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Swiss Transportation Safety Investigation Board STSB

Final Report no. 2329 by the Swiss Transportation Safety Investigation Board STSB

concerning the serious incident involving the aircraft PA-28RT-201T, registration HB-PGF,

on 22 October 2016

over Lenzerheide/GR

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General information on this report

This report contains the Swiss Transportation Safety Investigation Board's (STSB) conclusions on the circumstances and causes of the incident which is the subject of the investigation.

In accordance with Article 3.1 of the 10th edition, applicable from 18 November 2010, of Annex 13 to the Convention on International Civil Aviation of 7 December 1944 and Article 24 of the Federal Air Navigation Act, the sole purpose of the investigation of an aircraft accident or serious incident is to prevent accidents or serious incidents. The legal assessment of accident/incident causes and circumstances is expressly no concern of the investigation. It is therefore not the purpose of this investigation to determine blame or clarify questions of liability.

If this report is used for purposes other than accident/incident prevention, due consideration shall be given to this circumstance.

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

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

All times in this report, unless otherwise indicated, are stated in the local time applicable for the region of Switzerland (local time – LT) which corresponded at the time of the serious incident to Central European Summer Time (CEST). The relationship between LT, CEST and coordinated universal time (UTC) is:
LT = CEST = UTC + 2 hours.

Final report

Aircraft type	PA-28RT-201T		Registration HB-PGF	
Operator	Flugschule Basel AG, 4030 Basel, Switzerland			
Owner	BS Business Aviation AG, Schlossbergstrasse 1, 4132 Muttenz, Switzerland			
Pilot	Swiss citizen, born 1953			
Licence	Commercial Pilot Licence Aeroplane (CPL(A)) according to the European Aviation Safety Agency (EASA), issued by the Federal Office of Civil Aviation (FOCA)			
Flying hours	**Total**	1663:20 hours	**during the last 90 days**	15:37 hours
	on the type involved in the incident	729:44 hours	**during the last 90 days**	7:12 hours
Location	Over Lenzerheide/GR			
Coordinates	760 100/ 180 500 (Swiss Grid) N 46° 45' 23" E 009° 32' 04" (WGS)			
Date and time	22 October 2016, 12:02			
Flight rules	Instrument / Visual Flight Rules (IFR/VFR)			
Flight phase	Cruising			
Type of serious incident	Loss of engine power			

Injuries to persons

Injuries	Crew members	Passengers	Total number of occupants	Other
Fatal	0	0	0	0
Serious	0	0	0	0
Minor	0	0	0	0
None	1	2	3	Not applicable
Total	1	2	3	0

Damage to aircraft Minor damage

Other damage None

1 Factual information

1.1 Pre-flight history and history of the flight

1.1.1 General

The pilot's statement together with radar recordings and recordings of radiocommunications between the pilot and air traffic control were used for the following description of the pre-flight history and the history of the flight.

1.1.2 Pre-flight history

On the morning of 22 October 2016 the pilot intended to make a flight with two passengers from Basel Mulhouse Airport (LFSB) to Samedan aerodrome (LSZS). The pilot had been flying the aircraft intended for this flight, a Piper PA-28RT-201T Turbo Arrow, registration HB-PGF, regularly since 2001. The aircraft had been refuelled sufficiently for the intended flight. The pilot then carried out the usual pre-flight checks.

1.1.3 History of the flight

At 10:59 HB-PGF took off from Basel-Mulhouse. The flight was made as planned under IFR as far as the Willisau radio beacon, where the pilot instigated the change of flight rules and then reported to the Zurich Info flight information centre for the onward flight under VFR. HB-PGF then flew over Lucerne and to the south of the Walensee as far as the Rhine valley (cf. Figure 1).

At 12:02, approximately 12 km south of the city of Chur, on a southerly heading and at an altitude of 10,100 ft AMSL[1], the engine suddenly lost power and the aircraft began to vibrate. At the same time the pilot heard a rattling noise from the engine compartment and noticed a pronounced drop in manifold pressure from a norm of approximately 30 in Hg[2] to 15 to 20 in Hg. The pilot immediately initiated a 180 degree turn to the right, so as to avoid flying further into mountainous terrain. He then carried out the manipulations designated for an engine failure. Since the engine continued to provide only reduced power, the pilot then switched off the electric fuel pump. He also realised that moving the throttle control forwards and backwards in the higher power range did not result in any noticeable change in engine performance.

At 12:03:07 the pilot informed Zurich Info of the engine problems and stated his intention to divert to St. Gallen-Altenrhein aerodrome (LSZR). A rattling background noise is audible in this and subsequent recordings of the pilot's radiocommunications. St. Gallen-Altenrhein was known to the pilot from previous flights and the aerodrome weather forecast, which he had consulted in the morning before starting the flight, indicated visual flight conditions. He excluded a return to the departure airport of Basel-Mulhouse because of the noisy running of the engine.

Zurich Info designated Bad Ragaz (LSZE) as the nearest aerodrome, which was at this point in time approximately 30 km north-west of HB-PGF, and Hohenems-Dornbirn (LOIH) in a northerly direction along the Rhine Valley. In view of the short runway length and the unusually steep final approach at Bad Ragaz and the pilot's estimation that a go-around would not be possible because of the reduced engine

[1] AMSL: Above Mean Sea Level

[2] In Hg: inches of mercury, atmospheric pressure in mercury column inches; 1 inHg corresponds to 33.86 hPa

power, he ruled out a landing at this diversion airport. Shortly afterwards, at 12:06:09, he declared an emergency following an enquiry from Zurich Info.

In this flight phase, HB-PGF's engine power was sufficient for it to maintain the aircraft at an indicated airspeed of approximately 90 kt and a rate of descent of approximately 200 feet per minute. From this the pilot concluded that he would reach St. Gallen-Altenrhein at a sufficient altitude and that in the event of a further reduction in power or complete engine failure he would be able to land in the Rhine valley.

After a frequency change to ZURICH DELTA air traffic control centre at 12:06:38, the pilot enquired about the current weather in St. Gallen-Altenrhein, which as expected corresponded to visual flight weather conditions. When passing Vaduz/FL at an altitude of 7500 ft AMSL, he reported that he had already made visual contact with the aerodrome to the north, at a distance of 38 km. In the Hohenems region, he realised that the flight altitude of approximately 4500 ft AMSL was more than sufficient for the onward flight, and then increased his rate of descent. Entry into the St. Gallen-Altenrhein control zone occurred over reporting point Sierra; this was followed by a direct approach and a normal landing on runway 28 at 12:28:11.

The fire service, which was on standby at the runway threshold, followed HB-PGF to the north apron, where the local maintenance company is located, and the pilot brought HB-PGF to a standstill and switched off the engine. The fire service then informed the pilot about the unusual, rattling engine noise which had been audible on the final approach.

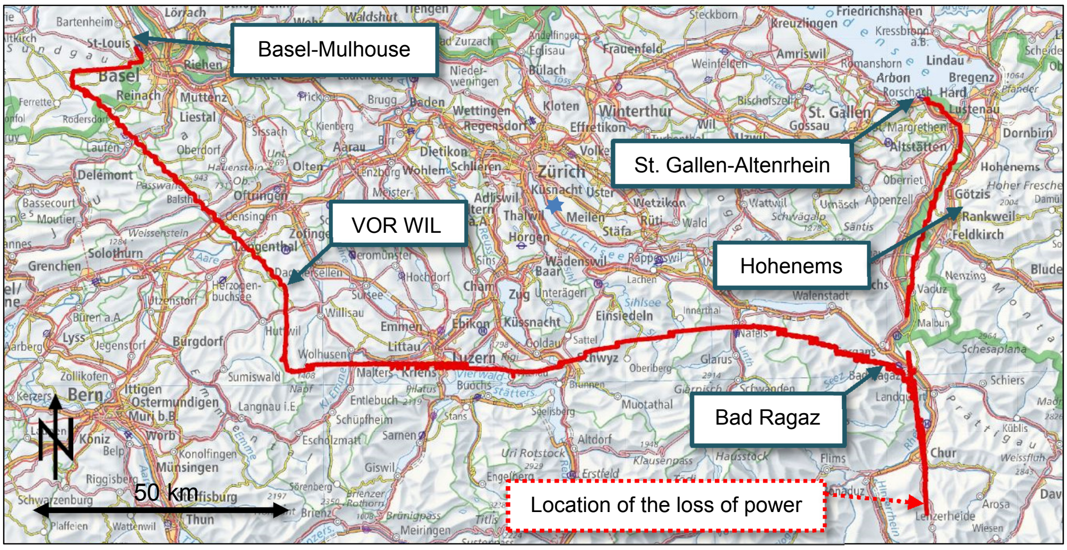


Figure 1: Flight path (red) from Basel to St. Gallen-Altenrhein according to the secondary radar recordings (interrupted points were not recorded by the radar); origin of base map: Federal Office of Topography

1.2 Meteorological information

1.2.1 General weather situation

The Alpine region was on the edge of a low centred over eastern Germany.

1.2.2 Weather at the time and location of the serious incident

The weather was dry; visibility was good. A light southerly wind was blowing along the valleys of the Grisons Alpine passes. Above approximately 10,000 ft AMSL the wind was turning to the west south-west. In the northern part of the St. Gallen Rhine Valley the mist was increasing slightly. Along the flanks of the Rhine valley there was flat-based cumulus cloud, which had developed from areas of morning low stratus.

Between the Lenzerheide and St. Gallen-Altenrhein dry weather prevailed, with visibility in excess of 10 km. Around the Alpstein and in the neighbouring Vorarlberg there was 2/8 CU with a base at 3300 ft AMSL. Fields of transparent altocumuli were moving above the Grisons.

Weather	Light cloud and dry
Cloud	3/8 AC (alto cumulus) at 20,000 ft AMSL
Visibility	20 km
Wind at 10,000 ft AMSL	250 degrees, 10-15 kt
Temperature/dew point at 10,000 ft AMSL	-7 °C / -17 °C
Atmospheric pressure (QNH)	1015 hPa (pressure reduced to sea level, calculated using the values of the ICAO[3] standard atmosphere)
Trend	No significant change

1.2.3 Astronomical information

Lighting conditions	Daylight	
Position of the sun	Azimuth: 163 degrees	Elevation: 30 degrees

1.3 Aircraft information

1.3.1 General information

Registration	HB-PGF	
Aircraft type	PA-28RT-201T (Turbo Arrow IV)	
Characteristics	Single-engine four-seater aircraft, full metal construction, constructed as a low wing aircraft with T-tail and retractable landing gear	
Manufacturer	Piper Aircraft Corporation, Vero Beach Florida, USA	
Engine	Manufacturer:	Continental Motors Inc., Alabama, USA
	Type:	TSIO-360-FB1B
	Serial number:	1010301
	Power:	200 PS at 2575 RPM[4]

[3] ICAO: International Civil Aviation Organisation,

[4] RPM: Revolutions per minute

Operating hours	Airframe: 9347:10 hours TSN[5] Engine: 716:04 hours TSN
Mass and centre of gravity	Both mass and centre of gravity were within the permissible limits according to the Aircraft Flight Manual (AFM).
Technical restrictions	None registered

1.3.2 Maintenance work on the engine

On 22 May 2014 the engine underwent a complete overhaul (factory-rebuilt engine) by the engine manufacturer and the TSN was reset to 0:00 hours. The engine was then installed in HB-PGF on 16 June 2014.

On 26 February 2015, at 194:21 hours TSN (engine), all paper gaskets on the valve covers were replaced with silicone gaskets.

On 15 October 2015, at 386:01 hours TSN (engine), cylinder number 3 was replaced because of excessively low compression.

The owner of the aircraft stated that after a flight on 10 June 2016 vibration in the right rudder control pedal had been reported by a pilot. The engine TSN at this time was 576:51 hours. A visual inspection of the engine compartment and the flight controls, a test retraction and extension of the landing gear in the hangar and a subsequent test flight did not reveal any faults. The event had accordingly been entered in the logbook and in the work order on the occasion of a 100-hour check on 16 June 2016.

According to the HB-PGF technical documents, the most recent 100-hour check on the airframe and engine was carried out on 7 September 2016, at 9312:59 hours TSN (airframe) and 681:53 hours TSN (engine), and the work was certificated in the maintenance documentation.

1.3.3 Engine information

The Continental IO-360 is a 6-cylinder aircraft engine made by the US manufacturer Continental Motors Inc. and developed for service in light aircraft. Among others, the turbocharged TSIO-360 engine variant is fitted in the following aircraft types: Cessna T-337 Skymaster, Piper PA34 Seneca and Mooney M20K.

On this type of engine one inlet valve and one exhaust valve is installed in each cylinder head; these are installed in the cylinder from the combustion chamber (an OHV engine). Each valve is controlled by a cam on the cam shaft in the crankshaft casing. The cam lift is transferred to the rocker arm via a pushrod. This rocker is mounted and actuated externally on the cylinder head on the rocker shaft, i.e. it opens and closes the valve. The rocker shaft is mounted on the cylinder head at both ends by means of a retainer, a tab washer and a hex nut, on stud bolts (cf. Figure 2). Each rocker arm is hermetically sealed by the valve/rocker cover, made from deep-drawn sheet metal. This prevents engine oil from leaking or contaminants from entering the engine.

[5] TSN: Time Since New

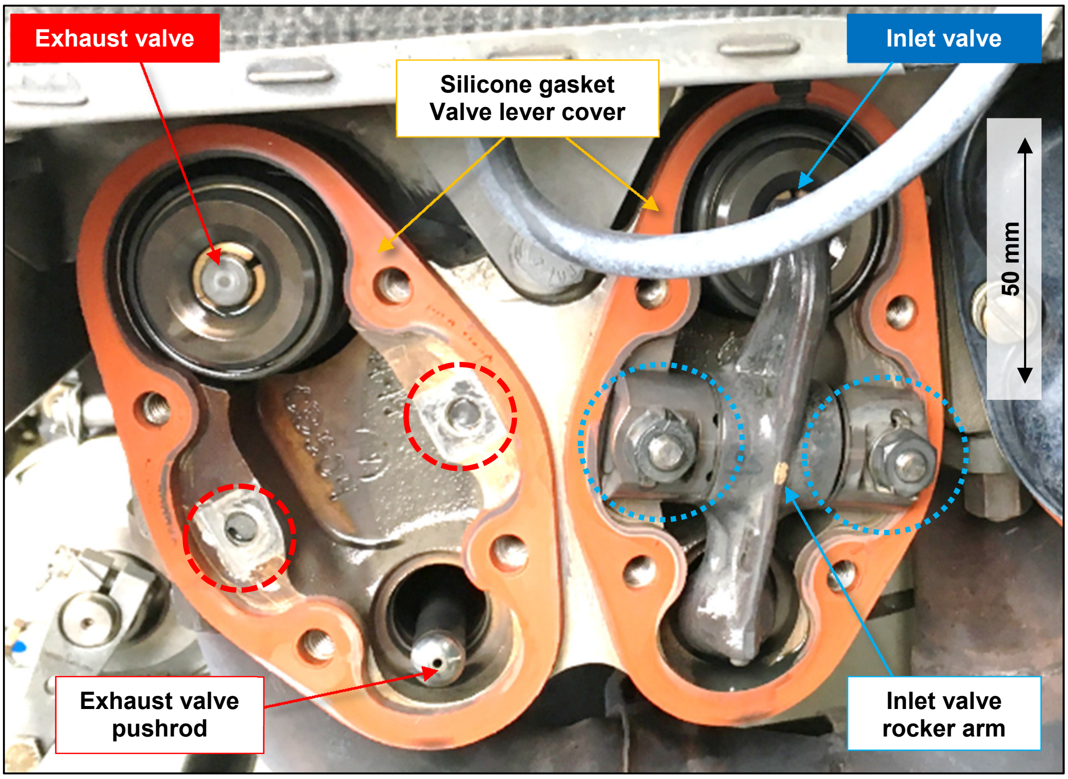


Figure 2: Cylinder no. 6 after dismantling the valve lever cover; inlet valve (right) with installed rocker arm, the axis of which is secured at both ends by a retainer, a tab washer and a hex nut on the stead bolts (dashed blue circles); exhaust valve (left) with sheared stud bolts (dashed red circles)

Installation of the studs and the subsequent installation of the rocker/rocker arm and the two retainers, the tab washers and the hex nuts is carried out during manufacture of the engine in the factory. Tightening torques must be complied with for these assembly operations. These tightening torques are not checked during periodic maintenance operations.

1.4 Engine findings

After the landing, cylinder no. 6 was removed from HB-PGF and disassembled. The findings were as follows:

- The two studs for the assembly of the rocker shaft for the exhaust valve were broken (Figure 3).
- The fracture occurred at the end of the fully screwed-in threaded part, at a point where the studs exhibit the smallest cross-section and the greatest notch sensitivity.
- No loosening was detectable on the remaining sheared-off sections of these studs, which were still mounted in the threads in the aluminium cylinder head.
- On the inside of the valve cover (rocker arm cover) and on various parts of the mechanism of the exhaust valve, various types of contact damage were found (Figure 4).
- The inlet valve pushrod was bent.
- The exhaust valve pushrod was undamaged.

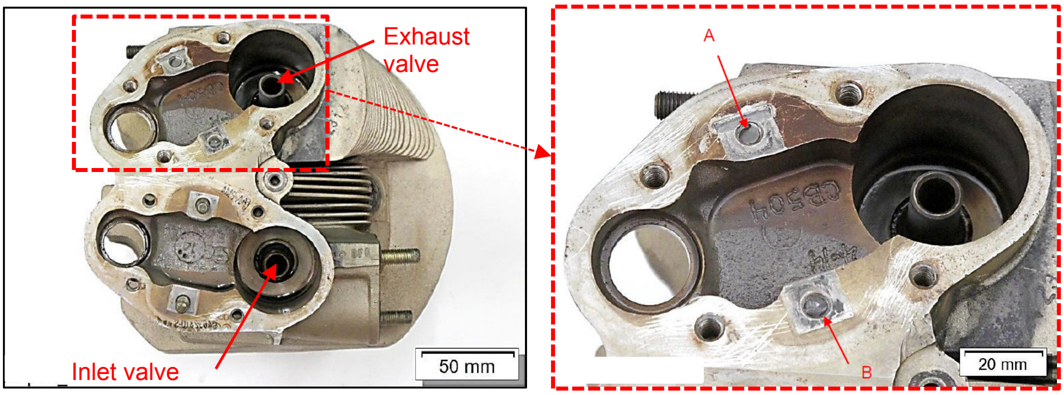


Figure 3: View of cylinder no. 6, from the valve side; the area bordered in red with the two sheared studs A (outside) and B (inside) of the exhaust valve is shown on the right, enlarged.

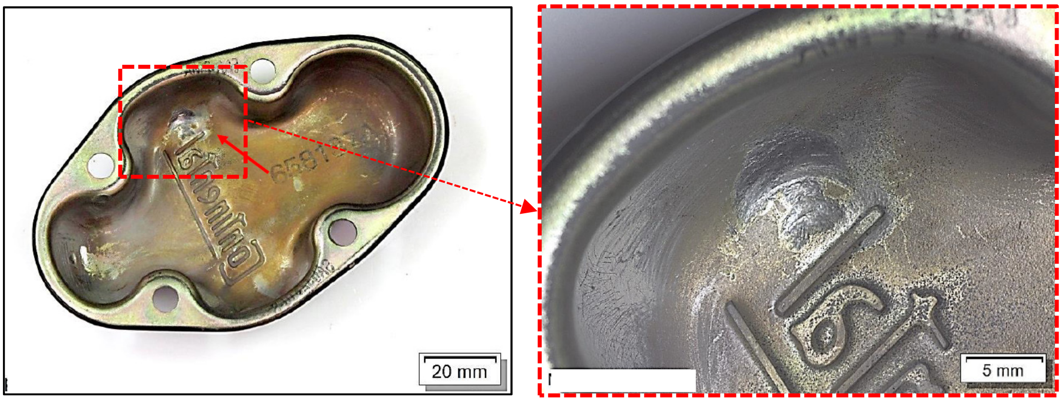


Figure 4: Inside of the exhaust valve cover with contact damage (red arrow); the area outlined in red is shown on the right, enlarged.

The cylinder no. 6 exhaust valve cover and the rocker with all individual parts are shown in

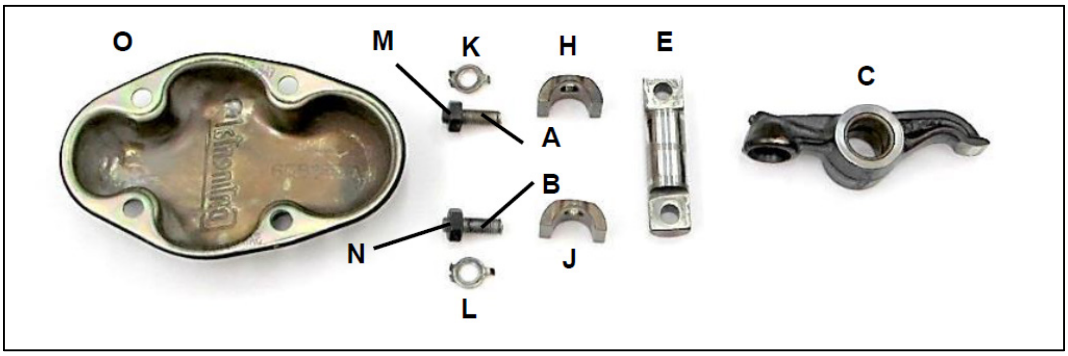


Figure *5*. The designations of the individual parts can be seen in the table below:

Part	Designation	Description
A	*Stud.25-20-28X1.41#401850 outside*	Sheared part of the stud, outside
B	*Stuc.25-20-28X1.41#401850 inside*	Sheared part of the stud, inside
C	*Rocker assy-valve*	Rocker
E	*Shaft-valve rocker*	Rocker shaft with running marks
H	*Retainer-R/arm thrust outside*	Retainer for rocker arm, outside
J	*Retainer-R/arm thrust inside*	Retainer for rocker arm, inside
K	*Washer-tab .26 diameter outside*	Tab washer, outside
L	*Washer-tab .26 diameter inside*	Tab washer, inside

M	*Nut-plain outside*	Hex nut, outside
N	*Nut-plain inside*	Hex nut, inside
O	*Cover-valve rocker*	Valve/rocker damaged inside

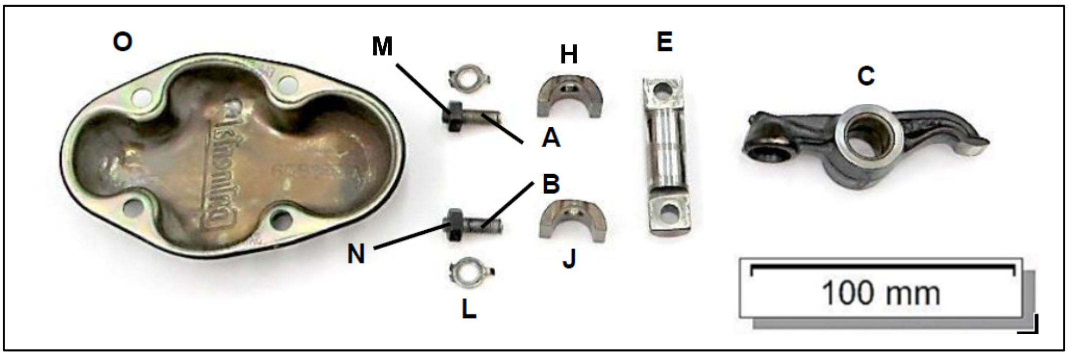


Figure 5: Exhaust valve cover with rocker and individual components of cylinder no. 6

1.5 Tests and research results

1.5.1 Metallurgical investigations

The two fracture surfaces were examined in the laboratory using a scanning electron microscope (SEM). From this investigation it is possible to clearly establish whether this was an oscillation fracture, commonly known as a fatigue fracture, or an overload fracture.

According to the test results the fracture of the inside stud was a fatigue fracture, whereas the outside stud failed because of an overload fracture.

In addition, other components of the two broken bolt connections were examined. For purposes of comparison of these results, components of the adjacent inlet valve on the same cylinder, which were intact after the serious incident, were examined. The strength and chemical composition of the material of the cast cylinder head and of the retainer were also determined in the laboratory.

The two sheared-off parts of the studs and the intact inlet valve stud, which was dismantled and intact, were examined by applying the Vickers hardness testing method[6]. The same procedure was used to examine the three tab washers and nuts used in the assembly.

According to the test results, the strength values of the three studs were identical. The same was also true of the tab washers and the nuts. None of the tested components exhibited insufficient strength.

According to the chemical analysis of the cylinder head material and the retainers, the measured strength values of these materials are as expected; inadequate quality or strength can therefore be excluded.

1.5.2 Forensic comparison

In the area of the sheared-off studs the following damage was found:

- The valve/rocker cover exhibited a plastic deformation indentation caused by the front surface of the inside stud (cf. Figure 4). The indentation was clearly visible and is congruent with this front surface.

[6] Hardness test, penetration of a test piece according to the Vickers method

- The tab washer for the rocker shaft assembly with the inside stud was bent off. This tab prevents the washer from rotating during assembly.
- Marks on the inside of the valve/rocker cover are congruent with the marks on the end of the rocker.
- In the immediate vicinity of the clamping area of the outside stud, the contact area of the cylinder head had oblique indentations (cf. Figure 6). This oblique indentation came from a rocker shaft which was positioned accordingly.
- In the case of the fixing of the rocker shaft, the clamping and contact surfaces exhibited impact wear, cavitation wear, tribooxidation (reaction layer wear) and some adhesive deposits.
- The inside sheared-off part of the stud exhibited pronounced surface damage (cf. Figure 7). Such damage is caused by an oscillating counterpart.

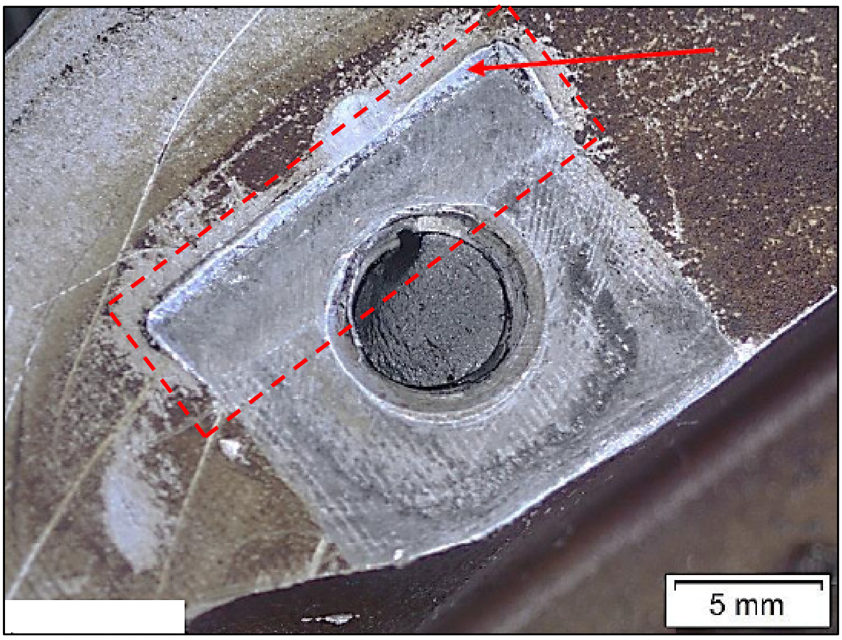


Figure 6: Contact surface of the cylinder head in the retention area of the outside stud with the oblique indentation (red arrow and border)

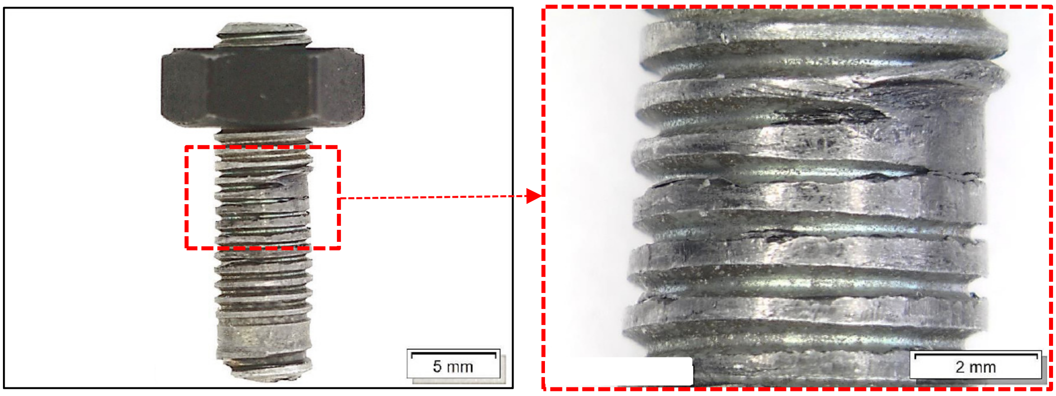


Figure 7: Inside sheared part of the stud bolt exhibiting pronounced surface damage

1.5.3 Investigation of the inlet valve pushrod

The bent inlet valve pushrod of cylinder no. 6 was examined. The critical buckling load at which this pushrod is bent is 7.2 kN. In the case of a non-opening exhaust valve, the pushrod is subjected to a compressive force of approximately 10.0 kN. This value is based on a cylinder internal pressure of 60 bar.

1.6 Assembly of the engine by the engine manufacturer

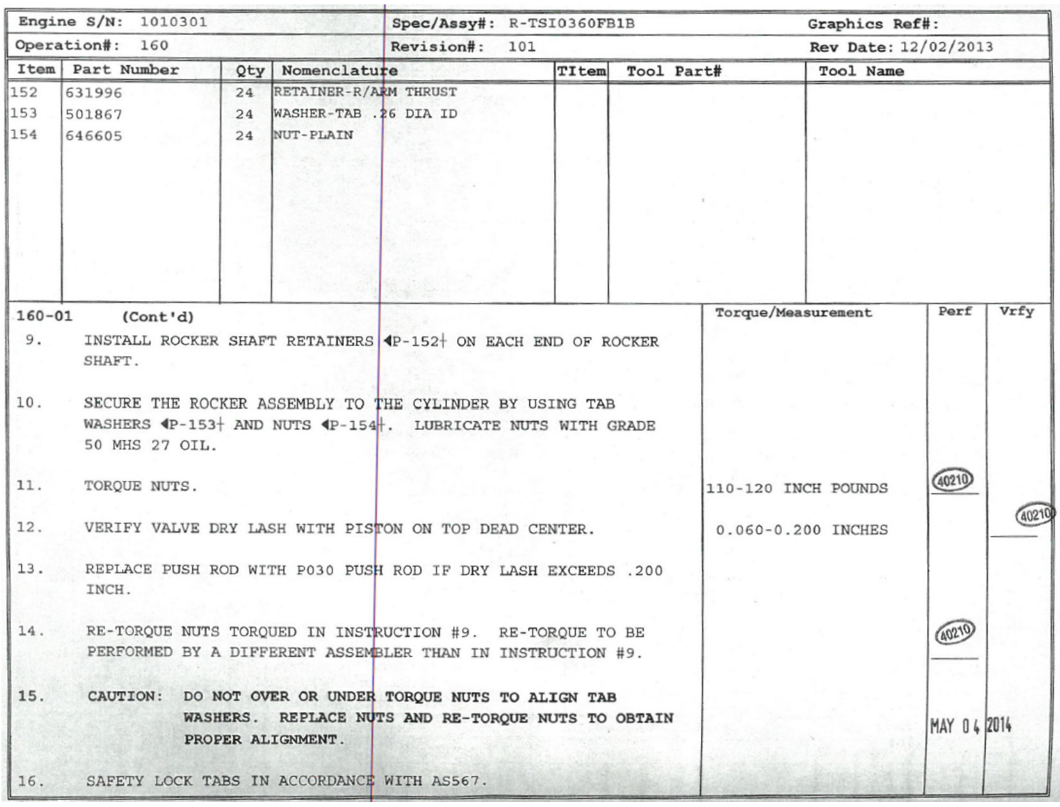
1.6.1 Installation of the studs

The studs were screwed into the cylinder head by the engine manufacturer using an assembly device applying a defined torque. The recorded torque procedure, which is contained in the “Torque Signature and Bolt Stretch Report” document, did not reveal any anomalies.

1.6.2 Installation of the rockers

The rockers were installed manually by the engine manufacturer and the nuts on the studs were tightened to a defined torque. The assembly of the rockers was recorded in the build record excerpt document (cf. Figure 8). From this it is evident that the tightening of the nuts (work procedures 9 to 11) and the checking of the tightening torque (work procedure 14) were written off using the same stamp number. According to the engine manufacturer's statement, each stamp number is uniquely assigned to one individual.

In addition, according to the build record excerpt it is prescribed that the check on the tightening torque must be carried out by a different person: “*Re-torque to be performed by a different assembler than in instruction #9*”.



Engine S/N: 1010301 | Spec/Assy#: R-TSI0360FB1B | Graphics Ref#:
Operation#: 160 | Revision#: 101 | Rev Date: 12/02/2013

Item	Part Number	Qty	Nomenclature	TItem	Tool Part#	Tool Name
152	631996	24	RETAINER-R/ARM THRUST			
153	501867	24	WASHER-TAB .26 DIA ID			
154	646605	24	NUT-PLAIN			

160-01 (Cont'd)	Torque/Measurement	Perf	Vrfy
9. INSTALL ROCKER SHAFT RETAINERS ◄P-152┼ ON EACH END OF ROCKER SHAFT.			
10. SECURE THE ROCKER ASSEMBLY TO THE CYLINDER BY USING TAB WASHERS ◄P-153┼ AND NUTS ◄P-154┼. LUBRICATE NUTS WITH GRADE 50 MHS 27 OIL.			
11. TORQUE NUTS.	110-120 INCH POUNDS	40210	
12. VERIFY VALVE DRY LASH WITH PISTON ON TOP DEAD CENTER.	0.060-0.200 INCHES		40210
13. REPLACE PUSH ROD WITH P030 PUSH ROD IF DRY LASH EXCEEDS .200 INCH.			
14. RE-TORQUE NUTS TORQUED IN INSTRUCTION #9. RE-TORQUE TO BE PERFORMED BY A DIFFERENT ASSEMBLER THAN IN INSTRUCTION #9.		40210	
15. CAUTION: DO NOT OVER OR UNDER TORQUE NUTS TO ALIGN TAB WASHERS. REPLACE NUTS AND RE-TORQUE NUTS TO OBTAIN PROPER ALIGNMENT.		MAY 04	2014
16. SAFETY LOCK TABS IN ACCORDANCE WITH AS567.			

Figure 8: Build record excerpt

2 Analysis

2.1 Technical aspects

2.1.1 Fracture of the studs

After the landing, the engine in HB-PGF, which had not seized, was examined. During disassembly of the cylinder no. 6 valve covers, it was found that both studs on the exhaust valve had fractured. The rocker arm is mounted on the cylinder head using these stud bolts. As a consequence of this failure, the exhaust valve could no longer be opened, so the engine disproportionately lost power, vibrated and stopped running smoothly.

After the fracture of the two studs, the rocker arm together with the rocker was moved back and forth over the pushrod by the cams on the camshaft. This caused the indentations found on the inside of the valve cover and on the rocker. This process was perceived by the pilot as a rattling engine noise.

The strength of the fractured studs and that of the disassembled intact studs was determined in the laboratory using the Vickers hardness testing method. The strength of the corresponding tab washers and nuts was determined using the same method. None of the tested components exhibited insufficient strength. The cylinder head is an aluminium alloy casting, and the retainers used for assembly corresponded to normal values in terms of strength and chemical composition. From the above-mentioned investigations, a material defect can be excluded.

The service life of a dynamically stressed bolted connection is dependent on the pre-tensioning, i.e. on the elasticity of the bolt and stud respectively, the retained parts, the tightening torque and the type and magnitude of the load. Under dynamic stress, screws and studs which are not sufficiently pre-tensioned exhibit insufficient durability; fracturing of the bolt occurs due to fatigue

The fracture of the inside stud is clearly a fatigue failure. The retaining or contact areas of this bolted connection exhibited impact wear, cavitation wear, tribooxidation and some adhesive deposits, all of which suggest micro-movements in this area. Such micromovements occur in the event of insufficient clamping force of a bolted connection and dynamic load. The surface damage to the thread of the sheared inside stud was caused by the oscillating counterpart, i.e. one end of the rocker arm. This and the bent tab of the washer used in the assembly also indicates that the bolted connection was loose before the stud fractured.

The cause of the failure of the inside stud was insufficient tightening of the nut during assembly of the rocker. This assembly error resulted in insufficient gripping force of this bolted connection. It came loose in operation and the bolted connection then fractured.

The fracture of the outside stud was a forced rupture. There were no indications of any fatigue. After the failure of the inside stud, the rocker was bolted to the cylinder head only at the outside end. This resulted in extreme stress on this bolted connection, due to the lever effect which occurred. The outside stud then fractured. The outermost part of the bearing surface of the rocker arm was pressed plastically and obliquely into the cylinder head. The fracture of the outside stud is attributable to the failure of the inside stud.

The investigations also revealed that the threaded ends of the studs, screwed into the cylinder head, had not worked loose. From this it can be concluded that incorrect screwing of the studs into the cylinder head can be excluded.

2.1.2 Evaluation of the bent inlet valve pushrod

During operation, the inlet valve is opened by the corresponding cam on the camshaft via the pushrod and the rocker arm. The force which is applied to the pushrod in the process results from the force of the valve spring and the counter-pressure in the cylinder. In normal operation this counter-pressure is low. If the exhaust valve does not open, the counter-pressure in the cylinder becomes extremely high, which means that the pushrod can be excessively stressed when the inlet valve opens and as a result may undergo deformation.

From the calculations it is apparent that the compression stress on the inlet valve pushrod when the exhaust valve did not open was excessive. The bending of the pushrod is therefore due to the exhaust valve not opening, which was in turn due to the fracture of the two studs.

2.2 Human and operational aspects

2.2.1 Flight management

The pilot was not aware of the impending failure of the valve rocker arm which caused engine power loss.

The decision not make an approach on the diversion airport of Bad Ragaz, which was closer though had a short runway and terrain which represented an obstacle situation, but to follow the Rhine Valley with its various emergency landing options as far as St. Gallen-Altenrhein, is comprehensible and prudent.

2.2.2 Assembly of the engine by the manufacturer

The insufficient tightening of the nuts, which was the cause of the failure of the inside stud, was not detected when the engine was assembled on the manufacturer's premises. The principle of a check being carried out by a second person, as prescribed in the validation documentation for the assembly of these nuts, had clearly not been applied in the present case.

3 Conclusions

3.1 Findings

3.1.1 Technical aspects

- The aircraft was licensed for IFR and VFR operation.
- The mass and centre of gravity of the aircraft at the time of the serious incident were within the permissible limits according to the AFM.
- On 22 May 2014 the engine underwent a complete overhaul by the engine manufacturer.
- The last maintenance activities within a 100-hour check were carried out on 7 September 2016 at 681:53 hours TSN (engine).
- In the case of cylinder no. 6 a stud used to secure a rocker arm suffered a fatigue fracture leaving a small residual broken section.
- The cylinder's exhaust valve no longer opened, resulting in high counter-pressure in the cylinder. This caused a disproportionate reduction in engine power.

3.1.2 Crew

- The pilot was in possession of the licences necessary for the flight.
- There are no indications of the pilot suffering any health problems during the flight involved in the serious incident.

3.1.3 History of the flight

- At 10:59 the pilot took off in the Piper PA-28RT-201T, registration HB-PGF, with two passengers on board, from Basel-Mulhouse airport on a private flight to the Samedan aerodrome.
- At 12:02, at an altitude of 10,100 ft AMSL over the Lenzerheide the engine lost power and the aircraft began to vibrate.
- The pilot heard a rattling noise from the engine compartment and noted a reduction in engine power.
- He decided to divert to St. Gallen-Altenrhein aerodrome.
- The reduced engine power allowed the pilot to control the aircraft as it descended at an average rate of descent of 200 feet per minute.
- At 12:28 HB-PGF landed in St. Gallen-Altenrhein on runway 28 after a direct approach.

3.1.4 General conditions

- The weather had no effect on the serious incident.
- The prescribed dual verification principle for assembly of the nuts onto the threaded studs was not applied in accordance with the validation documentation.

3.2 Causes

The serious incident, in which a reduction in engine power occurred, is attributable to a failure of the exhaust valve rocker arm mount on one cylinder due to an assembly error; as a result of this, the exhaust valve no longer opened.

4 Safety recommendations, safety advices and measures taken since the serious incident

4.1 Safety recommendations

None

4.2 Safety advices

None

4.3 Measures taken since the serious incident

None

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

Bern, 26 April 2018 Swiss Transportation Safety Investigation Board