



Investigation report

C3/2007L

Emergency water landing off Helsinki on 27 May 2007

Translation of the Finnish original report

Registration: OH-FDA

Aircraft type and model: Diamond DA40D

According to Annex 13 to the Convention on International Civil Aviation, paragraph 3.1, the purpose of aircraft accident and incident investigation is the prevention of accidents. It is not the purpose of aircraft accident investigation or the investigation report to apportion blame or to assign responsibility. This basic rule is also contained in the Investigation of Accidents Act, 3 May 1985 (373/85) and European Union Directive 94/56/EC. Use of the report for reasons other than improvement of safety should be avoided.

SUMMARY

An emergency landing occurred on Sunday, 27 May 2007 at around 11:40 (Finnish time) off the shoreline of Helsinki. The gearbox clutch of a single-engine Diamond DA40D four-seat aircraft, registration OH-FDA, failed and the aircraft was subsequently forced to make an emergency landing in water. The OH-FDA was owned by the Aviation Club of Helsinki University of Technology.

On 31 May 2007, Accident Investigation Board Finland (AIB) appointed investigation commission C3/2007L for this incident. Chief Investigator Esko Lähteenmäki was named Investigator-in-Charge with Investigator Asko Nokelainen as member of the commission.

The pilot intended to fly two passengers to Tallinn airport and return to Helsinki-Malmi aerodrome in the afternoon.

The Full Authority Digital Engine Control (FADEC) unit executed a pre-takeoff engine runup test. The test passed, with the engine providing full power. The takeoff and climb to 1000 ft were uneventful. The pilot was cleared to 4000 ft in Helsinki Terminal Control Area (TMA). When he began to climb he selected full power, at which time engine power fluctuated between 80–100% for 5 to 10 seconds. He then remembered that the pilot of the previous flight on the OH-FDA had told him that he, too, had noticed similar power oscillations. However, the power stabilized at 100% and all engine instrument indications were normal. Nevertheless, the pilot felt that the engine did not provide as much power as it had earlier. When he set the autopilot to a 500 ft/min climb, the engine suddenly overrevved (exceeded maximum RPM). The pilot then reduced power and tried to establish what the matter was. Meanwhile, he reported engine troubles to the air traffic control (ATC) and said that he would turn back to Helsinki-Malmi. At that time he was over the sea next to Harmaja Island, approximately 15 km from Helsinki-Malmi aerodrome.

Even though the pilot checked the emergency checklist regarding engine trouble, he soon realized that the engine would either idle or overspeed. The pilot deemed that the malfunction involved either the fuel supply or the FADEC. He let the engine run at a high rpm so as to make it back to land.

When they were at about 700 ft the pilot realized that they could not make it to the shore. Instead, they would have to make an emergency landing into the sea. The pilot reported the impending emergency landing and his estimated landing spot to the ATC and informed the passengers of the same. He landed the aircraft in the strait between Valkosaari Island and Katajanokka. The aircraft came to a halt approximately 15 metres from Valkosaari shore.

The pilot and the passengers climbed out onto the wings. Momentarily, a boat arrived next to the right wing, into which they boarded. Soon after, a police patrol boat also arrived at the scene, transporting the pilot and the passengers to Helsinki South Harbour where ambulances were already waiting. The Border Guard fastened the aircraft to Valkosaari shore, where it was encircled with oil spill booms.

The aircraft was transported to Katajanokka Quay, where the wings were detached. Then the aircraft was taken to Helsinki-Malmi aerodrome for test and research. The gearbox was disconnected from the engine, at which stage it was noticed that the friction surfaces on the clutch plate were worn.

The FADEC was sent to the German accident investigation authority, under whose supervision the engine manufacturer downloaded vital On-Board Diagnostic (OBD) data from the FADEC.

The cause of the emergency landing was clutch slippage and clutch plate surface wearing out. Clutch slippage was caused by engine oil which entered through a leak in the crankshaft's lip seal. Fissures were detected in the seal and engine manufacturer assumes they are due to high internal crankcase pressure

The investigation commission issued three recommendations.

First: The investigation commission recommends that the engine manufacturer design a system indicating changes in the rotational ratio between the crankshaft and propeller, i.e. clutch slippage. Clutch slippage indication should be recorded in the FADEC's On-Board Diagnostics system.

Second: The investigation commission recommends that the engine manufacturer redesign the clutch breather orifice so that oil leaks internal to the clutch housing could be reliably distinguished from other, external, oil leaks.

Third: The investigation commission recommends that the aircraft manufacturer expedite the time of compliance for mandatory service bulletin to improve the crankcase breathing system.

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SYNOPSIS

An emergency landing occurred on Sunday, 27 May 2007 at around 11:40 (Finnish time) off the shoreline of Helsinki. The gearbox clutch of a single-engine Diamond DA40D four-seat aircraft, registration OH-FDA, failed and the aircraft was subsequently forced to make an emergency landing in water. The OH-FDA was owned by the Aviation Club of Helsinki University of Technology. The aircraft was badly damaged. The pilot and the two passengers sustained no injuries.

The shift supervisor at Helsinki-Vantaa ATC reported the emergency landing to AIB's Chief Investigator Esko Lähteenmäki at approximately 11:50. Mr. Lähteenmäki then went to the site and supervised the transport of the aircraft. The aircraft was hoisted onto a harbour tugboat and taken to Katajanokka Quay. At quay, the wings were detached and the aircraft was transported to Helsinki-Vantaa airport for test and research.

Due to the incident, the pilot and the passengers in the aircraft were interviewed, as were the aviation club's maintenance manager, the pilot of the previous flight as well as the person who was first to arrive at the scene of the emergency landing. He was also an eyewitness.

On 30 May 2007 the gearbox was demounted and the clutch was examined while a representative of the engine manufacturer was present. The Full Authority Digital Engine Control FADEC was sent to the German accident investigation authority, who supervised the download of diagnostic engine data at the manufacturer's plant on 1 June 2007. On 3 July 2007 the engine and the gearbox were sent to the manufacturer for further investigation.

The draft final report was dispatched to the German and Finnish civil aviation authorities and to the European Aviation Safety Agency (EASA) for statement as well as to German Federal Bureau of Aircraft Accidents Investigation, the aircraft manufacturer, the engine manufacturer, the maintenance chief of the flying club and the pilot for comment. AIB received the comments from the engine manufacturer, maintenance chief and pilot. No statements were received.

The investigation was completed on 18 June 2008.

1 FACTUAL INFORMATION

1.1 History of the flight

The pilot intended to fly two passengers to Tallinn airport and return to Helsinki-Malmi aerodrome in the afternoon. They arrived at the aerodrome at approximately 10:15. The pilot said that he performed a pre-flight check during which he did not notice anything out of the ordinary. He calculated the weight and balance and filed the operational flight plan (OFP). After going through customs the pilot and the passengers boarded the plane. The passengers wore life vests but the pilot's vest was kept on the back seat. The pilot instructed the passengers on how to use their life vests and safety harness as well as how to open the doors.

The pilot switched on the pre-flight engine runup test, controlled by the Full Authority Digital Engine Control FADEC. The test passed normally and the engine provided full power. Takeoff time was 11:30. The climb to 1000 ft was uneventful. After passing reporting point Nokka the pilot contacted Helsinki Radar and was cleared to 4000 ft in Helsinki TMA. When he began to climb, he selected full power, at which time engine power fluctuated between 80–100% for 5 to 10 seconds. He then remembered that the pilot of the previous flight on the OH-FDA had told him that he, too, had noticed similar power oscillations. However, power stabilized at 100% and all engine instrument indications were normal. Nevertheless, the pilot felt that the engine did not provide as much power as it had earlier.

The pilot set the autopilot to a 500 ft/min climb. Right after this the engine suddenly oversped. Propeller speed reached 2700 RPM (maximum allowable 2500 RPM). The pilot then reduced power and tried to establish what was on the matter. Meanwhile, he reported engine troubles to the ATC and said that he would turn back to Helsinki-Malmi. At that time he was over the sea next to Harmaja Island.

Even though the pilot checked the emergency checklist regarding engine trouble, he soon realized that the engine would either idle or overspeed. The pilot deemed that the malfunction involved either the fuel supply or the FADEC. He let the engine run at a high RPM so as to make it back to land. When they were at about 700 ft the pilot realized that they could not make it to the shore. Instead, they would have to make an emergency landing into the sea.

The pilot reported the impending emergency landing and his estimated landing spot to the ATC. He also informed the passengers of the same and told them to brace for the landing. He landed the aircraft in the strait between Valkosaari Island and Katajanokka, along the Valkosaari shoreline. During the landing the engine was at idle and the airspeed was 60–70 kt. The pilot detected that the aircraft stalled right at touchdown.

As the aircraft made contact with the water, it skimmed the surface of the sea for quite a distance until the nose dove so deeply that water reached the top of the windscreen. The side windows of the passenger compartment remained above water. After the air-

craft came to a halt approximately 15 metres from shore it floated to the top, having turned almost 180 degrees into the direction from which they landed. The wing roots were submerged but the rest of the wings remained above the surface.

The pilot and the passengers climbed onto the wings and the pilot donned his life vest. At the same time, a boat came up alongside the right wing and they climbed into it. The pilot then towed the aircraft close to the shore.

The pilot called Helsinki-Malmi ATC and reported that they had landed without any injuries to persons. Soon after this a police patrol boat arrived and transported the pilot and passengers to Helsinki South Harbour, where ambulances were already waiting. The Border Guard fastened the aircraft to Valkosaari shore, where it was encircled with oil spill booms.

1.2 Injuries to persons

Injuries	Aircrew	Passengers	Others
Mortal	-	-	-
Serious	-	-	-
Minor / no injuries	1	2	-

1.3 Damage to aircraft

The aircraft was substantially damaged.

1.4 Other damage

There was no other damage.

1.5 Personnel information

Pilot-in-command, age 24.

The pilot had a PPL (A) licence and he was SEP (land) certified. He flew the OH-FDA for the first time in October 2006. The other gasoline and diesel engine powered aircraft types he has flown comprise: Cessna 172, Cessna 152, AS 202 Bravo and Piper PA-28 Archer.

Flying experience	Last 24 h	Last 30 days	Last 90 days	Total hours
All types	10 min 1 landing	2 h 51 min 4 landings	10 h 11 min 23 landings	189 h 6 min 435 landings
Type in question	10 min 1 landing	1 h 23 min 2 landings	5 h 50 min 8 landings	14 h 19 min 19 landings

1.6 Aircraft information

The Diamond DA40D is an all-composite airframe, single engine, four-seat, nose gear-steered monoplane equipped with fixed landing gear.

Aircraft

Type: Diamond DA40D
 Registration: OH-FDA
 Certificate of registration: 1865
 Manufacturer: Diamond Aircraft Industries GmbH
 Serial number and year of manufacture: D4.029, 2003
 Certificate of airworthiness: Valid until 31.10.2007
 Owner and operator: Aviation Club of Helsinki University of Technology (Polyteknikkojen Ilmailukerho ry)
 Airborne time: 496 h, 995 landings

Engine: TAE 125-01 diesel engine
 Manufacturer: Thielert Aircraft Engines GmbH, Germany
 Serial number: 02-01-0301-SL01-004-0180
 Running time: 534 h
 Fuel: JET A-1

Gearbox: TAE 02-7210-07901R1
 Production number: 2935
 Running time: 276 h

Clutch:
 Running time: 284 h

Propeller:	MTV-6-A/187-129 3-blade natural-composite constant speed propeller with fibre reinforced epoxy cover
Manufacturer:	MT-Propeller
Production number:	2237
Running time:	496 h

The takeoff weight (TOW) of the aircraft was 1123 kg. The maximum TOW was 1150 kg. The Centre of Gravity (CG) was slightly forward of the mean aerodynamic chord, but well within the approved range.

Engine

The Centurion 1.7 is a turbo charged diesel engine delivering 99 kW (135 DIN hp) at 3900 rpm. There is a dry overload clutch between the engine and the 1.69:1 reduction gearbox for the purpose of providing momentary slippage during engine start and engine stop. This is when the engine provides about 20% more torque on the gearbox compared to the maximum torque while airborne. Momentary clutch slippage prevents gearbox overload.

A Full Authority Digital Engine Control controls engine power and speed. There are two computers in the FADEC: A and B.

The engine is a so-called single lever engine. The pilot "requests" more power from the FADEC by using the fly-by-wire power lever. Computers then provide the desired power by adjusting manifold pressure, fuel supply and propeller pitch.

Propeller speed is indicated in the instrument panel, converted from engine speed by the gearbox reduction ratio. The engine's power percentage is also displayed. There is no indication of true propeller RPM, nor of engine RPM.

There is an On-Board Diagnostics system memory unit in the FADEC.

1.7 Meteorological information

At the time of the accident the weather at Helsinki-Malmi was as follows: Wind 220 deg, 3 kt, visibility 30 km, CAVOK, temperature 16 °C, dew point 13 °C, QNH 1006 hPa. Weather at the site of the emergency landing was similar.

1.8 Aids to navigation and radars

Aids to navigation and radars played no role in the incident.

1.9 Communications

The pilot maintained radio communications with Helsinki-Malmi TWR and Helsinki Radar. He reported the engine trouble to the ATS units. After the landing the pilot called Helsinki-Malmi TWR on his mobile phone and reported that the emergency landing was successful and that no persons were injured.

1.10 Aerodrome information

The aircraft took off from RWY 18 at Helsinki-Malmi aerodrome.

1.11 Flight recorders

There were no flight recorders. However, the FADEC recorded engine information.

1.12 Wreckage and impact information

The aircraft made the emergency water landing into the sea off the shoreline of Helsinki. The aircraft came to a halt and remained afloat approximately 15 metres from the shore of Valkosaari Island. The seas were calm.

The nose gear was damaged and the engine cowlings came off during the landing. The upper cowling was never found. The leading edge of the right wing was torn. All propeller blades snapped approximately in half. Once the aircraft was towed to shore, it sank so deep that it was completely submerged.

There were traces of black oil leaks on the front inner surface of the lower engine cowling. Oil could also be detected on the nose gear and the belly of the fuselage.



Figure 1. The aircraft at the shore

1.13 Medical and toxicological information

The pilot and both passengers were taken to hospital to be checked. No injuries were detected.

1.14 Fire

There was no fire

1.15 Rescue operations and survival aspects

1.15.1 Rescue operations

When the pilot reported the imminent emergency landing to the ATC, the air traffic controller called rescue and ambulance units to Helsinki South Harbour. The pilot also informed the passengers of the imminent emergency water landing and told them to brace for it.

While the aircraft was gliding towards the landing site at a low altitude, a boater who was travelling from Helsinki to Suomenlinna realized that the aircraft was going to land in the water. He then turned his boat around and went after the aircraft. As sea traffic was busy around the landing site, the emergency landing was followed from several crafts.

After landing the pilot opened the front canopy and one of the passengers opened the rear canopy. Prior to takeoff the pilot had demonstrated the operation of the canopy lock to the passengers. The passengers were wearing their life vests and the pilot, too, donned his vest which had been lying on the back seat. When the pilot and the passengers climbed onto the wings, the boat which had been following the aircraft heaved to on the front side of the right wing and they climbed into it. The owner of the boat called Suomenlinna Coast Guard Station and reported the emergency landing. They, however, had already received the information.

The boat was used to tow the aircraft to shore. Soon after, a police patrol boat also arrived at the scene and transported the pilot and the passengers to Helsinki South Harbour where ambulances were already waiting. Approximately 10 minutes later, a Border Guard zodiac arrived at the scene. The crew fastened the aircraft to Valkosaari shore and encircled it with oil spill booms.

1.15.2 Survival aspects

The pilot and the passengers escaped without injuries. The main reasons for this were that the airspeed at touchdown was low and that the wings were level. This also contributed to the fact that the aircraft remained relatively intact and afloat the right way up. The busy sea traffic at the site also contributed to their rapid rescue and prevented the danger of them ending up in the sea. Instead, they climbed directly from the plane into a boat.

The safety harnesses played a key role because deceleration in emergency water landings is extremely rapid.

1.16 Test and research

1.16.1 Powerplant

Engine

When the aircraft was disassembled it was noticed that it took very little force to turn the propeller without rotating the crankshaft. This led the investigators to mainly focus on the condition of the clutch.

Engine oil was drained and the filter was examined. There were approximately 5 l of oil (the normal oil quantity is 5.5–6.5 l) and about 6.5 l of sea water. The oil filter was clean. The FADEC was sent to the German accident investigation authority, under whose su-

pervision the engine manufacturer downloaded vital On-Board Diagnostic (OBD) data from the FADEC. Sea water had not significantly damaged the FADEC.

Clutch

The gearbox was removed and the clutch was inspected at Helsinki-Malmi aerodrome. The engine manufacturer's representative was present.

Gearbox

The gearbox was undamaged from the outside. The lower side of the gearbox was oily, especially around the clutch housing breather orifice. Clutch limit torque was measured before the gearbox was removed. It measured at 55 Nm, but it should have been approximately 290 Nm. After this, the gearbox was detached from the engine in order to inspect the condition of the clutch.

The clutch is a dry single plate clutch. The clutch is set to a limit torque by eight Belleville spring stacks. A spring stack consists of 13 conical steel washers.



Figure 2. The badly damaged clutch plate

The clutch friction plates were almost totally worn off. Clutch plate shavings were found on the bottom of the clutch housing. The clutch assembly was corroded by sea water. When the assembly was dismantled, bolt tightness was measured at only 4 Nm, when it should have been 25 Nm. It is probable that this was caused by clutch slippage generated by heat, followed by rapid cooling. The Belleville assembly was correctly assembled.

When the gearbox was removed it was detected that the gearbox housing was oily. There was also oil on the rear surface of the flywheel. In addition, there was oil on the seal between the crankshaft flange and the flywheel mating surfaces.



Figure 3. The oily rear surface of the flywheel

There were approximately 0.6 l of oil (the normal quantity is 1 l) and 2.4 l of sea water in the gearbox. The filter was uncontaminated. The gearbox was not disassembled. The engine, clutch and gearbox were sent to the manufacturer for further examination.

The flywheel-side crankshaft seal was microscopically examined at the manufacturer's plant. Normal wear was detected around the edges. However, at the very edge of the seal there were two fractures. The first was 332 μm long and about 100 μm wide. The second was 906 μm long and approximately 100 μm at its widest.

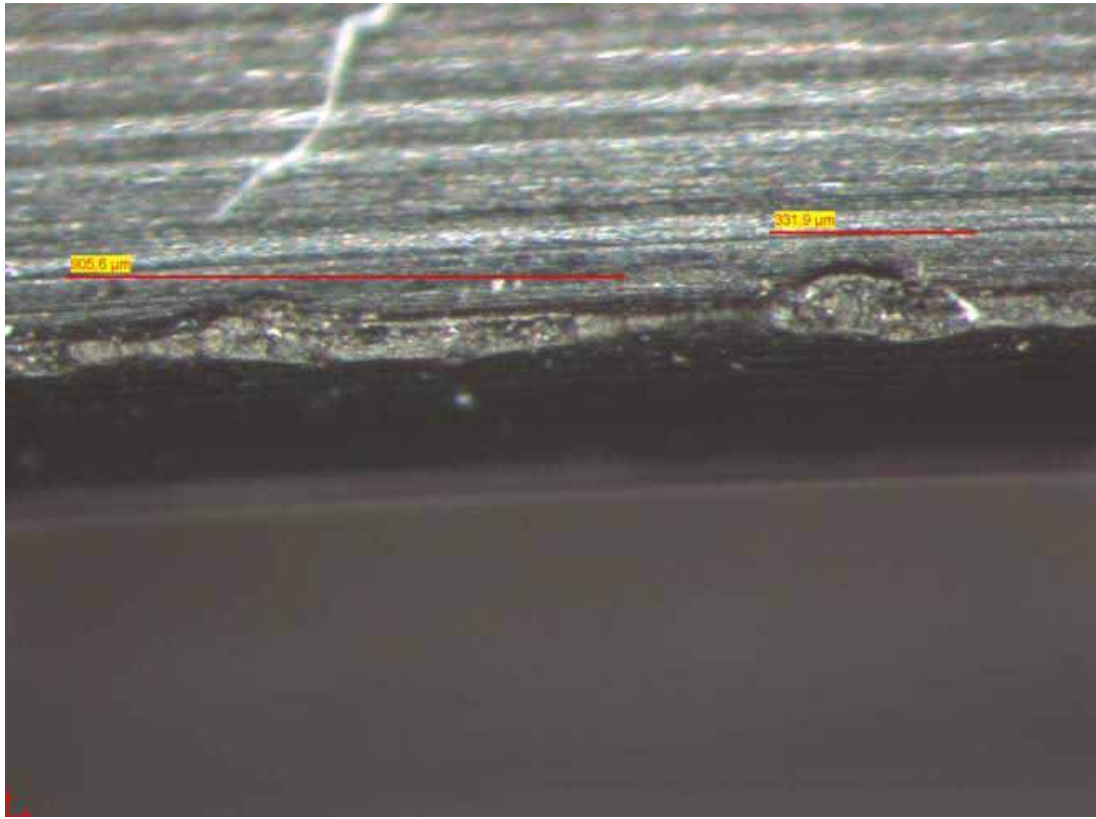


Figure 4. Crankshaft seal damage

1.16.2 Engine parameters

The pre-flight engine runup test, executed by the FADEC, passed normally and the engine provided full power. Takeoff occurred at 11:32.

All engine parameters were within normal range during takeoff and climb to 1000 ft.

At 1000 ft power was set to 82.4 % for three minutes. Power was set to 99.99 % at 11:37, (clearance to climb to 4000 ft). Engine parameters fluctuated for six seconds as follows: engine speed 4136–3494 RPM (2447–2067 propeller rpm), manifold pressure 2364–2078 mbar, fuel pressure 1358–1172 bar. Power was set to 90.72 % for two seconds at 11:37, after which it was set to 99.99 %.

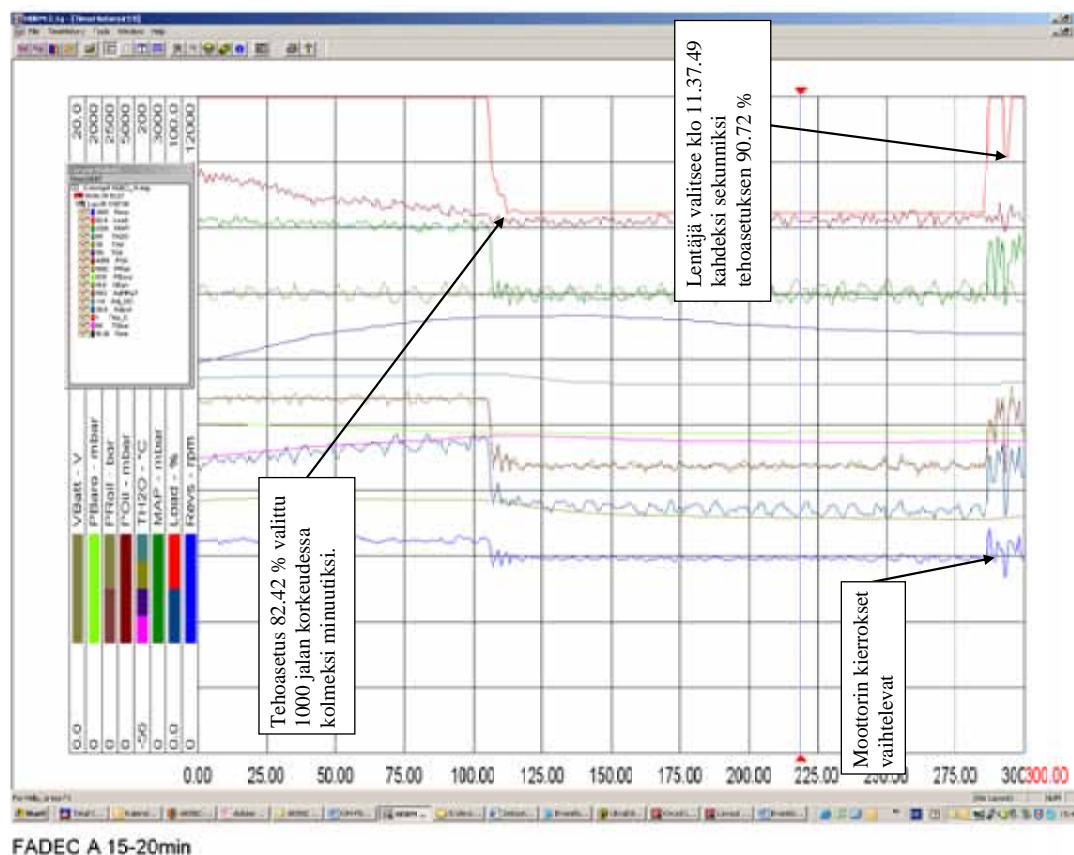


Figure 5. FADEC parameters at 15–20 min into the flight

Engine speed varied between 3554–4106 rpm. (maximum engine speed is 4225 rpm, maximum propeller speed is 2500 rpm). The engine oversped (overrevved) at 11:39 (4608 rpm), which was recorded by the FADEC's diagnostic unit. When power was set to 15% engine speed decreased to 2144 rpm for one second. Hereafter, the engine was overspeeding until landing, even though the power lever position varied from 16.21–99.99 %. The FADEC's B channel was selected at 11:41.

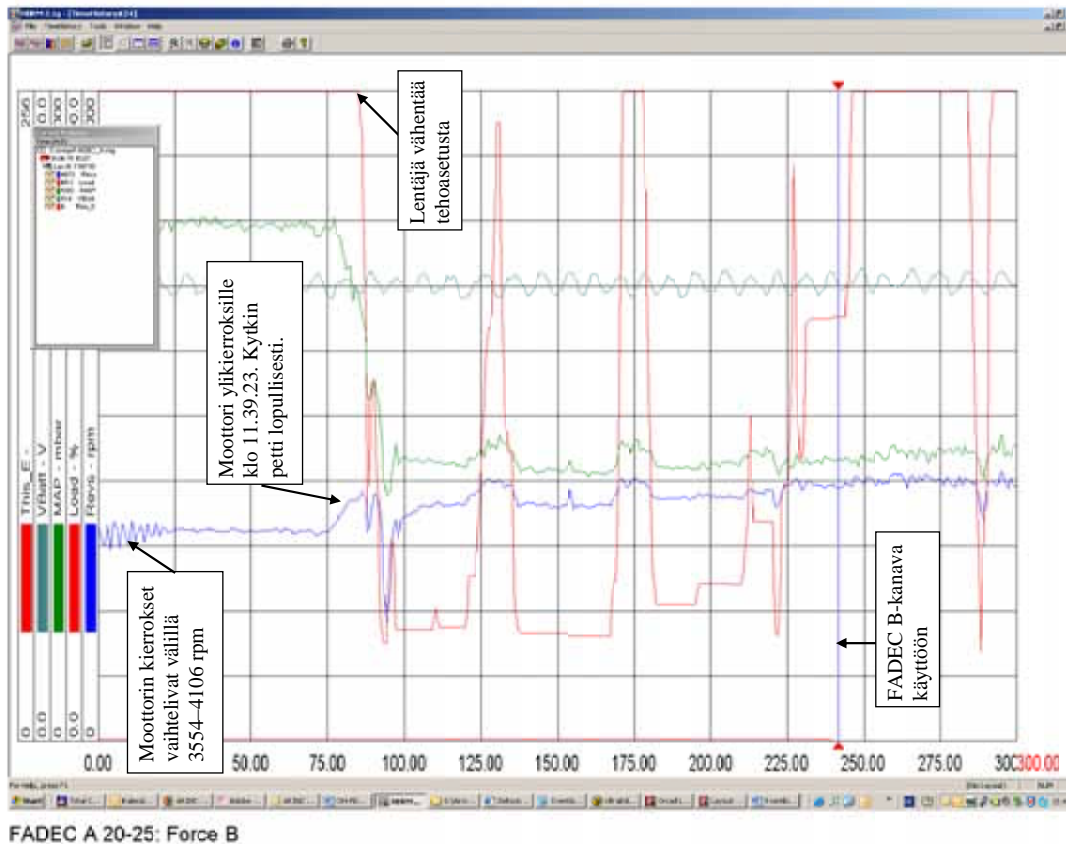


Figure 6. FADEC parameters at 20–25 min into the flight

The following are FADEC-recorded events in chronological order. Times are Finnish time minus 1 hour.

- 27.5.2007 10:39:23 – Info only: High RPM: up to 4608 rpm for 1.8 seconds
- 27.5.2007 10:39:27 – Info only: High RPM: up to 4701 rpm for 1.9 seconds
- 27.5.2007 10:40:06 – Info only: High RPM: up to 4903 rpm for 10.0 seconds
- 27.5.2007 10:40:12 – Info only: High RPM: up to 4903 rpm for 15.7 seconds
- 27.5.2007 10:40:54 – Info only: High RPM: up to 4921 rpm for 10.0 seconds
- 27.5.2007 10:40:58 – Info only: High RPM: up to 4921 rpm for 13.6 seconds
- 27.5.2007 10:41:48 – Info only: High RPM: up to 4898 rpm for 10.0 seconds
- 27.5.2007 10:42:43 – Info only: High RPM: up to 5011 rpm for 65.1 seconds
- 27.5.2007 10:44:29 – Valve Power switched off

The FADEC had also recorded the previous flight's engine parameters. They involved four instances of overrevving when power was set to 99.9%.

1.16.3 Previously detected oil leaks

Approximately one and a half months prior to the emergency landing the aviation club's maintenance manager had continually detected engine oil on the front surface of the gearbox. The leak was monitored and it was then noticed that engine oil was seeping from the seal between the dual Combi pump (oil pump) on the front of the gearbox and the turbocharger oil line. Oil was still leaking even after the oil line was replaced. Approximately two weeks later it was noticed that the leak did not involve the seal after all. Rather, it came from the space between the Combi pumps where there was a case drain aperture. The leaking oil ran down the front of the gearbox onto its lower edge from where it dripped into the inside front of the lower engine cowling. Airflow then sprayed the oil onto the nose gear and the belly of the fuselage, all the way back to the empennage.

It was difficult to exactly determine the volume of the leaking oil. However, during the year 2006, total of 2 litres of oil was added. Furthermore, according to the log book, approximately one and half months before the emergency landing and 81 hours from the previous maintenance, one litre of oil had to be added. The second time the oil needed to be topped up by one litre was 7 hours from the previous top-up, a little less than one month before the emergency landing. The maintenance manager said that, according to stock control, one litre of oil had been added even later, although it was not entered in the log book. Maximum permissible oil consumption is 0.1 l/h.

The maintenance manager had noticed that there were traces of oil leaks in two separate places inside the engine cowling. They also differed in colour. The front oil leak was lighter whereas the one behind it was darker.

The plan was to replace the leaking Combi pump during the next maintenance in May–June.



Figure 7. The oil leak from the Combi pump ran down the front of the gearbox onto its lower edge, from where it dripped into the inside front of the lower engine cowling.

1.17 Organizations and management

The aircraft was owned by the Aviation Club of Helsinki University of Technology. The club operated three piston aircraft and five gliders. Only members of the club who were appropriately certified on the Diamond aircraft were permitted to fly it.

1.18 Additional information

1.18.1 Previous Diamond DA40D clutch failures

The investigation commission has learned of two previous clutch failures. One of them occurred in Sweden on 15 February 2005. As a result of clutch failure the pilot made an emergency landing on land. The landing gear was totally destroyed but there were no injuries.



The Swedish accident investigation authority conducted an accident investigation (Report RL 2006:08e) and the engine manufacturer conducted its own investigation. The probable cause of clutch slippage included mistakes when the clutch was assembled, such as insufficient bolt tightness, incorrect Belleville spring stack assembly and using an old flywheel with a new clutch assembly.

According to the manufacturer's defect statistics the second incident took place on 10 January 2005, involving a Diamond DA40D registered in France. Statistics do not reveal the details of this incident.

2 ANALYSIS

2.1 Engine oil leaks

The maintenance manager had taken photographs of the oil leaks on the inner surface of the lower engine cowling. The first photos were taken on 16 April and 17 April, i.e. approximately one and a half months before the emergency landing. The photos reveal quite extensive oil leaks from the Combi pump as well as traces of leaked oil on the lower cowling at the pump location as well as where the clutch housing breather aperture is located. The pictures show that the oil leak at the aperture is lighter in colour compared to the colour of the leak in front of it. The leaked oil had also made it to the nose gear and, possibly, to the belly of the fuselage. At that time the oil leak traces were cleaned off.



Figure 8. Oil leak traces on the lower engine cowling. Left photo taken on 17 April 2007. Right photo taken on 26 April 2007.

The second photo, taken on April 26, also shows oil leaks at two spots. The biggest leak is situated in front of the breather aperture. However, there are also traces at the aperture itself. This oil is lighter in colour compared to the previous time and no oil had leaked onto the nose gear. This time, too, the oil leak traces were cleaned off.

Similarly, the photo taken after the emergency landing shows oil on the inner side of the lower engine cowling. Most of it is fairly light in colour, except for the oil at the breather orifice, which is dark brown and contains remnants of clutch plate friction coating. There was also oil on the nose gear as well as on the belly of the fuselage. Some of the oil

may have been washed off as the engine cowling was breaking up in the impact with the water.

Traces of oil leaks were mostly found in two places on the inside of the engine cowling. The front trace was caused by a leak in the Combi pump on the gearbox. Some of the oil from this leak had dripped directly onto the cowling. The rest of it ran down the front wall of the gearbox and dripped behind the previous spot, at the clutch housing breather aperture. The oil from inside the clutch housing also dripped onto the same spot. It was darker in colour because it was contaminated by the friction material from the clutch.



Figure 9. Oil leak traces after the emergency landing

The external oil leak dripped onto the inner surface of the lower engine cowling at the edge of the clutch housing breather orifice. In other words, at the very same place from where the oil leak inside the clutch housing was coming out. Checks during flight operations had focused on the external oil leak from the oil pump. Therefore, the internal leak was only discovered after the emergency landing. Combined, these leaks were quite significant, as oil was detected under the fuselage all the way to the tail section and had required a need to top up the oil reservoir.

2.2 Crankcase breather system inspection

On 21 February 2006 Diamond Aircraft Industries GmbH published a Mandatory Service Bulletin DAI MSB-D4-049 regarding engine breather system inspection. As per the bulletin, a clogged breather system generates increased pressure in the crankcase, resulting in engine oil leaks, ruptured crankcase seals and excessive oil consumption. These symptoms are similar to the ones in this incident.

The maintainer of the aircraft had performed the bulletin-mandated inspection on 1.8.2006. At that time it was noted that the breather tube was correctly installed and no blockage was detected.

The breather system was also inspected after the emergency landing but no blockage was detected. The inner diameter of the fitting of the air/oil separator vent pipe is 5.5 mm (24 mm²). Downstream from the clamp the pipe continues in the form of a rubber hose to the firewall, where it runs inside an aluminium pipe. Inside this aluminium pipe it is joined by the vent pipe from the coolant reservoir. Even though the lower end of the aluminium pipe is bent parallel to the fuselage, the airflow-generated ejector effect does not increase the effect of the breather system. This is because the upper end of the aluminium pipe is open.

On a Cessna 172 fitted with a similar TAE 125 engine the inner diameter of the air/oil separator vent pipe is 12 mm (113 mm²), thus being almost five times bigger than the one on the Diamond DA40D. Automotive breather pipes run typically in the 12 mm range and they are also connected to the intake manifold. Manifold vacuum increases the efficiency of the breather system.

After the accident Diamond Aircraft Industries GmbH published Mandatory Service Bulletin Diamond MSB-D4-057 on June 5th 2007. Bulletin states that installation of new breather line and oil separator is mandatory at next engine change. The breather line on bulletin's image seems to be larger diameter than the old design.

The investigation commission does not rule out the possibility that more volumetric flow was generated in the crankcase than the possibly underpowered breather system could handle. In the opinion of the investigation commission the installation of new breather line should be carried out even before next engine change.

2.3 Clutch contamination by engine oil

Clutch slippage was caused by engine oil which got between the friction surfaces of the clutch. There were three possible sources of oil leaks into the clutch housing: the crankshaft's lip seal, the Combi pump and the oil sump gasket. The seal of the oil sump gasket could not be tested. However, it looked pristine and even if there was a leak, it would not have made it into the clutch. Instead, it would have vented out into the atmosphere.

The Combi pump oil leak was external to the gearbox. The investigation commission has no evidence of external oil making it through the clutch housing's breather aperture

into the clutch. Most probably the flywheel/clutch arrangement generates a centrifugal pump effect, resulting in inside-out airflow through the breather orifice.

When the crankshaft lip seal is defective, engine oil makes it to the rear surface of the flywheel from where the oil vapour is slung into the clutch housing, contaminating the clutch. The clutch housing and the rear surface of the flywheel were oily in this case.

Under a microscope the engine manufacturer detected fissures on the crankshaft lip seal surface. These could have caused the leak. According to the manufacturer these kinds of seal defects have not been detected earlier, but manufacturer assumes they are due to high internal crankcase pressure.

2.4 Recognizing clutch slippage during the flight

The clutch torque limit was exceeded for the first time when the aircraft commenced the climb to its clearance altitude. As the clutch slipped, the engine rpm-limiter (FADEC) automatically reduced fuel feed for six seconds. Had the pilot become aware that the malfunction was caused by clutch slippage, he could have continued the flight at a lower power setting (see figure 5).

When the clutch finally failed, propeller speed was no longer appropriate for the corresponding engine speed. Fuel feed constituted only 20–25 % of the normal full power fuel requirement (figure 6).

Judging by engine data, engine speed exceeded 4000 rpm four times during the previous flight. This had probably resulted in clutch slippage. Similar fleeting power drops had occurred in the past as well. One happened on 7 May 2005, after which the governor was replaced.

The investigation commission considers it plausible that these previously inexplicable malfunctions, which occurred when cruising power was changed to full power, caused temporary clutch slippage. It is the understanding of the investigation commission that ground runups do not generate torque similar to in-flight conditions where, from cruising, a climb is commenced using full power.

No explicit explanation was found for the previously experienced malfunctions, as detailed above. Neither could the pilot on this flight determine where in the powerplant the fault lay. The investigation commission holds that it is decisively more difficult to locate a malfunction when engine RPM is not displayed. Instead, the only relevant parameter indicated is propeller RPM, which is converted from engine RPM by gearbox reduction ratio. This being the case, true propeller RPM is neither measured nor indicated. Furthermore, there is no indication of possible clutch slippage. Clutch slippage indication by, for example, a warning light could point the pilot in the right direction with regard to making correct conclusions and measures allowing him to control the slippage. He could then possibly continue the flight at reduced power. This kind of indication could be a telltale sign of intermittent slippage even before clutch disintegration. Furthermore, a clutch

slippage indicator would also be useful in tracing unclear engine malfunctions. Slippage should also be recorded in the FADEC's On-Board Diagnostics system.

2.5 Emergency landing

As the aircraft made contact with the water, it skimmed the surface of the sea for quite a distance until the nose dove so deeply that water reached the top of the windscreen. The side windows of the passenger compartment, however, remained above water. When the nose plunged into the water, the tail pointed up almost vertically for a moment. After the aircraft came to a halt it rose to the surface, having turned almost 180 degrees into the direction from which they had landed. The wing roots were submerged but the rest of the wings remained above the surface. The aircraft came to a rest approximately 15 metres from shore.

The landing was made into nearly a tailwind. The pilot considered the proximity of the shore more important than wind direction. A headwind landing would have taken them further out to sea. Furthermore, a landing in a heavily trafficked strait guaranteed eye-witnesses to the event and, hence, rescuers. Considering that the winds were mild, the investigation commission deems the choice of landing direction and the landing spot as warranted.

The pilot did not wear a life vest. Instead, the vest was on the back seat. Had the aircraft tipped over or sank rapidly, it would have been impossible for him to don the vest. One should always wear a life vest when flying over open water.

The pilot forgot to use flaps during the landing. Had he used the flaps, his stall speed would have been somewhat lower (approx. 3 kt).

One should make an emergency water landing with the minimum possible airspeed at touchdown. This entails a headwind landing and the most effective use of flaps. There is always a risk of capsizing in a water landing. This risk increases with higher speed. In addition to a minimum possible airspeed it is important to keep the wings exactly level. Otherwise the aircraft will cartwheel, increasing the possibility of breaking up and rapidly sinking. It is generally very difficult to deplane an inverted aircraft and especially difficult to do with this type of aircraft, whose canopies open upwards.

3 CONCLUSIONS

3.1 Findings

1. The pilot's licence and medical certificate were valid.
2. The airworthiness certificate and the certificate of registration of the aircraft were valid.
3. Engine oil made it into the clutch housing and onto the clutch, which connects the engine and the gearbox, through a leak in the crankshaft's clutch-side lip seal.
4. The clutch began to slip and the clutch plate was destroyed.
5. Once the engine overrevved, the pilot was not able to determine the cause of the malfunction.
6. There was no system for the purpose of indicating clutch slippage.
7. There was an oil leak in the Combi pump which is on the front wall of the gearbox. Oil ran down the front of the clutch housing onto the breather orifice from where it dripped into the inside front of the lower engine cowling and onto the belly of the fuselage. The oil leak had been detected approximately one and a half months earlier. The leak was monitored but not fixed.
8. The trail of the oil leak, as described above, concealed a crankshaft lip seal leak, enabling oil to get into the clutch.
9. The crankcase breather pipe is possibly too thin, which might have generated overpressure in the crankcase.
10. The running time of the clutch was 276 h. Its time between overhauls is 300 h.
11. The pilot was forced to land in the sea.
12. The pilot forgot to use flaps during the landing.
13. No-one sustained injuries in the course of the landing.

3.2 Probable cause

Clutch slippage was the probable cause of the emergency landing. Clutch slippage was caused by engine oil which entered through a leak in the crankshaft's lip seal. Fissures were detected in the seal and engine manufacturer assumes cause for them to be high internal crankcase pressure.

4 RECOMMENDATIONS

1. A 1.69:1 reduction gearbox reduces engine speed to the propeller. Only the engine (crankshaft) RPM is measured. However, it is indicated as propeller RPM. True propeller RPM is not measured and therefore clutch slippage, if any, is not indicated by the engine instruments.

The investigation commission recommends that the engine manufacturer design a system indicating changes in the rotational ratio between the crankshaft and propeller, i.e. clutch slippage. Clutch slippage indication should also be recorded in the FADEC's On-Board Diagnostics system.

2. The crankshaft's lip seal had probably leaked for several weeks before the emergency landing. However, an external and less serious oil leak concealed its trace.

The investigation commission recommends that the engine manufacturer redesign the clutch breather orifice or its shape so that oil leaks internal to the clutch housing could be reliably distinguished from other, external, oil leaks.

3. The crankcase breather line is only 5.5 mm in diameter. This can be regarded as quite small, considering the high engine volume and speed. As piston blowby increases, it is possible that the current breather line size causes crankcase overpressure and oil leaks. Diamond Aircraft Industries GmbH has published Mandatory Service Bulletin Diamond MSB-D4-057 on June 5 2007. Bulletin states that installation of new breather line and oil separator is mandatory at next engine change. The breather line on bulletin's image seems to be larger diameter than the old design.

The investigation commission recommends that the aircraft manufacturer expedite the time of compliance for installation of a redesigned components as stated on Mandatory Service Bulletin Diamond MSB-D4-057.

Helsinki 18 June 2008

Handwritten signature of Esko Lähteenmäki in black ink.

Esko Lähteenmäki

Handwritten signature of Asko Nokelainen in black ink.

Asko Nokelainen

The investigation commission received 11 comments from Thielert Aircraft Engines GmbH through German Federal Bureau of Aircraft Accidents Investigation.

Investigation commission revised the report according the comments, except on the comment made on recommendation 4.1. Commission's view is that the original recommendation remains valid despite of the comment.

Please find attached the comments from TAE to your draft report.

BFU concurs with the comments, except the TAE-comments to:

Chapter 1.16.1 Gearbox,
Chapter 3.2 Probable cause,
Chapter 4, Recommendations, 4.2

BFU does not have the information available neither to concur, nor to disagree to these comments from TAE.

However, these comments are transmitted to you for further consideration.

Best regards
BFU - Bundesstelle für Flugunfalluntersuchung
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Lichtenstein, 2008-05-13

Draft final report 3/2007L, Emergency water landing off Helsinki on 27 May 2007

Dear Sir,

Thank you very much for getting the ability to comment the final draft report.
We would like to share with you the following comments:

Chapter 1.5, page 3:

We think that there is mistake in the flying experience of the last 30 days. Within the last 30 days the pilot had 4 landings on a DA40, but only 2 landing in total. The number of landings in total must be at least equal to the number of landings on DA40.

Chapter 1.6, page 3:

The correct engine designation is TAE 125-01.

Chapter 1.6, page 4:

Please remove the supplier name Mercedes Benz. As the TC-holder, TAE has the responsibility for entire engine type design. This type design includes industrial parts; including parts from the automotive industry, as well as TAE-designed parts are used.

Due to the high moment of inertia of the propeller the momentary slippage of the clutch prevents the gearbox and the crankshaft from overload; especially during the engine starting, engine stoppage and during sudden or immediate engine power changes by the pilot.

Chapter 1.16.1 Gearbox, page 8:

Single plate dry clutch systems are not limited to automotive use, but also tooling machines or even locomotives. The clutch of the Centurion 1.7 was designed especially to the needs of an aircraft engine. Therefore we recommend to remove the comparison with the automotive application.

Chapter 1.16.1 Gearbox, page 10:

Another interesting point of observation of the fractures was that they were located 180° in opposite to each other. This let us assume that one half of the sealing lip flipped over due to high internal crankcase pressure and created these fractures.

• Seite 2, 2008-05-26



Chapter 2.2 Crankcase breather system inspection, page 19:
AED is an Auxilliary Engine Display, not an engine

In automotive application the main reason for connection of the breather line to the intake manifold are environmental reasons.

In all piston engines blow-by gas passes from the combustion chamber through the piston rings into the crankcases independent of the compression ratio. Of course the amount of blow-by gas is different.

Chapter 2.4 Recognizing clutch slippage during the flight, page 20:

The highest torque values are on ground during engine starting and engine stoppage. Torque changes in flight are much less severe, due to the fact that the propeller is already in turning.

The engine - RPM signal is measured digital with a 60-2 signal per revolution. The annunciated propeller speed is calculated by dividing with the ratio of the gearbox.

Chapter 3.2 Probable cause, page 23:

From our knowledge there was no disintegration of the clutch. Due to the slippage of the clutch the friction pads were heavily worn or burnt, but the clutch was to our knowledge not disintegrated. Could you please check that for us?

Chapter 4, Recommendations, page 25:

4.1 From TAE's point of view a measuring of both rpm, the true engine rpm and the true propeller rpm, do not increase the level of safety. The clutch is designed as overtorque limiter which limits the overtorque by slipping. Slipping of the clutch is therefore part of the normal operation during engine start, engine shut-off and immediate changes of engine power. Therefore n annunciation could neither be a caution nor a warning.

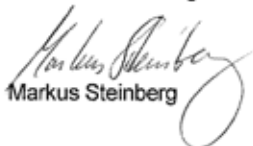
However, a "permanent (longer than 3 seconds)"slipping of the clutch results always in overspeed which is indicated if overspeed exceeds more than 10 seconds 2300 but not 2400 or reaches 2500rpm independent of the time as a warning.

The only reactions/emergency procedures the pilot initiate in such cases, are described under chapter 3 of the POH. An additional light which annunciate the same information during overspeed events does not increase the safety, more or less it might confuse the pilot during troubleshooting.

4.2 From our knowledge there was a leakage on the dual stage pump detected during maintenance. The normal breather orifice of the gearbox showed to our knowledge no signs of leakage.

4.3 The breather system is under responsibility of the airframer. The design was improved in-between. Please see: Diamond MSB-D4-057

With kind regards
Thielert Aircraft Engines GmbH


Markus Steinberg