MINISTRY OF CONSTRUCTION AND TRANSPORT

TRANSPORTATION SAFETY BUREAU

FINAL REPORT

Arcus Air GmbH&Co.KG, Dornier 228-212/1, D-CAAL

Győr-Pér Airport (LHPR), 21 March 2019

Serious Incident

2019-0164-4

Introduction

Synopsis

Occurrence class		Serious Incident
Aircraft	Manufacturer	DORNIER Luftfahrt GmbH / RUAG / General Atomics
	Model	Dornier 228-212
	Registration	D-CAAL
	Operator	Arcus Air GmbH&Co.KG
Occurrence	Date and Time	21 March 2019, 17:10 LT
	Location	Győr-Pér Airport (LHPR)
Fatalities / Severe Injuries		0 / 0
Damage to Aircraft		No Damage

On 21 March 2019, the pilots performed a non-scheduled commercial IFR flight from Paderborn Lippstadt (EDLP) airport to Győr-Pér (LHPR) airport with a Dornier-228-212 aircraft (reg. sign: D-CAAL). During take-off from the departure airport, the pilots smelled a slight smell of smoke which disappeared shortly afterwards and as the pilots did not experience any abnormalities, they continued their flight to the destination airport. During approach to Győr-Pér airport the nose landing gear indicator showed an anomaly and the crew performed a go-around. They retracted the landing gear and then extended it again to solve the problem (name of the process: recycle). After a successful re-extension, the hydraulic pressure was normal and then started to decrease and eventually ceased before landing. After landing, the aircraft stopped on the right side of Runway 12, from where the PIC attempted to taxi the aircraft, but due to the inoperative nose wheel steering, this was unsuccessful and the aircraft rolled slightly off the runway. After the final stop visible smoke appeared in the cockpit. No personal injuries occurred during the incident.

During the investigation, the Investigating Committee (hereinafter: IC) found that the electric motor that drives the pump pressurising the hydraulic system had suffered internal damage and had failed completely shortly before touchdown.

The IC concluded during the investigation that:

- the direct cause of the runway excursion was the captain’s decision to attempt to continue taxiing after stopping on the runway,
- the direct cause of the cockpit smoke after the final stop was the failure of the internal structure of the electric motor that operates the hydraulic pump.

During the investigation, the manufacturers concerned specified the use of a new improved carbon brush for the electric motor, reduced the time between overhauls of the electric motor concerned and required the replacement of the carbon brushes during the 200-hour or 600-landing checks. The IC of the TSB found the risk mitigating measures taken by the organisations to be adequate on the basis of the supporting documents provided by the manufacturers and therefore found no circumstances that would justify a safety recommendation.

Figure 1 The aircraft involved, at the scene of the occurrence

Table of Contents

Definitions and abbreviations

Aerodrome	*A defined area (including any buildings, installations and equipment) on land or water or on a fixed offshore or floating structure intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft*
ARP	*Airport Reference Point*
BEA	*Bureau d'Enquêtes et d'Analyses pour la Sécurité de l'Aviation civile / the Transportation Safety Bureau of France*
CPL(A)	*Commercial Pilot Licence (Aeroplane)*
EASA	*European Union Aviation Safety Agency*
Flight plan	*Specified information provided to air traffic service units, relative to an intended flight or portion of flight of an aircraft;*
IC	*Investigating Committee*
ICAO	*International Civil Aviation Organization*
IFR	*Instrument Flight Rules*
IR	*Instrument Rating*
Kbvt.	*Act CLXXXIV of 2005 on the safety investigation of aviation, railway and marine accidents and incidents and other transportation occurrences*
LOAP	*List of Applicable Publications*
LT	*Local Time*
MTOM	*Maximum Take-Off Mass*
NFM	*Ministry of National Development*
PIC	*Pilot In Command*
PSI	*Pounds per Square Inch*
SB	*Service Bulletin*
SIL	*Service Information Letter*
TBO	*Time Between Overhaul*
TSB	*Transportation Safety Bureau*
UTC	*Coordinated Universal Time*
VFR	*Visual Flight Rules*

General information

All times indicated in this report are in local time (LT). LT at the time of the occurrence: UTC+1 hour.

Geographic locations throughout this document are provided by WGS-84 standard.

The capitalised positions used throughout this document (e.g. Captain, Pilot, etc.) refer to the particular persons concerned in the event investigated.

The format and content of this report is in harmony with Chapter 6 of Annex 13 of Act XLVI of 2007 promulgating the Appendices to the Convention on International Civil Aviation, signed in Chicago on 7 December 1944. Appendix, as well as with the requirements set out in ICAO Doc 9756 Part IV.

Reports and Notifications

The occurrence was reported to TSB's call center at 18:03 on 21 March 2019, by the on-call officer of the destination airport.

In line with Article 9, Section (2) of Regulation (EU) No 996/2010 of the European Parliament and of the Council, TSB of Hungary notified the following organisations:

- Accident Investigation Authority of the State of Registry at 10:48 on 22/03/2019,
- Accident Investigation Authority of the State of Operator, at 10:56 on 22/03/2019,
- Accident Investigation Authority of the State of Manufacture at 10:48 on 22/03/2019,
- EASA at 11:02 on 22/03/2019,
- ICAO at 11:06 on 22/03/2019,
- Accident Investigation Authority of the State of Manufacture of the malfunctioned part at 10:36 on 29/11/2019,

The following of the notified foreign organisations appointed an accredited representative for the investigation.

- State of the manufacture and registry of the aircraft:
  German Federal Bureau of Aircraft Accident Investigation (BFU)
- State of the manufacture of the malfunctioned part:
  Bureau of Enquiry and Analysis for Civil Aviation Safety (BEA)

Investigating Committee

The Head of TSB appointed the following persons in the Investigating Committee:

Investigator-in-Charge	Mr Gábor Erdősi	investigator
Member	Zsuzsanna Nacsa JD	investigator

Overview of the Investigation Process

Receiving event notification, the on-duty TSB supervisor mandated an immediate dispatch to the site. The TSB classified the event as a serious incident due to the runway excursion after landing and the appearance of smoke after the final stop.

Pursuant to Article 5 of REGULATION (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/ECA the TSB is required to initiate an investigation in the following circumstances.

1. *Every accident or serious incident involving aircraft to which Regulation (EU) 2018/1139 of the European Parliament and of the Council applies shall be the subject*

of a safety investigation in the Member State in which the accident or serious incident occurred.

2. *Where an aircraft to which Regulation (EU) 2018/1139 applies and which is registered in a Member State is involved in an accident or a serious incident the location of which cannot be definitely established as being in the territory of any State, a safety investigation shall be conducted by the safety investigation authority of the Member State of registration.*
3. *The extent of safety investigations referred to in paragraphs 1, 2 and 4 and the procedure to be followed in conducting such safety investigations shall be determined by the safety investigation authority, taking into account the consequences of the accident or serious incident and the lessons it expects to draw from such investigations for the improvement of aviation safety.*
4. *Safety investigation authorities may decide to investigate incidents other than those referred to in paragraphs 1 and 2, as well as accidents or serious incidents to other types of aircraft, in accordance with the national legislation of the Member States, when they expect to draw safety lessons from them.*
5. *By way of derogation from paragraphs 1 and 2 of this Article, the responsible safety investigation authority may decide, taking into account the expected lessons to be drawn for the improvement of aviation safety, not to initiate a safety investigation when an accident or serious incident concerns an unmanned aircraft for which a certificate or declaration is not required pursuant to Article 56(1) and (5) of Regulation (EU) 2018/1139, or concerns a manned aircraft with a maximum take-off mass less than or equal to 2 250 kg, and where no person has been fatally or seriously injured.*

Based on the findings of the site inspection and with regard to Article 5 (1) of Regulation (EU) No 996/2010 of the European Parliament and of the Council, the head of the TSB decided that an investigation is required and will be launched.

In the course of the investigation the IC has taken the following steps:

- took photographs on the spot, recorded flight data, made copies of the documents of the aircraft and the pilots and interviewed witnesses;
- held an additional inspection to remove the parts involved in the incident and to carry out a preliminary examination of them;
- had the components involved in the incident examined by the manufacturers (under the supervision of the competent accident investigation bodies);
- obtained data recorded by HungaroControl Zrt;
- obtained data and information on the parts involved in the incident from the aircraft's operator and manufacturer;
- interviewed witnesses;
- analysed the data and information collected.

Investigation Principles

This investigation is being carried out by Transportation Safety Bureau on the basis of the following disciplines

- Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/EC,
- Act XCVII of 1995 on aviation,
- Annex 13 identified in the Appendix of Act XLVI. of 2007 on the declaration of the annexes to the Convention on International Civil Aviation signed in Chicago on 7th December 1944,

- Act CLXXXIV of 2005 on the safety investigation of aviation, railway and marine accidents and incidents (referred to as Kbvt. throughout the document),
- NFM (Ministry for National Development) Regulation 70/2015 (XII.1) on safety investigation of aviation accidents and incidents, as well as on detailed investigation for operators,
- In matters not covered by Kbvt., Act CL of 2016 on General Public Administration Procedures prevails.

The competence of the Transportation Safety Bureau of Hungary is based on Government Regulation № 230/2016. (VII.29.) on the assignment of a transportation safety body and on the dissolution of Transportation Safety Bureau with legal succession.

Pursuant to the aforesaid legislation,

- Transportation Safety Bureau of Hungary shall investigate aviation accidents and serious incidents.
- Transportation Safety Bureau of Hungary may investigate aviation and incidents which – in its judgement – could have led to accidents of more severe consequences in different circumstances.
- Transportation Safety Bureau of Hungary is independent of any person or entity that may have interests in conflict with the objectives of the investigating body.
- In addition to the aforementioned legislation, TSB of Hungary shall conduct safety investigations in line with ICAO Docs 9756 and 6920 Manual of Aircraft Accident Investigation.
- This Report shall not be binding, nor shall an appeal be lodged against it.
- The original of this report was written in Hungarian.

No conflict of interest has been identified between safety investigators appointed to the IC. No investigator assigned with a safety investigation has been involved as an expert in any other procedure pertaining to the same case and shall not do so in the future.

The IC shall retain all data and information having come to their knowledge in the course of the safety investigation. Furthermore, the IC shall not be obliged to make such data and information available to other authorities, whose disclosure could have been legally refused by their original owner.

This Final Report is based on the Draft Report prepared by the IC that was sent to all involved parties for comments, as set forth by the relevant regulations.

No alternative or contradictory opinions concerning the draft report were received from the interested parties within the legal deadline.

Copyright

Translation

This document has been translated from Hungarian. Although efforts have been made to provide a translation as accurate as possible, discrepancies between the versions might occur. In such eventuality, the Hungarian version shall prevail.

1. Factual information

1.1 Flight History

On March 21, 2019 the pilots conducted a non-scheduled commercial IFR flight in accordance with their flight plan with the Dornier-228-212 aircraft (D-CAAL).. The pilots felt a slight smell of smoke just after departure from Paderborn Lippstadt (EDLP) airport, which soon subsided, and as they did not experience any abnormalities they continued their flight to Győr-Pér (LHPR) airport. Based on the PIC previous experience, he assumed that there was a possible hydraulic failure, so the crew prepared en-route to manage any failures that may occur. During the approach to Győr-Pér airport, the nose landing gear indicator showed an anomaly (nose gear not in the down position), so they performed a go-around and requested the airport AFIS to visually check the extended position of the landing gears. The AFIS informed the flight crew that they could see the landing gears in the extended position. However, the crew retracted the landing gear and extended it again after a 1-1.5 minute wait. After retracting the landing gear and extending it again, the pilots reported that the indication system no longer showed any abnormalities (three green lights). The pilots then began their approach on Runway 12. According to the pilots, the hydraulic pressure continuously decreased before touchdown and then went to zero. They were aware that neither the normal braking system nor the nose wheel steering were working, but they tried to apply the normal brakes, and were unsuccessful. The crew slowed the aircraft by setting the propellers in the reverse position and using the parking brake. According to their report 5 short braking cycles were applied with the parking brake and direction control could only be achieved by using the rudder. Despite the problems encountered, they landed safely and stopped just before reaching the half-way point on the right-hand side of the runway and applied the parking brake. Subsequently, after releasing the parking brake, the PIC, aware of the inoperability of the nose wheel steering, attempted to taxi the aircraft towards the runway centreline using the engines. However, according to the report of the PIC this was not a good decision because it was unsuccessful and the aircraft rolled slightly off the runway to the right. After a complete stop, the pilots detected smoke in addition to the smell of electric burns. At 17:10, they shut down the engines, powered-off the aircraft (*Figure 1)*, and informed the airport services of the incident. No personal injuries occurred during the incident, and the aircraft was not damaged.

1.2 Injury to Persons

	Crew		Passengers	On the Aircraft	Others
	Flight Crew	Cabin Crew			
Fatal					
Serious					
Minor					
Not injured	2			2	
Summary	**2**			**2**	

1.3 Aircraft Damage

The aircraft structure was not damaged related to the occurrence.

1.4 Other Damage

The IC had got no information on other damage by the completion of the investigation.

1.5 Personnel Information

1.5.1 Pilot-in-Command

Age, nationality, gender		47 years old, German, male
Licence data	type	CPL (A)
	valid until	25/03/2023
	ratings	DO228 / PIC/IR
Medical class and valid until		Class 1 / 25/03/2020
Flight hours / take-offs	in the preceding 24 hours	8 hours 36 minutes / 6 take-offs
	in the preceding 7 days	24 hours 53 minutes / 12 take-offs
	in the preceding 90 days	75 hours 19 minutes / 37 take-offs
	total	12,120 hours 14 minutes
	total on this type	10,257 hours 28 minutes
Aircraft types flown		Dornier 228
Pilot function at the time of the occurrence		Pilot flying
In the preceding 48 hours		Rest period: 13 hours 30 minutes

1.5.2 First Officer

Age, nationality, gender		28 years old, German, female
Licence data	type	CPL(A)
	valid until	31/12/2019
	ratings	DO228 / PIC/IR
Medical class and valid until		Class 1 / 09/07/2019
Flight hours / take-offs	in the preceding 24 hours	0 / 0
	in the preceding 7 days	12 hours 04 minutes / 6 take-offs
	in the preceding 90 days	53 hours 52 minutes / 22 take-offs
	total	1,581 hours 53 minutes / 1.183 take-offs
	total on this type	1,303 hours 55 minutes / 645 take-offs
Aircraft types flown		DA20, A210, C182, P2006T, B95-55, PA42-200T
Pilot function at the time of the occurrence		Pilot monitoring
In the preceding 48 hours		Rest period: 48 hours

Both pilots on board were familiar with the destination airport, had several landings and take-offs there before.

1.6 Aircraft Information

1.6.1 General Information

Class	Fixed wing aircraft (MTOM > 5700kg)
Manufacturer	Dornier Luftfahrt GmbH / RUAG/ General Atomics
Model	DO 228-212
Year of manufacture	1989
Serial number	8155
Nationality and registration marks	D-CAAL
State of registry	Germany
Date of registry	Due to change of ownership, 29/09/2014
Owner	Arcus-Aviation AG
Operator	Arcus Air GmbH & Co. KG
Call sign	AZE42L

	Flight hours	Take-offs
Total	11,120 hours	13,411
Since overhaul	No data	No data
Since last inspection	34 hours	24

1.6.2 Airworthiness Certificate

Airworthiness Certificate	Number	39678
	Date of issue	18/03/2014
	Valid until	until withdrawal
	Restrictions	none

Airworthiness Review Certificate	Number	AFT910ARC7561/2019
	Date of issue	22/02/2019
	Valid until	25/02/2020
	Date of latest review	22/02/2019

1.6.3 Engines

Category	Turbo-prop engine	
Manufacturer	Honeywell	
Type	TPE331-10GP-511D	TPE331-10GP-511D
Position on the aircraft	Engine 1	Engine 2
Serial number	P-100004C	P-100040C
Date of installation in the given position	08/07/2015	06/11/2017
Last inspection	13/03/2019	13/03/2019

	Hours flown	
Total	10274.2 hours	21677.6 hours
Since overhaul	3212 hours	947.4 hours

1.6.4 Aircraft Loading Data

Aircraft data had no influence on the course of events.

1.6.5 Malfunctioning Systems or Equipment

Designation of malfunctioned system / part	Hydraulic Power Pack Pump with Electric Motor
Location of installation	LH Wheel Well
Date of installation	15/01/2013
Part number	Electric motor: 1259A Hydraulic Pump: P05V-076-2
Manufacturer	Electric motor: Thales Hydraulic Pump: Parker Hannifin
Serial number	Electric motor: 1299 Hydraulic Pump: AH16848

The aircraft's hydraulic system operates the retraction and normal extension of the landing gear, braking of the main landing gear wheels and ground steering of the nose landing gear. The 206 bar (3000PSI) pressure required to perform these functions is produced by an electrically driven, self-regulated, continuously variable piston type hydraulic pump. The system is controlled by the pilots using a switch on the hydraulic panel. The control switch has "OFF", "NORM" and "MAN ON" positions. During normal operation of the system, in the NORM position of the control switch the electric motor is activated and drives the hydraulic pump if the landing gear lever is in the DOWN position and the engine generator supplies the electric system. This ensures that during taxiing the main landing gear wheels can be braked and the nose wheels can be steered. During landing gear retraction, landing gear lever selected UP the electric motor and hydraulic pump will continue to run until the landing gear is retracted and uplocked. During the landing phase, when the landing gears need to be extended, the pilot sets the landing gear control lever to the "DOWN" position. The electric motor and the hydraulic pump are activated, providing the hydraulic pressure needed to extend the landing gear. After landing, the operating system again provides braking of the main landing gear wheels and steering of the nose landing gear. The pump can be switched off manually by setting the control switch to OFF or will be switched off automatically when the last engine is shut down. When the control switch is in the "MAN ON" position, the electric motor and the associated pump will operate continuously regardless of the phase of flight and the position of the landing gear control lever *(Appendix 1).*

During the on-site investigation, it was found that the electric motor was damaged due to exposure to high temperature. The pump assembly was removed and examined on site by the technicians of the authorised maintenance organisation of the operator, with the consent and in the presence of the accident investigators of the TSB. The on-site inspection of the electric motor showed that its shaft was jammed. The pump which was removed from the electric motor *(Figure 2)* remained rotatable, but the force during rotation was slightly higher than that of the already prepared replacement part.

Figure 2: The removed pump

The pump assembly (electric motor and pump) that failed during the incident was seized by the TSB for further investigation. The authorised technician replaced the failed motor and the pump unit *(Figure 3)*.

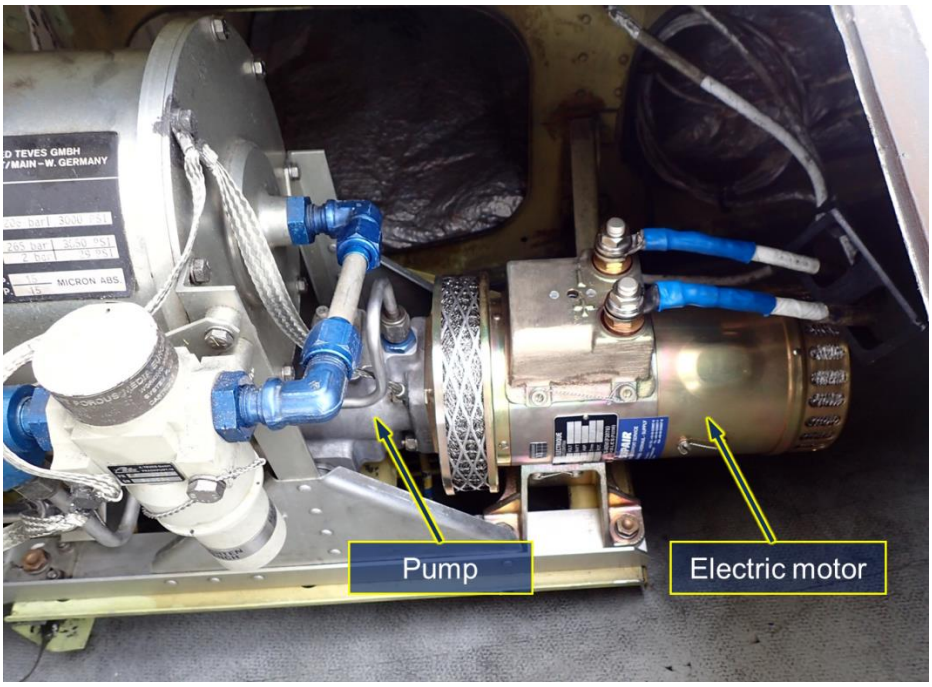


Figure 3: The replaced electric motor with the pump

During the on-site investigation it was found that the smell of smoke after take-off, followed by a drop in pressure in the hydraulic system before touch down and smoke after stop was probably due to the failure of the rotating parts of the electric motor (commutator, carbon brush) *(Figure 4*), which generated heat of such an extent that the internal structure of the electric motor melted and the molten component parts burned through the case of the electric motor (*Figure 5)*.

Figure 4: Burnt parts of the electromotor

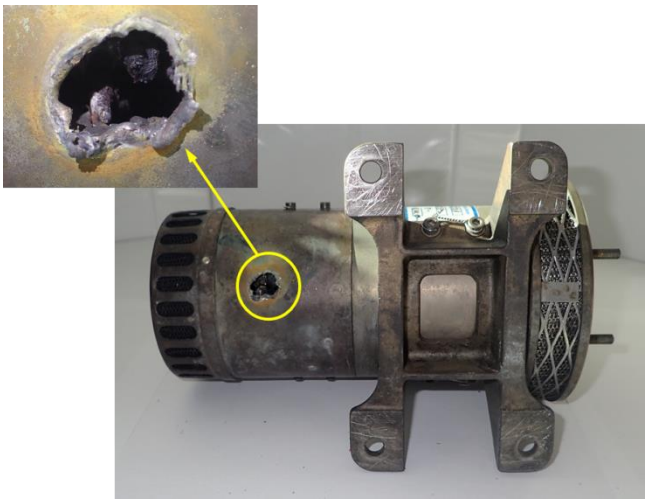


Figure 5: The melted motor casing

Simultaneously with the component replacements, the technical staff checked, among other things, the elements of the hydraulic and landing gear system (e.g. relays, electrical wiring, pipeline, leakage check, etc.) and after the performed necessary maintenance the Certificate Release to Service (CRS) was issued.

1.6.6 On-board Warning Systems

The aircraft was equipped with transponder, traffic alert and collision avoidance system (TCAS), ground proximity warning system (GPWS).

The systems worked in compliance with the requirements, and the IC made or received no comment relating to irregularity of their operation.

1.7 Weather Information

The occurrence took place at daytime in good visibility conditions.

On the day of the incident, the sun was shining in the morning, although there were high-level clouds in the northern counties. Temperatures had risen to 9 to 13 degrees by 11 a.m. The sunshine was filtered by cirrostratus clouds only; temperature varied between 12 and 16 degrees. There was no precipitation.

METAR and TAF issued for Győr-Pér airport valid at the time of the occurrence:

"METAR LHPR 211545Z VRB02KT CAVOK 13/M03 1033=

TAF LHPR 211415Z 2115/2124 VRB02KT CAVOK="

The wind was blowing from variable directions with a speed of 2 knots; CAVOK[1]; the air temperature was 13 degrees Celsius, the dew point was -3 degrees Celsius and the air pressure was 1033 hPa. The forecast predicted no change in weather.

1.8 Aids to Navigation

Navigation equipment had no influence on the course of events.

[1] CAVOK; The Visibility, Cloud, and Weather groups are replaced by the term CAVOK (cloud and visibility OK) when the following conditions exist simultaneously: Visibility is 10km or more. No thunderstorm (CB) or towering cumulus and no cloud below 5000 feet or Minimum Sector Altitude (MSA) (whichever is the greater).

1.9 Communication

Communication equipment had no influence on the course of events.

1.10 Aerodrome Information

Take-off was performed from Paderborn Lippstadt (EDLP) airport in Germany at 15:00 on 21 March 2019.

The scheduled destination aerodrome was Győr-Pér Airport (LHPR).

Actual landing was performed at Győr-Pér Airport (LHPR) airport took place at 17:10 on 21 March 2019.

The aerodrome had valid operation certificate.

Name of aerodrome	Győr-Pér Airport
Location indicator	LHPR
Airport operator	Győr-Pér Repülőtér Kft.
Reference point (ARP)	N473737,56 E0174830,07
Elevation	128.75 m / 422’4
Runway identification	11/29
Runway length	2030m x 30m
Runway surface	asphalt
Runway conditions	clean and dry

The parameters of the airport did not affect the incident, further details are not required.

1.11 Data Recorders

The aircraft had in place the data recorder(s) specified in the type certificate. Both FDR and CVR data were readout and downloaded at the occurrence site. The data from both devices could be evaluated and the IC used part of the data for its investigation. The flight data recorder does not record data on hydraulic system and brake accumulator pressures. Therefore, the IC was able to identify the chain of events leading to the malfunction of the electric motor only based on the crew’s report and the noises recorded on the cockpit voice recorder as well as crew communication.

At several relevant points, in various flight phases the already failed electric motor's electric arc and the electric noise which is superimposed (interfered) on the radio communication could be identified on a CVR channel.

FDR flight data recorder	Model	S703-1000
	Place of readout	Győr-Pér Airport
	Could recorded data be used?	Yes.

CVR cockpit voice recorder	Model	S200-0012-00
	Place of readout	Győr-Pér Airport
	Could recorded data be used?	Yes.

The airport flight tower services had the required data recording systems in place and the data they recorded was assessable.

Flight altitude and speed data are provided in Appendix 2.

1.12 Wreckage and Impact Information

There was no wreckage.

1.13 Medical and Pathological Information

There was no forensic medical examination. There was no indication of any physiological factor or other impediments affecting the Pilot's capacity or capabilities.

1.14 Fire

There was no fire, but smoke was visible in the cockpit after landing.

1.15 Survival Aspects

No one was injured, but, due to its nature, the incident could have led to a more serious outcome involving personal injury and significant damage to property.

1.16 Tests and Research

The IC sent the pump and the electric motor (seized at the scene of the incident) to the aircraft manufacturer for further examination. The aircraft manufacturer sent a report dated 30/05/2019 to the IC, in which it was found that the disassembled electric motor was damaged in terms of carbon brushes, brush holders, bearings, field coils and cooling fan. It was also noted that no evidence of condensation was found in the motor and that the brushes were long enough. No cause for the failure of the electric motor was found and their report recommended that further investigations needed, including an inspection of the pump. The IC asked the aircraft manufacturer to send the pump to its manufacturer for further inspection. The pump manufacturer carried out an inspection of the equipment on 10/01/2020 and found that, apart from two minor discrepancies, the pump was functioning correctly. Subsequently, the IC contacted the French accident Investigation body (BEA) to have the electric motor manufacturer carry out an extensive inspection of the electric motor, which had been previously dismantled and inspected by the aircraft manufacturer. On 04/03/2020, the BEA informed the IC that they did not see any point in further investigation on the already disassembled and examined electric motor by the aircraft manufacturer. The electric motor's manufacturer concluded from the photographs collected, the parts sent and the nature of the failure that an electrical arc inside the motor had caused the equipment failure and that the electrical arc had caused the motor casing to melt. However, they could not confirm this assumption beyond reasonable doubt because they had received the motor already disassembled.

1.17 Organizational and Management information

The aircraft manufacturer identified several similar electric motor failures before and after the occurrence. In investigating these failures, the manufacturer carried out a risk analysis using, inter alia, data on the severity of previous runway excursions and belly landings to determine the risk grade. A short-term as well as a long-term plan was developed to mitigate the risk. This included a meeting among the manufacturers of the electric motor, of the pump and of the aircraft on 21 January 2020, where the electric motor manufacturer provided information that, among other things, the motor had not been subject to any changes by the

manufacturer or the supplier in the years prior to the incident, that the components were within limitations and that the material composition of the carbon brush was correct. The electric motor's manufacturer anticipated modifications to the carbon brush manufacturing technology and possibly the use of an insulated brush holder to avoid an electrical arc between the brush holder and the commutator. In addition, it confirmed that during periodic inspection of the motor, if even one brush falls outside the tolerance, all brushes should be replaced.

During the meeting, the parties agreed on an action plan. In this plan, it was decided, inter alia, that:

- the time between overhaul (TBO) of the electric motor would be reduced,
- Service Bulletin (SB) would be published separately for the brush and the brush holder,
- a Service Information Letter (SIL) would be issued to describe in detail the brush inspection/replacement,
- the packaging of the carbon brushes would be checked,
- instead of individual brushes, a "brush replacement kit" containing all the relevant parts would also be assembled by the electric motor manufacturer for the overhaul parts as well.

Subsequently, the aircraft manufacturer published a SIL with reference of the electric motor manufacturer for the information of operators.

In line with these, the aircraft manufacturer has made first temporary and then final revisions to the operating times and the tasks to be performed for the hydraulic pump. Carbon brushes must be replaced every 200 pump operating hours on aircraft where a Hobbs meter gives information on operating hours, and the pump operating time between overhauls has been reduced from 1200 pump operating hours to 600 pump operating hours. On aircraft that do not have an operating time counter to indicate pump operation, the check-to-check operating time (including a carbon brush replacement) was set to 600 landings, while the TBO has been changed from 3,600 flight hours to 1,800 landings which the manufacturer believes is a more tangible value. The aircraft manufacturer has informed the IC that the change from flight hours to landings is more tangible because the pump's electric motor operates for approximately 0.33 hours per flight, so the calculated operating time per flight rather than the actual flight time is more appropriate for the calculation. According to their calculations, on average, 1 landing is associated to every 0.8 hours flown.

Regarding the inspection intervals, carbon brushes did not need to be replaced before the above mentioned revisions, but with the entry into force of this change, carbon brushes will need to be replaced every 200 pump operating hours or every 600 landings, regardless of their condition.

In January 2023, the manufacturer of the electric motor informed the IC that the carbon brushes had been improved and that only this new one could be installed in the motors in 2020, and it was stipulated that only the new version with the new part number could be used when replacing the carbon brushes. In their opinion, this will eliminate the possibility of a mixed version and reduce the likelihood of failures. In addition to the above, the electric motor manufacturer has issued Service Bulletin SB 1259-29-003, with an amendment date of 18 May 2020, entitled *'Modification of Brushes Grade of the Motor Part No. 1259A of the DO228 …'.*

The aircraft manufacturer did not consider the installation of insulated brush holders necessary, because the above changes were sufficient to solve the problem. The aircraft manufacturer has informed the IC that all relevant information has been incorporated into the List of Applicable Publications (LOAP) to inform operators. Furthermore, it has been reported to the IC that during 2018 and 2019 there were 6 cases of carbon brush failure with the electric motor Part No. 1259A, while after the post-amendment period (year 2020) there was no similar failure.

The manufacturer of the electric motor also states in its information that since the new version of the brush has been used, no brush failure similar to the present case has been reported to them.

1.18 Additional Information

The flight manual of the aircraft[2] contains a procedure and checklist for unsafe landing gear indication.[3] This specific procedure and checklist does not include an instruction to retract and extend (recycle) the landing gear when checking for unsafe landing gear indication in the DOWN position of the landing gear control lever. The checklist states that if, after checking certain items, there is still uncertainty in the indication of the landing gear down position, then the landing gear shall be extended by emergency gear extension. The flight manual draws the attention of pilots to the inoperative condition of the brakes due to the absence of a hydraulic system and the consequent increase in the landing roll.

1.19 Useful or Effective Investigation Techniques

The investigation did not require techniques differing from the conventional approach.

[2] Fairchild-Dornier: Pilot's Operating Handbook including the LBA approved Airplane Flight Manual Rev. 3 (Valid for Airplane serial No.8155 and No. 8176 through 8190);
[3] Pilot's Operating Handbook – Pages 3-58;

2. Analysis

2.1 Crew Activity

The flight crew had the appropriate licences and ratings to carry out the intended flight (1.5). Both pilots were highly experienced on the type of aircraft and were familiar with the airport involved, having made several landings there (1.5).
At the start of the flight, from the smell of smoke detected during take-off, the crew (based on the captain's previous experience with a similar incident) concluded that a failure of the hydraulic system could be expected. In view of this conclusion, they prepared for possible problems and actions during the flight. As a result of their experience and preparation, the problems encountered during the landing were not unexpected. According to the voice recorder they handled the situation calmly, quickly and effectively. However, in handling the incident (nose gear not down), they deviated from the flight manual by retracting and re-extending the landing gear (1.18). During the investigation, the IC found no explanation why the crew had deviated from the flight manual. And the decision to attempt to taxi after stopping on the runway was, by the captain's own admission, not the best one (1.1), because, given the circumstances, its outcome was doubtful.

2.2 The Process of the Malfunction

After take-off from the departure airport, the crew smelled smoke, which disappeared with time. This indicates that the electric motor that drives the hydraulic system pump was already in the phase before a complete failure. The disappearing of the smell of smoke shortly after take-off is due to the fact that the hydraulic pump was automatically switched off after the landing gear was retracted and locked in the up position (1.1; 1.6.5). After this automatic shutdown, the pump did not operate and therefore did not cause any abnormalities during the flight until the approach to the destination airport.

From the moment during approach, when one of the crew is heard calling out „Gear transition,", a cca. 10-second radio static is recorded, masking over some of the radio exchange (1.11). This white noise is consistent with both the duration of use and the characteristics of a radio interference generated by a compromised electric motor. The crackling radio static generated by the struggling electric motor is heard intermittently throughout the subsequent radio exchange, all the way up to the tower controller's verbal radio confirmation regarding the gear status. Shortly after this transmission ends, the static generated by the electric motor ceases, which conforms with the gear retraction cycle being completed with the motor disengaged and the hydraulic pump turned off. The static noise is not heard again for the next 1 to 1.5 minutes. The static noise starts over again about 15 seconds prior to a crew member calling „Gear down three green". In course of their landing checks, the crew are subsequently recorded to verbally confirm normal hydraulic pressure at 3,000 PSI. Following this callout, the static noise in the radio continuously increases, as in line with an ever more struggling electric motor on its way out, and ceases at 100 feet AGL, shortly before touchdown. The IC has concluded that this was when the failing electric motor succumbed and stopped working altogether – which is supported by crew testimonies accounting for a complete hydraulic pressure loss at this moment, rendering normal braking and nose wheel steering inoperative as well (1.1; 1.6.5) and warranting, as a consequence, the emergency use of the parking brake in addition to reverse power.

The IC's view is that the complete failure of the electric motor occurring *after* landing gear extension led to a less unfortunate outcome.

2.3 Organisational Measures

According to the IC, the 6 cases involving carbon brushes on electric motor 1259A in two years (1.17) appear to be a small number, but the loss of the hydraulic system due to the failure of the electric motor could have led to a more serious outcome than in our case (see Survival Aspects 1.15).

According to the IC, the respective manufacturers of the aircraft, of the electric motor and of the pump recognised the risk in time and took their first actions very soon, by issuing amendments requiring the replacement of carbon brushes every 200 operating hours or 600 landings, as well as reducing the TBO.
According to the IC the fact that with the drastic reduction in operating times the risk reduction measures process did not stop, but that the three parties concerned agreed on a joint package of measures to gather experience after the change had taken place (1.17), , demonstrates the positive attitude of the organisations towards risk reduction.

In the view of the IC, the above measures taken by the manufacturers of the electric motor and the aircraft following the incident (1.17) have effectively reduced the likelihood of similar incidents to an appropriate level. That is confirmed by the fact that, according to the information sent to the IC, no similar incidents have been reported since the introduction of the changes to either the electric motor or the aircraft manufacturer up to the date of writing this report. Furthermore, all that is confirmed by the fact that, when checking the European database, the IC found no similar report after 2020.
In the light of the above, the IC does not propose to issue a safety recommendation.

2.4 Survival Aspects

Due to the design of the hydraulic system, a failure in the pump or in the electric motor can lead to serious outcomes under unfortunate conditions (weather, runway length, etc.). The hydraulic system operates the landing gears, the normal braking system and the nose wheel steering, so its loss, either fast or slow, possibly combined with another circumstance (e.g. engine failure during take-off at a speed below V1, take-off or landing in crosswind), could put the crew in a difficult situation.

3. Conclusions

3.1 Findings

3.1.1 Aircraft

The aircraft was airworthy. (1.6.2)

The aircraft had a valid certificate of airworthiness. (1.6.2)

There was no structure damage of the aircraft. (1.3)

According to its documentation, it was equipped and maintained in accordance with the regulations in force and the accepted procedures. (1.6)

During the on-site investigation it was found that the smell of smoke after take-off, followed by a drop in pressure in the hydraulic system before touch down and smoke after stop was probably due to the failure of the rotating parts of the electric motor (commutator, carbon brush) *(Figure 4*), which generated heat of such an extent that the internal structure of the electric motor melted and the molten component parts burned through the case of the electric motor (1.6.5).

The electric motor manufacturer concluded from the photographs collected and the parts provided, as well as the nature of the failure, that an electrical arc inside the motor caused the equipment to fail and that the electrical arc caused the motor casing to melt. However, they could not confirm this assumption fully because they received the motor already disassembled. (1.16)

3.1.2 Aircrew or Pilot

The pilots had the appropriate licences and ratings carry out the intended flight. (1.5; 2.1)

Both pilots were highly experienced with the aircraft type and were familiar with the airport, having made several landings there. (1.5.1; 2.1)

3.1.3 Air operations

The aircraft loading data had no impact on the course of the event, so it needs not be discussed in detail. (1.6.4)

The flight was carried out according to the flight plan in good visibility at daylight. (1.1; 1.7)

3.1.4 Operator / Aircraft Manufacturer / Electric Motor Manufacturer

In the view of the IC, the measures taken by the electric motor manufacturer and the aircraft manufacturer following the occurrence have effectively reduced to an appropriate level the likelihood of similar incidents (2.3).

3.1.5 Air Traffic Services / Aerodrome

There was no information on the activities of air traffic control and the ground handling staff or on the characteristics of the airport that could be linked to the occurrence. (1.10)

No comments on the operation of the ground-based navigation equipment were found by or reported to the IC. (1.8)

The airport involved in the case had a valid operating certificate. (1.10)

3.1.6 Data Recorders

The aircraft was equipped with the recorders described in the type certificate. FDR as well as CVR data was readout and downloaded at the occurrence site. The data from both devices was available for evaluation. (1.11)

The flight data recorder does not record data on hydraulic system and brake accumulator pressures. Therefore, the IC was able to identify the chain of events leading to the malfunction of the electric motor only based on the crew's report and the noises recorded on the cockpit voice recorder as well as crew communication. At several relevant points, in various flight phases the already failed electric motor's electric arc and the electric noise which is superimposed (interfered) on the radio communication could be identified on a CVR channel. (1.11; 2.2)

For air traffic control equipment and aircraft, the required data recording systems were in place and the data they recorded could be evaluated. (1.11)

3.1.7 Medical Examinations

There was no evidence that physiological factors or other disabilities affected the capacity or capability of the aircrew. (1.13)

3.1.8 Survival Aspects

There was no personal injury. (1.1; 1.15)

Due to the nature of the incident, a more serious outcome could have occurred, which could have resulted in personal injury and/or significant damage to property. (1.15; 2.4)

3.2 Causes

As a result of the investigation, the IC concluded that

- the direct cause of the runway excursion was the PIC's decision to attempt to continue taxiing after stopping on the runway,
- the direct cause of the smoke in the cockpit after the final stop was a failure of the internal structure of the electric motor that operates the hydraulic pump.

4. Safety Recommendations

4.1 Actions Taken by the Manufacturers During the Investigation

During the investigation, the manufacturers concerned specified the use of a new, improved carbon brush for the Part No. 1259A motor, reduced the overhaul interval for the electric motor concerned and required the replacement of the carbon brushes during the 200-hour or 600-landing checks. (1.17; 2.3)

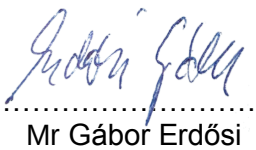
4.2 Interim Safety Recommendation(s)

TSB issued no safety recommendation during the investigation.

4.3 Concluding Safety Recommendation(s)

The Investigating Committee of the TSB found the risk mitigation measures taken by the organisations to be adequate on the basis of the supporting documentation provided by the manufacturers and therefore found no circumstances that would justify a safety recommendation.

Dated in Budapest, on 23 August 2023

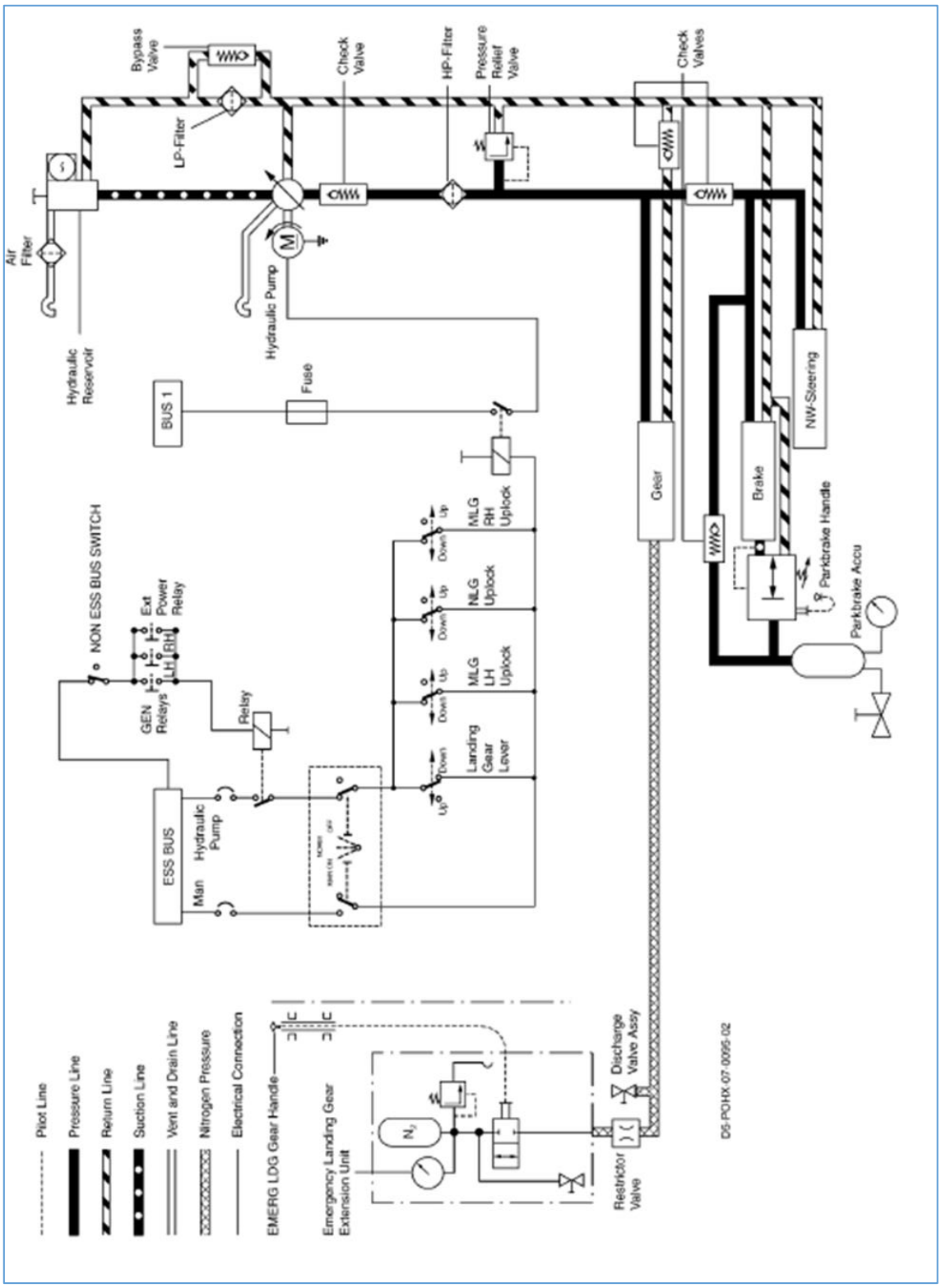


Mr Gábor Erdősi
Investigator-in-Charge

Nacsa Zsuzsanna JD
Investigator

APPENDICES

Appendix 1: DO228 Hydraulic System



Appendix 2: FDR Flight Altitude and Speed Data