DUTCH
SAFETY BOARD

Emergency landing after engine failure Diamond DA-40

Emergency landing after engine failure Diamond DA-40D

The Hague, July 2014

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Source photo cover: Airnews

Dutch Safety Board

The aim in the Netherlands is to limit the risk of accidents and incidents as much as possible. If accidents or near accidents nevertheless occur, a thorough investigation into the causes, irrespective of who are to blame, may help to prevent similar problems from occurring in the future. It is important to ensure that the investigation is carried out independently from the parties involved. This is why the Dutch Safety Board itself selects the issues it wishes to investigate, mindful of citizens' position of independence with respect to authorities and businesses. In some cases the Dutch Safety Board is required by law to conduct an investigation.

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NB: This report is published in the Dutch and English languages. If there is a difference in interpretation between the Dutch and English versions, the Dutch text will prevail.

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GENERAL

Figure 1: The PH-XJB. (Source: Airnews)

General information

Identification number:	2012028
Classification:	Serious Incident
Date, time[1] of occurrence:	21 March 2012, approximately 11.15 hours
Location of occurrence:	Near Hollandse Brug, Muiden
Aircraft registration:	PH-XJB
Aircraft model:	Diamond DA-40D
Type of aircraft:	Single engine piston
Type of flight:	Private
Phase of operation:	En route
Damage to aircraft:	Engine destroyed
Cockpit crew:	One
Passengers:	One
Injuries:	None
Other damage:	None
Lighting conditions:	Daylight

1 All times given in this report are local unless stated otherwise.

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SUMMARY

During cruise flight a loud bang was heard and the engine seized. The pilot made a successful emergency landing in a grass field; both occupants were unharmed after the landing. After the emergency landing the engine cowling was covered with oil. An inspection of the engine showed that two holes in the engine casing were visible, with the connecting rods of cylinder number 3 sticking out.

History of the flight

The aircraft with registration PH-XJB took off from Lelystad Airport (EHLE) for a local flight of approximately 1.5 hours. On board were the pilot and a passenger. Cruise altitude was 1000 feet and the airspeed 120 knots which corresponds to 70% engine power selection. No abnormal engine parameters were observed by the pilot during this time.

Suddenly the pilot heard a loud bang, followed by a complete loss of engine power. According to the pilot, the loss of engine power came totally unexpectedly; no advance warning of impending engine problems such as excessive noise, vibrations etcetera were observed. Following the loss of engine power a rattling sound, which originated from the engine compartment, was heard.

The pilot prepared for an emergency landing, switched off the "Engine Master" switch, made a first "Mayday" call and started the approach to a suitable field nearby. During the approach the pilot switched on the "Engine Master" switch again in an attempt to restart the engine. After the second "Mayday" message was sent, the "Engine Master" was switched off again, because of a burning smell.

When turning to final the pilot switched on the "Electric Master" switch again (briefly) in order to be able to lower the flaps to 10 degrees. According to the pilot he landed the aircraft in a grass field with an airspeed of 70 knots and applied full brakes after touchdown. After about 150 meters the aircraft came to a standstill. Both occupants left the aircraft without injuries. The engine cowling was found to be covered with engine oil; see figure 2.

Figure 2: Engine cowling covered with engine oil. (Source: Wings over Holland)

Personnel Information

The pilot was a 22 year old man who possessed a Private Pilot Licence (PPL(A)) with a rating for single engine piston (SEP). The pilot held a valid medical certificate, class II.

Number of hours total	95
Number of hours on DA-40D	9

Table 1: Flying experience pilot.

Aircraft and engine information

The Diamond DA-40D is a four-seat, single engined, light aircraft constructed from composite materials. It has a fixed nose-wheel type landing gear, low wing and a T-tail. The aircraft is powered by a TAE 125-01 4 cylinder diesel car engine. The engine is a modified diesel car engine with a cylinder displacement of 1.7 litres. The engine is liquid cooled, turbocharged and produces 99 Kw (135 hp) at 3,900 rpm. It has two separate oil systems for the engine and gearbox respectively. Oil is used for lubrication and cooling of the engine and gearbox parts. According to the aircraft manufacturer: 'The aircraft engine has a proved lifetime of a 1000 flight hours or 12 years whichever occurs first. For safety reasons it is strongly recommended to replace the entire aircraft engine after

1000 flight hours or 12 years whichever occurs first; Time Between Replacement (TBR)'.[2] According to the manufacturer approximately 1300 TAE 125-01 engines were manufactured between 2002 and 2006. The manufacturer indicates that 700 engines are still in use. A yearly download of data is requested to be sent to the manufacturer, as part of servicing the engine or when other maintenance activity is performed. Within the last 52 weeks (situation March 2014) TAE has received data from 520 engines of the 700 engines still in use.

2 For the core engine a recommended engine life has been established. The Time Between Replacement (TBR) is published in Service Bulletin TM TAE 125-0001.

Engine damage

After the event the aircraft was transported to a maintenance facility for an initial investigation. The investigation revealed that there was a hole in the upper left-hand side of the engine casing. Through the hole the crankshaft was visible; see figure 3. A second hole was visible in the lower left-hand side, with part of a connecting rod sticking out; see figure 4. Furthermore, the engine compartment was covered with engine oil. No signs of fire were found.

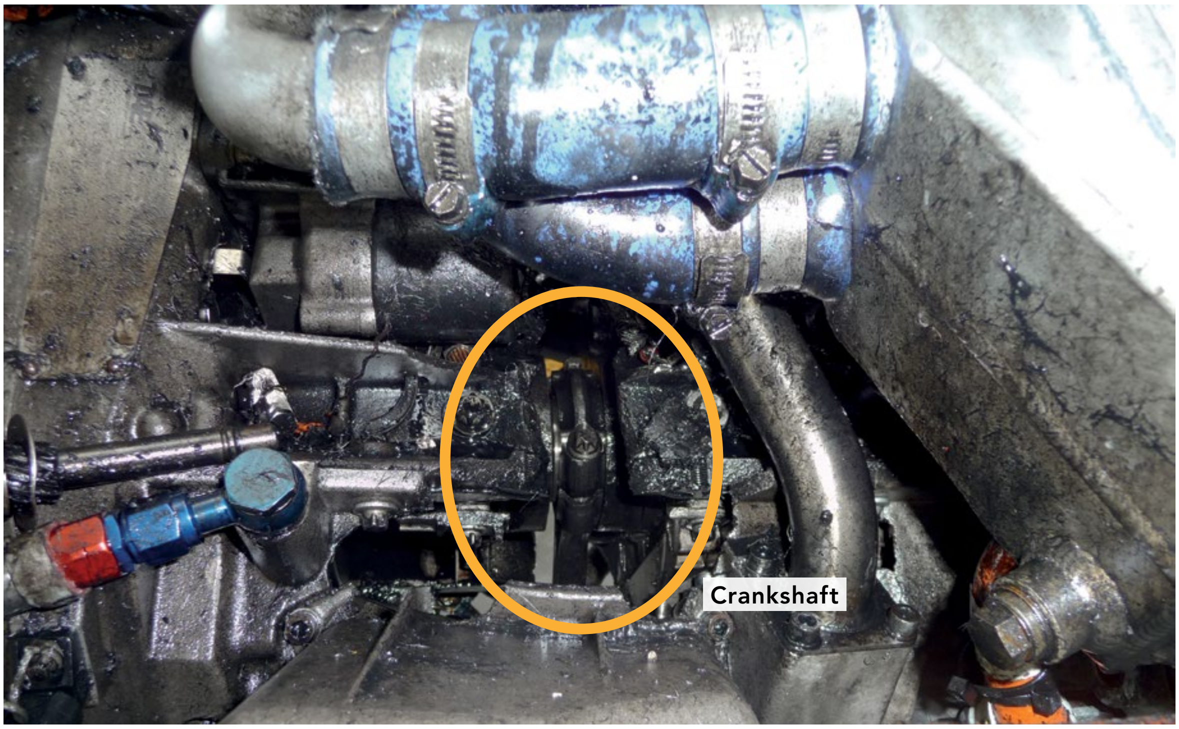

Figure 3: Upper left hand side engine. (Source: Wings over Holland)

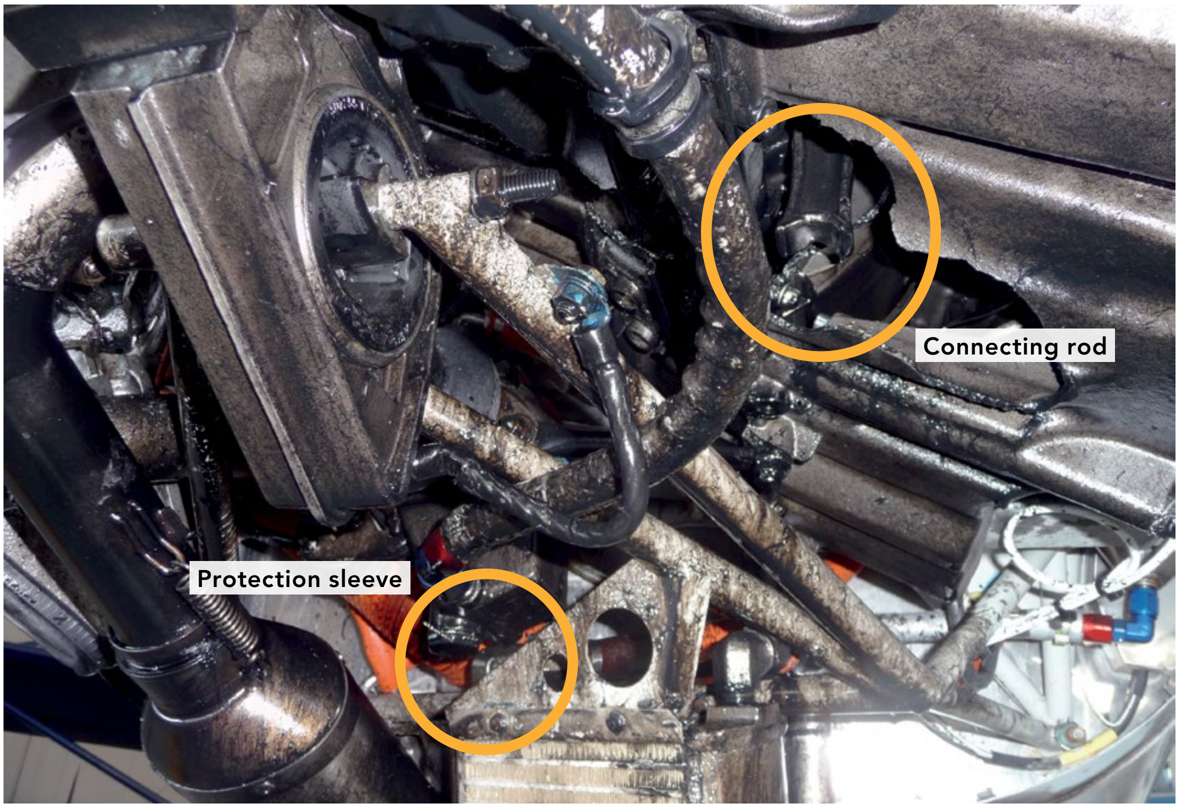

Figure 4: Lower left hand side engine. (Source: Wings over Holland)

The engine was removed from the aircraft and sent to the engine manufacturer in Germany for tear down and further inspection. An investigator from the German Bundesstelle für Flugunfalluntersuchung (BFU) was present and represented the Dutch Safety Board (DSB) during the tear down.

The inspection revealed no evidence of a general, overall lack of lubrication. All four piston cooling oil nozzles were in place. The upper half of the small end bearing of connecting rod number 3 was missing. The number 3 connecting rod was slightly bent and the fracture surfaces and the surface of the small end bearing were completely deformed; see figure 5.

For investigation purposes the crankcase was cut near cylinder number 3 to gain access to relevant engine parts and to avoid additional scratches on the piston and on the cylinder barrel. Due to mechanical damage of the connecting rod, it was not possible to identify the mechanical failure mechanism from the fracture surface. There was major damage to the underside and skirt of piston number 3; see figure 5. The piston pin was missing.

Figure 5: Small end bearing. (Source: BFU)

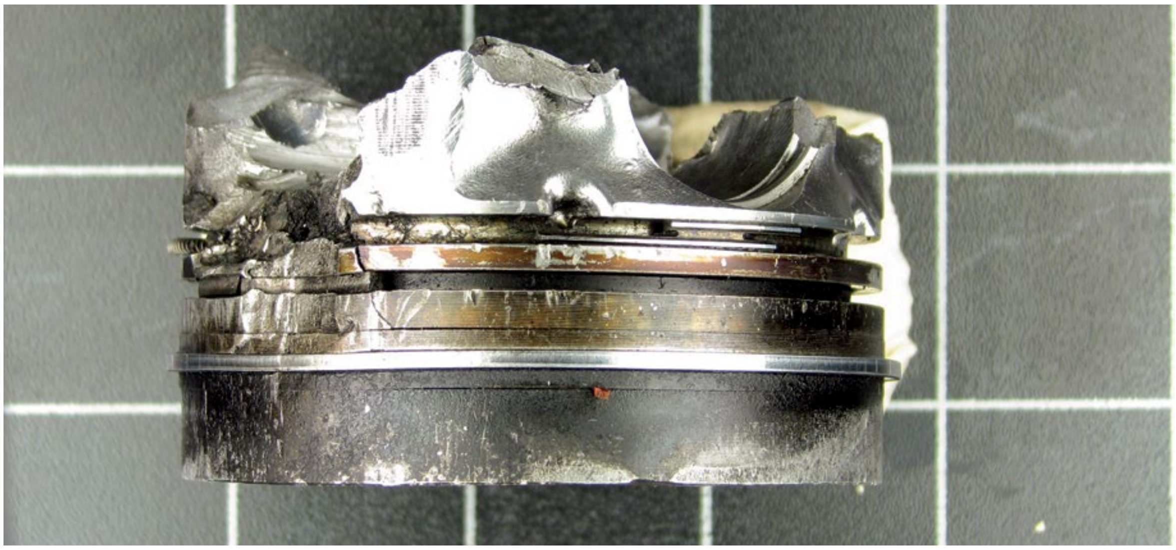

Figure 6: Piston number 3 with fire protection sleeve particle. (Source: BFU)

Red rubber particles and non-metallic fibres were found on piston number 3 and in the combustion chamber; see figure 7. According to the engine manufacturer, the rubber material and fibres were part of the fire protective sleeve from one of the oil hoses that ran across the outside of the engine block. The fire protection sleeve is used for both fuel and oil hoses and as prevention for scuffing of lines. A damaged hose was found on top of the engine during the investigation. With the exception of overload damage in cylinder number 3, all other cylinders were in good condition without significant wear and tear.

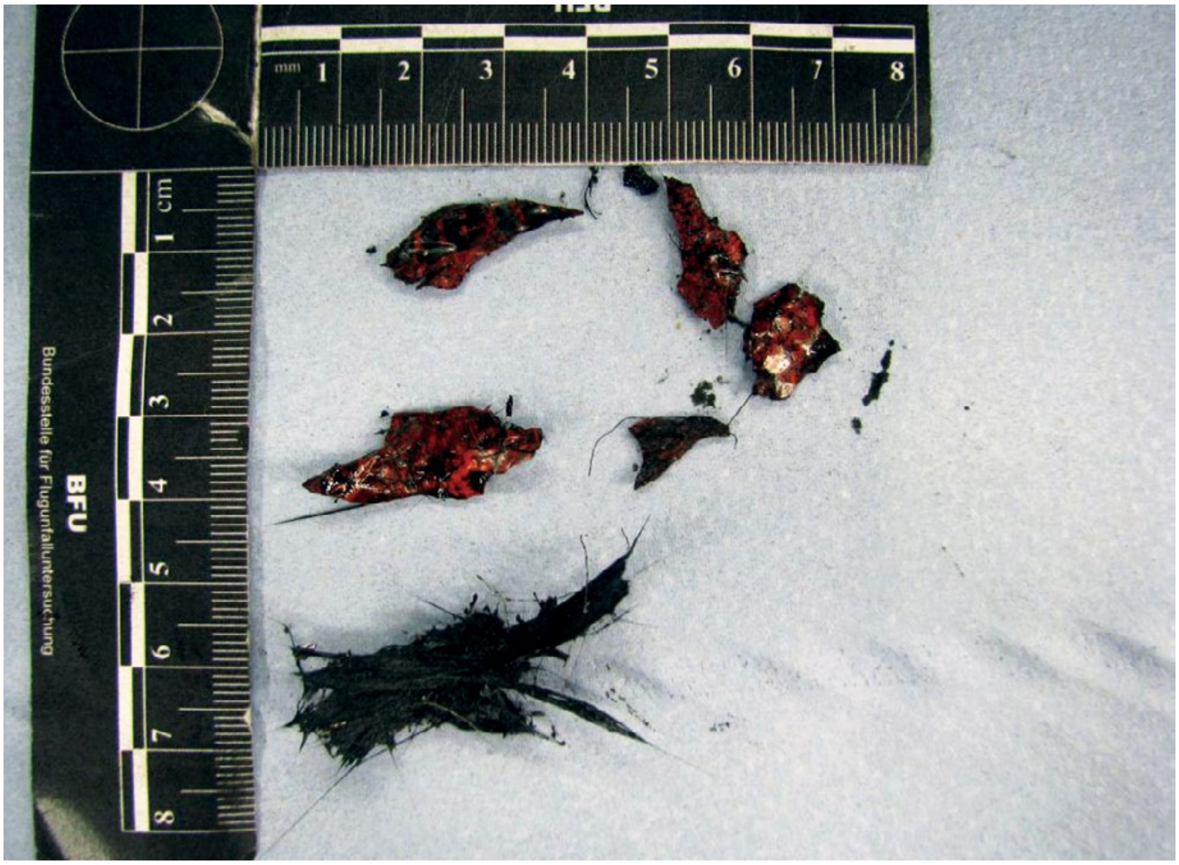

Figure 7: Red rubber particles and fibres found on piston number 3 and in the combustion chamber. (Source: BFU)

Analysis of digital data

The aircraft was equipped with a Full Authority Digital Engine Control (FADEC) unit to control the engine. The FADEC not only provides for efficient engine operation, it also records engine parameter data and warnings. On request of the Dutch Safety Board the FADEC data of PH-XJB was downloaded and subsequently analysed by the DSB. The FADEC data shows that no engine parameter exceedances were recorded during the flight. During the flight, five FADEC warnings were recorded. Analysis of the data shows that all the warnings occurred after the engine failure. Therefore these warnings are considered to be the result of the engine damage. The total engine (run) time was 807 hours including the event flight.

Engine failure sequence

As the small end bearing is one of the most heavily strained bearings in a piston engine, it is believed that the initial failure was that the small end bearing of the number 3 connecting rod failed. Consequently, the detached connecting rod could move freely, bent slightly and punctured the crankcase in two places.

The fibres of the fire protective sleeve were found inside the crankcase and could have been there before the engine failure.

According to the manufacturer engine failure sequence was due to the piece of fibre protection sleeve dropping into the air hose between the compressor and the intake manifold accidently during, for example, maintenance. This piece subsequently passed through the valves and was hammered/cut into small pieces. The fibres and very small rubber parts then prevented the free movement of the piston ring and consequently restricted the heat transition between the piston and cylinder wall. The piston slightly expanded and finally jammed due to fibres and rubber parts between piston ring and cylinder wall. As a consequence of this seizure, the small end of the connecting rod failed. This was evident by the fact that the pistons, which were jammed in the cylinder bore, could not be moved during disassembly. The piece of fire sleeve was found on both sides of the cylinder barrel. After cutting the cylinder bore, the piston could easily be removed. There were no signs of friction welding either on the piston ring or on the cylinder wall. There were no severe scratches on the cylinder wall and no signs of severe over-heating, which means that sufficient engine oil had been present.

Although the sequence of events provided by the manufacturer provides a plausible reason for the failure, the DSB would have expected more supporting evidence, for example local overheating. According to the maintenance organisation, the most recent maintenance was performed 103 flight hours before the accident. Additionally, the air hose between the compressor and the intake manifold was not replaced during the lifetime of the engine. No cause could be found for the fibre entering the intake manifold before the event. The fact that small fibres were present on both sides of the cylinder could be a result of, and not the cause of engine failure damage. The investigation revealed a damaged sleeve containing fibres on top of the engine. These fire sleeve pieces could have dropped onto the piston and subsequently jammed in that position. The DSB therefore concludes that due to damage as result of the incident, no clear and unambiguous reason for the small end bearing failure could be determined.

Similar events

On July 2nd 2005 a similar event took place in Norway. The Accident Investigation Board Norway (AIBN) investigated a serious incident with a Diamond DA-40D registered as LN-NEX[3] The damage to the number 3 piston and connecting rod showed similarities to that of PH-XJB. In the case of LN-NEX, the engine failure was caused by a connecting rod splitting in the small end bearing.

The connecting rod, which consequently was only connected to the crankshaft, penetrated the crankcase and the engine stopped. The colour differences of the pistons of this engine indicate that they have been considerably hotter than a reference piston that had run 1000 hours.

3 http://www.aibn.no/Aviation/Reports/2011-20-eng

The colour differences of the piston pins are indicative of exposure to high temperatures. From the downloaded FADEC data, the AIBN investigation established that about 2.5 months and 40 flying hours prior to the event, the engine had been run with insufficient oil and a low engine oil pressure (2.1 bar) for a short period of time. However, the oil pressure was well above the minimum oil pressure (1 bar) stated by the manufacturer. It could not be established if the engine had run for a short time (severe oil consumption during one flight) at low oil level (minimum oil level is 4,5 litre, 3 litre was present after the engine failure) or if the engine had operated for several hours with a low oil level. Despite the fact that the oil pressure was well above the prescribed minimum, the engine manufacturer concluded that the low oil level had caused overheating inside the engine and eventually led to the engine failure. No fibres or rubber pieces were found between the piston and the cylinder wall in this case.

The AIBN made a recommendation to include a warning in the aircraft flight manual that a low oil pressure (yellow warning) may damage the engine. In November 2013 the engine manufacturer informed the DSB that the oil pressure warning system has been re-assessed and had been considered as adequate. The warning has not been incorporated in the aircraft flight manual to date.

On September 9th 2008 a similar event took place in Germany. The German Federal Bureau of Aircraft Accident Investigation (BFU) investigated the accident that occurred with a Diamond DA-40D. The engine failure occurred at approximately 692 hours. Engine cylinder number 1 was damaged in this occurrence, however due to the extent of the damage the failure origin could not be determined. No fibres or rubber pieces were found between the piston and the cylinder wall in this case.

The observed damage in the LN-NEX and PH-XJB events seems identical. In both cases the number 3 cylinder / piston combination was affected and in both cases the connecting rod had penetrated the crankcase. However, in the Norwegian event there is evidence of running with a low oil level or low oil pressure; in the case of PH-XJB there is no such evidence. During the lifetime of the engine, no FADEC warnings regarding low oil pressure had been recorded. Also, with PH-XJB there were no visible signs of overheating of the pistons and piston pins. Due to the extent of engine damage in the German event, the failure mechanism could not be determined. In all three cases the engine crankcase was however punctured.

Engine liftetime limit

The Thielert TAE 125-01 is the first generation of this type of diesel engine modified for aviation use and was certified in 2002. According to the manufacturer's information it is recommended that this engine should be replaced when 1000 flight hours is reached. Other engine types produced by this manufacturer have a lifetime limit of 1200 and 1500 hours with an on going lifetime extension program. Due to the material used to manufacture the crankcase, rework or overhaul is not feasible.

As part of continued airworthiness activities the European Aviation Safety Agency (EASA) monitors the in-flight shutdown rate of TAE engines. According to EASA the failure rate of the TAE diesel engine is comparable to that of other aircraft reciprocating engines. Furthermore, the manufacturer recommended Time Between Replacement (TBR) does not give a lifetime guarantee; this is similar for Time Between Overhaul (TBO) for other engines. According to the engine manufacturer, TBR is a maintenance interval and there is no engine life limit for any TAE engine.

Although engine failure rate comparison shows similar performance between a TBR TAE diesel engine and a TBO aircraft engine there is a difference in engine design and manufacture philosophy. A proved lifetime as written in the SB is not a defined term; according to the engine manufacturer it is not an airworthiness limitation or a definition for a Life-Limited Part.

CONCLUSION

The engine manufacturer concludes that the engine failure was caused by a piece of engine fire sleeve (foreign object) in the engine, which caused the piston to expand and ultimately caused a seizure which broke the connecting rod and caused the engine failure.

The Dutch Safety Board concludes that limited supporting evidence has been found supporting the manufacturer's conclusion. The engine failure sequence is likely to have been caused by an undetermined failure mode of the small end bearing of the number 3 connecting rod. The number 3 connecting rod separated and subsequently damaged the number 3 piston and penetrated the crankcase. The total scenario of engine failure could not be established due to a lack of evidence and damage resulting from the failure.

This investigation has shown that in at least three cases, the recommended engine life (time) of the 700 TAE 125-01 engines has not been met.

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