ACCIDENT

Aircraft Type and Registration:	DA40D Diamond Star, G-HASO
No & Type of Engines:	1 Thielert TAE 125-01 Diesel piston engine
Category:	1.3
Year of Manufacture:	2003
Date & Time (UTC):	29 June 2004 at 1345 hrs
Location:	Field near Old Stratford, Northamptonshire
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - None
Injuries:	Crew - None Passengers - N/A
Nature of Damage:	Nose gear collapsed, broken propeller blade and right winglet damaged
Commander's Licence:	Student Pilot
Commander's Age:	23 years
Commander's Flying Experience:	77 hours (all on type) Last 90 days - 49 hours Last 28 days - 26 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot plus component examination and further enquiries by the AAIB

Synopsis

The aircraft's engine failed in flight when most of the oil was lost overboard. From an altitude of 2,000 ft the pilot carried out a successful forced landing into a field. The engine's turbocharger compressor had been damaged resulting in an imbalance that caused vibration. This vibration induced a fatigue failure of a bearing and a piece of this bearing passed into the oil scavenge pump, causing it to seize. With the pump seized, the oil separator overfilled causing the engine oil to escape via the breather vent line. This caused a loss of oil that resulted in the engine overheating and then seizing. Two safety recommendations were made to reduce the probability of a recurrence.

History of the flight

The pilot was returning to Cranfield Airport following a solo navigation exercise when the engine caution light illuminated on the annunciator panel. He then noticed that the oil pressure had decreased to the amber low pressure region of the digital oil pressure gauge. The engine then suffered from a sudden loss of power with the digital power reading reducing from 89% (cruise setting) to 65%. The pilot transmitted an urgency call to Cranfield Approach and then pressed the reset button on the annunciator panel. Moments later the oil pressure reduced into the red range, the engine failed and the propeller stopped. The pilot reported the engine failure and set his transponder to the '7700' emergency code. He then initiated the engine restart procedure while the aircraft was at an altitude of approximately 2,000 ft. The engine was successfully restarted and ran for approximately 20 seconds before stopping again.

The pilot committed himself to a forced landing, carried out his forced landing checks and then flew a constant aspect approach to a field. After touchdown in the field the aircraft rolled for approximately 20 m through crops and then slewed 45º to the left before coming to a rest. The nose gear collapsed during the landing roll but the pilot was able to vacate the aircraft normally via the front canopy door.

Engine instrumentation

The aircraft was equipped with an engine data logger which recorded the accident flight. The data showed that at a power lever setting of 94% the manifold pressure started to decrease followed by the oil pressure decreasing. The oil pressure decreased continuously for a period of 74 seconds before the engine stopped turning. The data showed that the engine was restarted 13 seconds later but the oil pressure began to reduce again immediately and the engine stopped after 23 seconds.

Aircraft examination

The aircraft was recovered and examined by the maintenance organisation. Apart from the collapsed nose gear and a broken propeller blade, the aircraft had sustained minor damage. The length of the aircraft's belly was coated in oil and the oil dipstick revealed that almost no oil remained in the engine's sump. Further examination revealed that most of the oil had escaped via the breather vent line of the oil separator (which exits under the belly) and a small quantity via the engine's exhaust. The engine was transported to its manufacturer for a more detailed inspection and teardown. The only other item of note from the aircraft examination was that an incorrect type of air intake hose had been fitted. The air intake hose fitted to G-HASO was a SCAT-10 hose without an inner lining. The approved hoses fitted at manufacture are SCEET-10 hoses with inner linings.

Engine description

The TAE 125-01 engine, also known as the Centurion 1.7, is a 4-cylinder turbocharged Diesel engine based on an automotive engine. The engine is liquid cooled and has a wet sump oil system. The constant speed propeller is driven by an integrated reduction gearbox and an electronic FADEC (Full Authority Digital Engine Control) system monitors and controls engine and propeller operation. The turbocharger boosts engine power output by compressing ambient air, which is then cooled by an intercooler, before the compressed air passes into the cylinders. The turbocharger is driven by the engine's exhaust gases as depicted in Figure 1.

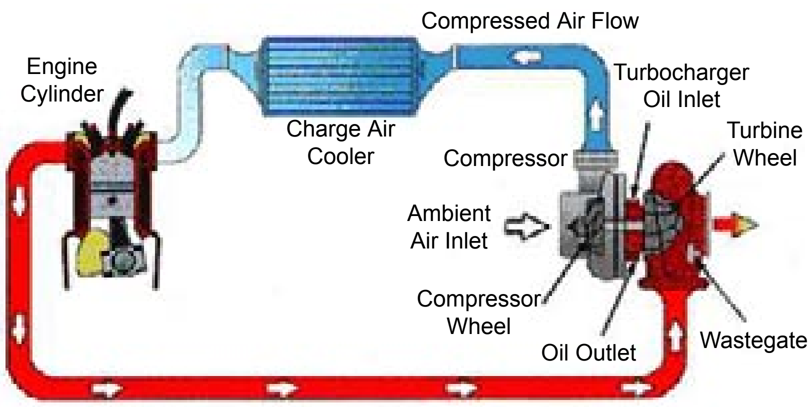

Figure 1

Schematic of turbocharger on TAE 125-01 engine

Turbocharger description

The TAE-125 turbocharger consists of a radial compressor and a centripetal turbine which are connected with a common shaft. The compressor is made up of a 12 bladed compressor wheel and a spiral compressor housing, both of which are made of aluminium. The turbine consists of an 11 bladed turbine wheel made of high-temperature-resistant nickel-ferrous alloy and a turbine housing made of grey cast iron alloy. The compressor wheel and a steel 'radial and axial' bearing are secured to the common shaft as shown in Figure 2. The radial and axial bearing is a plain bearing that supports the shaft and restricts its axial movement. Oil from the engine is fed to the turbocharger for bearing lubrication and then passes into a 'catchtank' beneath the turbocharger.

Engine oil system description

The engine has a wet sump oil lubrication system that is driven by an internal pump inside the engine and an external scavenge pump mounted on the gearbox. A schematic of the oil system is depicted in Figure 3. Oil passes from the engine to the turbocharger and then drops into the catchtank beneath the turbocharger. Oil also passes from the engine into an oil separator that is vented to atmosphere through a breather vent line. The oil separator separates the air from the oil and the recovered oil passes into the turbocharger catchtank. An engine driven scavenge pump then sucks the oil from the lowest point of the catchtank and pumps it back into the engine's sump. This scavenge pump has two stages; one stage pumps engine oil back to the sump and the other stage pumps gearbox oil to the propeller governor (not shown).

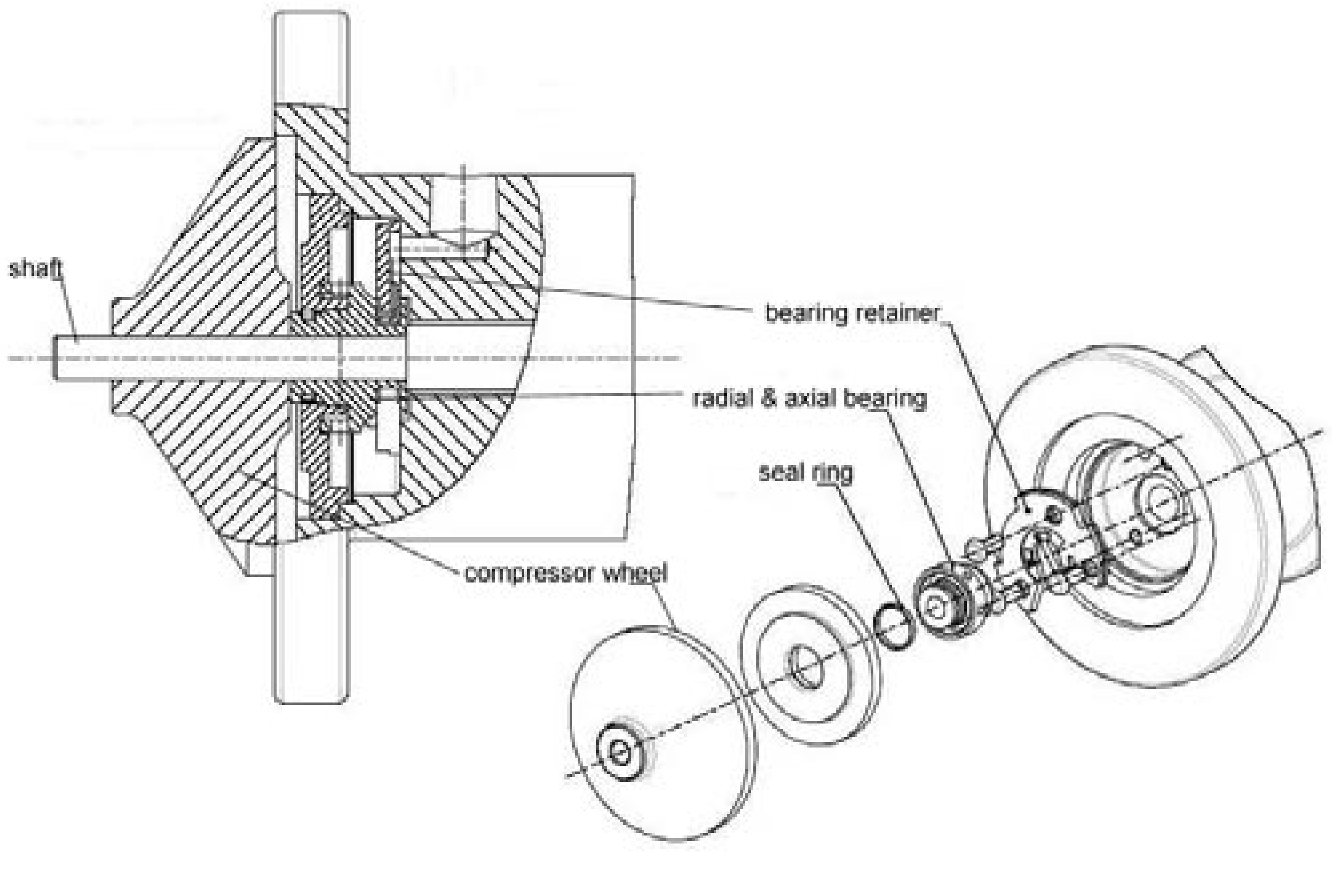

Figure 2

Layout of turbocharger compressor section

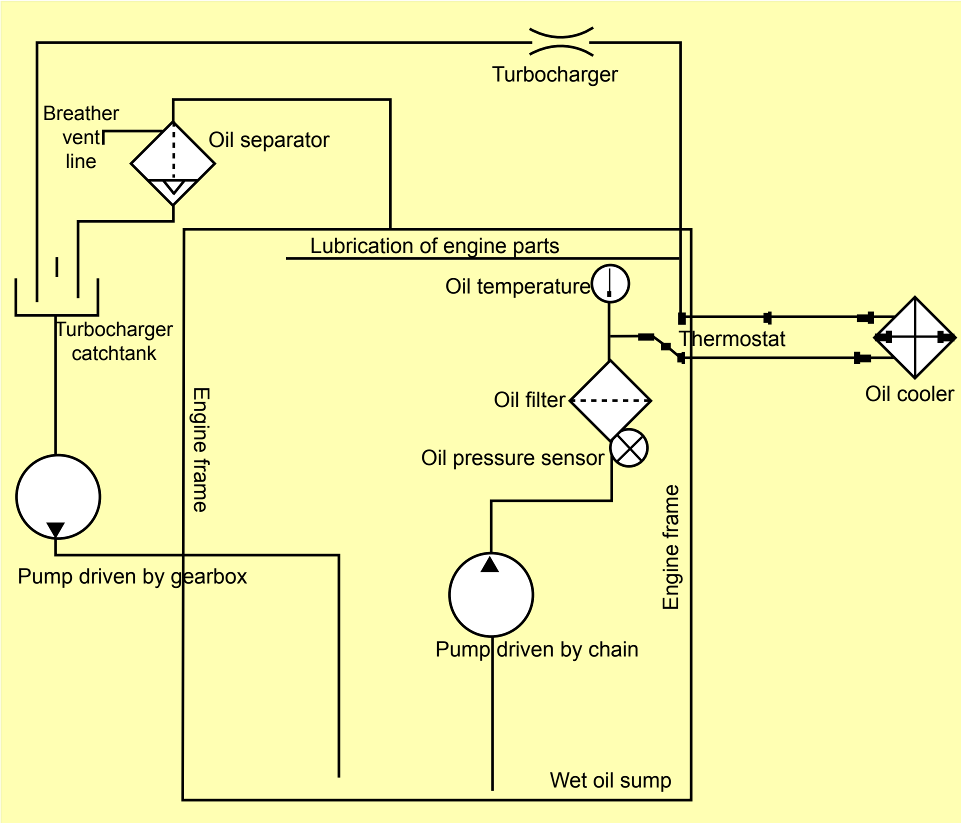

Figure 3

Oil system schematic diagram

Maintenance history

At the time of the accident the aircraft had accumulated 246 flight hours, the engine had accumulated 193 hours and the propeller 246 hours. The last maintenance carried out on the aircraft was a 200 hour inspection on 11 June 2004. During this maintenance check the air intake hose between the air filter and turbocharger was examined for leaks, damage and secure attachment but, reportedly, it was not removed. The air filter, oil filter and engine oil were changed. The maintenance work previous to this was an engine change carried out on 4 June 2004. The engine was changed due to a suspected cracked cylinder head. During the engine change the air intake hose would have been removed but not necessarily replaced.

Engine examination

The engine was stripped and examined by the aircraft manufacturer but it was also inspected by an air accident investigator from the German BFU (Federal Bureau of Aircraft Accidents Investigation). An examination of the combustion chamber revealed severe overheating damage as a result of loss of lubrication. The oil scavenge pump was found seized and its driveshaft had sheared. Disassembly of the scavenge pump revealed a piece of metal debris wedged between the gears (see Figure 4). The metal debris was identified as a part from the turbocharger radial and axial bearing.

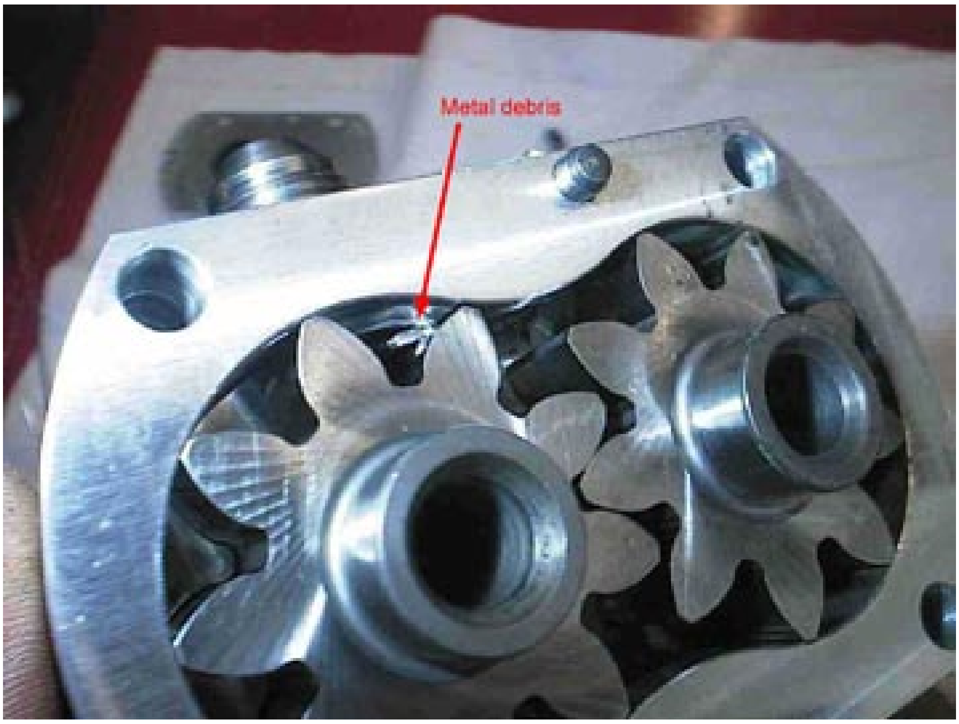

Figure 4

Metal debris wedged between gears of oil scavenge pump

Turbocharger examination

The turbocharger examination revealed that the radial and axial bearing had failed in three pieces. The thrust collar of the bearing had broken off and separated into two pieces (see Figures 5 and 6), one of which was found wedged inside the scavenge pump and the other was located inside the turbocharger catchtank. The bearing was examined by an independent metallurgist whose microscopic examinations revealed that the bearing had failed due to fatigue. The bearing was also examined by another engine manufacturer who concluded that the fatigue failure of the bearing was caused by increased vibrational loads.

The compressor wheel had suffered leading edge damage to many of its blades. To establish the cause of this damage the compressor wheel and its casing were sent to an independent engine manufacturer for examination. The compressor blade tips had evidence of tip rub. Four of the compressor blades had sharp nicks on their leading edges, as indicated with white arrows in Figure 7. Compressor blade No 5 had suffered the most damage with a 4 mm section of its leading edge torn away against the direction of rotation. Blade No 5 also exhibited small shallow impact marks on its concave side (hidden side in Figure 7) close to the leading edge damage. These impact marks were darker and therefore older than all the other shinier impact marks. The compressor casing exhibited rotational scoring marks where the compressor blade tips had rubbed against it, and a small (1.4 mm long) piece of debris was found in the gap between the casing and the inlet cone. This debris was analysed using energy dispersive x-ray which revealed that it consisted primarily of aluminium with small amounts of nickel and iron. Some of the damaged areas of the compressor were also analysed which revealed small amounts of iron at concentration levels exceeding those

Figure 5

New radial & axial bearing on the left and failed radial & axial bearing on the right (note the missing thrust collar)

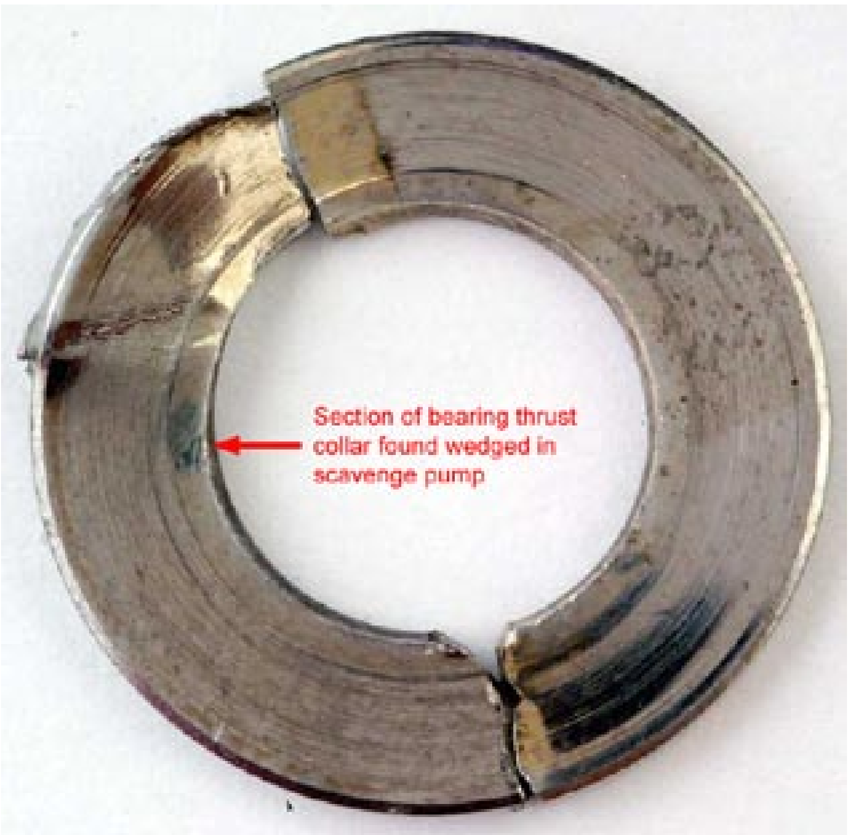

Figure 6

Failed thrust collar from radial & axial bearing (left section found inside scavenge pump; right section found inside turbocharger catchtank) in the compressor's base material. Although iron is an element within the material of the compressor, the nickel found on the debris was a foreign element - no part of the compressor section contains nickel. The examining engineer concluded from this evidence that some foreign object containing nickel had entered the compressor section and then either impacted a blade directly or become wedged between the blades and the compressor casing, causing casing rub and chipping of the blades. This would have led to an imbalance which would have caused vibration and rotational forces that could explain the bearing failure. Once the bearing had failed the compressor wheel would have moved forward causing additional damage and blade deformation (possibly causing the torn leading edge on blade No 5).

Air intake examination

An air filter filters all intake air before it passes to the turbocharger inlet via a hose, normally a SCEET-10 hose, but in G-HASO's case it was a SCAT-10 hose. The air filter exhibited no defects or signs of impact damage. The aircraft also has an alternate air system which, when selected by the pilot, allows air to bypass the air filter, and instead pass through a coarser metal mesh. However, this system is only used in an emergency when the air filter becomes blocked. The metal mesh also did not exhibit any impact damage. The last time the air intake hose had been removed was during the aircraft's engine change on 4 June 2004. The engine change was carried out by an engineer from the engine manufacturer whilst

Figure 7

Turbocharger compressor wheel
(note: green area is green dye applied at manufacture)

being overseen by the aircraft operator's maintenance engineer. Both engineers believed that it was the other engineer and not themselves who re-installed the air intake hose. It could not be established how (or if) any debris was introduced into the air intake system during maintenance. Also, it could not be established when or how the incorrect type of air intake hose was installed on the aircraft. However, the intake hose appeared undamaged and the metal used to reinforce the hose was examined and analysed. It did not contain any nickel.

Analysis

The engine failure was caused directly by a loss of lubricating oil which resulted in the engine overheating and its eventual seizure. The oil was lost overboard because the scavenge pump seized, resulting in the turbocharger catchtank and subsequently the oil separator over-filling. Once the oil separator overfilled, all the oil vented through the breather vent line which exits under the aircraft's belly. The scavenge pump seized because a piece of the failed radial and axial bearing dropped into the turbocharger's catchtank and was then sucked into the scavenge pump (there was no filtering element between the catchtank and the scavenge pump).

When it was first discovered that the radial and axial bearing had failed due to fatigue, two possible scenarios were considered: (a) the bearing had failed first resulting in a compressor imbalance which caused all the damage on the compressor wheel, or (b) the compressor was damaged first causing an imbalance which resulted in fatigue failure of the bearing. The engine manufacturer believed that (b) had occurred and that the compressor was damaged by ingestion of a foreign object, because they had never encountered a failure of the bearing before. The compressor was therefore examined by an engineer from an independent engine manufacturer. This engineer discovered some debris between the compressor casing and inlet cone that contained nickel. The existence of nickel in the compressor could not be explained as no compressor component contained nickel. Although none of the impact marks on the compressor could be directly linked to an impact from an object containing nickel, the possibility of such an impact could not be ruled out. It was also possible that an object had not caused a direct impact with the compressor but had become lodged between the compressor blade tips and the compressor casing, causing the imbalance and subsequent compressor damage.

If a foreign object had caused the compressor failure it is likely that it was introduced into the air intake system during maintenance, because there was no evidence of a foreign object having been ingested through the air intake filter. The last known time the air intake hose was removed was during the aircraft's engine change. The fact that a SCAT-10 hose was installed instead of a SCEET-10 hose was an anomaly, although it did not appear to be a contributory factor to the engine failure or a source of a foreign object.

Regardless of the mechanism of the compressor failure it remained clear that the failure of the engine itself was directly caused by seizure of the oil scavenge pump. Had the section of bearing not been sucked into the scavenge pump, the engine would have continued to operate, albeit at a lower power setting due to the reduced manifold pressure from the failed turbocharger. It would be desirable to have a system whereby a failure of the turbocharger for any reason would not lead to pieces from the turbocharger causing seizure of the scavenge pump. The possibility of installing a coarse mesh filter between the scavenge pump and the turbocharger catchtank was discussed with the engine manufacturer, but this idea was rejected by the manufacturer because it could introduce additional failure mechanisms such as mesh blockage and leakage due to faulty maintenance. Alternatively, the design of the turbocharger catchtank and oil exit point could be modified to reduce the likelihood of large pieces of debris passing from the catchtank into the scavenge pump.

Conclusions

The engine failure was probably caused by the following sequence of events:

1 The turbocharger compressor was damaged by ingestion of a foreign object containing nickel.
2 It is likely that the foreign object was introduced during maintenance.
3 The compressor damage resulted in an imbalance that caused vibration.
4 The vibration induced a fatigue failure of the axial and radial bearing's thrust collar.
5 A section of the failed thrust collar dropped into the turbocharger catchtank and was then sucked into the oil scavenge pump.
6 The oil scavenge pump promptly seized, shearing its driveshaft.
7 The turbocharger catchtank and subsequently the oil separator started to overfill with oil.
8 The engine oil pressure started to reduce.
9 Once the oil separator was full, the oil began to exit via its breather vent line under the aircraft's belly.
10 The loss of engine oil circulation resulted in the engine overheating and its eventual seizure.

Safety Recommendations

To help prevent a similar accident from occurring again the AAIB issued the following safety recommendations:

Safety Recommendation 2005-047

Thielert Aircraft Engines should modify the TAE-125-01 diesel engine's oil system to reduce the likelihood of sections from a failed turbocharger causing seizure of the oil scavenge pump.

Safety Recommendation 2005-048

The European Aviation Safety Agency (EASA) should consider requiring Thielert Aircraft Engines to modify its TAE-125 diesel engine's oil system to reduce the likelihood of sections from a failed turbocharger causing seizure of the oil scavenge pump.

Safety action taken

As a result of this accident the engine manufacturer has revised the TAE-125 engine maintenance manual to include a note which states: "When replacing the air filter check carefully that no loose parts are in it." The AAIB does not believe that this change is sufficient to prevent similar accidents from occurring again. A foreign object ingestion or a failure of the turbocharger for any reason should not lead directly to engine seizure.

Response to Safety Recommendations

The EASA delegated national aviation authority for oversight of Thielert Aircraft Engines is the LBA (Luftfahrt-Bundesamt) which is the German equivalent of the UK Civil Aviation Authority. The LBA responded to Safety Recommendation 2005-048 as follows:

> *'It is not appropriate to design the engine such that it will not fail in such a case of FOD'* (ie as a result of a foreign object being introduced into the air intake system during maintenance).

They stated furthermore that:

> *'It is also not appropriate to design the engine so that a failure of the turbocharger for any reason does not lead directly to an engine seizure. A failure of the turbocharger can cause a drastic power reduction or an IFSD (in-flight shutdown) for several reasons (reduction of air supply, releasing parts can seize intake valves of the combustion chamber and can destroy the valve train immediately). But all these failure cases are not probable and are considered in the failure analyses and safety assessments during engine certification. Never have considerations been taken to protect the intake pipe after the turbocharger and the combustion chamber from releasing parts of the turbocharger.*
>
> *We agree with the objection of the manufacturer that a coarse mesh filter between the scavenge pump and the catchtank can introduce additional failure mechanisms. Experience from turbine engines has shown that strainers on the suction sides of oil pumps can cause problems in the oil system, especially when it is not possible or difficult to maintain them. For that reason the former JAR-E paragraph 570 (a) (3) "The suction side of each pressure and scavenge pump shall be fitted with a strainer of adequate capacity to protect the pump and to ensure that the pump entry is not restricted under any starting or operating procedures." was deleted (NPA-E 23).*
>
> *A design change of the catchtank might be useful. But from our point of view there is no need for an immediate design change. Operation of the engine outside the certified limits and/or subsequent faulty maintenance may damage the engine at any time.'*

The response from Thielert Aircraft Engines to the Safety Recommendations expressed agreement with this response from the LBA.

The purpose of the AAIB is to improve aviation safety by determining the causes of air accidents and serious incidents and making safety recommendations intended to prevent recurrence. The AAIB therefore stands by Safety Recommendations 2005-047 and 2005-048 because they are formulated to prevent recurrence.