Air Accident Investigation Unit Ireland

FACTUAL REPORT

ACCIDENT
Cessna 172S, EI-DDX
Cork Airport

6 January 2020

An Roinn Iompair
Department of Transport

Foreword

This safety investigation is exclusively of a technical nature and the Final Report reflects the determination of the AAIU regarding the circumstances of this occurrence and its probable and contributory causes.

In accordance with the provisions of Annex 13[1] to the Convention on International Civil Aviation, Regulation (EU) No 996/2010[2] and Statutory Instrument No. 460 of 2009[3], safety investigations are in no case concerned with apportioning blame or liability. They are independent of, separate from and without prejudice to any judicial or administrative proceedings to apportion blame or liability. The sole objective of this safety investigation and Final Report is the prevention of accidents and incidents.

Accordingly, it is inappropriate that AAIU Reports should be used to assign fault or blame or determine liability, since neither the safety investigation nor the reporting process has been undertaken for that purpose.

Extracts from this Report may be published providing that the source is acknowledged, the material is accurately reproduced and that it is not used in a derogatory or misleading context.

[1] **Annex 13**: International Civil Aviation Organization (ICAO), Annex 13, Aircraft Accident and Incident Investigation.
[2] **Regulation (EU) No 996/2010** of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation.
[3] **Statutory Instrument (SI) No. 460 of 2009**: Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulations 2009.

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In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No 996/2010 and the provisions of SI No. 460 of 2009, the Chief Inspector of Air Accidents on 6 January 2020, appointed Clive Byrne as the Investigator-in-Charge, to carry out an Investigation into this accident and prepare a Report.

Aircraft Type and Registration:	Cessna 172S, EI-DDX	
No. and Type of Engines:	1 x Lycoming IO-360-L2A	
Aircraft Serial Number:	172S8313	
Year of Manufacture:	1999	
Date and Time (UTC)[4]:	6 January 2020 @ 13.12 hrs	
Location:	Cork Airport (EICK)	
Type of Operation:	Commercial Flight Training	
Persons on Board:	Crew – 1	Student Pilot – 1
Injuries:	Crew – Nil	Student Pilot – Nil
Nature of Damage:	Substantial	
Commander's Licence:	Commercial Pilot Licence (CPL) Aeroplanes (A), issued by the Irish Aviation Authority (IAA)	
Commander's Age:	26 years	
Commander's Flying Experience:	445 hours, of which 413 were on type	
Notification Source:	Duty Manager EICK	
Information Source:	AAIU Field Investigation AAIU Report Form submitted by the Pilot	

[4] **UTC**: Co-ordinated Universal Time. All times in this Report are quoted in UTC, which was the same as local time on the date of the accident.

SYNOPSIS

During an instructional flight at Cork Airport (EICK), a section of the left main landing gear assembly departed the aircraft following a touch-and-go landing on Runway (RWY) 25. The Instructor, after discussions with Cork Air Traffic Control (ATC), performed a controlled two-wheel landing at EICK following which he steered the aircraft onto the grass verge to the left of the runway. There were no injuries reported. There was no fire.

NOTIFICATION

The Cork Airport Duty Manager notified the AAIU Inspector-On-Call (IOC) at approximately 13.15 hrs, shortly after the event occurred. Two Inspectors of Air Accidents deployed to Cork Airport and commenced an Investigation.

1. FACTUAL INFORMATION

1.1 History of the Flight

At 12.52 hrs, EI-DDX, with a Student Pilot in the left seat, and an Instructor occupying the right seat, departed RWY 25 at EICK with the intention of conducting local circuit training. After completing a right-hand circuit, the aircraft performed a touch-and-go landing on RWY 25 at 12.58 hrs. The Pilot and Instructor did not observe any anomalies during the touch and go landing and the aircraft commenced the next circuit.

During the climb out, at approximately 300 feet AGL[5], and whilst checking the position of the aircraft in relation to the runway centreline, the Student Pilot noticed that the left main undercarriage wheel was missing and '*had broken away from the strut'* as shown in **Photo No. 1**. This was relayed to the Instructor who immediately took control of the aircraft.

Photo No. 1: Left Main Undercarriage post touch-and-go (Source: *Student Pilot*)

[5] **AGL:** Above Ground Level

At 12.59 hrs, the Instructor contacted Cork ATC and informed them of the situation regarding the damaged landing gear. Cork ATC routed the aircraft to the Dunkettle Hold[6], while both runways (RWY 07/25 and RWY 16/34) at EICK were inspected for possible debris and damage. At 13.03 hrs, Cork ATC asked the Instructor '*…what are your intentions?'* to which the Instructor replied that he *'… would like to just come in and land RWY 25 if possible.'* At this point and in discussion with ATC, the Instructor declared an emergency. When RWY 07/25 was declared clear of debris, the aircraft was given clearance by ATC to land on RWY 25.

At 13.04 hrs, the Instructor informed Cork ATC that they '*… were ready to come in now anytime you are ready'.* ATC gave the Instructor approval to proceed back to final approach on RWY 25 and requested the Instructor to '*report established finals RWY 25'.* ATC also ensured that the rescue services on the ground were kept informed of the unfolding situation. At 13.08 hrs, EI-DDX contacted ATC to advise that they were established '*… at 2 miles final RWY 25',* to which ATC gave landing approval.

The Instructor performed a controlled two-wheel landing on RWY 25 at 13.12 hrs and he then steered the aircraft onto the grass verge to the left of the runway. The emergency services, that were awaiting the aircraft's arrival, attended the scene immediately and reported the flight crew and aircraft safe.

1.2 Flight Crew Details

1.2.1 Instructor Information

The Instructor's CPL (A) contained a valid SEP (Land)[7] class rating. The Instructor's Medical Certificate was valid. The Instructor's total and recent flying experience is set out in **Table No. 1**.

Age:	26 years
Licence:	CPL (A)
Total all Types	445 hours
Last 90 Days:	121 hours
Last 28 Days:	27 hours
Last 24 Hours:	1 hour
Total on Accident Type:	413 hours

Table No. 1: Instructor flying experience

1.2.2 Student Pilot Information

The Student Pilot was undergoing training for a Private Pilot Licence (Aeroplane) under the guidance of his Instructor. The Student held a Class 2 Medical Certificate which was valid. The flying experience of the Student Pilot is set out in **Table No. 2**.

[6] **Dunkettle Hold:** One of the four visual holding patterns for EICK.
[7] **SEP (Land):** Single Engine Piston (Landplanes).

Age:	27 years
Licence:	N/A
Total all Types	65 hours
Last 90 Days:	1.35 hours
Last 28 Days:	1.35 hours
Last 24 Hours:	0 hours
Total on Accident Type:	65 hours

Table No. 2: Student Pilot flying experience

1.3 Meteorological Information

The Meteorological Aerodrome Report (METAR) issued by *Met Éireann* and broadcast on the aerodrome ATIS indicated generally benign conditions, with a westerly wind of 16 kts and a few clouds at 2,200 ft. The temperature was 10 degrees Celsius. The trend indicated that there would be no significant change in weather conditions during the subsequent two hours.

1.4 Aerodrome Information

EICK has two runways, both of which have a grooved asphalt surface. The occurrence runway, RWY 07/25, is 1,310 m in length and can be observed in **Figure No. 2 (Section 1.6)**.

1.5 Aircraft Information

The Cessna 172S is a high wing aircraft constructed from aluminium and powered by a single 180 horsepower (134 kW) Lycoming IO-360-L2A engine. It has a fixed tricycle landing gear configuration and was factory-built in 1999. At the time of the accident it had completed a total flying time of 14,674 hours. The total number of landings for the aircraft was not recorded in the aircraft's maintenance records, nor are they required to be as per the Manufacturer's requirements. The aircrafts main wheels are attached to the aircraft fuselage via an undercarriage leg assembly, which comprises a main landing gear tubular spring, axle, wheel, and associated sub-assemblies (**Figure No. 1**). For clarity, **Figure No. 1** illustrates the arrangement with the aerodynamic fairing removed from the undercarriage.

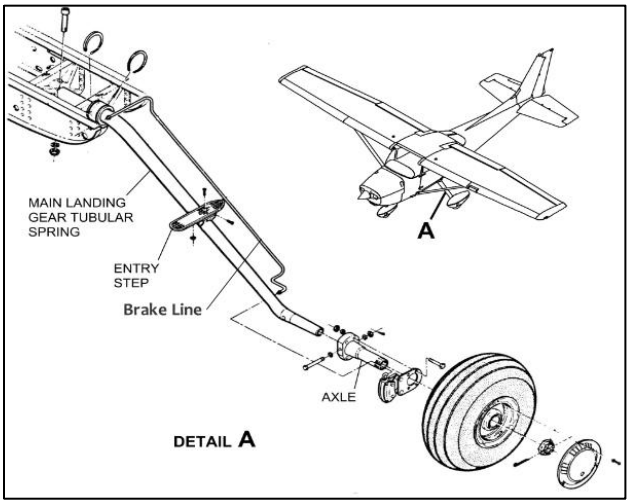

Figure No. 1: General undercarriage arrangement

(Adapted from Cessna 172 Maintenance Manual)

Between January 2000 and February 2004, the aircraft was registered as G-UFCA in the United Kingdom (UK) and was owned and operated by two different Flying Schools. On 19 February 2004, the aircraft was de-registered in the UK, for the purposes of registration to the Irish aircraft register, where it received the registration mark EI-DDX. The aircraft has been owned and operated by its current Operator from 19 February 2004 to 6 January 2020.

A Certificate of Airworthiness was issued for the aircraft by the IAA on 18 February 2015. At the time of the accident, the aircraft was operating on an Airworthiness Review Certificate (ARC) (2nd extension) issued by a UK Civil Aviation Authority (CAA) approved Part-M Subpart G Maintenance Organisation, on 18 May 2019 and was valid until 20 May 2020. The aircraft had completed a 100-hour maintenance inspection 13 hours prior to the accident and had completed an annual maintenance inspection 196 hours prior to the accident.

1.6 Damage to Aircraft

The aircraft sustained substantial damage to its left main undercarriage and associated sub-assemblies. The aircraft was steered off the runway and the aircraft's nose landing gear, propeller, left wingtip, left horizontal stabiliser and elevator all sustained ground impact damage. There was also possible shock loading to the engine. **Photo No. 2** shows the final position of the aircraft where it came to rest adjacent to RWY 25.

Photo No. 2: Final position of EI-DDX

The aircrafts left wheel and brake assembly, which departed from the aircraft during the touch-and-go landing, was recovered from the grass on the right side of RWY 25 as shown in **Figure No. 2** and **Photo No. 3**.

Figure No. 2: Wreckage locations (Source: *Google Earth*)

Photo No. 3: Detached Left wheel

The aircraft was left in-situ pending the arrival of the AAIU (the main runway at EICK, RWY 16/34, remained operational). Following an inspection by the AAIU and due to the fact that the remaining left main undercarriage strut was buried in the soil, the aircraft was prepared for lifting using a locally-sourced crane. The aircraft was then lifted from the accident site and placed onto the runway under the supervision of the Operator. Once stabilised on the runway using a transport bogey, as shown in **Photo No. 4**, the aircraft was moved to the Operator's maintenance facility at the airport for further examination of the damage. The remaining portion of the left main undercarriage and aerodynamic fairing were removed and provided to the Investigation for further analysis.

Photo No. 4: Damaged Left Main Undercarriage

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1.7 Survivability

The aircraft is fitted with 3 point harnesses which incorporate an inertia reel. During Interviews with both occupants, the harnesses were recorded as having operated satisfactorily and with no adverse effects or findings mentioned.

1.8 Examination of Fractured Undercarriage

1.8.1 Initial Fracture Surface Examination

The recovered left undercarriage wheel, which was still securely attached to its axle and a portion of the main undercarriage leg, was retrieved from the grass verge of RWY 25. The fracture surface on the leg displayed distinct markings and discolouration, which were consistent with fatigue cracking. At the fracture surface, a portion of base metal was absent and several cracks emanating from this area were evident (**Photo No. 5**). On subsequent inspection using a microscope, a number of additional areas of surface corrosion around the outside diameter of the leg and in the vicinity of the fracture were also identified. See also **Figure No. 6** and **Figure No. 7.**

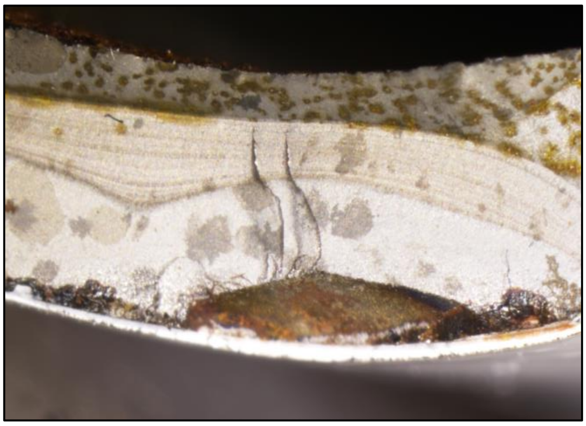

Photo No. 5: Microscopic examination of fracture surface (Wheel side)

1.8.2 Metallurgical Analysis

In order to assess the cause and mode of failure, the two sections of the undercarriage leg, were sent to a specialist laboratory for detailed metallurgical analysis. The analysis performed included detailed visual inspection, metallographic sectioning through the fracture surface, hardness testing and detailed examination using a Scanning Electron Microscope (SEM). A detailed report on the analysis and findings was provided to the Investigation and is discussed here.

1.8.3 Initial Findings of Metallurgical Analysis

As shown in **Figure No. 3**, the leg had fractured approximately 130 mm from the wheel axle flange. The outer diameter (OD) of the leg had been wrapped in a clear polyurethane type tape. On the wheel side of the failure, the fracture surface was relatively clean, undamaged and the chevron markings indicated that the failure had initiated within a thumbnail-shaped region, which was located on the underside of the spring (as fitted to the aircraft) and the failure had propagated in both directions around the circumference.

The corresponding fracture surface, on the fuselage side of the failure, appeared to have dragged along the ground post-fracture and the resulting abrasion had removed the thumbnail-shaped initiation region from it.

Figure No. 3: Failure position

1.8.4 Detailed Examination

In the vicinity of fracture initiation, the surface of the white enamel paint coating on the OD was uneven and showed a prominent bulge, 25 to 35 mm from the fracture plane. The fracture surfaces were microscopically examined and the paint coatings on the OD of the leg were chemically removed approximately 60 mm from either side of the fracture plane. After paint removal, it became apparent that the bulge was due to a bead of weld. Several other welds were also visible (**Figure No. 4(A)**). Two of the welds were coincident with the thumbnail-shaped region of crack initiation, on the fracture surface. There were indications that an attempt had been made to grind off the excess weld metal but it still remained slightly proud of the surface.

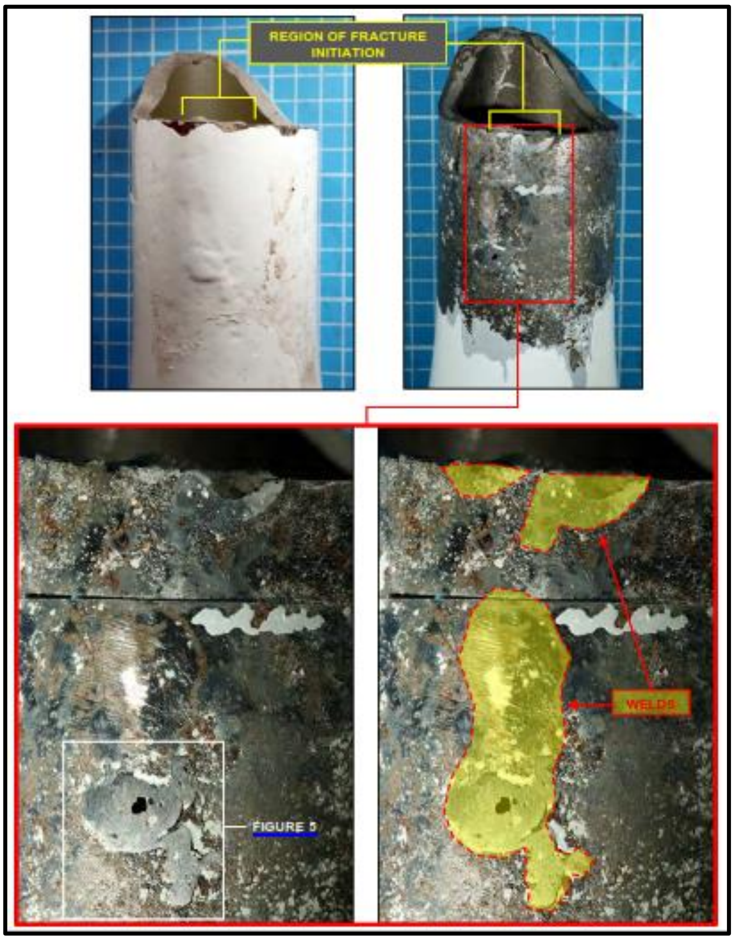

Figure No. 4(A): Initial examination

Metallurgical analysis identified that the welds were *'generally of very poor quality'*, showing a high degree of surface porosity, and there was no significant evidence of corrosion of the weld metal. However, the surrounding surfaces of the OD showed widespread and severe pitting corrosion to the base metal which can be observed in **Figure No. 4 (B)**. This indicated that the welds had been performed after the corrosion had occurred and that not all corrosion was removed prior to the weld repair.

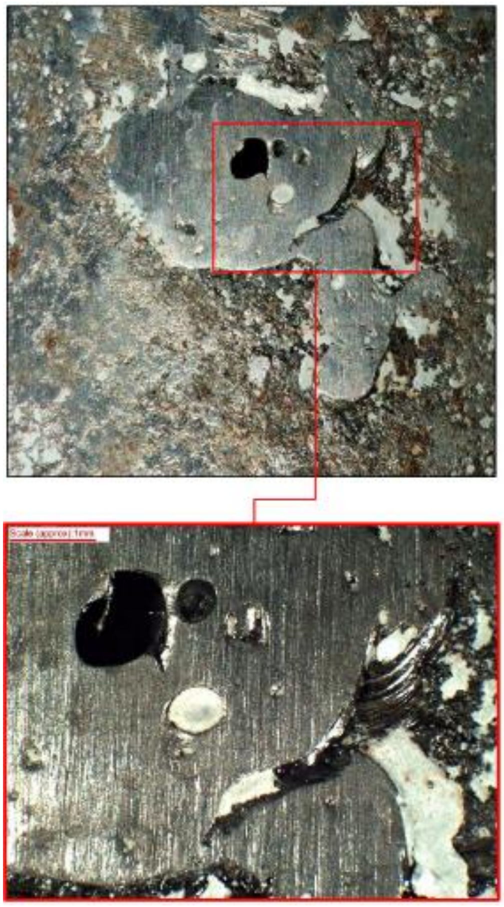

Figure No. 4 (B): Weld porosity and severe pitting corrosion surrounding the weld

There was evidence of mechanical abrasion of the surface, which suggested that an attempt had been made to blend out some of the corrosion, with limited success. The welds and the residual corrosion had been painted over, resulting in the unevenness and bulge in the coatings described above.

On the inner diameter (ID) of the leg, heat discolouration was evident in the green primer, at locations coincident with the location of the welds and this is shown in **Photo No. 6** below.

Photo No. 6: Internal heat discolouration

1.8.4.1 Detailed Examination of Fracture Surfaces

Both surfaces of the fracture can be observed in **Figure No. 5**. On the wheel side of the failure, the fracture surface was relatively clean and undamaged. Chevron markings present on the fracture surface indicated that the failure had initiated within a thumbnail-shaped region, which was located on the underside of the leg (as fitted to the aircraft) and had propagated in both directions around the circumference. The corresponding fracture surface, on the fuselage side of the failure, appeared to have dragged along the ground post fracture and the resulting abrasion had removed the thumbnail-shaped initiation region from it.

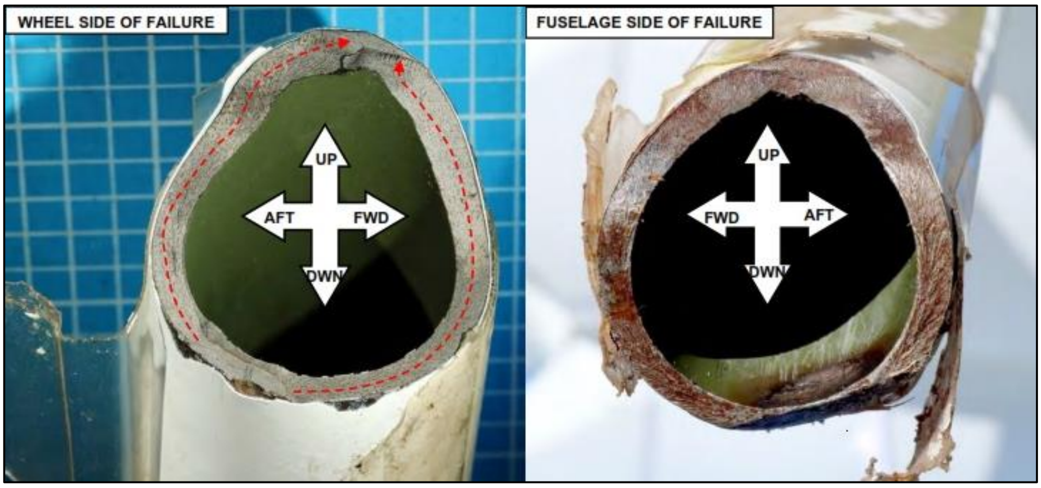

Figure No. 5: Fracture surfaces

The thumbnail-shaped region of the fracture surface on the wheel side of the failure consisted of three distinct Zones and a Final Separation Area, and is shown in more detail in **Figure No. 6** and **Figure No. 7**.

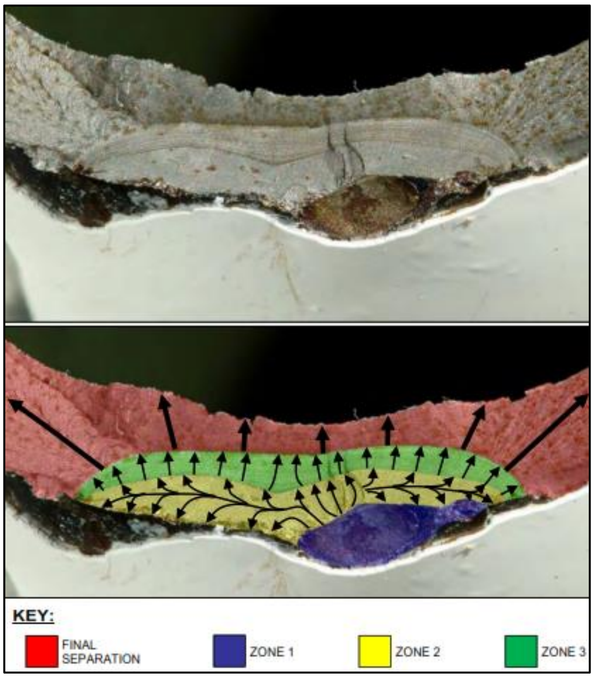

Figure No. 6: Zones identified in fracture surface

Zone 1

Zone 1 extended inwards from the OD, and was at a shallow angle to it. It showed evidence of straw to violet heat tinting[8], which indicated that it had formed whilst this region was hot. It also showed a light covering of red rust, which indicated that it had formed some considerable time before the date of the accident. When viewed on the OD, after paint removal, it was surrounded by weld metal.

Etched metallographic examination indicated that this zone was entirely within the Heat Affected Zone (HAZ)[9] of the weld (**Figure No. 7**).

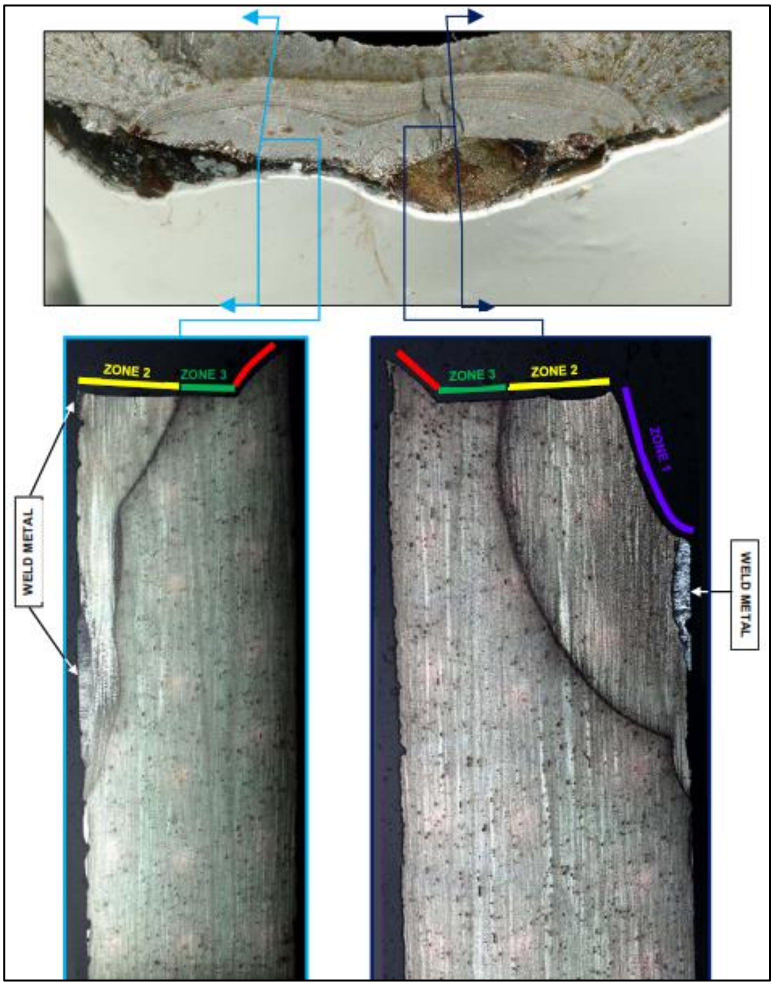

Figure No. 7: Etched metallographic sections

When viewed at high magnification in the SEM, the surface of this zone showed a high degree of intergranular character consistent with an instantaneous brittle fracture (**Figure 8 (A)**).

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[8] **Heat Tinting:** The apparent colouration on the surface of a metal caused by the formation of thin layers of oxide during exposure to elevated temperatures.

[9] **Heat Affected Zone:** That portion of the base metal which has not been melted, but whose mechanical properties or microstructure have been altered by the heat of welding. (ASM International, 1993, ASM Handbook, Volume 6, Welding Brazing, and Soldering).

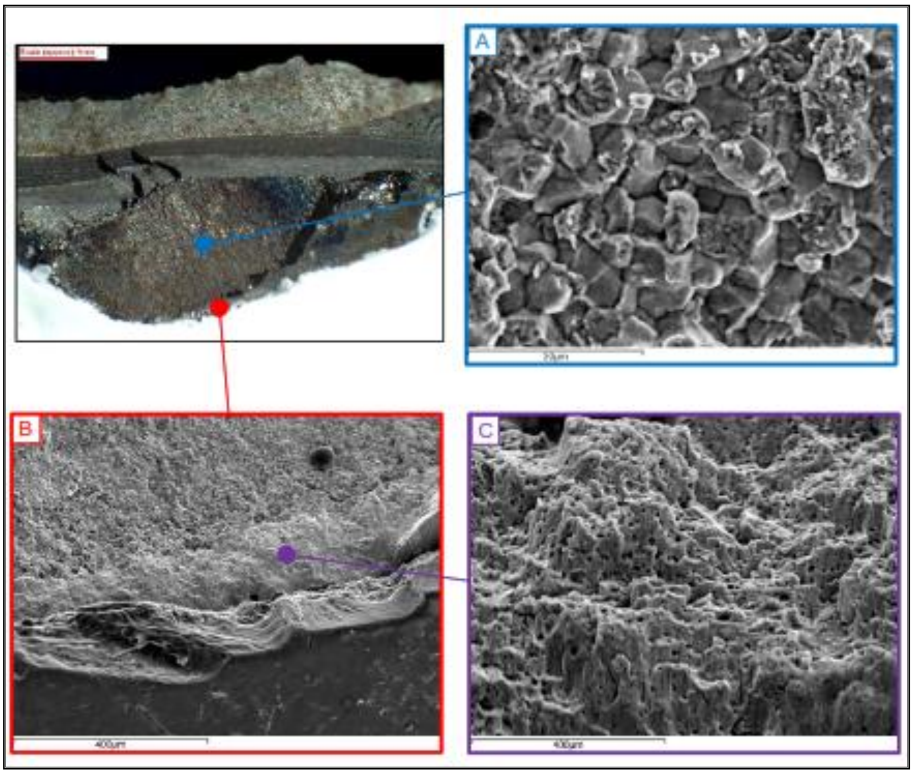

Figure No. 8: Secondary electron images of Zone 1

Around the edge closest to the OD, there was a narrow band of the fracture surface, which showed a dimpled texture, characteristic of ductile separation (**Figure No. 8 (B)** and **Figure No. 8 (C)**).

The characteristics of Zone 1 indicated that this crack had initiated sub-surface and spread outwards, towards the surface. It was considered most likely that damp conditions during welding had caused hydrogen embrittlement[10] in the HAZ and that the crack had formed whilst the weld was cooling.

Zone 2

Zone 2 extended inwards from Zone 1 and was perpendicular to the OD. **Figure No. 9** shows the radial markings on its surface, which indicate that it had initiated from the edge of Zone 1. Two steps in the fracture surface indicate that this zone had formed by the coalescence of three separate cracks. No fatigue progression markings (beach marks) were visible on the surface.

[10] **Hydrogen Embrittlement:** A delayed failure mechanism, which can affect hardened and tempered steels, with tensile strengths above approximately 1,100 Megapascal (MPa). Elemental hydrogen is absorbed into the steel and may result in delayed brittle fracture, at levels of stress well below the yield stress of the steel. The hydrogen may originate from environmental conditions, such as corrosion or from manufacturing or repair processes, such as acidic cleaning / pickling, etching, electroplating and welding in damp conditions. Hydrogen embrittlement fractures occur suddenly and without warning, anything up to several years after the process or condition, which was the source of the hydrogen.

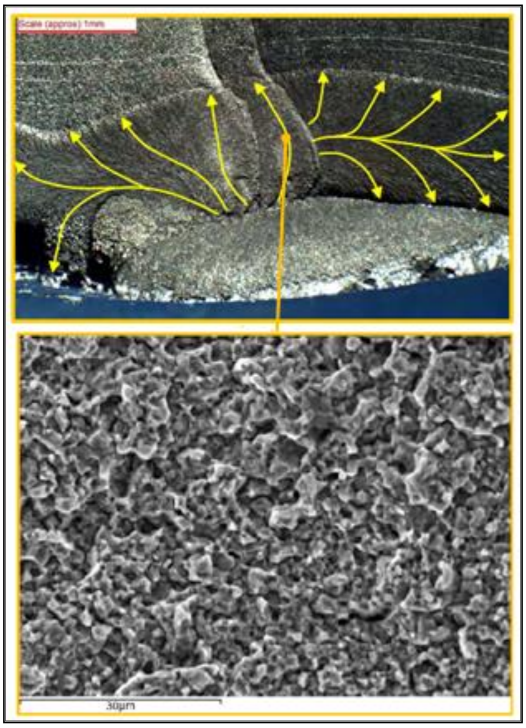

Figure No. 9: Radial markings and secondary electron images of Zone 2

Etched metallographic examination indicated that this zone represented the full extent of the HAZ of the weld as shown in **Figure No. 7**. When viewed at high magnification in the SEM, the secondary electron image (**Figure No. 9**) of the surface of this zone showed a significant degree of intergranular character. It was considered most likely to be an instantaneous but delayed fracture, which had occurred sometime after the welding had been performed. It was considered most likely that damp conditions during welding had caused hydrogen embrittlement and delayed fracture of the HAZ.

<u>Zone 3</u>

Zone 3 extended inwards from Zone 2 and was also perpendicular to the OD. Fatigue progression markings were clearly visible, which were concentric with the edge of Zone 2. Etched metallographic examination indicated that the transition from the instantaneous but delayed fracture of Zone 2 to the fatigue crack growth of Zone 3 had occurred at the edge of the HAZ of the weld as shown in **Figure No. 7**. When viewed at high magnification in the SEM, fatigue progression markings and fine striations[11] were evident, which were concentric with Zone 2 as shown in **Figure No. 10**.

[11] **Striations:** A series of ridges, furrows or linear marks on the fracture surface that show the incremental growth of a fatigue crack.

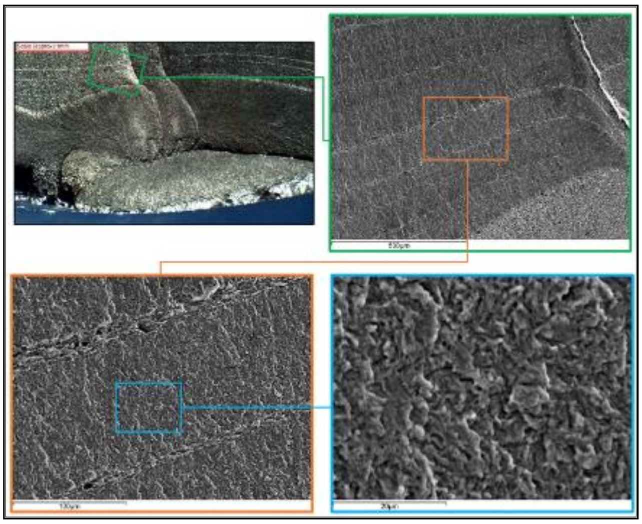

Figure No. 10: Secondary electron images of Zone 3

This indicated that, outside the HAZ of the weld, the crack had extended for a period by stable fatigue crack growth. It was not possible however, to estimate the number of landings over which the crack had extended with any degree of confidence, by evaluation of these markings.

Additional Observations

Zones 2 and 3 showed some spots of red rust, which had formed after the undercarriage leg had separated. The absence of any pre-separation rusting indicated that Zone 2 had formed shortly before the accident date and there had been a relatively brief period of stable fatigue crack growth between crack initiation and the accident date. The remainder of the fracture surface, outside of Zones 1, 2 and 3, was consistent with final separation of the leg, which occurred instantaneously during the accident while performing the touch-and-go landing.

Secondary cracks were also detected in the weld HAZ (Zone 2) and were found to be perpendicular to the fracture surface and are shown in **Figure No. 11**. It was considered likely that they had been caused at the same time and in the same manner as Zone 1.

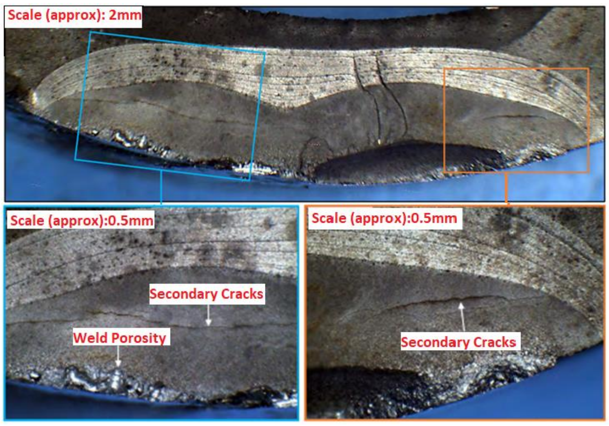

Figure No. 11: Secondary cracks on fracture surface

Outside the welds and Heat Affected Zones, the alloy microstructure of the undercarriage leg was found to be tempered martensite. Its hardness was measured as 50 HRC[12].

[12] **HRC:** Rockwell C hardness scale.

1.8.4.2 Metallurgical Summary

Detailed metallurgical analysis of the fracture surface identified poor quality weld repairs, most likely conducted in damp conditions, causing a degree of hydrogen embrittlement in the Heat Affected Zone thereby severely compromising the structural integrity of the undercarriage leg.

1.9 Information from Aircraft Manufacturer

The Aircraft Manufacturer was consulted and asked if a weld repair was permitted to the undercarriage leg. The manufacturer responded as follows:

> '[The Aircraft Manufacturer] *have no record in our files of a weld repair on Aircraft 172S8313. There is no way to weld this spring steel in the field and come up with an equivalent strength repair. The 0541198-7/-8/-9 LH/RH MLG Spring/Springs are to be removed and replaced'.*

When asked if the aircraft could have been delivered from production with a weld having been carried out, the Aircraft Manufacturer completed a background check of the aircraft's production documentation. The Aircraft Manufacturer responded that as part of a review of both the specific serial-numbered undercarriage leg in question and that of the aircraft's original production documents, it was confident that no weld repair was carried out by the aircraft production facility. In addition, the Aircraft Manufacturer stated that a review of its documentation indicates that during the aircraft production process *'… the gear was inspected and found to be in compliance with the process specifications'* and that *'the gear leg in question was not rejected or repaired at* [Aircraft Manufacturer]*'*.

The Aircraft Manufacturer also stated that a review of engineering documentation of this undercarriage spring part number series, dating from 1996, found that there was no weld dispositions issued from the Engineering Department.

The Aircraft Manufacturer provided the Investigation with details regarding the material type, strength properties and surface finishes of a newly manufactured undercarriage leg. The undamaged base material of the failed leg was analysed during the metallurgical examination and was found to be within the specifications provided to the Investigation.

Regarding the repeat interval for inspection of the main landing gear structure where the aerodynamic fairings are removed, the Aircraft Manufacturer informed the Investigation as follows:

> [Aircraft Manufacturer] *inspection requirements are every 100 hours as prescribed* [in Aircraft Maintenance Manual] Reference: *321002.* [The Aircraft Manufacturer] *requires/recommends maintenance practices and intervals but the regulatory agency determines whether to use the manufacturer's recommendations or their own. In the case of the FAA* [United States Federal Aviation Administration]*, CFR 14 Part 91.409 aircraft are required to be inspected in accordance with FAR 43.13 Appendix D once yearly, or every 100 hours if the aircraft is used for hire.*

1.10 Aircraft Maintenance

The Investigation was informed by the Maintenance Organisation responsible for maintaining the aircraft, that the aircraft had its aerodynamic undercarriage leg fairings removed on an annual basis '*to inspect the legs for corrosion, treat and re-protect as required'* in accordance with the aircraft's IAA Approved Maintenance Programme (AMP).

Maintenance records reviewed by the Investigation show that the aircraft had completed 196 flying hours since its last annual maintenance inspection, which was completed on 4 October 2019. There were no defects of undercarriage corrosion or undercarriage leg repairs noted in the annual inspection of 2019.

Maintenance records also indicate that the aircraft had undergone two 50-hour inspections and two 100-hour inspections since its last annual inspection. Similarly, notwithstanding the fact that there was no specific call up to inspect the undercarriage leg at the 50-hour or 100-hour inspection interval, there were no defects of undercarriage corrosion or undercarriage leg repairs noted in these four inspections.

The Investigation also reviewed Annual Inspection records for 2017 and 2018. There were no findings of corrosion defects or undercarriage leg repairs noted in the annual inspection of 2017. The 2018 Annual Inspection noted that both main undercarriage legs were removed for corrosion issues. Records indicate that the corrosion issues identified were addressed in accordance with Maintenance Manual instruction and the undercarriage legs were refitted accordingly. The Operator and Maintenance Organisation stated that they had no record or knowledge of any weld repair being carried out on the undercarriage leg while the aircraft was under their supervision.

The aircraft Operator in consultation with the Maintenance Organisation noted that:

> *The* [Manufacturers] *progressive care programme requires inspection every 100hrs but for those aircraft not utilising the* [Manufacturers] *progressive care program and instead using a standard Annual/100hr regime as the FAA and EASA both do, the* [Manufacturers] *maintenance manual requirements apply as recommendations which are listed in* [Manufacturers] *SIN 32-13-01 (chapter 05-14-03 of the* [aircrafts] *maintenance manual). The requirements of* [Manufacturers] *SIN 32-13-01 only requires the fairings to be removed and the tubular legs inspected for corrosion, in a severe environment, after 10 years from new and then repeat every 5 years. Our* (Maintenance Organisations) *maintenance program, which is fully compliant with EASA regulations, calls this inspection up annually from new, which far exceeds the OEM recommendation.*

The Maintenance Organisation stated that the application of clear anti-chafe (polyurethane) tape on the undercarriage leg was used in an effort to *'prevent the leg fairing from chafing through the paint on the leading edge of the leg, exposing bare metal which then attracts corrosion*'. The operation of the aircraft close to the coast is consistent with it being operated in a '*Severe'* corrosion environment from a maintenance perspective and as outlined in the aircraft maintenance manual.

The Operator informed the Investigation that the aircraft had not flown with its aerodynamic wheel spats installed for some time. An exact date for when they were last installed was not readily available but was estimated by the Operator to be '*at least 2 years*'. As noted in **Section 1.5**, the aircraft had accumulated 14,674 flying hours and while not required to be recorded, the number of landing cycles on the aircraft was estimated by the Operator to be in the region of 30,000 – 35,000 cycles.

1.10.1 Sheet-Metal Repair

A sheet-metal repair to the left undercarriage aerodynamic fairing was found to have initiated a corrosion point at another location on the undercarriage leg. One of the rivet fasteners (circled in black in **Photo No. 7**) on the repair was found to be in contact with the leg. The contact between the rivet and the undercarriage leg was such that, through the action of fretting, the rivet had worn through the locally applied polyurethane tape and the protective enamel paint. This had eroded the undercarriage leg significantly, thereby exposing the undercarriage leg's base material to corrosion (circled in red in **Photo No. 7**).

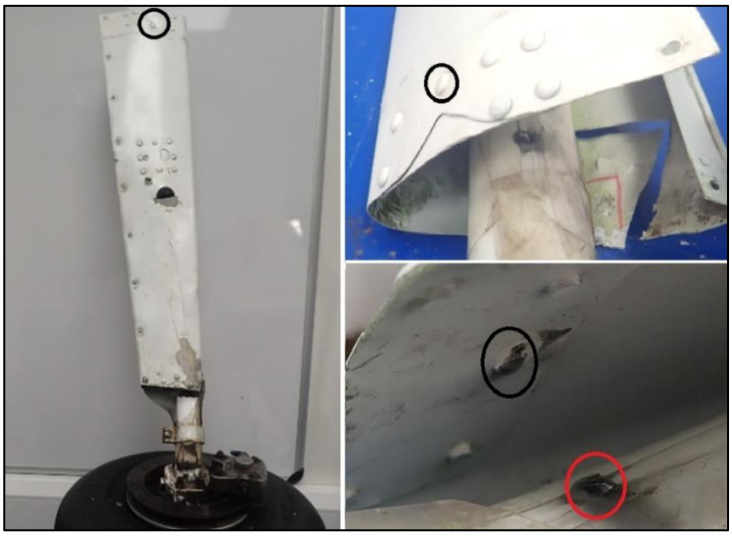

Photo No. 7: Sheet-metal repair & associated damage to undercarriage leg

Metallurgical analysis revealed that the rivet had worn through the polyurethane tape and enamel paint coating to a depth of approximately 0.2 mm below the surface of the base metal. This was not considered to be associated with the failure of the undercarriage leg; however, it is possible that the corrosion would be concealed by the undercarriage fairings and therefore would not be evident until the fairings were removed during the next Annual Inspection

1.11 Occurrence to other Operator's Aircraft

The United Kingdom's Air Accident Investigation Branch (AAIB) issued Bulletin 5/2017[13] included an occurrence in which a Cessna 172N Skyhawk aircraft experienced an accident where the aircraft suffered a detached right mainwheel assembly during landing. The report identified that:

> *'The failure occurred as a result of a fatigue crack in the landing gear leg that initiated at the position where a screw in the wheel fairing had made contact with the leg'.*

[13] **AAIB Bulletin:** G-DUVL EW/G2016/12/07 (5/2017).

The AAIB Bulletin focuses on issues relating to incorrect screw lengths being used in the attachment of aerodynamic wheel spat fairings to undercarriage legs. In the case of the event investigated by the AAIB, a dent of 1.6 mm in depth led to the failure of the undercarriage. This is a known issue and one which prompted the Operator of EI-DDX to remove the aerodynamic spats from their aircraft. While aerodynamic spat fairing attachment issues were not associated with the subject accident aircraft (EI-DDX), the AAIB Bulletin serves to highlight the danger of undetected corrosion and surface anomalies in undercarriage legs.

1.12 Follow Up Safety Action

Following the accident, the Operator, in conjunction with the Maintenance Organisation, undertook a number of follow up safety steps to reduce the risk of a reoccurrence. A fleet check, at the next annual inspection interval, on the Operator's Cessna 172 aircraft was instigated.

This check necessitated the removal of all undercarriage legs from the affected aircraft, paint strip them back to bare metal and the performance of a detailed inspection for corrosion, unauthorised repairs or cracks. During the fleet check, a number of undercarriage legs were rejected, for various corrosion-related reasons, which has given assurance to the Operator and Maintenance Organisation that the instigation of the fleet check was a prudent decision.

The Maintenance Organisation and the Operator also completed a review regarding the application of the clear polyurethane tape. The practice of applying polyurethane tape directly to the legs in an effort to protect the legs from chafing with the aerodynamic undercarriage leg fairing has now ceased. Anti-chafe protection in that area is now being provided via a protective tape being applied to the inside of the undercarriage leg fairing instead.

The Operator advised that new undercarriage legs were being supplied by the Aircraft Manufacturer with clear polyurethane tape applied to the undercarriage legs as standard. The Investigation sought clarification from the Aircraft Manufacturer in this regard. The Aircraft Manufacturer clarified that the tape *'… is listed on the blueprint for the landing gear spring assembly, therefore it is required'.* In light of this clarification, the Investigation has informed the Operator that clarification on the method (application to leg or fairing) of protecting the undercarriage leg with the tape should be discussed directly with the Aircraft Manufacturer.

In addition, the Maintenance Organisation informed the Investigation that:

> *'Since the incident* [Maintenance Organisation] *… have updated working practices and the corrosion check of the legs is now a line entry as a defect requiring a written closure action, i.e. no corrosion / minor, no action / or corrosion control measures taken and detailed'.*

The Investigation informed the Operator of the surface anomalies noted on the undercarriage leg during the Investigation and suggested that the Operator considers the possibility of increasing the undercarriage leg inspection interval to a frequency of every 100 hours rather than that of the current IAA Approved Maintenance Programme which calls for the undercarriage fairings to be removed annually to facilitate undercarriage leg inspection.

The Operator stated that following a review with relevant internal stakeholders, it considers its inspection frequency already exceeds the recommendations of the aircraft manufacturer and that 100 Hr checks on the undercarriage leg would be unnecessary and of no benefit based on their utilisation levels.

The Operator informed the Investigation that the maintenance programme remains in constant review. The Investigation is satisfied that the aircraft was being maintained in accordance and compliance with the IAA Approved Maintenance Programme extant at the time of the accident. Notwithstanding that the aircraft was being maintained in accordance with the IAA Approved Maintenance Program, the Investigation made a suggestion to the Operator to '*consider the possibility of increasing the undercarriage leg inspection interval to a frequency of every 100 hours*'. In response, the Operator advised that some of the undercarriage legs that had been paint stripped, inspected and repainted during the fleet inspection programme, had been re-inspected 12 months later and showed no signs of corrosion and therefore considers that the existing inspection frequency is adequate.

2. AAIU COMMENT

Detailed metallurgical analysis of the undercarriage leg identified that the failure of the component was due to unapproved and improper weld repairs, which had been performed on its outer diameter. Aside from the unapproved nature of the weld repair, the welds were of very poor quality, and were most likely conducted in damp conditions, such that they compromised the structural integrity of the leg causing a degree of hydrogen embrittlement in the Heat Affected Zone. Consequently, as the material cooled down after the welding process, cracks would have occurred within the material structure. With continued operation of the aircraft, a fatigue crack initiated from the tip of a crack within the Heat Affected Zone and propagated through the parent alloy material of the undercarriage during successive landing cycles. Eventually, the combined crack reached a critical length, which resulted in final separation of the leg during the touch-and-go landing. The Operator and Contracted Maintenance Organisation stated that they had no record or knowledge of any weld repair being carried out on the undercarriage leg while the aircraft was under their supervision and a review of aircraft maintenance documentation by the Investigation would support this. The aircraft has had a number of owners and operators since manufacture. The aircraft Manufacturer stated that on review of the aircraft production process, the undercarriage leg in question was inspected and found in compliance with the process specification. In addition, a review of the Manufacturer's engineering documentation for the undercarriage spring part number series, dating from 1996, found that there had been no weld dispositions issued from the Engineering Department to permit such a weld repair.

The exact time when the weld repair had been conducted could not be identified from a review of maintenance and production records. From the metallurgical analysis carried out it was not possible to determine the length of time that had elapsed between the weld repair and the accident.

During initial examination of the fracture area of the undercarriage leg, a layer of white enamel paint was found to be detached from the base material; the paint remained intact but was held in place by clear polyurethane tape. It would appear that the white enamel paint had been applied during routine maintenance; however, the base metal surface of the leg was not completely free from corrosion prior to the application of the paint.

In an effort to protect the leg from chafing damage with the aerodynamic fairing, a clear polyurethane type tape is applied by the Manufacturer as a blueprint requirement at manufacture and as a standard practice of the Operator and the Maintenance Organisation during ongoing maintenance. The application of this tape, while well-intentioned, possibly served to trap moisture at the surface of the leg, thereby exacerbating the potential for corrosion.

While the fracture itself was due to an unapproved and improper weld, other areas on the undercarriage leg displayed evidence of underlying surface corrosion. The layer of the polyurethane tape as applied over the leg, while not responsible for the fracture of the undercarriage leg, made it difficult to readily identify underlying corrosion or surface anomalies and it was only when the tape was removed that the extent of the issue was apparent. During an annual inspection, this tape was removed if it was considered that corrosion on the undercarriage leg was evident. However, although the tape was transparent to some degree, it would be difficult to detect the appearance of corrosion through the tape, which could result in corrosion going undetected.

Subsequent to the accident and in correspondence with the Investigation, the Operator and the Maintenance Organisation have reviewed the local maintenance practice regarding the application of the polyurethane tape between the undercarriage leg and its aerodynamic fairing and this practice is no longer being carried out. However, the Operator has been informed that clarification on the method (application to leg or fairing) of protecting the undercarriage leg with the polyurethane tape should be discussed directly with the Aircraft Manufacturer. In addition, a fleet check of the Operator's aircraft was conducted which necessitated the removal of all undercarriage legs from the affected aircraft, paint strip them back to bare metal and the performance of a detailed inspection for corrosion, unauthorised repairs or cracks and following evaluation, a number of undercarriage legs were replaced and the affected undercarriage legs were withdrawn from service. Due to the actions taken by the Operator, the Investigation considers that no Safety Recommendations are required.

3. SAFETY RECOMMENDATIONS

This Investigation does not sustain any Safety Recommendations.

- END -

In accordance with Annex 13 to the Convention on International Civil Aviation, Regulation (EU) No. 996/2010, and Statutory Instrument No. 460 of 2009, Air Navigation (Notification and Investigation of Accidents, Serious Incidents and Incidents) Regulation, 2009, the sole purpose of this investigation is to prevent aviation accidents and serious incidents. It is not the purpose of any such investigation and the associated investigation report to apportion blame or liability.

A safety recommendation shall in no case create a presumption of blame or liability for an occurrence.

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An Roinn Iompair
Department of Transport

Air Accident Investigation Unit,
Department of Transport,
2nd Floor, Leeson Lane,
Dublin 2, D02TR60, Ireland.
Telephone: +353 1 604 1293 (24x7): or
+353 1 241 1777 (24x7):
Fax: +353 1 604 1514
Email: info@aaiu.ie
Web: www.aaiu.ie
Twitter: @AAIU_Ireland