Serious Incident

Aircraft Type and Registration:	Cessna 152, G-BSZW
No & Type of Engines:	1 Lycoming O-235-L2C piston engine
Year of Manufacture:	1977 (Serial no: 152-81072)
Date & Time (UTC):	24 February 2024 at 1539 hrs
Location:	Blackbushe Airport, Surrey
Type of Flight:	Training
Persons on Board:	Crew - 1 Passengers - 1
Injuries:	Crew - None Passengers - None
Nature of Damage:	Rudder control bellcrank fractured
Commander's Licence:	Commercial Pilot's Licence
Commander's Age:	27 years
Commander's Flying Experience:	1,265 hours (of which 1,100 were on type) Last 90 days - 66 hours Last 28 days - 15 hours
Information Source:	Aircraft Accident Report Form submitted by the pilot and further AAIB enquiries

Synopsis

During an instructional flight the aircraft suffered a loss of right rudder authority. The instructor took control and landed the aircraft safely. Examination revealed that the right rudder bellcrank had failed due to stress corrosion cracking, causing the right rudder cable to detach. The cracking initiated at a point where the inboard edge of the bellcrank had been fouling against the aircraft fuselage. The exact reason for the fouling condition was not determined, but several possibilities that could result in misalignment of the rudder or the bellcrank were considered.

History of the flight

During the takeoff, while on an instructional flight, the instructor noted what he considered to be the student pilot's apparent lack of rudder control and prompted him to apply right rudder. The student confirmed that he had right rudder applied, but it made no difference to the external visual picture. The instructor took control and made a right rudder pedal input but the aircraft did not respond. However, full left rudder authority was available. He asked the student pilot once again to make rudder pedal inputs, confirming the lack of right rudder response.

The instructor resumed control, levelled the aircraft at circuit height on the crosswind leg and briefed the student on the situation. The remainder of the circuit and approach were uneventful, and the aircraft landed without further issue.

Upon subsequent inspection of the rudder, it was noted that right rudder cable linkage had snapped at the point where it attached to the rudder bellcrank (Figure 1).

Figure 1

View from rear of aircraft looking forward, showing right side rudder bellcrank and detached rudder cable clevis

Aircraft examination

Examination of the aircraft revealed that the rudder bellcrank had failed across its full width at the attachment point for the right rudder cable, such that the rudder cable was no longer connected to the rudder (Figure 2). The tip of the bellcrank was missing, presumably having separated in-flight.

Contact and paint transfer between the inboard edge of the bellcrank and the airframe rub-plate was evident, indicating the bellcrank had been fouling on the structure. However, the paint on the rub-plate was not fully worn through. Corresponding mechanical wear was present on the inner edge of the bellcrank with full paint removal and the underlying metal worn to an uneven, but shiny finish. Paint was also absent on the outboard edge of the bellcrank in the area of the failure. Surface corrosion was visible on the right and left rudder cable clevis at the bellcrank attachment.

Figure 2
Side view of rudder showing failed bellcrank (inset)

Metallurgical examination

The maintenance organisation retained the main body of the bellcrank, but the left and right bellcrank ends and the corresponding clevis assemblies were removed for metallurgical examination. The mechanical wear on the inboard edge of the right side bellcrank had resulted in extensive material removal and smearing but it appeared that the wear had reached a point where it had stopped progressing, possibly due to the rudder bumper stops limiting further contact (Figure 3).

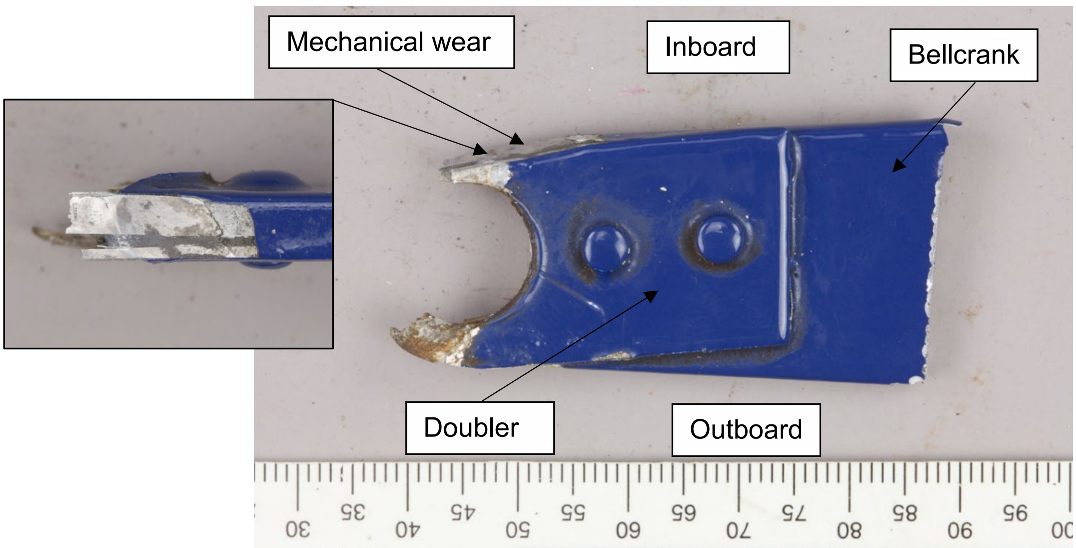

Figure 3
View on lower surface of bellcrank, showing failure across attachment hole and mechanical wear (inset)

Examination of the fracture surface identified that the failure was predominantly due to stress corrosion cracking (SCC), denoted by red shading in Figure 4.

Also of note was a small area of intergranular fracture on the outboard side of the fracture surface, which appeared to be the start of SCC. The paint on the outboard edge of the bellcrank was also missing, so corrosion protection had been compromised.

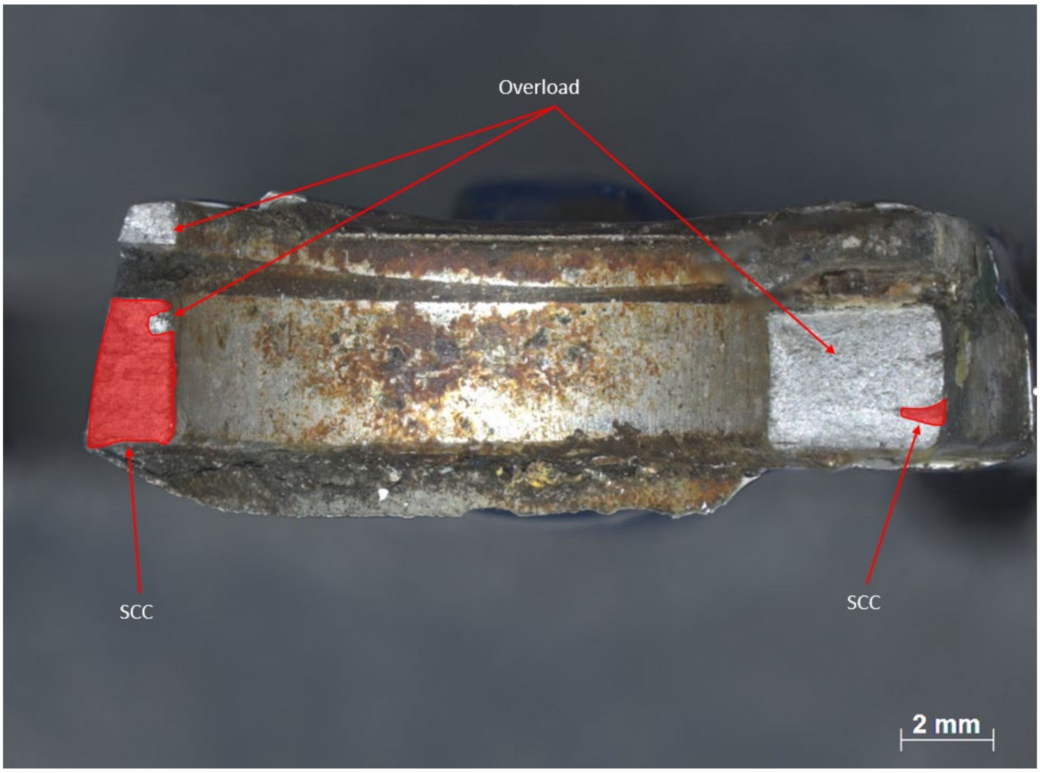

Figure 4

End-on view of fracture surface showing predominant failure mode of SCC

According to the Cessna 152 Illustrated Parts Catalogue (IPC), the rudder cable clevis is attached to the bellcrank by a bolt, plain bush and a castellated nut secured by a split pin. During the examination of the failed bellcrank, it was noted the bolt stack for the right rudder cable clevis included an additional washer and top-hat style bush, rather than a plain bush. The outer diameter of the top-hat bush was 12.71 mm and the internal diameter of the bellcrank attachment hole was 12.80 mm. By comparison, the outer diameter of the bush in the left side bellcrank attachment hole was 9.41 mm (Figure 5). The aircraft manufacturer stated that the bushings should be the same size and that the hole should be centred.

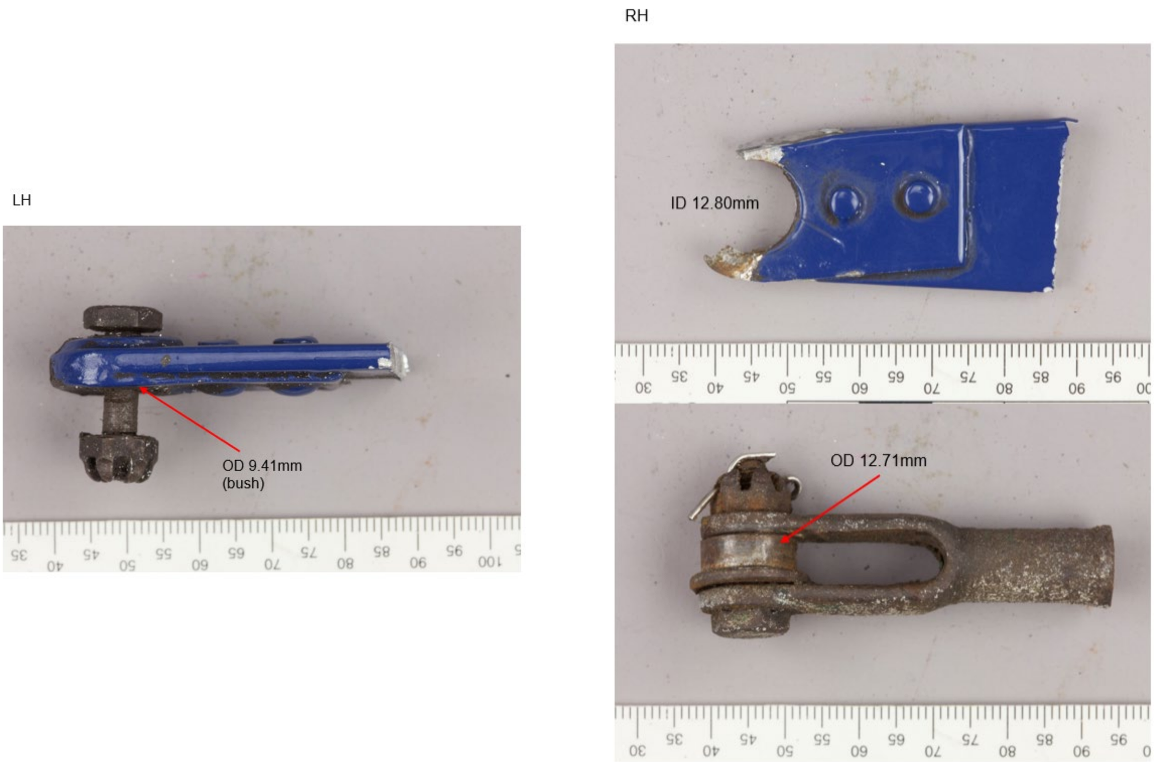

Figure 5
G-BSZW bellcrank attachment dimensions

Information from aircraft manufacturer

The aircraft manufacturer was asked what conditions could cause the inboard edge of the rudder bellcrank to foul against the airframe rub-plate. Among the possibilities it considered were a tailstrike which moved the tail fin, incorrect re-assembly of the fin and/or rudder following a tailstrike or incorrectly set rudder stops which allowed over-travel of the bellcrank.

The aircraft manufacturer reported that it was not aware of any previous bellcrank failures similar to that which occurred on G-BSZW. It was aware of a bellcrank failure on an aircraft that had previously been modified to comply with FAA Airworthiness Directive (AD) 2009-10-09, which mandated the installation of larger rudder stops in accordance with Textron Service Bulletin SEB01-1. In that case, the bellcrank had failed just forward of the right rudder stop. The failure was caused by corrosion due to dissimilar metals at the interface between the rudder stop and the bellcrank.

In 2019 Textron issued Service Letter SEL-27-02 which called for a general visual inspection of the rudder bellcrank for evidence of corrosion around the stops, a detailed visual inspection, removal of the stops and introduction of corrosion resistant sealant and inhibiting compound on aircraft which had complied with the AD by embodiment of the SB. Textron categorised SEL 27-02 as mandatory, according to its own processes, but it was not accompanied by AD. Additionally, Supplemental Inspection 27-20-02, which calls for inspection of the rudder bellcrank every 100 hrs or Annual, whichever occurs first, was added to the C-152 maintenance manual.

Aircraft and maintenance information

G-BSZW and several other aircraft operated by the flying school were owned, maintained and leased by the same organisation. The aircraft were routinely stored outside.

A review of G-BSZW's defect log back to December 2022 did not reveal any reported anomalies with rudder control, nor any hard landings or tail strikes which could have altered the geometry of the rudder. The aircraft had undergone its most recent Annual/100 hour inspection on 9 February 2024 at 14,823 airframe hours. This included an inspection of the flying controls; no anomalies were noted with the rudder bellcrank. The rudder was last removed when the aircraft was repainted in April 2023 at 14,430 hours and its reinstallation was subject to an independent inspection.

G-BSZW was equipped with the larger rudder stops installed under AD 2009-10-09 but the investigation did not determine when, and to which revision, the AD had been embodied. A review of the aircraft records by the maintenance organisation suggested that the AD had been embodied prior to 2016. The maintenance organisation stated that fitment of the larger rudder bumpers was a terminating action of AD 2009-10-09. It was not aware of the subsequent SEL and supplementary inspections but considered that, as the aircraft was maintained on an owner-declared maintenance programme, there was no requirement to carry out the manufacturer's inspection recommendations. As such, the aircraft had not been routinely inspected in accordance with Supplemental Inspection 27-20-02.

Following the bellcrank failure, a new rudder assembly was fitted to the aircraft. The maintenance organisation reported that the original rudder was later inspected and found to be straight along its entire length. A new bellcrank assembly was installed and the original rudder was subsequently refitted to G-BSZW at the next scheduled maintenance check. A rigging/range of movement check was carried out at that time and the bellcrank did not come in to contact with the fuselage.

The maintenance organisation considered that the fouling condition could have been caused by a misaligned or bent bellcrank and that the end of the bellcrank must have only just been touching on the fuselage rub-plate as it had not fully worn through the paint.

Discussion

The failure occurred as a result of SCC which initiated on the inboard edge of the bellcrank, in a location where the bellcrank had been fouling against the fuselage rub-plate. The resulting wear left bare metal exposed on the inboard edge of the bellcrank without any corrosion protection, leading to the initiation of corrosion on this surface. The associated material removal would have substantially reduced the cross section of the bellcrank inboard of the attachment hole, leading to increased stress in this area. The combination of corrosion and increased stress precipitated the initiation of a stress corrosion crack, which propagated through the thickness of the bellcrank, until it finally failed in overload when insufficient material remained to carry the loads imparted by the rudder control circuit. A second, much smaller SCC initiation site was also present at the outboard edge of the bellcrank, where the surface protection was also compromised, but the cracking had not progressed to the same extent as that on the inboard side.

The bolt stack attaching the right rudder cable to the rudder bellcrank did not conform to the C152 IPC. The bushing was larger and of a different style to that specified, which indicates that the attachment hole had been oversized at some point. This could also have contributed to the reduced cross section of the bellcrank.

The failure did not exhibit any similar characteristics to a previous bellcrank failure mechanism identified by the manufacturer on an aircraft that had been modified to incorporate larger rudder stops, in accordance with AD 2009-10-09. G-BSZW was not subject to supplementary inspection 27-20-02 but, had it been, this may have provided an opportunity for the developing stress corrosion crack on the bellcrank to be identified.

The rudder was last disturbed when the aircraft was repainted in April 2023. It is therefore reasonable to conclude that the contact between the bellcrank and aircraft rub-plate commenced at some point between then and February 2024, during which period the aircraft had operated for 400 hours. The bellcrank should not ordinally come into contact with the rub-plate and the reason for this was not determined. The manufacturer indicated that incorrect fitment of the fin and/or rudder, incorrectly set rudder stops allowing over-travel of the bellcrank or a change to rudder alignment, such as from a tailstrike, could potentially lead to contact between the bellcrank and fuselage. There was no record of a tailstrike in the recent maintenance history, and no deformation to the rudder was noted after its removal. The maintenance organisation suggested that a misaligned or bent bellcrank could have been a factor, but this was not obvious during the aircraft examination.

Conclusion

The right rudder cable detached from the rudder control circuit when the rudder bellcrank failed. The predominant failure mechanism was identified as SCC which initiated in an area of mechanical wear, caused by fouling of the bellcrank against the fuselage. However, the precise reason for the fouling condition was not established.