AIR ACCIDENTS INVESTIGATION
INSTITUTE
Beranových 130
199 01 PRAHA 99

Ref. No. CZ-22-0885

FINAL REPORT

Investigation on the accident to Hawker Hurricane Mk IV, registration OO-HUR 1 km SW LKCB on 14 August 2022

June 2023

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Contents

Used abbreviations

AAIB UK	Air Accident Investigation Branch United Kingdom
AAII	Air Accidents Investigation Institute
AGL	Above ground level
ARP	Aerodrome reference point
ATPL (A)	Airline Transport Pilot Licence
CAA	Civil aviation authority
CAVOK	Visibility, cloud and present weather better than prescribed values or conditions
Ci	Cirrus
CRE	Class Rating Examiner
CSV	Comma Separated Values file
Cu	Cumulus
CZ/FCL	The Czech Republic/Flight Crew Licensing
CHMI	Czech Hydrometeorological Institute
E	East
EBBT	Brasschaat airport (Belgium)
EDGE	Eisenach-Kindel airport (Germany)
FD	Flying Display (aerial public event “Cheb Airshow 2022)
FE	Flight Examiner
FI(A)	Flight Instructor – aeroplanes
FIE	Flight Instructor Examiner
FL	Flight level
GEO	Geographic or true
GO	Overhaul
GPS	Global positioning system
IR	Instrument Rating
IRE	Instrument Rating Examiner
IRS	Emergency and rescue services
LKCB	Public domestic aerodrome - Cheb
LKKV	Public international aerodrome - Karlovy Vary
LKRO	Public domestic aerodrome - Roudnice
LKTC	Private domestic aerodrome - Točná
LVO	Low visibility operation
KIAS	Knots indicated airspeed
METAR	Aerodrome routine meteorological report
MIFM	Military Institute of Forensic Medicine
N	Nord
NE	North-east
NOSIG	No significant change

NSC	Nil significant cloud
PBN	Performance-based navigation
Q (QNH)	Altimeter sub-scale setting to obtain elevation when on the ground
RWY	Runway
SEP land	Single engine piston land
SI	International system of units
SYNOP	Report of surfaceweather observation from a land station
SW	South-west
TOWING-S/BAN	Towing of sailplane/banner(s)
TRE	Type Rating Examiner
TRI(A)	Type Rating Instruktor - aeroplanes
TWY	Taxiway
ÚCL	Civil Aviation Authority of the Czech Republic
UTC	Coordinated Universal Time
V	Variations from the mean wind direction
V_{LO}	Maximum landing gear operating speed
VRB	Variable
W	West
Z	Coordinated Universal Time (in meteorological messages)

The non-SI units:

°C	Degrees Celsius
ft	Feet (dimensional unit - 0,3048 m)
h	Hour(s)
km	Kilometre(s)
kt	Knot(s) (1,852 $km \cdot h^{-1}$)
kW	Kilowatt
L	Litres
min	Minutes
NM	Nautical miles

A) Introduction

Operator:	Legal entity
Aircraft manufacturer and type:	Hawker Aircraft Ltd; Hawker Hurricane Mk IV
Registration mark:	OO-HUR
Location:	1 km SW of Cheb airport ARP
Date and time:	14 August 2022, 13:32 (all times are UTC)

B) Synopsis

On 14 August 2022, the AAII was notified of an accident of Hawker Hurricane Mk IV (hereinafter the “Hurricane”) during an aerial public event “Cheb Airshow 2022” (hereinafter the “Flying Display”). The pilot was a display pilot in the Flying Display programme. During the performance, after a pass towards RWY 23, he continued an aerobatic manoeuvre by a steep climb in the runway axis with transition to a turn with a great roll during which he started descending. During the descending manoeuvre, he tightened a turn, which resulted in asymmetrical flow separation on the wing. In the critical situation, the pilot attempted a counter-manoeuvre to take the aircraft from the steep turn position, but as the altitude above the ground was too low, the aircraft crashed against the ground. The pilot died. The aircraft was destroyed.

The cause of the accident was investigated by the AAII Commission. The investigation team comprised of:

Commission Chairman:	Ing. Stanislav SUCHÝ
Commission member:	Ing. Zdeněk FORMÁNEK
	Radim VOJTA, Consultant
	Václav HORÁK, M.D., MBA, MIFM

In accordance with established international arrangements, both the AAIB UK, representing the State of Design and Manufacture of the aircraft, and the the Air Accident Investigation Unit in Belgium, representing the State of Registration, appointed Accredited Representatives to the investigation.

The Final Report was issued by:

AIR ACCIDENTS INVESTIGATION INSTITUTE
Beranových 130
199 01 PRAGUE 9
On 12 June 2023

This Final Report consists of the following main parts:

1 Factual Information
2 Analyses
3 Conclusions
4 Safety Recommendations
5 Appendices

1 Factual Information

1.1 History of the Flight

The Commission used the testimonies of the Flying Display participants, the Flying Display documentation and the records obtained to describe the event.

1.1.1 Circumstances preceding the critical flight

On 12 August 2022, the pilot overflew with the Hurricane aircraft from LKTC to LKCB, where he landed at 15:48. After parking the aircraft in the hangar, he stayed at the airport approximately until 22:00, when he left for his accommodation in Cheb.

On 13 August 2022, the Hurricane pilot arrived at LKCB in the morning to prepare the aircraft. Approx. at 10:00, he participated in an organised briefing with other performers. He received instructions regarding the organisation and the course of the Flying Display programme. The programme was carried out as planned from 11:00 and the pilot gave his performance (including two aerobatic manoeuvres) from 13:20 to 13:38 without any problems. Having landed, he parked the aircraft at the performers' stand. The aircraft was refuelled. In late afternoon, the aircraft was again parked in the hangar. In the evening, the pilot took part in a social event for performers and invited guests. He left for his accommodation in Cheb approx. at 22:00.

On 14 August 2022, the Hurricane pilot was supposed to give performance in the Flying Display programme at the same time as on 13 August 2022. The Hurricane pilot arrived at LKCB and conducted the pre-flight preparation for the flight. Approx. at 10:30, he participated in an organised briefing. During the briefing, a request was made that the service providing information to known traffic (hereinafter the "RADIO unit") would advise the performers about 2 minutes remaining until the end of the performance. It was pointed out that this would only be for indicative purposes. After the briefing, the Hurricane pilot was near the stand, mostly close to the aircraft.

1.1.2 Critical flight of the Hurricane aircraft

At about 13:14, the Hurricane pilot entered the aircraft and conducted flight preparation. The video footage showed the use of shoulder straps while the pilot was in the cockpit. At about 13:20, the pilot started the engine, and at about 13:21, after landing of the preceding performer, he started taxiing to the holding position on RWY 05. After the preceding performer landed and vacated the runway, the Hurricane pilot was taxiing to the threshold of RWY 05. He was informed that RWY 05 was clear for take-off and was advised about wind direction and speed.

At 13:23:11, the aircraft took off from RWY 05. After the take-off, the aircraft was ascending and gradually made two right turns by about 270 degrees north-east of the airport at approx. 600–800 m AGL. Approx. 3 minutes after the take-off, the Hurricane pilot reported an indication of extended undercarriage to the RADIO unit. He asked for information whether the undercarriage was extended. He performed a flight parallel to the axis of RWY 23 at the altitude of approximately 400 m AGL. During the pass, the RADIO unit could not see the undercarriage extended. The RADIO dispatcher informed the pilot accordingly and he responded by saying he would make another pass. He made a turn beyond the airport boundary and flew towards the RADIO unit in the direction of RWY 05. At the level of the airport centre, the pilot entered a right turn with a roll of about 15 degrees. The RADIO unit could see the wheels retracted. The dispatcher informed the pilot accordingly. The Hurricane pilot neither requested nor confirmed anything.

At approx. 13:29:30, the Hurricane pilot started performance by descending in a pass in the line of RWY 23 at the speed of approx. 220–240 kt. After a pass, he made a half-loop and then, immediately after the top, he made a descending half-roll to the right to the normal position with levelling-off for a horizontal pass towards RWY 05. After a pass, he put the aircraft in a climbing turn by approx. 90 degrees to the right by a barrel three quarter roll, transitioning then to a descending turn by 270 degrees to the left in the direction of RWY 23, where he made a pass at the speed of approx. 180 kt. After a pass, he continued by a wingover[1] to the left completed by arrival in the direction to the centre of the performance area at an angle of about 30 degrees to the RWY 05 axis. When he approached the performance border, he made a right turn to a pass in the line of RWY 05. After a pass, he made a wings-level wingover to the right completed in the direction to RWY 23 at an angle of approx. 30–45 degrees. The pilot then made a relatively abrupt left turn, levelling off the aircraft for a pass along the line of RWY 23.

When the Hurricane aircraft was in a straight-line flight, the RADIO dispatcher advised the Hurricane pilot that there were 2 minutes left until the end of the performance.

At approx. 13:31:30, after a pass along the axis of RWY 23 at the speed of approx. 150 kt, approx. above the level of TWY F, the Hurricane pilot initiated the critical manoeuvre by a straight climb at an angle of approx. 40 degrees. Four seconds later, he entered a climbing right turn with an increasing roll up to 90 degrees at the top. Having rolled up to some 90 degrees, he transitioned into a sharp descending turn. Approx. 13–14 s after initiating the aerobatic manoeuvre and turning by some 120 degrees, while being in a sharp turn, he achieved a roll of approx. 45–60 degrees and the angle of descent of 35–45 degrees. In this phase of manoeuvre, the video footage clearly shows the opposite ailerons drive and a sudden rise in aircraft roll and pitch. It is highly probable that the aircraft stalled and right autorotation occurred. For a moment shorter than 1 s, the aircraft decreased the roll in the right turn. Immediately, some 1.5 s before the impact to the ground, the aircraft was again in a fast positive roll and the descent was steeper. Just before the crash, the roll decreased, the nose slightly rose, but the altitude was not sufficient for the aircraft to level off. At a small angle of pitch towards approx. 195 degrees, the aircraft crashed on the ground with the lower part of its fuselage and the right half of its wing. The aircraft was destroyed due to the impact.

1.1.3 Another pilot's statement

The pilot with class and type ratings and practical experience with the Hurricane type (hereinafter "another pilot"), who also performed during the PAS programme, explained that he had seen the pilot's aerobatic performance on 13 August 2022. It corresponded to what the pilot had trained on the Hurricane aircraft and the AT-6 Harvard trainer aircraft. It was in compliance with the Aerobatic Performance Approval. He further said that he had not noticed anything special that would draw his attention.

As regards the day of 14 August 2022, another pilot said that he had met the Hurricane pilot several times and had a talk with him. It was during the morning briefing, when talking with another former colleague who was in the audience, and when discussing one of the performances approx. 1–2 hrs prior to the critical flight. He talked with the pilot for the last time just before his flight which preceded the Hurricane pilot's performance in the Flying

1 An aerobatic manoeuvre intended for flying in the opposite direction from which the manoeuvre began. The aircraft first makes a climb to the top where the bank is the highest (up to 90 degrees) and the wing is unloaded or just slightly loaded (some 1 g). In the descending phase, as the speed increases, the bank smoothly decreases with slight rudder applying and angle of attack and the aircraft levels out. The manoeuvre advantages include its safety, low energy management and attractiveness for audience (the English literature describes this manoeuvre as the wingover).

Display programme. During all these talks, the Hurricane pilot looked normal, calm and composed as usual.

Another pilot further stated that after landing from performance at 13:22, he saw the Hurricane aircraft at the holding position on RWY 05 with its engine running. Having vacated RWY 05, he saw the Hurricane aircraft taxiing on it and taking off one minute later. Having stopped at the stand and disembarked the aircraft, he noticed the Hurricane aircraft was circling at the altitude of several hundreds of meters above the eastern edge of the airport. As he was no longer in radio connection, he paid no attention to it, assuming that the display area was not vacant for the performance for some reason. When he noticed the start of the Hurricane performance after a while, he was observing its course in order to see the acrobatics. However, it was very short. The pilot made the Half Cuban-Eight completed in the direction of RWY 05 and the Derry Turn[2], conducted in the form of a barrel three quarter roll with return to the axis of RWY 23. Another pilot said that as regards that type of manoeuvre performance, he had not seen the pilot perform the manoeuvre in this way until then. Originally, he used axial rolls; nevertheless, the performance on 14 August 2022 was safe. Another pilot said that the next manoeuvres had not been aerobatic. However, in his opinion, the flight of the Hurricane aircraft was slower and smoother in comparison with the previous day. Another pilot then stopped watching the show and paid attention to his aircraft. He noticed the pass in the axis of RWY 23, which drew his attention as it was, in his opinion, rather slow. He thought that the Hurricane pilot was finishing his performance because it was the time for the Me-262 aircraft to join directly the Flying Display programme.

Another pilot commented on the event manoeuvre as follows: *"I was curious how he would join the circuit from this manoeuvre for landing on RWY 05. Instead, he started climbing steeply in the axis of RWY 23. I stopped watching him for a moment and when I looked back a few seconds later, I saw the moment when he tightened a turn, which resulted in asymmetrical flow separation on the wing. When I saw the initial counter-manoeuvre after which he was descending at an angle of 35–45 degrees, I stopped watching him because I knew that was it. This aircraft category needs a high altitude to recover the fall or to level off and there was no way to save the situation. I estimate that he would need at least 150 m more – maybe even more than that – to level off."* He further said: *"It was my subjective opinion that the flight was unusually slow and on a smaller engine mode."*

1.1.4 Testimony of the RADIO dispatcher about the critical flight

The RADIO dispatcher said: *"At 15:31, I established connection with the pilot. It was at the moment when the aircraft was in the horizontal straight-line flight. I advised the pilot that there were 2 minutes left until the end of his performance."* The dispatcher is not sure whether the pilot confirmed the information. He said he was watching the aircraft pass above the runway in the direction of the municipal district of Podhrad and make a climbing turn. He further said: *"I noticed a short autorotating movement of the right wing with aircraft's transition to the vertical line on top of the turn. At that moment, I realised that the aircraft most probably "slid down the wing". Within seconds, the aircraft crashed against the ground. I could not see the contact with the ground as such as it happened some 300 m far away from the RADIO unit outside the area of the airport where the terrain descends toward the municipal district of Podhrad. Since 15:31, there has been no radio communication any longer. During the phase of the flight when the pilot was heading towards the ground, the pilot did not transmit any information to the radio service. Also, we did not notice any radio*

2 An aerobatic manoeuvre intended for flying in the opposite direction from which the manoeuvre began. It begins with a sharp turn by approx. 90 degrees to change the direction followed by a three quarter roll in the turn and transition to a sharp turn by 270 degrees in the opposite direction (manoeuvre named after pilot John Derry).

keying. Before the actual contact of the aircraft with the ground, I shouted at the dispatcher of ground traffic, who was near my office, to inform the IRS units about an emergency because I assumed, from my perspective, that a contact with the ground would occur."

1.2 Injuries to Persons

The pilot died at the accident site.

1.3 Damage to Aircraft

The Hurricane aircraft with the OO-HUR registration mark was destroyed.

1.4 Other Damage

Third-party's property was damaged; nevertheless, the total amount of damage has not been known to the Commission until the issuance of the Final Report.

1.5 Personnel Information

1.5.1 Aircraft pilot

1.5.1.1 Personal data

Male, age:	58 years
Licence:	CZ/FCL/ATPL(A)
Overview of ratings and certificates:	
• B737 300-900/IR/LVO:	valid until 31 August 2022
• SEP land:	valid until 31 May 2023
• TRI(A):	valid until 31 December 2023
• FI(A):	valid until 30 September 2022
• FE/CRE/IRE/FIE/TRE; TOWING-S/BAN	
• AEROBATICS	
• Flight test category 1	
• Hurricane:	valid until 30 June 2023
Class 1 medical certificate:	valid
General radio operator licence:	valid

1.5.1.2 Flying experience

The pilot flew as a pilot, instructor, examiner and test pilot on multiple types of single-engine and multi-engine aircraft. His SEP land rating was last extended on 24 March 2021. The Commission did not acquire the pilot logbook and also did not gain access to his flight records. For the purposes of issuance of the aerobatic display pilot licence for air shows, he stated the total number of flight hours as 16,100 hrs and the total number of performances as 7 out of which 1 in 2021. The air carrier, for which he flew as a transport pilot stated the total number of flight hours recorded by the company as 7,163 hrs.

The pilot started flying the Hurricane aircraft on 27 May 2021. According to the records in the aircraft logbook and the records of operating time maintained by the aircraft operator, the pilot carried out 11 flights on the aircraft in 2021 (5 hrs 50 min in total) and 10 flights, besides the critical flight, in 2022. For data on flights and flight time (*operation) in 2022 see Table 1.

Tab. 1 – Overview of flights conducted by the pilot on OO-HUR in 2022

Date	Airport	Airport	Duration [h:min]
6 Jan	LKTC	EDGE	01:20
6 Jan	EDGE	EBBT	01:45
3 May	EBBT	EBBT	0:45
4 May	EDGE	LKTC	01:44
11 May	LKTC	LKRO	0:35
11 May	LKRO	LKRO	0:20
4 Jun	LKTC	LKTC	0:45
4 Aug	LKTC	LKTC	0:26
12 Aug	LKTC	LKCB	0:37*
13 Aug	LKCB	LKCB	0:18*
Total	–	–	08:35

1.5.2 Competence for aerobatic display

In order to be able to engage in aerobatic display with the Hurricane aircraft, the pilot had to:

- Have a supervisor for his performance who guaranteed a thorough verification of the performer's competence;
- Be a holder of a valid Aerobatic Performance Approval issued by CAA.

The Civil Aviation Authority authorised the examiner for the given type to act as performance supervisor. The supervisor in his explanation stated the main principles governing the preparation of display pilots performing on aviation days with the use of events lasting 2–3 days with a mix of theory and practice. The practical initial flights then depended on the aircraft used and the possibility of flying two-man aircraft. The practical training further included monitoring of pilots from the ground, assistance in designing the aerobatic performance and demonstration of aircraft in the allocated space, thorough verification of performer's competence and/or consideration of the request for a change in the Aerobatic Performance Approval. As regards the preparation of the pilot concerned, the supervisor said that in 2021, when the Hurricane aircraft arrived to the Czech Republic, the pilot did not participate in the training camp with it as the insurance terms and conditions did not allow for the aircraft to perform in aerobatics. That is why another pilot of this aircraft, who has experience on several types of powerful historical military aircraft, decided that it would be possible to train only performances without aerobatic manoeuvres. In 2022, the pilot was practising an aerobatic performance on the AT-6 Harvard aircraft at a training camp. As the Hurricane aircraft had already been approved for aerobatic performances, the supervisor and the pilot assumed that the performance set on the AT-6 Harvard aircraft would serve as a basis for his aerobatic performance on the Hurricane aircraft. In May 2022, the pilot together with the supervisor and another pilot with experience on the Hurricane aircraft took part in a one-day event. The pilot flew his set of manoeuvres and the supervisor together with another pilot evaluated the performance. Based on the presentation of the performance, the pilot's Aerobatic Performance Approval was extended to include the Hurricane type.

1.5.2.1 Description of the performance

Based on the Aerobatic Performance Approval with Ref. No. 1214-22-301, dated 7 March 2022, the pilot was authorised to present aerobatic performances with AT-6 Harvard and Hurricane aircraft at public air shows permitted by CAA as per Section 78 of Act No. 49/1997 Coll., Civil aviation act. The performance presented in the Czech Republic had to be carried out in accordance with the Conditions for organising public air shows (CAA-SL-101-3-16). The description of the pilot's performance allowed for the set to be comprised of

aerobatic manoeuvres or their parts permitted by the aircraft logbook of the aircraft concerned in any sequence, subject to the following restrictions:

- No part of aerobatic manoeuvres shall be carried out below 100 m AGL.
- The minimum altitude for straight-line direct passes along the runway axis is 10 m AGL.
- Aerobatic manoeuvres with negative load factors and autorotation manoeuvres are prohibited.
- All the restrictions specified in the Flight Manual of the given aircraft shall be complied with.

The pilot presented the performance with the Hurricane aircraft at the Flying Display on 13 and 14 August 2022 for the first time. He did not practise the performance set in order to verify it given the display site at LKCB.

1.6 Aircraft Information

1.6.1 Basic characteristics

The Hawker Hurricane Mk IV aircraft was a single-engine, single-seat self-supporting low-wing monoplane with composite structure. The wing was two-spar with the centre plane robustly connected to the fuselage structure and two attached external parts. In the centre plane, there were two fuel tanks, oil tank, cooler for the coolant, the middle part of the flaps, and the main landing gear wheels which retracted into the centre plane. Weapons were placed in both outer parts of the wing. The ailerons were fabric-covered, while lightweight metal sheets were used on the wing.

The steel tube structure of the fuselage supported the engine bed in the front part. The fuselage was covered with moulded detachable cowling panels made of duraluminium from engine to the cockpit. Behind the cockpit, there were panels installed on steel tube structure connected with wooden longerons and covered with doped linen. The tailplanes had metal skeleton and were covered with fabric. The rudder, the elevator, ailerons and trimmer tabs were controlled by cables. The control of flaps and the landing gear was hydraulic and the brakes control was pneumatic.

For version Mk IV, the powerplant was standard liquid-cooled twelve-cylinder engine Rolls-Royce Merlin 2 with FAR224.

1.6.2 General specifications of the aircraft with the OO-HUR registration mark

1.6.2.1 Aircraft

Manufacturer:	Hawker Aircraft Ltd
Manufactured[3]:	in 1943 / renovation in 2003
Manufacturing No.:	10 911
Serial No:	KZ321 (new identity after GO)
Total hours flown of the aircraft frame:	244 hrs 40 min
Liability insurance:	valid

1.6.2.2 Power unit

Engine – type:	Rolls-Royce, Packard Merlin-224
Year of manufacture:	1943

3 Conversion of aircraft made in 1943.

Manufacturing No.:	306523
GO performed on:	25 July 2018
Total hours flown since GO:	81 hrs 52 min
Propeller – manufacturer:	Rotol Airscrews, Ltd
Type:	Dowty-Rotol RS5/13
Manufacturing No.:	A 355 N/P
Serial No:	28242
Performed GO:	1 October 2018
Total hours flown since GO:	77 hrs 52 min

1.6.3 History of the aircraft with the OO-HUR registration mark

The wreckage of Hawker Hurricane Mk. IV[4] was discovered in 1983 in Jaffa, Israel. In 1991, it was handed over to the company specialised in restoration of Hurricane aircraft for conversion into an airworthy condition. Extensive renovation using renovated and refurbished components put the aircraft in an airworthy condition. The fuel tanks were supplemented with auxiliary tanks in the wing at the place of weapon shafts. The main dummy cannons were placed in the wing. The instruments in the cockpit were analogue, supplemented with contemporary avionics. The controllers, system controls and their location in the pilot cockpit corresponded to the original type. The pilot seat was equipped with four-point seat belts.

The first flight of the aircraft was conducted in 2003 on the basis of Flight Clearance No. 27856. The aircraft was flying in the United Kingdom with the G-HURY registration mark and the JV-N code. In March 2006, the owner changed and the aircraft was flying in Canada with the CF-TPM registration mark. Since August 2018, it has been recorded in the Belgian Aircraft Register as OO-HUR. The Certificate of Airworthiness Inspection was issued by CAA in Belgium on 28 February 2019. In 2021, the Točná Aviation Museum purchased the aircraft. Since then, it has been operated in cooperation with the Belgian organisation for maintenance and restoration or war and historical aircraft. It became an exhibit in the Točná Aviation Museum with the OO-HUR registration mark, BE 150 identity and JX-E code.[5]

1.6.4 Operation of the aircraft with the OO-HUR registration mark

The aircraft was maintained by a qualified maintenance organisation in accordance with original manuals for engine, airframe and propeller maintenance and other regulations of CAA in Belgium to keep the aircraft airworthy. The maintenance reflected all instructions for airworthiness maintenance and service bulletins for the airframe, engine and propeller and followed the time-limited units. The service life of the engine until the next GO was determined as 600 hrs. New blades were installed on the propeller during GO.

On 29 April 2022, revision and annual inspection was carried out on the aircraft according to the planned maintenance programme after 100 hrs of operation. The Certificate of Airworthiness Inspection 2022-004 was issued.

On 13 August 2022, after performance at LKCB, the aircraft was refuelled with 179 L of aviation petrol AVGAS 100LL. Given the data on previous refuelling, there were approx. 427 L of fuel in the aircraft on 14 August 2022.

1.6.5 Emergency parachute

The aircraft was equipped with emergency parachute of the ATL-88/98-S-1 type, serial number 2196020. The last parachute packing was recorded on 23 October 2021.

4 It was probably KZ119 as KZ321 was lost in combat as was later discovered after the renovation.
5 The aircraft was painted as personal plane of Karel Miloslav Kuttelwascher, DFC.

The minimum permissible altitude for parachute use is 100 m at the aircraft speed of 110 km·h^{-1}.

1.6.6 Take-off weight of aircraft

Weight of an empty aircraft:	2,780 kg
Pilot's weight:	86 kg
Parachute weight:	8 kg
Fuel[6]:	320 kg
Total:	3,194 kg
Maximum take-off weight of aircraft:	3,368 kg

1.7 Meteorological Information

1.7.1 General Weather Information

The analysis prepared by CHMI for the day of 14 August 2022 shows that warm air was blowing from south-east to the territory of the Czech Republic along the shallow low-pressure area above Hungary. At 13:00–14:00, eastern or variable wind was blowing at a speed of 1–3 m·s^{-1} in the vicinity of LKCB. Visibility was over 10 km. The sky was covered with low clouds of Cu type and high clouds of Ci type. There was no precipitation or other weather phenomena. The temperature reached 26 °C. For an extract from SYNOP reports from the Cheb weather station see Table 2.

Tab. 2 – SYNOP reports – Cheb

Time [h:min]	Visibility [km]	Wind direction	Wind velocity [kt]	Weather	Cloud [oktas/m AGL]	Temperature [°C]
13:00	45	100°	6		3 Cu 1500, 3 Ci 9000	26
14:00	45	VRB	2		3 Cu 1800	26

Extract from the METAR report from the LKKV weather station (40 km NE from the incident site):
METAR LKKV 141300Z 12009KT 040V180 CAVOK 27/11QNH 1012=
METAR LKKV 141330Z VRB08KT CAVOK 26/11 Q1011=
METAR LKKV 141400Z 07007KT 030V100 CAVOK 25/12 QNH 1011=

1.8 Radio Navigational and Visual Aids

NIL

1.9 Communications

During the Flying Display, the radio-telephone connection was established with the Cheb RADIO unit for the provision of information on the frequency channel of 120.610 MHz. Connection on the frequency channel of 122.205 MHz was established as backup. Information to known traffic was also provided in English. Radiotelephone correspondence and telephone calls were not recorded.

6 Estimated weight of aviation petrol: 0.71–0.77 kg/L

1.10 Airport Information

The Cheb airport is located approx. 3 km GEO 135 degrees from the town of Cheb. One RWY 06/24 with the dimensions of 1,000 x 18 m is covered with concrete, and the second RWY 05/23 with the dimensions of 1,000 x 25 m is covered with grass. The ARP elevation above sea level is 1,585 ft / 483 m.

1.10.1 The Flying Display setup

For the period of the Flying Display duration, the grass RWY 05 was used. The concrete RWY 06/24 was used for taxiing. Marking on the operating area was in line with the requirements determined in Annex 14. The Flying Display was held in compliance with the Conditions for organising public air shows (CAA-SL-101-3-16). The performance boundaries were set so that the minimum prescribed distance of the performing aircraft from the public line would be in compliance with Article 3.5 of the Conditions. The performing pilots were also advised about the Flying Display limitation during the briefing: *"As far as possible during the air show do not fly over Podhrad village."*

1.11 Flight Recorders and Other Means of Recording

1.11.1 Flight Recorders

The aircraft was not equipped with flight recorders as it was not required by regulations. No navigation equipment was installed on board to record flight data.

1.11.2 Mobile phone record

During the critical flight, the pilot had his Apple iPhone 13 with the SkyDemon application with him. The mobile phone was found damaged at the accident site. Data in the format of .blackbox file were extracted from the phone memory. AAIB UK specialists decoded the data to the CSV format at the request of AAII. The data file in the CSV format marked 2022814 (flight on 14 August 2022) contained location data recorded at an interval of 1 s. The start of the recording was marked with time (GPS Date) 13:22:29. Based on the changed position on RWY 05 and gradual rise in speed, the start of take-off could be determined at 13:23:20, and the change in the altitude data showed the time of aircraft lift-off at 13:23:43. At time marked as 13:29:23, data integrity was temporarily lost for approx. 26 s. Another temporary data loss for approx. 4 s occurred at time marked as 13:30:32. The reason for loss of GPS signal integrity could not be identified. The record of the flight trajectory during the aerobatic part of the performance was not continuous and individual trajectory points were recorded inaccurately compared to the flight trajectory on video footage. The end of the location data recording was marked with time at 13:32:11. The total length of the recording was about 9 min 42 s. In Fig. 1, there is a visualisation of the flight trajectory points on 14 August 2022 in the Google Earth application. When comparing the flight trajectory record on 13 August 2022, obtained from the data set marked as 2022813, a similar data integrity loss occurred during the aerobatic part of the performance.

Fig. 1 – Visualisation of the flight trajectory points of the Hurricane aircraft on 14 August 2022

1.11.3 Video footage and photographs

The public audience participating on the Flying Display provided the Commission directly or via the Police of the Czech Republic with various video footages and photographs. The Commission analysed the video footages and photographs showing the state of the aircraft and the course of the accident. Neither photographs nor video footages showed any evidence of any aircraft anomalies. Given the distances from which the videos were taken, the control surface deflections and their relation to the aircraft movement in the critical phase of the flight could be determined only as estimation. The video footage shows that 13–14 s after the start of an aerobatic manoeuvre, while turning by approx. 120 degrees to the left in a sharp descending turn, the left aileron was deflected upwards and the right aileron downwards (against the rolling movement). See the video footage images of this flight phase in Fig. 2. It is obvious from the detailed photographs of the aircraft that the pilot put the rudder trimmer tab for take-off – left-hand side. Appendix No. 1 shows the aircraft position during the descending phase of the critical manoeuvre according to the video footage.

Fig. 2 – Aileron deflection against the rolling movement in a descending turn.

1.12 Aircraft and Impact Information

1.12.1 Description of air accident site

The air accident occurred in the field located between a built-up area of Cheb, the municipal district of Podhrad, K Letišti Street, and the premises of the Cheb airport. The surface of the stubble field after grain harvest was dry. The aircraft was destroyed by the forces of impact to the ground. The trace of the first impact of the aircraft crash against the ground was found about 22 m from the edge of the asphalt surface of K Letišti Street and some 61 m from the edge of the fence surrounding house No. 13. It corresponded to the impact of the aircraft at a slight angle in the heading of approx. 195 degrees. At the beginning of the debris trace,

there was a visible trench in the field, approx. 11.3 m long, as a result of the impact of the lower part of the aircraft fuselage to the ground. At the point of impact of the wing to the ground, the width of the wing imprint was about 12.4 m and there were visible traces of the impact of the dummy cannons in the leading edge of the wing.

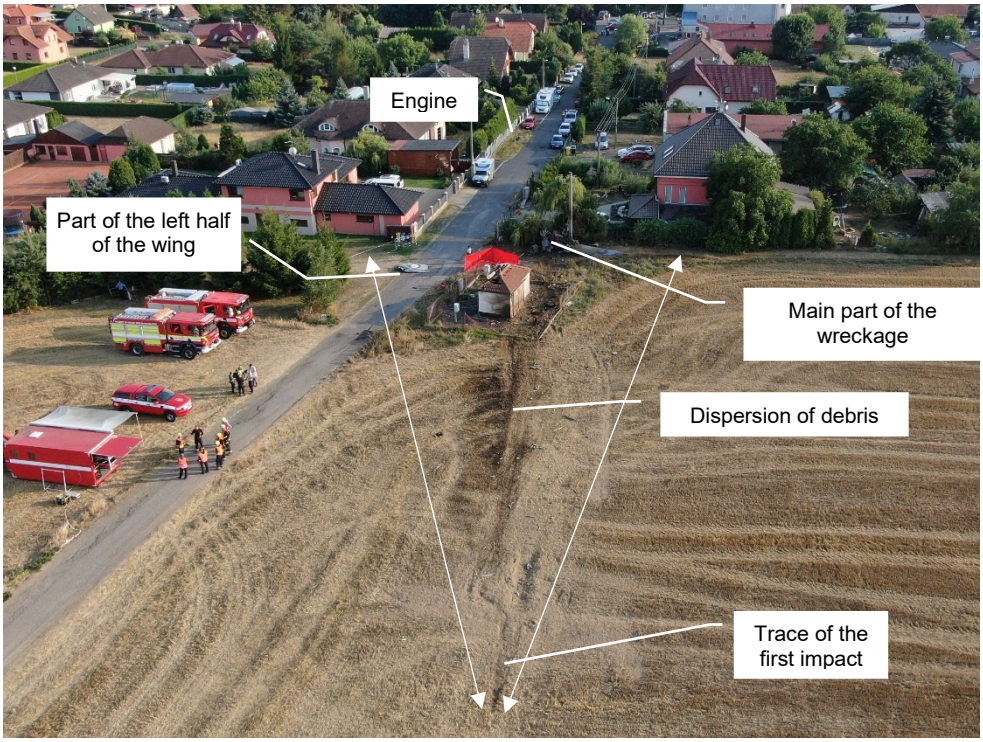


Fig. 3 – View of the place of the air accident of the Hurricane aircraft

Tab. 3 – Position of the first impact

Geographic coordinates:	N 50°03'43,28"
	E 12°23'55,14"
Elevation above sea level:	485 m

From the point of the first impact, the ground trace continued towards the edge of the natural gas control station. There was an expanding oil stain to the left of the trench. There were smaller parts of the fragmented wooden fuselage structure, fabric, metal structure components, lower part skin, and fragments of the wooden propeller blades on both sides of the trench in the soil.

The aircraft wreckage collided against the fence surrounding the natural gas control station, which consisted of metal frames with a wire mesh attached to metal columns placed in a concrete dwarf wall, and damaged the fence from three sides. Smaller parts of aircraft wreckage were scattered on both sides on the gravel surface of the space between the fence and the brick building of the station with a roof made of ceramic tiles. There was a canopy, plexiglass fragments of the canopy and cockpit frame, cockpit door, broken artificial horizon indicator, and a folder with printed procedures (checklists) to the left of the building. The fragments of aircraft systems and dummy cannons, deformed engine covers and fuselage skin panels could be found to the right of the building.

The debris was spread up to the fence surrounding the plot of family house No. 13 where the aircraft wreckage collided against the concrete column of power line standing at the edge of the plot. The fuselage structure with tailplanes was deformed round the column and stopped by the fence and the crown of a mature willow, which was behind the column and the fence. The right and left undercarriage legs with wheels remained in the centre-wing section. The right half of the wing was attached to the centre-wing section while it was torn at wing root at the leading edge and in the flap space and broken approximately at the point of internal aileron hinge. The root of the broken left half of the wing remained attached to the centre-wing section. The cockpit in the fuselage, a number of fragmented smaller pieces of the wooden aircraft structure, broken-off gearbox, centrifugal-flow compressor from the engine, and the propeller dome with blade fragments could be detected at the wreckage site.

Fig. 4 – The main part of the Hurricane wreckage

Part of the left half of the wing and a wingtip arc detached from it were located on the road to the left of the natural gas control station. The engine was torn out of its bed and fell about 50 meters from the place where most of the debris stopped. It was located on the grass between the bitumen-sealed K Letišti Street and the fence of the adjacent house.

The body of the pilot dressed in an unzipped pilot suit was lying at the edge of the road and the field at a distance of approx. 56 m from the place of the first impact of the aircraft against the ground and approx. 4 m from the fence of the natural gas control station. There was the back part of the parachute harness with the parachute pack above the pilot's body. The right-hand chest strap snap hook and the buckle on the left-hand chest strap were disconnected. The left leg of the pilot was strapped with the locked left-hand hip strap of the parachute harness. The released right-hand hip strap of the parachute harness was located under the pilot's body.

The pull-off parachute of the emergency parachute got caught on a lightning rod on the roof of the natural gas control station. The pull-off parachute was connected with the emergency parachute canopy partially lying on the roof of the building with a parachute cord. The

parachute shroud cords loosely connected the canopy and the loose ends of the parachute harness.

1.12.2 Detailed aircraft wreckage inspection

The Commission performed detailed inspection of the wreckage in the location of its depositing on the premises of a facility of the Police of the Czech Republic where it has been transported from the accident site.

1.12.2.1 Inspection of controls

The aircraft structure was destroyed, but the inspection of continuity of rudder controls and the right aileron, if possible, did not detect any signs of a malfunction in the control cables and drag links.

1.12.2.2 Inspection of engine and propeller

The engine sump cover and the propeller drive gearbox were broken. The crankshaft, main bearings and connecting rod bearings were visible. They were covered with oil. Bolt nuts were tightened. The generator and other units have been torn out of the engine housing. The exhaust pipes were deformed. The compressor has broken off from the engine housing. The carburettor has detached from the compressor body. The propeller drive gears were heavily deformed. The propeller dome with a part of the broken gearbox was strongly deformed with the stumps of broken propeller blades.

1.12.2.3 Inspection of instruments

Only some damaged instruments have been preserved in the parts of the instrument board. The turn indicator with broken glass remained in the middle section. The speed indicator, the variometer, the altimeter, and the artificial horizon indicator have been torn out of the instrument board and located damaged in the debris. The speed indicator was found with broken glass with the needle in the position of about 105 kt. Only a fragment of the altimeter and the barometric box were found. The pressure setting on the altimeter could not be determined. Only a variometer scale without a needle has been preserved. The identified artificial horizon indicator fragments included a broken body of the device, the scale and the gyroscopic part. The compass fragment has been broken off. There was a damaged tachometer with a large needle pointing approx. to 500 rpm and the manifold pressure indicator with broken glass on the right side of the instrument board. Other instruments were broken off and damaged. The fuel gauge was found with broken glass and a needle indicating “2 Gal” on the scale. Only damaged oxygen delivery indicators have been preserved on the left side of the instrument board. The chronometer, the magnet switch and other switches have been torn out.

1.12.2.4 Inspection of cockpit components

The deformation of the steel tube structure in the area of cockpit and the damaged gas control lever, mixture actuator and cable controls did not allow for determining the engine operation mode. The propeller controller has been detached from the steel tube structure and the lever was in the high RPM position. The pitch balance and rudder balance controls remained on the deformed steel tube structure on the left side of the cockpit, while the chain and trimmer tab cables were out of control. The fuel tap was in the “Reserve” position. The oil shutter control was in the “Normal” position.

The control lever was connected to the pitch control assembly. It has been broken off at the joint site of the roll control. The chain transmitting motion to the roll control rods was detached.

Two lap fastening belts were attached to the deformed pilot seat. The central quick-release buckle, which should have been fixed on the right-hand belt, could not be found. Two shoulder straps have been attached to the locking hook of the strap locking mechanism placed behind the pilot seat on the partition. The mechanism control cable has been broken and the spring return mechanism has been damaged.

1.12.2.5 Inspection of the landing gear system

Due to the aircraft destruction and deformation, it was not possible to inspect the hydraulic system of landing gear extraction and retraction. The aggregate landing gear/flaps lever on the right side of the cockpit with a partially deformed lever, lever quadrant, and safety lock remained fixed to the steel tube frame. Because of the deformation, it was not clear whether the lever was in the neutral position. Due to the large extent of damage to the legs, struts and retractable mechanism of the main landing gear, it was not possible to determine whether it was in the locked position. The clips on both wheels of the main landing gear have been broken off at the point of attachment to the wheel axis.

1.13 Medical and Pathological Information

The immediate cause of pilot's death was polytrauma. Death occurred immediately after the aircraft crash against the ground. The sustained injuries were clearly fatal due to their general nature. From the forensic medical and aviation medical point of view, it is possible to state, given the nature and location of injuries, that blunt violent force of great intensity impacted the pilot's body in the pilot's seat mostly from the front, from below and from the left. According to investigation at the accident site, it is not possible to confirm that the pilot was fastened with safety belts at the time of accident.

The pilot's autopsy has not detected any traumatic changes which could not have been explained by the mechanism of the air accident concerned. The autopsy has not detected any severe pathologies. No morphological changes have been detected that would bear witness to a sudden deterioration of pilot's health condition and could thus lead to the occurrence of the emergency situation or which could have contributed to the cause of death. Biochemical tests have been performed in the pilot in order to determine his somatopsychic condition. Prior to death, the pilot's energy metabolism was activated, drawing on carbohydrate reserves mostly in the striped muscle tissue and the brain resulting in an increase of lactic acid level in the brain. The said changes may be explained, for instance, by pilot's experiencing rather intensive mental and partially also physical strain in the last dozens of seconds of the flight. Before his death, the pilot was conscious, and did not experience any changes indicating hypoxia, stress or acute illness associated with pain.

1.14 Fire

No fire broke out.

1.15 Search and rescue

The LKCB traffic dispatcher immediately activated the relevant units of rescue and fire rescue services at the airport. The Fire-fighting service vehicle arrived at the place of the air accident right away. The Flying Display Flight Manager activated the Emergency Plan. The paramedic who arrived at the place of the air accident and to the pilot's body first stated that he had released the snap hook of the parachute chest strap. The pilot suit was unzipped.

1.16 Tests and Research

1.16.1 Analysis of damage to safety seat belt clamps

When analysing the damage to the holes in metal clamps on shoulder and lap safety seat belts, the following facts were identified.

No significant variations in the regularity of the holes in lap safety seat belts were detected. The rear part of the clamp on the right lap seat belt shows hole bevelling in the direction of locking and several longitudinal surface grooves. See Fig. 5. These may be traces of pulling out of the central quick-release buckle. The rear part of the clamp on the left lap seat belt shows more prominent hole bevelling in the direction of locking. In comparison with the clamp on the right lap seat belt, the surface damage on the rear part of the clamp is not so significant. See Fig. 6.

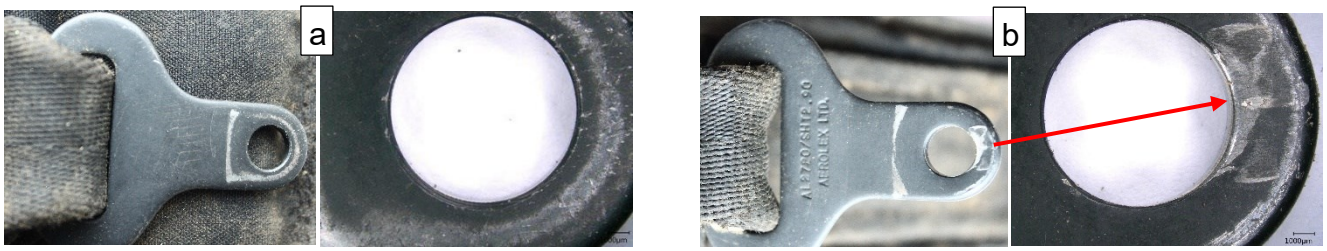


Fig. 5 – The right clamp on the lap seat belt; (a) front part of the right clamp; (b) rear part of the right clamp.

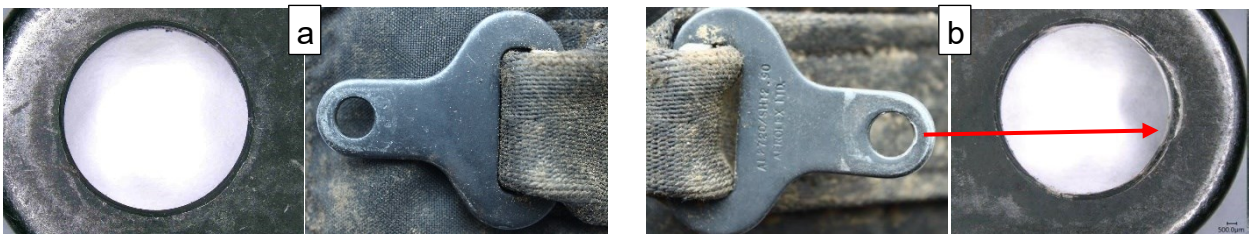


Fig. 6 – The left clamp on the lap seat belt; (a) front part of the left clamp; (b) rear part of the left clamp.

The holes in shoulder straps do not show significant deviations in regularity. Damage caused by significant sharp notches at the edge of the hole was detected on the rear part of the clamp on the right seat belt. See Fig. 7. Significant crushing of the inner edge of the hole can be seen on the rear part of the clamp on the left seat belt.

Fig. 7 – Rear side of clamps on shoulder seat belts; (a) right seat belt; (b) left seat belt

As regards the shoulder straps, the origin of the damage to the inner hole of the right seat belt clamp cannot be clearly determined as a result of either normal wear and tear or the accident.

1.17 Organisational and Management Information

1.17.1 Aircraft operator

Aircraft operator – Letecké Muzeum Točná, s.r.o. (Točná Aviation Museum) operates the Točná airport and the museum of airworthy historic aircraft.

1.17.2 Cheb Airshow 2022

The Flying Display "Cheb Airshow 2022" was held by the Cheb airport operator on 13–14 August 2022 based on the Decision of approval issued by the CAA and determination of terms and conditions dated 29 July 2022. The operator designated the Flying Display Manager, implementation committee and the Flying Display organisation, prepared the Risk Management and the Emergency Plan, written briefing and drew up the Flying Display programme. The performing pilots submitted documents proving the aircraft airworthiness and pilot's documents, including the Aerobatic Performance Approval, in writing in advance or upon arrival.

The main Flying Display programme took place on both days from 11:00 to 15:00. NOTAM A0789/22 was issued in connection with this event. The Flying Display was assigned an area with a radius of 3 NM, with vertical boundaries of GND – FL 075. The LKCB was rendering the service of providing information to known traffic. Information to known traffic was also provided in English.

There was a clear line delineated for the public and the aircraft stands at LKCB and the minimum distance between the performance threshold for passes and aerobatics, including checks, was determined in accordance with the CAA directive CAA-SL-101-3-16.

1.18 Supplementary Information

1.18.1 Aircraft undercarriage issue

Another pilot commented on the fact that the pilot reported an indication of extended undercarriage to the RADIO unit and a pass for the purpose of visual check of the undercarriage position. He said that it sometimes happened in Hurricane aircraft that after undercarriage retracting, one red light indicating landing gear leg retracting and securing did not come on. It was probably caused by the limit switch. The landing gear leg was, however, always retracted, which could be seen through the glass panels in the floor – on the one hand, the landing gear wells could be seen and, on the other hand, the stop of landing gear leg clips in locks could be felt. The given aircraft flight manual specifies the procedure when the manual hydraulic pump is used to complete the retracting process. It is also possible to extend and retract the undercarriage again. The Hurricane aircraft has a low maximum speed for undercarriage operation (V_{LO} = 104 KIAS); therefore, it must be adhered to. If undercarriage retraction is attempted at a higher speed, incomplete retraction may occur due to the effect of aerodynamic force generated by the shape of the landing gear leg door. In case of emergency extension, this force helps to overcome the resistance and correctly extend the legs. However, the same force also acts against retraction.

1.18.2 Statement of the signalman in the movement area

The person who had the role of a signalman in the movement area during the Flying Display said that she was standing at the stand near the Hurricane aircraft at the time of engine starting and taxiing from the stand for the critical flight. She commented on the situation before the take-off as follows: *"I am convinced that the pilot had fastened and checked the seat belts because before taxiing from the stand, the pilot touched his seat belts (fastening*

check), checked the cockpit lock, nodded as a sign of readiness for taxiing and based on that, I put my thumb up."

1.18.3 Flight characteristics of the Hurricane aircraft

The Hurricane Mk. IV Operations Manual in the sections Flight speed limits and Stall speed aerobatics and recommended speeds for manoeuvres provides the following facts – see Table 4:

Tab. 4 – Stall speeds and recommended speeds for manoeuvres

Speed	KIAS	Comment
Stall speed (undercarriage and flaps retracted)	70–78	Stall speeds vary depending on the weight of the airframe
Stall speed (undercarriage and flaps extended)	52–65	Stall speeds vary depending on the weight of the airframe
Loop	240	Recommended speeds for manoeuvres
Immelman turn	>260	
Roll	190–220	

Another pilot commented on flight characteristics: *"The Hurricane aircraft was a relatively easy type to fly if the pilot was in the middle of the flight envelope during manoeuvres. At the edge of the flight envelope, however, specific flight characteristics, unique for this type, were beginning to show. His effort to tighten the turn was the most relevant for the critical manoeuvre either after reaching a certain g-load factor or when flying in a slip with the left leg declutched. We all were aware of these characteristics and often discussed them. As he was a very experienced pilot who also worked as a test pilot in Aero Vodochody, I thought he was sufficiently aware of this fact and I had no doubt that he would be careful in the future."*

As regards stall characteristics, he said: *"The stall characteristics of the Hurricane aircraft were in many ways typical of this category of aircraft. The warning of reaching the critical angle of attack was not very pronounced as it appeared in the last minute and died away in omnipresent vibrations. If the critical angle of attack is exceeded, the right wing usually sinks. Recovery is standard, but it required several hundreds of feet. For the Hurricane aircraft, the combination of a late warning with a high altitude necessary for recovery was relatively dangerous. However, we all were aware of this."* He also mentioned other characteristics of the Hurricane aircraft that could have also contributed to the cause of the air accident: *"Rather negligible signs that could have warned the pilot of slipping or skidding-in and rather poor ability to detect speeds below 150 kt by feeling. In the first case, it was necessary to monitor the inclinometer where, contrary to the customs, the British aircraft have a needle pointing upwards instead of a ball. In the second case, it was necessary to carefully monitor the speed indicator. The course of forces in the pitch control differed in some manoeuvres from the customs and it was especially true when flying in a slip, in particular, the right one."*

As for the above-mentioned sensitivity of the Hurricane aircraft in terms of slipping, another pilot said: *"It was manifested when upon left leg declutching the pitch started increasing and upon right leg declutching the pitch started decreasing. The Flight Manual even warns that*

if the pilot does not reset the rudder trim after take-off, leaving it in the fully right position, as the speed rises, the pitch increases ("heavy nose") and the aircraft seems to be unstable in terms of pitch. The control force may then reach such values that the pilot does not have a sufficient force to recover the nose-dive flight until he slightly declutches with left leg. On the other hand, prior to achieving the critical angle of attack, with the right leg, the aircraft seems stable (decreasing the pitch), with the "ball in the middle" as almost neutral, and with the left leg as unstable and starting slightly stalling."

2 Analyses

The air accident occurred during an aerobatic manoeuvre – sharp descending turn at a slow speed when the aircraft in low altitude above the ground stalled, asymmetrical flow separation on the wing occurred, the pilot lost control of the aircraft and the aircraft crashed against the ground. No device whose data records could be used in analysis of the critical flight phase was present in the aircraft.

2.1 Qualification and Health Condition of the Pilot

The pilot was a holder of the licence of corresponding qualifications and had years of experience as an instructor, examiner and test pilot.

He became a display pilot in 2019. Due to the drop in the number of air shows during the period when anti-COVID-19 measures were in force, he had relatively little performance record.

The pilot's competence for aerobatic performance with the Hurricane aircraft was verified by the supervisor and the pilot was a holder of a valid Aerobatic Performance Approval. The pilot presented the aerobatic performance with the Hurricane aircraft at the Flying Display on 13 and 14 August 2022 for the first time. He did not practise the performance set in order to verify it given the space for performers at LKCB.

The pilot held a valid medical certificate. The pilot's health was good. The comprehensive forensic medical examination discovered no current changes in the pilot's condition that could have been considered as a causal link with the air accident. The pilot was not under the influence of alcohol or any other substances prohibited for aviation duty (medicines or psychotropic drugs).

2.2 Aircraft

It had a valid airworthiness inspection certificate and valid statutory liability insurance coverage. During performing the flight at the Flying Display on 13 August 2022, the pilot did not notice any defect that could endanger the safety of the flight. The calculation based on the estimated fuel weight at the time of the air accident shows that the aircraft was operated within the permitted weight and balance. On the basis of video footage, checking of pilot's movement during manoeuvres, and debris inspection, no evidence of a defect or failure that would contribute to the occurrence of the air accident was detected.

2.3 Conditions for the Flight

The meteorological conditions were in compliance with prescribed minimum values for performing flights at the Flying Display. There were no dangerous weather phenomena during the flights at the Flying Display.

2.4 Aerobatic Performance on 13 August 2022

The analysis of the videos and the observations of another pilot show that the aerobatic performance on 13 August 2022 corresponded to what the pilot had trained on the Hurricane and AT-6 Harvard aircraft and it was in compliance with the Aerobatic Performance Approval. The performed manoeuvres, including aerobatic ones (two consecutive half-loops and rollouts – Cuban-Eight) were well managed by the pilot.

2.5 Critical Flight

2.5.1 Aircraft undercarriage indication issue

Approx. 3 minutes after the take-off, the pilot reported an indication of extended undercarriage to the RADIO unit and asked for information whether the undercarriage was extended. He made several passes above the airport during which the RADIO unit could not see the undercarriage extended. The pilot received this information. The pictures taken during the performance of the Hurricane aircraft show the undercarriage in the retracted position. The likely cause of the indication of the extended undercarriage could be a malfunction of the limit switch. The pilot could visually check the undercarriage retraction by looking through the transparent panels. All in all, whether the indication of the extended undercarriage continued or not, the pilot subsequently started the aerobatic performance.

2.5.2 Aerobatic performance

The pilot first carried out two manoeuvres similar to those of 13 August 2022. The piloting method was slightly different. During the previous performance, the pilot made the Half Cuban-Eight with a half-roll after passing the top point, when descending at an angle of approx. 20 degrees. During the critical flight, the pilot started the half-roll sooner, just behind the top, visibly tightening, which caused a significant error in the direction of the audience. He then corrected the error in the descending part so that he would not fly over the performance limit. The second manoeuvre differed by the barrel performance of the climbing Derry Turn. Originally, the pilot made this manoeuvre using axial rolls. According to another pilot's statement, the conduct of the turn during the critical flight was safe.

After two aerobatic manoeuvres, the pilot made a pass at a low altitude, turned in the opposite direction by means of a slight left-hand wingover, and having passed at a low altitude, made a slight right-hand wingover followed by an abrupt left turn, levelling off for a pass along the line of RWY 23. From the beginning of the aerobatic part of the performance, the set lasted 2 minutes.

2.5.3 Critical manoeuvre

The pilot started the critical manoeuvre by climbing where, based on the video footage analysis, approx. after 4 s, he put the aircraft in a climbing right turn with a continuous increase of the roll up to approx. 90 degrees on its top. Having climbed, the aircraft was probably in the speed instability mode. In the sharp turn with a large roll, the aircraft was quickly decelerating.

We are not sure why the pilot attempted the manoeuvre in this way. One possibility is that he decided for such a manoeuvre in order to avoid the built-up area with family houses in the municipal district of Podhrad at a low altitude. If, given the information about the remaining time until the end of his performance he intended to carry out the final pass (by a turn with a slight roll towards the audience) to finish his performance, he probably tried to accelerate the reverse turn in a small space. Nevertheless, during the critical manoeuvre, he was too close to the airport and the space for spectators. He might have also responded

to the fact that during his performance on 13 August 2022, before the final pass, he made a reverse manoeuvre by a right-hand turn and the manoeuvre required too much space.

Having turned by some 90 degrees, the pilot continued by transitioning into a sharp descending turn. The video footage analysis shows that when the aircraft turned by approx. 120 degrees, the roll reached approx. 45–60 degrees and the angle of descent was 35–45 degrees. Based on the evidence from the video footage, there was clear action in roll control, ailerons deflection counter the roll to the right, but, at the same time, a sudden increase in the aircraft roll and pitch. It is obvious from the analysis of video footage and detailed photographs that the aircraft rudder trimmer tab was in the position for take-off – left-hand side. The rudder was therefore slightly tilted to the right. It contributed to creation of non-standard control forces at higher speeds and with a lower engine mode in comparison with other aircraft.

It is highly probable that in a sharp turn, the speed decreased below the stall speed, the aircraft stalled, asymmetrical flow separation on the wing occurred, and the aircraft started autorotating to the right. For less than 1 s, the roll decreased, but then, approx. 1.5 s before the aircraft hit the ground, it was quickly rolling to the right and the descent became steeper. Just before the crash, the nose slightly rose, but the altitude was not sufficient for the aircraft to level off. At a small angle of pitch, the aircraft crashed on the ground with the lower part of its fuselage and the right half of its wing.

3 Conclusions

3.1 Findings

- The pilot was fully qualified to carry out the flight, was medically fit and was a holder of the aerobatic pilot licence for aerobatic performance with the Hurricane aircraft in air shows.
- The performance on 13 August 2022 was in compliance with the Aerobatic Performance Approval and the conducted aerobatic and other manoeuvres were well managed by the pilot.
- On 14 August 2022, it was the pilot's second public aerobatic performance with the Hurricane aircraft during the Flying Display.
- The aircraft was airworthy and was duly maintained.
- The weight of the aircraft was within the prescribed limits.
- There was no evidence of a defect or failure that could have contributed to the occurrence of an air accident.
- After take-off, the pilot detected a signal of extended undercarriage and asked for a check of the undercarriage state.
- The performance set on 14 August 2022 differed from the performance set on 13 August 2022 in terms of manoeuvre types and execution.
- During the performance on 14 August 2022, the pilot first carried out two aerobatic manoeuvres in a different way than in the previous aerobatic performance, with positive load factors.
- During the last manoeuvre, the pilot made a steep climb with transition to a sharp turn.

- When the pilot started the descending phase at the top of the manoeuvre, the aircraft was probably in the second mode.
- The air accident occurred in a sharp and steep descending turn which the pilot probably used to attempt faster turning to the opposite direction in a small space.
- During the sharp and steep descending turn, the speed dropped below the stall speed corresponding to the roll and the aircraft stalled.
- As autorotation occurred, given the steepness of aircraft pitch, the altitude above the ground was not sufficient for recovery which the pilot attempted.
- It is not possible to confirm that the pilot was fastened with safety belts at the time of air accident.
- The aircraft was destroyed by a strong impact of the lower part of the fuselage, wing and running engine onto the ground and subsequent crash into the structure of the natural gas control station and the concrete power line column.

3.2 Air Accident Cause

The cause of the air accident was the pilot's attempt to make a vertical manoeuvre to quickly reverse the flight direction using a sharp and steep descending turn in a small space when the aircraft stalled and started autorotating. Given the steep aircraft position, the altitude was not sufficient for recovery which the pilot attempted. As a result, the aircraft crash against the ground.

3.2.1 Factors that contributed to the occurrence of the air accident:

- Resolving the issue with fastening of safety seat belts;
- Resolving the undercarriage state during the flight before the performance;
- Change in the set of presented manoeuvres after the start of the performance.

4 Safety Recommendations

The AAII has not issued any safety recommendations.

4.1 Measures Taken by the Aircraft Operator

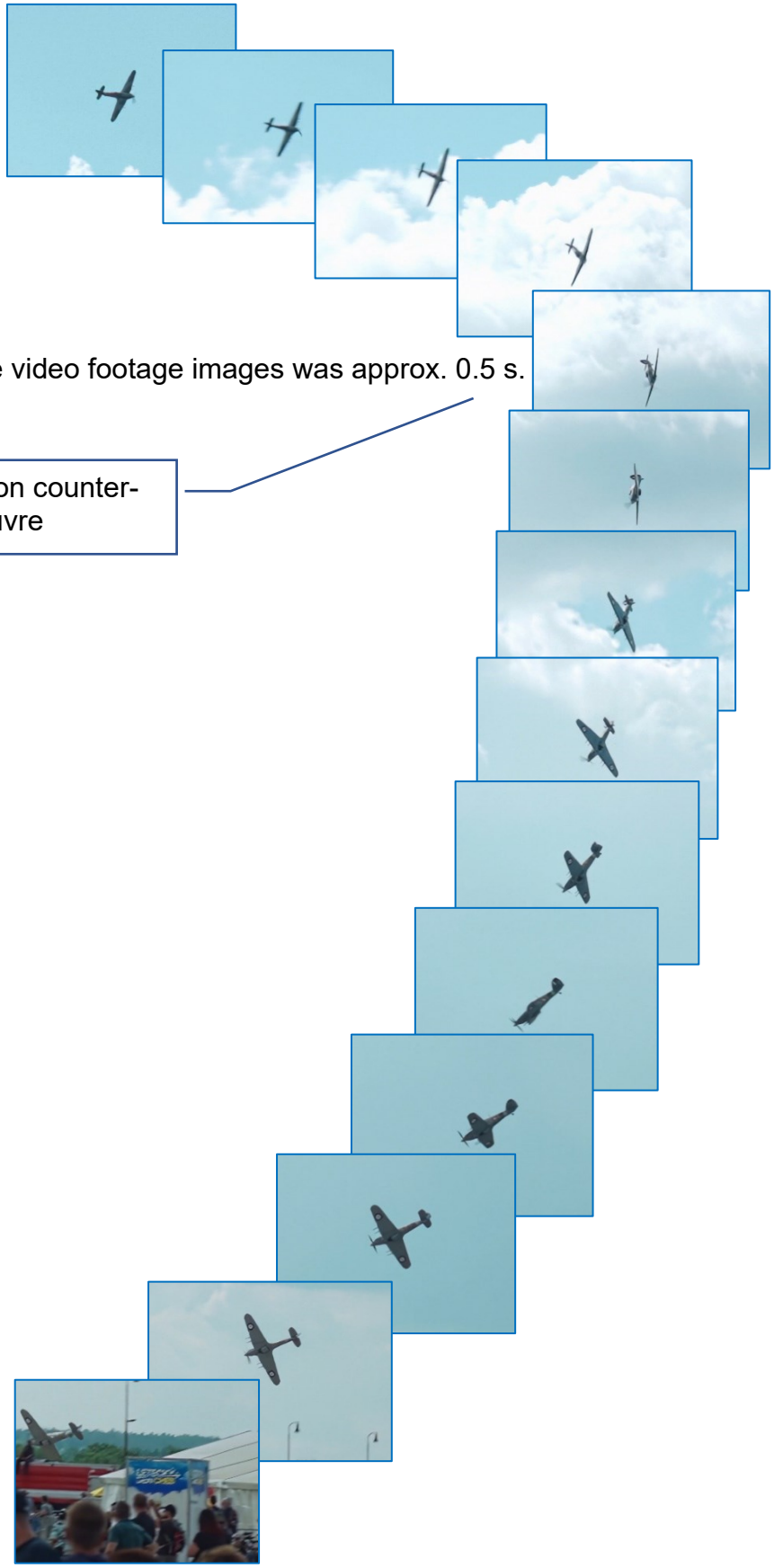
Based on the evaluation of probable contributing causes, the operator adopted internal measures for historical aircraft performances on air shows and for risk assessment. In particular, attention shall be paid to the hours flown by the crew and the implementation of an independent flight readiness review.

5 Appendices

Appendix No. 1 Aircraft positions during the descending phase of the critical manoeuvre

Appendix No. 1

Aircraft positions during the descending phase of the critical manoeuvre according to the video footage



The interval between the video footage images was approx. 0.5 s.

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