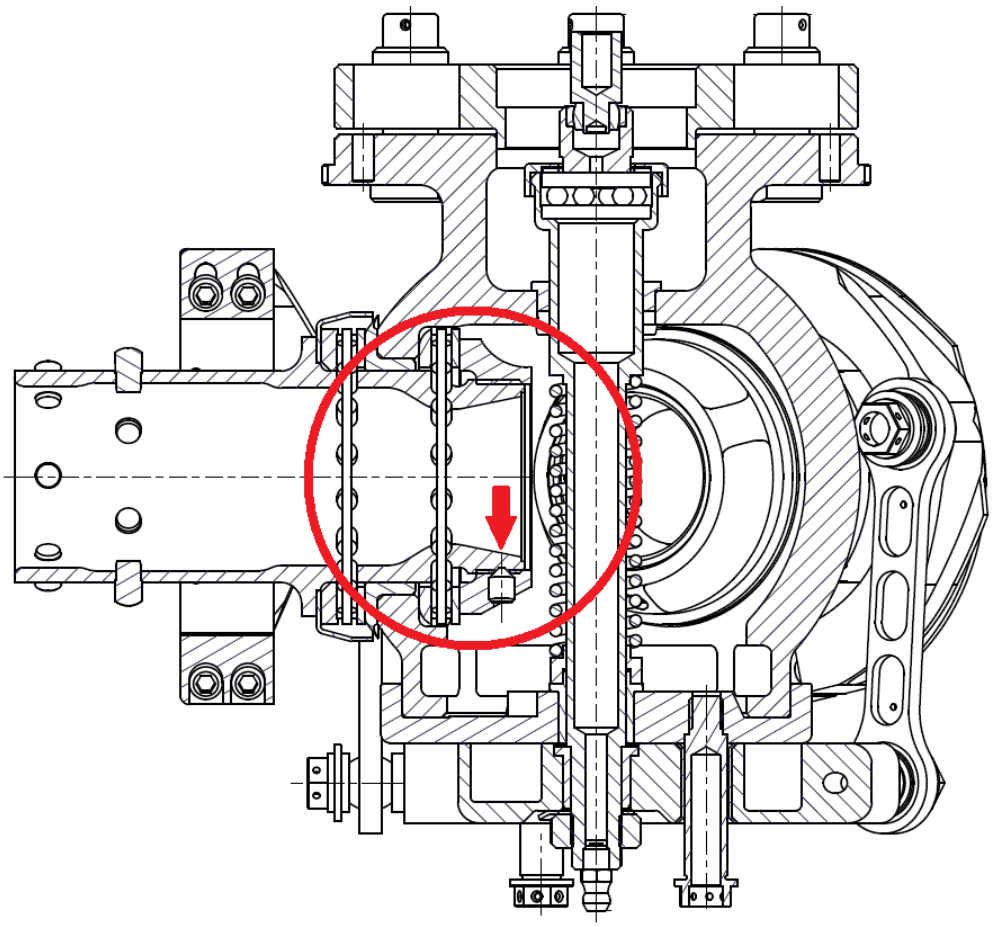

Fig. 5. Kašpar propeller KA – 2/3-LT hub – cross-section through the blade mounting. The circular marking indicates the element that was damaged, the arrow marks the location of the grubscrew. [source: Kašpar a synové - strojírna Kalmar s.r.o.]

Fig. 6. Propeller condition as delivered.

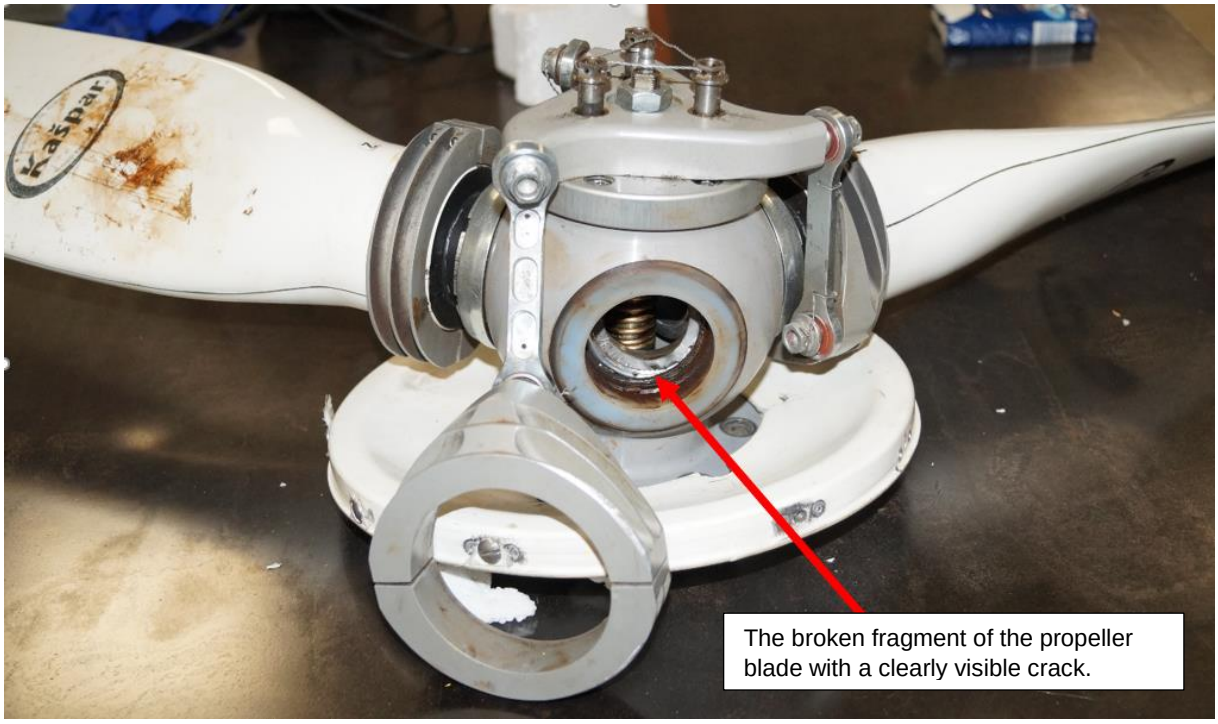

Fig 7. Propeller hub mechanism prior to disassembly.

During tests, it was found that the propeller blade broke off inflight as a result of a crack in its mounting part in the area of the thread securing the blade to the propeller hub. Based on visual tests, it was found that the intact mounting element of the damaged blade had fatigue cracks. Analysis of the deformation shape of the damaged blade fragment showed a characteristic fracture area with a clear narrowing indicating large plastic deformations and the surfaces of the fatigue crack. A very characteristic part of the crack is a spherical chipping and bending of the thread. It can be assumed with high probability that the fracture was initiated on the opposite side of the chipping, but the focus is not clearly visible.

Fig. 8. Damaged propeller blade fragment [source: Warsaw University of Technology]

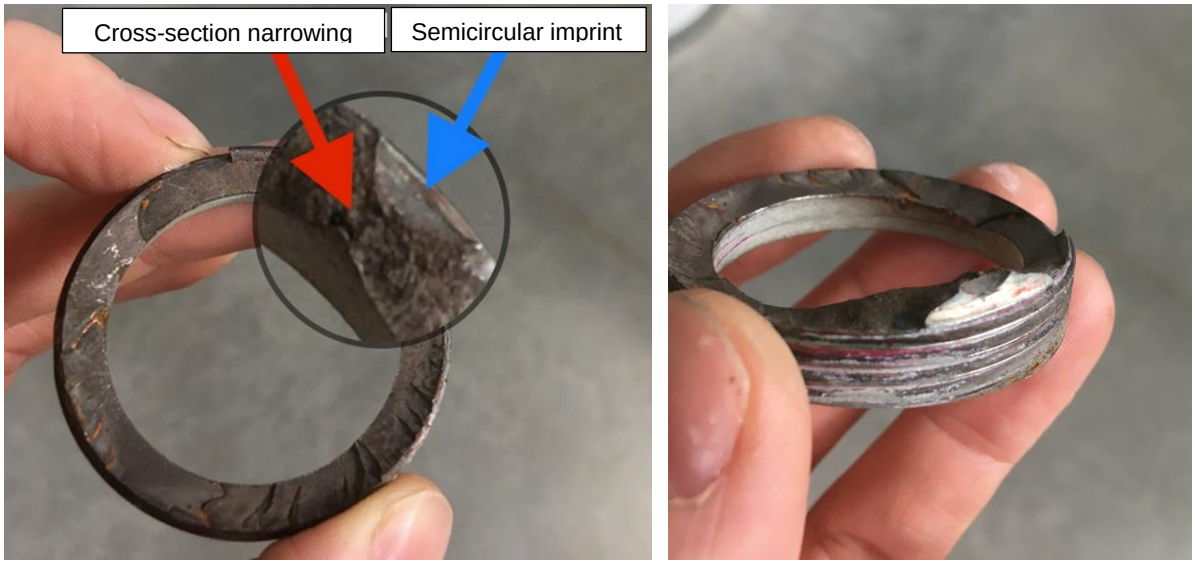

Fig. 9. The place of the breakage with a characteristic semicircular imprint and narrowing area [source: Warsaw University of Technology]

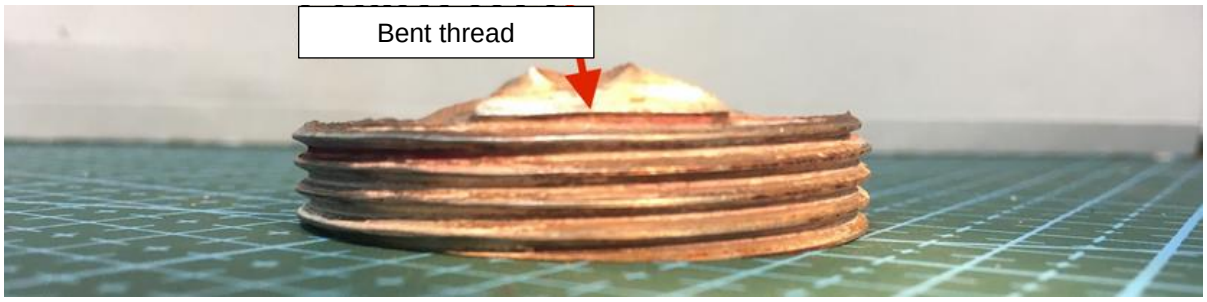

Fig. 10. The place of the breakage with a characteristic bend of the thread [source: Warsaw University of Technology]

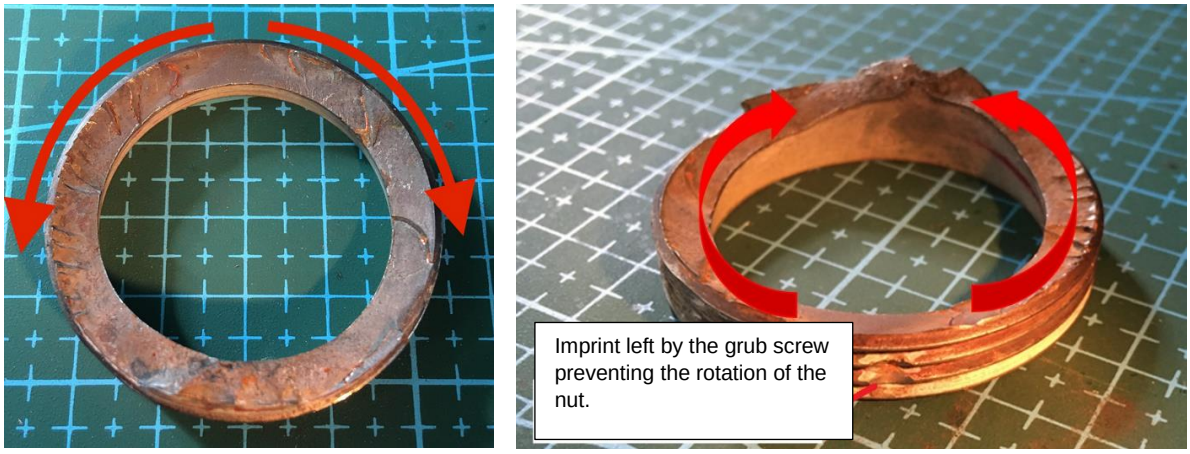

Fig. 11. Direction of crack propagation [source: Warsaw University of Technology]

Based on the examination with a stereoscopic microscope, it was found that the fatigue breakthrough occurred in the threaded area of the propeller blade mounting, close to the end of that area.

Penetrant tests were carried out on two undamaged propeller blades and on the remaining element of the third, broken blade. Spotcheck SKL-SP1 penetrating agent was used for the test.. No irregularities were found on the undamaged blades, while open circumferential cracks appeared on the damaged element. They were present under the fracture surface. A characteristic place was the area of the grub screw.

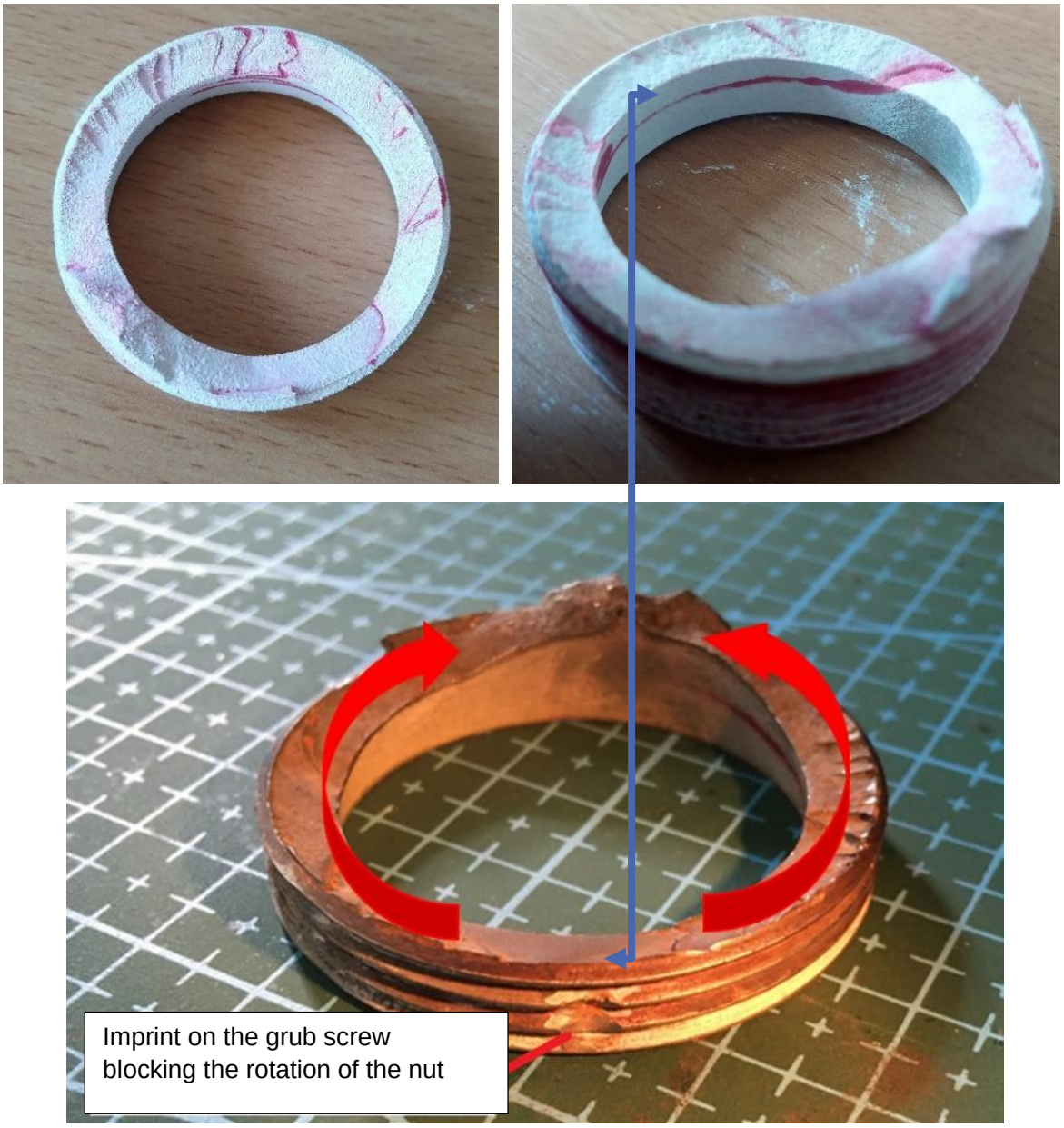

Fig. 12. The results of the colour penetration method test – damaged element – clearly visible subsurface crack [source: Warsaw University of Technology]

Examination of undamaged blades with an ultrasonic flaw detector showed no cracks. X-rays were made on a blade trimmed to fit it in the chamber of the testing device. Recess places for grub screws were examined. Those places showed no signs of breakage.

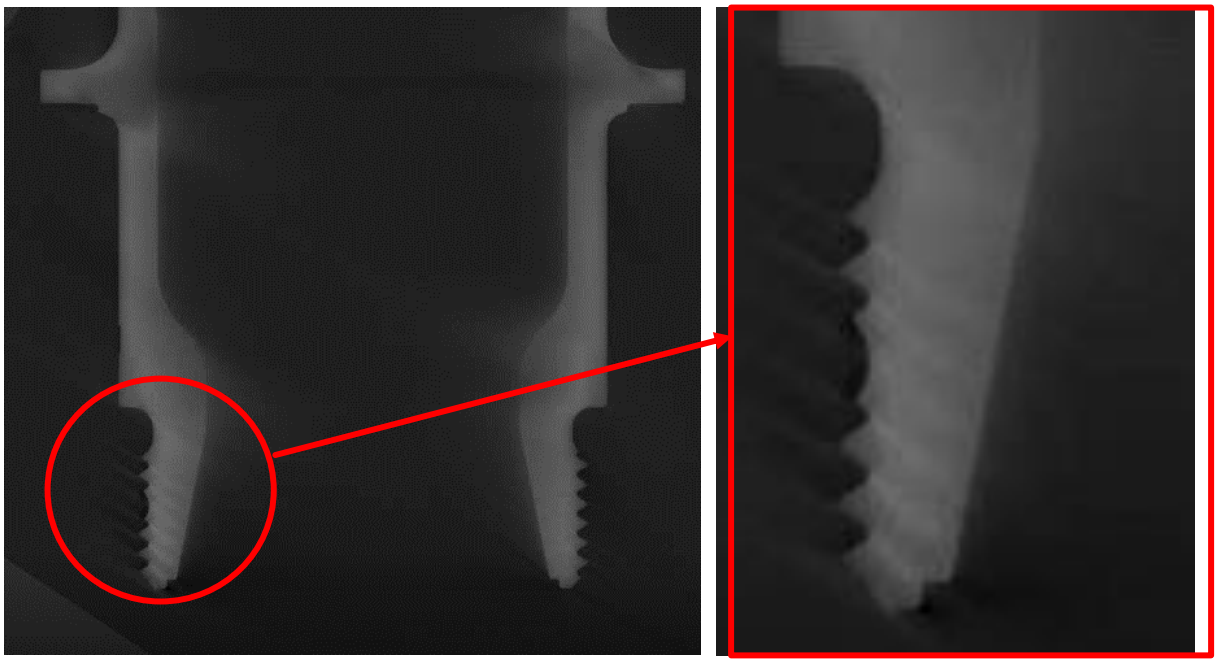

Fig. 13. Place of imprint from the grub screw in an undamaged blade - no visible breakage [source: Warsaw University of Technology]

The mounting of the damaged propeller blade was thoroughly examined. The characteristic cross-sections with visible microcracks are shown below.

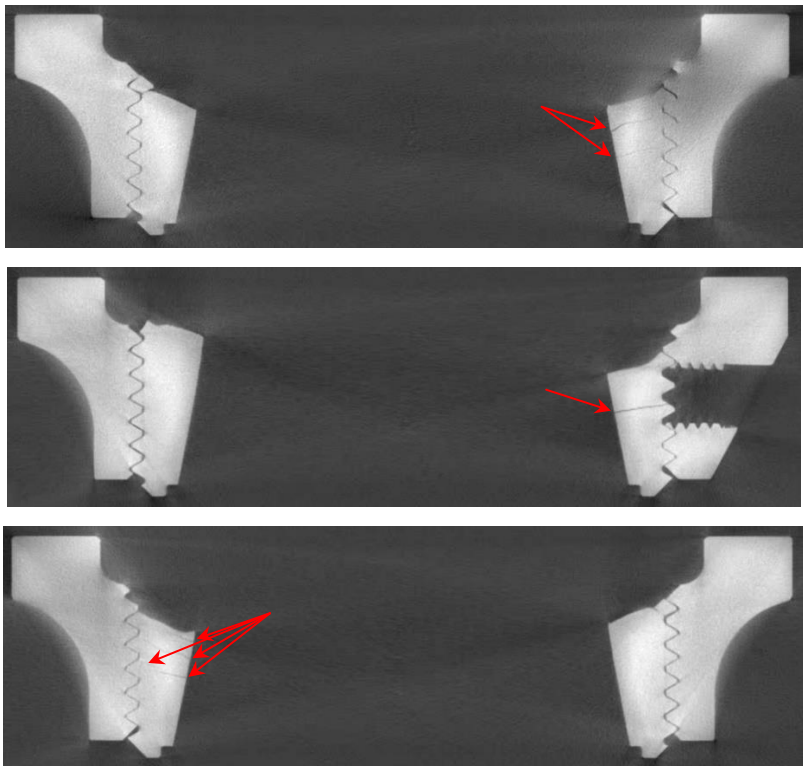

Fig. 14. Cross-sections of the blade element with visible microcracks marked with red arrows [source: Warsaw University of Technology]

The breakage area with a characteristic spherical chipping is shown on the figure bellow.

Fig. 15. Spherical breakage area [source: Warsaw University of Technology]

The place of the breakage origination was probably located on the imprint from the grub screw (Fig. 16).

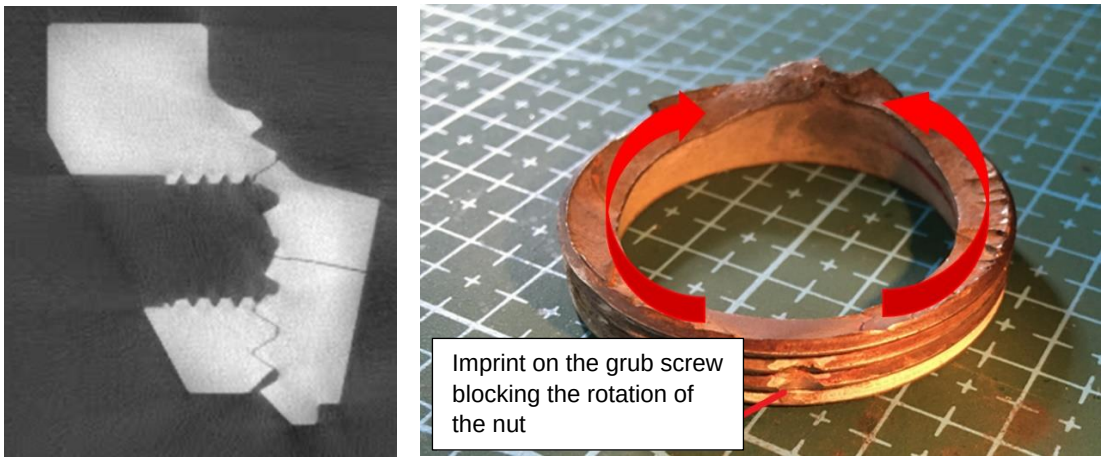

Fig. 16. The probable place of the fatigue breakage origination [source: Warsaw University of Technology]

The hardness measurement was carried out in accordance with the PN-EN ISO 6507-1 standard on the cut-off ring of the sample taken from the mounting material of the damaged propeller blade. The measurement was performed using the micro-Vickers method, using a TESTLAB MHVD-1000IS machine. On the basis of the hardness

measurement, the value of immediate strength was estimated, determined from the tables included in the PN-93 / H-04357 standard. Destruction strength was Rm ≈ 915MPa.

Several tests were made to analyse the chemical composition of the damaged propeller blade mounting. A high content of zinc in the outer layer and a small amount of zinc in the deep layers suggested that the tested element was galvanized from the outside.

Basic mechanical tests of the material, i.e. immediate strength, yield point and Young's modulus, were carried out on the basis of a tensile test of a sample with a circular or rectangular cross-section. Detailed information can be found in the PN-91 / H-04310 or ASTM E 8 standard. However, due to the small dimensions of the tested element of the damaged blade, it was only possible to collect and test a micro-sample in the form of an electro-erosion ring from the existing blade fragment from the thread start side. The cut fragment was stripped of the thread. The test was conducted in two stages. The first one was stretching the ring until it became plastic, in order to estimate the yield strength "Re". The second stage involved stretching the cut micro-sample from the straightened ring to determine the "Rm". strength

After loading the sample on a testing bench, the force was recorded as a function of the displacement of the sample clamps. The value of the yield strength was determined based on maximum stresses determined from theoretical formulas. The “Re” value has been estimated to be around 700MPa.

Due to the risk of breakage in the place of attachment and the difficulty in interpreting the results, in particular determining the impact strength, it was decided that the destruction would be performed on the cut-out micro-sample from the tested ring. Thus, the cross-sectional dimensions of the measuring part were 1.8 mm x 1.8 mm. The loading and testing was performed on a Heckert FP100 testing bench with hydraulic clamps. The maximum force at the formation of the neck was recorded and the micro-sample was broken. Based on the performed activities, the approximate impact strength was calculated and determined at the level of Rm ≈ 846 MPa, which is a value similar to the results recorded in the microhardness test, which was 915 MPa.

Based on the presented tests and research, the following conclusions were drawn:

1. The crack in the mounting of the gyrocopter blade had a fatigue nature;
2. The blade mounting material was structural steel with relatively high impact strength. This material can be sensitive to brittle fracture and can be very sensitive to the notch effect. Precise determination of the material properties, i.e. the critical stress intensity factor and the fatigue properties, would require in-depth research in this area;
3. There is a high probability that the crack initiator could have been the grub screw, which, by crushing a thread fragment, led to a local increase of stresses in the thread bottom, and thus increased the average value of stresses in that area. That phenomenon, combined with the cyclic stresses resulting from the blade operating conditions, could lead to a fatigue crack which developed up to the maximum load capacity of the entire joint;

4. The cross-sections of the separated blade fragment showed a greater number of cracks, indicating that the blade material could be very prone to brittle fracture development;
5. The thrust bearing locknut is not designed properly. The grub screws are located in a highly stressed area;
6. No cracks were found in the mounting parts of the intact blades.

15. Causes of the accident:

The direct cause was detachment of one the three blades of the Kašpar Ka-2/3-LT rear propeller used in the gyrocopter.

Root causes:

- improper material used for the propeller manufacturing – material prone to brittle fracture;
- inadequate design of the propeller blade mounting part – sharply intended mounting thread and a recess for the grub screw of the blade-nut joint.

16. Safety recommendations

2021-1048-1

The Investigation of the accident showed that the material and design solutions applied in the Kašpar Ka-2/3-LT propeller did not ensure its adequate strength and were the cause of the occurrence.

Therefore, PKBWL has proposed the following safety recommendation:

It is recommended that the manufacturer of the Kašpar Ka-2/3-LT propeller considers the necessity of introducing changes in the material and design solutions leading to an increase in the durability of the Kašpar Ka-2/3-LT propeller blades to the necessary level.

Comments on the safety recommendation:

1) On April 21, 2022, PKBWL sent the Draft Final Report containing the above safety recommendation to the Aircraft Accident Investigation Institute of the Czech Republic and to EASA, inviting their comments.
2) On June 6, 2022, the Aircraft Accident Investigation Institute of the Czech Republic sent to PKBWL a document titled: "Significant comments to be attached to the SCAAI Final Report on the accident of the gyrocopter TERCEL, SP-XERO Event No. - 2021/1048", which was developed by the propeller manufacturer and was questioning the need to implement the safety recommendation - see Appendix 1. - see: Appendix 1.
3) On June 21, 2022, EASA notified PKBWL, that they have no comments to the Draft Final Report.
4) As the next step, PKBWL analyzed the propeller manufacturer response and confirmed the previous position to implement the recommendation, and following this, on November 8, 2022 sent to EASA "Significant comments to be attached to the SCAAI Final Report on the accident of the gyrocopter TERCEL, SP-XERO

Event No. - 2021/1048" and SCAAI's comments on the above comments with a request to take a position on the matter - see: Appendix 2.

5) EASA confirmed the receipt of the documents, however, within 90 days of sending the documents listed in item 4, PKBWL did not receive a new response, which PKBWL considered as confirmation of the EASA position of June 21, 2022, i.e. acceptance of the PKBWL Draft Final Report together with the recommendation.

17. System changes proposals

None.

18. Other comments

The pilot's experience and his flying skill allowed him to avoid serious injuries.

19. Annexes

Appendix 1. The significant comments to the Draft Final Report.

Appendix 2. PKBWL Comments to Czech comments.

THE END

Investigator-in-Charge

Signature on original