CIVIL AVIATION AUTHORITY
OF NEW ZEALAND
Te Mana Rererangi Tūmatanui o Aotearoa

CAA Safety Investigation Report

Engine failure after take-off

ZK-SMF Titan T-51D Mustang

Matamata Aerodrome

18 October 2016

CAA Final Report 16/5545
[04 October 2018]

Contents

Executive summary

At approximately 1152 hours New Zealand Daylight Time[1] on 18 October 2016, the Civil Aviation Authority (CAA) received notification from the Rescue Coordination Centre that ZK-SMF, a Titan T-51D Mustang amateur-built aircraft, had crashed on Matamata aerodrome fatally injuring the pilot. The Transport Accident Investigation Commission was notified but chose not to investigate. A CAA field investigation was commenced the following day.

On the day of the accident the pilot had intended to carry out a local flight. During take-off, an engine power loss occurred at approximately 250 feet above ground level (AGL). The aircraft was observed to descend steeply and strike the ground approximately 40 metres off the end of the runway.

ZK-SMF was a three-quarter scale replica aircraft, which had been built from a kitset by a team of aircraft engineers with assistance from the pilot. The pilot had chosen to fit a Mazda 13B Renesis rotary engine to the aircraft; this was the only known example with this engine installation.

The pilot had carried out unsupervised maintenance on the #2 Engine Control Unit (ECU[2]) when he had the fuel schedule map modified. This may have accounted for the loss of engine performance and subsequent total engine power loss.

When the aircraft struck the ground, the shoulder harness failed to restrain the pilot's upper body allowing him to strike the instrument panel and control stick, resulting in fatal injuries. The positioning of the pilot's shoulder harness attachment to the pilot's seat frame caused the seat frame to fail.

The CAA safety investigation determined that the accident forces involved when the aircraft struck the ground, were within the range considered survivable for human tolerance.

First responders to the aircraft had difficulty opening the cockpit canopy to gain access to the pilot. The pilot had incorporated a modification to the aircraft and had installed internal canopy locks which could not be accessed externally.

Safety action

The CAA issued a Continuing Airworthiness Notice (CAN) 25-001 *Titan Aircraft Company T-51D Mustang – Seat Belt Attachment* in September 2017. The CAN advises owners of the recommended shoulder harness attachment location. (Refer to Appendix 1).

[1] New Zealand Daylight Time is GMT + 13 hours

[2] ECU Engine control unit, is a type of electronic control unit that controls functions such as ignition and fuel on an internal combustion engine to ensure optimal engine performance

Safety messages

Modifications to the aircraft

During the construction of an amateur-built aircraft, the owner may incorporate modifications to the original design. The suitability of those modifications is generally overseen by a licenced aircraft engineer and then ultimately proven during the flight testing phase.

Following construction, all modifications to an amateur-built aircraft must be carried out subject to the conditions on the airworthiness certificate and requires careful analysis to ensure the aircraft remains safe to fly.

In the case of ZK-SMF, the pilot made a modification to the aircraft by installing internal canopy locks. Given a different set of circumstances, this modification had the potential to affect the chances of the pilot's survival in an accident. First responders to the aircraft would not be able to easily open the canopy to gain access to the pilot.

Pilot maintenance

It is likely that the majority of aircraft owners will want to carry out maintenance work on their aircraft themselves, either in an attempt to keep maintenance costs to a minimum, or just for the fact that they enjoy working on the aircraft.

Owners of aircraft issued with an airworthiness certificate must have a clear understanding of CAR 43 *General maintenance rules* relating to what specific maintenance tasks they may perform.

CAA *Vector* magazine issues September/October and November/December 2017 contain articles providing advice and information on pilot maintenance.

Incident dateline

2006	Aircraft construction commenced from kitset under guidance of a local maintenance provider
2009	Aircraft construction completed and aircraft registered with the CAA as ZK-SMF
December 2009	Initial inspection of aircraft for issue of Special Category Airworthiness Certificate to enable test flying to begin.
December 2009	First flight completed on 24 December and test flight programme commenced
June 2010	Aircraft damaged during taxiing when the left-hand landing gear collapsed causing significant damage
November 2010	Repair work completed following left hand landing gear collapse completed
September 2012	Test flying completed, CAA issued Special Category – Amateur-built Airworthiness Certificate
February 2014	Engine ignition switch positions and functions modified
November 2015	Engine starter ring gear broke free in flight causing damage to engine gearbox and engine mount. Aircraft grounded until August 2016
17 October 2016	ZK-SMF observed to carry out two local flights. Duration unknown as flights not recorded in pilot logbook or aircraft records.
18 October 2016	At approximately 1110 hours, witnesses observe ZK-SMF take off at Matamata aerodrome. Moments later the engine was heard to cut out. ZK-SMF then strikes the ground resulting in fatal injuries to the pilot.

Incident maps, plans, and photographs

Figure 1: ZK-SMF (Image source nzcivair.blogspot.com)

Figure 2: Accident location (Image source Google Earth)

Figure 3: Accident site (CAA photograph)

Findings and conclusions from the investigation

As a result of the CAA safety investigation, a number of findings and conclusions were determined relevant to the pilot and aircraft. These are listed below and then described in more detail:

Human factors	· Experienced pilot but little recent flying in the Titan T-51D Mustang
	· Pilot may have inadvertantly switched the engine off
	· Startle effect
	· Accident forces were within the human survivable range
	· Unsupervised maintenance carried out by the pilot (ECU re-map)
Equipment factors	· Aircraft observed to be climbing slower than normal
	· The pilot's shoulder harness restraint failed when the aircraft struck the ground
	· Unsuitable location for the pilot's shoulder harness attachment
	· Recent engine ECU re-map
	· The pilot had installed internal canopy locks
Environmental factors	· Pilot maintenance requirements

Human factors

The pilot had considerable previous flying experience

At the time of the accident, the 80 year old pilot held a current Recreational Pilot Licence (fixed wing) with a current medical certificate. He was also an active qualified glider pilot. The pilot also held a Commercial Pilot Licence with a B Cat Instructor rating and multi-engine instrument rating but these were no longer active. At the time of the accident, the pilot had accrued approximately 5085 hours as recorded in his pilot logbook.

Lack of recent flying experience in the Titan T-51D Mustang

The pilot had recorded flying 1.1 hours in ZK-SMF during the previous 90 days.

Information provided by witnesses indicates the pilot had carried out two flights in ZK-SMF two days before the accident. The details or duration of these flights were not recorded in either the pilot's or aircraft logbooks. Prior to the 1.1 hours being flown, no flights were recorded for the aircraft having flown for the previous 12 months. This was due to ZK-SMF being repaired following engine mechanical issues in November 2015.

The pilot may have switched the engine ignition off by mistake

During February 2014, the pilot made a modification to the switches located on the centre console panel which control the operation of the two engine ECUs. In comparison with the new and previous set-up there was a considerable difference in switch operation and function.

Examination of the ECU switches in the cockpit during the field investigation found that the master switch was in the OFF position. The safety guard which prevents the inadvertent selection of the switch was found to be bent around the switch toggle.

The safety guard had been bent around the switch toggle by the pilot striking the instrument panel when the aircraft struck the ground.

It is considered possible that during the take-off phase, when presented with poor engine performance, the pilot may have attempted to switch between the two ECUs to rectify the problem. The pilot may have made a cognitive error and reverted to the earlier method of ECU changeover. Given the revised ECU switch configuration, this would have switched the master switch off, stopping the engine. This is consistent with the eyewitness reports of a sudden decrease in engine sound.

The pilot may have been affected by the startle effect when the engine failed

The sudden and unexpected loss of engine power would probably have taken the pilot by surprise. In such situations pilots may be subjected to a human factor called startle effect[3] which leads to a delayed response and action to an unexpected situation.

Startle effect may have robbed the pilot of vital time to attempt to take corrective actions when the engine failed. Given the low height of the aircraft when the engine lost power, the pilot had only a matter of seconds remaining in the air before striking the ground.

Accident forces were within the human tolerance range for survival

By calculation, the safety investigation determined that the accident forces which the pilot would have been subjected to were within the range for human survival. The forces calculated were approximately 19.6g vertical and 7.3g horizontal. These forces were based on an estimated airspeed of 70 knots when the aircraft struck the ground.

The range for human tolerance is much higher than those the pilot was subjected to during the accident sequence[4]. If the pilot's shoulder harness had prevented him from flailing forward as designed, he would have most likely survived the accident.

The pilot carried out unsupervised maintenance on the aircraft

At some time before the accident flight, the pilot had the fuel map in the #2 ECU modified by a local car tuning specialist to help overcome an issue of the engine rough running at idle when the #2 ECU was selected. The maintenance conducted on the #2 ECU to alter the fuel map was not documented in the aircraft logbook.

After the aircraft was issued with an Airworthiness Certificate by the CAA, maintenance such as that carried out on the #2 ECU by the pilot, was required to be carried out or supervised by a person who meets the requirement of Civil Aviation Rule 43.51 *Persons to perform maintenance.*

Equipment factors

The aircraft was observed to be climbing slower than normal

The aircraft was observed by witnesses to taxi to the end of the 1000-metre grass runway and begin the take-off roll.

One of the witnesses, who was familiar with the aircraft, was standing on the south-western side of the grass runway and witnessed the entire accident flight. They stated:

[3] Startle effect – Refer to SKYbrary Aviation www.skybrary.aero/index.php/Startle_Effect
[4] Refer to a paper titled: Human Tolerance and Crash Survivability by Dennis F. Shanahan M.D., M.P.H.

> *"The pilot took a long run-up from the end of the runway 28 as was his usual practice and took off heading to the north-west. It [ZK-SMF] climbed slowly with an angle of attack quite high, to approximately 200 feet. It didn't sound as though it was at full power. The engine cut like somebody pulling the throttle back to idle, with the way it screams [the engine] after doing that it was very noticeable. The aircraft's right wing dipped and the aircraft proceeded to lose altitude until it subsequently struck the ground off the end of the runway in a wings level, nose slightly down attitude".*

Due to the low forward airspeed during the descent and a lack of engine power, the pilot would have had no options available to arrest the rate of descent before the aircraft struck the ground.

The aircraft was built from a kitset

ZK-SMF was built from a kitset by a team of aircraft engineers with assistance from the pilot. The kitset was manufactured by the Titan Aircraft Company. The construction of the aircraft began in 2006 and was completed in 2009. The pilot had chosen to install a Mazda 13B Renesis rotary engine with a later addition of a four-bladed MT-Propeller constant speed propeller.

In November 2012, following the required period of flight testing, the aircraft was issued with a Special Category Amateur-Built Airworthiness Certificate by the CAA. At the time of the accident, the aircraft had flown approximately 100 hours. Finite hours could not be determined as there were a number of flights that weren't recorded in either the pilot or the aircraft logbooks. Most of the hours flown and recorded in the aircraft logbooks were for test flight purposes.

The pilot's shoulder harness mounting point failed when the aircraft struck the ground

When the aircraft struck the ground, the forces applied to the seat back frame by the pilot's weight on the shoulder harness caused the pilot's seat back to fail (Refer to figure 4). This resulted in the pilot's upper body being unrestrained allowing him to flail forward and strike the instrument panel. The resulting blunt force trauma injuries proved to be fatal.

During aircraft construction, the top bar of the pilot's seat back frame was chosen as the anchor point for the seat belt shoulder harness. The CAA safety investigation determined that the shoulder harness attachment point to the aircraft structure, had not been specified by the Titan Aircraft Company. However, given the length of the harness webbing supplied with the kitset, it can only be attached to the upper or lower horizontal bars on the pilot's seat back.

The CAA safety investigation found that a number of Titan T-51D Mustang aircraft, both within New Zealand and overseas, utilised the top seat back bar as the anchor point for the shoulder harness, as was found on ZK-SMF.

As a result of this accident, and following advice from the kitset manufacturer, CAA Continuing Airworthiness Notice 25-001 *Titan Aircraft Company T-51D Mustang – Seat Belt Attachment* was raised. The Continuing Airworthiness Notice advises that the Titan Aircraft Company does not recommend attaching the shoulder harness restraint to the upper bar on the seat back frame (Refer to Appendix 1).

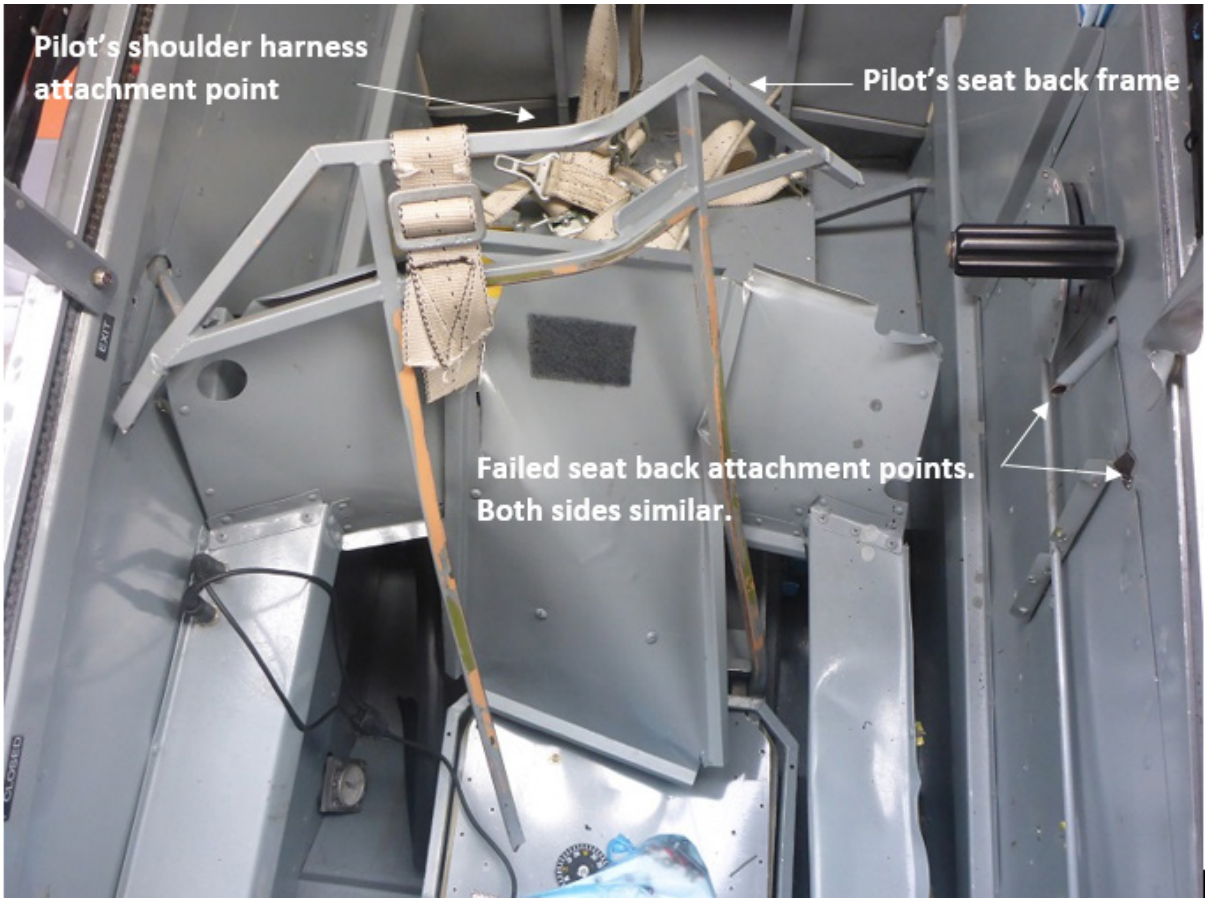

Figure 4: Failed pilot seat back frame. Shoulder straps were cut by first responders (CAA photograph)

Seat back frame and welded joints metallurgical testing

The seat back frame, and sections of the fuselage were sent to a specialist company for visual examination, microstructural assessment, and hardness testing. The fuselage sections were taken from the area where the seat back had been welded to the airframe.

The aim of the assessment was to complete a qualitative assessment of frame design, materials and loading, based on the results of the metallurgical assessment and engineering design practice.

The assessment concluded that:

- *The failure of the frame was due to the inability to accommodate the load applied during impact to the frame by the seat belt without dynamic deformation and ductile fracture of the frame elements and fixtures*
- *The weld quality was acceptable*
- *The frame material was identified as low alloy steel AISI 4130 in a normalised and tempered condition*

It is recommended that the seat structure could be strengthened by repositioning the seat belt attachment and by using larger stay tube, or adding additional bracing to the seat structure.

The pilot had the #2 ECU fuel map modified

The aircraft used two independent ECUs to control the ignition timing and fuel flow to the engine while it was operating. Only one ECU was used at one time, the other being a standby unit in case of primary ECU failure. The selection of the ECUs was controlled by the pilot via a switch on the centre console in the cockpit.

At some time prior to the accident flight, the pilot had the fuel map in the #2 or standby ECU modified by a local car tuning specialist to help overcome an issue of the engine rough running at idle when the #2 ECU was selected.

During the CAA safety investigation, the two ECUs were evaluated by another performance car tuning specialist, familiar with the model of ECU fitted to ZK-SMF. It was found that the #2 ECU fuel map was not smooth, and at some throttle settings, could provide an excessively rich fuel mixture which reportedly could affect engine power output.

It is considered highly likely that the pilot had the ignition system selected to the #2 ECU position during the take-off, which as mentioned, could adversely affect the power output of the engine.

The aircraft canopy could not be easily opened externally

First responders to the aircraft accident found they could not easily open the canopy to gain access to the pilot.

The Titan T-51D Mustang design provides for an external canopy release button, which on ZK-SMF was located on the right side of the fuselage. The pilot had modified the method of locking the canopy closed, by installing a locking mechanism which was accessible only from inside the cockpit (refer to Figure 5).

This modification made external access to the cockpit extremely difficult for the first responders until they managed to forcibly gain access to the internal canopy locks and open the cockpit canopy.

In the case of this accident, quick access to the pilot would not have made any difference to survivability. Given a different set of circumstances, however, it may have made the difference between a survivable and non-survivable accident.

Figure 5: internal canopy latches installed by the pilot

Environmental factors

Rules regarding pilot maintenance

For aircraft required by Part 91 *General Operating and Flight Rules* to have an airworthiness certificate issued, Part 43 *General Maintenance Rules* prescribes the requirements for the maintenance and release to service after maintenance on the aircraft.

Maintenance must be carried out by persons who meet the requirements of rule 43.51 *Persons to perform maintenance,* for the performance of maintenance, or a person who is under the direct supervision by any person who meets that rule requirement.

A pilot with a current licence and type rating, may perform maintenance specified in Part 43 Appendices A.1 and A.2 on an aircraft not used to perform air operations. They must be authorised in writing by the operator and be appropriately trained by the holder of a current and appropriate aircraft maintenance engineer licence and rating. Rule 43.51(b) and (c) refers to this.

Aircraft owners are reminded that when carrying out maintenance on their own aircraft, they must be conversant with, and comply with the relevant Civil Aviation Rule requirements.

Safety actions

Actions already taken

Continuing Airworthiness Notice 25-001 raised

Following the accident, the CAA published Continuing Airworthiness Notice (CAN) 25-001 *Titan Aircraft Company T-51D Mustang - Seat Belt Attachment* in September 2017. The CAN advises owners of the recommended location of the shoulder harness attachment (refer to Appendix 1).

This relates to the following factors from our investigation:

- Pilot's shoulder harness restraint failed
- Unsuitable location of pilot's shoulder harness attachment

Titan Aircraft Company pilot advisory notice

Following a recommendation by the CAA to the Titan Aircraft Company, the company has agreed to publish a T-51 advisory notice. The notice will advise that the use of the top rail on the pilot seat back for the mounting of the shoulder harness is not recommended. At the time of completing the CAA safety investigation report, the publishing of the Titan Aircraft Company advisory notice had not been completed.

Further recommended actions

There are no other formal recommendations for action in response to this accident. We encourage all readers to follow the safety messages and Continuing Airworthiness Notice, where applicable, outlined in this report.

Accident data summary

Aircraft make and model, registration, and serial number and total hours:	Titan Aircraft Company T-51D Mustang, ZK-SMF, s/n 57, approx 100 hours total time (99.6 hours recorded)
Year of manufacture:	Build completed 2009
Engine make and model, type of engine:	1 Mazda 13B Renesis Rotary engine (190 horsepower)
Propeller:	MT-Propeller MTV-10-8
Last inspection:	04 August 2016
Accident Date and time:	18 October 2016, 1110 NZDT (approx)
Location:	Matamata aerodrome Latitude: S 37° 44' 04" Longitude: E 175° 44' 31"
Altitude:	182 feet above mean sea level
Type of flight:	Private local
Persons on board:	Crew: 1
Injuries:	Crew: Fatal
Nature of damage:	Substantial
Pilot's licence:	Recreational pilot licence
Pilot's age:	80 years
Pilot's total flying experience:	5085 hours total (approx) 100 hours on type (approx)
Information sources:	Civil Aviation Authority safety investigation
Investigator in Charge:	Mr C Grounsell

Appendix 1: Continuing Airworthiness Notice

CAA CAN 25-001 *Titan Aircraft Company T51 Mustang - Seat Belt Attachment* in September 2017.

Continuing Airworthiness Notice – 25-001

CIVIL AVIATION AUTHORITY OF NEW ZEALAND

Titan Aircraft Company T51 Mustang - Seat Belt Attachment

13 September 2017

Issued by the Civil Aviation Authority of New Zealand in the interests of aviation safety. A Continuing Airworthiness Notice (CAN) is intended to alert, educate, and make recommendations to the aviation community. A CAN contains non-regulatory information and guidance that does not meet the criteria for an Airworthiness Directive (AD). The inspections and practices described in this CAN must still be carried out in accordance with the applicable NZCAR Parts 21, 43 and 91.

The contents of this notice are ADVISORY ONLY and are NOT MANDATORY.

CAN numbering is by ATA Chapter followed by a sequential number for the next CAN in that ATA Chapter.

Applicability:

Operators of Titan T51 Mustang aircraft with a Flight Permit (Class 2 microlight) and aircraft with a Special Category – Amateur Built Airworthiness Certificate.

Purpose:

This Continuing Airworthiness Notice (CAN) alerts operators of affected aircraft of the importance of attaching the shoulder harness to the lower bar of the seatback frame.

Background:

This CAN is prompted by a CAA safety investigation of an accident with a Titan T51 Mustang aircraft. The aircraft experienced an engine power loss on take-off at approximately 250 feet AGL. The aircraft landed heavily resulting in the pilot sustaining fatal injuries due to the high load applied to the shoulder harness and failure of the seatback frame.

The seatback frame on these aircraft has two horizontal bars, an upper and a lower bar. Examination of the pilot seat revealed that the shoulder harness was attached to the upper bar of the seatback frame.

Shoulder harness attachment – correct position.

Recommendation:

According to Titan Aircraft Company the attachment of the shoulder harness to the upper bar of the seatback frame is not a factory recommended position. To reduce the leverage on the seatback frame the shoulder harness should be attached to the lower bar of the seatback frame.

The CAA recommends an inspection of the shoulder harnesses for both the front and rear seats to determine the attachment position of the shoulder harness. If a shoulder harness is found attached to the upper bar, then reposition and attach the harness to the lower bar of the seatback frame.

Enquiries:

Enquiries with regard to the content of this Continued Airworthiness Notice should be sent to:

Owen Olls

Airworthiness Specialist

Email: owen.olls@caa.govt.nz

Phone: 04 560 9569.

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About the CAA

New Zealand's legislative mandate to investigate an accident or incident is prescribed in the Transport Accident Investigation Commission Act 1990 (the TAIC Act) and Civil Aviation Act 1990 (the CA Act).

Following notification of an accident or incident, TAIC may conduct an investigation. CAA may also investigate subject to Section 72B(2)(d) of the CA Act which prescribes the following:

> **72B Functions of Authority**
>
> (2) The Authority has the following functions:
>
> (d) To investigate and review civil aviation accidents and incidents in its capacity as the responsible safety and security authority, subject to the limitations set out in section 14(3) of the Transport Accident Investigation Commission Act 1990

The purpose of a CAA safety investigation is to determine the circumstances and identify contributory factors to an accident or incident with the purpose of minimising or reducing the risk, to an acceptable level, of a similar occurrence arising in the future. The safety investigation does not seek to ascribe responsibility to any person but to establish the contributory factors to the accident or incident, based on the balance of probability.

A CAA safety investigation seeks to provide the Director of Civil Aviation with the information required to assess which, if any, risk-based regulatory intervention tools may be required to attain CAA safety objectives.

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