FINAL REPORT

ACCIDENT 2022/6240

STATE COMMISSION ON AIRCRAFT ACCIDENTS INVESTIGATION

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FINAL REPORT

ACCIDENT

OCCURRENCE NO. – 2022/6240

AIRCRAFT – GLIDER MDM-1 „Fox", SP-3828

DATE AND PLACE OF OCCURRENCE – 23 OCTOBER 2022, EPRU (Rudniki near Częstochowa)

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

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

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

The Commission does not apportion blame or liability.

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

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

WARSAW 2024

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Acronyms and abbreviations

AGL	Above Ground Level
AMIA	Aviation and Maritime Investigation Authority, Slovakia
ARC	Airworthiness Review Certificate
ARP	Aerodrome Reference Point
ATS	Air Traffic Services
BMK	Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology; aviation occurrence investigation authority, Austria
CRS	Confirmation of Release to Service
CAO	Combined Airworthiness Organisation
CAVOK	Cloud and Visibility OK; visibility, clouds and weather at the moment of observation are better than the recommended values of conditions
CofA	Certificate of Airworthiness
CofI	Certificate of Insurance
CofR	Certificate of Registration
daN	Dekanewton
DTO	Declared Training Organisation
E	East / Eastern longitude
EASA	European Aviation Safety Agency
EGT	Exhaust Gas Temperature
FE(S)	Flight Examiner (Sailplanes)
FIE(S)	Flight Instructor Examiner (Sailplanes)
FI	Flight Instructor
HT	Head of Training (at a DTO)
IIC	Investigator-in-Charge

LAPL	Light Aircraft Pilot Licence
LMT	Local Mean Time
LSA	Light Sport Aircraft
METAR	Meteorological Aerodrome Report
MON	Motor Octane Number
Mth	Motohour
N	North / Northern latitude
PIC	Pilot-in-Command
PKBWL	Polish State Commission on Aircraft Accidents Investigation (Polish: *Państwowa Komisja Badania Wypadków Lotniczych*)
MP	Maintenance Programme
PCA	Polish Centre for Accreditation
PPL(A)	Private Pilot Licence (Aeroplanes)
QNH	Query: Nautical Height
RON	Research Octane Number
RPM	Revolutions per minute
RWY	Runway
S	South / Southern latitude
SEP(L)	Single Engine Piston (Land)
SPL	Sailplane Pilot Licence
TBO	Time Between Overhaul
TCDS	Type Certificate Data Sheet
TCH	Type Certificate Holder
TMG	Touring Motor Glider
TT	Total Time
TTSN	Total Time Since New

ULC	Polish Civil Aviation Authority (Polish: *Urząd Lotnictwa Cywilnego*)
UTC	Coordinated Universal Time
WGS 84	World Geodetic System
W	West / Western longitude
VFR	Visual Flight Rules
VLI	Vapor Lock Index
VMC	Visual Meteorological Conditions

General information

Occurrence reference number	**2022/6240**			
Type of occurrence	ACCIDENT			
Date of occurrence	23 OCTOBER 2022			
Place of occurrence	EPRU (Rudniki near Częstochowa)			
Type and model of aircraft	GLIDER MDM-1 „Fox"			
A/C registration marks	SP-3828			
A/C user/operator	Aeroklub Częstochowski / Aeroclub of Poland			
Pilot-in-Command	Sailplane pilot-instructor, SPL			
Number of victims/injuries	Fatal	Serious	Minor	None
	2	0	0	1
Domestic and international authorities informed about the occurrence	ULC, EASA, BMK, AMIA			
Investigator-in-Charge	Michał Ombach			
Investigating Authority	State Commission on Aircraft Accidents Investigation			
Accredited Representatives and their advisers	None designated			
Document containing results	FINAL REPORT			
Recommendations	None			
Addressees of the safety recommendations	Not applicable			
Investigation completion date	22 July 2024			

Synopsis

On 23 October 2022, a team composed of a WT-9 "Dynamic" tow plane and an MDM-1 "Fox" glider took off from the Rudniki aerodrome (EPRU). The aeroplane pilot reported an engine failure shortly after take off. The team commenced a turn towards the aerodrome at a low height. During the turn, the glider released itself after which it stalled onto the right wing and nose, and collided with the ground. The trainee pilot and the instructor died on the spot. The glider was destroyed.

The tow plane landed at the aerodrome uneventfully.

The occurrence was investigated by an investigation team in the following composition:

Michał Ombach	- Investigator-in-Charge (IIC);
Ireneusz Boczkowski	- member of the investigation team;
Krzysztof Błasiak	- member of the investigation team.

PKBWL has established the following cause of the aviation accident:

A stall of the glider either in a towed flight or shortly after release of the tow cable, resulting in a spin situation at an insufficient height for recovery to the level flight.

Contributing factors:

1) An engine failure in the tow plane, disrupting the teams' ascent and causing a progressive decrease in the airspeed down to an insufficient towing speed.
2) The team turning in the direction of the forest, "downwind".
3) A very low height over the forest coupled with the glider's lack of speed, as well as a disadvantageous location relative to the aerodrome – the only landing site.
4) Possible initiation of a turn to the aerodrome by the glider crew shortly after releasing the tow cable, without first accumulating airspeed.
5) Possible too strong tightening of a turn to the aerodrome.
6) Possible concurrent control by both pilots, resulting in the lack of mutual coordination and restricted "feel of the controls" by each of them.
7) "Extra forward" centre of gravity, affecting the glider's control characteristics, the character of the stall, and translating into a delay in recovery from the dive.
8) Exceeding the allowed mass in flight – a high wing loading.

PKBWL has not proposed any safety recommendations.

1. FACTUAL INFORMATION

1.1. History of the flight

On 23 October 2022, at 10:00 hrs[1], glider flights commenced at the Rudniki aerodrome, initially with winch towing.

After about 1 hour, preparations started for flights of an MDM-1 "Fox" aerobatic glider using a WT-9 "Dynamic" as the tow plane. The purpose of the flights was to conduct a pilot training programme for the "aerobatics" rating in accordance with the Programme of Aeroklub Częstochowski.

The towing operations were performed by an aeroplane made available by a private owner.

The pilot of the aeroplane performed a pre-flight inspection and run the engine. After that, he taxied to the launch point, where he performed an engine check and found all parameters normal.

The first glider towing was carried out at 11:22 hrs, with a trainee pilot and an instructor in the glider cockpit. The flight went uneventful, with the landing taking place 19 minutes after take-off.

The trainee pilot performed the second flight solo, practising manoeuvres demonstrated in the previous flight.

The third flight (Fig. 1), during which the glider accident took place, was performed again in a two-person crew.

A summary of the flights of the MDM-1 "Fox" glider on the day of the occurrence is depicted in Table 1.

Table 1. A summary of the flights of the MDM-1 "Fox" glider on the day of the occurrence

#	Crew	Take-off time	Landing time	Flight time in minutes	Break time between successive flights
Flight 1	Trainee pilot + instructor	11:22	11:41	19	7 minutes
Flight 2	Trainee pilot	11:48	12:09	17	4 minutes
Flight 3	**Trainee pilot + instructor**	**12:13**	**---**	02	**Accident flight**

After a proper take-off run and getting airborne from the concrete runway [1][2], the team commenced a climb. After passing the threshold of RWY 26, at an altitude of approximately 80÷90 m AGL [2], the pilot of the tow plane reported by radio: "Fox, I have an engine problem!". At the same time, the pilot checked the power plant's operating parameters and made sure that the carburettor heating was off. The engine was vibrating and losing power, giving the pilot the impression that (as quoted from the

[1] All times in this Report are provided in LMT; on the day of the accident LMT=UTC+2 h.
[2] The references to the numerical markings in white in Fig. 1 are provided in square brackets.

interview) "the aeroplane is getting stuck". The team maintained the flight direction in line with the take-off direction.

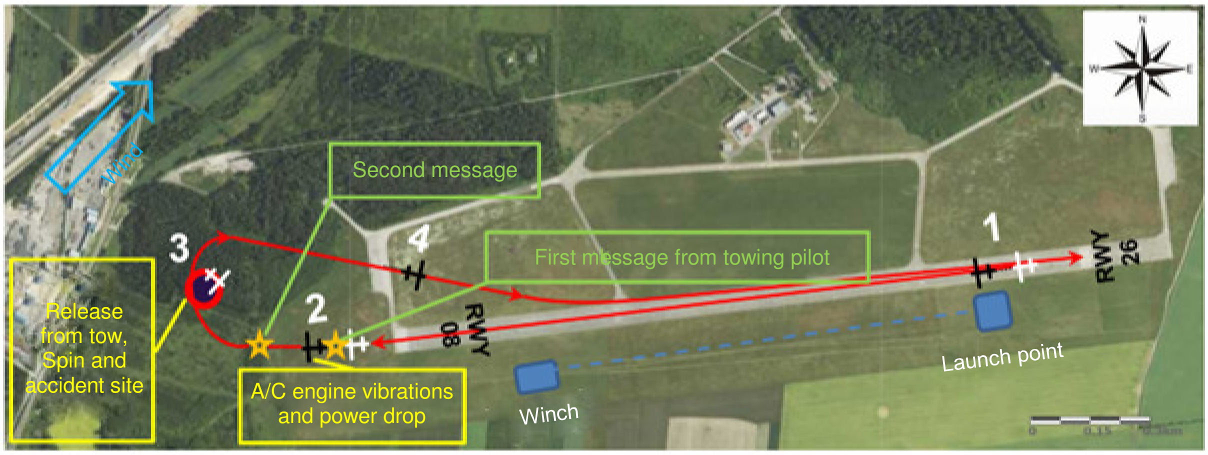


Fig. 1 The path of the flight made by the team, the glider accident site, and the path of the flight and landing of the tow plane [source: Geoportal / PKBWL]

The aeroplane pilot then commenced a right turn (to the north) in order to return to the aerodrome and suggested by radio that the glider crew release the tow if possible. During the turn, the tow cable was released from the glider [3]. Although the towing pilot felt the release, he could not see the glider in his rear view mirror. The pilot completed the turn, reduced the engine speed and landed "down wind" [4]. The aeroplane completed the landing run near the threshold of RWY 26, on the eastern side of the aerodrome.

According to witness accounts, after the cable was released, the glider, while still in the turn, slightly raised its nose and entered into a right spin. After a moment, it disappeared from the witnesses' sight, plunging into the forest to the north-west of the aerodrome, where it collided with the ground.

The witnesses to the occurrence who were at the aerodrome notified the accident to the rescue services. After around 3 minutes, they found the crashed glider (Fig. 2). The pilot and the instructor were found in the cockpit but showed no signs of life. The rescue services that arrived on site confirmed their deaths. The glider was destroyed.

Fig. 2 The wreckage of the glider on the accident site; the photograph was taken from a drone [source: PKBWL]

1.2. Injuries to persons

Table **2. Injuries to persons – general figures**

Injuries	Glider crew	Tow plane pilot	Others	TOTAL
Fatal	**2**	**0**	**0**	**2**
Serious	**0**	**0**	**0**	**0**
Minor	**0**	**0**	**---**	**0**
None	**0**	**1**	**---**	**1**

1.3. Damage to the aircraft

The glider was destroyed as a result of the collision with the ground (Fig. 3, 4, 5).

The cockpit was broken in the front seat area, and was crushed and torn open. The composite structures of the nose, floor, sides, both instrument panels and canopy, as well as the glider control systems were completely destroyed.

The wings and the horizontal stabiliser were destroyed, but did not detach from the fuselage. The fuselage broke in the section behind the wings and at its transition into the vertical stabiliser.

Fig. 3 The crushed and broken tail, and the torn right wing [source: PKBWL]

Fig. 4 Destruction to the glider's cockpit [source: PKBWL]

Fig. 5 The wreckage of the glider at the crash site – a view from the right wing [source: PKBWL]

1.4. Other damage

None.

1.5. Personnel information (crew data)

1.5.1. Pilot-in-Command – instructor (in the glider)

A glider instructor pilot – male, aged 58, holder of:

- a valid Sailplane Pilot Licence SPL with an instructor rating (FI/FI) and an "aerobatics" endorsement;
- a valid Class 2 aero-medical certificate and a LAPL with a VML[3] limitation;
- a valid Private Pilot Licence (Aeroplanes) PPL(A) with a SEP(L) rating a night endorsement.

Overall flight time: as a sailplane pilot 1390 hours in 4295 flights, including:

- as a Pilot-in-Command – 940 hours;
- as an instructor – 450 hours.

Of which:

- in the last 24 hours before the accident: 0 hours 19 minutes; 1 flight;
- in the last 7 days before the accident: 0 hours; 0 flights;
- in the last 90 days before the accident: 8 hours 27 minutes; 42 flights.

1.5.2. Trainee pilot (in the glider)

A pilot – male, aged 17, holder of:

- a Sailplane Pilot Licence SPL with a TMG rating;
- a valid Class 2 aero-medical certificate and a LAPL without any limitations;
- a Private Pilot Licence (aeroplanes) PPL(A) with a TMG rating and "night" and glider towing endorsements.

Overall flight time: as a sailplane pilot 153 hours 52 minutes in 334 flights, including:

- as a Pilot-in-Command (solo) – 115 hours 42 minutes.

Of which:

- in the last 24 hours before the accident: 0 hours 36 minutes; 2 flights;
- in the last 7 days before the accident: 0 hours; 0 flights;
- in the last 65[4] days before the accident: 16 hours 47 minutes; 33 flights.

1.5.3. Tow plane pilot

Male, aged 45, holder of:

- a valid PPL(A) with a SEP(L) rating and glider towing and night endorsements;

[3] VML – a limitation in the aero-medical certificate requiring the holder to wear multifocal glasses and carry a spare pair of glasses.
[4] Flight time in the 65 days before the accident was established.

- an SPL with an instructor rating and an "aerobatics" endorsement, with overall flight time on sailplanes 1309 hour 45 minutes;
- a valid Class 2 aero-medical certificate and a LAPL with a VDL limitation[5].

Overall flight time: as an aeroplane pilot 161 hours 8 minutes, including:

- as a Pilot-in-Command – 122 hours 49 minutes.

Of which:

- in the last 24 hours before the accident:

Date (dd/mm/yyyy)	Aeroplane type	Number of flights/ Comments
23/10/2022	WT-9	2 towings, 28 minutes[6]
23/10/2022	WT-9	Towing during which the glider accident took place

- in the last 7 days before the accident: 0 hours; 0 flights;
- in the last 90 days before the accident: 14 hours; 40 flights.

The pilot's flight time on the WT-9 "Dynamic", as PIC, was 35 hours 31 minutes.

He performed 142 towings in that aeroplane.

Furthermore, he towed gliders in to other aeroplane types: MS893E Morane and Socata Rallye 235. Overall, he performed a total of 396 towings. He obtained his glider towing endorsement in September 2020.

The tow plane pilot was also an active glider instructor. While training pilots for the "aerobatics" endorsement, he performed 165 flights, of which 67 were in the MDM-1 "Fox" glider.

1.6. Aircraft information

1.6.1 General information about the glider

Description of the design

The MDM-1 "Fox" (Fig. 6) is a two-seater high-performance aerobatic glider built in the mid-wing design with a classic cruciform tail.

The glider was certified in the JAR-22 aerobatics category and later received an EASA.A.039 type certificate[7]. The type certificate is held by Zakłady Lotnicze Margański & Mysłowski Sp. z o.o.

[5] VDL - a limitation in the aero-medical certificate concerning far vision, resulting in the obligation to wear corrective glasses and carry one reserve pair of glasses.
[6] Flight time is presented as the aggregate time spent by in the air and on taxiing, as shown in the pilot book.
[7] In 2005, EASA issued the European certificate on the basis of the recognition of national (Polish) certificate no. BG-197, which in turn had been issued in accordance with JAR-22.

The Type Certificate Date Sheet (TCDS) includes two deviations from the regulations which the glider did not comply:

1. the glider stall speed with a two-person crew exceeded 80 km/h (JAR 22.49), and
2. the air brake operating force exceeded 20 daN (JAR 22.143).

The maximum allowable take-off mass of the glider is 530 kg, with the empty mass being around 350 kg.

Fig. 6 The MDM-1 "Fox" SP-3828 glider involved in the accident [source: JetPhotos.net]

The glider is characterised by a compact silhouette, a zero-degree wing dihedral with a low aspect ratio and high wing surface load. In flight, it is characterised by high manoeuvrability and lower stability compared with classic gliders. In a two-person crew configuration, the allowable g-loads are within the range of +7 g and -5 g.

<u>Basic data:</u>

- aircraft type (class) – aerobatic category glider (Fig. 6);
- structure – composite mid-wing;
- purpose – advanced training in advanced and unlimited aerobatics; training and competition;
- number of seats – 1+1;
- registration marks – SP-3828;
- year of manufacture – 2012,
- serial no. – 243;
- aircraft owner – Aeroclub of Poland;
- aircraft operator – Aeroklub Częstochowski.

Certificate of Registration (CofR) – valid on the occurrence day:

- no. in registry – 3828 (Polish civil aircraft register);
- date of entry – 8 February 2022

Certificate of Airworthiness (CofA) – valid on the occurrence day:

- date of issue – 23 June 2012;
- limitations – entry in the certificate "for training purposes".

Airworthiness Review Certificate (ARC)[8] – valid on the occurrence day:

- date of issue – 19 April 2022;
- date of expiry – 18 April 2023.

Confirmation of Release to Service (CRS)[9]:

– 50 FH check:

- date of issue – 9 September 2022.

Radio Licence:

- date of issue – 8 July 2019;
- date of expiry – 8 July 2029.

Certificate of Insurance (CofI) – valid on the day of the occurrence.

Overhaul life data[10]

Total time since new	809 hours 31 minutes
Number of take-offs	3025
Time since last maintenance	34 hours 32 minutes
Number of take-offs since last maintenance	116
Date of last maintenance (50 h)	9 September 2022
– at TTSN / no. of take-offs	774 hours 59 minutes / 2909;

- carried out by a Part-CAO Combined Airworthiness Organisation.

Maintenance

The glider maintenance was provided by a non-local contracted Part-CAO organisation.

The following was established on the basis of Maintenance Programme compliance statuses obtained:

- scheduled maintenance of the glider was carried out on time;
- applicable airworthiness directives and service bulletins, both one-off and recurrent, were implemented;

[8] Issued by a Combined Airworthiness Organisation (CAO).
[9] Issued by a CAO. The CRS from last maintenance shows also the glider stability check.
[10] Established on the basis of the aircraft status report provided by the CAO.

- the equipment installed in the instrument panels met the TCDS requirements and the provisions of the Flight Manual;
- life-limited parts and components were maintained and replaced in accordance with the prescribed service life and requirements;
- the seat belt straps were replaced (in both seats) in June 2022, when straps with new service life of 15 years (until 2037) were installed;
- the tow hook was overhauled in May 2019; as of the accident day, 970 cycles (releases) remained until the next overhaul.

Mass and balance

The glider weighing report – valid on the day of the occurrence:

- date of issue – 13 April 2022;
- empty weight Q_1: 370.7 kg[11];
- max. allowable weight of the two-person crew with the balancing weights installed: 159.3 kg.

Further information and an analysis of the glider's longitudinal balance can be found in Section 2.1.

1.6.2 General information about the tow plane

Description of the design

The WT-9 "Dynamic" (Fig. 7) is a two-seater, single-engine, low-wing design aeroplane built in the carbon composite technology. It was approved for VMC operations (in accordance with VFR). The aeroplane is manufactured in Slovakia in ultra-light (as SP-SHEL) and light sport aircraft (LSA) versions. The retractable landing gear is optional and was used on the SP-SHEL aircraft. The WT-9 is characterised by high stability, smooth stall characteristics and no tendencies to enter into a spin. The aeroplane is powered by a four-stroke, four-cylinder Rotax 912 ULS engine running on car fuel. The aeroplane received type certificate no. 61179 issued by the German Civil Aviation Authority (LBA) in accordance with the German certification and airworthiness regulations for ultralight aeroplanes, and type certificate no. V-80/2004 issued by the Civil Aviation Authority of Slovakia.

In Poland, the WT-9 was approved[12] on the basis of Aerospool (manufacturer) documentation and released for operation in the "ultralight" category, in accordance with the Regulation of the Minister of Infrastructure of 25 April 2005 on the exclusion of the application of certain provisions of the Aviation Law to certain types of aircraft (...), Annex 5 (Journal of Laws of 2005 No. 107, item 904).

[11] With two balancing weights in the cockpit: 2 x 5.5 kg.
[12] Based on the information contained in the WT-9 "Dynamic" Flight Manual.

Fig. 7 The WT-9 "Dynamic" tow plane, SP-SHEL [source: PKBWL]

In 2021, at the owner's request, the SP-SHEL was reclassified to the K4 qualified flying device, Subcategory UL-A "Aeroplane", and received a ULC registry certificate (registry no. 0654).

According to the related Flight Manual, the aeroplane's maximum take-off weight is 472.5 kg[13], with an empty weight of 323.2 kg[14].

The SP-SHEL was equipped with a 100HP BRP Rotax 912 ULS 2 engine with a composite three-blade controllable pitch Woodcomp SR-2000/DN propeller.

The aeroplane was fitted with a Tost tow hook. The maximum allowable weight of a towed glider was 750 kg[15]. Moreover, the SP-SHEL was equipped with a USH-52 S Softpack rocket emergency parachute system.

The airworthiness of the SP-SHEL was confirmed by an entry in the airframe logbook (Permission to Fly) with the expiry date of 23 May 2023. The airworthiness was confirmed by a mechanic from the company servicing the aeroplane.

According to the documentation presented by the owner, since the date of issue of the Permission to Fly, the following scheduled maintenance works had been carried out on the aeroplane:

- on 23 May 2022 – "100FH/annual airframe maintenance" – at airframe TTSN of 1296 hours 55 minutes[16];
- on 18 July 2022 – "100FH/annual engine, propeller maintenance" – at airframe TTSN of 1345 hours 30 minutes.

[13] As per the Flight Manual, with the USH-52 S "Softpack" rescue system installed, the aeroplane's maximum take-off weight is 472.5 kg.
[14] The aeroplane's empty weight as per the SP-SHEL weighing report of 15 October 2014.
[15] Applicable to the SP-SHEL; data as per the Flight Manual.
[16] As per aeroplane maintenance entries in the airframe logbook.

The performance of the maintenance works was described in an oral statement by the aviation mechanic involved, who provided details of the maintenance carried out. The maintenance facility provided *inter alia* a control data sheet from the last engine maintenance (dated 18 July 2022). After that maintenance, a check flight was performed to verify the correctness of operation of the power plant, during which no irregularities were identified.

The aeroplane had OC and Aero Casco insurance, covering glider towing. Endorsed in the insurance policy were the names of the pilots authorised to perform towing operations. The name of the pilot towing on the day of the accident was on the list included in the policy.

The aeroplane's maximum take-off weight was not exceeded.

The aeroplane's Mth counter, as read from FLYdat, was 558:29 Mth. This means that there were 1 441:31 Mth remaining before the next engine overhaul (the engine's TBO is 2000 hours).

Entries in the airframe logbook ("Aeroplane Operating Logbook”) did not include the flights performed on the day of the occurrence nor the flights performed in around two preceding months. PKBWL summoned the owner to complete the entries on the basis of lift-off lists kept by the aeroplane lessee (the Aeroclub). The owner completed the entries and submitted copies of the Aeroplane Operating Logbook. As of 23 October 2022, the total flight time of the airframe was 1 423 hours 44 minutes.

The owner of the aeroplane made available the shared airframe and engine logbook, in which the last two maintenance activities were entered: one on the airframe – maintenance of May 2022, and one on the engine – maintenance of July 2022. In both cases, the number of operating hours generated on the airframe was provided (i.e. TTSN). The entries in the logbook did not refer to the respective maintenance tasks listed in the applicable Airframe Maintenance Manual (Section 3.6 "Periodic work") or Engine Maintenance Manual (Section 05-20-00 "Scheduled maintenance"), but only ascertained the fact that the work had been performed.

The owner of the aeroplane had not received relevant Confirmations of Release to Service (CRSs) from the maintenance company where the maintenance was carried out[17]. However, the entries in the airframe logbook can be treated as confirmation of release to service. At PKBWL's request, the owner submitted CRS copies for the years 2018 – 2021.

The aeroplane's maintenance records lacked references to the execution of service bulletins.

1.7. Meteorological information

At 12:00 hrs, 15 minutes before the accident, the following METAR was issued for the Katowice-Pyrzowice aerodrome (EPKT) located 47 km to the south:

[17] Such confirmations were not obligatory.

METAR EPKT 231000Z 20011KT 9999 BKN006 12/10 Q1020=

- date: 23 October 2022;
- time: 10:00 UTC;
- wind direction: 200°;
- wind speed: 11 kt;
- visibility: over 10 km;
- clouds 5÷7/8 from 600 ft AGL;
- ambient temperature: 12ºC;
- dew point temperature: 10ºC;
- pressure: QNH 1020 hPa.

At the time of the occurrence, the Rudniki aerodrome had sunny weather (CAVOK) with moderate wind from S-W.

The weather is illustrated by a photograph taken at the aerodrome in the afternoon hours (Fig. 8) and by the aerodrome CCTV recordings (Fig. 9).

Fig. 8 Weather around the EPRU aerodrome on the day of the occurrence [source: Dziennik Zachodni, website]

At 12:00 hrs, the weather station recorded wind from the 225° direction, speed 16 km/h, in the area of the EPRU aerodrome. The data comes from the: earth.nullschool.net weather service (Fig. 9).

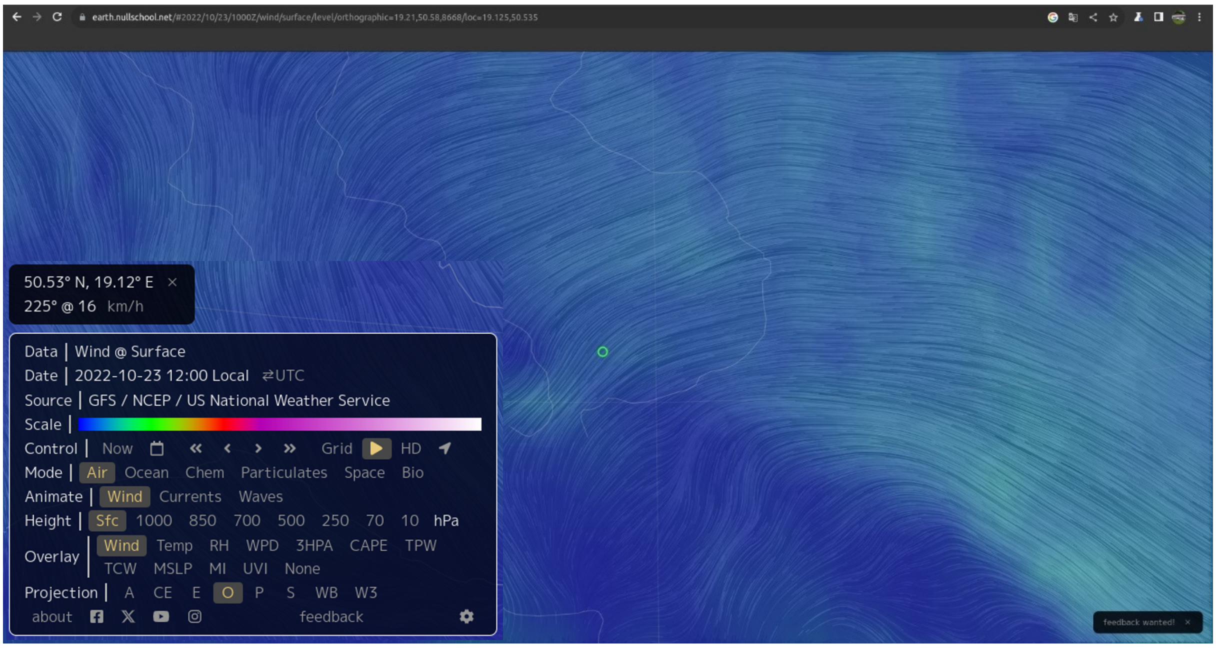


Fig. 9 Meteorological data obtained from earth.nullschool.net

The green dot represents the location of the EPRU aerodrome [source: earth.nullschool.net]

1.8. Aids to navigation

Not applicable.

1.9. Communications

The glider and tow plane were equipped with radios operating on the aviation frequency of 122.8 MHz.

Th aeroplane had a valid radio licence to use an ICA-210E on-board transceiver and a GTX-327 Garmin transponder. The radio was serviceable on the day of the accident.

As regards the radio licence, the President of ULC had issued a deviation concerning the obligation to use a radio with 8.33 kHz interchannel separation - the deviation was valid on the day of the accident.

Before taking-off for the accident flight, the tow plane pilot had carried out a communications check.

The aerodrome ground station received the aeroplane pilot's correspondence addressed to the glider crew after take-off.

Neither during the tow flight nor after the release of the line did the glider crew sent any messages.

1.10. Aerodrome information

Aerodrome Rudniki near Częstochowa – EPRU (Fig. 10); general information:

a) ARP – WGS-84 coordinates and location: 50°53'05"N, 019°12'11"E;
b) permitted air traffic: VFR;
c) aerodrome operator: Aero Partner Sp. z o.o.;

d) working hours: Monday-Friday, 07.00-15.00 hrs, or as arranged with the Operator;
e) air traffic services (ATS): none, contact with Rudniki Radio on 122.800 MHz;
f) rescue and fire service: none.

Meteorological information for the EPRU aerodrome is provided by the Central Bureau of Meteorological Forecasts in Kraków.

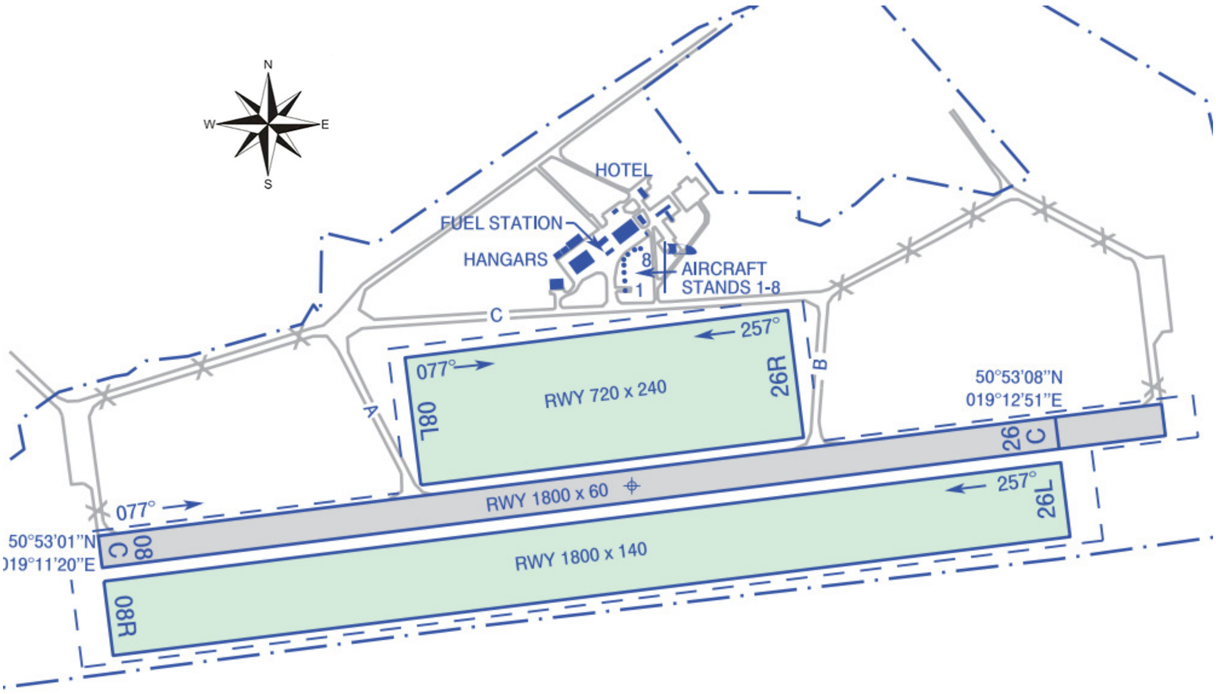


Fig. 10 EPRU aerodrome – positioning runways [source: AIP Poland]

1.11. Flight recorders

MDM-1 Fox glider, SP-3828

The glider was not equipped with any electronic flight recorders. No recorder was required under applicable regulations.

WT-9 "Dynamic" tow plane, SP-SHEL

No type of a flight recorder was required under applicable regulations.

The aeroplane had a Garmin 296 GPS which did not have any memory card. The aeroplane's instrument panel also had a FLYdat device for monitoring the performance parameters of the Rotax engine (Figure 11).

Dedicated to cooperating with Rotax engines, the FLYdat delivers power plant operating parameters to the pilot. The device compares the readouts with the data stored in the memory on an on-going basis (in real time). The warning and alarm levels had been preset by the manufacturer (see the list below). In the event that any of the parameters are exceeded, the FLYdat generates warnings for the pilot, signalled by a flashing warning light. The values exceeded are recorded in the device.

A more detailed description is provided in Chapter 2 "Limitations" in the aeroplane's Maintenance Manual and in the device manual.

Fig. 11 The tow plane's instrument panel: (a) GPS Garmin 296, (b) FLYdat [source: PKBWL]

The values which the system could record included:

- motohours;
- exhaust gas temperatures (EGT1÷EGT4);
- coolant temperature;
- oil temperature;
- minimum and maximum oil pressure;
- engine revolutions per minute (RPM).

The units and values of the warnings and alarms for the respective parameters were configured as shown below (Fig. 12):

```
-------------------------------------------------------------------------------
FLYDAT DOWNLOADER ver.2.00                  ROTAX AIRCRAFT ENGINES/TL elektronic
FLYDAT INSTRUMENT ver.2.50                                     IID: 0936773130
---------------------------- CONFIGURATION DATA --------------------------------
Engine Log                                        Created: 12.01.2023 16:56:04

Engine Type: Rotax 912ULS EV                      Serial No.: 9 570 443
Date of Configuration: 19.9.2018                  Mark of Configuration: 047

                                       Maximal                Minimal
Channel     Input      Units     Warning   Alarm        Warning  Alarm
   1         EGT2      [°C]        880      900
   2         EGT1      [°C]        880      900
   3        Water      [°C]        135      145
   4         Oil       [°C]        130      140
   5         EGT4      [°C]        880      900
   6         EGT3      [°C]        880      900
   7        Press     [bar]        6.0      8.0           2.0      1.0
   8         RPM    [1/min]       5800     6000


------------------------------ OPERATION DATA ----------------------------------
Hours of Operation: 558:29                          Time to next TBO: 1441:31
```

Fig. 12 The configuration of the Flydat device in the SP-SHEL aeroplane [source: Flydat]

PKBWL read the data from the device.

The device was configured in September 2018, i.e. after the new engine had been installed. At the same time, the Mth counter was reset.

The device recording interval was set at "5 s" – the parameters were measured every 5 s. Extracted from the file (log) were records corresponding to the aeroplane's operating period before the flight that ended in the glider accident, and the record of the accident flight.

The retrieved data was consulted with the engine manufacturer, BRP Rotax, 4623 Gunskirchen, Austria (see Section 2.6 Airworthiness of the WT-9 "Dynamic" tow plane), via the Austrian safety investigation authority (BMK).

1.12. Wreckage and impact information

The glider collided with the ground at a very large angle (nearly vertical), with a slight right-wing slip. This is evidenced by the lack of any traces of the glider's movement on the ground. The impact energy was absorbed first by the cabin with the pilots and the right wing, as evidenced by the injuries sustained by the crew and the damage to the glider.

An AM-10 g-meter with an indication range of +10g/-5g (Fig. 13) was installed on the instrument panel in front of the trainee pilot's seat. During the occurrence, the device was ripped out from the instrument panel.

The pointers (red colour) of the device are designed to stop at the maximum positive and negative g-load values reached in flight - the pointer stopped at +9 g. This is an unreliable value because the g-load during the collision with the ground was several times greater and off the instrument's scale.

Fig. 13 The g-meter found in the wreckage – a frame from a video recording from the accident site [source: PKBWL]

1.13. Medical and pathological information

As a result of extensive internal multiorgan trauma, the trainee pilot and the instructor died on the spot.

No evidence was found to show that the crew's actions had been affected by any disease, incapacity or physiological factors.

The crew was not under the influence of alcohol or any other substances affecting their actions[18].

1.14. Fire

No fire occurred.

1.15. Survival aspects

The energy of the glider's collision with the ground excluded the possibility of crew survival. The glider's cabin was destroyed. The injuries of the pilots were caused by the g-forces and the destruction of the glider's structures.

It was calculated that with the estimated vertical speed of 160 km/h (i.e. the speed of the impact on the ground) and stop (deceleration) on the distance of 3 m (i.e. the distance from the glider's nose to the wing spar), the time to stop was only 0.135 s, and the deceleration g-load reached 33 g.

Before the collision with the ground, the pilot (or pilots) stopped the glider's autorotation. Therefore, the configuration of the collision was extremely dangerous to the crew, more dangerous than in the case of a potential autorotation where the wing hits the ground first. On entering subcritical angles of attack (after the spin situation is

[18] Based on the information obtained from the Police.

stopped, the aircraft enters into a dive), the glider accumulated kinetic energy (gained speed) pointing its nose to the ground.

The tall trees, sparsely growing in the forest, in no manner dampened the energy or changed the configuration of the collision. The large mass, high speed and small wingspan of the glider did not permit generating sufficient force pairs (moments), even if the glider had caught the treetops so that the configuration of the collision could have been changed. Thus, there were no factors that could mitigate the impact.

Based on experience in flying the MDM-1 "Fox" in a two-person crew, it was estimated that the airspeed after establishing a dive (stopping the autorotation) was around 160 km/h. It is also the lowest speed at which it is possible to control the MDM-1 in curve flight, at recovery from a dive. This is why the said speed could have been even higher.

The pointer of the destroyed speed indicator installed in the instrument panel in front of the instructor's seat stopped at 260 km/h. It is an unreliable value, as the glider was unable to accelerate to such a speed from the altitude at which the release from the tow plane/spin situation occurred.

Even if the pilots had intentionally maintained autorotation by fully moving the rudder in the direction of the spin and pulling the control stick[19] to hit the ground while spinning, then at best they would have sustained serious injuries. This said, their chances for survival – particularly of the pilot in the front cockpit – would have been extremely low.

The deficit of flight altitude at which the spin situation occurred, and the lack of time until impact, precluded any use of emergency parachutes worn by the pilots.

Both pilots were strapped in by tightly fastened 5-point safety belts. During the occurrence, the belts did not snap, were not torn off or become delaminated, and their mounting points did not detach from the glider's structure. The fastening elements of the safety belts, such as latches, became deformed. The locked and fastened belts could not have increased the crew's chances of survival.

1.16. Tests and research

1.16.1. MDM-1 "Fox" glider, SP-3828

The glider wreckage was inspected. Two balancing weights, mounted to the floor near the control stick base in the front cockpit, were found. One of the weights had been ripped out of its mounting during the collision with the ground.

During the inspection of the wreckage at the site of the accident, it was found that the kinematic continuity of the control surface actuators had been maintained in flight until the moment of impact with the ground had been maintained.

[19] It is a practice generally recommended to pilots – avoid frontal collision when a collision with the ground in the spin is inevitable. Such a situation can be contemplated in the event of a spin at a height that prevents effective recovery to the level flight.

1.16.2. WT-9 "Dynamic" tow plane, SP-SHEL

Shortly after the occurrence, the WT-9 "Dynamic" SP-SHEL landed at the aerodrome, at the take-off location, where pilot shut down the engine. The aircraft was towed to the hangar with a towing car.

The aeroplane was secured for the purpose of an inspection by PKBWL and a preparatory investigation by the prosecutor's office. The prosecutor's office ordered an expert examination of the power plant. The engine was examined by an authorised Rotax maintenance station, whereas the propeller was examined by its manufacturer. As of the date of publication of this report, the prosecutor's office had not made copies of the examination reports available to the Commission.

During its inspection, PKBWL established that:

1. In cylinder no. 1 there was a minimal compression, and there were a significant carbon deposits on both spark plugs (Fig. 14).

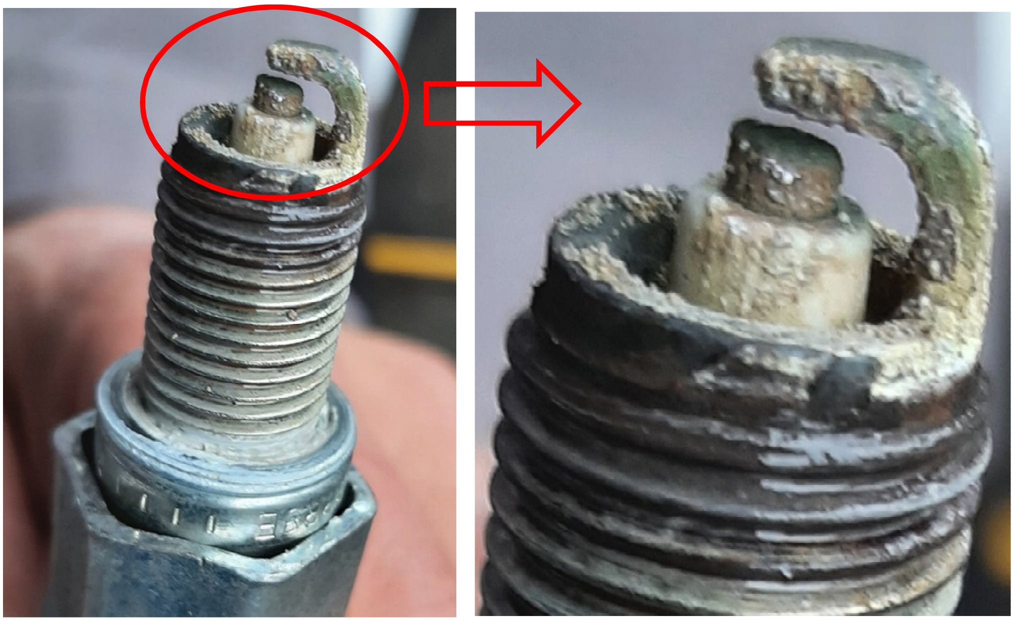


Fig. 14 Carbon deposit on the electrode of the spark plug of cylinder no. 1 [source: PKBWL]

2. The electrodes of cylinders no. 2, 3 and 4 did not have any carbon deposits, but their colour was light grey.
3. The NGK DCPR7E spark plugs installed in the engine did not meet the recommendation provided in the Rotax Service Manual (instruction no. SI-912 i-013 / SI-912-027 / SI-914-028) concerning the use of 297656-type spark plugs (double-electrode spark plugs). However, BRP Rotax notes in the said document that it is not obligatory to use the new type of spark plugs.
4. There were significant carbon deposits in all cylinders. The condition of the interior of cylinder no. 1 is shown in Fig. 15.

Fig. 15 Borescope camera photographs of the interior of cylinder no. 1 [source: PKBWL]

5. In order to directly examine the condition of the combustion chamber and piston, the cylinder head and the body of cylinder no. 1 were disassembled, exposing the piston. Numerous carbon deposits were found on the bottom. The condition of the piston bottom (left) and the head valves (right) is shown in Fig. 16. White "ceramic" carbon deposit was found in the head. The same deposit was found on the surface of both valves and on the exhaust valve stem.

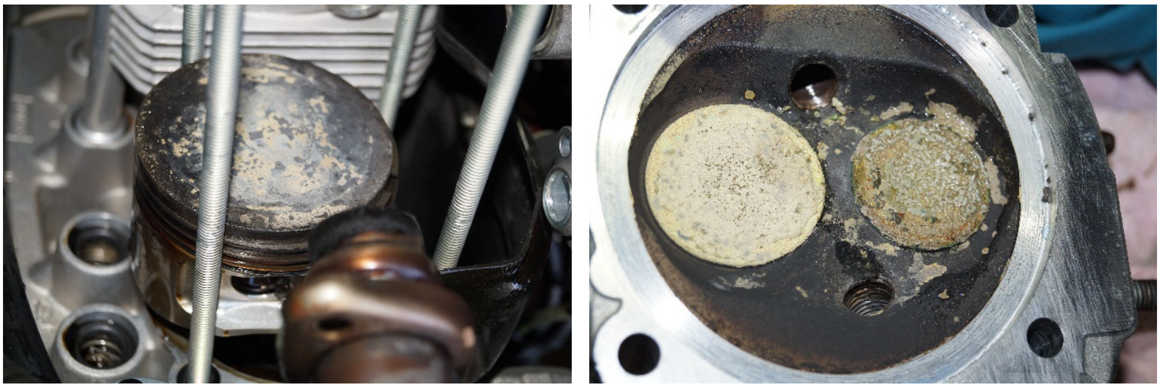


Fig. 16 The piston of cylinder no. no 1 and cylinder head valves [source: PKBWL]

6. No damage to piston rings in cylinder no. 1 was found. The condition of the piston rings was described as correct.
7. Visual assessment of the quality of the fuel (unleaded 95 petrol), drained twice from the aeroplane's settlers, showed that the fuel was clean, clear and without any water inclusions.
8. Fuel was found to be present in the fuel filter installed in the engine compartment (Fig. 17).

Fig. 17 Fuel in the filter on the engine [source: PKBWL]

9. Both engine carburettors were opened, and no irregularities were found inside. Based on a visual assessment, the condition of the needles and throttles was found to be correct. The carburettor needles were uninstalled together with the membranes. It was confirmed that the needle settings (Fig. 18), and thus the calibration of the carburettor, met the recommendations of the engine manufacturer (Maintenance Manual. Base maintenance, "Fuel Systems and Distribution", doc. no. 73-00-10, Edition 2 of September 2022).


Fig. 18 The carburettor needle and its setting [source: PKBWL]

10. The rubber membranes in the carburettors did not show signs of wear.
11. The carburettor floaters uninstalled from floater chambers were examined and no irregularities were found. The floaters were weighted and found to be correctly marked with letter "R", as prescribed in the applicable Rotax service bulletin.
12. Fuel samples from the aeroplane's tanks as well as fuel separations and samples taken from the fuel distributor at the fuel station where the fuel had been purchased were secured for the purpose of laboratory tests.

The said samples were tested by the Research Laboratory Team of the Petroleum Technology Division at the Oil and Gas Institute, National Research Institute (Polish: *Zespół Laboratoriów Badawczych Pionu Technologii Nafty Instytutu Nafty i Gazu – Państwowego Instytutu Badawczego*) accredited by PCA (certificate no. AB 009).

All the samples were found to be in compliance with the requirements of applicable specifications[20]. The said requirements included *inter alia* the appearance, water content, density at 15°C, resin content, vapour pressure, research octane number (RON), motor octane number (MON) and other.

The fraction composition of the samples, oxygen content, the content of oxygen-containing organic compounds, volatility index (VLI) and other parameters were also determined.

1.17. Organizational and management information

The pilots were authorised to fly gliders under their SPLs. The glider, owned by the Aeroclub of Poland, had been operated by a regional aeroclub[21], where it had been operated as part of the association's statutory activities.

Aeroklub Częstochowski held an applicable DTO declaration in its range, to provide glider training in aerobatics. Training was provided in accordance with the AKRO(S) programme developed for the DTO (2021 edition).

The tow plane used by the aeroclub had been operated under a valid agreement concluded by the aeroclub with the owner.

1.18. Additional information

1.18.1 Comments of the Commission concerning operation of the MDM-1 "Fox" glider

Handling characteristics, stall characteristics

The MDM-1 "Fox" glider was designed for training in advanced aerobatics (advanced and unlimited) and for competition in aerobatic competitions at all levels. For many

[20] These specifications are: the Regulation of the Minister of Economy of 9 October 2015 on the quality requirements for liquid fuels (Journal of Laws, item 1680 of 23 October 2015), Annex 2 and PN-EN 228+A1:2017-06 "Unleaded petrol".
[21] As established on the basis of an entry in the glider's Certificate of Registration.

years, it was the monotype in the co-pilot method training for advanced and unlimited aerobatics in Poland.

The MDM-1 is not a trainer glider. Among two-seater gliders operated by training centres, it is distinguished by demanding handling characteristics. This applies in particular to flying at around-optimal speeds, as the glider is prone to dynamic stalls. When stalled, at a wide range of speeds, is has a tendency to autorotate. A stall, at any flight asymmetry and in a turn (including circling), often leads to autorotation which requires time to stop and comes with a significant loss of height. In every loading configuration (in particular with two persons present in the cockpit), the glider requires very careful handling.

It must be noted that in the certification process, in the stall speed range, the MDM-1 "Fox" glider did not meet the JAR-22 regulations for glider construction. Due to the higher stall speed than required by the rules, in order for the glider to obtain a type certificate, the Civil Aviation Authority issued a deviation from the rules.

Although the glider warns the pilot of a stall by giving perceptible vibrations, it must be borne in mind that maintaining lateral balance (by intensive aileron control movements) is possible only in straight flight (a static stall in a straight flight), and that it is an action that requires very good mastery of the glider handling. Maintaining lateral balance in a turn (maintaining the defined bank angle) is not possible in the event of a stall – the glider sinks to the wing, tending to autorotate.

Stall speeds in a turn increase with the bank angle and mass of the crew (see also Section 2.2 Analysis).

A dynamic stall is possible in a wide range of speeds, up to V_A[22].

Towed flight

In a tow plane-glider team, the aeroplane pilot remains the team commander until the glider is released. The tow plane pilot can give instructions to the glider crew. Under special circumstances, the tow plane pilot may also release the glider by unhooking the tow cable from the aeroplane.

Where the towing speed is low at a low height, and if the glider pilot (crew) is able to maintain balance relative to the aeroplane (mainly the lateral balance), the glider can, and rather should, "stay on the tow cable" and not release it.

Such a situation can be imagined in the following cases:

- shortly after take-off when the tow plane is accelerating;
- where towing takes place over terrain and/or in weather conditions that do not ensure that the glider can land safely at an aerodrome after the tow cable is released, and more so in random terrain;
- where the towing height is insufficient and does not allow the glider pilot to form the landing manoeuvre;

[22] V_A - means the manoeuvring speed (full deflections of the control surfaces). For the MDM-1 "Fox", V_A was determined at 214 km/h.

- where towing takes place at a low speed for the glider, and the tense tow cable still stabilises the flight (enables keeping the glider behind the tow plane).

If it is not possible to maintain the lateral balance, the tow cable should be released sufficiently early, the flight speed ensured, and emergency landing should be performed in random terrain.

Situations where the tow plane pilot releases the cable are rare. There are no statistics on this topic. The team leader may release the tow cable with the glider in a situation that threatens safety, for example when the glider pilot loses control of the glider's attitude behind the aeroplane (e.g. during a take-off run or in towed flight), when the continued linkage between the tow plane and the glider poses a threat of collision or prevents continuing the flight. The tow cable may also be released due to a power plant failure in the aeroplane at or after take-off, or for any other special reason, e.g. aeroplane fire. In such a situation, the towing pilot is either forced to perform an emergency landing immediately or is unable to continue the flight with the parameters that allow glider towing.

The tow plane pilot, with a defined engine power reserve and using the aeroplane's performance, must first ensure a safe glider towing speed and effective climb after take-off. As the team commander, the tow plane pilot is responsible for safe take-off and towed flight by choosing proper flight speeds, climb speeds, route and manoeuvres. The recommended towing speeds are normally specified in flight manuals of gliders and aeroplanes, and they also arise from experience-based "good practices".

Where the tow plane's engine power is low, higher towing speeds translate normally to lower climb rates of the team, or even no climb at all. The towing pilot - taking into account the qualifications of the pilot in the towed glider, the glider's flight characteristics, weather conditions and other factors - will limit the towing speeds to optimise the process of climbing.

Towing speeds depend on the glider type and the tow plane's performance. Furthermore, they result from the engine power, take-off mass, as well as aerodynamic and handling characteristics. They may also depend on terrain obstacles in the take-off direction, weather conditions and pilot qualifications.

Towing of gliders by ultralight aeroplanes is popular in Poland as well as abroad. It results from the increasing availability of ultralight aeroplanes and lower costs of their keeping in service compared with certified aeroplanes. The towing parameters, such as the towed flight speed and team's climb rate, are competitive compared with the parameters offered by certified aeroplanes. Ultralight aeroplanes are normally characterised by a longer take-off run and greater susceptibility to turbulences.

The lower costs of towing by ultralight aeroplanes are associated with:

- lower administrative costs relating to formal airworthiness;
- nearly twice lower price for automotive fuel used in ultralight aeroplane engines (mainly Rotax engines) compared with Avgas 100LL;

- growing availability of ultralight aeroplanes and aircraft classified as "flying devices", accompanied by the ever closer end of the service life of expensive-to-maintain aeroplanes that were dedicated to towing operations earlier (in Poland, mainly the Jak-12M and PZL-104 "Wilga").

During take-off run and in the first phase of climb after take-off in a towed flight, the glider pilot concentrates first on maintaining the proper attitude behind the aeroplane. The MDM-1 "Fox" glider Flight Manual does not specify the recommended or minimum towing speed. However, as practice shows, those speeds – in a two-person crew – should never be lower than 115÷120 km/h. Towing pilots often increase the speed to 130÷140 km/h, and even higher.

A towed flight at a speed or around or even below 100 km/h is also possible, but in such a case, the MDM-1 Fox glider "hangs" on the cable and is very susceptible to disturbance in its lateral balance, which is difficult to maintain. Near-ground turbulences or the tow plane's prop wash may additionally disturb that balance. The glider then shows a tendency to sink to the wing, is nervous, unpleasant in handling, and susceptible to a dynamic stall. At such a speed, the team is practically unable to execute a turn.

At the optimum speed (v_{opt}) in a towed flight, the MDM-1 "Fox" requires precise and careful handling[23].

Such characteristics as controllability and stability are in principle opposite to each other. An aerobatic glider is expected to have high manoeuvrability, which in turn results directly from controllability. In order to satisfy that requirement, designers use *inter alia* small wing aspect ratio (smaller moments of inertia), large control surfaces, non-standard deflections of the control surfaces, as well as flat and laminar profiles of the lift surfaces. Such geometrical parameters can lead to local air flow separation. It can take place within a wide range of air speeds, when the pilot operates the controls excessively, or especially in an uncoordinated manner. A sudden change in the airfoil camber (e.g. by jerking, or sometimes even just holding the control stick in a narrow turn at a low speed) often leads to flow separation[24]. The disturbance tends to propagate across the control surfaces (a separation vortex generates further separations) which cease to work even though the glider moves at a much higher speed than V_{S1}[25].

Safe height for manoeuvres

Due to operational safety, it is a recommended practice during aerobatics training in the "Fox" glider to warn the trainee against performing snap rolls solo at heights below 600 m AGL. When not stopped in time or not stopped properly by the pilot, a flick roll will result in a sequence of one or few additional rolls during which attempts to control

[23] As read from the speed polar curve, the optimum speed for a glider with mass in flight equal to 515 kg is around 115 km/h (the Flight Manual, Section 5.3.2 Polar speed curve).
[24] In a turn, this is coupled by a constant change of the angle of attack on the tail plane, resulting from its circular motion (together with the entire glider), which – combined with the airfoil camber (the deflected elevator) – increases the likelihood of flow separation on the tail plane.
[25] V_{S1} – means the stall speed in a straight flight.

(stop the rotation) will not be effective for some time. After the flick roll is stopped, the attitude of the glider in the air will be totally random. It must be noted that a spin (normal) is a kind of a flick roll.

Therefore, when considering execution of a spin or a potential spin situation, the pilot should every time take into account the safe height to recover. The following things should be borne in mind: a delay in stopping the autorotation and the necessary height to recover from the dive. The loss of height (particularly in the first turn and when the crew is very heavy) is several dozen metres or more, and it is the greatest in the first turn of the spin. When the crew is heavy (the front location of the glider's centre of gravity), the spin is steep and the loss of height is greater than with just one pilot.

The speed of flying on a curve, when recovering from a dive, must not be too low either. With a too wide and, at the same time, sudden pulling of the control stick (deflecting the elevator), at an insufficient flight speed and too small radius of recovery, there is a risk of flow separation on the empennage. The elevator loses effectiveness completely and the glider does not recover from diving. There is also a risk of a dynamic re-entry into a spin.

Aborted take-off procedure

Emergency procedures should be clear and generally known. They stem primarily from the so-called good practices, which are sometimes described in Flight Manuals or the Operations Manual of a given aerodrome.

Good practices are behaviours developed on the basis of actual situations or accumulated experience. They concern recommended behaviour in case of emergency. When the glider towing speed after take-off drops to the value that does not allow maintaining lateral balance, and therefore also maintaining the attitude behind the tow plane, the tow cable should be released. In such a situation, the glider pilot should first and foremost secure flight speed in the "forward" direction. Where a safe return (turn to the aerodrome) is not possible or there are concerns whether it can be performed safely, then the pilot should continue flying forward, with slight deviations in the direction, and prepare for emergency landing outside the aerodrome. For gliders, the height of 100 m AGL is accepted as the minimum height for performing a return turn (around 180°) to land. Below that height, the direct/forward landing applies.

To gain height that would allow any manoeuvres other than securing the flight speed "forward", the glider pilot must rely on the tow plane. However, securing the speed in a "forward" flight must be possible at every stage of towing, which is the responsibility of the glider pilot (pilot-in-command).

Both the glider pilot and the tow plane pilot should prepare, foresee and perform the flight so that they can respond properly to any situation at any time. This is why it is critical for the pilot to think, before take-off, what they would do in an emergency. Routine and repetitiveness reduce the need to think ahead.

It is a good practice for the flight manager at the launch point to discuss emergency procedures before take-off.

In training flights, it should even be required that the student (trainee pilot) explained to the instructor before take-off, with understanding, how they would behave in an emergency at respective heights and in specific circumstances (arrangement and type of take-off, aircraft type, weather and traffic situation, obstacles around the aerodrome etc.). Pilots and organisations in many countries recommend a short procedure to be carried out along with the so-called actions-on list prior to take-off:

EVENTUALITIES - consider launch failure and other options

1.18.2 Comments from the Commission concerning good practices in obtaining pilot ratings and practical qualifications by pilots

The process of obtaining formal qualifications is regulated to a certain degree. These rules condition the pilot's access to successive advanced training modules on the possession of licences, current ratings, possibly flight time.

However, progress in training and acquisition of practical skills result from many factors, often other than provisions of law or the regulations of aviation organisations. In the first place, one should enumerate here: the trainee's psychomotor abilities, previously gained experience, commitment, financial resources, the instructor's qualifications and commitment, availability of equipment, spare time, and even factors such as airspace and appropriate weather for performing flight.

Experience in training has shown that excessively fast progress in acquiring qualifications is not advisable. Acquiring practical skills in aviation should be spread out reasonably over time. Training programmes take into account the level of difficulty of successive exercises and define the basic requirements which the pilot must meet to commence another course. Training load should be adjusted to the trainee's psychomotor capacity, which is affected by emotional maturity, discipline, talent, ability to assess, mood, perception, spatial orientation (observation), ability to predict, motor and physical capacities, understanding of phenomena, as well as ability to manage non-standard situations.

Many stages of learning (especially aerobatics) require a thorough ground preparation before gradual and, ideally, systematic in-flight training could begin.

Advanced and ultimately unlimited aerobatic courses on a high-performance/competitive glider must be preceded by solid command of not only handling of basic aerobatic figures but also matters relating to safe execution of advanced aerobatic flights.

Accumulation of experience is therefore connected with the passage of time and covers execution of flights, time spent on observation from the ground, learning, presence in the environment, joint work at take-off, and participating in explanatory discussions.

Operation of gliders which are distinguished by their flying and handling characteristics, such as aerobatic gliders, must be preceded by proper preparation and experience gained with conventional equipment. In other words, a pilot (even one already licenced) should be required, or at least suggested, to continuously develop aviation skills in an appropriate sequence and timing.

The above is summarised by the old, but proved in aviation, Latin adage *festina lente* (make haste slowly). Prudence, accuracy, diligence and orderliness are the keys to safe exercise and development of aviation skills, of which flying is just one of many. In this context, gliding is particularly demanding.

This does not mean that training in and flying on high-performance gliders, including learning of advanced aerobatics elements, cannot be pursued by young people. Young pilots very often acquire skills much faster and better than their older colleagues. Consequently, young age can favourably translate into subsequent development of aviation career, and sometimes even guarantee success in sports or professional competition.

It is the role of educators (HT, trainers, instructors and even take-off managers) to assess how fast a young pilot acquires new skills and whether particular flights are safe for them.

1.19. Useful or effective investigation techniques

Standard investigation techniques were applied.

The Research Laboratory Team of the Petroleum Technology Division at the Oil and Gas Institute, National Research Institute carried out comprehensive specialised tests of the fuel samples taken from the tow plane tanks, fuel drained before the flight day for settling, and the fuel samples taken from the fuel station where the fuel had been purchased.

1.20. Consultation of the draft final report

Before publication of the final report, PKBWL consulted its draft, requesting the interested entities, authorities and persons to submit their comments:

a) Aeroklub Częstochowski – the operator of the glider submitted the comments;
b) the operator of the towing plane did not submit comments;
c) the Pilot-in-Command of the towing plane who submitted his comments;
d) BMK – did not submit comments;
e) BRP Rotax – (via BMK) – submitted the comment[26] ;

[26] BRP Rotax has informed that the deposits on the pistons, particularly on the engine valves, show the AvGAS fuel was used. The aircraft user denied to apply AVGAS during the whole exploitation of the aircraft equipped with this engine. The PKBWL has not confirmed to apply the AVGAS on its aircraft.

f) AMIA – did not submit comments;

g) EASA – did not submit comments.

2. ANALYSIS

2.1. Mass analysis of the glider

Centre of gravity X_{SC} (location) of the glider in flight – limits[27]:

- front limit of X_{SC}: 213 mm aft of datum (representing 22.0% MAC);
- rear limit of X_{SC}: 379 mm aft of datum (representing 39.0% MAC).

The Mean Aerodynamic Chord (MAC) is 971 mm (0% MAC) and is located 2.1 mm aft of datum.

Calculating the mass of the pilots in the cabin

The mass of the trainee pilot in the front cabin [m_{pp}]:

$$m_{pp} = \text{mass of the pilot} + \text{mass of the parachute}^{28}\ [\text{kg}]$$

$$m_{pp} = 85^{29} + 8.4 = 93.4\ \text{kg}$$

The mass of the instructor in the rear cabin [m_{pt}]:

$$m_{pt} = \text{the mass of the instructor} + \text{the mass of the parachute}\ [\text{kg}]$$

$$m_{pt} = 78 + 8.4 = 86.4\ \text{kg}$$

Calculation of actual loading

The allowable mass for a 2-person crew in the SP-3828 glider in which balancing weights were installed is: 159.3 kg

Actual crew mass: 179.8 kg.

The glider mass and location of the centre of gravity in flight

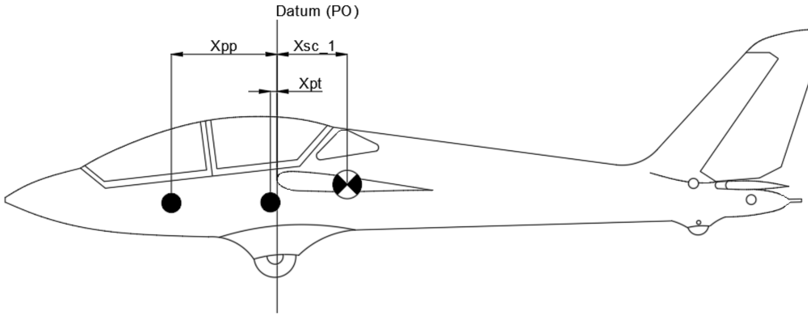
$$Q_{TO} = Q_1 + m_{pp} + m_{pt}\ [\text{kg}]$$

$$Q_{TO} = 370.7 + 93.4 + 86.4\ \text{kg}$$

$$\mathbf{Q_{TO} = 550.5\ kg}$$

where Q_{TO} means the glider's take-off mass, Q_1 means the glider's empty mass, m_{pp} means the mass of the trainee pilot, m_{pt} means the mass of the instructor.

[27] The values as per TCDS/FM Section 2.7 for the maximum allowable mass of the glider in flight
[28] The mass of one MarS ATL-88 emergency parachute (as worn by the pilots) is (up to) 8.4 kg (manufacturer data).
[29] The masses of the pilots in the cabin – based on information obtained from the prosecutor's office.



The equation for the balancing moments relative to the datum (reference plane):

$$\sum M = 0$$

$$Q_{TO} * X_{SC\_TO} = Q_1 * X_{SC_1} + m_{pp} * X_{pp} + m_{pt} * X_{pt} = 0$$

$$X_{SC\_TO} = \frac{Q_1 * X_{SC_1} + m_{pp} * X_{pp} + m_{pt} * X_{pt}}{Q_{TO}} \; [mm]$$

$$X_{SC\_TO} = \frac{370{,}7 * 566{,}20 + 93{,}4 * (-950{,}0) + 86{,}4 * (-60{,}0)}{550{,}5} \; mm$$

The location of the glider's centre of gravity in flight

$\boldsymbol{X_{SC\_TO} = 209,95\ mm}$ within the allowable range of 213÷379 mm.

Parameter	Minimum value	Allowable maximum value	Actual value	Deviation
Glider take-off mass	not applicable	530 kg	**550.5 kg**	**+20.5 kg**
Load in cabin	not applicable	159.3 kg	**179.8 kg**	**+ 20.5 kg**
Location of centre of gravity in flight	front	rear	**209.95 mm**	**>3 mm to the front**
	213 mm	379 mm		

Conclusions:

1. The glider's maximum take-off mass (flying mass) was exceeded by 20.5 kg.
2. The glider cabin load was exceeded by 20.5 kg.
3. The glider's centre of gravity in flight was not within the prescribed limits.
4. The glider's maximum allowable mass for towed flight behind the WT-9 SP-SHEL aeroplane was not exceeded.

2.2. Conditions of the towed take-off and flight which ended in the accident of the glider

The path of the aeroplane-glider team from take-off to release of the glider was established on the basis of recordings from the aerodrome's CCTV system, the statement by the towing pilot, the statements of witnesses, and the practice of towing the MDM-1 "Fox" glider behind the WT-9 "Dynamic" aeroplane.

The aerodrome CCTV recording allowed the recreation the towed take-off and flight by the vicinity of the end of RWY26, i.e. until the moment when the towing pilot experienced engine vibrations and a drop in the power plant power. Until that moment, the take-off and climbing after take-off were progressing as normal.

Such flight parameters as the towing speed and its changes from the moment of the aeroplane's engine failure to the release of the glider, and the rate and profile of climb of the team were estimated on the basis of witness accounts, including one provided by the aeroplane pilot.

Compared to other ultralight aeroplanes used for glider towing, the WT-9 "Dynamic" is distinguished by *inter alia*:

- a wide range of towing speeds;
- satisfactory climb when towing gliders;
- good visibility from the cockpit (especially when compared with high-wing monoplanes).

The SP-SHEL had additional advantages:

- a variable pitch propeller;
- a retractable landing gear, which reduces the drag after take-off.

This aeroplane has been used for many years been used for towing gliders, including heavy two-seater gliders, aerobatic gliders, open class gliders and gliders with water ballast.

The team took off from RWY26. During the take-off run, the wind blew from SW at a speed of around 16 km/h. The aeroplane lifted off first (V_{S1} of the WT-9 is around 65÷70 km/h). After lift-off, the aeroplane pilot was building up speed, waiting for the glider to lift off. After reaching 130 km/h, the team proceeded to climb.

In the vicinity of the end of RWY26, the team reached the height of around 70÷90 m AGL (Fig. 19a). After passing the RWY end, flying past a group of model-makers, the aeroplane pilot felt engine vibrations. He notified the glider crew by radio: "Fox, we have an engine problem!"

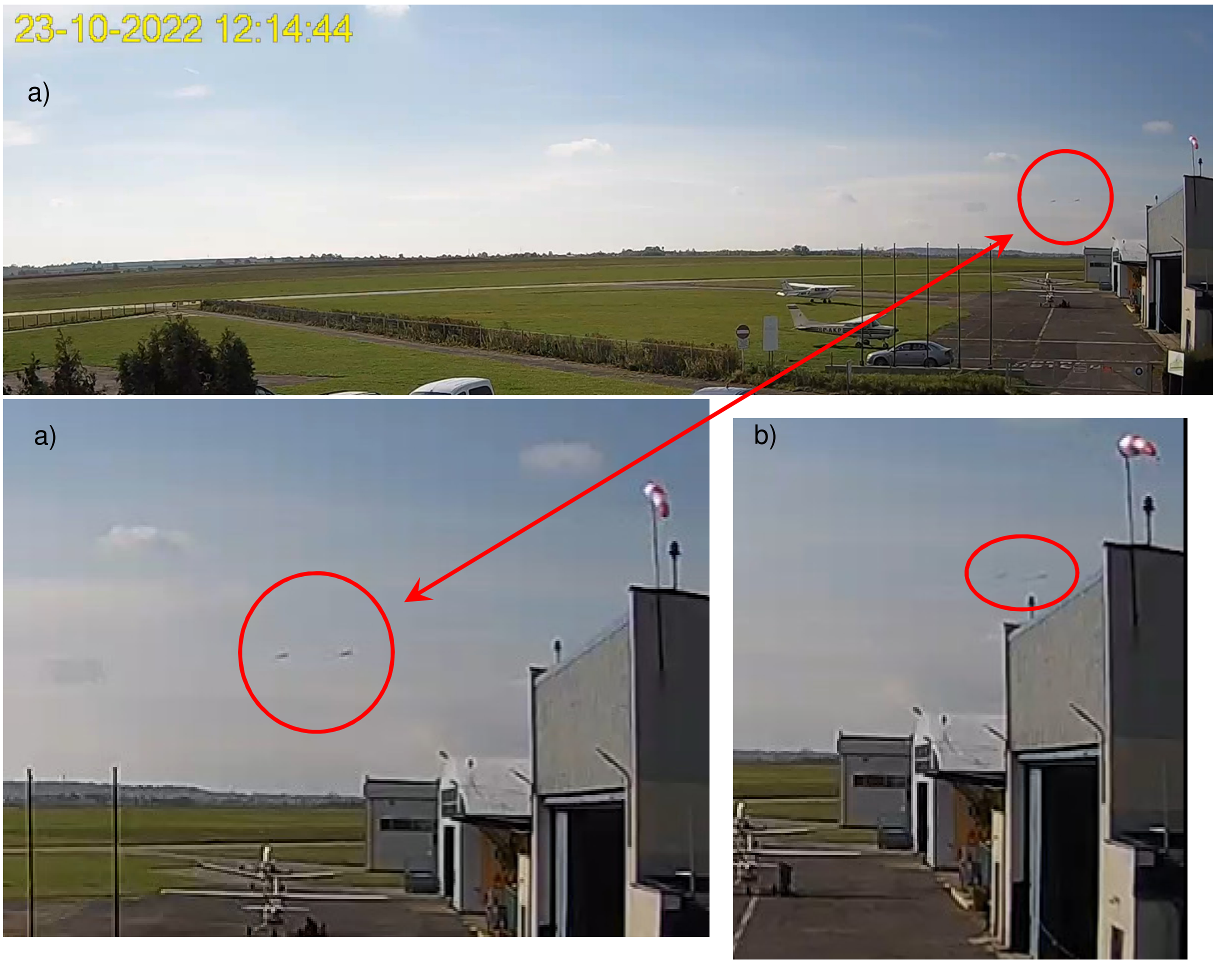


Fig. 19 a) The aeroplane-glider team after take-off from RWY26. A wind cone on a hangar can be seen on the right of the photos; b) A 6 sec. interval relative to a) – it is the last recorded position of the team [source: aerodrome CCTV/PKBWL]

Continuing the straight flight, the pilot attempted to diagnose the cause of the vibrations.

<u>The drop in the aeroplane's engine power after take-off triggered the causal sequence that led to the accident, but was not the cause of the occurrence.</u>

The second contributing factor was the towing pilot's decision to take a turn with the glider still on the line and – additionally – "down wind", to the right from the take-off axis, in the direction of a forest complex.

The pilot of the SP-SHEL explained his decision to take that turn by the repetitive nature of glider towing over the EPRU aerodrome, usually on N circle. In the Commission's opinion, he commenced the turn intuitively, as during the previous flights, and his decision – as often happens in a crisis situation and in time deficit – was faster than the assessment of the situation. The pilot said that he had rejected the option to turn in the opposite direction (to S) for the fear of colliding with the group of model-makers located in the vicinity of the end of RWY26 (the group's location is marked in Fig. 20). Such a danger could not materialise, however, as the group would have found themselves in the centre of the circle representing the path of the aeroplane's turn, even with a small[30] radius of that turn.

Glider towing operations on N circle (to the right after take-off) were dictated by the intention not to overfly the buildings to the south of the aerodrome at a low height due to noise. Also, on the day of the accident, there was a winch take-off was arranged on the southern runway. After releasing the winch line, gliders took a circle S (left) to RWY26. For that reason, the aerobatics area for the "Fox" was situated N to RWY26. Such a division of the airspace over the aerodrome ensured separation between the aerobatics zone and winch flight zone, and provided for convenient observation of the "Fox" in the zone ("behind the sun").

The tailwind during a turn which the towing pilot continued caused a larger radius of that turn and moved the team away from the lift-off field.

Ultimately, the aeroplane landed on RWY08.

During a hypothetical landing of the glider (following successful completion of the turn "toward the aerodrome"), due to the height deficit, the landing would have taken place more or less across the runway. Continuing the straight flight after take-off would not have caused an increase in the glider's stall speed by a few km/h (the stall speed in straight flight is lower than the stall speed in turn). Those few km/h could have been salutary in avoiding the spin situation which took place.

In a hypothetical left turn of the team upwind, the glider crew, after releasing the tow line, could have considered emergency landing "directly" on the wastelands or fields to SW or even S of the aerodrome (Fig. 20). Such a landing would have likely ended in damage to the glider and, probably, injuries to the crew, but it would have ensured survival. Landing in the direction "toward the forest" and downwind, with the ground speed increased by the wind speed (the tailwind component) would have had to end in the glider's collision with obstacles (trees) and would have immensely exposed the crew to at least serious injuries. Hence, this is probably why the "Fox" crew decided to continue the turn "toward the aerodrome".

When the aeroplane's engine failure occurred, the climb was aborted and the flight speed decreased significantly. The towing pilot transmitted the second radio message to the glider crew: "Fox, I have a problem, release when you can!" The aeroplane's engine was still running, but the loss of power was clear. After a brief flattening ("straightening") of the turn in the direction of around 70°, to the right of RWY26, the aeroplane pilot continued the turn to the aerodrome. According to witnesses observing the situation from the ground (from the launch point), the release from tow took place during the turn.

[30] Due to the critically low towing speed for the glider, a potential left turn should have taken place at a possibly large radius, so as to protect the glider against stalling in a turn (the stall speed in a turn is a derivative of the turn radius, and it increases as the turn becomes tighter). That precluded any collision with the group of model-makers.

Since there was no correspondence from the glider crew and no recorded electronic flight data, the following three hypotheses regarding why the tow line had been released were formed:

1. The glider's flight speed in tow was too low and did not allow continuing the flight behind the aeroplane (no possibility to maintain lateral balance);
2. Under the influence of emotions, the line could have been released by the trainee pilot against the instructor's will and too early;
3. The glider crew (either the instructor or the trainee pilot) released the line prompted by the message from the towing pilot "(…) release when you can!", without assessing the situation properly.

The release of the line from the glider and the loss of communication with the aeroplane were probably critical elements of the flight leading to the spin situation. The line connection, as long as it was established and the crew was able to maintain their position of balance (lateral) behind the aeroplane, stabilised the flight. It should be presumed that the glider crew maintained the flight in tow for as long as it was possible. Having poor stability[31], and bereft of line stabilisation and effective control, the MDM-1 "Fox" entered into a spin as a result of a dynamic flow separation on the wing.

The analysis of the development of the spin situation and collision with the ground is provided in Section 2.3.

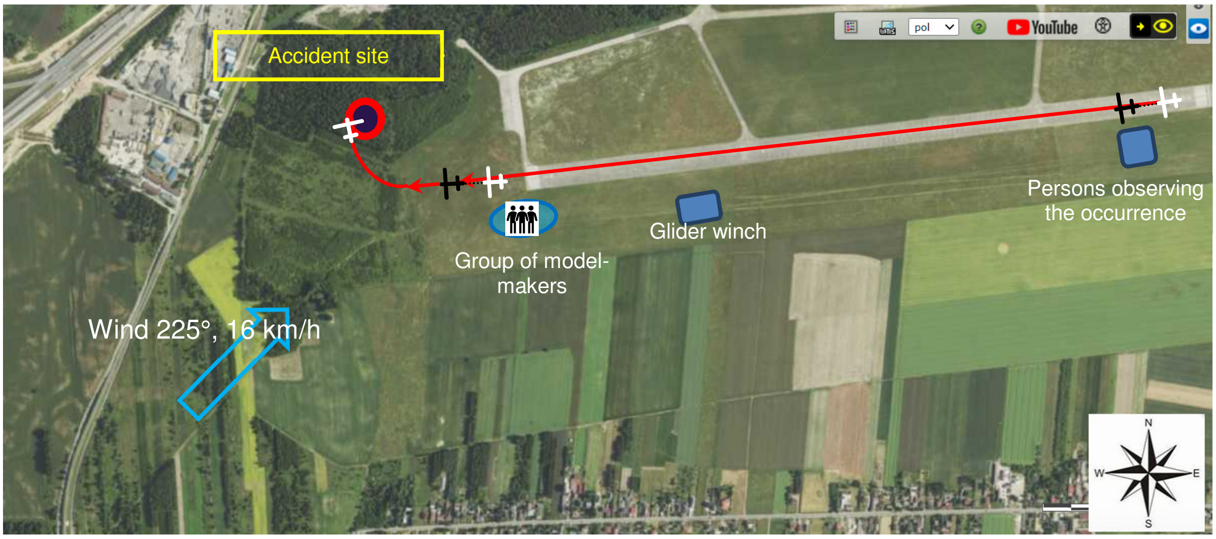


Fig. 20 The position of fields to S of RWY26 of the EPRU aerodrome [source: Geoportal / PKBWL]

It must be found that neither the glider crew nor the towing pilot made a proper assessment before the flight regarding procedures for emergencies such as a possible aborted towing.

[31] The most general definition of stability describes it as a feature of a glider that allows either maintaining the position of balance (static stability) or recovering the position of balance after a strong disruption of stability (dynamic stability). As a high-performance aerobatic glider, the MDM-1 "Fox" can be considered as a design with low stability.

After the aeroplane's engine failure occurred, it was advisable for the team to continue the flight upwind towards the fields and, more importantly, towards the non-forested area. This guaranteed *inter alia* several additional metres of height (no trees, no increased descent rate in turn) for building up the flight speed following the release of the glider, which was necessary for safe manoeuvres.

The Operations Manual of the Rudniki aerodrome provided by a representative of the aerodrome operator (2nd edition from 2019) did not contain any procedures for failed/aborted take-off.

2.3. Analysis of the course of the occurrence after the release of the glider from the tow plane

The spin situation took place either at the moment of releasing the tow line or during the turn to the aerodrome. However, witness statements are discordant on this matter. Presumably, just after the release, the glider crew attempted to control the glider and secure the low flight speed. One of the witnesses (glider pilot) described that at the moment of the release, the glider suddenly raised its nose by a small angle above the aeroplane, and then suddenly pitched down – probably in order to build up speed. Then, without waiting for the speed to increase, at a decreasing height of no more than 70 m over the forest, the glider commenced a sharp turn. When describing that turn, the witness used the phrase "fighter-like", which meant: dynamic, tight, sharp. Such a turn, executed with a significant bank to the wing, is initiated and controlled by a pilot with the use of the elevator (the control stick pulled "to the pilot"). In a turn with a steep bank (45° and more), a partial exchange of the control functions takes place: the elevator takes over the function of the rudder, and the main responsibility for controlling the pitch rests on the rudder. During such a turn, the rudder is most often deflected opposite to the direction of the turn – serving to keep the nose of the glider on the horizon, and the pilot generates angular velocity by deflecting the elevator.

In fact, entering the turn could be a dynamic spin entry – dynamic stall at high bank. With a distance of around 2200 m that separated the witness from the glider, it was very difficult to accurately differentiate between a dynamic entry into a turn and a dynamic entry into a spin.

The spin situation that[32] took place led to the accident. At such a low height, it was not possible to recover from diving towards the ground.

A spin in the MDM-1 "Fox" in a two-person crew is characterised by a steep nature and there are no longitudinal oscillations in the first turn of the spin. In such a situation, the pilots lost control of the glider.

Faced with the decreasing towing speed when flying over a forest at a low height, the instructor most likely took over control. It is very likely that the trainee pilot still held the control stick with his feet resting on the rudder pedals. It is unlikely that the instructor

[32] What must be considered here is a spin situation, not a spin. A spin is an established flight condition, and to initiate and maintain (continue) it after entry, full deflection of the controls is required. A glider with an "extra-forward" centre of gravity is difficult to enter into a spin, and it does not continue it. With the elevator deflected and the rudder fully deflected, it proceeds to a spiral dive and accelerates.

ordered the trainee pilot "to let go of the controls!". The instructor was operating in a time deficit and was likely concentrated on executing the turn to the aerodrome to avoid further development of the spin situation. Dual control did not allow the instructor (or the trainee pilot) to "feel the controls" properly and fully[33]. The controls could have been blocked to a degree by the trainee pilot, or the trainee pilot might have thought he was still in control.

The entry into a turn following the release was likely initiated too decisively by the trainee pilot, and the instructor did not counter it in time. In a deep bank to the wing, without speed (the first phase of entering into a spin), the glider would have been uncontrollable.

In all likelihood, the decrease in the towing speed was so large that the towed glider decelerated to a flight speed that did not allow for maintaining lateral balance (see the hypotheses in Section 2.2.). Controlling with ailerons was effective until the stall speed. Below that speed, it would not be possible to maintain the wings in the desired position.

The allowable mass of the glider in flight was exceeded by at least 20.5 kg. In consequence, the centre of gravity in flight took the "extra-forward" position, which is neither provided for nor allowed by the glider's operating conditions.

The aerodyne's flying and spin characteristics change significantly with an increase in the lift surface load and depend on the position of the centre of gravity.

In the case of the MDM-1 "Fox", the stall speed in straight flight at the maximum allowable take-off mass, i.e. 530 kg, is defined as 84 km/h (FM, Section 5.2.2). The estimated stall speed for the mass in flight of 550.5 kg (the accident flight) for a glider in straight flight was around 90 km/h.

Because the aeroplane-glider team, or the glider alone, were executing a turn, the stall speed was higher.

The relation between the stall speed and bank angle in a turn for the maximum allowable mass in flight is shown in Fig. 21. It must be noted that stall speeds of the "Fox" SP-3828 glider for a mass of more than 530 kg were even greater than depicted below.

[33] The concept of "feeling the controls" has been introduced by the rules on constructing gliders, currently CS-22.

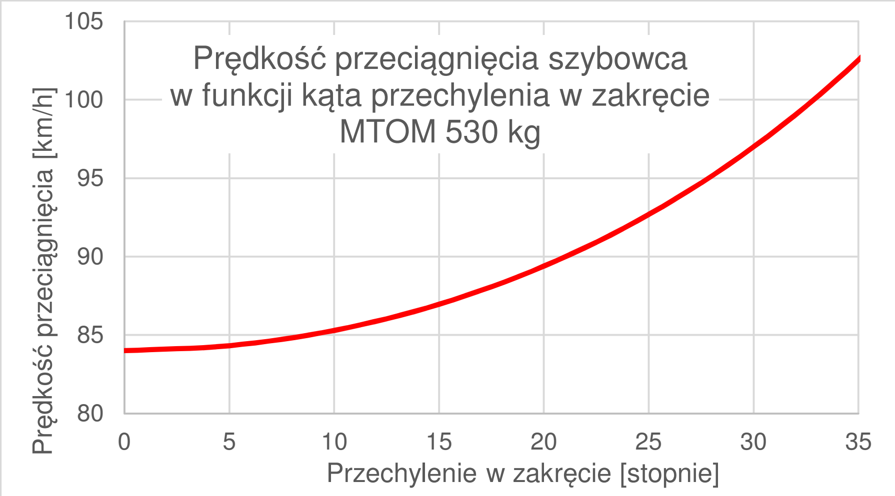


Fig. 21 Estimated relationship between the stall speed of the glider and the bank angle in a turn [source: PKBWL]

The glider collided with the ground in one spot. There were no signs of movement of the wreckage. This means that the fall took place in a steep (vertical or nearly vertical) dive, which was a result of counteracting the spin situation. Certainly, it was not a phase of recovering from the dive, as there was no sufficient height for that. Stopping the rotation (provided that it actually took place) could also have resulted from chaotic movements of the controls, which were not connected with controlling the glider, but rather caused by the inevitable impact.

One of the witnesses claimed that "after making at least one full spin turn, the glider stopped spinning just before the collision". Due to the very low height at which the spin situation started (around 70 m AGL), it was not possible for the glider to execute a full spin turn, not to mention another one.

In the circumstances described, recovering the heavy "Fox" glider from a spin situation, i.e. entering into level flight, was not possible. Considering the glider's flying characteristics and based on experience, it was established that the height for recovering the glider to established level flight after regaining control in a spin situation was at least twice too low.

2.4. Analysis of the preparation of the instructor to perform training flights on the MDM-1 "Fox" glider

Below is a summary of the instructor's flights in the 90 calendar days prior to the accident day.

Table 3. Summary of glider flights performed by the instructor in the last 90 flying days[34]

Flying day	Date (day month)	Location (aerodrome)	Glider type	Nature of flight	Flight time (h : min)	Comments
1	6 August	Rudniki	Fox	As an instructor[35]	0:17	1 flight, aeroplane tow
2	7 August		Fox	Solo flight	0:14	1 flight, aeroplane tow
			SZD-50-3	As an instructor	1:07	2 flights, aeroplane tow
3	3 September		SZD-9 bis	As an instructor	0:13	1 flight, winch tow
			SZD-50-3		1:38	6 flights, aeroplane tow
4	4 September		SZD-9 bis	As an instructor	0:36	4 flights, winch tow
			Fox		0:49	3 flights, aeroplane tow
5	8 October	Turbia	SZD-50-3	Practice flight	0:17	1 flight, aeroplane tow
			SZD-32 Foka 5	Practice flight	0:13	1 flight, aeroplane tow
			SZD-50-3	As an instructor	0:40	7 flights, aeroplane tow
6	9 October		SZD-50-3	As an instructor	0:35	6 flights, winch tow
			SZD-50-3		0:47	6 flights, aeroplane tow
			KR-03		1:01	3 flights, aeroplane tow
7	23 October 2022	Rudniki	Fox	As an instructor	0:20	2 flights, The second one was the accident flight

At the EPRU aerodrome, between May and October 2022, the instructor performed a total of 30 flights on MDM-1 "Fox", SZD-50-3 "Puchacz" and SZD-9 bis "Bocian 1E" gliders, totalling 9 hours 12 minutes.

The instructor had nearly 30 years of experience as a glider pilot. He received his Class II glider instructor rating in 2003, Class I in 2007. He was involved in conducting glider training - teaching the basics of glider handling, training for licences, performing refresher and check flights, and teaching aerobatics. Until 2021, he held an FE(S) and FIE(S) examiner authorisation issued by LKE.

He performed flights on 22 glider types, including four types cleared for advanced aerobatics.

[34] Drawn up on the basis of the instructor's personal flight logbook.
[35] Time and character of the flights on 6 and 7 August were recreated on the basis of timing provided by the aero club.

He obtained an advanced aerobatics endorsement in 2000, unlimited aerobatics endorsement in 2004. For several years he took part in national aerobatic competitions at national and international level in MDM-1 "Fox", S1 "Swift" and SZD-59 "Acro" gliders. He trained and supervised training flights of glider pilots raising their qualifications and aspiring to obtain the "aerobatics" rating.

In his personal logbook, the instructor recorded 527 flights for advanced and unlimited aerobatics.

The instructor enjoyed recognition in the aviation community and was considered as conscientious and committed to the training which he conducted. He complied with flight rules and observed limitations on operation of aircraft in flight. He did not show any signs of non-conservative flying or bravado, and did not allow his trainees to fly like that.

He was well liked and often chosen as an instructor.

It must be noted that the Rudniki aerodrome was not his home aerodrome. The instructor commuted several hundred kilometres to conduct dual training.

He performed single flights in the MDM-1 "Fox" at intervals of around a month (see Table 3). It must be said that he did not maintain training currency in that glider, which is very special in terms of flying.

The response time in the situation that occurred was very short and expired at the moment of the release.

Delaying the release of the line after receiving information about the engine problem, or even failure to consider releasing while it was still possible to perform emergency landing "direct" on the wastelands located to the west of the EPRU aerodrome, resulted in a situation which the glider crew could not handle.

2.5. Analysis of the preparation, predisposition and progress of the pilot trained in aerobatics

The Commission notes the variety and large number of formal aviation qualifications of the trainee pilot as for his young age – only 17 years.

The pilot's logbook included entries about *inter alia* qualifications to perform solo flights in Standard Class gliders (SZD-48-3, SZD-55-1), which are regarded as "challenging in terms of handling". The pilot performed single short flights, which means that his experience in flying the aforementioned gliders was minimal.

The pilot trained for the advanced aerobatics rating, and performed his first solo flight in the MDM-1 "Fox" high-performance glider shortly before the accident flight.

By the day of the accident, the trainee pilot had performed 7 flights in the MDM-1 "Fox" glider lasting a total of 1 hour 57 minutes.

All 7 flights were performed as part of practical training for the "aerobatics" rating in accordance with the training programme of Aeroklub Częstochowski's DTO. The pilot was qualified for training under a decision of the HT, who assigned a responsible instructor to him.

The subject of the theoretical training was confirmed by the instructor in the theoretical training sheet. The training covered the following topics:

- human factor (1 hour);
- technical subject (1.5 hour);
- limitations applicable to a specific aircraft category (and type) (1.5 hours);
- aerobatic manoeuvres and recovery (1.5 hours);
- emergency procedures (1 hour).

On the day of attesting the training report, the pilot was admitted by the HT to practical training, which was confirmed by an entry in the practical training sheet.

Before starting the practical training in aerobatics, the pilot had a total flight time of 107 h in gliders (according to the sheet) and met the conditions for admission to the training.

The last entry in the training sheet was made on 4 September 2022.

As part of the "aerobatics" training, between August and October 2022, the trainee pilot performed 19 flights in SZD-50-3 "Puchacz" and MDM-1 "Fox" gliders lasting a total of 6 hours 14 minutes.

Due to the age of the trainee (a minor), permission for training was granted by a parent.

2.6. Airworthiness of the WT-9 "Dynamic" tow plane

As of the day of the accident, the aeroplane's TTSN was 1423 hours 44 minutes. It was demonstrated that the 100-hour interval to the next scheduled airframe maintenance, recommended in the Maintenance Manual (MM), was exceeded by 26 hours 49 minutes:

1423 hours 44 minutes – 1296 hours 55 minutes = 126 hours 49 minutes.

Furthermore, the value of 1296 hours 55 minutes is the TTSN value at which the last scheduled maintenance of the airframe was carried out (in May 2022).

The MM provides for tolerance of the scheduled maintenance times within the range of ±5 h (MM, Section 3.6.1 "Periodic work schedule"). This means that the recommended maintenance time for the airframe was exceeded by 26 hour 49 minutes – 5 hours = 21 hours 49 minutes.

<u>The lack of scheduled maintenance at a date prescribed in the maintenance calendar had no impact on the occurrence because it was not connected with concurrent maintenance of the engine/power plant.</u>

An inspection of the aeroplane's power plant revealed significant carbon deposits in all 4 cylinders of the Rotax 912 ULS engine. The electrodes of the spark plugs in cylinders 2, 3 and 4 were not deformed, were clean, without carbon deposits, and their spacing was correct, but their light grey colour indicated an increased combustion temperature. That could result from a depleted fuel mix fed by the carburettors to the cylinders in a high-power demand circumstance: during take-off and climb with a heavy aerobatics glider.

The condition of the electrodes in both spark plugs in cylinder 1 and the degree to which both valves (intake and exhaust) were soiled with carbon deposits were poor and must have had a negative impact on the engine operation and performance. Due to the carbon deposits, the exhaust valve in cylinder 1 did not fully close, which caused drops in compression pressure, thus reducing the engine power. The valve became leaky because of the formation of carbon deposits. The condition of the valves in cylinder 1 clearly contributed to the disturbance of the combustion process, which reduced the engine power and accelerated the deposition of soiling on the bottom of the piston, cylinder head and spark plugs.

Installed in the cylinders were spark plugs other than recommended in the Rotax Service Manual issued in March 2017. NGK DCPR7E spark plugs (with a single electrode, Fig. 22) were recommended earlier and are still universally used in Rotax engines. However, the manufacturer recommends using double-electrode spark plugs (P/N 297656, Fig. 23), arguing that it is required by the standardisation of the equipment. No indication has been provided to state that a reason for the change might be possible build-up of carbon deposits on earlier used NGK spark plugs. The Commission has not established any link between build-up of carbon deposits and the type of the spark plugs used.

Build-up of carbon deposits in a combustion engine is a normal process and always takes place. Its intensity depends on a number of factors and the process cannot be eliminated.

Fig. 22 An NGK DCPR7E spark plug

Fig. 23 A Rotax 297656 spark plug

The build-up of carbon deposits and poor condition of the spark plugs in cylinder 1 could not occur over a short period of time. The process of build-up of harmful carbon deposits had lasted for many weeks and progressed with the operation of the engine. The substances generated by the fuel combustion process deposited on the bottom of the piston, valves and spark plug electrodes. The build-up of carbon deposits was the cause of leakage in the exhaust valve in cylinder 1, which led to reduced engine power.

It is likely that overheating of the engine during glider towing operations (especially in summer) contributed to the intensification of the process.

Observation of the sudden drop in the engine power during the accident flight can be explained by a fragment of the carbon deposit that detached and penetrated under the exhaust valve in cylinder 1, which caused a loss of pressure in the cylinder. Furthermore, the vibrations were generated as a result of irregular load on the engine crankshaft exerted by the connecting rod of cylinder 1.

Since the maintenance carried out on the engine on 18 July 2022 [36] (at the airframe's TTSN of 1345 hours 30 minutes), the engine had worked for 78 hours 14 minutes (the airframe's TTSN as of the day of the accident was 1423 hours 44 minutes). <u>The 100h engine maintenance interval was therefore not exceeded.</u> The maintenance provider stated that the prescribed work was carried out in accordance with the annual/100h maintenance programme, as per the Rotax 912 Maintenance Manual[37], and involved *inter alia* an assessment of the condition of the spark plugs (a requirement of the 100h

[36] The work on 18 July 2022 – "100FH/annual engine, propeller maintenance" – at flight time of 1345 hours 30 minutes

[37] Manual reference: Maintenance Manual Line, REF NO.: MML-912 | PART NO.: 899196

maintenance programme). It can therefore be assumed that the carbon deposits had been building up since July 2022.

The 200h maintenance was carried out at the airframe's TTSN of 1260 hours in October 2021, and was documented by an applicable Confirmation of Release to Service (CRS).

At the airframe's TTSN of 1423 hours as of the day of the accident, the 200h interval was not exceeded.

Pilots flying the SP-SHEL aeroplane on days preceding the accident did not observe any engine problems. They did not notice any failures, neither during pre-flight engine checks nor in flight. Under an agreement with the aero club, the responsibility for ensuring maintenance for the aeroplane rested on the owner of the aeroplane.

The unused 100h limit from the previous 100h engine maintenance (the engine had worked 78 hours 14 minutes) allowed further operation – with around 22 hours (plus possibly 10 hours of tolerance, as provided for by the MM) remaining.

There were 37 hours (plus 10 h tolerance) remaining until the 200h maintenance.

A detailed analysis of the content of the file retrieved from Flydat did not reveal any deviations in the operation of the power plant during the accident flight or during the previous flight (flights).

This was confirmed by the manufacturer of the engine (Rotax of Austria) and indirectly by BMK.

Until the time marked in the log as 558:22:10, i.e. until the moment when the engine lost power, all operating parameters of the engine were normal. The record does not give any indication as to the cause of the engine failure. No exceeded operating limits were recorded in the error memory.

Despite that, an analysis of the history of the record showed that some operating parameters had been exceeded in the past, such as:

- excessive revolutions (RPM);
- very high exhaust gas temperatures, recorded by the EGT;
- exceeded oil pressure.

Those records were archived in the documentation of the occurrence, but are not referred to in this report because they are not related to the occurrence.

The analysis of the fuel samples taken from the aeroplane's tanks did not show any deviations from the parameters provided in the specifications. The fuel used was not conducive to any excessive build-up of carbon deposits, but it cannot be ruled out that the fuel tanked earlier could have not meet the standards.

Based on the significant carbon deposit build up revealed during the inspection, poor technical condition of the spark plugs in cylinder 1 and reduced compression pressure in cylinder 1, as well as based on other verifications (including the assessment of the condition of the carburettors, including the needles controlling the mixture, and floaters), it was established that the engine's poor technical condition was the cause of the engine power drop after take-off. The excessive amount of carbon deposits and poor condition of the spark plugs in cylinder 1 led to instability of the operation of the power plant, thus leading to the aborted climb and reduction of the towing speed to the critical value for the glider.

The Commission ruled out carburettor icing because the prevalent weather conditions were not conducive to icing.

The laboratory tests of the fuel samples used on the day of the accident ruled out any contamination and any other factors that could indicate that the fuel did not meet the specifications.

3. FINAL CONCLUSIONS

3.1. Commission findings

1) The pilots of the glider and the pilot of the tow plane held licences, ratings as well as formal and practical qualifications to perform the flight.
2) The pilots held all the applicable aero-medical certificates, and the limitations endorsed in the certificates of the instructor and the towing pilot bore no impact on the occurrence.
3) None of the pilots was under the influence of alcohol or intoxicating substances.
4) The glider was technically fit.
5) The technical condition of the aeroplane's engine resulted in an engine failure in flight.
6) The glider's maximum take-off mass was exceeded, which had a negative impact on the spin characteristics and deteriorated the performance of the glider. However, it was not a decisive factor for the course and effects of the occurrence.
7) Maintenance of the aeroplane was carried out by qualified personnel. The excessed airframe maintenance time bore no impact on the accident. It transpires from the maintenance documentation that the engine (power plant) was maintained as required and in accordance with the maintenance calendar prescribed by the manufacturer.
8) It was not established that the engine maintenance ignored or inappropriately carried out any works required by the Maintenance Manual. The scheduled maintenance works were properly documented.
9) The engine failure initiated a chain of events that ended in the accident.
10) The towing speed did not allow maintaining the glider in the position of balance behind the aeroplane (staying on the line).
11) Both the glider pilots and the tow plane pilot did not comply with good aviation practices that prescribe – in the case concerned – continuing the flight "forward".
12) The glider pilots did not manage to control the glider during the towed flight or just after the release of the tow line and allowed a spin situation to develop.

3.2. Cause of the occurrence

A stall of the glider either in a towed flight or shortly after release of the tow cable, resulting in a spin situation at an insufficient height for recovery to the level flight.

3.3. Contributing factors

1) An engine failure in the tow plane, disrupting the teams' ascent and causing a progressive decrease in the airspeed down to an insufficient towing speed.
2) The team turning in the direction of the forest, "downwind".
3) A very low height over the forest coupled with the glider's lack of speed, as well as a disadvantageous location relative to the aerodrome – the only landing site.
4) Possible initiation of a turn to the aerodrome by the glider crew shortly after releasing the tow line, without first accumulating airspeed.
5) Possible too strong tightening of a turn to the aerodrome.
6) Possible concurrent control by both pilots, resulting in the lack of mutual coordination and restricted "feel of the controls" by each of them.
7) "Extra forward" centre of gravity, affecting the glider's control characteristics, the character of the stall, and translating into a delay in recovery from the dive.
8) Exceeding the allowed mass in flight – a high load on the glider's surfaces.

4. SAFETY RECOMMENDATIONS

The Commission has not formulated any safety recommendations.

5. ANNEXES

None.