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GENERAL INFORMATION

Identification number:	2008078
Classification:	Serious incident
Date, time[1] of occurrence:	12 July 2008, 20.10 hours
Location of occurrence:	Near Lekkerkerk, the Netherlands
Aircraft registration:	PH-SVU
Aircraft model:	Apex Robin DR400/135CDi
Type of aircraft:	Single-engined propeller aircraft
Type of flight:	Training flight
Phase of operation:	Landing
Damage to aircraft:	Serious
Number of crew:	Two
Number of passengers:	One
Injuries:	None
Other damage:	None
Lighting conditions:	Daylight

SUMMARY

During a training flight the instructor and student pilot practised an emergency landing exercise. During reduction of the engine power, both engine control system warning lights started to flash, and the engine stopped. Subsequently the instructor took over control of the aircraft and executed an emergency landing on a meadow. The aircraft was seriously damaged however the occupants suffered no injuries.

This report is based on own investigation and a written statement of the instructor.

[1] All times in this report are in local time, unless indicated otherwise.

FACTUAL INFORMATION

Occurrence description

The instructor and student pilot conducted a training flight from Rotterdam Airport (EHRD) under visual flight rules. The aircraft carried one passenger. After having entered the low flying area between Rotterdam and Gouda and flying at an altitude of approximately 1400 feet, the instructor reduced engine power for an emergency landing exercise. Sometime after that, both engine control system warning lights started to flash and the engine stopped. Subsequently the instructor decided to execute an emergency landing in a meadow. During the landing manoeuvre the right hand wheel of the main landing gear entered a ditch, causing the aircraft to turn over right and nose over into the ditch whereupon it came to a stop. The aircraft was seriously damaged. The occupants could leave the aircraft uninjured.

Figure 1: PH-SVU after the emergency landing

Aircraft and engine

The Apex Robin DR400/135CDi is a four-seater aircraft and equipped with a Thielert TAE 125-01[2] common-rail diesel engine. The engine has been designed to operate using Jet A1 fuel, which has similar properties compared to diesel fuel. The aircraft is equipped with a singular power lever, allowing the pilot to adjust power by using only one handle, without the need to adjust propeller pitch, fuel mixture or other engine parameters.

Figure 2 shows a functional diagram of a common-rail diesel engine operation. From the fuel tank, fuel is passed to a high pressure fuel pump. The fuel pressure is increased and subsequently passed to the distribution tube, as from now to be called the common-rail, of the engine. The engine RPM is determined by the existing fuel pressure in the common-rail. The pressure in the common-rail in part determines the engine revolutions (power). The pressure in the common-rail is regulated by the rail pressure control valve and sensed by the rail pressure sensor. The electrically operated injectors inject fuel under high pressure into the engine for combustion.

[2] The TAE 125-01 engine is a liquid cooled, four cylinder in line, four-stroke common-rail diesel engine with a turbo compressor.

Electronic control of the engine is regulated by a digital Full Authority Digital Engine Control[3] (FADEC) unit. The FADEC is equipped with two independent engine control units (ECU) [4], distinguished as ECU-A and ECU-B. Under normal conditions the engine is controlled by ECU-A, the ECU-B being redundant (fail-safe principle). By manipulating a switch, the ECU control can be selected by the pilot to automatic or manual. Standard selection is AUTOMATIC, resulting in the engine being controlled by ECU-A.

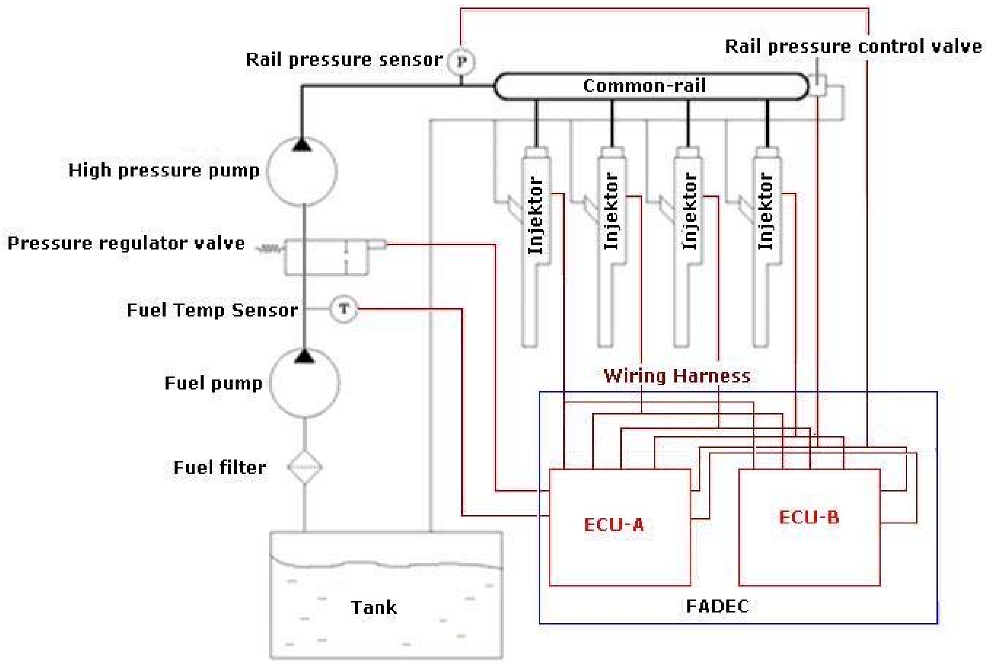

Figure 2: functional diagram of the TAE-125-01 fuel- and electronic control system

If the monitoring system within the FADEC detects a failure, ECU-B will take over control automatically. This is indicated by a warning light in the cockpit. ECU-B may also be selected by the pilot manually. The different engine systems are electrically connected to the FADEC by a bundle of wires, the wiring harness, so as to allow the engine to be controlled and monitored. Each monitoring sensor and engine control unit is wire-connected to the FADEC via one cable. Redundancy in these connections is not provided for and thus not fail-safe.

The FADEC includes a failure- and data recording system, which may be utilised for engine trouble shooting. The data also may be downloaded after a flight, for analysing purposes.

The pilot

The instructor possessed a valid Commercial Pilot Licence (CPL(A)) with the qualifications, instrument flying – single-engine (IR-SE(A)), flying-instructor (FI(A)), night-flying (NQ(A)) and radiotelephony (RT). He possessed a valid medical certificate and his total flying experience was 1510 hours of which 400 hours on type.

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3 Full Authority Digital Engine Control is a system utilising a digital computer, engine control units (ECU's) and accessory components for complete aircraft power plant control.

4 Engine Control Unit, a digital control unit determining the required output signals for engine control on the basis of input-signals received from the engine sensor.

INVESTIGATION AND ANALYSIS

During the investigation conducted at the occurrence location, no fuel leakage or lack of fuel in the fuel tanks was found.

Analysis of the FADEC data.

Analysis of the FADEC data learned, that the engine was started at 19.49 hours and an engine check had been performed before starting. Both the ECU-A and the ECU-B were tested and no deficiencies were encountered. At 19.58 hours full power was selected for take-off. At 20.01 hours the altitude of 1400 feet[5] was reached. At 20.05 hours engine power was reduced to idle (power 0%) and ten seconds afterwards the FADEC switched over to the ECU-B. This changeover concerned an automatic selection without pilot intervention.

The switchover from ECU-A to ECU-B caused the warning light in the cockpit to light-up, which was observed by the instructor. The FADEC data show that subsequently the instructor tried to increase the engine power several times. However no increase in engine RPM was recorded. Now the engine was controlled by the redundant (back-up) ECU-B. Analysis of engine data shows that the engine oil pressure and the oil- and cooling fluid temperatures, were within the limits specified by the engine manufacturer. Analysis of the FADEC shows that during flight, before the failure occurred, the demanded common rail-pressure[6] ('AdPrat') was equal to the actual common-rail pressure[7] ('PRail'). It also shows that at the time the engine stopped operating, these values were not

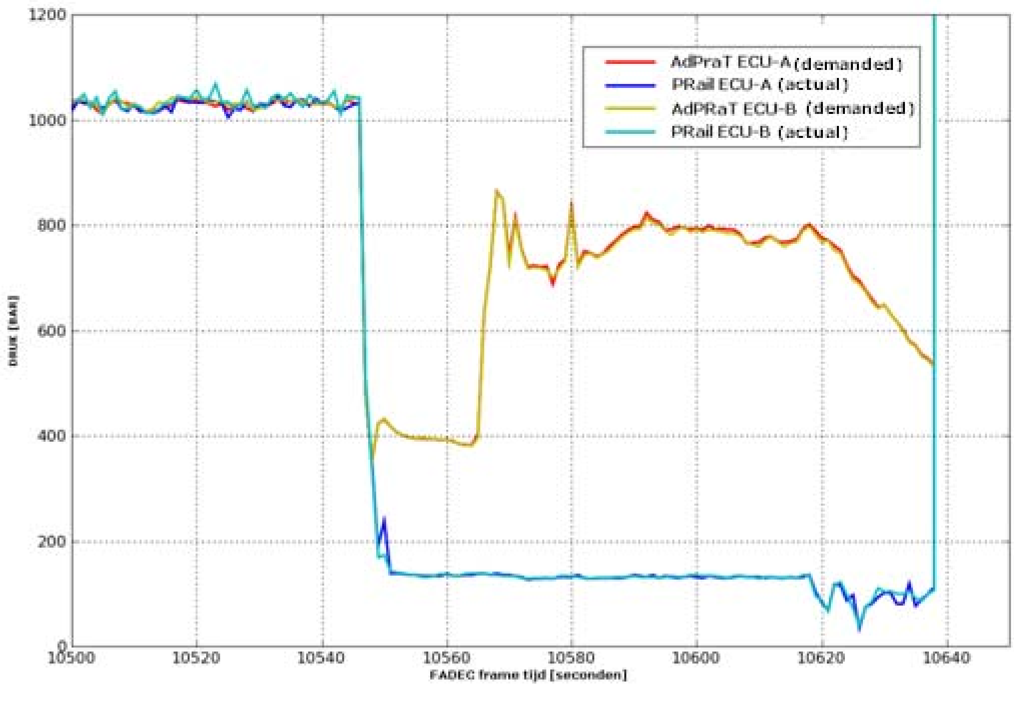

Figure 3: demanded ('AdPRaT') and actual common-rail pressure ('PRail') during the last 140 seconds of the incident flight

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5 Altitude in this report is calculated on the basis of recorded barometric pressure and ground-barometric pressure as a reference (QFE Rotterdam Airport).

6 Demanded common rail-pressure is the pressure in the common-rail demanded by engine power lever position.

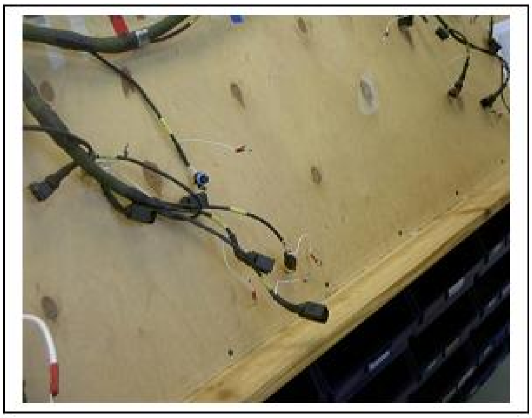
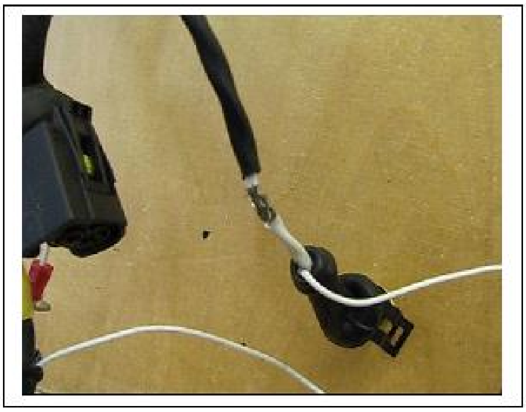
7 The actual common rail-pressure is the pressure existing in the common-rail of the engine.

identical. These differences in value between the demanded and actual common-rail pressure are shown in figure 3.

Analysis of the data further indicated that the demanded pressure was in accordance with the engine power selected by the pilot. According to the engine manufacturer, the actual rail pressure appeared to be in line with the wind mill effect of the propeller, indicating that the engine did not supply any power.

Analysis of the failure data recording system learned, that during the incident flight several failures were recorded. In particular the fault message "valve power current too high" was recorded several times. A similar message indicates that an (excessively) high voltage had been applied to the valve, regulating the common-rail pressure. After the investigation at the incident location and the analysis of the FADEC data information had been completed, the engine was removed from the aircraft and shipped to the engine manufacturer for further examination.

Engine test at engine manufacturer Thielert
The engine, including its wiring harness and FADEC-unit, was shipped to engine manufacturer Thielert in Germany. Several tests were conducted, which were attended by investigators of the German Bundesstelle für Flugunfalluntersuchung (BFU) and investigators of the Dutch Safety Board. The first test, a bench-test[8], was aimed at verifying the correct operation of the engine mechanically. This was accomplished by positioning the engine, with its original FADEC and a new wiring harness, on a test bench. The engine operated without showing any deficiencies, and the acceptance test of the manufacturer was completed without any irregularities. The test resulted in the conclusion that the engine with its accessory FADEC-system, was mechanically in working condition.

Figures 4 en 5: wiring harness on installation board (left). Detailed picture of "VRail" cable (right)

Subsequently the attention was focussed on the original wiring harness of the incident aircraft. Extensive examination of the harness learned that part of the wiring (regulating cable) inside the connector to the common-rail pressure control valve ("VRail"), was uncovered and insulation material was missing. To facilitate the examination, the wiring harness was connected to an installation board, and an acceptance test procedure was started (figures 4 and 5). When electrical power was applied to the "VRail", sparks appeared and a short-circuit was found. No further deficiencies were found in the wiring-harness cables.

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8 A test environment and –procedure to verify the engines mechanical operation.

Subsequently a short-circuit, similar to the defect that was found in the wiring-harness of the incident aircraft, was simulated in the cable to the rail-pressure control valve (“VRail”). This short-circuit test was executed with the engine on the test bench, operating under full power. As soon the simulated short-circuit was introduced in the wiring, the engine stopped. Analysis of the recorded test-bench engine data confirmed that they were in accordance with the FADEC data as recorded during the incident flight. Therefore this test provided an additional indication that the engine had stopped as a result of a short-circuit in the wiring to the “VRail”.

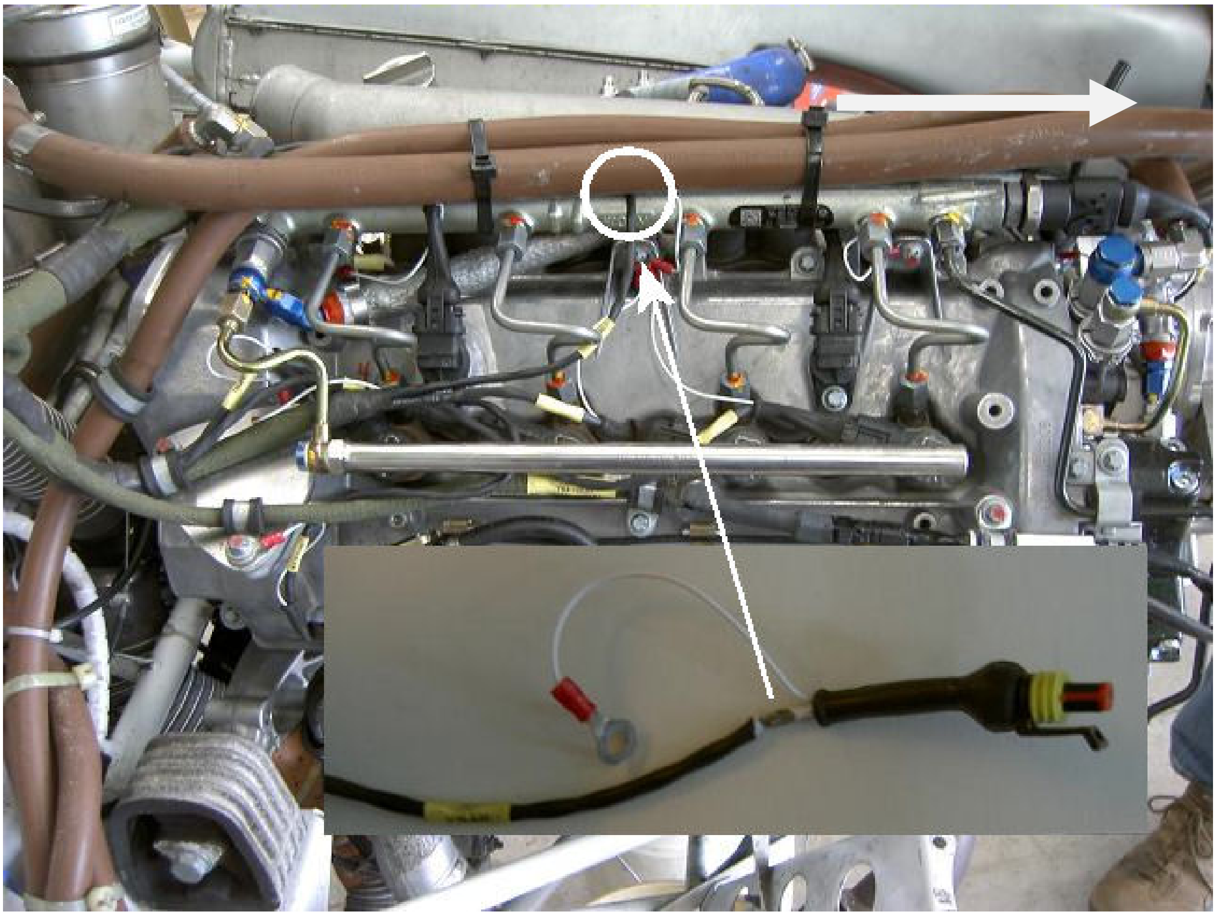

Figure 6: view of right side of engine

The white circle in figure 6 shows the position of the “VRail” cable being guided over the engine. The detailed picture shows the “VRail” wiring as found during the investigation. Part of the insulation material is missing and the wiring is uncovered.

Cable-chafing

In aviation history several aircraft accidents have occurred as a result of chafing of electrical wiring.[9] In general, chafing is a result of a mechanical failure. Sometimes wiring is guided erroneously across sharp edges of aircraft material, which than can cut through the insulation material, causing short-circuits. Another type of chafing is “wear-through”. This could occur if the wiring is in physical contact with an oscillating or vibrating aircraft component. The mechanically oscillating action causes the insulation material of the wiring to wear, which finally can result in a

9 Cable-chafing is a process, causing wear-through of a cable by friction against a hard, more often then not, metal object.

short-circuit. Analysis of the “VRail” wiring indicated that the failure probably was caused by chafing, caused by a kind of wear-through; see figure 6.

Evidence of chafing is not easy to detect and a detailed inspection is required to enable determination of the phenomena to have occurred. The engine maintenance manual of Thielert indicates that the FADEC sensors must be checked during every periodical inspection of 100 hours. According to appendix 7 of the operation- and maintenance manual, as part of the FADEC sensors check, states: “the wiring harness must be checked on evidence of chafing”. No explanation is given in which manner this must be accomplished.

CONCLUSION

The investigation can be summarized with the following conclusions:

- Mechanically the engine was in a working condition (operated as designed).
- Sufficient fuel was available to enable the engine to be operated.
- The FADEC system (ECU-A and ECU-B) operated as designed.
- The “VRail” cable, the regulating cable to the rail pressure control valve, was found to be subjected to cable-chafing.

It is concluded that cable chafing of the “VRail” wiring probably caused an electrical short-circuit, resulting in the normal electrical power supply to the rail pressure control valve to be interrupted. This caused the engine to stop operating. The chafing was very likely caused by the installation method of the wiring, in combination with normal engine vibration during flight.

It may be noted that engine power could not be maintained, in spite the fact the engine was mechanically sound, as well as the availability of a redundant electronic control system (ECU). In spite of this redundancy, a cable failure in the wiring harness can cause the engine to stop operating completely. The question may be raised if a similar design is compatible with the applied fail-safe principle.

RECOMMENDATIONS

The European Aviation Safety Agency (EASA) is recommended to:
revise the certification requirements for the TAE-125-01 diesel engine design, with the emphasis being put on the fail-safe principle being applied to an individual engine component, as well as to the complete power plant system including its electronic failure mode.

Note: This report has been published in the English and Dutch language. If there are differences in interpretation the Dutch text prevails.