Australian Government
Civil Aviation Safety Authority

AIRWORTHINESS BULLETIN

Trim Tab System Degradation - Flutter / Loss of Control

AWB 55-010 **Issue** : 1
Date : 11 June 2015

1. Effectivity

Aircraft incorporating pilot-operated primary flight control surface trim tab systems and trimmable horizontal stabilizers.

2. Purpose

To identify the critical importance of adequate trim system maintenance, and observing the applicable operational airspeed limitations. While this AWB mainly draws examples from the pitch trim systems of Cessna 100, 200 and 400 Series aircraft, the recommendations are applicable to a wide variety of aircraft types.

3. Background

Should any unbalanced flight control trim tab linkage develop excessive play or become disconnected from its control, it may immediately develop severe in-flight vibration (flutter) resulting in rapid loss of structural integrity of the tab, elevator and associated structure. The Cessna 206 tailplane failure below (Figure 1) occurred soon after take-off when the threaded rod end in the trim tab actuator failed and allowed the trim tab to flutter.

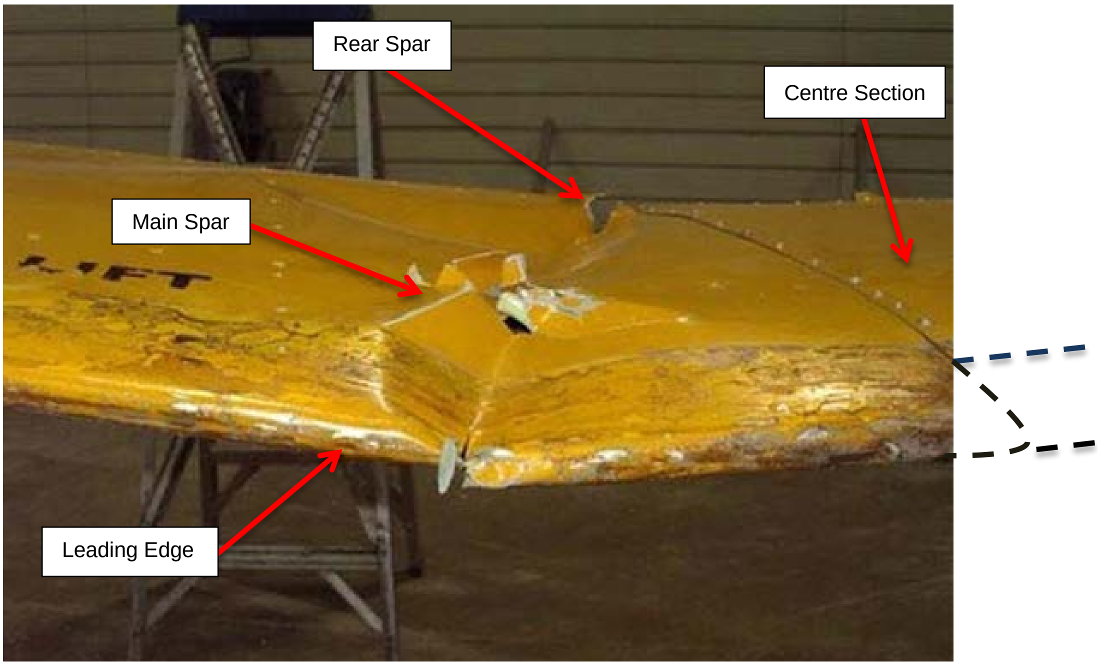

Figure 1. Cessna U206F. Failure of both the front and rear spars in the right hand horizontal stabilizer following failure of the trim jack threaded rod end (Transport Canada Civil Aviation SDR RDIMS No: 5537310.)

Transport Canada Civil Aviation Safety Alert 2011-06:
"The threaded rod end fractured and separated from the actuator assembly which then jammed the elevator assembly. When the jam cleared, a serious tailplane flutter occurred that caused major damage to the elevator, elevator trim tab and the horizontal stabilizer.

Shortly after departure, the pilot noticed that only limited elevator authority was available. To prevent the impending airframe stall, the pilot increased the engine power and pushed on the control column to get the nose of the aeroplane down. The pilot suddenly heard a loud noise, which was immediately followed by significant airframe vibrations. Fortunately, the pilot was able to regain enough elevator (pitch) authority to execute a forced landing at the nearby airfield.

Once the elevator jam cleared itself, the fractured rod end (still attached to the push-pull tube) began to thrash and flail about, causing significant damage to the tail section. The tailplane "flutter" (unstable oscillations) became so severe that both the front and rear spars of the R/H horizontal stabilizer completely fractured. Although, the R/H elevator assembly hinges were still attached, the R/H elevator and horizontal stabilizer assemblies were severely bent, twisted and buckled."

Design

A fundamental aeroplane design requirement is that the wings, tail and all control surfaces are to be free from flutter. This is typically achieved by mass balances in the control surfaces. Trim tabs which do not incorporate a mass balance are 'unbalanced' and prone to flutter. Unbalanced trim tab control systems typically incorporate an irreversible screw jack mechanism to hold the tab rigidly in the desired position and prevent the tab developing flutter (FAR 23.677 (c) Trim Systems).

There are some aircraft types with unbalanced trim tabs which do not have an irreversible screw jack operating mechanism, and rely entirely on a friction device to hold the trim tab firmly in place. The Cessna 180/185 models have trimmable horizontal stabilizers operated by "irreversible" screw jacks, which require an additional friction system to prevent trim creep or 'runaway'.

Should the trim tab, trim actuator, attaching structure, linkages, etc. become loose or disconnected, or if the degree of friction restraint should decrease, the tab, now being "free" and energised by the airstream, can vibrate (flutter) quite violently. Depending on the failure sequence, the tab, elevator and/or tailplane may fail before the aircraft can be safely landed. This classic destructive flutter behaviour can occur over a range of airspeeds.

Trim Tabs
The typical trim tab is a long thin (high aspect ratio) aerodynamic surface with a lever close to one end of the tab which connects to a rod coming from the trim actuator. Aerodynamic loads over the length of the tab and resistance to trim control inputs both tend to twist the tab. Atmospheric turbulence and the turbulent wake from the tab trailing edge can excite vibrations, and at high speeds this can cause the tab to flutter (even though the linkages and actuator remain ‘tight’) Destruction of the tab and associated control surface may result.

Foam filled tabs.
Some aircraft types, including approximately 16,000 Cessna 206, 207 and 210 aeroplanes manufactured between1960 and 1986 incorporated an elevator trailing edge and trim tab filled with foam to achieve the desired structural rigidity. Over time it was found that this foam can disbond from the tab skin and trap moisture inside the tab between the foam and the aluminium skins, causing control surface balance problems and corrosion from the inside out. Not only can the tab become flexible and more liable to develop flutter, the trim actuator can pull the tab lever rivets out of the thin corroded skin and disconnect from the tab, allowing the tab to flutter. Refer FAA SAIB CE-05-27 and NTSB Safety Recommendation A-06-54 and 55 for further information.

A Yakovlev 52 suffered pitch trim tab / control rod failure and the tab developed flutter at high speed, causing structural failure of the elevator as the tab broke up. (Figures 2a and 2b). Refer AWB 55-009 - Yak 52 Trim Tab Failure.

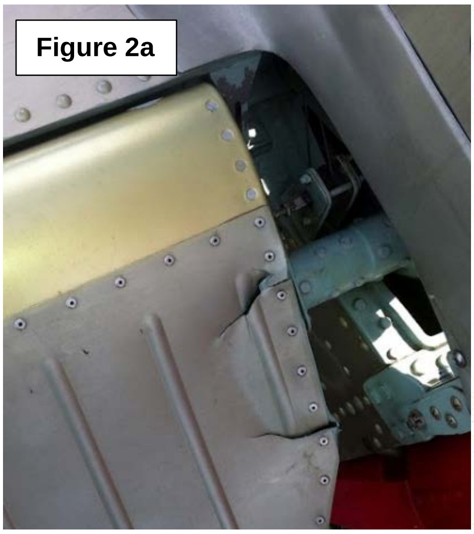
Figure 2a


Figure 2b

Watch the event **here**.

Tab Control Rod End Assembles.
The connection between the control rod and the tab typically consists of a fork end which is designed to clamp on a free-moving bush in the tab lever. Should the bush seize and/or the rod end be incorrectly clamped

up, the control rod end connection to the lever will become stiff and force the rod or shaft to flex or bend back and forth whenever the tab is moved (Figures 3 and 4).

Figure 3. Beech King Air C90 Failed elevator trim tab push rod due to fatigue.

Figure 4. The Inner and outer bushing arrangement had become seized.

Fatigue failures typically initiate at the thread roots in the shaft and final overload failure results in rod separation and a free tab, with associated loss of control and / or tab flutter, as occurred in a Beech King Air C90A (Transport Safety Board of Canada Report A03C0068).

Extract: TSB Report A03C0068
"A Transport Canada Beech King Air C90A, registration C-FGXU, serial number LJ1140, departed Winnipeg, Manitoba, on a routine training flight to Prince Albert, Saskatchewan. The crew heard a loud bang accompanied by severe airframe vibration and a substantial pitch up in aircraft attitude. The captain disconnected the auto-pilot, reduced engine power, selected full nose-down trim, and applied forward pressure on the control column to regain control. As the airspeed reduced to below approximately 150 knots, the vibrations stopped. With limited elevator control remaining, the captain reduced engine power and established a descent while maintaining hard nose-down pressure on the control column to keep a constant level aircraft attitude. The co-pilot declared an emergency and requested a diversion to Dauphin, the nearest suitable airport for landing. At 15 000 feet, the captain elected to extend the landing gear to effect a more rapid descent and as a precaution to give more time to stabilize the aircraft in the event that lowering of the landing gear would affect airflow past the tail. Prior to landing, at approximately 200 feet above ground level, the crew detected another brief vibration followed by a sudden pitch down, requiring aggressive trim and elevator control inputs to control. The crew completed a flapless landing without further incident. After exiting the aircraft, the crew observed that the left elevator trim-tab pushrod had failed."

Elevator Trim Tab Separation: GROB 115

CASA has been advised of two in-flight trim tab separation events in GROB 115 aircraft (Figure 5). The student pilot reported he had descended rapidly from cloud base and heard a “Thud”.

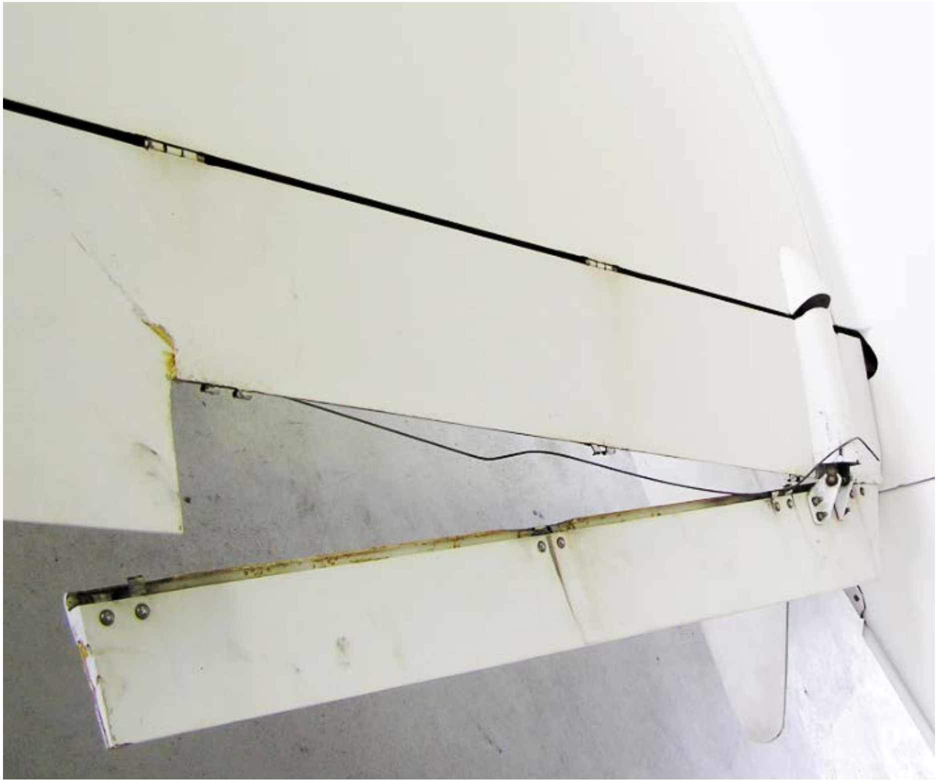

Figure 5. GROB Aerospace 115C. Elevator trim tab separation.

After landing and return to the hangar, the elevator trim tab was found torn from its hinge attachments. The left hand Elevator had also suffered major structural damage.

Tab Actuator Push Rods

During a Cessna Supplemental Inspection Document (SID) inspection on a C441 aircraft, the elevator trim control rods were found to be corroding from the inside out (Figure 6). When the paint was stripped off the rods, it was found that the internal corrosion in one of the rods was so severe that it had completely penetrated sections of the tube wall. A radiographic inspection revealed that all four rods were severely corroded internally.

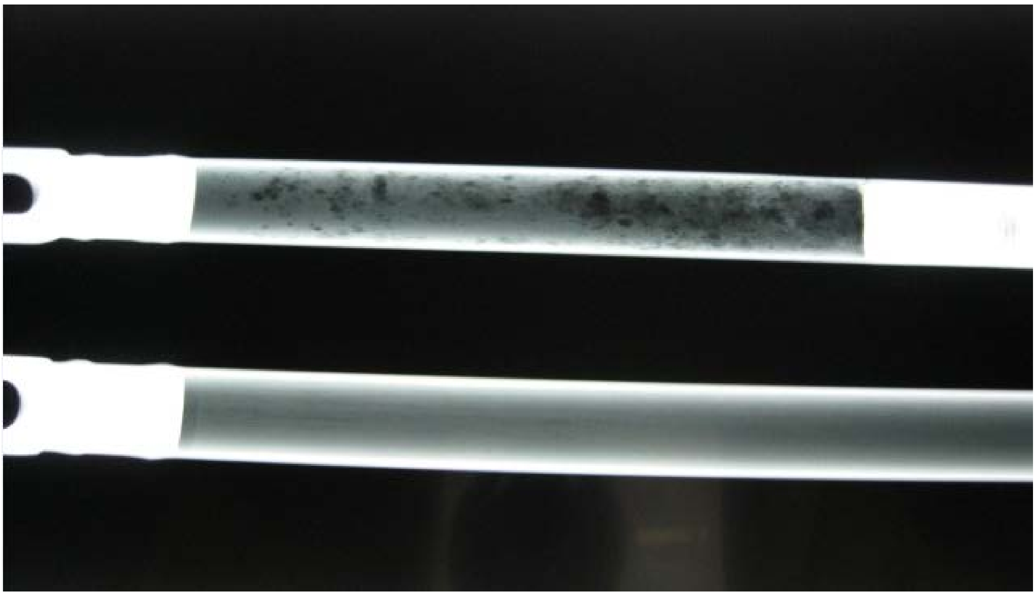

Figure 6. The top rod in this radiographic image is corroded internally. For comparison, the bottom rod has no detectable internal corrosion.

This is not an isolated occurrence. Many aircraft types have trim tabs operated by hollow rods (tubes) and which are highly susceptible to internal corrosion. Control rod failure due to corrosion has the same effect as the loss of the control rod end. Pilots who have survived in-flight failures of the elevator trim control rod end or rod report great difficulty in holding pitch control and severe airframe vibration.

Trim Jack Actuator Support Structure
There have been several reports of Cessna 206 trim jack mounting brackets P/N 1232139-1 cracking and becoming completely detached from rear tailplane spar and the adjacent rib, allowing the trim jack to float freely within the tailplane structure. The uncontrolled movement of the elevator trim tab assembly typically results in severe vibration, extreme difficulty in maintaining control of the aircraft in the pitch plane and structural damage to the elevator (Figure 7).

Figure 7. A Cessna 206 elevator trim actuator (rod end removed) still secured to a detached actuator mounting bracket**.**

A survey shows that Cessna 206 series trim jack detachment failures have occurred predominantly in aeroplanes engaged in parachute or skydiving operations, where the cargo doors are removed.

The cargo doors are on the same side as the elevator which has the trim tab installed. When operating with the doors removed, not only is the aircraft’s performance reduced due to the increased drag, but the right hand tailplane, elevator and tab are exposed to an increased turbulent wake.

While the Cessna TU206G Flight Manual SECTION 2 LIMITATIONS, states “Red Line 183 Knots Indicated Air Speed (KIAS) maximum speed for all operations”. However, the Cessna TU206 G Pilots Operating Handbook SUPPLEMENT SKYDIVING KIT overrides this limit, and reduces the maximum indicated speed by more than 50 KIAS when configured for parachute /skydiving operations, that is, with the rear cargo doors off and deflector fitted (Figure 8).

CESSNA
MODEL TU206G

SECTION 2
LIMITATIONS

MARKING	KIAS VALUE OR RANGE	SIGNIFICANCE
White Arc	46 - 100	Full Flap Operating Range. Lower limit is maximum weight V_{S_O} in landing configuration. Upper limit is maximum speed permissible with flaps extended.
Green Arc	55 - 149	Normal Operating Range. Lower limit is maximum weight V_S at most forward C.G. with flaps retracted. Upper limit is maximum structural cruising speed.
Yellow Arc	149 - 183	Operations must be conducted with caution and only in smooth air.
Red Line	183	Maximum speed for all operations.

Figure 2-2. Airspeed Indicator Markings

PILOT'S OPERATING HANDBOOK
SUPPLEMENT

13
SKYDIVING KIT
MODEL TU206G

SUPPLEMENT

SKYDIVING KIT

SECTION 2
LIMITATIONS

Removal of the cargo doors requires that a spoiler be installed. With the doors removed and the spoiler installed, the following placard must be displayed on the instrument panel:

WITH CARGO DOORS REMOVED
DO NOT EXCEED 130 KTS IAS.

Original Issue

1 of 2

The maximum speed of 183 Knots IAS is reduced to 130 Knots IAS when configured for parachute operations.

Figure 8. Cessna Flight Manual / Pilots Operating Handbook extracts.

It seems likely that the in-flight trim jack structural attachment failures may be attributed to the combined effects of the structural buffeting from the increased turbulent wake created by operating with cargo doors removed, and by exceeding the 130 KTS IAS limit during rapid descents from high altitude after a parachute drop.

Elevator Trim Tab Actuator Threads

The typical Cessna 200/400 Series screw jack trim tab actuator consists of a threaded shaft with the male threaded rod end running in an internally threaded shaft, which is driven by a chain and sprocket. There have been reports of severe control difficulties following worn elevator trim jack actuator threads stripping and the actuator jamming in an untrimmed position.

"The aircraft had just commenced descent, and the pilot was trimming the elevator for the descent, when the pilot heard a loud noise and the elevator control pitched down. The pilot was able to arrest the aircraft's nose-down pitch, but was unable to trim out the nose-down forces. He managed to control the aircraft sufficiently to carry out a straight-in approach and landing. After landing, it was found that the elevator trim tab was jammed in the nose-down position. The trim tab was removed for investigation. X-ray examination showed that the threads in both the male and female screw assemblies were severely worn (Figure 9).

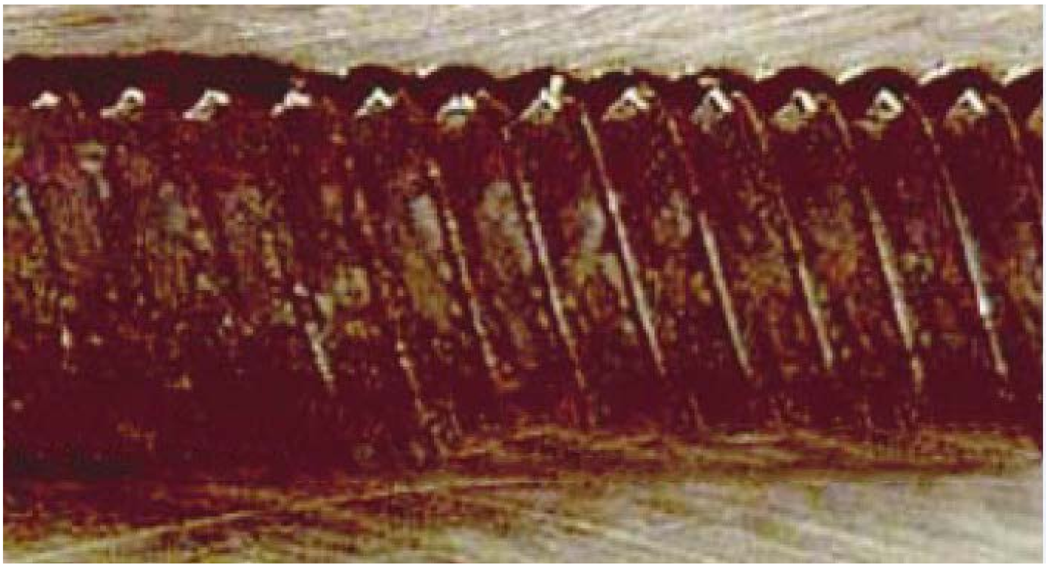

Figure 9. Worn trim actuator screw threads. (Flight Safety Australia "The Trouble with Trim Tabs")

The shaft was bent over its entire length and had jammed in a position that corresponded to the nose-down position of the tab. It is suspected that the male threads had disconnected from the female threads when the pilot turned the elevator trim wheel. The elevator trim tab was then unrestrained and entered a flutter mode that only ceased when the flutter forces bent and jammed the male end of the rod.

The manufacturer's maintenance manual states that, should one thread require replacing, both the male and female threads must be replaced as a pair. The local spare parts supplier advised that they sell the male and female threads as separate components and their recent stock records *showed that they had sold 27 male ends and three female ends. Another supplier confirmed this purchasing imbalance.*

The ATSB also identified that a number of incidents have occurred where the elevator trim-tab actuator jackscrew thread contact area of Cessna 300/400 series aircraft has deteriorated to a point where the threads either disengaged or "jumped" threads. This event appears to be the result of non-adherence by operators to the instructions in the manufacturer's technical manuals. This condition could result in control surface flutter or a jammed control surface, with a resultant loss of flight control.
Extract from: ATSB Investigation 199805359 Cessna 402B.

Trim Actuators 'freezing' in flight
CASA has received a report of an elevator trim tab actuator which jammed or became 'frozen' at high altitude, but operated normally on the ground. The investigation found that the jack had been lubricated with incorrect grease which was not suitable for operation at high altitudes and low temperatures.

Adjustable Horizontal Stabilizer Actuator 'Runaway' & Jamming
A large range of aeroplane types have adjustable tail planes where the angle of tailplane incidence is changed by screw jacks. Some aircraft may also incorporate trim tab(s) set in the elevator for standby pitch trim. The following provides an historical insight into the development of the Cessna 180/185 adjustable horizontal stabilizer pitch trim system.

"As the airplanes aged in rough service, we [Cessna] received reports of stabilizer slippage in high-speed letdowns. To our amazement the two "irreversible" jack screws that supported the stabilizer were slipping in an airplane-nose-up direction. In production flight tests at redline speed, this produced an alarming "g" load, pitching the nose up vertically. We were unsuccessful in reworking the jack screw tolerances, and the decision was made to add a friction device to the longitudinal trim wheel mechanism. This produced a "ratcheting" noise in the cockpit and increased the force required to make trim changes. However, it solved the stabilizer slippage problem, and the device remained on the C-180/185's throughout the production run". (Extract adapted from ***Cessna, Wings for the World*** **by William D. Thompson**).

Horizontal stabiliser trim jack 'creep' or runaway is not limited to small aircraft such as the Cessna 180/185. Additional trim system friction and locking devices are frequently incorporated into trimmable tailplane designs. Undetected trim jack thread wear may adversely affect the safety and operation of trim tabs and trimmable horizontal stabilizers in other ways.

“A pilot operating a Cessna 185 reported to maintenance personnel of having the horizontal stabilizer trim “freeze up in flight” (i.e. jam due to mechanical wear). Maintenance personnel inspected the system and found the trim screw barrels in the tail to be excessively worn (Cessna Part Number (P/N) 0712500-13). One of the barrels was stripped out and the second barrel had approximately one-third of the threads missing. The screws that thread into the barrels (Cessna P/N 0712500-11) also were worn. Eight similar occurrences have been reported in service difficulty reports. Cessna 180, 182, and 185” (FAA SAIB CE-08-02).

Had both trim jack threads become stripped, the horizontal stabilizer would have been immediately free to take up extreme angles of incidence, making the aircraft very difficult to control. There is no assurance that increasing levels of trim jack friction or trim jack jamming will occur as a warning before complete double trim jack thread failure.

Actuator In-Flight Disconnect

CASA has received two defect reports describing low-time Cessna 206 elevator trim tab actuators becoming disconnected from the trim control system in flight. In one case, the elevator trim actuator drive disconnected in the nose down trim position during cruise. A power setting of 26” manifold pressure (MAP) with 2600 RPM was required to keep the aircraft straight and level (Figure10)

Figure 10. The elevator trim actuator drive failed in the area where the chain sprocket shaft is secured to the drive shaft by roll pins.

A preliminary investigation suggests that the drive sprocket shaft failure could be attributed to high side-loadings from the elevator trim cable system, due to over-tension. The system had been factory rigged at a considerably lower ambient air temperature than the daily high ambient air temperature at the aircraft’s location, which is commonly in excess of 40°C. The temperature of the aluminium skin of an aircraft sitting on the ground in direct sunlight in this climate can be in excess of 80°C. Because the aluminium fuselage expands (and contracts) at a greater rate than the steel control cables, the manufacturer's cable tension limits could have been exceeded.

4. Additional Reference

1. FAA AC 43.13.1B SECTION 3. Precautionary Measures 4-36. Flutter and Vibration Precautions.

5. Recommendations

1. Maintain aircraft pitch trim systems in accordance with the approved data. Any maintenance program that does not include a requirement to periodically inspect the integrity and correct function of all aspects of the trim system, including cables, trim jack mounting structures, operating mechanisms, friction devices, hinges and rod-end connections and free-play should be considered inadequate and amended accordingly.

2. Adhere to the manufacturers trim tab free-play limits. Do not consider that out of limits free-play in the trim tab or horizontal stabilizer screw jack actuator threads is acceptable because it will be "loaded" one way in flight and that the free play will be eliminated. Atmospheric turbulence combined with the slightly turbulent airflow at the tab trailing edge can cause the trim tab to flutter, and worn horizontal stabilizer jack screw threads can lead to failure of the pitch trim control in flight.

3. Ensure the primary and secondary flight control cables, including the trim control cables, are correctly tensioned for the conditions under which the aircraft will be operating.

4. Cessna Single Engine Bulletin (SEB) 85-5 provides an improved elevator trim actuator mounting bracket design. An Engineering Order / 21M Approval will be required to modify or repair the horizontal stabilizer for an aircraft model / serial number not identified in the applicable illustrated parts catalogue (IPC) or SEB 85-5. The installation of an improved elevator trim actuator mounting in a Cessna 206 series aeroplane, for example, does not remove the 130 KTS IAS limitation when operating with cargo doors removed.
5. Ensure any required placards are in place for Skydiving operations. Observe the Aircraft Flight Manual Supplement airspeed limitations applicable to the configuration.

6. Reporting

Report all defects in relation to any aspect of aircraft trim tab or adjustable horizontal stabilizer systems to CASA via the CASA SDR system.

7. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link e-mail address:

AirworthinessBulletin@casa.gov.au

or in writing, to:

Airworthiness and Engineering Standards Branch
Standards Division
Civil Aviation Safety Authority
GPO Box 2005, Canberra, ACT, 2601