DUTCH
SAFETY BOARD

Engine failure followed by emergency landing

Diamond DA 50 RG, Kempen Airport

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The Hague, April 2025

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The Dutch Safety Board

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N.B: This report is published in the English language, with a separate summary in the Dutch language. If there is a difference in interpretation between the Dutch and English version, the English text will prevail.

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SUMMARY

On 2 September 2023, a Diamond DA 50 RG aircraft, registered OO-HAN, departed from Runway 21 at Kempen Airport in the Netherlands for a private flight. During the initial climb, the engine experienced two noticeable drops in revolutions per minute. In response, the pilot chose to remain within the airport traffic circuit and declared a precautionary return to land. While on the downwind leg, the engine's performance deteriorated further, culminating in a complete power loss as the aircraft turned towards final approach for Runway 03.

Despite the pilot's attempts to glide the aircraft towards the runway, the high rate of descent at low altitude resulted in the aircraft impacting the terrain short of the intended runway. Upon impact, the right wing detached from the fuselage, rupturing the integrated fuel tank. The ensuing fuel spillage ignited, causing a fire that consumed significant portions of the aircraft, including the left wing and the tail section.

The pilot, who was the sole occupant, sustained minor injuries and was able to evacuate the aircraft unaided before the fire spread. Emergency services at Kempen Airport extinguished the fire shortly thereafter.

The investigation identified that the engine failure was caused by the destruction of crankshaft main bearing #2, which led to overheating and seizure of other critical engine components. Why bearing #2 failed could not be determined. However, residues of casting sand embedded in the casting within the engine's oil gallery – likely originating from the manufacturing process – were considered a potential contributing factor to the bearing failure. The manufacturer deemed this contamination a single incident, as no structural deficiencies or recurring issues were identified during the analysis of similar engines. To mitigate contamination risks in future engines, the manufacturer enhanced its cleaning protocols by incorporating measures such as an ultrasonic bath and residual dirt analysis.

The pilot's decision to remain in the circuit was consistent with current training protocols, which primarily address complete engine failures. Even if partial engine power loss is not explicitly covered under the Dutch licensing syllabus, pilots are expected to be prepared for a total power loss and an emergency landing. The DA50 Flight Manual provides procedures for various engine-related issues, including situations where power is degraded but not entirely lost. However, this accident highlighted the challenges of responding to initial signs of engine performance degradation, reinforcing the value of training for such scenarios.

Although the aircraft complied with EASA Certification Specifications (CS) 23 for fuel system integrity, the forces exerted during the crash exceeded these design standards. The right wing's detachment led to a rupture of the fuel tank, directly contributing to the post-impact fire. However, the structure of the cockpit remained intact, significantly increasing the pilot's chances of survival.

ABBREVIATIONS

Abbreviation	Description
AAIB	Air Accidents Investigation Branch
ATSB	Australian Transport Safety Bureau
CFRP	Carbon Fibre Reinforced Plastic
CS	Certification Specifications
EASA	European Union Aviation Safety Agency
EHBD	Kempen Airport
EHEH	Eindhoven Airport
FADEC	Full Authority Digital Engine Control
GFRP	Glass Fibre Reinforced Plastic
KNMI	Royal Netherlands Meteorological Institute
LVNL	Air Traffic Control the Netherlands
METAR	Meteorological Aerodrome Report
PPL(A)	Private Pilot Licence - Aeroplane
RPM	Revolutions Per Minute
SEM	Scanning Electron Microscope
SEP	Single Engine Pilot
UTC	Universal Time Coordinated

GENERAL OVERVIEW

Information type	Information detail
Identification number:	2023182
Classification:	Accident
Date, time of occurrence:	2 September 2023, 08.00 hours[1]
Location of occurrence:	Kempen Airport (EHBD)
Operator:	Private
Registration:	OO-HAN
Aircraft type:	Diamond DA 50 RG
Aircraft category:	Aeroplane, single engine piston
Type of flight:	Local flight, leisure
Phase of operation:	Initial climb
Damage to aircraft:	Destroyed
Flight crew:	One
Passengers:	None
Injuries:	Minor
Other damage:	Runway damaged
Light conditions:	Daylight

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[1] All times in this report are UTC times (local time - 2 hours), unless otherwise specified.

1 INTRODUCTION

1.1 The accident

On 2 September 2023, a Diamond DA 50 RG took off from Kempen Airport. After take-off the engine's revolutions per minute (RPM) dropped twice. The pilot decided to remain in the airport traffic circuit and to return to the airport. During the turn towards the runway, the engine stopped functioning entirely. Shortly thereafter, the aircraft crashed, followed by a fire that lasted several minutes. The aircraft was destroyed as a result of the crash and the post-impact fire. The pilot sustained minor injuries.

1.2 Investigation questions

The Dutch Safety Board classified the occurrence as an accident for which an investigation and reporting obligation stands. The Dutch Safety Board conducted the safety investigation into this accident. After the preliminary investigation, the Board focused on answering the following questions:

1. What were the factors that contributed to the engine failure?
2. What factors contributed to the extent of the post-impact damage?

1.3 Investigation approach

The Dutch Safety Board conducted this investigation in accordance with Regulation (EU) No 996/2010 of the European Parliament and of the Council of 20 October 2010 and the Dutch Safety Board's Kingdom Act. Air safety investigators of the Dutch Safety Board visited the scene of the accident and carried out the initial investigation of the wreckage. The aircraft wreckage was stored at a secured location where the investigators examined it further. The aircraft engine was transported to the engine manufacturer in Germany for further examination.

The Dutch Safety Board conducted the investigation on behalf of the state of occurrence. The Sicherheitsuntersuchungsstelle des Bundes (Austria)[2], Air Accident Investigation Unit (Belgium)[3] and the Bundesstelle für Flugunfalluntersuchung (Germany)[4] participated in the investigation. The European Union Aviation Safety

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[2] Representing the state of design and manufacture of the aircraft.
[3] Representing the state of registry.
[4] Representing the state of design and manufacture of the engine.

Agency (EASA), the aircraft manufacturer Diamond Aircraft Industries and the engine manufacterer Continental Aerospace Technologies were appointed as technical advisers.

Additionally, the Dutch Safety Board collected information from Air Traffic Control the Netherlands (LVNL), ADS-B Exchange, the Royal Netherlands Meteorological Institute (KNMI), interviews with the pilot and the airport authority.

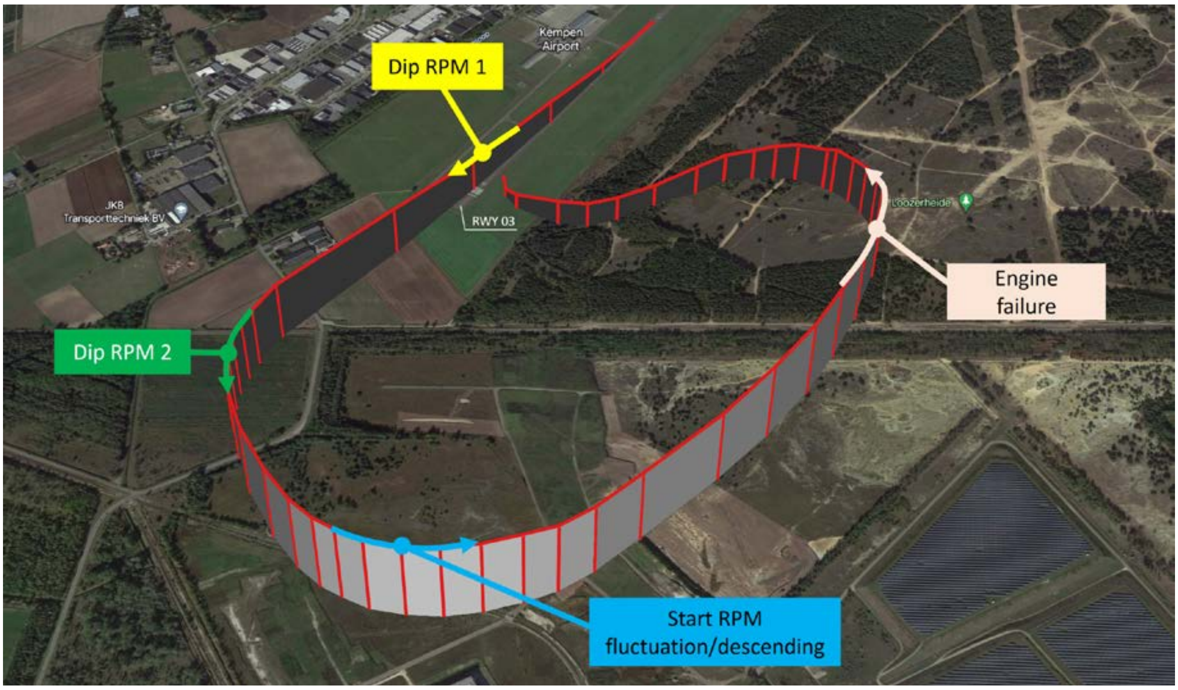
Chapter 2 presents the relevant factual information. Chapter 3 contains the analysis of the data collected. Findings and conclusions are summarised in Chapter 4.

2 FACTUAL INFORMATION

2.1 History of the flight

On the morning of 2 September 2023, the pilot of the Diamond DA 50 RG aircraft (registered as OO-HAN) conducted his preflight preparations, including evaluating the procedure for handling an engine failure during takeoff. In addition, he performed a preflight inspection and found no anomalies. At approximately 08.00 hours, he took off from Kempen Airport in the Netherlands for a private local flight. Just a few seconds after departure from Runway 21 on the take-off leg, the aircraft's engine revolutions per minute (RPM) temporarily decreased unexpectedly. After about twenty seconds, the RPM temporarily dropped a second time as the pilot was executing a climbing left turn on the crosswind leg. At this point, the aircraft was at approximately 375 feet altitude above ground level.

The pilot stated he chose to remain within the airport's traffic circuit for safety and adjusted the flight path to fly a short downwind leg for Runway 21. During this phase, while the pilot was communicating the engine issues on the frequency of the airport authority (Budel Radio) and declaring the intention to return to the airport, the engine's RPM started to fluctuate again, prompting the pilot to declare a 'MAYDAY'. The aircraft was at an altitude of about 475 feet on the crosswind leg, turning to downwind, when these fluctuations occurred. Budel Radio then confirmed that Runway 03 was available.



▲ *Figure 1: ADS-B flight track including markers of the behaviour of the engine. (Source: ADS-B Exchange and FADEC of OO-HAN)*

According to the pilot, the engine stopped functioning completely during the turn towards the downwind leg. This total power loss forced him to attempt a glide towards Runway 03. During the final approach, the pilot made a right turn to align the aircraft with the runway. During his manoeuver with an increased bank angle, the stall warning activated, indicating the aircraft was nearing its stall speed.

Ultimately, the pilot believed a normal landing became unachievable due to insufficient airspeed. The aircraft crashed on the grass to the right of the runway.

After impact, the right wing was detached and the aircraft spun 180 degrees before coming to rest on the runway surface. The aircraft was destroyed.

▲ *Figure 2: Accident location. (Source: Dutch Aviation Police)*

The pilot, who was the sole occupant, evacuated the aircraft with minor injuries. After the evacuation, the pilot noted smoke emanating from the engine area. Fuel spilled from the aircraft caught fire that affected the left wing and tail. The fire persisted for several minutes before being extinguished by the airport's fire services.

2.2 Injuries to persons

The pilot sustained minor injuries.

2.3 Damage to aircraft

The aircraft was destroyed from both the impact and the fire. The right wing detached from the fuselage and showed significant charring. The outer half of the left wing was almost entirely destroyed, while the inboard part of the left wing is mostly intact. The tail section had broken forward of the rudder and was inverted relative to the fuselage, but remained largely intact, though with visible fire damage on the right side.

The fuselage exhibited heavy scorching and soot, with the forward section near the cockpit showing significant crushing and fragmentation. Despite this, the cockpit structure itself remained intact. The pilot had opened the cockpit door and the cabin doors were found open.

Extinguishing foam covered much of the ground around the wreckage. Scorch marks and blackened areas on the runway and surrounding terrain indicated the extent of the post-impact fire. Remnants of the landing gear were visible, appearing crushed or detached, with debris scattered along the runway.

▲ *Figure 3: Aircraft wreckage*

2.4 Personnel information

The pilot of OO-HAN, aged 41, held a Private Pilot Licence – Aeroplane (PPL(A)), with Single Engine Piston (SEP) rating, initial issued on 15 March 2022. The Class 2 medical certificate of the pilot was valid until 2 December 2023.

▼ *Table 1: Flight hours of the pilot.*

Licence	Hours on type	Total hours	Pilot in command hours
PPL(A)	61.8 hours	152.9 hours	84.7 hours

2.5 Aircraft information

2.5.1 General information

The aircraft involved in the accident, registered as OO-HAN, is a Diamond DA 50 RG. It was produced in Austria in 2022, bearing the serial number 50.C.A.A.028. This model has been under a Type Certificate from the European Union Aviation Safety Agency (EASA) since September 2020. Registered in Belgium on 8 November 2022, OO-HAN had a valid Certificate of Airworthiness issued on 21 November 2022. By the time of the accident, it had accumulated 63 flight hours. The pilot was the owner of the aircraft. Since the start of production, 60 Diamond DA 50 RG aircraft had been produced by September 2023. The aircraft is designed to carry up to five occupants, with configurations allowing for one pilot and four passengers or two pilots and three passengers. It has a maximum take-off weight of 1,999 kg.

2.5.2 Engine

The Diamond DA 50 RG is equipped with a Continental Aerospace Technologies Centurion 3.0 engine, also known as the Continental CD-300. The propeller is driven via an integrated reduction gearbox with dual mass flywheel. The V6-cylinder four-stroke diesel engine operates on Jet-A fuel. It features two redundant Full Authority Digital Engine Controls (FADEC) that manage fuel injection, engine RPM, and propeller pitch. The CD-300 holds a Type Certificate (EASA.E.104) issued by EASA since June 2017, meeting the airworthiness standards outlined in EASA CS-E, Amendment 3. The engine is approved for installation in EASA Part 23 normal and utility category airplanes.

2.5.3 Maintenance

According to the maintenance documentation, the first scheduled maintenance was required either 1 year or 100 flight hours after the previous inspection. The accident occurred before reaching either 1 year or 100 flight hours. The owner did not detect any anomalies in the interim. Therefore, no scheduled or unscheduled maintenance had been performed on the aircraft since the aircraft was delivered from the factory in October 2022.

2.5.4 Aircraft structure

The aircraft's structure utilizes predominantly carbon-fibre reinforced plastic (CFRP) and glass-fibre reinforced plastic (GFRP). The fuselage is a semi-monocoque moulded construction, made from a CFRP shell with GFRP bulkheads and stiffeners. The engine compartment – located in front of the cockpit – is segregated from other sections by a firewall. This firewall is enhanced with fire-resistant matting covered by stainless steel cladding for added protection.

Each wing features two I-shaped spars with webs made from a GFRP/rigid foam sandwich and caps constructed from CFRP tapes. The wings are further composed of top and bottom shells made of a CFRP sandwich construction, bonded to the spars. The ailerons and flaps are primarily made from a combination of GFRP and CFRP in a sandwich construction. The aircraft has aluminium fuel tanks installed in each wing between the wing spars. Each fuel tank comprises three fuel chambers. The fuel tanks are supported to allow for wing deformation under load.

The T-shaped tail of the Diamond DA 50 RG is constructed in a semi-monocoque style. The top and bottom shells of the horizontal stabilizer are crafted from a blend of GFRP and CFRP. Both the rudder and the elevator follow a sandwich construction approach.

2.5.5 Fuel system integrity

The aircraft was designed and built to comply with EASA Certification Specifications (CS) 23 Amendment 4[5] fuel system certification requirements, which are intended to reduce the risk of post-impact fire in minor crash conditions. These regulations are designed to ensure that the fuel system integrity is maintained even under force, to prevent fuel spillage that could lead to fires in crash scenarios. The requirements include:

- CS 23.967 Fuel Tank Installation: The regulation stipulates that fuel tanks must be designed, located, and installed to retain fuel under inertia loads resulting from the ultimate static load factors. Additionally, they must retain fuel under conditions likely to occur during a landing, whether in a normal attitude with the landing gear retracted or with the most critical landing gear leg collapsed and the other landing gear legs extended.

- CS 23.994 Fuel System Components: This specifies that fuel system components within the engine nacelle or fuselage must be protected from damage that could result in spillage sufficient to constitute a fire hazard, especially during a wheels-up landing on a paved runway.

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[5] EASA, *Certification Specifications and Acceptable Means of Compliance for Normal, Utility, Aerobatic, and Commuter Category Aeroplanes CS-23*, https://www.easa.europa.eu/sites/default/files/dfu/CS-23%20Amendment%204.pdf [consulted 10 July 2024].

2.6 Aerodrome information

Kempen Airport is an aerodrome located near Budel in the southern part of the Netherlands. The airport features two runways: one asphalt runway designated as 03/21 and a grass runway, 03R/21L. The asphalt runway has a length of 1,199 metres, accommodating a range of aircraft. The grass runway, measuring 600 metres, is exclusively used for ultralight aircraft operations. Kempen Airport is surrounded by an industrial area, meadows, forest area and heathland. The aerodrome layout and other details are illustrated in the Aerodrome Chart, which can be found in Appendix B.

2.7 Meteorological information

The Royal Netherlands Meteorological Institute does not issue a Meteorological Aerodrome Report (METAR) for Kempen Airport (EHBD). The closest airport for which a METAR is issued is Eindhoven Airport (EHEH), located approximately 26 kilometres northwest of Kempen Airport. The Eindhoven Airport report details the weather conditions around the time of the accident from 35 minutes before, 5 minutes before and 25 minutes after the accident are also provided in Table 2.

▼ *Table 2: Eindhoven Airport METARs on 2 September 2023. (Source: KNMI).*

Time (UTC)	METAR
07.25	020725Z AUTO VRB01KT 9999 OVC070 18/17 Q1019 BLU NOSIG
07.55	020755Z AUTO 08001KT 9999 OVC068 18/17 Q1019 BLU NOSIG
08.25	020825Z AUTO VRB01KT 9999 OVC066 19/17 Q1019 BLU NOSIG

The KNMI indicates the presence of few clouds between 500 feet and 1,000 feet, with overcast conditions prevailing above 6,500 feet at Kempen Airport. Flight visibility was reported to be in excess of 10 kilometres.

2.8 Communications

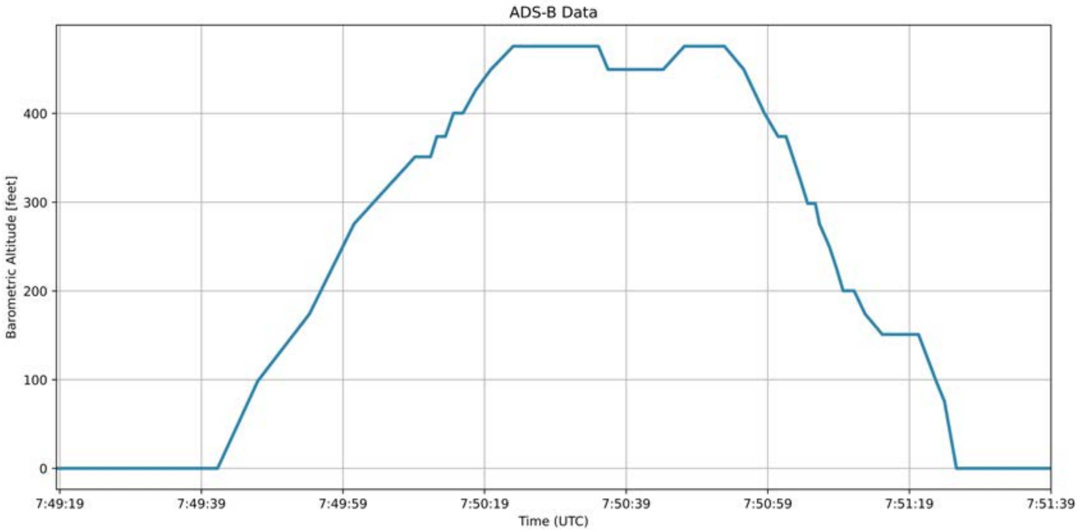
Audio recordings obtained from the airport authority provided a detailed account of the exchanges between the pilot of OO-HAN and Budel Radio during the accident flight. These recordings show that shortly after take-off, the pilot reported a reduction in engine power and expressed the need to return to the airport. Approximately twenty seconds later, the pilot made a mayday-call. Following this call, Budel Radio confirmed that Runway 03 was available for the emergency landing.

2.9 Flight data

The Dutch Safety Board obtained data from the Full Authority Digital Engine Control (FADEC), capturing the data of the full accident flight. The data were analysed at the Dutch Safety Board's laboratory in The Hague, the Netherlands, with software provided by Continental Aerospace Technologies. The FADEC started recording upon engine start and stopped recording after the aircraft came to a stop after the crash. The FADEC recorded parameters such as engine revolutions, applied load and oil pressure throughout the flight.

The engine data indicate that shortly after the engine load was set to 100%, the oil pressure began to drop. Additionally, two drops in engine revolutions were recorded, as marked in Appendix C.

Additionally, ADS-B flight data has been obtained from ADS-B Exchange, giving the barometric altitude for the duration of the flight. The barometric altitude of the flight is presented in Figure 4.



▲ *Figure 4: ADS-B altitude data. (Source: ADS-B Exchange)*

2.10 Post-impact fire

The fuel tank located within the right wing ruptured, resulting in fuel spillage on the runway. The spilled fuel, combined with other combustible materials and sources of ignition present at the scene, led to a fire that damaged the left wing (see Figure 3) and tail section (see Figure 5 and Figure 6). The fire persisted for several minutes before being successfully extinguished by the airport's fire service.

▲ *Figure 5: Right side of tail*

▲ *Figure 6: Left side of tail*

2.11 Tests and research

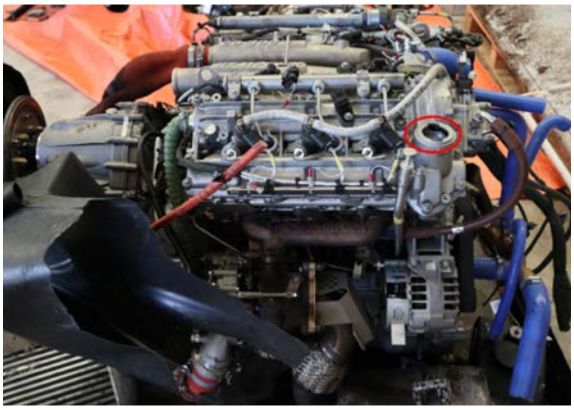
Following the accident, the Dutch Safety Board examined the engine's condition and particularly the oil system of the Continental CD-300 engine series. Initially, the Board performed a field investigation, followed by the engine's transport to the manufacturer's facility in Sankt Egidien, Germany for a complete teardown. The tear down inspection was performed in presence of the Dutch Safety Board, the German and Austrian safety investigation authorities, and representatives from Diamond Aircraft. Finally, the manufacturer conducted a detailed investigation, which included FADEC data analysis and a teardown inspection of the engine.

2.11.1 Field investigation

The Dutch Safety Board conducted a field investigation of the engine. Investigators found that the crankshaft could not be rotated. Several areas of damage were observed, including holes in the engine crankcase (see Figure 11) and oil pan (see Figure 10). The engine oil filter and its bowl were not found during multiple search attempts, with evidence indicating that the filter bowl had torn off (see Figure 7 and Figure 9).

Additionally, the oil filler cap was also missing and could not be located (see Figure 8). In spite of these findings, no traces of engine oil were observed on the exterior of the engine.

▲ *Figure 7: Teared off filter bowl*



▲ *Figure 8: Missing oil filler cap*

Soot traces were visible on the engine, likely resulting from the post-crash fire. The engine manufacturer conducted a borescope inspection during the field investigation and observed a broken glow plug of the #1 cylinder and severe internal damage. Engine data were also retrieved from the FADEC for further analysis.

2.11.2 Engine teardown

The FADEC data analysis revealed dips in oil pressure and RPM (as described in Section 2.9), directing the focus of the investigation towards the engine's oil system. During the teardown, all components were inspected thoroughly. A summary of findings related to the oil system is provided:

- Two holes were observed in the upper oil pan, caused by the tearing off of the engine rear mounts.
- Several holes were found in the crankcase.
- A hole was noted in the bottom oil pan[6], with no oil remaining in the sump.
- The oil filler cap and oil filter bowl were missing.
- The oil pump exhibited severe damage and was blocked by metal chips.
- Despite metal chips in the camshaft housing, all camshafts and their bearings were sufficiently lubricated, no signs of wear or overheat.
- The crankshaft could not rotate.
- Several big-end bearings were damaged.
- Main crankshaft bearings:
  - Bearing #1 showed fretting marks and a heat imprint (see Figure 12) on the crankcase.
  - Bearing #2 was destroyed. Initial visual inspection in the material lab of the one screw showed possible signs of fatigue cracking, the other showed unclear signs of failure.
  - Bearings #3 and #4 were in normal condition.
- Three oil nozzles (each lubricates two pistons): #1 and #2 were damaged, while #3 remained intact.
- Various broken parts were found in the oil sump.

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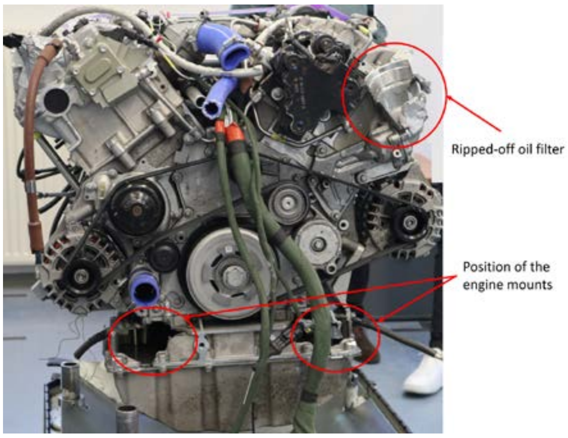
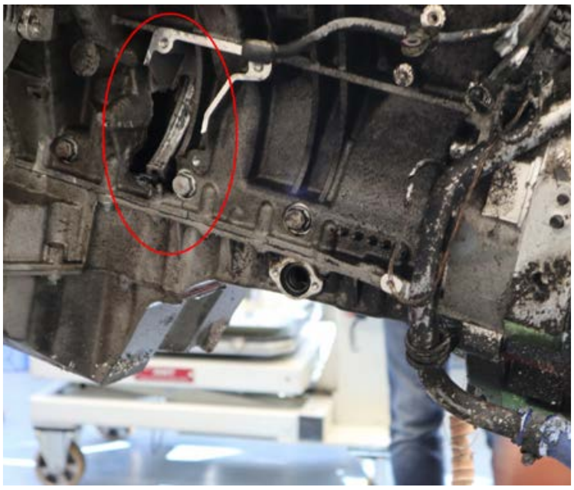
[6] The bottom oil pan is also referred to as the oil sump.

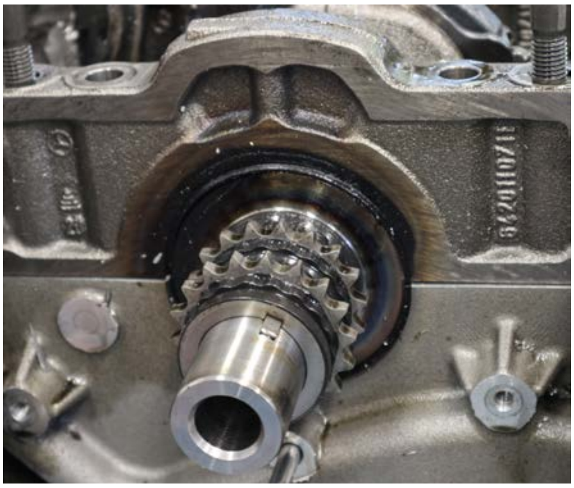


▲ *Figure 9: Damaged oil filter bowl and oil pan*

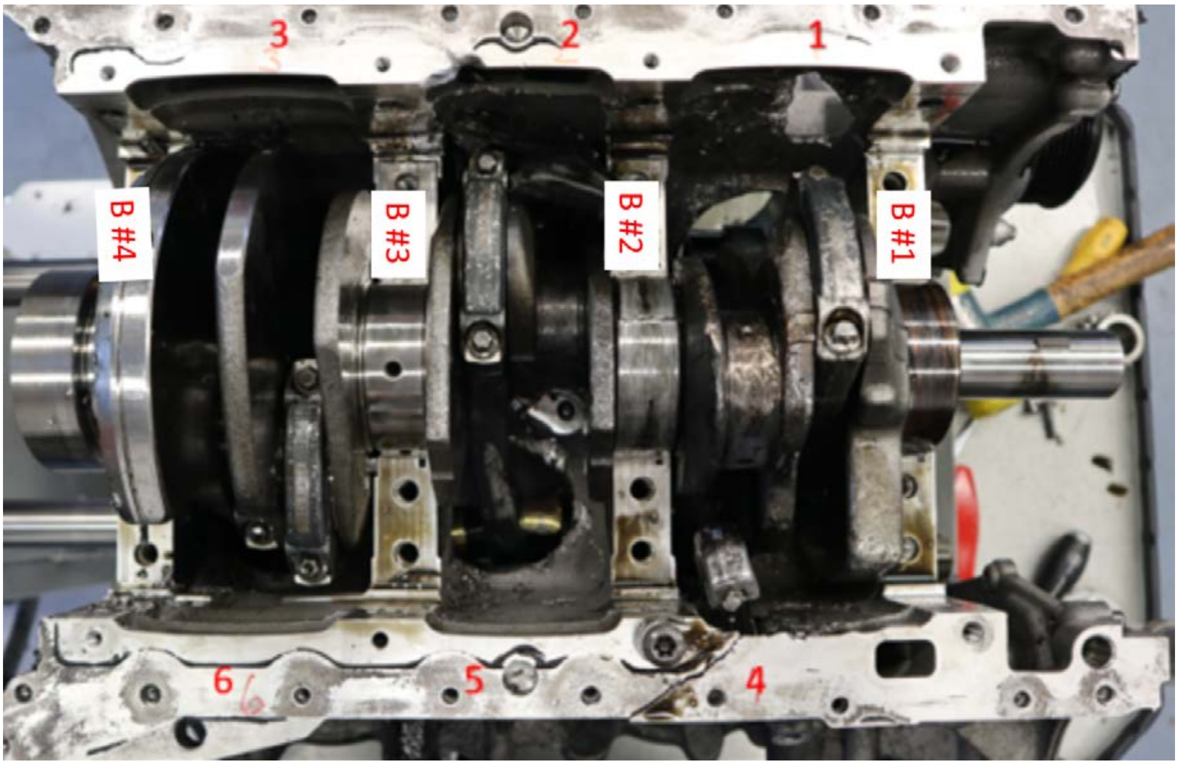
▲ *Figure 10: Hole in oil pan*



▲ *Figure 11: Damaged crankcase*



▲ *Figure 12: Main #1 bearing heat imprint*



▲ *Figure 13: Positions main crankshaft bearings and big ends (bearings)*

The crankshaft rotates on four main bearings, which are lubricated via an oil gallery supplied by a gear-type, engine-driven oil pump. The crankshaft contains internal oil channels that provide lubrication to the big-end bearings. Each main bearing is connected to specific big-end bearings as follows:

- **Main bearing B #1**: Lubricates big-end bearing #1.
- **Main bearing B #2**: Lubricates big-end bearings #2 and #4.
- **Main bearing B #3**: Lubricates big-end bearings #3 and #5.
- **Main bearing B #4**: Lubricates big-end bearing #6.

The destruction of main bearing #2 (see Figure 13) disrupted the lubrication of big-end bearings #2 and #4, causing their failure.

2.11.3 Summary of manufacturer's investigation

The FADEC data from the accident flight recorded two notable drops in engine RPM, followed by a rapid decline in oil pressure to zero. On-site and teardown inspections confirmed extensive internal damage, including holes in the oil pan, a broken gearbox, and the absence of the oil filter and oil cap. The teardown identified main bearing #2 as the likely point of initial failure. This failure disrupted lubrication to connecting rod bearings #2 and #4, causing them to overheat and seize.

Small amounts of casting sand were discovered embedded in the casting in the oil gallery. These residues, originating from the casting process, may have interfered with the oil flow, preventing the formation of a consistent oil film at bearing #2. Additionally, an oil analysis was carried out (see Appendix F). The results of the oil analysis showed elevated levels of copper (Cu) and silicon (Si). The engine manufacturer examined this potential connection during the investigation, but no definitive causal link was established at the time of report finalisation.

2.11.4 Service Bulletin and oil analysis

In response to the technical investigations, the manufacturer issued a service bulletin[7] on 9 October 2023, requiring all CD-300 operators to perform oil analyses and submit oil filters for inspection. This action aimed to detect potential abnormalities across the fleet.

As part of this initiative, the manufacturer collected 55 oil samples from various CD-300 engines. While it is normal for oil samples to contain some copper due to standard wear and tear of components, the analysis identified five samples with elevated copper levels. Elevated levels can indicate increased wear of copper-containing components, such as bearings.

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[7] Continental Aerospace Technologies GmbH, SB CG 300-1011 P1, Revision 1, 9 October 2023.

2.11.5 Additional investigations and follow-up actions

The manufacturer's inspection of the five engines with elevated copper levels did not reveal signs of the same failure mode observed as in OO-HAN's engine. To further assess copper development, the manufacturer is conducting a 600-hour test bench run on an engine with higher copper levels.

In four of the five engines examined, casting sand residues were found embedded in the oil galleries, similar to those observed in OO-HAN's Engine 06-01-0056. However, no evidence of the same failure mode observed in OO-HAN was found.

Additionally, the engine manufacturer reported changes to the cleaning process used in the engine assembly procedure. Since the OO-HAN accident, an ultrasonic cleaning bath and residual dirt analysis have been added to the cleaning procedure. Previously, cleaning was performed manually.

2.12 Pilot training for partial engine failures

During the accident flight, the pilot encountered fluctuating engine revolutions per minute (RPM), which ultimately led to a complete engine power loss. This situation presented the pilot with significant challenges in decision-making, particularly as the initial engine symptoms reflected a decrease in performance rather than a total failure. Partial engine power scenarios require decisions that are not currently addressed within the Dutch licensing syllabus, as neither EASA nor Dutch regulations mandate specific training for handling such situations. The existing training syllabus focuses on complete engine failures, which include established procedures and checks.

While training for complete engine failures is part of the EASA licensing requirements, the absence of mandated partial power failure training leaves a gap in preparing pilots to manage these more nuanced situations. This is notable because such scenarios can create additional complexity in decision-making, particularly when the remaining engine power is insufficient for continued safe flight, but might delay the urgency of selecting an immediate off-airport landing site.

Investigations by the British Air Accidents Investigation Branch (AAIB) [8] and the Australian Transport Safety Bureau (ATSB) [9] have highlighted the importance of training for partial power loss scenarios.

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[8] AAIB, *AAIB investigation to Grumman AA-5, G-BBSA*, https://www.gov.uk/aaib-reports/aaib-investigation-to-grumman-aa-5-g-bbsa [consulted 20 October 2024].

[9] ATSB, *Avoidable Accidents No. 3, Managing partial power loss after takeoff in single-engine aircraft*, https://www.atsb.gov.au/sites/default/files/media/4115270/ar-2010-055_no3.pdf [consulted 30 October 2023].

3 ANALYSIS

The accident involving the Diamond DA 50 RG with registration OO-HAN at Kempen Airport resulted from an engine failure caused by a crankshaft #2 bearing failure. Consequently, a disruption of lubrication to other components took place, which caused the engine to seize. This mechanical failure prompted the pilot to return to the airport. However, during the critical phase of the approach, while executing a turn towards the runway, the aircraft's low airspeed and higher than normal bank angle resulted in a high rate of descent, preventing a controlled landing. This led to a crash outside the runway, causing the aircraft's right wing to break off and fuel to spill. The spilled fuel ignited, resulted in a fire that consumed parts of the aircraft.

3.1 Bearing failure

The engine failure that led to the accident resulted from a crankshaft main bearing #2 failure. This main bearing #2 plays a key role in distributing oil to the connecting rod bearings for cylinders #2 and #4 via internal oil channels in the crankshaft. The lubrication to these components was interrupted, leading to their overheating, seizure, and eventual breakage of the connecting rods. Some of the connecting rods protruded through the crankcase.

The first signs of the #2 bearing failure were observed shortly after take-off, with a dip in Revolutions Per Minute (RPM) recorded by the Full Authority Digital Engine Control (FADEC). These fluctuations in RPM and oil pressure progressively worsened, culminating in a complete loss of oil pressure and total engine failure. The subsequent engine teardown confirmed that:

- Main bearing #2 was destroyed.
- Big-end bearings #2 and #4, which rely on lubrication downstream of main bearing #2, had also overheated and seized.
- The crankshaft could not rotate due to bearing failure.
- Extensive damage was present in the crankcase and oil pump.
- Signs of overheating of main bearing #1.

The overheating of main bearing #1 was likely a secondary consequence of the loss of oil pressure caused by the initial failure of bearing #2. Once lubrication to the downstream components was disrupted, the entire system rapidly degraded, resulting in mechanical seizure. Metal chips originating from broken engine components inside the engine, caused damage to the engine oil pump. Additionally, insufficient filtration of engine oil can contribute to contamination, but there is no evidence that the oil filter was missing before take-off or that oil impurities played a role in this failure.

The engine manufacturer's investigation identified embedded residues of casting sand within the oil gallery, a potential contributing factor to the lubrication failure of main bearing #2. These residues likely originated from the casting process of the crankcase. While the contamination was minimal, its location within the oil gallery may have restricted the flow of oil to bearing #2, preventing the formation of a consistent oil film and accelerating wear.

Although the oil sump was empty following the accident, this was attributed to a hole in the oil pan caused by ground impact. The absence of oil traces on the exterior of the engine makes it unlikely that the missing oil filler cap contributed to the loss of oil, oil pressure or lubrication failure.

The manufacturer determined that the embedded casting sand contamination likely stemmed from a single incident during the crankcase casting process. Inspections of other engines revealed five other engines in the field containing similar contamination. As a preventative measure, the manufacturer implemented changes to the cleaning process used in the engine assembly procedure, introducing an ultrasonic bath and residual dirt analysis to reduce the risk of contamination in future engines.

The engine failure was caused by the destruction of main bearing #2, which disrupted lubrication to other components inside the engine, including big-end bearings #2 and #4. Why main bearing #2 failed could not be determined. It was, however potentially exacerbated by contamination from embedded casting sand within the oil gallery. This resulted in rapid overheating, mechanical seizure, and a total engine power loss.

3.2 Engine failure training

During the accident flight, the pilot experienced a drop in engine revolutions per minute (RPM) shortly after take-off, which later developed into a complete engine power loss during the downwind leg. The period of partial engine power gave the pilot time to assess the situation and attempt to return to the airfield. Anticipating that the engine would not provide sufficient power to complete the circuit, the pilot turned towards Runway 03. During this turn, the engine failed completely, leaving the aircraft in a glide. While aligning with the runway, the stall warning system activated. The pilot noted that the turn involved a higher-than-normal bank angle, which increased the rate of descent and resulted in the aircraft impacting the terrain short of the runway. The need for this manoeuvre resulted from the aircraft's preceding flight path.

The decision to remain in the traffic circuit aligns with the pilot's training, which focuses on responding to total engine failures. Even more so, as the engine continued to function, allowing the pilot to reach the downwind leg, which is a densely forested area unsuitable for an emergency landing. Current Dutch licensing requirements provide detailed guidance for scenarios involving complete engine failures, such as selecting an appropriate emergency landing site immediately after take-off. At Kempen Airport, this could include nearby open fields when departing from Runway 21. The engine's continued but unreliable operation may have influenced the pilot's decision to attempt a return to the airfield instead of an off-airport landing, as would typically be recommended in a total power loss scenario. The reduced and unreliable power experienced during this flight introduced complexities not directly addressed in the syllabus. The pilot had not received specific training on handling partial engine power loss, which may have further influenced his decision-making process.

A partial engine power loss typically refers to a situation where the engine delivers less power than commanded by the pilot but more than idle thrust. In this occurrence, the pilot's decision-making during the early stages was influenced by the symptoms of reduced engine performance rather than the certainty of a complete failure.

Partial engine failure training
Partial engine failures present unique challenges. Unlike total power loss, the presence of some power can delay the decision to execute an emergency landing, potentially increasing the risk during critical phases of flight such as low-altitude manoeuvring. Currently, neither EASA nor Dutch regulations mandate specific training for partial engine power loss scenarios. The absence of such training means that pilots must rely on general principles and personal judgement when confronted with these situations, which are less predictable and not explicitly covered during licensure or standardized training.

3.3 Survivability and post-impact fire

Remnants of the landing gear appear to be crushed or detached. The fuselage forward section near the cockpit shows significant crushing and fragmentation. The loads experienced on the aeroplane during the crash are mostly absorbed by the landing gear and the fuselage forward section near the cockpit. As a result, the cockpit structure itself remained intact. Therefore the cockpit and cabin doors could also be opened. This all resulted into increased chances for the pilot to survive the crash. The pilot suffered minor injuries due to the crash and was therefore able to leave the aeroplane by himself through the cockpit door before the fire and the fire related fumes could harm him.

The cockpit structure, including the doors, remained intact. This increased the survivability chances for the pilot.

The aircraft's fuel system integrity and the subsequent post-impact fire were significant factors in this accident. Despite compliance with CS 23 fuel system certification requirements, the crash with the landing gear extended, resulted in severe structural damage that compromised the integrity of the fuel tank. The detachment of the right wing, which housed the fuel tank, exceeded the design conditions anticipated by CS 23 and led to a rupture, causing fuel to spill onto the runway. The spilled fuel, combined with other combustible materials and sources of ignition, triggered the subsequent fire.

The CS 23 requirements, such as CS 23.967 and CS 23.994, are intended to ensure fuel containment in typical landing scenarios or emergencies like a collapsed landing gear leg. However, these standards do not account for the extreme forces exerted during a crash of the severity experienced in this accident. The significant impact forces caused the right wing to detach, leading to the fuel tank rupture and spillage beyond what the certification requirements are designed to address.

Following the impact, the spilled fuel ignited, resulting in a fire that consumed parts of the aircraft, including the left wing, tail section, and engine. Extinguishing foam was observed around the wreckage, indicating the involvement of the airport fire service. The actions of the fire service prevented further spread of the fire and contained it to the wreckage area.

> The fuel tank rupture and subsequent fire were direct consequences of the impact forces experienced during the crash. The spilled fuel combined with other combustible materials and ignition sources, led to a fire that consumed parts of the aircraft.

4 CONCLUSION

The accident involving the Diamond DA 50 RG with registration OO-HAN at Kempen Airport was caused by an engine failure resulting from the destruction of crankshaft main bearing #2. This mechanical failure disrupted lubrication to other engine components, causing them to overheat and seize, ultimately leading to total engine failure. The investigation identified residues of embedded casting sand within the engine's oil gallery as a potential contributing factor to the bearing failure. This contamination is believed to have originated during the manufacturing process but was determined to be a single incident, as no structural deficiencies or recurring issues were identified during the manufacturer's inspection of other engines. The manufacturer addressed the contamination risk by refining the cleaning procedure during engine assembly, including the addition of ultrasonic cleaning and systematic dirt residue analysis.

Following the engine failure, the pilot attempted to return to the airport. During the critical phase of the approach, the aircraft descended rapidly at low altitude. This led to an impact outside the runway, resulting in the detachment of the right wing, which ruptured the fuel tank. The spilled fuel ignited upon contact with other combustible materials, causing a fire that consumed parts of the aircraft. Despite this, the pilot sustained minor injuries and was able to evacuate the aircraft unaided before the fire spread.

The pilot's decision to remain in the airport circuit was consistent with current training, which emphasizes managing complete engine failures. However, the initial engine performance degradation presented symptoms of reduced power rather than a complete failure, adding complexity to the pilot's decision-making process. This occurrence highlights the challenges pilots may face when responding to partial engine failures, a scenario that is not explicitly addressed in the current EASA and Dutch licensing syllabus. Enhanced focus on these situations in training could further support pilots in making critical decisions under similar circumstances.

The detachment of the right wing and subsequent rupture of the fuel tank were direct consequences of the severe impact forces experienced during the crash. These forces exceeded the design parameters of the aircraft's fuel system, which complies with EASA CS 23 certification standards. Even more so, the structure of the cockpit remained intact, significantly increasing the pilot's chances of survival.

The engine manufacturer has taken mitigating measures to reduce the risk of similar occurrences. While the effectiveness of these measures has not been assessed by the Dutch Safety Board, they address the identified issue. Therefore, no safety recommendation is issued.

APPENDIX A

Responses to the draft report
In accordance with the Dutch Safety Board Act, a draft version of this report was submitted to the parties involved for review. The following parties have been requested to check the report for any factual inaccuracies and ambiguities:

- Air Accident Investigation Unit (Belgium)
- Bundesstelle für Flugunfalluntersuchung (Germany)
- Continental Aerospace Technologies
- Diamond Aircraft Industries
- European Union Aviation Safety Agency
- Human environment and transport inspectorate
- Kempen Airport
- Pilot
- Sicherheitsuntersuchungsstelle des Bundes (Austria)

The responses received were processed in the following way:

- If the Safety Board decided to adopt responses, they were amended into the final version of the report.
- If the Safety Board did not adopt responses, an explanation is given of why it decided to do so.

The responses received, as well as the way in which they were processed, are set out in a table that can be found on the Dutch Safety Board's website (https://www.safetyboard.nl).

APPENDIX B

Kempen Airport aerodrome chart

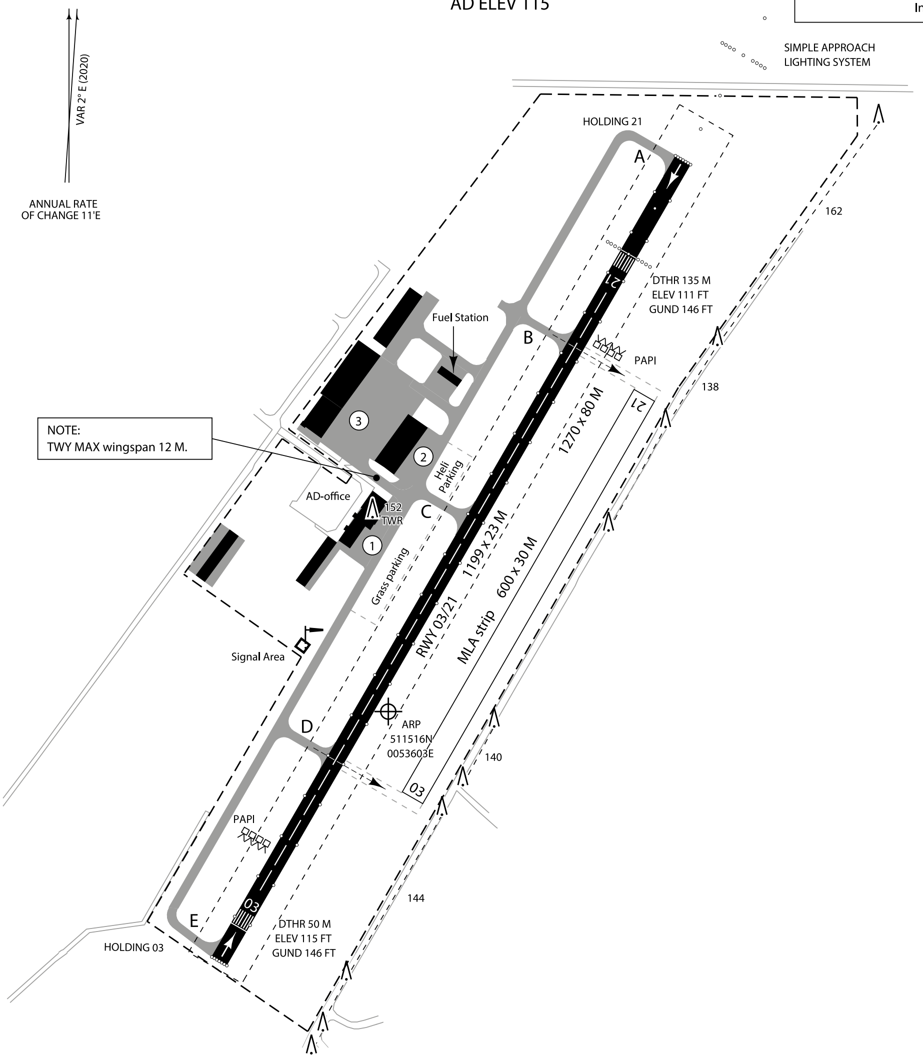
AIP NETHERLANDS

WEERT/Budel
AERODROME CHART

AD 2.EHBD-ADC
12 AUG 2021

AD info	122.155	Budel Radio
AFIS	122.155	Budel Aerodrome Information

AD ELEV 115



LEGEND

① Parking area

SCALE 1 : 7 500

metres 0 100 200 300 400 500

feet 0 500 1000 1500

PHYSICAL CHARACTERISTICS					
RWY	DIRECTION	MAX AUW	MAX TYRE PRESS	SURFACE	THR COORDINATES
03	028°	25/F/B/W/U	0.84 MPa	ASPH	511506.9N 0053552.8E
21	208°	25/F/B/W/U	0.84 MPa	ASPH	511535.1N 0053619.0E

DIRECTIONS ARE MAGNETIC
ELEVATIONS IN FEET AMSL
DIMENSIONS IN METRES

MICRO LIGHT AIRCRAFT (MLA):

STRIP	DIRECTION	SURFACE	MARKING AIDS
03	028°	GRASS	Red / white markers on corners
21	208°		

MARKING AIDS:

RWY : THR, centre line, RWY designators.
TWY : centre line, HLDG positions.
Red / white mandatory instruction signs on all taxi HLDG positions;
Yellow / black info signs.

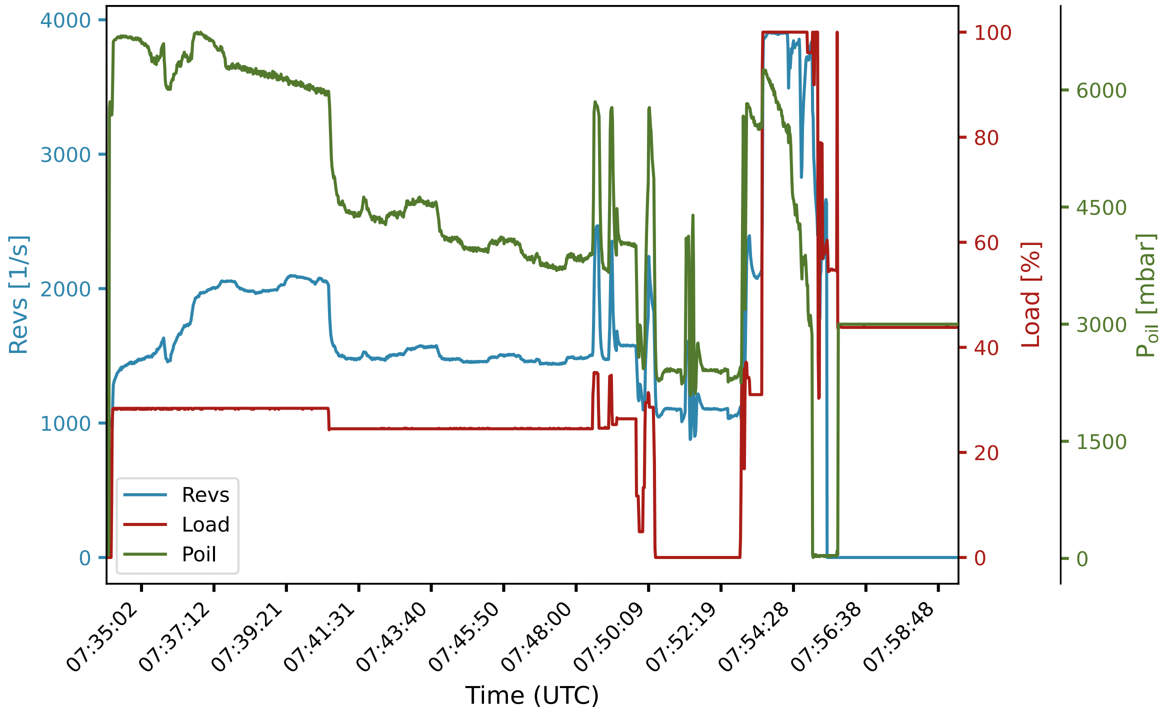
CHANGE: MAG VAR 2020; editorial.

AIRAC AMDT 08/2021

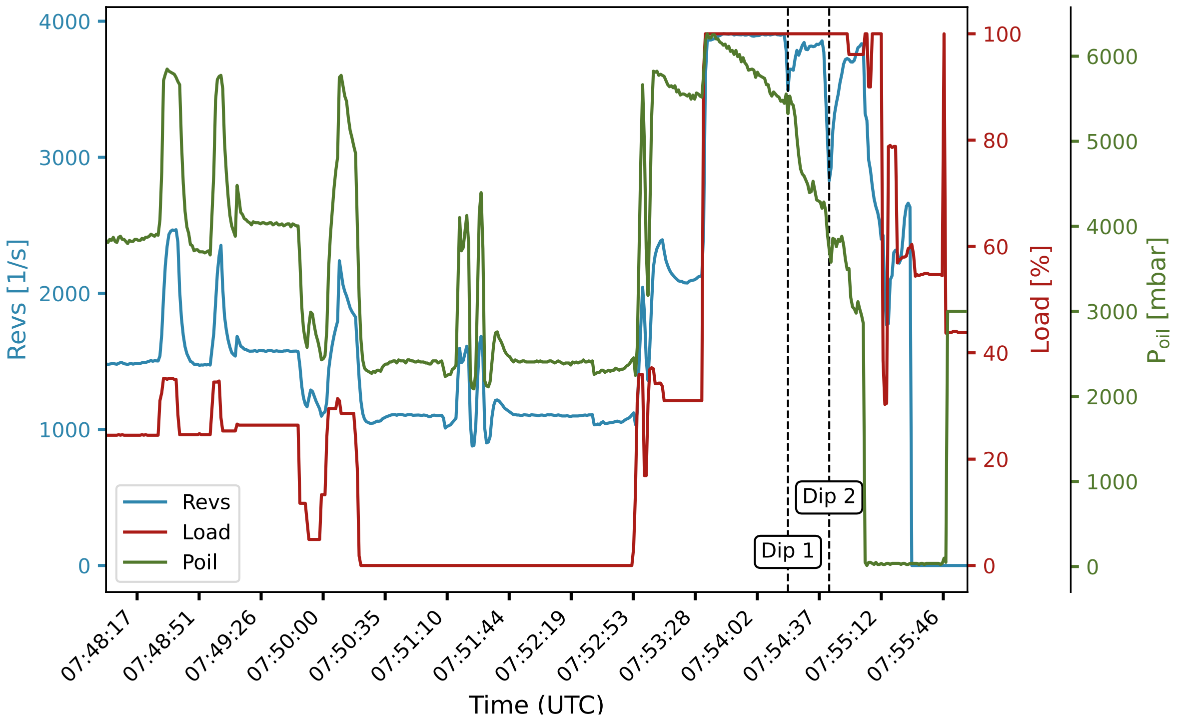
▲ *Figure 14: Budel aerodrome chart. (Source: AIP Netherlands)*

APPENDIX C

FADEC data of OO-HAN



▲ *Figure 15: FADEC data of OO-HAN on 2 September 2023*

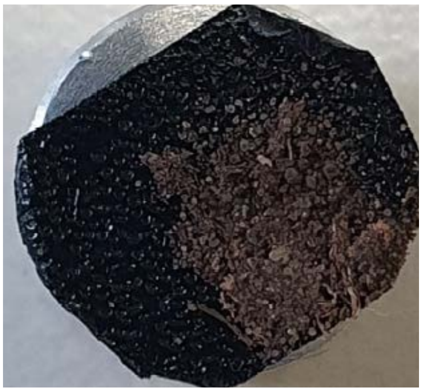


▲ *Figure 16: Part of FADEC data of OO-HAN on 2 September 2023 indicating dips in engine revolutions*

APPENDIX D

Fuel sample analysis

A sample of Jet-A1 used by OO-HAN was taken and analysed at SGS[10] testing facility. The density of the Jet-A1 fuel sample was measured according ISO 12185, resulting in a value of 0.7992 kg/L at 15 °C (typical range is 0.775 to 0.840 kg/L at 15 °C).



▲ *Figure 17: Visual representation by optical microscope of the prepared sample for SEM analysis. (Source: SGS)*

Further analysis included a simulated distillation according ASTM D 2887[11], procedure B, which helps in understanding the boiling rang and the compositional characteristics of the fuel. A representative portion of the sample was prepared for analysis using a Scanning Electron Microscope (SEM) coupled with an X-ray detector (EDX). The SEM analysis provided information about the fuel's morphology, revealing the micro-structural composition. The EDX component provided a qualitative element analysis, identifying specific elements present in the fuel sample.

The results from the SEM and EDX analyses were evaluated in accordance with ASTM E1508, which governs the comparison and identification of spectra in these studies.

▼ *Table 3: Composition of three different particles (grey/brown area/particle) of the Jet-A1 fuel sample.*

Element	Area 1 (Mass %)	Particle 2 (Mass %)	Particle 3 (Mass %)
Carbon (C)	45.96	40.72	37.04
Oxygen (O)	40.19	41.60	43.06
Aluminium (Al)	2.10	2.08	1.46
Silicon (Si)	11.24	14.91	18.43
Calcium (Ca)	0.50	0.70	-

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[10] SGS is known by its abbreviation. The abbreviation stands for Société Générale de Surveillance.

[11] ASTM D2887 Standard Test Method for Boiling Range Distribution of Petroleum Fractions by Gas Chromatography.

APPENDIX E

Engine teardown findings

- Rear engine mounts broken out
- 2 holes found on upper part of oil pan at the position of the rear engine mounts
- No oil after removal of oil screw
- Only limited amount of oil and fuel could be collected
- 3 holes found at in the engine crankcase
- Both turbochargers rotating
- Gear box drive shaft broken and not rotatable
- Oil filler cap missing
- Oil filter and housing missing
- Oil pump shows excessive damage and was blocked
- Gear box housing was found broken
- Fuel present at fuel lines (also to the fuel pump)
- Fuel injector corrosion and residues in fuel injector bore holes
- Chips found in L/H side cylinder head, a limited number of chips in R/H side cylinder head
- Chips in camshaft housing
- Braking torque on the bearing connecting rod bolts are provided in Table 4.

▼ *Table 4: Braking torque on the bearing connecting rod bolts.*

Arm	#1	#2	#3	#4	#5	#6
Long arm [Nm]	N/A	N/A	84	N/A	59	79
Short arm [Nm]	78	N/A	85	N/A	40	86

- Lower connecting rod bearing shell #2 and #4 missing
- #5 connecting rod was bend
- Torque check cylinder head bolts are provided in Table 5.

▼ *Table 5: Torque check cylinder head bolts.*

Position	#1	#2	#3	#4	#5	#6	#7	#8
L/H [Nm]	200	200	200	250	270	250	250	250
R/H [Nm]	250	250	225	225	225	225	>300	225

- All camshafts and camshaft bearings found to be ok
- Exhaust camshaft chain wheel of L/H cylinder bank was deformed through the broken camshaft cover
- Pistons:
  - #1 missing
  - #2 broken, separated form connecting rod
  - #3 ok
  - #4 broken, separated form connecting rod
  - #5 broken, separated form connecting rod
  - #6 ok
- 3 piston pin securing rings are missing
- Connecting rods:
  - #1 big end bearing shows wear marks
  - #2 destroyed
  - #3 ok
  - #4 big end bearing damaged, lost lower bearing shell, both screws are missing
  - #5 bent
  - #6 ok, some fretting marks at the big end bearing
- Main crankshaft bearings:
  - #1 fretting marks, imprint on crankcase
  - #2 destroyed
  - #3 ok
  - #4 ok
- Parts in oil sump
- Cylinder #1 glow plug tip broke off and is missing
- Cylinder head showed signs of damage inside combustion chamber of cylinder #1
- Braking torque on the main bearing caps is provided in Table 6

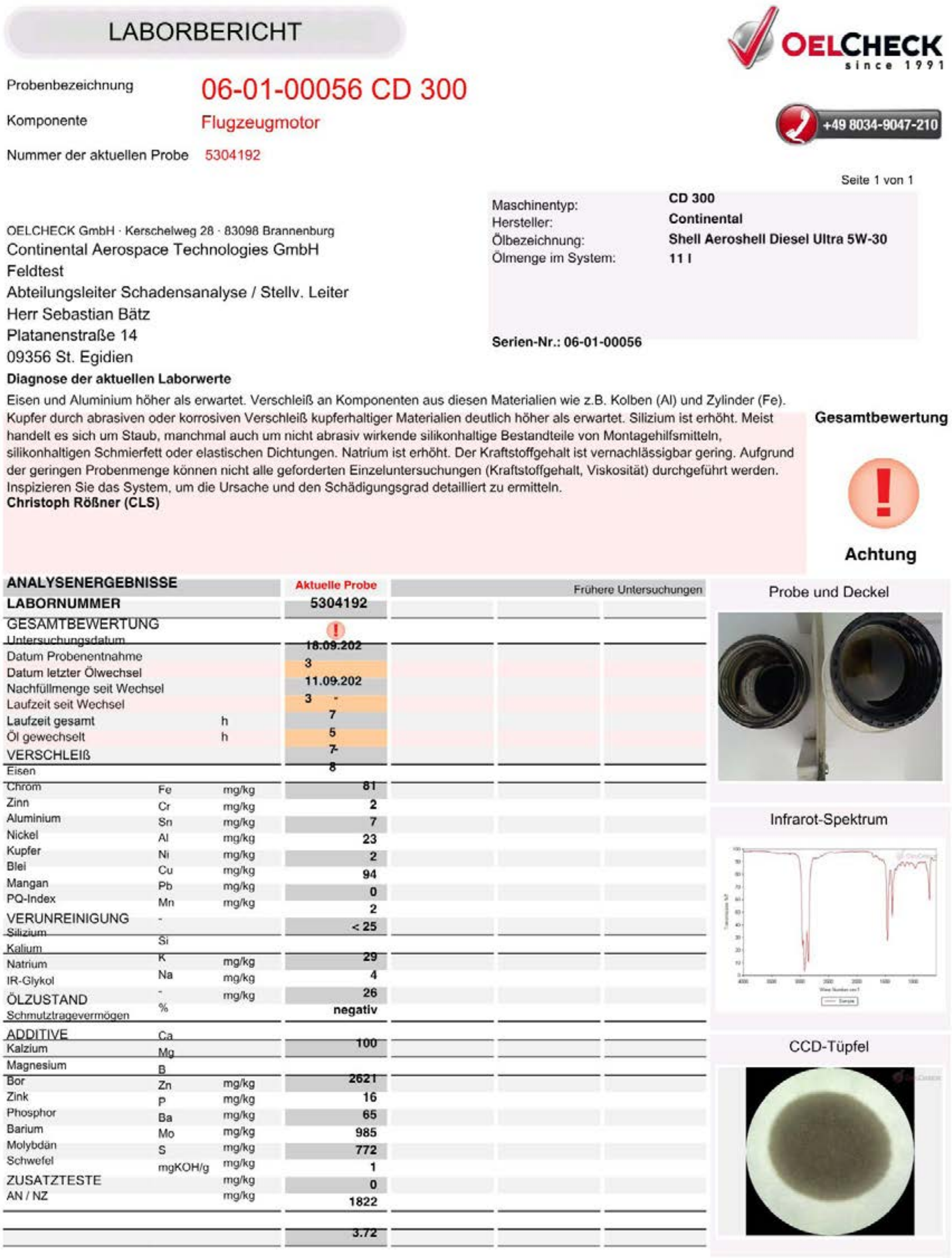
Table 6: Braking torque on the main bearing caps.

Bearing	L/H side Screw	Top Screw #1	Top Screw #2	Top Screw #3	Top Screw #4	R/H side Screw
Bearing #1 [Nm]	84	131	125	146	125	63
Bearing #2 [Nm]	72	122	140	129	132	56
Bearing #3 [Nm]	76	146	140	147	144	69
Bearing #4 [Nm]	90	150	153	147	145	75

- Crankshaft not rotatable
- Timing chain was found to be ok
- Scratch marks found in Cylinder #1 into 4 directions; one small scratch mark in cylinder #5
- Oil nozzle #1 and #2 were found damaged; oil nozzle #3 was intact
- Balance shaft was ok
- High pressure fuel pump and fuel feed pump were rotatable
- No metal chips and signs of metal debris found within the engine oil-water heat exchanger

APPENDIX F

Oil sample analysis



LABORBERICHT

OELCHECK since 1991

+49 8034-9047-210

Probenbezeichnung 06-01-00056 CD 300

Komponente Flugzeugmotor

Nummer der aktuellen Probe 5304192

Seite 1 von 1

Maschinentyp:	CD 300
Hersteller:	Continental
Ölbezeichnung:	Shell Aeroshell Diesel Ultra 5W-30
Ölmenge im System:	11 l

Serien-Nr.: 06-01-00056

OELCHECK GmbH · Kerschelweg 28 · 83098 Brannenburg
Continental Aerospace Technologies GmbH
Feldtest
Abteilungsleiter Schadensanalyse / Stellv. Leiter
Herr Sebastian Bätz
Platanenstraße 14
09356 St. Egidien

Diagnose der aktuellen Laborwerte

Eisen und Aluminium höher als erwartet. Verschleiß an Komponenten aus diesen Materialien wie z.B. Kolben (Al) und Zylinder (Fe). Kupfer durch abrasiven oder korrosiven Verschleiß kupferhaltiger Materialien deutlich höher als erwartet. Silizium ist erhöht. Meist handelt es sich um Staub, manchmal auch um nicht abrasiv wirkende silikonhaltige Bestandteile von Montagehilfsmitteln, silikonhaltigen Schmierfett oder elastischen Dichtungen. Natrium ist erhöht. Der Kraftstoffgehalt ist vernachlässigbar gering. Aufgrund der geringen Probenmenge können nicht alle geforderten Einzeluntersuchungen (Kraftstoffgehalt, Viskosität) durchgeführt werden. Inspizieren Sie das System, um die Ursache und den Schädigungsgrad detailliert zu ermitteln.
Christoph Rößner (CLS)

Gesamtbewertung

!

Achtung

ANALYSENERGEBNISSE			Aktuelle Probe	Frühere Untersuchungen		
LABORNUMMER			5304192			
GESAMTBEWERTUNG			!			
Untersuchungsdatum			18.09.202			
Datum Probenentnahme			3			
Datum letzter Ölwechsel			11.09.202			
Nachfüllmenge seit Wechsel			3 -			
Laufzeit seit Wechsel			7			
Laufzeit gesamt		h	5			
Öl gewechselt		h	7-			
VERSCHLEIß			8			
Eisen						
Chrom	Fe	mg/kg	81			
Zinn	Cr	mg/kg	2			
Aluminium	Sn	mg/kg	7			
Nickel	Al	mg/kg	23			
Kupfer	Ni	mg/kg	2			
Blei	Cu	mg/kg	94			
Mangan	Pb	mg/kg	0			
PQ-Index	Mn	mg/kg	2			
VERUNREINIGUNG	-		< 25			
Silizium	Si					
Kalium	K	mg/kg	29			
Natrium	Na	mg/kg	4			
IR-Glykol	-	mg/kg	26			
ÖLZUSTAND	%		negativ			
Schmutztragevermögen						
ADDITIVE	Ca					
Kalzium	Mg		100			
Magnesium	B					
Bor	Zn	mg/kg	2621			
Zink	P	mg/kg	16			
Phosphor	Ba	mg/kg	65			
Barium	Mo	mg/kg	985			
Molybdän	S	mg/kg	772			
Schwefel	mgKOH/g	mg/kg	1			
ZUSATZTESTE		mg/kg	0			
AN / NZ		mg/kg	1822			
			3.72			

▲ *Figure 18: Oil sample analysis OO-HAN. (Source: Continental Aerospace Technologies)*

DUTCH
SAFETY BOARD

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