AIRCRAFT INCIDENT REPORT AND EXECUTIVE SUMMARY

				Reference:	CA18/3/2/1288		
Aircraft Registration	**ZS-OBD**	**Date of Incident**	16 October 2019		**Time of Incident**	1402Z	
Type of Aircraft	Cessna 172P		**Type of Operation**		Training (Part 141)		
Pilot-in-command Licence Type	Commercial Pilot Licence		**Age**	36	**Licence Valid**	Yes	
Pilot-in-command Flying Experience	Total Flying Hours		1780.9		Hours on Type	71.4	
Last Point of Departure	Rand Aerodrome (FAGM): Gauteng Province						
Next Point of Intended Landing	Rand Aerodrome (FAGM): Gauteng Province						
Location of the incident site with reference to easily defined geographical points (GPS readings if possible)							
A farm in Kalbasfontein, Randfontein, approximately 24nm south-west of FAGM at the following GPS co-ordinates: 26˚38´26.73˝S 027˚47´12.38˝E at an elevation of 4881 feet							
Meteorological Information	Wind: Light & variable, Temperature: 32˚C, Visibility: CAVOK						
Number of People On-board	2+0	**No. of People Injured**	0		**No. of People Killed**	0	
Synopsis							

On 16 October 2019, an instructor, accompanied by a student pilot on-board a Cessna 172P with registration mark ZS-OBD, departed the Rand Aerodrome (FAGM) on a training flight with the intention to land back at the same aerodrome. The pair flew to the general flying area (GFA) where the instructor demonstrated Exercise 6 S*traight and Level Flights*, to the student pilot. On their return flight from the GFA, the student pilot was the pilot flying (PF) and, while the aircraft was on cruise at 7000 feet (ft) above mean sea level (AMSL), the engine stopped. The instructor took over the control of the aircraft and attempted to re-start the engine; but was unsuccessful. He then elected to perform an emergency forced landing on an open field in Kalbasfontein farm. The aircraft landed safely without any damage and both occupants were not injured during the forced landing.

The investigation revealed that the engine stoppage was caused by the timing chain that had failed, resulting in the valve timing being out of synchronisation and the valves rubbing against the pistons. Contributing factors include the timing chain that had been incorrectly fitted and the incorrect alignment of the camshaft gears.

SRP Date	13 October 2020	Publication Date	16 October 2020

ABBREVIATION	DESCRIPTION
°	Degrees
AIID	Accident and Incident Investigations Division
AMSL	Above mean sea level
AME	Aircraft Maintenance Engineer
AMO	Aircraft Maintenance Organisation
AR	Accredited Representative
C	Celsius
CAM	Computer-aided manufacturing
CAR	Civil Aviation Regulations
CAVOK	Ceiling and Visibility OK
E	East
FADEC	Full Authority Digital Engine Control
FAGM	Rand Aerodrome
FAOR	O.R. Tambo International Aerodrome
GAV	Grasmere VOR
GFA	General Flying Area
GPS	Global Positioning System
kts	Knots
MHz	Megahertz
NM	Nautical Miles
PF	Pilot Flying
S	South
TMA	Terminal Manoeuvering Area
UTC	Co-ordinated Universal Time
VFR	Visual Flight Rules
VOR	Very High Frequency Omnidirectional Range

Reference Number	**:** CA18/3/2/1288
Name of Owner	**:** JetA1Only (PTY) LTD
Name of Operator	**:** African Aviation Academy
Manufacturer	**:** Cessna Aircraft Company
Model	**:** 172P
Nationality	**:** South African
Registration Marks	**:** ZS-OBD
Place	**:** Kalbasfontein Farm, Randfontein at GPS 26˚38´26.73˝S 027˚47´12.38˝E
Date	**:** 16 October 2019
Time	**:** 1402Z

All times given in this report are Co-ordinated Universal Time (UTC) and will be denoted by (Z). South African Standard Time is UTC plus 2 hours.

Purpose of the Investigation:

In terms of Regulation 12.03.1 of the Civil Aviation Regulations (CAR) 2011, this report was compiled in the interest of the promotion of aviation safety and the reduction of the risk of aviation accidents or incidents and ***not to apportion blame or liability****.*

Investigations process:

The incident was notified to the Accident and Incident Investigations Division (AIID) on 16 October 2019 at about 1430Z. The investigator/s dispatched to the farm in Kalbasfontein, Randfontein, on 17 October 2019. The investigator/s co-ordinated with all authorities on site by initiating the accident investigation process according to CAR Part 12 and investigation procedures. The AIID of the South African Civil Aviation Authority (SACAA) is leading the investigation as the Republic of South Africa is the State of Occurrence.

Notes:

1. Whenever the following words are mentioned in this report, they shall mean the following:

- *Incident – this investigated incident*
- *Aircraft – the Cessna 172P involved in this incident*
- *Investigation – the investigation into the circumstances of this incident*
- *Pilot – the pilot involved in this incident*
- *Report – this incident report*

2. Photos and figures used in this report were taken from different sources and may be adjusted from the original for the sole purpose of improving clarity of the report. Modifications to images used in this report are limited to cropping, magnification, file compression; or enhancement of colour, brightness, contrast; or addition of text boxes, arrows or lines.

Disclaimer:

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1. FACTUAL INFORMATION

1.1 History of Flight

1.1.1 On 16 October 2019, an instructor, accompanied by a student pilot on-board a Cessna 172P aircraft with registration mark ZS-OBD, departed the Rand Aerodrome (FAGM) at approximately 1333Z on a training flight. The aircraft had 26 US gallons of Jet A1 (Diesel) on-board. The pair flew to the general flying area (GFA) where the flight instructor was to demonstrate Exercise 6, which is *Straight and Level Flights*, to the student pilot. The flight was conducted under the provisions of Part 141 of the Civil Aviation Regulations (CAR) 2011 as amended, and under visual flight rules (VFR) by day.

1.1.2 The training flight lasted for approximately 30 minutes and the student pilot completed the exercise successfully. During their return flight to FAGM, the student pilot was the pilot flying (PF) and had the engine power for cruise flight set at 62%; the fuel (diesel) consumption was approximately 4.5 US gallons per hour.

1.1.3 The instructor reported that at approximately 1402Z and about 5 nautical miles (nm) east of GAV (Grasmere VOR), which is O.R. Tambo International Aerodrome (FAOR) TMA (Terminal Manoeuvring Area) boundary very high frequency Omnidirectional Radio Range (VOR), the engine stopped while they were cruising at approximately 7000 feet (ft) above mean sea level (AMSL). The instructor then took over the control of the aircraft. He stated that the aircraft's back-up Full Authority Digital Engine Control (FADEC) system, which controls the engine's start and re-start, had failed to provide engine power or to automatically come online. He then proceeded to activate the FADEC system manually to re-start the engine; but he was unsuccessful. The instructor then elected to perform a forced landing on an open field in Kalbasfontein farm. The aircraft landed safely at 1406Z with damage limited to the engine. Both occupants were not injured in the incident sequence.

1.1.4 The incident occurred at approximately 1402Z during daylight and the aircraft was forced landed at a geographical position (GPS) determined to be 26°38´26.73˝South 027°47´12.38˝East at an elevation of 4 881ft.

1.2 Injuries to Persons

Injuries	Pilot	Crew	Pass.	Other
Fatal	-	-	-	-
Serious	-	-	-	-
Minor	-	-	-	-
None	2	-	-	-

1.3 Damage to Aircraft

1.3.1 The aircraft was not damaged in the incident sequence.

Figure 1: The aircraft after the forced landing on a farm.

1.4 Other Damage

1.4.1 None.

1.5 Personnel Information

1.5.1 Instructor

Nationality	South African	Gender	Male	Age	36
Licence Number	0271038176	Licence Type	Commercial Pilot Licence (CPL)		
Licence Valid	Yes	Type Endorsed	Yes		
Ratings	Night, Instrument and Instructor Grade 2				
Medical Expiry Date	31 October 2020				
Restrictions	To wear corrective lenses				
Previous Accidents	None				

Flying Experience:

Total Hours	1780.9
Total Past 90 Days	88.2
Total on Type Past 90 Days	48.5
Total on Type	71.4

1.5.1.1 The instructor was issued a Class 1 medical certificate on 15 October 2018 with an expiry date of 31 October 2020. The instructor did his re-validation skills test on 9 October 2019 and was reissued a CPL with an expiry date of 31 October 2020.

1.5.2 Student Pilot

Nationality	South African	Gender	Male	Age	15
Licence Number	Nil	Licence Type	Nil		
Licence Valid	No	Type Endorsed	None		
Ratings	None				
Medical Expiry Date	Not issued				
Restrictions	N/A				
Previous Accidents	None				

1.5.2.1 The student pilot did not have a licence or a medical certificate at the time of the incident. This was in contravention of the Civil Aviation Regulations (CAR) 2011 as amended, which requires the following:

61.01.2 (1) No person may act as a pilot of a South African registered aircraft, except in the case of dual instruction with an appropriately rated flight instructor, unless such person holds a valid pilot licence with applicable ratings issued, reissued, validated or revalidated by the Director or by an appropriate authority in terms of this Part or Part 62: Provided that a SPL may have been issued without a class rating or type rating.

61.02.1 STUDENT PILOT LICENCE (SPL)

Requirements for a SPL

(1) An applicant for a SPL shall—

(a) be 15 years or older, except where provided otherwise in Part 62;

(b) hold a valid medical certificate issued in terms of Part 67;

(c) be registered with an approved aviation training organisation for training towards a PPL.

61.02.4 Validity of a SPL

(1) A SPL is valid for a period of 2 years from the date of issue, provided the annual currency fees are paid.

(2) The holder of a valid SPL may not exercise the privileges of that licence unless he or she—

(a) is in possession of a valid medical certificate, issued to him or her in terms of Part 67; and

(b) has submitted a copy of the medical certificate to the licensing authority, as required in regulation 61.01.6 (6), in the event that the aviation medical examiner is unable to submit electronic data to the Director.

Flying Experience:

Total Hours	9.5
Total Past 90 Days	3.4
Total on Type Past 90 Days	3.4
Total on Type	3.4

1.5.2.2 The Aviation Training Organisation (ATO) contravened the Civil Aviation Regulations 2011 Part 61 Subpart 2, which relates to the requirements for student pilot licences.

Aircraft Maintenance Engineer (AME) experience:

1.5.2.3 The aircraft maintenance engineer (AME) was initially issued the licence on 17 December 2017. He did his revalidation and was reissued the licence and the TAE 125-02-09 engine was endorsed on it. The licence was issued on 17 January 2019 with an expiry date of 28 July 2020.

1.6 Aircraft Information

1.6.1 The Cessna 172 Skyhawk is an American four-seat, single-engine, high-wing, fixed-wing aircraft manufactured by the Cessna Aircraft Company. The Cessna 172P is powered by a 1 Thielert TAE 125-02-99 diesel engine which uses Jet A1 fuel.

Airframe:

Type	Cessna 172P	
Serial Number	172-75121	
Manufacturer	Cessna Aircraft Company	
Date of Manufacture	1978	
Total Airframe Hours (At time of Incident)	13837	
Last MPI (Date & Hours)	27/06/2019	13789.6
Hours Since Last MPI	47.4	
C of A (Issue Date)	18/01/2011	
C of A (Expiry Date)	31/01/2020	
C of R (Issue Date) (Present Owner)	19 September 2019	
Operating Categories	Standard Normal	
Recommended Fuel Used	Jet A1(Diesel)	

Engine:

Type	Thielert Centurion
Serial Number	02-02-03881
Hours Since New	752.1
Hours Since Overhaul	Not yet reached (TBO is 1500 hours)

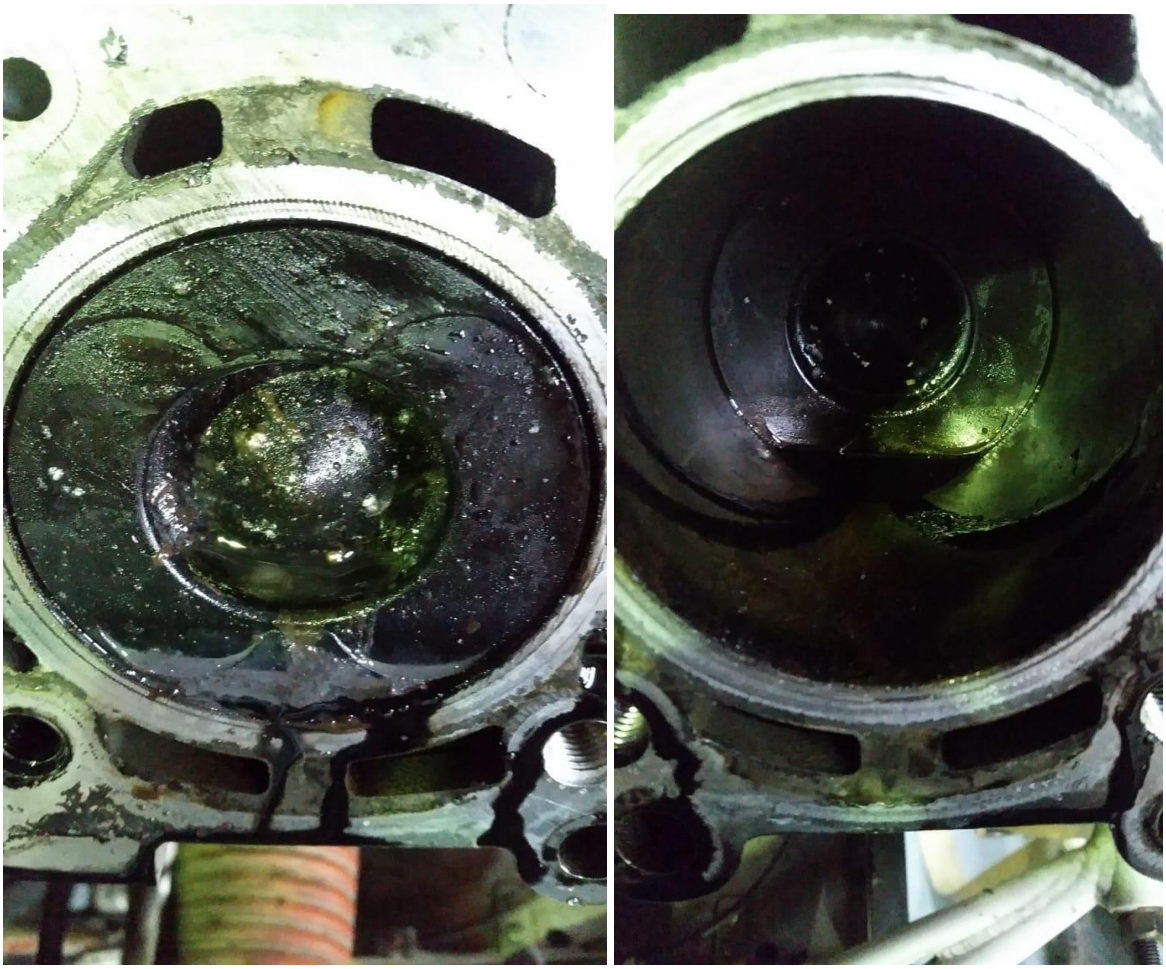
Centurion 2.0 (TAE 125-02-99), source: https://en.wikipedia.org/wiki/Thielert Centurion

- *The Thielert Centurion is a series of Diesel cycle aircraft engines for general aviation originally built by Thielert, which was bought by Aviation Industry Corporation of China's Technify Motors subsidiary and is currently marketed by Continental Motors.*
  All Centurion engines are water-cooled, turbocharged, and employ a single-lever power control (SLPC) associated with a Full Authority Digital Engine Control (FADEC) system. This simplifies engine management for the pilot, as well as improving reliability as it prevents the engine being operated improperly. The series utilizes either jet fuel or diesel fuel. The high compression ratio of the engine combined with the digitally controlled fuel injection system mirrors similar advances in automotive technology.

1.6.2 Source: Aircraft Maintenance Organisation (AMO) report

- The AMO stated that the aircraft was brought for its annual 100-hour inspection with snags reported by the pilot. A major snag was of the difficulty of the engine to start daily. A FADEC download was done and sent to the factory for analysis. The AMO was informed by the factory to conduct a glow plug test and confirm that all four glow plugs were working. The glow plugs were removed and tested; and were found satisfactory.

- It was also noted that when the propeller was turned over by hand, a mixture of water and oil was pumped out of the open holes in the cylinder head (see Figures 2 and 3). The water issue was also reported to the engine factory and it was confirmed that this was the cause for the engine’s difficulty to start as well as overheating that was reported by the instructor.



Figures 2 and 3: Water in the cylinder head.

- Work order was raised to replace the cylinder head and the AMO stated that the replacement was carried out in accordance with (IAW) RM-02-02 Chapter 73-30.03. Replacement of the cylinder head requires the timing chain to be disconnected and re-connected, which the AMO stated was carried out in accordance with RM-02-02 Chapter 72-30.02. (See timing chain installation procedure, pages 1, 2, 7, 8, 13, 14, 15, 16 17 and 18 attached as Appendix C).

- The AMO did not follow the instructions as indicated in Appendix C and as indicated by the engine investigation report following the incident, which indicated the following amongst others:
    - Synchronisation of the camshaft drive gears was wrong.
    - Timing chain fitted incorrectly
    - Chain tensioner fully in end position.

Propeller:

Type	MTV-6-A/187-129
Serial Number	03424
Hours Since New	1609.6
Hours Since Overhaul	Not yet reached

1.7 Meteorological Information

1.7.1 The weather information in the table below was obtained from the pilot questionnaire.

Wind direction	Light & variable	Wind speed	>5 kts	Visibility	CAVOK
Temperature	32˚C	Cloud cover	Nil	Cloud base	Nil
Dew point	Unknown				

1.8. Aids to Navigation

1.8.1 The aircraft was equipped with standard navigational equipment as approved by the Regulator (SACAA).

1.9 Communication

1.9.1 The aircraft was equipped with standard communication equipment as approved by the Regulator. The instructor communicated his intention to execute an emergency landing and their position to FAGM control tower on frequency 118.70 megahertz (MHz).

1.10 Aerodrome Information

1.10.1 The incident occurred during daylight, approximately 5nm east of GAV and 7.7nm south of Baragwanath Aerodrome (FASY) in the Gauteng province, at GPS co-ordinates determined to be: 26°38´26.73˝ South 027°47´12.38˝ East and at an elevation of 4 881ft.

Aerodrome Location	Lenasia, Gauteng Province
Aerodrome Co-ordinates	S26°21'08" E027°46'43"
Aerodrome Elevation	5 400 feet
Runway Designations	13L/31R
Runway Dimensions	1 100m x 10m
Runway Used	n/a
Runway Surface	Asphalt
Approach Facilities	Unmanned airfield

1.11 Flight Recorders

1.11.1 The aircraft was not equipped with a flight data recorder (FDR) or a cockpit voice recorder (CVR). Neither recorder was required by the relevant aviation regulations.

1.11.2 The aircraft was fitted with a FADEC system, which is a computer-managed engine ignition and engine control system used in modern commercial and military aircraft to control all aspects of engine performance digitally, in place of technical or analogue electronic controls. The FADEC controls engine starting and re-starting.

1.12 Wreckage and Impact Information

1.12.1 On the return flight to FAGM, the aircraft experienced an engine failure at approximately 7000ft AMSL and at approximately 5nm east of GAV. The instructor decided to execute an emergency landing on an open field. The aircraft landed safely and did not sustain any damage.

1.12.2 The aircraft was recovered to a hangar at the Grand Central Aerodrome (FAGC). The aircraft's wings were removed, and the aircraft was placed on a trailer.

1.13 Medical and Pathological Information

1.13.1 None.

1.14 Fire

1.14.1 There was no evidence of a pre- or post-impact fire.

1.15 Survival Aspects

1.15.1 The incident was considered survivable because the cockpit and the cabin areas were not damaged. Both occupants had made use of the aircraft's safety harnesses.

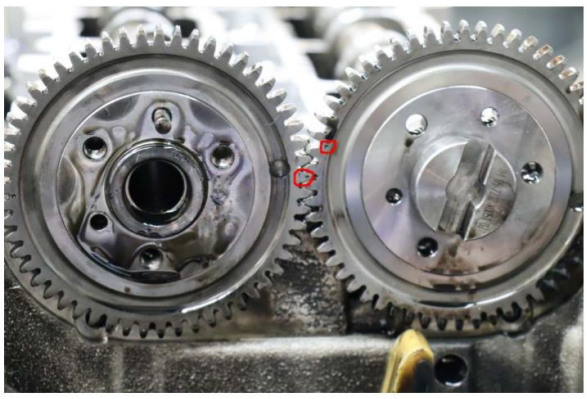
1.16 Tests and Research

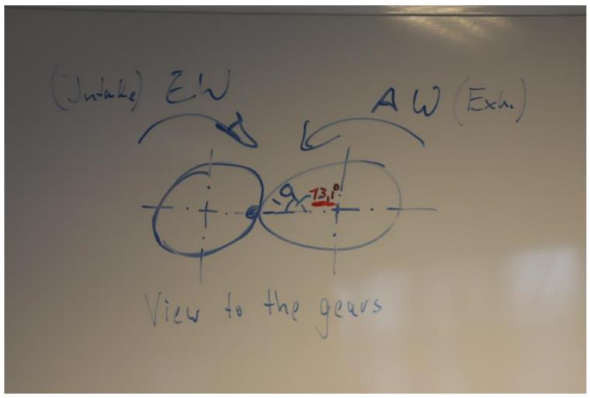
1.16.1 The FADEC was sent to Continental Aerospace Technologies in Germany, which is the engine manufacturer, for data downloading. The FADEC downloading had determined that there were several failed entries of the computer-aided manufacturing (CAM) sensor. The FADEC was missing the CAM sensor of the crankshaft and the rail pressure had dropped from 880-bar down to 2-bar in 157.6 seconds. (See report attached as Appendix A)

Note: Rail Pressure - The fuel rail sensor, commonly referred to as the fuel pressure sensor, is an engine management component that is commonly found on diesel, and some gasoline injected vehicles. It is a part of a vehicle's fuel system and is designed to monitor fuel pressure that is present in the fuel rail.

1.16.2 The incident engine S/N 02-02-03881 was sent to the manufacturer (Continental Aerospace Technologies) in Germany for a detailed inspection. The investigators did not travel to

Germany for the engine strip. The engine strip was overseen by an Accredited Representative from the Federal Bureau of Aircraft Accidents Investigation. Synchronisation of the camshaft was found to be fitted incorrectly with gears moved two-teeth clockwise (see Figures 4 & 5) and the timing chain was found broken. The report concluded that the cause of the engine failure was due to a crack on the timing chain which led to its failure as well as caused damage to the valve timing system. (See engine strip report attached as Appendix B)





Figures 4 & 5: Picture and a diagram for synchronisation of the camshaft drive gears which had shifted two-teeth clockwise (~13°).

1.16.3 Further communication with the manufacturer revealed the following:

- It is possible to disconnect the timing chain using a special tool. But if the timing chain has been disconnected, it would not be possible to reconnect the same timing chain again. In that case, one would need to install a new timing chain. The new timing chain comes open with a special new pin which is closed by being pressed using a special tool. According to the AMO, a new pin was used to re-connect the timing chain, and part number VR 00308-00-01 and VR 00308-00-02 tools were used for the removal and assembly. (See Figures 6, 7, 8 and 9)

Figures 6 & 7: Special tools used by the AMO for the removal and installation of the timing chain.

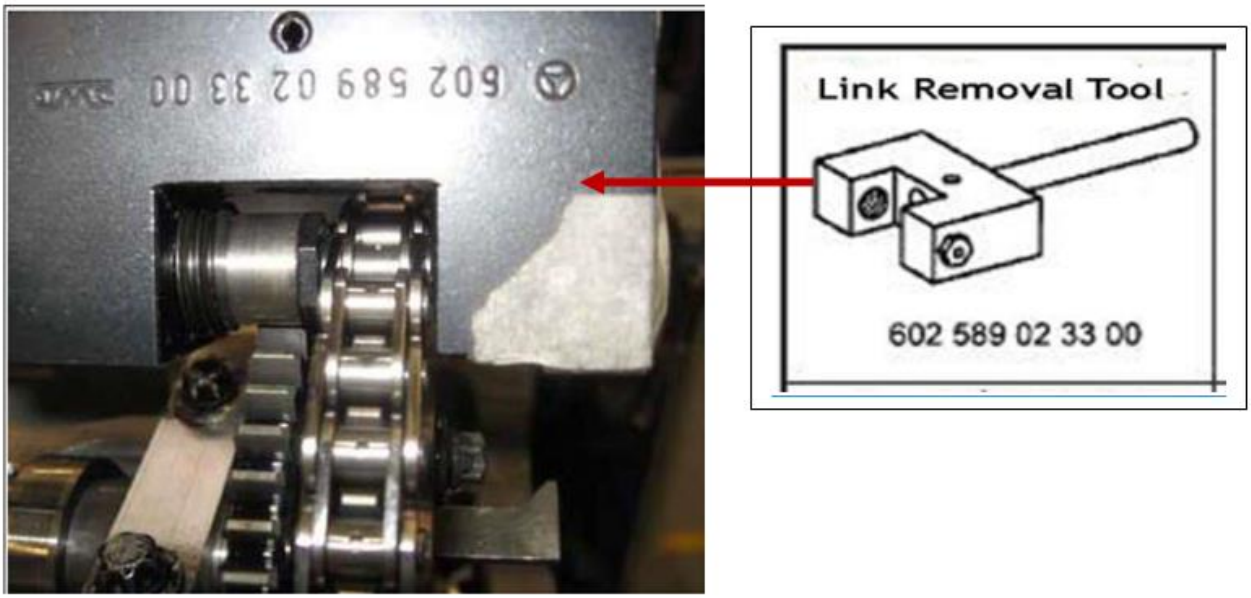


Figure 8: A special tool recommended by the manufacturer for the removal of the timing chain.

Figure 9: A special tool recommended by the manufacturer for the installation of the timing chain.

- The affected timing chain was measured by the manufacturer's engineers. The elongation actual value was calculated to be 0.124%, which was a normal value for this engine run time. If the elongation was higher than 0.5%, the timing chain might have snapped.

- The chain showed a broken side plate at the connecting bolt (pin area). (See Figures 10 and 11). The surface of the bottom connecting bolt showed a damaged surface.

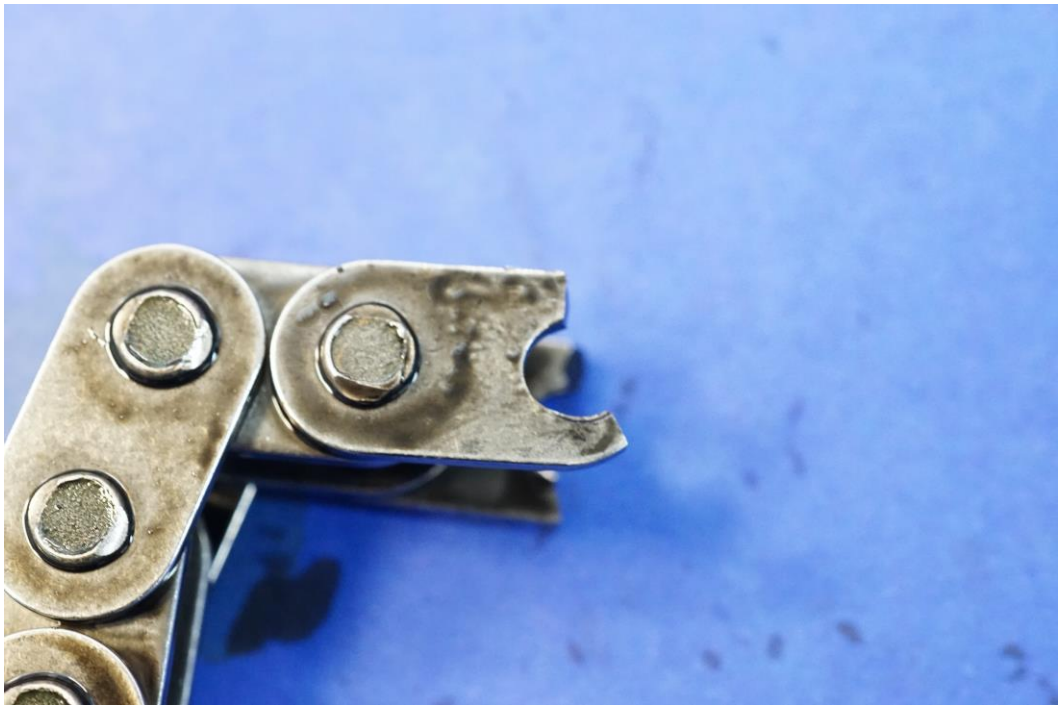


Figure 10: A broken plate.

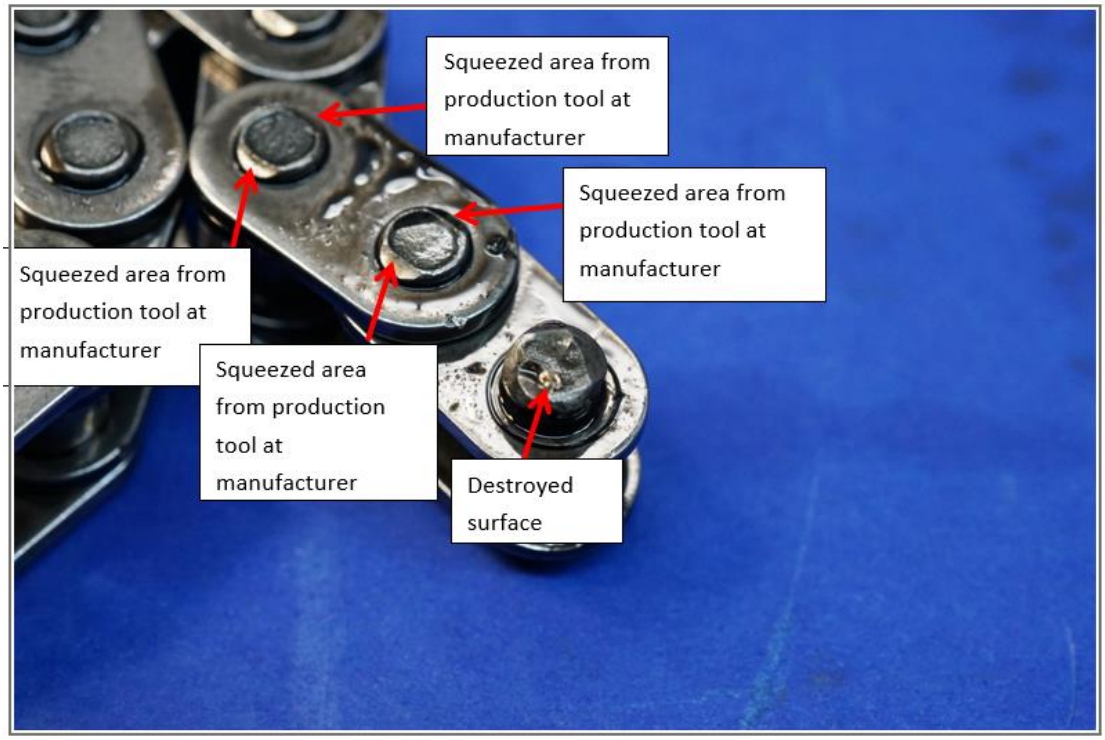


Figure 11: Bolts squeezed by the manufacturer and a damaged bolt/pin.

1.17 Organisational and Management Information

1.17.1 This was a training flight which was conducted under the provisions of Part 141 of the Civil Aviation Regulations (CAR) 2011 as amended.

1.17.2 The training was conducted by an approved Aviation Training Organisation (ATO) which was issued a certificate number CAA/0355 on 6 March 2018 with an expiry date of 31 January 2023.

1.17.3 The ATO allowed the instructor to start training with the student who was not issued a student licence, thus, contravening the provisions of Part 141 of the CAR 2011 and the South African Civil Aviation Technical Standards (SA-CATS), which requires the following:

CAR 141.02.3 QUALITY ASSURANCE SYSTEM

The ATO shall establish a quality assurance system, acceptable to the Director which complies with all requirements as prescribed in Document SA-CATS 141.

CATS 141.02.3 QUALITY ASSURANCE SYSTEM

1. Minimum standards for a quality assurance system

(1) The training organisation shall establish a quality assurance system, acceptable to the Director granting the approval, which ensures that training and instructional practices comply with all relevant requirements.

1.17.4 The last maintenance inspection that was carried out on the aircraft was certified on 26 June 2019 by an approved Aircraft Maintenance Organisation (AMO) number 1223. The AMO was in possession of an approved AMO certificate which was issued on 1 July 2019 with an expiry date of 30 June 2020.

1.17.5 The AMO did not follow the manufacturer's requirements when carrying out the maintenance on the engine, which resulted in the incorrect fitting of the timing chain and the incorrect synchronisation of the camshaft timing gears. This contravened Part 43 of the CAR 2011 as amended, which requires the following:

Carrying out of maintenance

43.02.3 *Any person who carries out maintenance on an aircraft or aircraft component shall—*

(a) have available adequate accommodation and facilities for the necessary disassembly, proper inspection and re-assembly of the aircraft or aircraft component;

(b) use methods, techniques and practices which are—

(i) prescribed in the current manufacturer's maintenance manual or in any instructions for safe operation and continued airworthiness;

(ii) in accordance with the approved maintenance programme for the aircraft;

1.18 Additional Information

1.18.1 Sourced from the internet: https://www.skybrary.aero/index.php/Duplicate_Inspection

Duplicate Inspection

Definition

A second and certified inspection by an appropriately qualified and approved Mechanic which is made during or upon completion of an aircraft maintenance task which is designated as being of sufficient safety significance to require such checking. Most such Duplicate inspections are usually made because of a requirement imposed by a Regulatory body but may sometimes arise just from a requirement internal to a particular maintenance organisation. Careful consideration is always given to introducing a requirement for a duplicate inspection because they are viewed by many as an admission that the standards implicit in Good Maintenance Practice may not always be followed. There is also the additional concern that a duplicate inspection should be specified at such a stage or stages in a maintenance task that it is feasible to make an objective assessment of whether a task has been correctly accomplished.

1.18.2 Sourced from: *Civil Aviation Regulations, 2011*

43.04.8 Duplicate inspections of flight and engine controls

43.04.8 (1) No person shall certify a control system component after the initial assembly, subsequent disturbance or adjustment of any part of such control system, unless—

(a) a duplicate safety inspection of the control system has been carried out; and

(b) the duplicate safety inspection is recorded and certified in the appropriate logbook or other maintenance record approved by the Director.

(2) A duplicate safety inspection authorised in terms of sub-regulation (1), shall consist of—

(a) an inspection by a person referred to in regulation 43.04.1 to certify the release to service of the control system after maintenance; and

(b) a second inspection carried out by another person who is a person referred to in sub-regulation (1) for an aircraft with a MCM in excess of 5700 kg, as prescribed in Document SA-CATS 43; or

(c) a second inspection carried out by another person who is a person referred to in sub-regulation (1) for helicopters with a MCM in excess of 3 175 kg, as prescribed in Document SA-CATS 43; or

(d) a second inspection carried out by another person who is a person referred to in sub-regulation (1) for an aircraft with a MCM below 5 700 kg and helicopters with a MCM below 3 175 kg, as prescribed in Document SA-CATS 43.

1.19 Useful or Effective Investigation Techniques

1.19.1 None.

2. ANALYSIS

2.1 General

From the evidence available, the following analysis was made with respect to this incident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

2.1.1 The instructor was issued a Commercial Pilot Licence (CPL) and a valid medical certificate with a restriction to wear corrective lenses. The instructor was appropriately qualified and type rated to conduct the flight as per the provisions contained in the Civil Aviation Regulations (CAR) 2011 as amended.

2.1.2 The student pilot was not licensed by the Regulator (SACAA) and was not issued a medical certificate as required by Part 61.02.1 of the CAR 2011 as amended, and that was a contravention in terms of the regulation.

2.1.3 The ATO allowed the instructor to conduct training for the student pilot with a knowledge that the student pilot had not been issued a Student Pilot Licence and an aviation medical certificate; this was in contravention of Part 141 of the CAR 2011 as amended.

2.1.4 This was a training flight. On its return flight to FAGM, the aircraft experienced an engine stoppage at a height of approximately 7000ft AMSL and at approximately 5nm east of GAV. The instructor stated that the aircraft's back-up FADEC system had failed to provide engine

power. He then proceeded to activate the FADEC system manually to re-start the engine; but he was unsuccessful. This was due to the rail (fuel) pressure which had dropped from 880-bar down to 2-bar, resulting in an imbalanced air-fuel ratio and causing the engine to experience performance issues such as a decrease in power. The instructor executed a successful forced landing in an open field and the aircraft landed safely with both the instructor and the student pilot reporting no injuries.

2.1.5 The post-incident investigation of the engine revealed that the timing chain had failed, the camshaft timing gears were not synchronised correctly, and the timing chain tensioner was fully adjusted to end. A probability exists that the timing chain tensioner was faulty and, thus, caused the timing chain to be overly tensioned (tightened) and, hence, its failure. The fact that the camshaft gear timing was not correctly synchronised would cause the engine to have a hard start and the valve timing system to not operate correctly.

2.1.6 The aircraft was not maintained in accordance with the approved maintenance schedule and there were misdiagnosed defects of the engine having difficulty to start and of oil and water mixing. Both defects were signed out.

2.1.7 The aircraft had accumulated a total of 13789.6 hours and a further 47.4 hours since its last MPI. The engine had accumulated a total of 752.1 hours since new and had not reached its time for overhaul or replacement at the time of the incident.

2.1.8 During the last MPI, one of the cylinder heads was replaced due to the presence of water in the cylinder head, and work was not done in accordance with RM-02-02 Chapter 73-30.03. The post-incident investigation of the engine was carried out by the manufacturer and it was discovered that there was a crack on the timing chain which caused the distortion of the engine timing, resulting in an engine failure. The AMO stated that they disconnected the timing chain during the cylinder head replacement. It is likely that during the timing chain link assembly, the pin was overly-torqued, resulting in a crack on the side plate and causing the chain to break.

2.1.9 The investigation revealed that the engine stoppage was caused by the timing chain that had broken off, probably due to over tension of the timing chain tensioner, resulting in the valve timing being out of synchronisation and the valves rubbing against the pistons. The contributing factors include incorrectly fitted timing chain and the incorrect alignment of the camshaft gears. The aircraft managed to operate for 47.4 hours because even though the method used to join the chain was not correct, so were the tools used. Under normal circumstances, the rivets/joining pins once pressed by the joining tool, they will have the two overlapping lips consistent with the machined pins (see figure 11), but the ones on ZS-OBD appeared to have been pressed or forced into place by a blunt straight object similar

to a punch and did not form the necessary overlapping lips which lock the joining plate into place. Over time, the joining plate failed due to stress and resulted in the chain separating, causing the engine to cease.

3. CONCLUSION

3.1 General

From the evidence available, the following findings, causes and contributing factors were made with respect to this incident. These shall not be read as apportioning blame or liability to any particular organisation or individual.

To serve the objective of this Investigation, the following sections are included in the conclusions heading:

- **Findings –** are statements of all significant conditions, events or circumstances in this incident. The findings are significant steps in this incident sequence, but they are not always causal or indicate deficiencies.
- **Causes –** are actions, omissions, events, conditions, or a combination thereof, which led to this incident.
- **Contributing factors –** are actions, omissions, events, conditions, or a combination thereof, which, if eliminated, avoided or absent, would have reduced the probability of the accident or incident occurring, or mitigated the severity of the consequences of the incident. The identification of contributing factors does not imply the assignment of fault or the determination of administrative, civil or criminal liability.

3.2 Findings

3.2.1 The instructor conducted his skills test on 25 October 2018 and was issued a Commercial Pilot Licence on 30 October 2018 with an expiry date of 31 October 2020. The instructor was issued an aviation medical certificate on 17 October 2018 with an expiry date of 31 October 2020.

3.2.2 The student pilot did not have a licence or medical certificate at the time of the incident. The student pilot had accumulated a total of 9.6 flying hours, of which 3.4 hours were on the aircraft type.

3.2.3 The ATO contravened Part 61 Subpart 2 of the Civil Aviation Regulations 2011 as amended, which relates to the requirements for student pilot licences.

3.2.4 The aircraft was maintained by an approved AMO number 1223 which was in possession of an approved AMO certificate issued on 1 July 2019 with an expiry date of 30 June 2020. The AMO did not follow the instructions as indicated in Appendix C and as indicated by the engine investigation report following the incident, which indicated that the synchronisation of the camshaft drive gears was wrong, and the timing chain was fitted incorrectly.

3.2.5 The aircraft took off from FAGM on a training flight around Johannesburg general flying area. The aircraft had an engine failure and the pilot executed an emergency landing on an open field.

3.2.6 The last Mandatory Periodic Inspection (MPI) was carried out on 26 June 2019 at 13789.6 hours. The aircraft had accumulated a total of 13837 hours at the time of the incident.

3.2.7 Following the incident, the engine's FADEC system was sent to the manufacturer to determine the cause of failure. According to the report, the FADEC downloading had determined that there were several failed entries of the CAM sensor. The FADEC was missing the CAM sensor of the crankshaft and the rail pressure had dropped from 880-bar down to 2-bar in 157.6 seconds.

3.2.8 Following the engine strip, the synchronisation of the camshaft drive gears and the timing chain were found to have been fitted incorrectly, thus, the AMO failed to follow the requirements of the manufacturer in the maintenance of the engine.

3.2.9 The chain showed a broken side plate in the connecting bolt and the surface of the connecting bolt was also damaged.

3.2.10 The investigation revealed that the engine stoppage was caused by the timing chain that failed, probably due to over tension of the timing chain tensioner, resulting in the valve timing being out of synchronisation and the valves rubbing against the pistons. The contributing factors include the incorrectly fitted timing chain and the incorrect alignment of the camshaft gears.

3.3 Probable Cause/s

3.3.1 The engine stoppage was caused by the timing chain that failed, probably due to over tension of the timing chain tensioner, resulting in the valve timing being out of synchronisation and the valves rubbing against the pistons.

3.4 Contributory Factors:

3.4.1 The timing chain fitted incorrectly.

3.4.2 The incorrect alignment of the camshaft timing gears.

3.4.3 The over tensioning of the timing chain probably due to a faulty timing chain tensioner.

4. SAFETY RECOMMENDATIONS

4.1 General

The safety recommendations listed in this report are proposed according to paragraph 6.8 of Annex 13 to the Convention on International Civil Aviation and are based on the conclusions listed in heading 3 of this report; the AIID expects that all safety issues identified by the Investigation are addressed by the receiving States and organisations.

4.2 Safety Recommendation/s

4.2.1 Safety message: It is recommended that the maintenance organisations establish procedures such as dual inspections to ensure that critical aircraft/engine components do not fail, and to ensure that their maintenance engineers adhere to established procedures.

5. APPENDICES

5.1 FADEC downloaded report – Appendix A

5.2 Engine strip report – Appendix B

5.3 Extracts of Repair Manual CD- 135/ CD-155 RM 02-02 – Appendix C

This Report is issued by:

Accident and Incident Investigations Division
South African Civil Aviation Authority
Republic of South Africa

CONTINENTAL™
AEROSPACE TECHNOLOGIES

DATA ANALYSIS REGISTRATION ZS-OBD

INVESTIGATION

- Date of occurance 16 october 2019
- Aircraft type Cessna C172P
- Engine S/N 02-02-03881
- Investigation of FADEC S/N 10327 D4 data recording

FADEC READ OUT AT BFU

Eventlog entry at date of occurance FADEC A:

10/16/2019 2:02:15 PM - CAM Sensor broken

10/16/2019 2:02:15 PM - Warning Class 137

10/16/2019 2:02:17 PM - CAM Sensor failed 34 times during the last 100 cycles

10/16/2019 2:02:17 PM - Warning Class 136

10/16/2019 2:02:21 PM - Warning Class 119

10/16/2019 2:02:21 PM - Warning Class 45

10/16/2019 2:02:25 PM - High negative PRail delta: up to 855 bar for 10.0 seconds

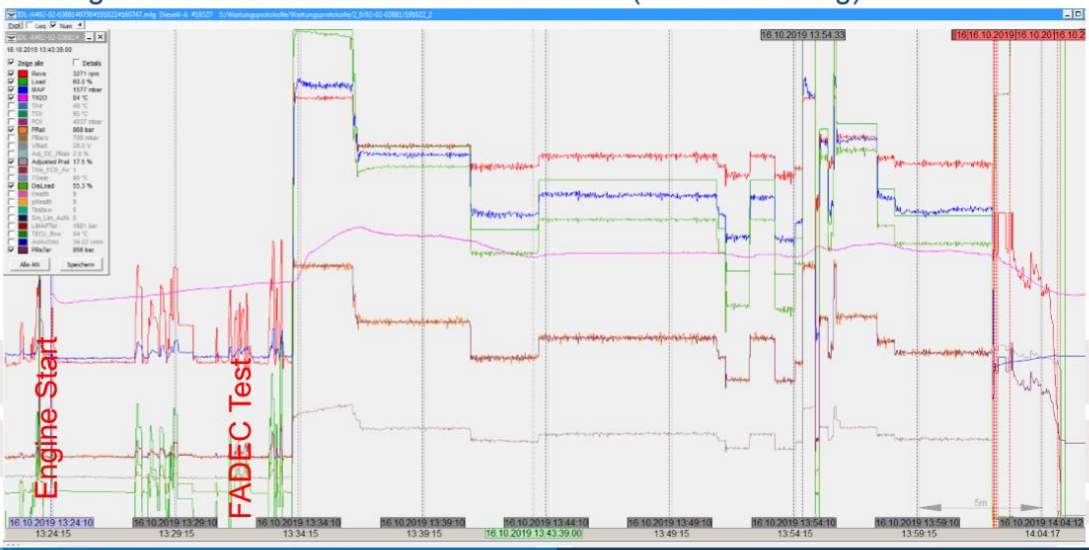
10/16/2019 2:02:25 PM - Low PRail: down to 4 bar for 10.0 seconds

10/16/2019 2:02:54 PM - High negative PRail delta: up to 857 bar for 38.9 seconds

10/16/2019 2:04:53 PM - Low PRail: down to 2 bar for 157.6 seconds

FADEC DATA

- FADEC A
- Engine has been started at 13:24:10 o`clock(FADEC A timing)



FADEC READ OUT

- FADEC A
- 11:45:52 Engine has been stopped
- 13:24:10 Engine has been started again
- 13:31:37 FADEC Test was performed
- 13:33:54 Load @100% selected and Take off performed
- 14:02:13 @62,7% Load; rpm dropped from 3200 1/min down to 2400 1/min
- At this point also the Railpressure decrases from 880bar down to 2bar
- Cam sensor broken was detetecd and a delta in Railpressure
- 14:06:21 engine was shut down after landing

FADEC READ

- Conclusion:
  - The engine quiet at 14:02:13 O`clock FADEC A clocking
  - At this point we got several CAM Sensor broken and failed entries meening that the FADEC is missing the CAM Signal after der Crank Signal
  - We also got the information that the Rail Pressure dropped from 880bar down to 2bar
  - So we have to investigate the engine regarding a fuel system failure or a failure regarding the timing of the engine.
  - This should be done at the Continental Aerospace Technologies GmbH in Germany

Appendix B: Engine Strip Report

Field Notes: Investigation Engine CMG 125-99

Call Sign: **ZS-OBD** **Model: Cessna 172P**

BFU / Continental

St. Egidien/Germany, 11.03.2019

Participants: Thomas Karge / BFU
Sebastian Bätz / TAE

1. Check of serial numbers

The engine was found stored in a box. The box did not show any signs of un-authorized access. The box was sealed by the authority but the seals were found boken.

Engine: TAE 125-02-99 SNo: 02-02-03881

TT: 752:10 Fh

2. General

- The engine was delivered without the kit installation.
- There was no visible damage on the engine.
- Samples of coolant, fuel and oil were collected

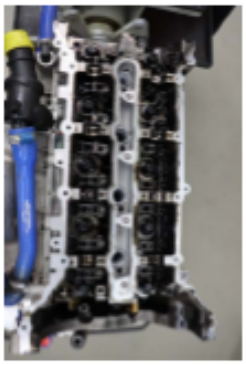
3. Maintenance history

- Cylinder head replacement: 673 Fh
- Dual mass flywheel: 673 Fh

4. Findings

- Crankshaft was rotatable, but with hard stops
- Engine oil was drained
- Leak Test – not possible
- V-Belt in good condition
- CAM sensor #B removed – CAM sensor drive did not turn
- No fuel in the return line (common rail)
- Fuel High Pressure Pump free rotatable
- Synchronization of the cam shaft drive gears was wrong; 2 gears clockwise (~13°)
- CAM-Shaft was checked against then drawing – no difference
- Timing chain was found broken
- Timing chain model G67
- Rocker arm INTAKE #5&6 and Exhaust #7&8 were found broken

- Timing chain was found in the wrong position – holes were on the inner side
- Chain tensioner: fully in end position
- breakaway torque [Nm] Cylinder Head



Intake	Exhaust
210	200
230	210
250	250
200	230
250	200

5. Preliminary conclusion:

The engine failure was caused by the crack of the timing chain. The crack of the timing chain caused the distortion of the engine timing and subsequent contact of the valves and the piston. It is not possible to determine the cause of the crack at that stage of investigation.

6. Further actions

- Investigation of oil sample – Continental
- Investigation of the timing chain – TBD (Continental, Manufacturer, AIB South Africa, ?)
- Engines will be stored at Continental for about 3 month; AIB South Africa should provide a decision about the engine box a.s.a.p.
- AIB South Africa should interview the maintenance personal. It should be clarified if and why the timing chain was disconnected. And if so, how it was connected after that (tooling, procedure etc.).

Thomas Karge

7. Pictures

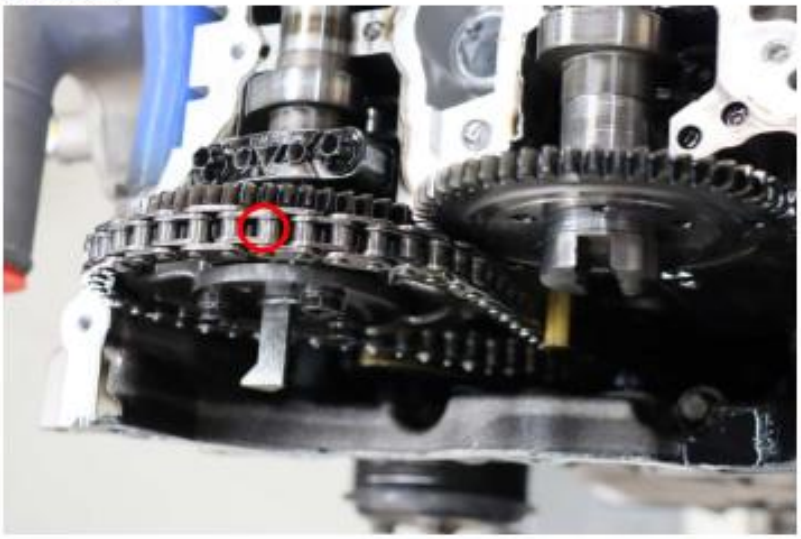


Figure 1: Assembly of the time chain - holes in the bushings not visible

Figure 2: Original assembly of the time chain, holes in the bushings visible Source: TAE Repair Manual

Figure 3: Fracture of the time chain

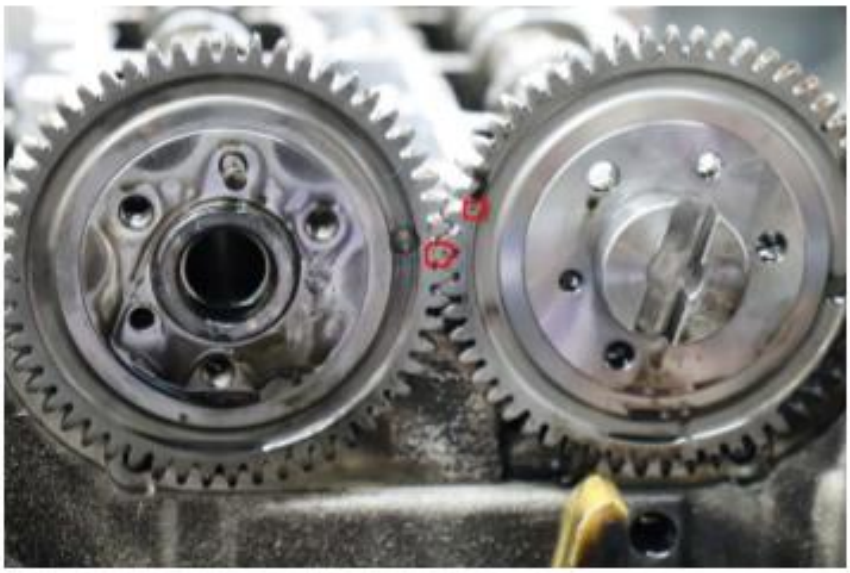


Figure 4: Synchronization of the cam shaft drive gears; shift 2 gears clockwise (~13°)

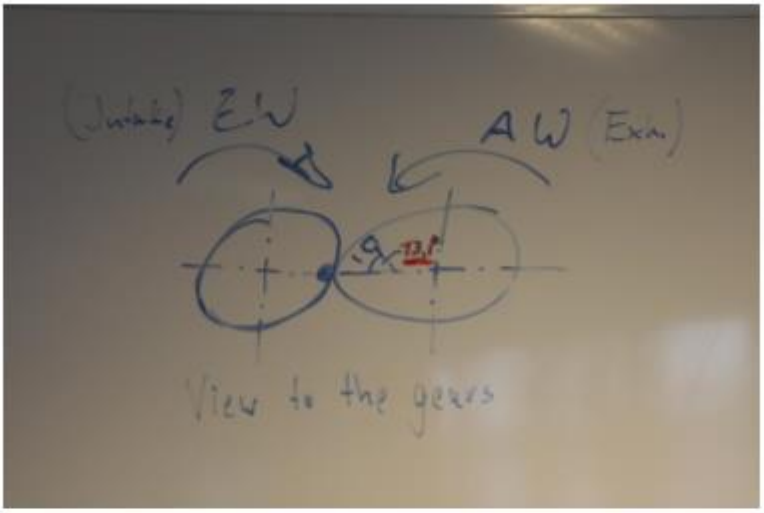


Figure 5: Drawing, Synchronization of the cam shaft drive gears

Source: Extract from Repair Manual CD-135 / CD-155 RM-02-02, Chapter 72-30.02

Repair Manual
CD-135 / CD-155
RM-02-02

Technify Motors

72-30.02 Exchanging the Timing Chain

Parts:

Item	Part Number	Description 1	Description 2	Quantity
1	05-9900-S000603	parts set timing chain exchan.	CD-135 / CD-155	1
	05-9900-S000604	parts set timing chain exchange	CD-135 / CD-155	
		with additional parts for K16 turbocharger		
1.1	02-7250-03144R1	sealing compound	black	1
1.2	05-3710-K000201	gasket	vacuum pump	as req'd up to 1
1.3	05-7231-K001301	gasket valve cover	outside	1
1.4	05-7231-K001401	gasket valve cover	inside	1
1.5	05-7233-K000501	chain wheel		1
1.6	05-7233-K001901	camshaft timing chain	rep. kit	1
1.7	05-7251-K000301	screw with external torx	M7x27 -8.8-E10	3
		only to use with the older version of the emitter P/N: 05-7231-K002602		
1.8	05-7313-K001801	o-ring	for injector	4
1.9	NM-0000-0021601	hose clamp	Aba 26-38x12-W1	as req'd up to 4
1.10	NM-0000-0024401	sealing ring	for injector - Cu	4
1.11	NM-0000-0029601	sealing ring	chain tensioner	1
1.12	NM-0000-0034401	sealing ring	DIN 7603-A12x18-Cu	as req'd up to 2
1.13	05-7313-K000801	screw with internal torx	M6x77 -8.8-TB40	4
	NM-0000-0106601	screw with internal torx	M6x77 -8.8-TB40-A2E	
1.14	NM-0000-0114401	socket cap screw with collar	M7x25 -10.9-A2E	3
1.15	NM-0000-0141201	o-ring	6x2 elastomer	1
	NM-0000-0142401		6x2-80FPM610	
1.16	NM-0000-0143901	o-ring	DIN 3771-9x2-80FKM610	as req'd up to 1
1.17	NM-0000-0149401	o-ring		as req'd up to 1
1.18	VM01678	special grease	timing chain exchange	0,2

Rev. No.: 6
Rev. Date: 01.09.2017

Chapter: 72-30.02
Issue: 3
Issue Date: 30.07.2014
Page: 1
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Item	Part Number	Description 1	Description 2	Quantity
2	05-7231-K002801	cover	chain side - machined	as req'd up to 1
3	VR00308-00-0004	Special Tool Set	cam timing chain	1
3.1	VR00308-00-1901	chain breaker		1
3.2	VR00308-00-2101	riveting tool		1
3.3	VR00308-00-1401	downholder		1
3.4	VR00308-00-1501	assembly link		1
3.5	NM-0000-0216701	parallel pin	ISO 2338 - 6m6x70	2
3.6	05-7231-K001701	downholder (steel)		1
	05-7231-K009201	downholder (aluminum cast)		1
3.7	NM-0000-0107801	screw with external torx (with steel downholder)	DIN 34800-B M6x16-8.8-A2E	1
	NM-0000-0102601	screw with external torx (with aluminum cast downholder)	DIN 34801-B M6GFx28-10.9-A2E	1

4. Disconnect the chain. Use the appropriate special tool and locate it as shown in Figure 6 on one pin. Choose a pin in the middle between downholder and cable tie in the counterclockwise hole of the inner link, it is necessary for the next step. Cover the open end of the pin hole in the tool with a piece of adhesive tape to prevent the loosened pin from falling into the chain slot. See Figure 6.

◆ Note: Before you press out the connecting pin of the chain, screw out bolt which holds the chain in the tool. See Figure 6. The bolt of the tool puts the pin of the chain in position and guides the pressure pin of the tool.

Figure 6

5. Connect the new chain with the old one using a connection link which is part of the special tool set. Take care that the holes in the pin sleeves of the inner chain link are on the outside of the chain (the holes are visible when the chain is lying on the chain wheel). See Figure 7, Figure 8 and Figure 9.

Figure 7

Figure 8

Figure 9

◆ Note: Before turning the engine, remove the coverage from the chain slot.

Figure 15

12. Turn back the spindle and take the pressure pad out of the tool, turn it (see Figure 15) and remount it in the riveting position.
13. To rivet the pin heads place the rivet tool back on the chain and place the pad centered over the head over one of the to-be-riveted pins. They have to be riveted one by one. Turn the spindle slowly until the pad gets in contact with the pin head. Check again the alignment of pad and pin, then turn down the spindle with the correct tightening torque.
Tightening Torque:
32 Nm (283 inch-lbs.)

14. Remove the tool and check the riveting of the pin head. The riveting must look like the one shown in Figure 16.

Figure 16

15. Repeat the riveting accordingly on the second pin.
16. Remove the downholder. Clean the surfaces of shell and camshaft and use fresh oil for the reassembly on the bearing surfaces of camshaft and bearing shell. Remount the bearing shell. Turn in the screws equally and fasten them with the correct tightening torque.
    Tightening Torque:
    12 Nm (106 inch-lbs.)
17. Turn the engine two or three times and check the setting of the cam timing.

■ CAUTION: You must rotate the engine clockwise in flight direction.

◆ Note: Turn the engine very carefully. If there is a stop or resistance TURN BACK and check the timing setup once again!

18. Turn the engine on TDC. See Figure 17.

■ CAUTION: You must rotate the engine clockwise in flight direction.

Figure 17

19. The punch marks on the camshafts teeth must be aligned as shown in Figure 18. Both camshafts have a 6 mm hole, the one of the intake camshaft is shown in Figure 18. These holes must point to the exhaust side and the lower edge must be aligned with the cylinder head surface.

◆ Note: To ensure the correct setting of the camshafts insert P/N: NM-0000-0216701 (part of special tool set P/N VR00308-00-0004) or a cylindrical pin with a diameter of 6 mm and a length of min. 70 mm in both 6 mm holes of the camshaft gears. The cylindrical pins must lie in contact with the cylinder head and must point toward the exhaust side. See Figure 19.

Figure 18

Figure 19

20. Loosen the three screws of the chainwheel and throw them away. They are not usable a second time.
21. Remove the chain tensioner.
22. Remove the old chainwheel and the impulse emitter for the CAM2 sensor (also refer to chapter 72-30.06 / 72-30.07). Do not let the chain fall into the chain slot.

Figure 20

23. Assemble the new chain wheel (item 1.5) and the impulse emitter (also refer to chapter 72-30.06 / 72-30.07). Pay attention to the correct alignment to the camshaft. The wheel must slip easily onto the centering collar and guiding pin, the small hole (Ø5.5 mm) in the emitter must be aligned to the pin. The pin does not sit in the emitter! Oil the threads and the head bearing surfaces of the three new screws. Mount three new screws (item 1.7 / item 1.14) and fasten them hand-tight (see Figure 21, small hole in upper position in the emitter).

◆ Note: Make sure that the impulse emitter is exactly aligned as in Figure 21. Check the points which follow to be sure:

- The small hole (Ø5.5 mm) in the impulse emitter is aligned to the pin on the camshaft
- The small hole (Ø5.5 mm) in the impulse emitter points upwards
- The signal pin of the impulse emitter points to the intake side

◆ Note: Screw (item 1.7) P/N: 05-7251-K000301 is only to use in combination with emitter P/N: 05-7231-K0026XX.
See Figure 21.
In other combinations use screw (item 1.14) P/N: NM-0000-0114401 (also refer to chapter 72-30.06 / 72-30.07).

Figure 21 Figure shows the older version of the emitter P/N: 05-7231-K002602