Final Report No. 2399 by the Swiss Transportation Safety Investigation Board STSB

concerning the accident oft the aircraft Diamond DA20-C1, HB-SGI,

on 17 June 2021

170 m northeast of runway threshold 26 of Birrfeld airfield (AG)

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General information on this report

In accordance with

Article 3.1 of the 12th edition of annex 13, effective from 5 November 2020, to the Convention on International Civil Aviation of 7 December 1944 which came into force for Switzerland on 4 April 1947, as amended on 18 June 2019 (SR 0.748.0);

Article 24 of the Federal Act on Civil Aviation of 21 December 1948, as amended on 1 May 2022 (CAA, SR 748.0);

Article 1, point 1 of Regulation (EU) No. 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation and repealing Directive 94/56/EC, which came into force for Switzerland on 1 February 2012 pursuant to a decision of the Joint Committee of the Swiss Confederation and the European Union (EU) and based on the agreement of 21 June 1999 on air transport between Switzerland and the EU (Air Transport Agreement); as well as

Article 2, paragraph 1 of the Ordinance of 17 December 2014 on the Safety Investigation of Transportation Incidents, as amended on 1 February 2015 (OSITI, SR 742.161);

The sole purpose of an investigation into an aircraft accident or serious incident is to prevent further accidents or serious incidents from occurring. It is expressly not the purpose of the safety investigation and this report to establish blame or determine liability.

Should this report be used for purposes other than those of accident prevention, this statement should be given due consideration.

The definitive version of this report is the original report in German.

All information, unless otherwise indicated, relates to the time of the accident.

All times in this report, unless otherwise indicated, are stated in Local Time (LT). At the time of the accident, Central European Time (CET) applied as Local Time (LT). The relation between LT, CET and Coordinated Universal Time (UTC) is:

LT = CET = UTC + 2 h.

Summary

Aircraft type	Diamond DA20-C1 «Eclipse»	HB-SGI
Operator	Fliegerschule Birrfeld AG, Flugplatz Birrfeld, 5242 Lupfig	
Owner	Fliegerschule Birrfeld AG, Flugplatz Birrfeld, 5242 Lupfig	

Pilot	Swiss citizen, born 1972
Licence	Commercial Pilot Licence Aeroplane (CPL(A)) according to the European Union Aviation Safety Agency (EASA), issued by the Federal Office of Civil Aviation (FOCA)

Flying experience	**total**	620:46 h	**during the last 90 days**	7:43 h
	on type[1]	22:26 h	**during the last 90 days**	3:32 h

Location	170 m northeast of runway threshold 26 of Birrfeld airfield (LSZF)		
Coordinates	660 428 / 255 278 (*Swiss Grid* 1903)	**altitude**	397 m/M
Date and time	17 June 2021, 6:22 p.m.		

Type of operation	Private
Flight rules	Visual Flight Rules (VFR)
Point of departure	Birrfeld airport (LSZF)
Destination	Birrfeld airport (LSZF)
Flight phase	Take-off and climb
Type of accident	Loss of control after engine failure

Damage to persons

Injuries	Crew	Passengers	Total number of passengers	Third persons
Fatal	0	0	0	0
Serious	1	0	1	0
Minor	0	0	0	0
None	0	0	0	Not applicable
Total	1	0	1	0

Damage to aircraft	Seriously damaged
Other damage	Minor damage to the field

[1] Flying experience on DA20-C1 “Eclipse” at the time of the accident. This type is equipped with a Continental IO-240 engine, but is otherwise largely identical in construction to the DV20 "Katana" equipped with a Rotax 912. There are differences between the two types in terms of fuel consumption and engine operation. The pilot last flew an "Eclipse" on May 6, 2019, and a "Katana" on June 14, 2021.

1 Factual information

1.1 Flight preparations and history of flight

1.1.1 General

The following description of the history and course of the flight is based on a GPS[2] recording, photos, documents from the wreckage, traces at the crash site and information from the pilot and an eyewitness.

1.1.2 Pre-flight history

The pilot intended to take off from Birrfeld airfield (LSZF), follow the national border westwards and finally fly from Lake Geneva over the Mittelland back to the take-off airfield. On the flight notification, he indicated a planned flight time of 2:45 h and a maximum flight duration (endurance) of 4:00 h. As an alternate airfield, he indicated Triengen airfield (LSPN). The preparations for the flight proceeded as usual and he fully refuelled the aircraft until the overflow.

1.1.3 History of flight

At 2:59 p.m., the pilot took off with the Diamond DA20 C1, registered as HB-SGI, from Birrfeld airfield and followed the planned flight route with a few detours and delays. After a flight time of 2:05 h, he reached the westernmost point of his route by flying over Geneva Airport. After the planned flight time of 2:45 h, he was still 20 NM (37km) west of Bern. After 3:22 h, he touched down on runway 08 of Birrfeld airfield. The fuel level was indicated as ¼.

After touchdown, the pilot performed a touch-and-go. His intention was to perform a single circuit and final landing. Shortly after take-off, he noticed vibrations and the engine failed. A left turn occurred, which involved a change of direction of about 90° towards the fields and meadows to the left behind the runway (cf. Figure 1).

Figure 1: Final position of the HB-SGI northeast of runway threshold 26 of Birrfeld Airfield (circle) and location of impact (arrow). The A1 motorway runs about 500m behind the end of the runway, with the Reuss river behind and parallel to it (drone image of the Aargau cantonal police looking east).

[2] GPS: *Global Positioning System*

At 6:22 p.m., the aircraft struck a meadow 170 m north-east of runway threshold 26, left wing first, and came to rest shortly afterwards. The pilot was seriously injured. The left wing was separated from the fuselage on impact and the fuselage broke in two behind the wing. No fuel spilled and there was only minor third party damage.

1.2 Meteorological information

The Alpine region was on the front side of a shallow low-pressure zone over Western Europe. With a weak south-westerly flow, warm and increasingly humid and unstable air was brought to Switzerland. At the nearest commercial airport, Zurich (LSZH), the following weather conditions were observed shortly before the time of the accident:

Clouds	None below 8000 ft above ground
Visibility	Over 10km
Wind	5 knots from 070 degrees
Temperature / dew point	31 °C / 14 °C
Atmospheric pressure (QNH)	1013 hPa (pressure reduced to sea level, calculated using values of standard atmosphere)

1.3 Aircraft information

1.3.1 General information to the type

Aircraft type	DA20-C1 "Eclipse"
Manufacturer	Diamond Aircraft Industries, Canada
Characteristics	Single-engine, two-seat low-wing monoplane of fibre composite construction with piston engine and fixed landing gear
Maximum permissible masses	800kg
Engine	Continental IO-240-B3B, 125 PS
Fuel tank volume	93 litres in a fuselage tank, 91 litres of which usable
Fuel consumption	About 24 litres per hour (cf. chapter 1.5)
Fuel indicators	An analogue cockpit display with scale in quarter divisions. A dipstick for determining the fuel level before flight.[3]
Cruising speed	About 120 kt

1.3.2 Special information on HB-SGI

Year of manufacture	2011
Operating hours	2266:38 h since new
Operating hours of engine	40:03 h since major overhaul

[3] The fuel dipstick is part of the aircraft's basic equipment and, like the cockpit display, has a scale in quarter divisions. The manufacturer's flight manual contains a note on possible inaccuracies of the cockpit display, combined with the procedure for using the dipstick before each flight: "*Electric fuel gauges may malfunction. Check fuel quantity with the fuel dipstick before each flight.*"

Last maintenance	200-h-inspection with installation of the overhauled engine, certified on 21 May 2021 at an operating time of 2226:35 h
Mass and centre of gravity during flight of accident	Within the permissible limits

1.4 Findings on the wreckage

The fuel tank was empty. A total of 4 dl of fuel could still be drained from the fuel system. The fuel system showed no signs of damage or leaks. The engine oil was already heavily blackened by sooting, measured against its operating time of around 40 hours. The spark plugs were heavily sooted and slightly oily, which indicates a very rich fuel-air mixture.

The tank gauge, a single pointer instrument graduated in quarters, was checked by filling and emptying the tank. It showed good accuracy at fill levels of over ½. However, at lower fill levels, the instrument consistently showed too much; when the tank was completely empty, it showed around ¼ (cf. also Figure 2). After filling to overflow, the tank held a total of 95.2 liters.

The pointer instrument for displaying the tank content had an adjustment screw that was accessible through a hole in the unit housing. A manufacturer's safety sticker over this hole was no longer present. An earlier position of the adjusting screw, which was in an end stop, was marked on the unit housing.

1.5 Information on the fuel consumption

Fuel consumption is given by the aircraft manufacturer for cruising flight and depending on power setting and altitude with values between 19.3 and 32.6 litres per hour[4]. For a common power setting of 65%, the consumption is 23.5 litres per hour. In a flight planning aid provided by the aircraft operator to his pilots, an average consumption of 24 litres per operating hour is calculated.

After the accident, the average fuel consumption per operating hour of HB-SGI was determined using records of flight times and refuelling. This resulted in a value of around 24 litres per hour for the time before the engine change and a value of around 30 l/h for the time after the engine change.[5] On the accident flight itself, the average fuel consumption was 28 litres per hour.

Several refuellings after the engine change were carried out with conspicuously high fuel quantities of over 70 litres, measured against the available tank capacity of 91 litres and the fuel reserve specifications.[6] For example, the first refuelling after the engine change already involved a quantity of 71.6 litres, and the third refuelling involved a quantity of 91.1 litres.

[4] For a common cruising altitude of 4000 ft above sea level, cruise power settings range from 51% (19.3 l/h, 109 kt) to 76% (32.6 l/h, 127 kt)

[5] Records of refilled fuel and oil quantities were not kept in the aircraft's logbook. The corresponding information was therefore not available to the pilots.

[6] According to the flight school, the fuel planning had to include a trip fuel, an alternate fuel and a final reserve of 45 minutes.

1.6 Information on the maintenance

The fuel quantity sensor was last changed in 2017. Since then, no work on the fuel quantity indication system has been certified. The aircraft's technical files do not contain any information on the accuracy or calibration of the indicator.

The engine was tested on the test bench as part of the major overhaul. The fuel flow was adjusted in such a way that at full throttle an engine power of 121 hp was achieved with a fuel flow of 48.4 litres per hour. The engine manufacturer specifies a range of 38.8 to 41.7 litres per hour for this power setting. After installing the overhauled engine in HB-SGI, no further adjustment of the fuel flow was made.[7]

The engine was running on Philips 20W-50 Type M (non-dispersant engine oil) running-in oil. The oil had not yet been changed. The manufacturer prescribes an initial oil change for overhauled engines after 25 operating hours or 6 months, whichever comes first, and to monitor the oil consumption.

[7] An adjustment of the fuel flow is to be carried out, among other things, after the installation of a new, repaired or overhauled engine in an aircraft (see the maintenance manual of the engine manufacturer, Standard Practice Maintenance Manual, Chapter 6.47 Engine Operational Check).

2 Analysis

2.1 Technical aspects

The engine failed due to lack of fuel. The aircraft's fuel supply was exhausted, which the pilot could not recognise solely by the fuel gauge nor solely by calculating the remaining fuel reserve: The fuel gauge showed a fill level of about ¼ when the tank was empty, and the fuel consumption on the accident flight averaged 28 litres per hour, which was higher than 24.0 litres per hour according to the flight planning documents.

The inaccuracy of the fuel gauge was a known and expected phenomenon, which is why the procedural requirement to use a dipstick before the flight existed. This procedure also corresponds to common practice on comparable aircraft.

A fuel consumption of 28 litres per hour corresponds to a normal cruise power setting (see chapter 1.5). Considered on its own, it is not yet an indication of increased fuel consumption on the accident flight due to technical reasons. Only when looking at the average consumption since the installation of the overhauled engine does it become apparent that the newly installed engine was accompanied by an increase in consumption. This additional consumption was not to be expected by the pilot.

The additional consumption could not be attributed to technical malfunctions. The adjustment of the fuel flow made during the major overhaul of the engine already generated increased consumption values on the test bench and was not changed after the engine was installed on HB-SGI (see Chapter 1.6).

An additional consumption could have been identified on previous flights by comparing flight times and refuelling quantities (see chapter 2.2.4). Another clue could have possibly been provided by the sooty engine oil during the oil change scheduled after 25 hours of operation.

2.2 Human and operational aspects

2.2.1 Flight planning

The pilot calculated a maximum flight duration (endurance) of 4:00 h. This value can be achieved according to the manufacturer's specifications by a low cruise power setting, but is higher than the value of 3:47 h, which results after a full refuelling from the usable tank capacity of 91 litres and the indication of an average fuel consumption of 24 litres per hour by the flight school.

In addition to the fuel requirement for the flight of 2:45 h duration (trip fuel), the pilot planned a reserve for the flight to the alternative airfield Triengen, which requires a flight time of about 15 minutes (alternate fuel). In addition, a final reserve of 45 minutes had to be planned in accordance with the flight school's specifications. According to the legal requirements, only a final reserve of 30 minutes was prescribed.

The minimum amount of fuel required for the planned flight thus corresponded to a maximum flight duration of 3:45 h according to the pilot's planning in accordance with the flight school's specifications. Based on his assumption of an endurance of 4:00 h, the pilot could thus count on a quantity of fuel available for contingencies (extra fuel) corresponding to a flight time of 15 minutes.

2.2.2 Flight operation

The flight along the national border to the west contained several detours and delays for which, according to the pilot's calculation, there was initially still a sufficient amount of fuel available. However, after the planned flight time of 2:45 h had elapsed, the aircraft was only 20 NM (37km) west of Bern, from where a remaining flight time of about 40 minutes could still be expected to reach the destination airfield.

At this point, the fuel supply had already dropped to less than ¼ of what could not be seen on the display (cf. Figure 2). However, on the basis of the mentioned flight times and the pilot's calculation, it was recognisable that only about the legal final reserve of 30 minutes would be available when landing in Birrfeld, and that consequently an emergency situation[8] would arise due to further delays.

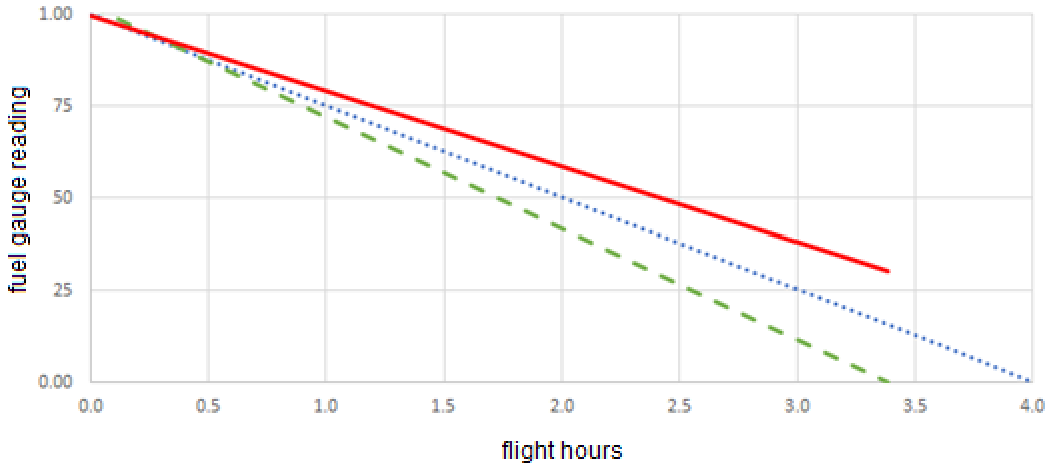

Figure 2: Fuel gauge readings of the HB-SGI, plotted over the flight time assuming constant consumption values: Correct indication at 22.75 litres per hour (consumption according to pilot's assumption, dotted blue), correct indication at 28 litres per hour (actual consumption, dashed green), and erroneous indication at 28 litres per hour (from checking the fuel gauge after the accident, indication error taken into account, red).

Touchdown took place after a flight time of 3:22 h. With a fuel gauge of ¼, there seemed to be about one hour of fuel left. According to the pilot's calculation, the legally prescribed final reserve would still have been available. In fact, however, the fuel supply had just been used up at this point.

With the subsequent touch and go, a new flight was started for which just enough fuel was available according to the display, but not according to the calculation; even under the assumptions made by the pilot, only an endurance of 38 minutes could be assumed. The pilot did not take advantage of the possibility to stop after landing and determine the amount of fuel with the dipstick (see also chapter 2.2.3).

Shortly after take-off, the engine failed due to lack of fuel. The pilot then headed for the fields and meadows to the left behind the runway. This choice of flight path may have seemed advantageous in view of the obstacle situation, but it led to a loss of control close to the ground due to the stalling speed increased by the bank angle.

2.2.3 Interpretation of fuel gauges by pilots

Fuel gauges on small aircraft are sometimes known to have low accuracy, which is why dipsticks or similar aids are used to determine the amount of fuel before take-off. In this case, the aircraft was fully fuelled, so the initial fuel quantity was known exactly and also matched the fuel gauge.

[8] With regard to fuel quantity, an emergency situation is already identified if it becomes apparent that the landing will take place with a fuel quantity below the final reserve.

During the flight, the fuel gauge can be checked for plausibility by comparing the previous flight time with the endurance calculated in advance. Instruments that measure the fuel flow and calculate the remaining fuel quantity (fuel totalizer) serve the same purpose. In the present case, the pilot did not have such instruments at his disposal; moreover, the recognition of the additional consumption towards the end of the flight was made difficult by the excessively high fuel gauge (cf. Figure 2).

Without such additional instruments, only two pieces of information on the remaining fuel quantity are available, namely the fuel gauge and the calculation. In this case, the fuel gauge was higher than the pilot's calculation towards the end of the flight; at the time of landing, the pilot could assume 60 minutes by fuel gauge or 38 minutes by calculation.

In view of the final reserve requirements, it is obvious that the pilot interpreted the inaccurate fuel gauge as correct and decided to continue the flight contrary to the flight time calculation. In a comparable case of excessive fuel consumption and engine failure, another pilot interpreted a correct fuel indication as inaccurate and decided to continue the flight based on the flight time calculation.[9]

What both cases have in common is that the pilots favoured the information available to them on the remaining amount of fuel that was better suited to their flight plan and thus more likely to fulfil their expectations. This behavioural pattern is known in cognitive psychology and leads to so-called confirmation bias.

2.2.4 Monitoring of fuel consumption by owner and pilots

The refuelling of the aircraft and the measurement of the fuel quantity by means of a dipstick was carried out before each flight and by alternating pilots, as is customary in flight schools, which made the discovery of excessive fuel consumption more difficult, but not impossible. An additional measurement using a dipstick after the flight already makes it possible to determine one's own fuel consumption.

Unusually high refuelling amounts can also indicate that the engine is consuming too much fuel. In the present case, there were several such opportunities to discover the excessive fuel consumption, but they passed by unused. Records of refuelled fuel quantities, for example in the flight logbook, make the discovery of unusual values much easier.

[9] Final report No. 2295 (in German) on the emergency landing of a Piper Archer III on 12 July 2015

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was certified for traffic.
- The engine failed because the fuel supply was exhausted.
- The fuel gauge showed too much when the fuel level was low.
- The fuel consumption of the engine was above the expected value.
- The engine had been overhauled shortly before the accident.
- After installing the overhauled engine in the HB-SGI, no further adjustment of the fuel flow was made.
- The most recent maintenance work on the engine had not been carried out.

3.1.2 Crew

- The pilot had the necessary licence for the flight.
- There are no indications for health or fatigue-related impairments of the pilot during the accident flight.

3.1.3 History of flight

- The pilot took off alone on board from Birrfeld airfield, where he touched down again after a flight time of 3:22 h.
- After touching down on runway 08, he performed a touch-and-go. Shortly after take-off, the engine failed.
- In the course of the emergency landing, the aircraft crashed out of a left turn 170m northeast of runway threshold 26 onto a meadow.
- The pilot was seriously injured by the impact and the aircraft was badly damaged.

3.1.4 General conditions

- The aircraft was fully fuelled and thus had a maximum flight duration (endurance) of 4:00 h according to the pilot's calculation or 3:47 h according to the flight school's calculation.
- Indications of increased engine fuel consumption during previous flights went undetected by the pilots and the flight school.
- The weather was good and had no influence on the accident.

3.2 Causes

> In order to achieve its objective of prevention, a safety investigation authority shall express its opinion on risks and hazards that have been identified during the investigated incident and which should be avoided in the future. In this sense, the terms and formulations used below are to be understood exclusively from the perspective of prevention. The identification of causes and contributory factors does not, therefore, in any way imply assignment of blame or the determination of administrative, civil or criminal liability.

The accident, in which the aircraft suffered a loss of control shortly after take-off and crashed into a meadow, was caused by an engine failure due to lack of fuel.

The combination of the following factors was found to be causal:

- The fuel consumption of the engine was above the expected value;
- Indications of the increased fuel consumption during previous flights remained undetected;
- The fuel gauge showed too much when the fuel level was low;
- The pilot did not interpret the course of the fuel gauge critically enough.

The choice of flight path after the engine failure required a turn near the ground, which encouraged a loss of control.

4 Safety recommendations, safety advice and measures taken since the accident

4.1 Safety recommendations

None

4.2 Safety advice

None

4.3 Measures taken since the accident

The measures taken, of which the STSB is aware, are mentioned below without further comment.

- The Fliegerschule Birrfeld AG removed its flight planning aid (cf. Chapter 1.5) from its homepage for revision in order to encourage the pilots to reflect more carefully and to calculate the hourly consumption to be expected according to the flight profile.
- The accident was communicated within the Fliegerschule Birrfeld AG as “lessons learned”.
- The maintenance operation of the Fliegerschule Birrfeld AG introduced a software for quality assurance and monitoring of the planning of the inspection intervals.

This final report was approved by the Board of the Swiss Transportation Safety Investigation Board STSB (Art. 10 lit. h of the Ordinance on the Safety Investigation of Transportation Incidents of 17 December 2014.

Bern, 28 March 2023 Swiss Transportation Safety Investigation Board