AIR ACCIDENTS
INVESTIGATION INSTITUTE
Beranových 130
199 01 PRAGUE 99

CZ-19-0144

FINAL REPORT

**Investigation of causes of an accident
helicopter ENSTROM 480 B
registration mark OK-CLV
on the field near Blažkov,
on 22 March 2019**

Prague
March 2020

Contents

Abbreviations Used

Ac	Altocumulus
ACC	Air Control Centre
AFIS	Aerodrome Flight Information Service
AGL	Above ground level
ALT	Altitude
AME	Aviation Medical Examiner
AMSL	Above mean sea level
ATO	Approved training organisation
BASE	Cloud base height
BKN	Broken
Ci	Cirrus
CG	Center of gravity
PPL (H)	Commercial Helicopter Pilot Licence
CHMI	Czech Hydrometeorological Institute
E	East
FI	Flight Instructor
FL	Flight level
FEW	Few (amount of clouds)
GS	Ground speed
ARS	Air Rescue Service
FRS	Fire Rescue Service
ICAO	International Civil Aviation Organisation
IFR	Instrument flight rules
IRS	Integrated rescue system
KIAS	Knot indicated air speed
L	Left
FIR	Flight information region of Prague
LKHK	Domestic public / international private airport Hradec Králové
LKNM	Public domestic airport Nové Město
ARS	Air Rescue Service
MSL	Mean sea level
N	North
NIL None	
PA	Pressure altitude
PPL (H)	Private helicopter pilot licence
R	Right
REG QNH	Regional pressure, the lowest atmospheric pressure in the area (reduced to mean sea level according to standard atmospheric conditions)

ATCS	Air traffic control service
RWY	Runway
QNH	Atmospheric pressure in the area (reduced to mean sea level according to standard atmospheric conditions)
SYNOP	Report on surface synoptic observations made by weather stations
SCT	Scattered
CET	Central European Time
SSR	Secondary surveillance radar
TOW	Take-off weight
CAA	Civil Aviation Authority
UTC	Coordinated Universal Time
AAII	Air Accidents Investigation Institute
VDL	Correction for defective distant vision
VFR	Visual Flight Rules
V_{NE}	Not-to-exceed airspeed
VRB	Variable
MIFM	Military Institute of Forensic Medicine

Used Units

Ah	Ampere hour
°C	Degree centigrade
cm	Centimetre
ft	Foot (unit of length – 0,3048 m)
g	Normal acceleration
h	Hour
hPa	Hectopascal (unit of atmospheric pressure)
in	Inch (unit of length – 2.54 cm)
km	Kilometre
kg	Kilogram
kt	Knot (unit of speed – 1.852 $km.h^{-1}$)
lb	Pound (unit of weight – 0.445 kg)
m	Metre
min	Minute
m^3	Cubic meter
MHz	Megahertz
V	Volt

A) Introduction

Operator:	legal entity
Aircraft manufacturer:	Enstrom Helicopter Corporation, USA
Type of aircraft:	ENSTROM 480 B
Identification mark:	OK-CLV
Location of incident:	Field at the east end of the village of Blažkov
Event date and time:	22 March 2019, 08:15 UTC

B) Synopsis

On 22 March 2019, the AAII received an accident notification of the ENSTROM 480 B helicopter on the field 100 m east of Blažkov near Nové Město nad Metují. A student pilot, a foreign national, (hereinafter the “pilot”) was conducting a training flight together with the pilot-instructor (hereinafter the “instructor”). It was air drill for instrument flight according to training syllabus approved by the foreign customer ordering the training. Following approx. one-hour flight, the pilot made two left turns by 360 degrees. Having completed them in the heading of 060 degrees at the altitude of 4500 ft AMSL, he went on making a continuous right turn. Having turned by some 270 degrees, the helicopter ended up in an unusual “upward” position. In this position, at a sharp nose angle of approx. 20 degrees, the helicopter was descending abruptly and then exploded when crashing on the ground. Due to the crash and subsequent fire, the helicopter was totally destroyed. The crew died in the helicopter wreckage.

An accidental witness reported the accident to the operator at the emergency number 158. The Police of the Czech Republic, the FRS, the ARS helicopter, and the AAII inspectors with a forensic doctor arrived at the location of the accident and performed professional investigation of the location and of the helicopter wreckage, including the crew corpses.

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

Investigator-in-charge:	Ing. Josef BEJDÁK
Commission members:	Karel BURGER
	Doc. MUDr. Miloš SOKOL, Ph.D., VÚSL Prague

The Final Report was issued by:

AIR ACCIDENTS INVESTIGATION INSTITUTE
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Dated: 09 March 2020

This Final Report consists of the following main parts:

1. **Factual Informations**
2. **Analyses**
3. **Conclusions**
4. **Safety Recommendations**
5. **Annexes**

1. Factual Information

1.1. History of the Flight

Instructor's colleague, who took part in organised flights in training of foreign student pilots, and the persons observing the helicopter shortly before the critical flight phase provided the following information about the course of the flight.

1.1.1. Circumstances preceding the event flight on the day of the accident

The instructor met with his colleague in the operator's office on Friday at 05:40. The instructor's colleague described their joint activities within the planned flight. In his testimony, he said exactly: "*(Instructor's name) seemed refreshed, full of energy and vigour, looking forward to instrument flying on that day. We had a chat and explained the flight tasks and the methods. After that, at 7:00 (CET), (instructor's name) gave the students the morning briefing lasting 40 minutes. During the briefing, he and the students went through the information regarding weather forecast, areas, NOTAMs, and individual flight tasks we were supposed to fly during instrument flying. I prepared the flight schedule of the day.*" It was obvious from the flight schedule of the day that the instructor had planned four flights with four foreign pilots. Two flights were planned for the morning from 07:00 to 08:30 and from 09:00 to 10:30. After a lunch break, two afternoon flights were planned from 11:30 to 13:00 and from 13:30 to 15:00. He further said: *"After that, we gave the first students a solo briefing and then went to the helicopters to carry out a standard pre-flight inspection. On the way, we agreed that I was taking the area north of Hořice as on Wednesday, and (instructor's name) was taking the area around Dvůr Králové and Nové Město, and that we would be maintaining clone on the common frequency of 123.450 MHz. (Instructor's name) was departing from the airport at about 8:10 (CET), approx. 5 minutes after me.*"

1.1.2. Witnesses' Observations

The witnesses testified that shortly before the accident, they saw a helicopter flying over the fields between the villages of Slavoňov and Blažkov, and described the critical situation that ended up by its fall. The witnesses found themselves at various locations in the close vicinity of the above mentioned municipalities and at different distances from the place of the helicopter crash on the ground.

Witness No. 1, who was training horses at a distance of approximately 1,100 m eastward from the place of helicopter crash, literally stated: "*It could have been 09:15 (CET), when I heard the helicopter. It was flying at high altitude from the north and it passed over my head. I then saw the helicopter with my peripheral vision on the eastern edge of the village of Blažkov. I saw papers falling from the spinning helicopter, issuing a fluctuating sound. This is what I heard; something was wrong. It was then nose-diving, and the papers were falling on it. I did not see the impact. Before the crash, it was as if the engine was idle, the sound was continuous, not fluctuating. When the helicopter was falling down, I didn't see any smoke coming out of it. I didn't see any other aircraft or drone. At that time, the weather was fine and the sun was shining.*"

At about 9 (CET), witness No. 2 was walking from home to Nové Město on road No. 285 and was observing the helicopter at a distance of approx. 200 m south-east of the place of crash. He said exactly: "*When I was close to the church in Slavoňov, I heard a strange booming sound. I looked up and I saw a helicopter flying high in the sky. I then paid no more attention to it. I went on and when I was on the plain in front of Blažkov, I noticed an abnormal increase of engine revolutions. I looked up and I saw papers falling from the helicopter. It* *was essentially covered with papers that were dropping on the ground. I noticed that the helicopter was turning around its axis and then started descending at an angle of some 30 degrees. The time that elapsed from the moment I saw the papers falling from the helicopter until the moment of the crash was about 15 seconds. At that time, the weather was fine, the visibility was good, and the sun was shining. I can't recall seeing a drone or aircraft there.*"

At about 9 (CET), witness No. 3 was with her husband at the cemetery in Slavoňov, which is approximately 500 m east of the place of helicopter crash. She said exactly: "*On that day, the weather was beautiful and the sun was shining. A helicopter was flying in circles above us. We said that they might be searching for somebody yet again or taking some pictures. I was watching the helicopter out of curiosity. Suddenly, I heard such a strange sound. My husband confirmed it to me while we were getting into our car. I saw some silver components falling off the helicopter. It was when it was over the field behind the football pitch, on the left side of the road. As we were going by car, I saw the helicopter falling down. It was nose-diving. I called the 158 emergency line from my mobile. After the impact, I saw a flash and immediately, smoke started pouring and we saw flames.*"

At about 9 (CET), witness No. 4 was with his wife at the cemetery in Slavoňov, which is approximately 500 m east of the place of helicopter crash. He said exactly: "*The day was nice, it was sunny and calm. We were watching a circling helicopter and I thought it might be a training flight because it was a smaller helicopter. As we were then standing by our car at a car park, we were still watching the helicopter. The helicopter was making figure-eight turns above the dairy farm and the cemetery. I didn't notice anything suspicious regarding the flight. Later, when the helicopter reached the point over the first intersection on its way towards Blažkov, and, from my perspective, was flying from left to right when it seemingly released some dust. It was still at the same altitude. As soon as the dust was released, the helicopter crashed on the ground. We were still standing by our car. It was nose-diving. I don't remember hearing the engine sound during the fall. I didn't notice anything else flying above us except for the said helicopter. Neither any aircraft nor any drone. As far as I know, there are predatory birds all around, but as I said, I didn't see even a bird. I told my wife to call the police. We got into our car and went round the dairy farm. There is a transit road there. I saw there was an ambulance already at the site and also a fire burning.*"

At about 09:14 (CET), witness No. 5 was in the courtyard of the ZBA Slavoňov facility, which is approximately 350 m south-east of the place of helicopter crash, and was making a phone call on his mobile. He said exactly: "*At that time, a helicopter passed over us maybe three times. It was at an unusually high altitude when compared to other flights. I wasn't watching it all the time, but all of a sudden, I heard a change in the helicopter sound. I immediately looked up and at that moment, I saw some papers falling down. It then turned with its rotor down and another bunch of papers flew out. The pilot was trying to level out; from below it looked as if he was trying to correct the position. Just above the ground, it went down nose first; in fact, it was nose-diving from the higher altitude. I thought it would make a pass, but it failed. I saw it tail up when it was just above the ground. I called the emergency line promptly.*"

At about 09:15 (CET), witness No. 6 was in the courtyard of the ZBA Slavoňov facility together with his colleague, witness No. 5. They were approx. 20 m one from the other and were burning the brushwood. He said exactly: "*Out of a sudden, I saw a helicopter circling above us at high altitude. We thought it was circling above us because they were monitoring us as we were burning something, and we also continued watching it. Suddenly, we heard a hollow sound, and shortly after that, papers started falling down from the helicopter. It then* *started turning to the left and nose-diving. The rotor was down and further papers were falling from the helicopter. The pilot was trying to pass just above the ground, but he failed to do so, and the helicopter crashed on the ground. It all happened in about 5 seconds. It was sunny. I didn't notice any movement of any drone or any aircraft or a larger bird.*"

1.1.3. Description of the flight according to the ACC summary display records

The SSR position symbol appeared on the ACC summary display at 07:19, when the helicopter was flying at ALT 2000 ft approx. 4.7 km north of LKHK and continued climbing to ALT 3000 ft in the area of Nové Město nad Metují. At 08:05, the crew completed the activities over LKNM at ALT 1100 ft and the helicopter continued climbing in the south-east direction to ALT 4500 ft. Having finished their activities over LKNM, both instructors were communicating shortly, and the instructor's colleague literally said in his testimony: "*All was going according to the plan and at 9:05 (CET), (instructor's name) contacted me and asked me how we were doing, what tasks we were flying and that his student pilot was skilful and he was very satisfied. His voice sounded peaceful. I said we were flying well too, and we would be returning back to the Hradec airport in a few minutes. He said he would follow us shortly. We said goodbye and I switched the radio to the first channel with the Hořice airport. I still kept the agreed frequency clone. We then returned to LKHK where I learned upon touchdown that an ARS helicopter flew to a site with a crashed helicopter.*"

At 08:09:57, the crew started making the first left turn by approx. 360 degrees, and completed it in the heading of 060 degrees at 08:11:20 while the helicopter was flying in this heading for 10 s. During the turn, it was flying at ALT 3000–4500 ft at the speed of 60–80 kt. The vertical speed did not exceed the value +/- 600 ft·min^{-1}.

At 08:11:30, the crew started making the second left turn by approx. 360 degrees, and completed it in the heading of 060 degrees at 08:12:30 while the helicopter was flying in this heading for 30 s. During the turn, it was flying at ALT 4400–4600 ft at the speed of 60–100 kt. The vertical speed did not exceed the value +/- 600 ft·min^{-1}.

1.1.4. Critical flight phase

At 08:13:00, at ALT 4500 ft, the crew started making a right turn in the heading of 060 degrees. During the turn, the vertical speed, altitude and flight speed were changing considerably. Approx. 55 s after the start of turning, the helicopter turned upside down. At 08:14:10, the position symbol disappeared from the SSR records. See the following table for flight elements from the last minute of the records.

Tab. 1 – Flight elements from the last minute of the records

Time [h: min: s]	Heading [°MAG]	ALT [ft]	Vertical speed [ft·min^{-1}]	Speed [GS]
08:13:00	062	4500	+906	60
08:13:04	062	4500	0	70
08:13:08	108	4500	0	70
08:13:12	127	4500	0	80
08:13:16	152	4400	-656	90
08:13:20	179	4300	-1112	100
08:13:24	199	4300	-1181	100
08:13:28	220	4300	-925	100
08:13:32	238	4200	-625	100
08:13:36	257	4100	-869	110
08:13:40	280	4000	-1175	100
08:13:44	309	3900	-1425	90
08:13:48	010	3700	-2056	90
08:13:52	342	3500	-2031	90
08:13:56	010	3500	-2000	80
08:14:00	018	3500	-1494	50

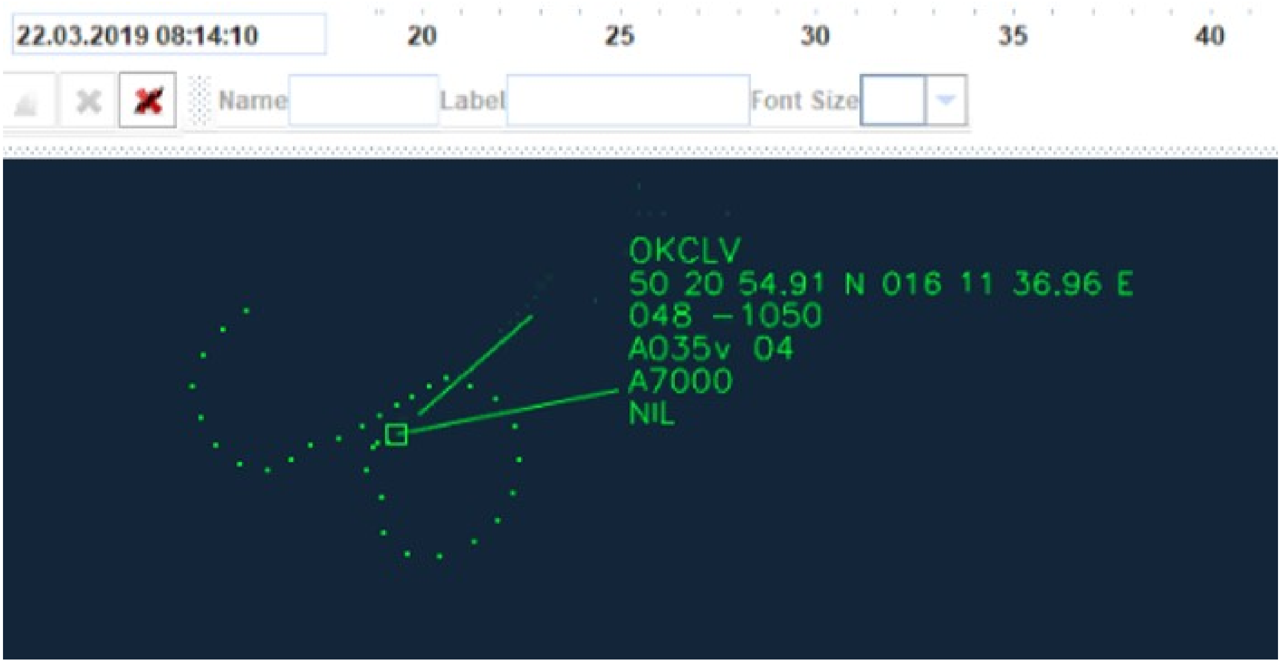


Fig. 1 – Last ACC summary display record

1.1.5. Last 1.2 s of the flight on video

The Commission was able to obtain footage from an industrial camera located on the building of the agricultural firm ZBA Slavoňov. Last 1.2 s of the flight were recorded by an industrial camera located at a distance of approx. 300 m from the place of crash.

Fig. 2 – Individual footage images with an enlarged helicopter in the upside down position

1.2. Injuries to Persons

Tab. 2 – Summary of injured persons

Injury	Crew	Passengers	Other persons (inhabitants, etc.)
Fatal	2	0	0
Serious	0	0	0
Light/No injury	0/0	0/0	0/0

1.3. Damage to Aircraft

Upon its crash on the ground and the subsequent fire, the helicopter was completely destroyed.

1.4. Other Damage

The topsoil contaminated with working fluids, which was underneath the helicopter wreckage and in its close vicinity, has been stripped, and temporarily stored in a transport container. It was altogether about 10 m^3 of soil.

1.5. Personnel Information

1.5.1. Student pilot

Personal data:

- Male, aged 27 years,
- Valid class 2 medical certificate,
- Valid pilot trainee certificate.

Flying experience

The pilot started practice flight training on helicopter Robinson R 22 on 16 October 2018 and completed it on 1 February 2019 (55 hrs and 195 cycles). On 10 December 2018, the pilot started training on R 44 and completed the training on 5 February 2019 (20 hrs and 58 cycles). The training on R 44 was divided into instrument flights (10 hrs 30 min) and VFR night flights (8 h). The training was carried out according to training syllabus approved by CAA for training of helicopter pilots with PPL (H) qualification. The training was always conducted with an instructor on board.

On 5 March 2019, the pilot started training on the ENSTROM 480 B helicopter according to training syllabus approved by the foreign customer ordering the training. Having flown 6 hours, he continued training instrument flights on 18 March 2019. It was a navigation instrument flight lasting 1 hr 30 min. During practical flight training on the ENSTROM helicopter, the pilot had flown for 8 hrs 30 min and performed 34 flights.

Evaluation of the pilot by flight instructors

ATO instructors made records of each flight in the student's checklist where they evaluated the performance of set elements in the given exercise by a grade ranging from 1 to 5 and using verbal report evaluation as well. The pilot received an average grade 3 for flying of the ENSTROM helicopter while the verbal assessment contained frequent comments on the coordination of movements with controllers and inadequate interference with control during VFR and instrument flying.

Tab. 3 – Helicopter pilot's total hours flown recorded in the Pilot Logbook

Hours flown over:	24 hours	90 days	Total
This type of helicopter:	01:00	07:30	08:30
All helicopter types:	01:00	34:30	83:30

1.5.2. Pilot-instructor

Personal data:

- Male, aged 44 years,
- valid class 1 medical certificate with VDL limitation,
- valid Private Pilot Licence with qualification CPL (H),
- valid ENSTROM 480 B helicopter type rating,
- valid EC 135/635, R 44, R 22, HU 269 helicopter type rating,
- valid FI (H) qualification,
- valid ICAO English Level 4 endorsement,
- valid general licence of the aeronautical mobile service radio operator.

Flying experience

The instructor, who commenced practical flight training on the R 22 helicopter in 2007, was in the left seat. He met the conditions for issuance of the Private Pilot Licence in 2008 when his PPL (H) was issued by the CAA on 8 July 2008. He was a valid CPL (H) holder since 29 June 2010. Having flown 835 h, he started the conversion training for the EUROCOPTER EC 135 type on 1 November 2012 and finished it on 11 April 2014 with a licence to fly as helicopter captain on EC 135 T1/T2/T2+. He had extensive flying experience with the EC 135 helicopter with which he regularly flew in HEMS. According to the data recorded in the Pilot Logbook, his total hours flown amounted to 2,214 hrs 39 min on five helicopter types (R 22, R 44, HU 269, EC 135/635, ENSTROM 480 B). He flew a total of 51 hrs 59 min as an instructor.

He started his type transition training for ENSTROM 480 B on 28 November 2018 and completed it by proficiency check on 30 November 2018. On 8 January 2019, he performed a check flight on the type within the FI qualification. Further check flights followed on 20 and 21 February 2019 to acquire a licence for instrument flights and NIGHT FI on the ENSTROM 480 B type. He commenced the training of student pilots with the ENSTROM 480 B helicopter on 20 March 2019. Since that time, the helicopter flew 5 h 30 min and performed 4 flights, including the event flight. He was flying for the first time with the event flight pilot.

Tab. 4 – Helicopter pilot-instructor’s total hours flown recorded in the Pilot Logbook

Hours flown over:	24 hours	90 days	Total
This type of helicopter:	01:00	08:00	14:00
All helicopter types:	01:00	41:03	2,214:39

1.6. Aircraft Information

1.6.1. General Specifications of the Aircraft

The ENSTROM 480 B helicopter is a light multi-purpose, five-seat, all-metal helicopter with one three-bladed left-hand main lift rotor and one two-bladed tail propeller. It is equipped with a fixed skid landing gear. The main structural material of the cabin is laminate. The helicopter has an enclosed glass fibre cabin with maximum seating capacity of 2+3 seats; it can be accessed through left and right doors. The doors are front-opening. The helicopter is controlled by one pilot always from the left seat. Under the helicopter operator’s internal regulation, pilot training was always organised with the student pilot sitting in the right seat.

The helicopter is powered by one Rolls-Royce 250C20W turboshaft engine. Power is transmitted from engine to the main rotor shaft using two pulleys driven by a multi-ribbed belt. The tail rotor is driven by the transmission shaft on the outer upper part of the tail beam.

The helicopter is certified only for VFR operations.

1.6.2. Crashed helicopter

The ENSTROM 480 B helicopter, Identification Mark OK-CLV, was fitted with the Garmin G1000H glass cockpit in the P/N 4220650-3 configuration.

Fig. 3 – Garmin G 1000H system integrated into the instrument panel

Prior to the event flight, fuel tanks were filled with the JET A1 kerosene up to the amount of 400 lb, representing approx. 67 per cent of the full tank volume. Upon the crash on the ground, there were approx. 200 lb of kerosene in the helicopter tanks.

Type:	ENSTROM 480 B
Identification mark:	OK-CLV
Manufacturer:	Enstrom Helicopter Corporation, USA
Year of manufacture:	2018
Serial number:	5244
Certificate of airworthiness inspection:	valid
Total hours flown:	65 h 45 min
Liability insurance:	Valid until 30 June 2019

Propulsion unit:	
Engine/Type:	Turboshaft Rolls-Royce/250C20W
Manufacturer:	Rolls-Royce, United Kingdom
Serial number:	CAE-845405
Year of manufacture:	2018
Total hours flown:	65 h 45 min

1.6.3. Helicopter Operation

The helicopter was purchased from the manufacturer by the Czech owner in 2018 and recorded in the Aircraft Register of the Czech Republic on 17 December 2018. It was flying under the OK-CLV identification mark for the operator. The helicopter was used mainly for training of foreign pilots.

Fig. 4 – Crashed Enstrom 480 B helicopter, identification mark OK-CLV.

1.6.4. Determination of the not-to-exceed airspeed V_{NE} for the event flight

Procedure for individual calculations and V_{NE} determination complies with the Flight Manual of the helicopter ENSTROM 480 B, serial number 5244, Chapter 6 – Mass and Centre-of-gravity Location and Chapter 1 – Operating Limitations

- Calculation of the total weight (TOW) and take-off torque,

	Weight [lb]	Arm [in]	Torque (in·lb)
Empty helicopter	1,920	145.05	278,469
Pilot	199	99	19,701
Instructor	176	99	17,424
Baggage	15	119	1,781
Fuel	400	145	58,000
TOW	2,710	-	375,406

- Calculation of the centre-of-gravity location L_{CG},

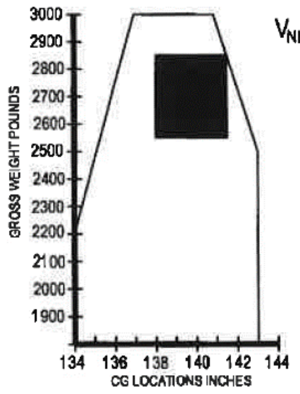
L_{CG} = torque/TOW

L_{CG} = 375,406/2,710

L_{CG} = 138.52 in

- Finding the relevant placards and determination of V_{NE},

The set of relevant placards No. 1–11 is placed over the instrument panel in the pilot's visual field (Fig. 3). For the placards see the Flight Manual, p. 1-27 through 1-32. According to the chart on p. 1-20, we can determine the relevant placard for the centre of gravity within the range from 138.51 to 141.5 in. CG and ALT 4,500 ft – it is ENVELOPE 7. Under the conditions when ALT is 4500 ft, REG QNH 1,029 hPa, PA 4,068 ft, and air temperature is +5°C, the placard specifies V_{NE} 93 KIAS.



V_{NE}-KIAS(KNOTS) TAKE OFF GROSS WEIGHT 2551 LBS TO 2850 LBS C.G. AS SHOWN

PRESSURE ALTITUDE	OUTSIDE AIR TEMPERATURE °C °F								
°C	-34.5	-29.0	-18.0	-6.5	4.5	15.5	26.5	38.0	49.0
°F	-30	-20	0	20	40	60	80	100	120
SEA LEVEL	110	110	110	110	110	110	104	98	93
2000	110	110	110	110	104	98	93	87	82
4000	110	110	106	99	93	87	81	76	71
6000	105	101	94	88	82	76	70	65	60
8000	93	90	83	77	70	65	59	54	
10000	81	78	71	65	59	54			
12000	70	66	60	54					
14000	58	55							

ENVELOPE 7

Fig. 5 – Placard No. 7 (the set of relevant placards No. 1–11 is placed over the instrument panel in the pilot's visual field)

1.7. Meteorological Information

The analysis of the meteorological situation at 08:15 is based on the expert estimate of probable weather at the place of air accident made by the CHMI for the day of 22 March 2019.

1.7.1. General Weather Information

The situation:	A high-pressure area was influencing the weather on the territory of the Czech Republic.
Ground wind:	VRB up to 4 kt or northern 4–8 kt
Upper wind:	2,000 ft AMSL 060°/05 kt, 5,000 ft AMSL 100°/06 kt
Visibility:	over 10 km
Weather:	Few of cloud amount, scattered clouds
Cloudiness:	FEW/SCT Ac, Ci, BASE above FL 100
Turbulence:	NIL
Ice:	NIL
Zero isotherm level:	FL 075-095
Regional QNH:	1,029 hPa at 06:00−09:00 UTC

1.7.2. Abstract from SYNOP reports

Tab. 5 – An extract from SYNOP reports from the closest professional weather stations of the ACR and CHMI. Polom (POL), Pardubice (LPD) and Ústí nad Orlicí (UOR) on 22 March 2019 at 08:00 UTC.

Station code	Visibility [km]	Wind direction	Wind velocity [m·s^{-1}]	Cloud [oktas/m AGL]	Temperature [°C]	Dew point [°C]
POL	15	340°	3	3 Ci/6 900	9.6	4.0
LPD	20	030°	2	6 Ci/7 200	8.3	2.0
UOR	15	VRB	1	4 Ci/9 000	7.0	3.3

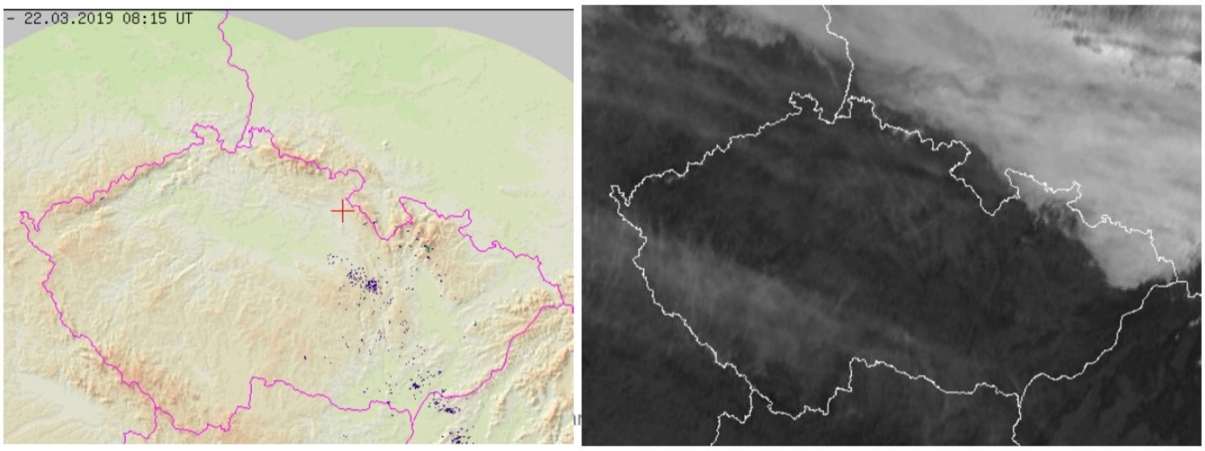


Fig. 6 – Radar and satellite images (the cross marks the location of Nové Město nad Metují)

At the time and place of the accident on 22 March 2019, the sky was clear with a few clouds up to scattered clouds with occurrence of clouds only of Ci type. Temperature stratification was stable. Visibility was over 10 km (15–20 km). Air temperature equalled some 9°C and humidity was around 60–70%. Wind was blowing from the northern direction or varied at a speed of 4–8 kt without gusts. The upper wind at the level of 5000 ft AMSL was blowing from the north-eastern direction at the speed of 6 kt, air temperature was around 4°C. There were no dangerous weather phenomena.

Fig. 7 – Photograph taken by the aircraft pilot during the flight over LKNM approx. at 07:30.

1.8. Radio Navigational and Visual Aids

The crew was conducting a VFR training flight within the airspace of class G and E. The pilot was instrument flying the helicopter as instructed by the instructor. The instructor was keeping the helicopter positioned within the said airspace based on comparison orientation.

Visual aids at the LKHK corresponded to the airport category in line with L-14 (ICAO Annex 14).

1.9. Communications

On the day of the accident, the AFIS service at the LKHK was activated in compliance with the VFR Manual Czech Republic issued by the Flight Information Service of ŘLP ČR, s.p.

The helicopter crew was communicating with the LKHK AFIS station on 122.005 MHz frequency. The crew of the other ENSTROM 480 B helicopter was flying within the airspace north of Hořice. Pilot-instructors of both helicopters were maintaining clone during the flight and shortly communicated on 123.450 MHz frequency.

1.10. Aerodrome Information

The crew took off and planned landing at the Hradec Králové airport. LKHK is a domestic public / international private airport. It has two runways, concrete 15L/33R 2,400 m long and 60 m wide, and grass 15R/33L 800 m long and 25 m wide. The airport is approved for VFR Day/Night operations. The aviation training centre carries out specific training with helicopters in compliance with the Airport Regulation.

1.11. Flight Recorders and Other Means of Recording

No logger, the record of which might be used in the flight analysis, was installed on the helicopter board.

The ACC summary display records showed the route of the event flight at the given place at that time. The Commission used the records of the last two minutes of the event flight as background material (flight altitude) for determination of the not-to-exceed airspeed V_{NE}. Furthermore, the records were used to calculate the approximate airspeed values and their comparison with V_{NE}.

1.12. Wreckage and Impact Information

1.12.1. Wreckage and Impact Information

The helicopter crashed on the grain field (approx. 10 cm high) at a distance of approx. 100 m far from the eastern edge of the village of Blažkov. For a precise location of the impact place see the below table.

Tab. 5 – Coordinates of air accident site

Geographical coordinates:	N 50°20´47,526´´
	E 016°11´31,713´´
Altitude:	420 m

The considerably deformed and burnt helicopter fuselage was lying upside down with its nose pointing north-east. The helicopter frame was damaged by the forces generated by the helicopter impact at a sharp angle in the upside flying position with simultaneous forward movement. Subsequently, the fuselage was destroyed by fuel explosion and fire (JET A1 kerosene) which splashed out from fuel tanks upon the crash on the ground. Various significant construction elements disintegrated from the helicopter fuselage upon the crash on the ground were located both in the close proximity and in the surrounding area of the wreckage. Upon the first contact of the main rotor, one of the three blades (T2) was separated and found approx. 48 m north of the wreckage. The left stabiliser was found north of the wreckage at a distance of approx. 20 m. The fragmented accumulator was found north-east of the wreckage at a distance of approx. 25 m.

South of the wreckage, at a distance of approx. 300 m, a number of paper documents were scattered over the field. A bag with documents and a few pieces of the plexi-glass glazed overhead window were found in this area.

Fig. 8 – Helicopter wreckage at the place of crash

1.12.2. Pilot cabin technical inspection

During the impact, primarily the pilot cabin was destroyed. Majority of the glass areas in the cabin, except for a few larger pieces in the overhead windows, were found scattered in the helicopter surroundings at the impact site. The frames of the chin windows were loosened from the front lower part of the cabin. The front part was made of laminate shell that was destroyed by the impact and only fragments of the fibreglass cloth and the landing headlight remained from the whole structure. Fragments of the lower parts of the cabin frame in the door area were preserved. Both the doors were found in the vicinity of the helicopter. The windows were missing from the doors. The doors were seriously damaged by fire. The right door was severely devastated by the fire. The handle and lock were missing from this door. Only the fibreglass cloth was remaining in greater part of this door. Two securing pins were preserved. Both of the pins were in the extended position confirming that at the moment of impact the door was closed. The left door was found on the right side of the helicopter in the distance of approx. 1.8 m. An unharmed pneumatic brace was fixed to it, in an extended position. The condition of the said pneumatic brace showed that at the time of impact this brace was in retracted position. The door was closed. The closed position of the door was confirmed also by the control lever position, the lock position, as well as the extended position of the securing pins. Due to intensity of fire, only the parts with hinges remained preserved.

1.12.3. Pilot seats technical inspection

Both the pilot seats were damaged mechanically and by fire. The degree of mechanical damage to the seat construction caused the seat cushions were torn apart from the backrests and bent by some 40° downwards. The rear side of the seats, the cushions, as well as the backrests showed distinct traces of damage caused by the burning fuel. The seats attachment rails were deformed, partly melted by the fire, partly mechanically damaged – broken apart. Guiding and securing parts of the seats on the bottom part were damaged in the accident by fire. Until the moment of impact, these parts of the seats had been fixating the seats in the selected positions. At the moment of impact, the right seat was torn out completely from the guiding rails. The left seat remained fixated in its guiding rails. The positions of the seats at the accident site and the mechanical damage to their structures corresponded with the helicopter impacting the ground in the upside down position. The back (middle) seat and part of the back partition in the cabin separating the cabin area from the engine area was deformed by the explosion and destroyed in the subsequent fire.

Both the pilots had the safety belts on, fastened, the locks of the buckles were locked. Greater parts of the safety belts were preserved on the bodies of the pilots. Parts of the safety belts in the points of their attachment to the seat were separated from the belt by fire. The clips attaching the belts were functional and unharmed.

1.12.4. Controls technical inspection

The helicopter flight controls are entirely mechanical applying control rods and transmitting bellcranks. The cyclic is equipped with two kinematically mutually joined control levers. Collective control and throttle control was performed by levers placed to the left from the pilot seats. Each of the collective control levers had a rotating handle controlling the engine output power. The left lever of the collective control was equipped with a friction arresting system. The tail rotor was controlled by pedals via cables and pulleys.

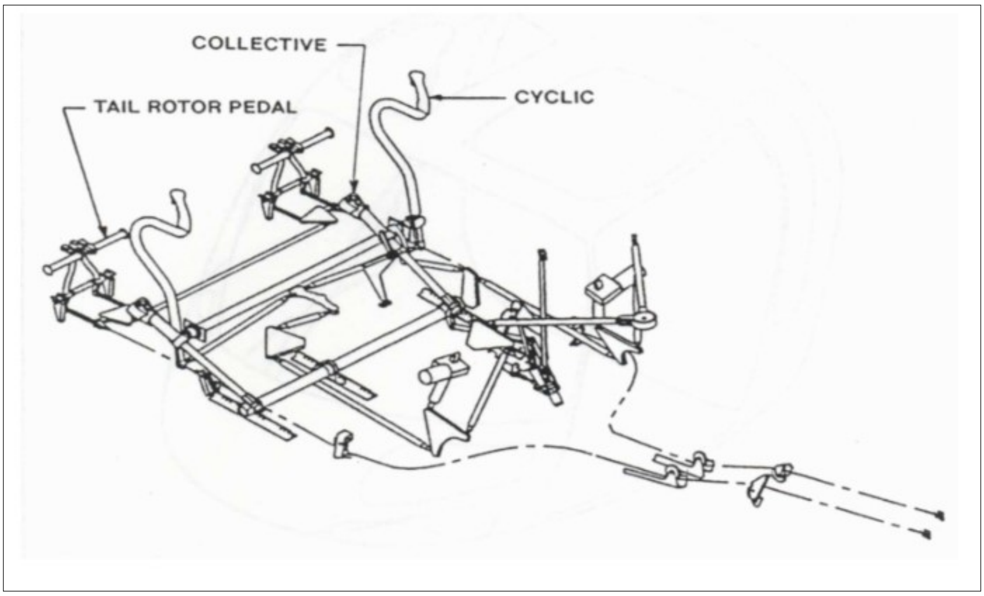


Fig. 9 – Diagram of the helicopter controls

All the controls in the pilot cabin were damaged due to the impact to the ground and subsequent fire. All the controls were disconnected from the rods, mostly broken at the attachment points of bellcranks. The control cables of the tail rotor were disconnected from the pedal control levers linkage as a consequence of fire and explosion. The cables were annealed in the area where the fire took place. All the pulleys were affected by the fire, but the cables laid in them were in secure positions. Further, the cables were torn apart in the vicinity of the tail rotor gearbox.

The left lever of the cyclic was bent due to breakage in approx. one third of its length. The plastic handle melted due to the fire. The collective lever was damaged by the fire. The end part connected to the linkage and the engine control cable outlets were melted by the fire. The left pedal was damaged by the fire. The left pedal was broken off from the main part of the foot control. Despite the damage caused by the fire all the parts were demountable and the arresting parts of the foot controls were secured by the securing parts. The connecting rod between the right and left foot controls was broken off from the transmitting elements and also damaged by the fire.

The right cyclic lever was bent and damaged by the fire. The lever of the collective was complete, slightly damaged by the fire in its upper part. Both the levers were melted off in their lower parts and partly broken off from the transmission linkages. The right foot control was damaged by the fire. The pedal rods were melted off in their bottom parts in the connection points with the pedals. The right pedal was deformed, with a great probability, by mechanical forces at the moment of impact. The left pedal was bent from the main part (a bracket of square cross section) in the upward-front direction.

In the helicopter control system, there were installed two electromotors with screw rods used for trimming. Both the electromotors including the screw rods were found as mechanically damaged due to the impact and subsequent fire. Assuming from their condition and traces implying the screw rods positions, it could be assessed that at the moment of the air accident they were fully functional.

1.12.5. Main rotor

The main rotor of the helicopter was a three-blade type with the left direction of rotation. The blade structure was fully metal, self-supporting (hollow), half-shell. The leading edge of each blade is formed by an extruded spar. Each blade had two firm laminated phenolic pads. There was oil in each blade hinge pivot lubricating oil reservoir. The main rotor head was torn into three parts alongside the blade hinges. Two parts remained on the blades. One on 2T blade, and one on 3T blade. The third part of the head together with the blade 1T remained attached to the main rotor shaft. All the breakages and other damage were caused by an extreme strain at the time of impact of individual blades into the ground. Part of the rotor head with the blade 1T and the main shaft were, besides the mechanical damage, also damaged by the fire. The blade controls in the upper part of main rotor head were broken off due to the impact.

1.12.6. Main rotor blades

The principal part of each blade is the extruded leading edge spar and Duralumin skin. Each blade was ended with a Duralumin rib. The upper as well as the lower blade skin were bonded to the leading edge and, along the tracking edge bonded to each other.

During the inspection at the accident site and also during the follow-up inspection at the site of debris storage, it was found that all the bonded joints were of good quality and bore no signs of being open or other damage. All the three blades were functioning properly until the point of impact. The damage to the blades (tearing off of the upper and lower blade skins or, as the case may be, tearing off of the skin from the leading edge) was caused by mechanical forces and deformation forces at the point of impact.

1T blade was found at the accident site alongside the helicopter fuselage. It remained hinged on in the main rotor head. The lead-lag damper and the kinematic elements of the collective were broken off. The breakages were of fragile nature. The blade was bent in the horizontal plane. The leading edge was showing distinct traces of a forcible contact with rocky ground. Upper as well as the lower skins were deformed lengthwise. The lower skin was torn from the leading edge in the length of 3 m from the blade root. The end of the blade was deformed in the length of approx. 2 m and the profile ending of the blade was torn off. The phenolic pad was deformed by the forces of impact.

2T blade broke off from the main rotor head and was catapulted by the centrifugal force to the distance of approx. 48 m from the helicopter debris. First, 2T blade fell with its root part (with the hinge) to the ground and the stabilising rod was torn off. The lower skin of the blade was torn off from the blade leading edge and from the upper skin along almost the full length of the blade. All the bonded areas were clean and compact. In the distance of 1.5 m from the root, there were traces of fuel contamination on the blade surface. The upper skin was torn off from the leading edge in the extent between 1.0 m to 1.7 m from the root. The phenolic pad was torn out from two rivets. The blade leading edge bore traces of forcible contact with soil.

3T blade was found under the helicopter debris, dug into the ground, mechanically the most deformed one of all the three blades. The leading edge was considerably bent along its full length. Both, the upper as well as the lower skin were completely separated from the leading edge.

1.12.7. Main rotor shaft

The main rotor shaft with the main gear around hypoid transmission was found at the accident site to the left from the helicopter debris. At the bottom part, there was the main driven gear with torsos of a ball bearing and main gearbox. From the mechanical traces and damage, it can be assessed that it was broken out from the main gearbox at the moment of the contact of the main rotor blades or of the main rotor head with the ground. The driven wheel cogs were damage free. The bearing was damaged at the moment of breakage of the shaft from the main gearbox. There were no traces of any damage occurring prior to the helicopter impact to the ground. The upper part of the shaft with the rotor head was damaged due to the impact and partially also by the fire.

Three control rods which run axially through the centre of the shaft were mechanically damaged at both ends. The nature of the damage proves that it took place only at the moment of helicopter impact to the ground and during the subsequent fire of the debris.

1.12.8. The tail rotor and its drive

The tail rotor was driven from the upper belt pulley of the main rotor shaft drive with transmission shaft. The rotor was two-bladed, located on the left side of the tail beam. The blade setting controls were mechanical by means of two steel cables running through a system of pulleys. The tail rotor was found partly dug in the ground (one blade) in the distance of approx. 70 cm from the end of the transmission shaft. In the soil, under the tail rotor, the tail gearbox was found and next to it there was a control yoke with the remaining part of the cable duct. Both the blades were deformed by the forces generated due to the rotation of working blades at the moment of contact with the ground.

The transmission shaft was running on the upper side of the tail beam. The connection with the tail gearbox was unharmed. Like the tail beam, approximately in the half of its length, the transmission shaft was broken. From the point of breakage, the transmission shaft was compact including the undamaged connection to the upper belt pulley.

1.12.9. The power plant and the main gearbox drive

The helicopter was powered by one Rolls-Royce 250C20W turboshaft engine. Power was transmitted from engine to the main rotor gearbox using two pulleys driven by a multi-ribbed belt. The power to the tail rotor was provided by the transmission shaft connected to the upper belt pulley of the main rotor gearbox drive.

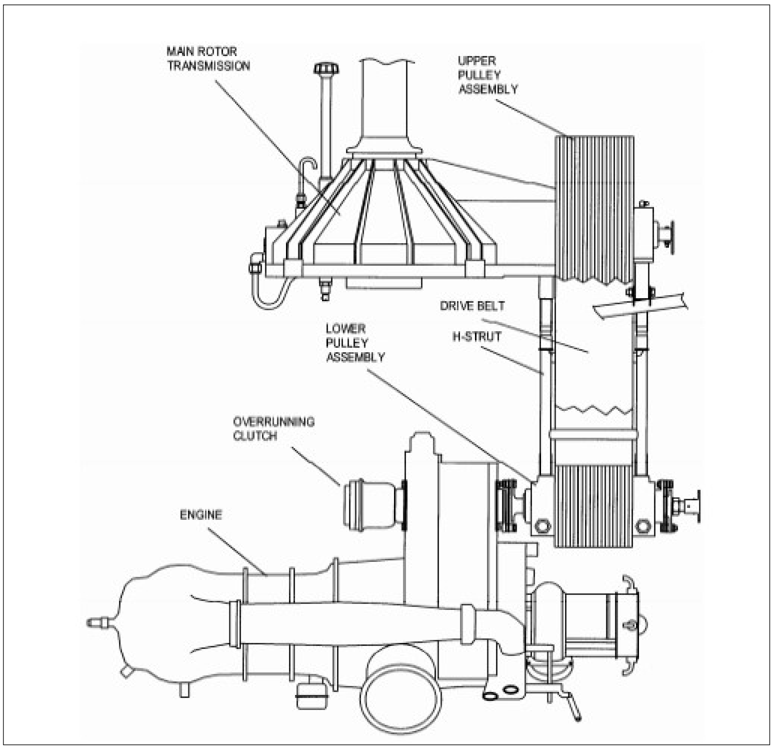


Fig. 10 – Transmission of power from the engine to the gearbox

During the inspection of the power plant (engine, drive box, transmission of power from to the main rotor) it was found that both belt pulleys were damaged by the fire. The multi-ribbed belt burnt completely thus it was not possible to inspect its condition prior to the accident.

The lower belt pulley powered from the engine drive gearbox could be rotated without any resistance. It was disconnected from the engine. The cross connection flange bore traces of cutting of the connecting bolts following the great difference between momentums created by the working engine at high output and a sudden braking of the main rotor at the moment of contact with the ground.

The upper belt pulley driving the hypoid gears of the main rotor shaft were damaged both, mechanically by the forces working at the moment of impact and subsequently by the fire, or more precisely high temperature. The remains of the belt were melted onto its surface. The cogs of both parts of the hypoid transmission (the main rotor shaft cone drive gear and planetary cog) were free of mechanical damage.

1.12.10. Engine and its systems

The air intake system was damaged in the extent exceeding 80 per cent by the fire. The whole system was formed from laminated parts. Only small fragments were preserved. The engine intake system was formed from a flange facilitating the connection of the air intake system and an intake channel with 7 directing vanes. Both, the flange as well as the intake channel were deformed. The first two compressor stages were also mechanically damaged. The compressor box and the diffuser body were free from mechanical damage; they, however, bore traces of having been exposed to high temperature generated by the fire.

The air distributing system (both pipelines) into the counterflow combustion chamber was deformed. The combustion chamber and the generator as well as the gas turbine unit were destroyed by inertial forces during the impact and in the subsequent fire. The exhaust pipes were also deformed by exerting forces during the helicopter impact to the ground. Regarding the fact that the contact of the helicopter with the ground took place when the aircraft was in the upside-down position and the exhaust pipes together with the deflector are on the bottom of the fuselage, their damage was not extensive.

The drive gearbox was torn, broken in transverse direction and partly melted. The individual cogs were unharmed. The traces of usual wear and tear showed that the transmissions had been working properly in a standard manner and there had not been any sign of mechanical defect. In the bottom part of the gear box, there were remnants of oil and the oil remains baked to the walls showed that there was a sufficient amount of oil in the gearbox to lubricate the transmissions to a satisfactory degree. Some aggregates mounted to and driven by the drive gearbox were damaged partially due to the mechanical pressure exerted by the impact and in greater part by high temperatures generated by the fire in which their cases and bodies were partially melted.

The output power controls and engine systems were destroyed mechanically due to inertial forces and by the subsequent fire. Majority of fuel and air pipelines were burnt completely. Only the armoured pipes were preserved albeit damaged by the fire. The metal parts were deformed, the rods, and the bowden cables were bent or broken. Majority of pipes were deformed, none of them, however, was mechanically broken or damaged. The output power control kinematics was, at the time of helicopter debris inspection at the accident site, set to the maximum output power limit.

1.12.11. Electric wiring and power supplies

The main power supplies were provided by electric starter generator 150 SG117Q driven by the engine, and electric accumulator 24 V with 18 Ah capacity. The starter generator stator body was partially melted due to the high temperature generated by the fire. The APC Model GCSG 501-2 generator control unit was torn out from its place of attachment, and it was catapulted to the distance of approx. 8.5 m from the helicopter debris.

The wiring and electrics were damaged by the fire ignited upon the impact. Individual distribution busbars and the fuse block were completely destroyed in the fire. The harness assemblies as well as the individual cables in the engine area of the cabin debris were free from their insulation which burnt in the fire; the cables themselves, however, were not broken at any point.

The accumulator that was located in the right-hand side of the engine area was catapulted upon the helicopter impact onto the ground to the distance of approx. 25 m from the helicopter debris. The videofootage and the traces found in the field showed that the accumulator exploded immediately upon being catapulted from the helicopter debris.

1.12.12. Avionics equipment

The helicopter was equipped with glasscockpit Garmin G1000H. The flight data was shown on the upper display unit (PFD – primary flight display) and the navigation information was displayed on the lower display unit (MFD – multifunctional flight display). The avionics further contained the backup artificial horizon, altimeter, and speed indicator. The avionics blocks including the multifunctional flight display units were destroyed in the fire. Both the flight displays (PFD as well as MFD) were provided with the slots for data cards on the right-hand side. Both these cards were found in the flight display units that had been damaged by the fire. The helicopter operator was not using the third memory card usually applied in the recording of up to 56 flight and navigation parameters of power plant operation.

The data from the memory card, recorded in 1s intervals, can easily be transferred into .xls chart for the subsequent flight analysis. The chart headings include the basic parameters such as AltMSL [ft], OAT [°C], IAS [kt], GndSpd [kt], VSpd [ft·min^{-1}], Pitch, Roll, etc.

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Fig. 11 – Part of the check flight recording performed on 30 April 2019

Fig. 12 – Both the MFDs destroyed by fire (left) and the MFD with the double data card slots (right)

The avionic equipment included also Appareo Systems Vision 1000 camera recording pilots' activities and some of the data displayed on the screens located on the instrument panel. The camera was built in the middle column in the ceiling part and was fitted with a proprietary recording memory card. Given the fact that the pilot cabin was one of the first parts (except for the main rotor) that touched the ground upon the helicopter crash, the same part was damaged and subsequently destroyed by the fire, including the camera.

1.13. Medical and Pathological Information

The corpses of both crew members were clearly identified. The corpses of both pilots were located in the cabin, both in the prone position, fastened with four-point seatbelts in the seats. The instructor's corpse was pulled out from the left pilot seat marked number 1. The pilot's corpse was located in the right seat of the said helicopter.

Severe polytrauma, i.e. multiple injuries to several organ systems, was the immediate cause of both pilots' death. Death of both occurred immediately after injury and was absolutely unavoidable. Both crew members were not alive during the fire and were not inhaling the fumes.

Mechanism of injury – an intensive blunt force was affecting the bodies of both the crew members with great harmful intensity, the force vector being in the transversal (anteroposterior) axis, affecting the bodies slightly more from the left side. Unambiguous alterations to instructor's extremities bear witness to his active approach to piloting the helicopter. At the moment of helicopter crash on the ground, his right upper extremity was located in front of his body, clutching a cylindrical object in his hand, while both lower extremities were placed on the foot control pedals. No injuries of the pilot's upper extremities which could be attributed to the controllers (collective lever, cyclic stick) were identified. Right foot injury may be an evidence of its possible placement on the control pedal while no similar injury was detected on the left foot.

The autopsy has detected no traumatic alterations on crew corpses which could not have been explained by the mechanism of the said accident, such as a projectile wound, an explosion on board, etc.

The results of both pilots' autopsy and subsequent histological analysis of their tissue samples have not disclosed any pathological changes that might have been involved in the causes of the accident, or that could have been considered as a causal link with the pilots' death.

The weight of both pilots, as determined during the last medical check, was 77 kg (at the height of 197 cm) for the instructor and 88 kg (at the height of 170 cm) for the pilot.

The instructor had a valid class 1 medical fitness certificate. He underwent the last medical check on 13. March 2019 at aeromedical examining centre Centrum letecké medicíny s.r.o., CZ/AME/161-R, with the conclusion "fit for class 1". Insignificant visual correction was recommended.

The student pilot had a valid medical fitness certificate – LA 2. He underwent a medical check on 4 September 2018 in the Institute of Aviation Medicine, Prague, with the conclusion "fit for LA 2".

The toxicological analysis showed no influence of alcohol, addictive substances or presence of any substances prohibited for aviation duty in either pilot.

The biochemical examination of tissue samples collected during autopsy has been performed to determine both crew members' somatopsychic condition. Based on the examination results, statistical processing for evaluation, autopsy results, findings complementary to laboratory tests, and available data about the course of the flight, it may be deduced that both pilots' energy metabolisms were considerably activated during the flight shortly before their death, drawing on the reserve sugar and raising the level of lactic acid in various tissues. Both were conscious before the accident situation and were responding to the course of the flight. Over at least last one or two minutes, the pilot experienced a significant negative emotion (stress), which exceeded the ongoing constructive mental strain caused by the flight. At the same time, the instructor responded with a significant mental strain, concentrating on the unusual flight course, when over the last approximately 10 to 20 seconds, he also developed a stress reaction, probably realising the great danger or inability to handle the emergency situation.

It follows from the complex forensic medical analysis that the air accident at issue was not caused by any health condition of either crew member.

1.14. Fire

Having crashed on the ground, the helicopter wreckage caught fire. The attempt to extinguish the helicopter wreckage made by a witness using a hand extinguisher from his car was not successful. Fire was eventually extinguished by the professional FRS. Helicopter wreckage affected by fire was considerably damaged. The helicopter crash on the ground made the fuel splash out in immediate vicinity where it burnt without causing any large-scale environmental damage. At the moment of the accident, there were 110 l of kerosene in the helicopter tanks.

1.15. Survival Aspects

No search and rescue procedures were organised. Random observers of the event reported the accident to emergency line 158 and the IRS units came directly to the accident site. The FRS, the Police of the Czech Republic units as well as ARS helicopter came to the accident site.

Both pilots' corpses were found in the wreckage of the deformed helicopter cabin without any signs of life. Until the arrival of the Commission to the place of accident, the corpses were not handled in any way. MIFM forensic doctor investigated the corpses in cooperation with the AAII inspectors.

1.16. Tests and Research

Specialised analyses of selected elements of the crashed helicopter, described in Chapters 1.16.1. through 1.16.4., were carried out in specialised Criminal Institute centres of the Police of the Czech Republic. The Laboratory of Aviation Safety and Security, Department of Air Transport, Faculty of Transportation Sciences, Czech Technical University cooperated on analysis 1.16.5.

1.16.1. Mechanoscopic and biological survey of a plexiglass fragment

A plexiglass fragment from the pilot cabin overhead window of the size of approx. A4 format, found in the field, approx. 300 m from the place of helicopter crash, was used to determine the origin of probably biological trace on the outer side of the plexiglass. Furthermore, the origin and nature of mechanical damage to the material structure in the middle of the fragment, visible to the naked eye, were examined. The biological trace was not confirmed, and the mechanism of crack occurrence was not clearly demonstrated.

1.16.2. Analysis of data and examination of SD card data records

At the place where the severely damaged GARMIN 1000 display units are located, two memory SD cards were found. The objective of examination was to find out what type of cards they were and if they were memory cards designed for recording of manufacturer-defined data, to download the data for their subsequent analysis in the specialised centre of the Army of the Czech Republic. The examination showed that neither card was designed for records of flight and technical parameters.

1.16.3. Examination of video recording

The records of the last 1.2 seconds of the last phase of the event flight were downloaded from the safety camera located on the premises of ZBA Slavoňov at a distance of approx. 300 m south-east from the place of crash. The record was processed in the format of individual images which confirmed that the helicopter was falling down upside down (with its main rotor downwards). The footage shows that the rotor was rotating. The slowed-down footage shows one main rotor blade visibly coming off and the accumulator shot up upon the helicopter crash on the ground.

1.16.4. Test for the presence of traces of explosives on the surface of the instructor's jacket

During the flight, the jacket was most probably located in the back seat of the helicopter and was found approx. 100 m away from the place of wreckage after the air accident. The test for the presence of traces of explosives on board of the helicopter was negative.

1.16.5. Analysis in the context of systemic view

The air accident was investigated also using the FRAM to acquire a broader context for the issue of training new crews. For a detailed analysis, including a chart see the Annex.

1.17. Organisational and Management Information

The helicopter was operated by a legal entity in compliance with the Aircraft Operating Manual and the Directive for Aerial Work Operations issued by CAA. The helicopter was mostly used for aviation training of foreign pilots in the CZ/ATO-006 aviation training centre.

1.18. Supplementary information

1.18.1. Rotor at maximum forward speed

The helicopter rotor flow-over at high flight speed is illustrated in Fig. No. 13. The figure makes it clear that during forward rotor speed, the retreating blade, which is moving within 180–0 degrees, is flown over in the central part from the trailing edge to the leading edge (negative speed) and does not create a lift. High flight speeds require high setting angles on the retreating blade and the end part of the blade is thus in the angle of attack when the blade works with flow separation accompanied by a loss of lift. The maximum forward speed of helicopter flight is limited mainly by this phenomenon.

At the same time, the peripheral speed on the inflow blade, which moves within 0–180 degrees, at the blade end is added up with the forward speed. The local speeds of inflow air are close to the speed of sound and exceed the critical Mach number. There are profile areas with supersonic flow-over terminated by a shock wave and flow breakaway on the shock wave. Flow breakaway is accompanied by increased vibrations.

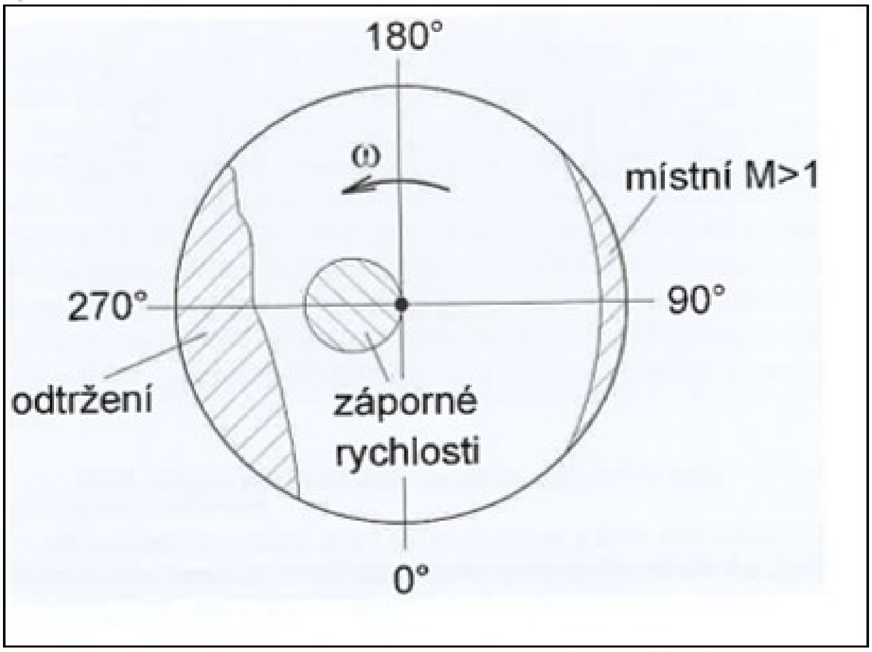


Fig. 13 – Rotor at maximum forward speed (Helicopter pilot's textbook, Ludvík Kulčák et al., scan of the figure on p. 337)

1.18.2. Flight Manual, Supplement, Flight speed limitations

Although the helicopter is equipped with *glasscockpit* Garmin G 1000H, the indication of V_{NE} is the same as for the analogue speedometer, i.e. by fixed marking with a red bar at 125 KIAS

1-4 ENSTROM 480B RFM SUPPLEMENT

1.3.6 Maximum Airspeed

1.3.6.1 Airspeed Limits

This rotorcraft was originally equipped with a set of placards for determining maximum airspeed (V_{NE}) based on pressure altitude, temperature, takeoff gross weight and takeoff center of gravity; those placards remain as the means to determine V_{NE}. However, like the analog airspeed indicator, the airspeed tape has a red bar at 125 knots, the maximum power V_{NE}.

Figure 1-1. Maximum Power-On V_{NE}

Fig. 14 – Scan of the Flight Manual, p. 1–4. Electronic speed indicator with the fixed index V_{NE}

1.18.3. Helicopter Flight Manual, Chapter 1. Operating limitations

Rotorcraft Flight Manual, Chapter 1. Operating Limitations

1-14 Manoeuvres: Acrobatic manoeuvres, (over 90 degrees in pitch or roll) are prohibited.

Caution: The engine is approved for operation at 90 degrees pitch up and down and zero (0) g for 10 seconds only. Dwelling at these conditions longer than 10 seconds can damage the engine.

1.18.4. Rotorcraft Flight Manual, Chapter 2. Normal Procedures Before Starting Engine, p. 2-15

Rotorcraft Flight Manual, Chapter 2. Normal Procedures

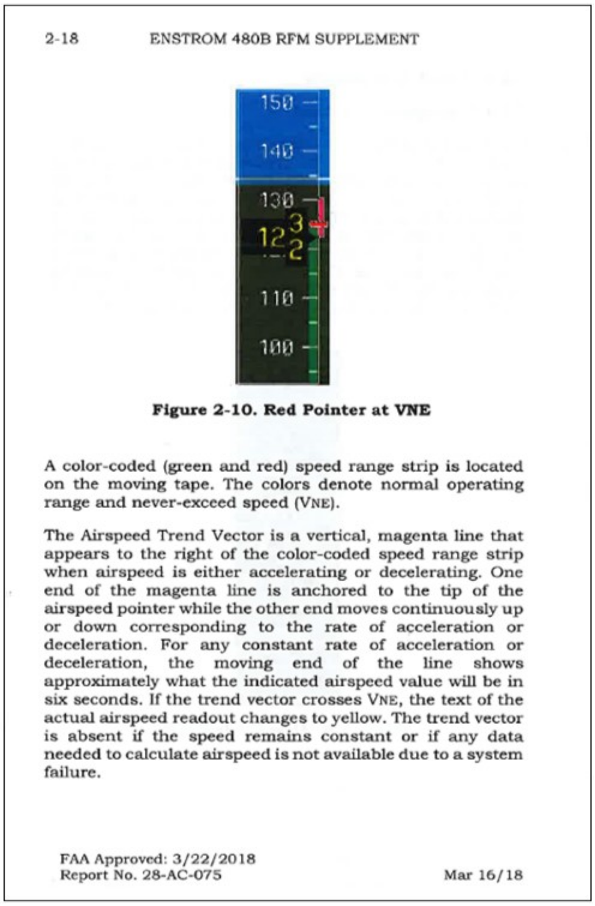
2-18. Before Starting Engine

24. Check the temperature and select correct V_{NE}/CG placard.

Note:

V_{NE} is based on a combination of pressure altitude and temperature at flight conditions and take-off gross weight and take-off c.g. Proper determination of take-off gross weight and c.g. is required to determine the appropriate V_{NE} envelope.

1.18.5. Flight Manual, Supplement



2-18 ENSTROM 480B RFM SUPPLEMENT

Figure 2-10. Red Pointer at VNE

A color-coded (green and red) speed range strip is located on the moving tape. The colors denote normal operating range and never-exceed speed (VNE).

The Airspeed Trend Vector is a vertical, magenta line that appears to the right of the color-coded speed range strip when airspeed is either accelerating or decelerating. One end of the magenta line is anchored to the tip of the airspeed pointer while the other end moves continuously up or down corresponding to the rate of acceleration or deceleration. For any constant rate of acceleration or deceleration, the moving end of the line shows approximately what the indicated airspeed value will be in six seconds. If the trend vector crosses VNE, the text of the actual airspeed readout changes to yellow. The trend vector is absent if the speed remains constant or if any data needed to calculate airspeed is not available due to a system failure.

FAA Approved: 3/22/2018
Report No. 28-AC-075 Mar 16/18

Fig. 15 – Scan of the Flight Manual, p. 2–18. Fixed marking VNE

1.18.6. Training syllabus – Training of instrument flying

The training of student pilots in helicopter instrument flights started by exercise No. II-01 Basic Instruments, which, among other things, assigned the horizontal flight speed at 80 kt, ascending and descending flight speed at 65 kt, and manoeuvre speed within 50 and 85 kt.

The training continued by exercise No. II-02 IFR Area Flying – Fig. 16. The flight includes a horizontal flight at a speed of 80 kt, left and right turns with a roll of 10 and 20 degrees, making turns in the set heading, transition to main rotor autorotation, drill of unusual positions, instrument descent with transition to visual reference flight, and landing.

Exercise No.: II-02 and II-102
IFR Area Flying

Purpose
To train SPs ability to control helicopter during flight using instruments only.

Description
1. Crew action
   a. Perform flight planning for the flight.
   b. Perform crew resource management appropriate to IFR operations.
   c. Perform visual departure and then switch to instrument flight.
2. Procedure
   a. Horizontal flight with speed 80 kt
   b. Turns L and R 10° and 20 °
   c. Rate 1 turn computation and execution into selected heading
   d. Entering into ART mode
   e. Unusual attitude recovery created by the instructor,
   f. Instrument descent to selected altitude, change to VFR flight and landing

Note:
ART descent executes to illuminated RWY only.

Duration
Day: 2,0 hrs. Night: 1,0 hr.

Performance Standards:
Appropriate standards from deviation sheet.

Fig. 16 – Training syllabus scan. Description of exercise No. II-02 IFR Area Flying

1.19. Useful or Effective Investigation Techniques

Accident investigation was carried out in compliance with L-13 (ICAO, Annex 13).

2. Analyses

Majority of facts pointing to the determining of the causes of the accident arise from the evidence found in the helicopter wreckage, from the findings following from the detailed inspection of the air accident location, conclusions of forensic medical examination, from the information provided by the witnesses in their testimonies, the industrial camera footage, multiradar ACC recording, and the results of professional criminal examinations.

No device whose recordings could be used by the investigators in analysis of the critical stage of the event flight was installed in the helicopter. The avionic equipment included also a camera recording the pilot cabin interior and the pilots' activities in relation to controllers operation and some data displayed on the screens located on the instrument panel. The camera was built in the middle pillar and was fitted with a proprietary recording memory card. Given the fact that the pilot cabin was one of the first parts that touched the ground upon the helicopter crash, it was damaged and subsequently destroyed by fire. In spite of this fact, the Commission members thoroughly examined approx. 10 m^3 of stripped contaminated soil with a negative outcome.

The helicopter operator was not using the SD memory card, which is usually used for recording of up to 56 flight and navigation parameters, including technical parameters of power unit operation, located in one of the slots in the multifunctional display units.

2.1. Crew Qualifications

The pilot underwent the theoretical and practical training in the extent necessary to acquire the Private Pilot Licence – PPL (H). Following intensive practical training on the R 22 and R 44 helicopters, he continued training on the ENSTROM 480 B helicopter in line with the syllabus approved by the foreign customer ordering the training. He was smoothly fulfilling individual tasks prescribed by the approved syllabus without interruptions. Flight instructors often assessed his flying with grade 3 and in their verbal assessment, they often pinpointed gross interference with control during error correction. A detailed study of the event flight records revealed that the pilot was unable to keep the flight speed prescribed by the syllabus. He shortly exceeded the speed in horizontal flight by up to 20 kt and in ascent by up to 30 kt. Deviations from the prescribed flight parameters appeared mostly in the course of the implementation of the second half of the set manoeuvre.

The instructor was employed as the HEMS professional pilot where he was flying the EC 135 helicopter. He acquired his FI qualification on 23 November 2017 and flew in total approx. 50 hours as pilot-instructor on the R 22, R 44, and HU 269 helicopters. He was flying the ENSTROM 480 B helicopter from 28 November 2018. In order to acquire type qualification, he performed all check flights on the type within the FI qualification.

He commenced training of foreign student pilots on the ENSTROM 480 B helicopter on 20 March 2019. The total hours flown amounted to 14 hrs, including 5 hrs 30 min during the training of student pilots. He was flying for the first time with the event flight pilot.

2.2. Flight Performance

The instructor performed the pre-flight preparation with the pilot in the required extent and quality. When instrument flying the helicopter, the pilot wore specialised polarised glasses which limited a natural view from the pilot cabin, but allowed for reading of instrument panel data. The helicopter crew gradually went through individual manoeuvres in exercise No. II-02. A detailed study of the multiradar ACC recording revealed multiple short-term surpassing of the speed set by the training syllabus for ascent and horizontal flight by 20–30 kt.

The witnesses did not notice any other aircraft in the airspace; therefore, it is highly unlikely that the crew carried out a sudden manoeuvre in order to avoid another aircraft. No biological traces of birds were found on the helicopter wreckage; therefore, a bird strike may be excluded with high probability.

2.3. Critical Situation

The comparison of individual witness testimonies, the results of detailed investigation of the wreckage, and the detailed study of the multiradar ACC recording yielded the conclusion that a quick series of consequent events caused by errors in instrument flying of the helicopter occurred on board of the helicopter during the flight in the right turn.

Over at least last one or two minutes before the accident, the pilot experienced a significant negative emotion, which exceeded the ongoing constructive mental strain caused by the flight. Such a state may be attributed to an increased strain during instrument flight. The multiradar ACC recording makes it clear that the pilot was finishing the second left turn at an increased speed of up to 90 kt and subsequently managed to decrease the speed to the required 60 kt in the straight flight segment. At such speed, he entered the right turn with a vertical descent of 600 $ft{\cdot}min^{-1}$. After a few seconds, the vertical and forward speeds gradually grew, and the helicopter was flying at a speed of 100–110 kt for the period of 22 seconds and the vertical speed reached the level of 2,056 $ft{\cdot}min^{-1}$. It was probably at this moment that the instructor strongly advised the pilot to amend the flight mode with regard to extreme descent. In an attempt to reduce the descent as soon as possible, the pilot vigorously lifted the collective pitch control instead of continuous pulling of the cyclic pitch control in order to reduce the forward speed below V_{NE} with subsequent correction of the vertical descent. At that moment, the angle of attack on the retreating blade increased. In combination with the flight speed exceeding V_{NE}, flow lines breakaway accompanied with a lift loss occurred on that blade. As a result, the helicopter turned upside down through half-roll inverted with its rotor down. The bag with helicopter documentation broke the plexiglass overhead window of the pilot cabin. Loose sheets of papers appeared in the sky first, followed by other papers from the helicopter cabin.

The instructor, most probably, immediately took hold of the controllers and was trying to recover the unusual position of the helicopter. It has been confirmed by the forensic medical examination which mentions that at the moment of helicopter crash on the ground, his right upper extremity was located in front of his body, clutching a cylindrical object in his hand, while both lower extremities were placed on the foot control pedals. At the same time, the instructor responded with a significant mental strain when over the last approximately 10 to 20 seconds, he also developed a stress reaction, probably realising the great danger or inability to handle the emergency situation. The detailed footage of the industrial camera clearly shows that the main rotor, and thus the power unit as well, were operating for the entire period while the helicopter was flying upside down. This fact was confirmed by the state of wreckage found at the place of accident. With regard to the helicopter Flight Manual, which allows for flight manoeuvres with a pitch and a roll up to 90°, there was a theoretical possibility to recover the unusual position of the helicopter. This, however, cannot be expected from an instructor with minimum experience on the type. It is thus obvious that the crew were unable to recover the unusual position and the helicopter continued in its uncontrolled flight with its rotor down and then crashed on the ground at a sharp angle.

2.4. Helicopter

The helicopter was operated within the range of the authorised weight and centre-of-gravity position, which ensured sufficient range of control for its safe piloting. The maximum take-off weight of the helicopter was not exceeded. The technical inspection of the helicopter and technical examinations confirmed that there was no technical failure of mechanical parts necessary for helicopter control and drive.

With regards to the type and nature of the damage to main rotor blades, rotor head, main rotor shaft, and cyclic and collective control mechanisms the main rotor was operating in a standard manner until the impact on the ground. All the damage, including the breakdown of the gearbox into small pieces, was caused by forces generated upon the helicopter's crash with an operating rotor on the ground and subsequent forced rotor stall upon contact with the ground. Upon the first contact of the helicopter in the inverted position (with rotor down) with the ground, T2 blade was broken away and thrown away approx. 48 m to the left of the helicopter. None of the bonded joints of rotor blades had any signs of weakening or delamination. All the damage to main rotor blades was caused by the helicopter's crash on the ground.

Based on the nature of damage, the tail rotor was operating in a standard manner until the impact on the ground. All the damage, including the damage to the transmission shaft, was caused by the helicopter’s crash on the ground and subsequent forced tail rotor stall upon contact with the ground.

With regards to the type and nature of the damage, the engine was operating with high output in a standard manner until the impact on the ground. All the damage to the engine, its aggregates and the system of power transmission from engine to the main rotor shaft occurred upon the crash of the helicopter in inverted position (the main rotor blades crashed first) on the ground. The fuel system, including fuel tanks, was damaged and fire was ignited. The high temperature during fire caused further destruction of the engine and its systems. The investigation revealed no defects or damage that could have occurred before the accident.

Based on the condition of the electrical equipment, wiring and power supply sources immediately after the accident and investigation of helicopter wreckage, no proof was found that would possibly attribute the air accident to a defect or incorrect operation of electric circuit.

Based on the condition of preserved avionic equipment, it may be assumed that the equipment was functioning without any defects. It was a significant drawback that the helicopter operator did not use the memory card designed for recording of flight and technical parameters. The duty to install such a card is not required by the relevant regulation for this helicopter category.

The top glazing of the pilot cabin was smashed by the bag with helicopter documents, which had been freely lying in the cabin, during sharp and big changes in the values of the vertical overload.

The nature and type of all the other damage to the helicopter and its components show that all such damage was caused upon the crash on the ground. The helicopter hit the ground in inverted position with a pitch of approx. 20 degrees at a great vertical and smaller forward speed. All the damage was caused by the effect of inertial forces. All the fractures and cracks were of fragile nature. None of the investigated components or parts bore any signs of any destruction or damage caused by material fatigue.

Some components and parts, in particular of the cabin, engine and engine compartment, were either totally destroyed or seriously damaged by the subsequent fire of fuel (Jet A-1 kerosene) upon the helicopter’s crash on the ground.

Upon investigation of the place of accident and subsequent technical investigation of the helicopter wreckage in a specialised AAII unit, no facts that would indicate that the accident was caused by a technical defect of the helicopter were detected.

2.5. Weather Effects

Weather conditions had no negative effect on the flight.

2.6. Accident analysis in the context of systemic view

The accident of the ENSTROM 480 B OK-CLV helicopter was also analysed by means of the Functional Resonance Analysis Method (FRAM) which allows for revealing a broader context for occurrence of the accident based on more profound examination of the whole system/process. See Annex 5.

3. Conclusions

3.1. Conclusion of the Commission

3.1.1. Pilot

- held the required and valid licence and was medically fit for performing the given flight,
- his knowledge of English was sufficient for communication in the crew,
- had, from the skills point of view, minimum piloting experience with flying this specific type of helicopter,
- was piloting the helicopter according to the instructor's instructions,
- when instrument flying the helicopter, he made gross errors which he, most probably, corrected only upon instructor's advice,
- during the drilling of individual manoeuvres for instrument flying, he responded too late to the errors arisen,
- his errors in instrument flying were augmented by stress, which negatively affected his ability to adequately respond to instructor's instructions,
- responded to the dangerous flight mode caused by an increased vertical and forward speed in a headlong manner, and forcefully pulled the collective pitch control in an attempt to remedy the flight mode as required,
- entirely lost control of the helicopter after an erroneous interference with the collective control,
- in the critical situation, stopped piloting the helicopter most probably upon instructor's demand.

3.1.2. Instructor

- held the required and valid licence and was medically fit for performing the given flight,
- had a valid general licence of the aeronautical mobile service radio operator,
- had little practical experience with flying on the given type,
- had little experience with practical training of student pilots,
- had sufficient English language skills to verbally instruct the student pilot in English, and had very good prerequisites for teaching of student pilots,
- was flying with the pilot for the first time,
- was satisfied with the pilot's performance during the first 45 min of the flight,
- in an attempt to interfere with pilot's control as little as possible, he probably did not create such conditions which would limit the movement of controllers within a permissible extent, and which would enable him to promptly remedy the errors occurred during piloting,
- probably trusted the pilot too much and was not vigilant enough to prevent him from the excessive pulling of the collective pitch control during vertical speed control,

- probably failed to realise the relation between the current speed and the calculated V_{NE},
- had no experience with recovering the helicopter from the unusual inverted position.

3.1.3. Helicopter

- had a valid certificate of airworthiness inspection and was airworthy,
- had a valid liability insurance;
- was filled with the fuel necessary for the given flight,
- the power unit worked perfectly normally during the whole flight and all control elements were fully functional,
- the described structural damage to the helicopter and the key main rotor blades control components occurred only upon the crash on the ground,
- the overall damage to the helicopter structure was caused by the crash on the ground from a great altitude and by subsequent fire.

3.2. Causes

The cause of the accident was exceeding of the maximum not-to-exceed airspeed V_{NE} in extreme engine descent when flow lines broke away on the retreating blade with a consequent lift loss on the left side of the rotor disc probably as a result of vigorous pulling of the collective pitch control. The helicopter turned into an unusual inverted position, which the crew failed to manage.

4. Safety Recommendations

4.1. Operator’s Measures

Prior to resuming the training of student pilots at ATO/CZ-006, the helicopter operator issued the Safety Notice – 03/2019 focusing on the repetition of the procedure for calculating the not-to-exceed airspeed V_{NE} for the ENSTROM 480 B helicopter.

4.2. Safety Recommendations for the Operator

The helicopter was equipped with the Appareo Systems Vision 1000 camera system designed for video recording of the interior of the front part of pilot cabin, including the instrument panel. Recorded data are saved on the SD card which can be later used for flight analysis. The Vision 1000, including the SD card, was completely destroyed during the air accident with a specific course.

4.2.1. Safety Recommendation CZ-20-001

The Air Accidents Investigation Institute recommends the operator of helicopters equipped with *glasscockpit* Garmin G 1000H, to introduce a system of using the SD card where the data set from this system would be saved. Such acquired data should be used for checking the basic flight parameters and technical parameters of the power unit during comprehensive evaluation of flights.

5. Annexes

5.1. Accident analysis in the context of systemic view

The accident of the ENSTROM 480 B OK-CLV helicopter was also analysed by means of the Functional Resonance Analysis Method (FRAM) which allows for revealing a broader context for occurrence of the accident based on more profound examination of the whole system/process.

5.1.1. FRAM description

The Functional Resonance Analysis Method (FRAM) is one of the latest operational safety methods intended for analysis of accidents in a broader, systemic context. This method allows for investigation of modern, comprehensive accidents caused by a number of seemingly negligible factors which may not necessarily contain any human error or technical failure, just routine, everyday work. The FRAM requires creation of a functional chart of the system in order to be able to explain the causes of the accident. The functional chart describes what and how the investigated system usually does, i.e. which activities in which sequence are usually conducted in the operation. The FRAM helps to identify variability of system functions in the functional chart, i.e. everyday variations from the optimum course of procedures or activities. According to the FRAM, an accident occurs as a concurrent combination of several such variations and this notion is called functional resonance.

In the FRAM, the functional chart is made of interlinked hexagons. Each hexagon represents one function, i.e. activity, whereas each function may have five types of inputs and one output. The inputs may be of the following types: (1.) “I” (Input), necessary and sufficient input to carry out a function, (2.) “P” (Precondition), a formal precondition necessary to carry out a function, (3.) “R” (Resource) input that is needed or consumed while a function is carried out, (4.) “C” (Control), input providing instructions as to how the function is to be carried out, and (5.) “T” (Time), input determining when the function is to be carried out. In the FRAM functional chart, the output is marked as “O” (Output). The function output is a situation or an object which further serves as an input for other, subsequent functions according to the chart. The output of each function is described on the link going from the given function. Peripheral chart functions, i.e. functions without inputs or an output, are coloured grey. If some functions in the investigated event deviate from the optimum course, i.e. were variable, such situation is illustrated with a sinus function symbol in the specific hexagon.

The aim of the FRAM analysis is to explain how the given accident occurred, i.e. to explain the specific functional resonance. As the functional chart contains the description of which standard activities caused the resonance, the corrective measures are derived directly from the chart. They respond to specific findings and offer opportunities how to capture and reduce variability.

5.1.2. Use of the FRAM for investigation of accident of the helicopter ENSTROM 480B OK-CLV

The first step in addressing the event by means of the FRAM is to draw up a functional chart. This chart containing a simplified training system is shown in Figure XY where each hexagon represents an activity/function carried out during the training. The links between individual functions show the results of such functions and how the results are input into other functions – see the description of the FRAM above.

Another step in the FRAM is assessment of individual functions in terms of possible variability. Variability represents a tendency to change the output from the given function, simply a deviation from an optimum condition.

It is followed by an overall analysis of the given system, impact of individual variabilities on the incidence of resonance and occurrence of an event (accident).

5.1.3. Training model variability

The created general simplified training model served as a base for investigating the occurrence and effect of possible variabilities and subsequent resonance. See below for the description of possible types of variability of individual functions from the chart and the description of possible variability occurrence in such functions.

Variability of the function “Evaluation of the theoretical preparation”

The function variability is determined both by an input from the functions “Determination of the criteria of preparedness evaluation” and “Theoretical preparation of student pilots” and own course of the function. The function output variability – i.e. “theoretically prepared student” – occurs at the moment when the specific conditions of theoretical preparation are not precisely set for the function “Determination of the criteria of preparedness evaluation” and/or evaluation of theoretical knowledge is influenced by the examiner’s subjective opinion.

Variability of the function “Choice of the instructor for practical training”

Variability of the function is influenced by determination of the criteria for the choice of the instructor where unclear criteria allow for choosing an instructor who is not suitable for the given student and/or the given task of the practical training because of their knowledge and experience.

The function variability then rests with the selection process based on criteria where in spite of clearly set criteria, it may happen that an unsuitable instructor is selected on the basis of subjective impressions of the selecting person.

Variability of the function “Acquisition of the suitable type of helicopter”

As in the previous cases, the function variability is determined both by an output from the previous function “Determination of requirements...” where the requirements for a helicopter, whether in terms of equipment or helicopter characteristics, may not be clearly and precisely defined. Furthermore, there may be a variability directly in the given function where the process of selecting the right type of training aircraft may be influenced by many (financial, subjective, etc.) factors not respecting the criteria in full and/or re-assessing and adjusting the criteria for the selection process in favour of the preferred vehicle and/or some criteria may be compromised in favour of more economical offers.

Variability of the function “Performance of the practical training task”

The function variability is again determined both by the course of the function and other functions whose outputs are linked to the function (“Evaluation of the theoretical preparation”, “Choice of the instructor for practical training”, and “Acquisition of the suitable type of helicopter”).

The variability “inside” the function is again dependent on the course of the practical task where with regards to the variability of preceding functions and thus influenced outputs, the students develop some incorrect habits, and there is a danger that the instructor will not pay attention to the critical aspects of the flight, etc.

The function result in the form of a "completed task", i.e. namely knowledge acquired by the instructor and the student, the background material for assessment of performance of the given task, may be, to a large extent, affected and may represent an inaccurate background/input for further functions.

Variability of the function "Evaluation of the practical task"

The function variability develops mainly by an input in the form of data on the completed practical task (see above) and by subjective evaluation of the instructor who may not be selected properly (see "Choice of the instructor") and/or conducts evaluation which is not based on robust data but rather on personal insight gained during the flight. The accuracy of the evaluation may be thus once again very much affected and questionable.

Variability of the functions "Planning of training flights" and "Decision-making on continuation of training or task repetition"

The last functions, taking over the variability of the preceding functions, are the functions "Planning of training flights" and "Decision-making on continuation of training or task repetition", which affects the former function. These functions are rather dependent on all outputs from the previous functions and if the outputs are affected, in these functions, there is no option how to mitigate the variability.

5.1.4. Training system evaluation

It follows from the above that the process of training students is composed of functions that are very prone to variability, primarily to the variability of the quality of outputs where such variability may not be detected. The function that can reveal the variability in previous functions is the "Evaluation of the practical task" where if the internal processes are correctly set up, on the basis of previous outputs, the whole system performance is evaluated (on the basis of the performance of the evaluated student), which should lead to the detection of the possible causes of the variability and its mitigation.

Thanks to the function "Evaluation of the practical task", the variability of the entire system may be mitigated or escalated. The mitigation will occur in case that the evaluation processes are set up correctly, i.e. such processes are based on objective parameters where "subjective impressions" are supplemented by conclusive parameters collected from various available flight data recorders. Thanks to such hardly influenceable data, the variability of the entire system may be mitigated and/or the variability in previous functions may be detected by means of data analysis. Without such an approach, the variabilities remain latent and are then demonstrated trough an air accident.

5.1.5. Evaluation of the model for the investigated air accident

In the case of the investigated air accident, it is possible to find a variability in the function "Setting of criteria for the instructor" and the related function of the choice of an instructor for practical training (flying on the type, practical experience with student training). It is also possible to see a variability in the function "Evaluation of the practical task" – the evaluation is based on instructor's subjective impressions, it is not supported with "fast" measurable outputs (data sets from panel instruments), and the evaluation could be supported only with a video recording. This function is linked to the decision-making on continuation of training where the function is strongly influenced by an output from the previous function and does not allow for correcting the variability of preceding functions.

The total variability of individual functions is escalating in the function "Performance of the practical training task" where the system function becomes variable due to the partial variabilities.

In order to eliminate/mitigate the effect of variability, it is advisable to focus on the function "Evaluation of the practical task" and adopt in this function such measures that will identify and eliminate the effect of variabilities of preceding functions (see the safety recommendations in the present Final Report).

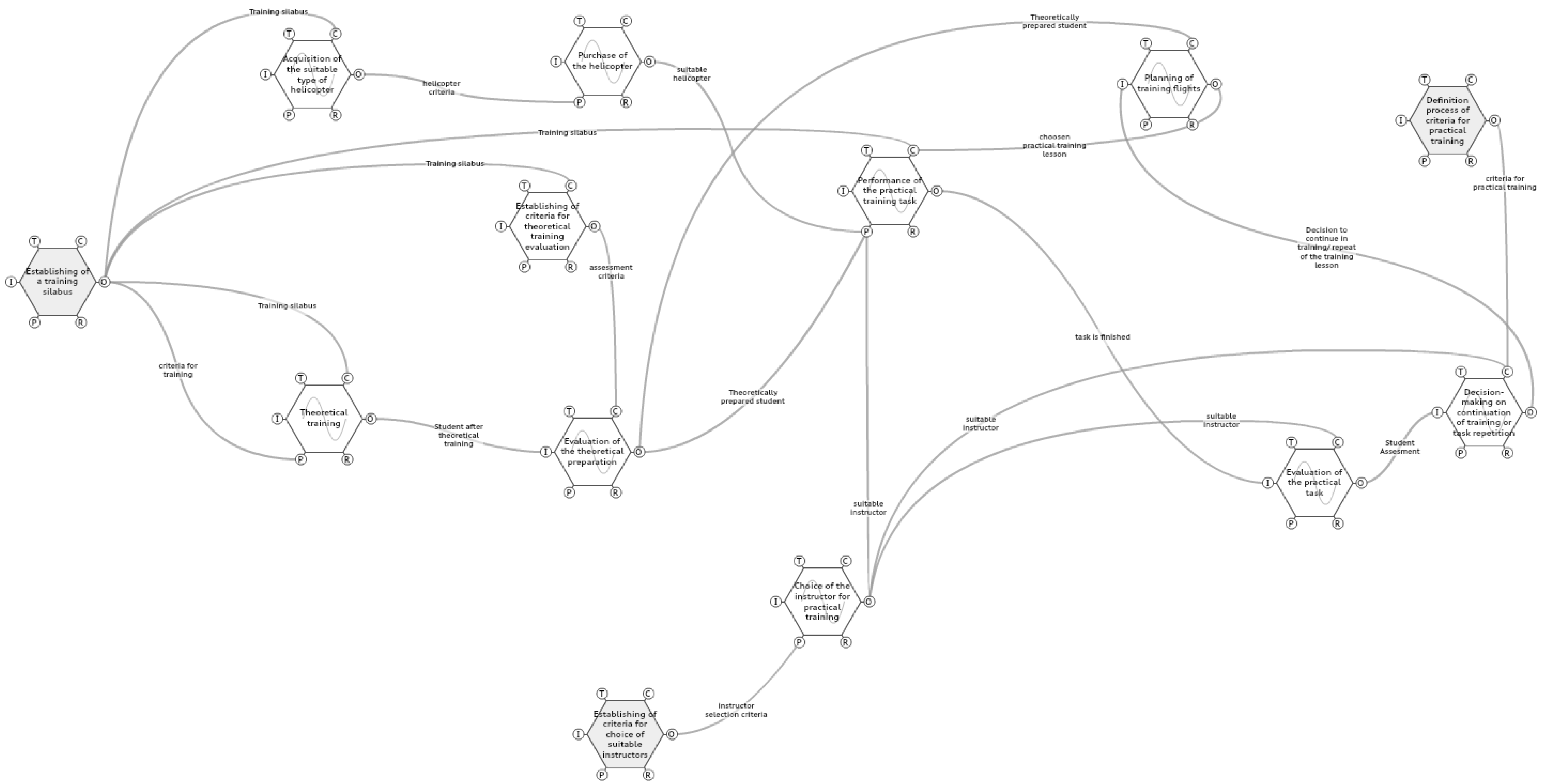


Fig. 17 – Chart of the simplified system of flight crew training for the needs of FRAM