Appendix A: Technical Analysis Report

Examination of failed landing gear struts
MD Helicopters, Model MD520N
VH-MPI
21 June 2004

Report No. 35/04

Task No. BE/200400015

Occurrence No. BO/200402243

CONTENTS

1 FACTUAL INFORMATION

1.1 Examination brief

The right front and rear landing gear strut assemblies from the helicopter (without fairings) were submitted to the ATSB's Canberra Technical Analysis Laboratory for examination and analysis of the failures. The parts were identified as follows:

Front strut: 91 - 369H 6001-42 D
Rev. 6 1-24-91
S/O. A0201132

Rear strut: PNo: 369H 6001-32

The front strut carried the identification as ink stencilled print on the elbow section of the assembly. The rear strut did not carry any permanent markings and was identified solely by reference to the attached tag.

1.2 Examination findings

1.2.1 Visual inspection

Front strut
The front landing gear strut had fractured approximately mid-way along its external length at a location coincident with the lower riveted attachment point of the cabin step (see Figure 1). Fracture was predominantly transverse in nature, although the tubular strut section had cracked axially in two locations for approximately 170 mm above the primary fracture plane (see Figure 2). All fracture surfaces were typical of tensile or shear overload failure of the strut material, with no visible evidence of prior cracking or other pre-existing defects. The strut had sustained a degree of bending deformation about the point of fracture, consistent with the outward movement of the strut as the landing gear collapsed.

FIGURE 1: Right front landing gear strut, as received

FIGURE 2: Right front landing gear strut – point of fracture

Note the extension of fracture axially and the bending deformation of the associated tube section.

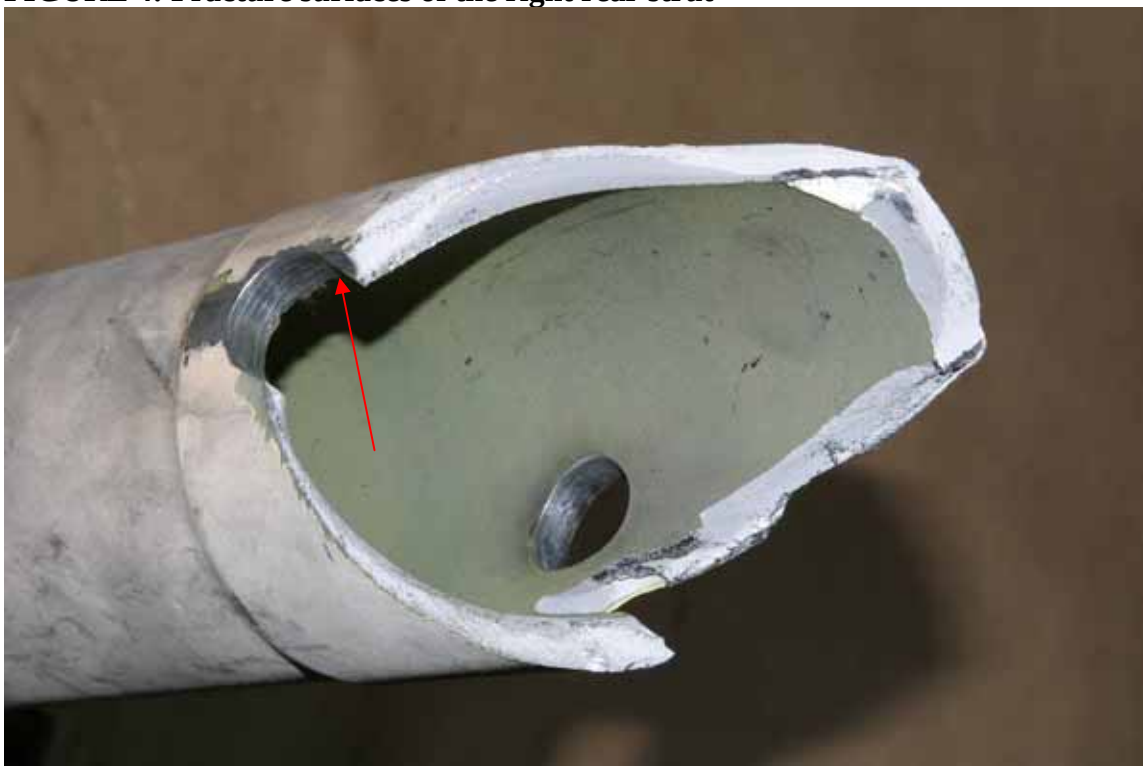
Rear strut

The rear strut had fractured in an irregular, diagonal fashion through the inner end of the reinforced elbow (see Figure 3). The fracture coincided with the lower hole of the skid to drag brace attachment point (see Figure 4). Evidence of a small area of pre-existing cracking was found at the point the fracture intersected the hole bore (see Figure 5) and on closer study, a second area of cracking was noted extending radially from the same hole (see Figures 6 & 7). The main cracked area was triangular in shape and extended radially into the parent strut tube for approximately 0.25" and transversely for almost the full thickness of the tubular strut wall. From external measurement, the second cracked area appeared similar in size.

The bore of the hole itself was roughly machined and contained a distinct lip of metal (typical of machining flash) around the inside edges. Irregular areas of dark, oxide like compound were apparent within in the hole bore (see Figure 8) and also extended onto the crack surfaces. There was no evidence of paint or other protective coating material having been applied to the bore surfaces. The bulk of the rear strut fracture resembled that of the front strut and exhibited similar ductile overload morphology.

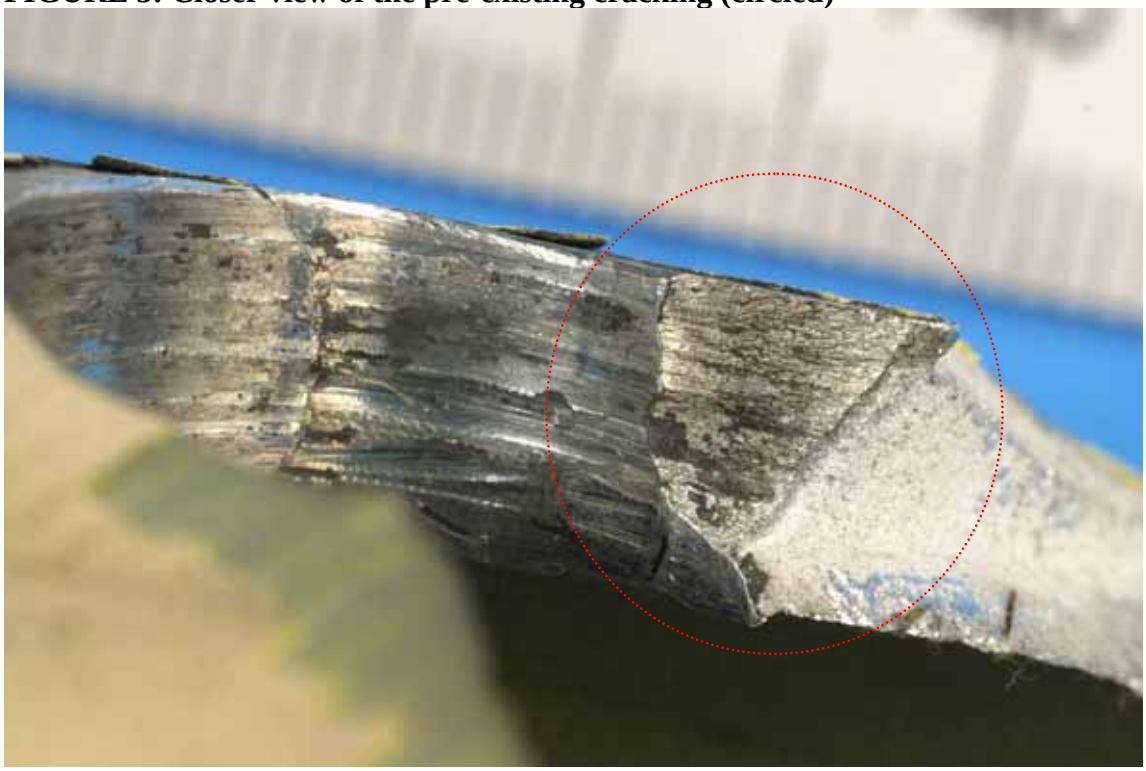
FIGURE 3: Right rear landing gear strut, as received

FIGURE 4: Fracture surfaces of the right rear strut



Pre-existing cracking within the drag brace lower connection hole is arrowed

FIGURE 5: Closer view of the pre-existing cracking (circled)



Note the surface oxide products

FIGURE 6: Bore of the drag brace hole with the secondary cracking indicated

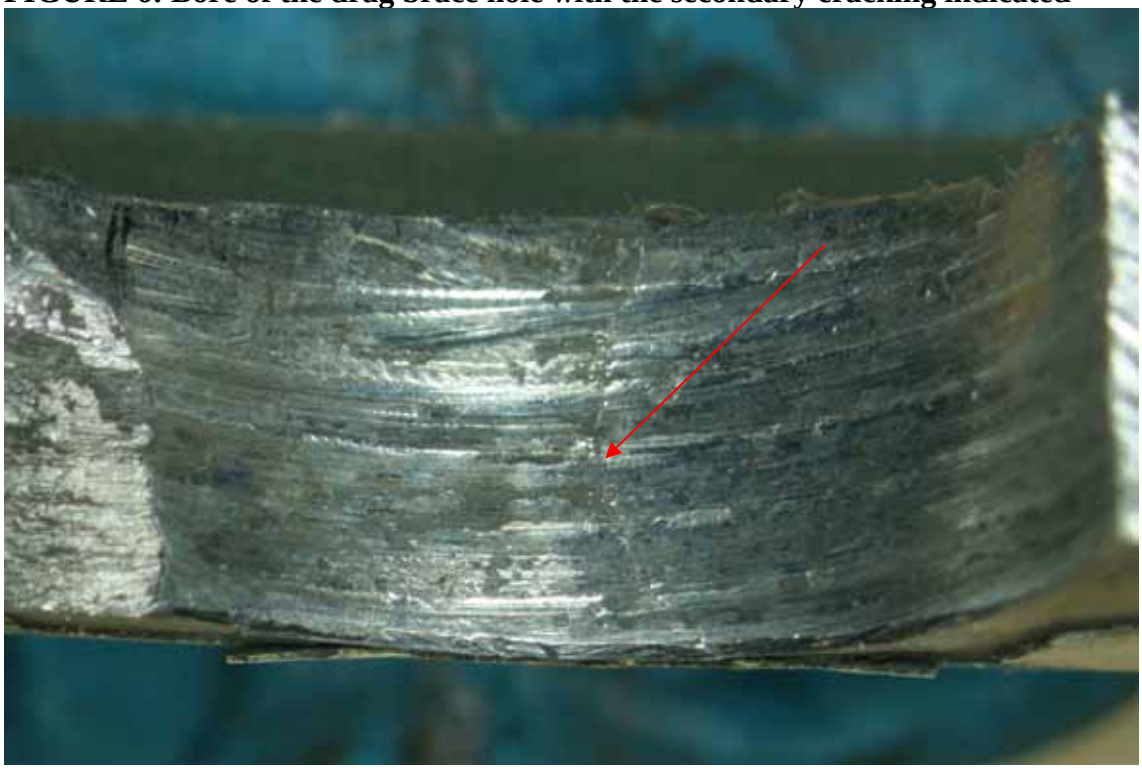
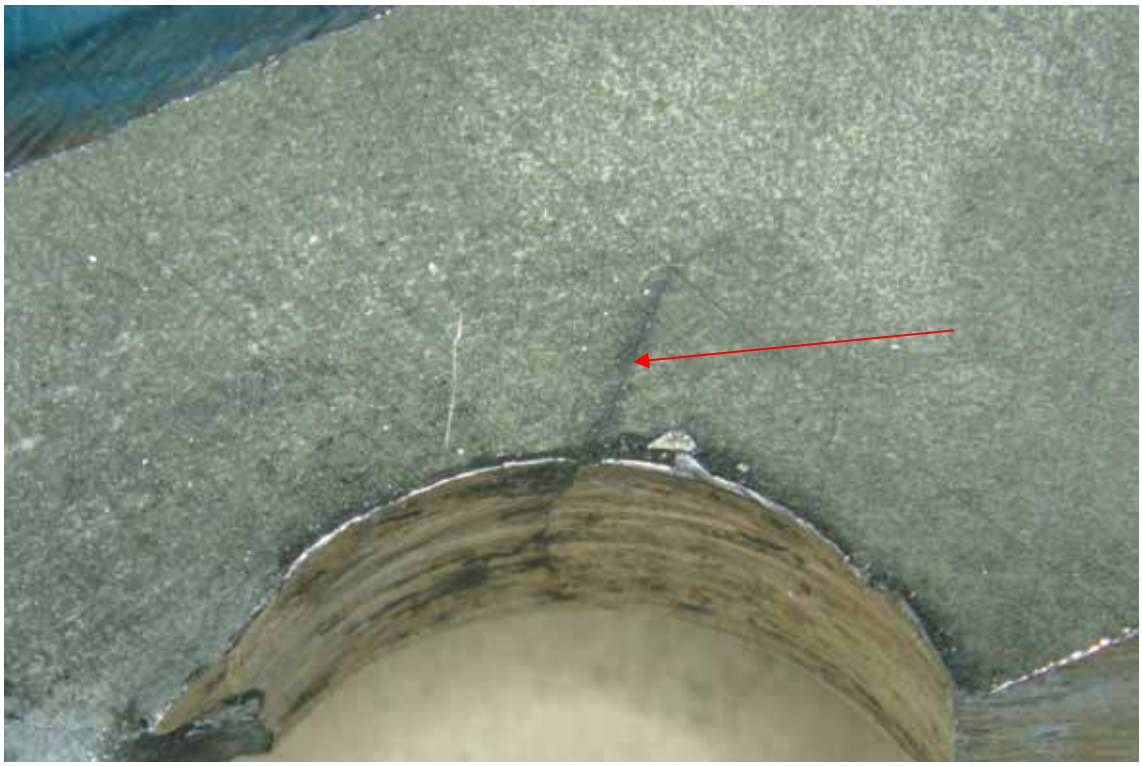
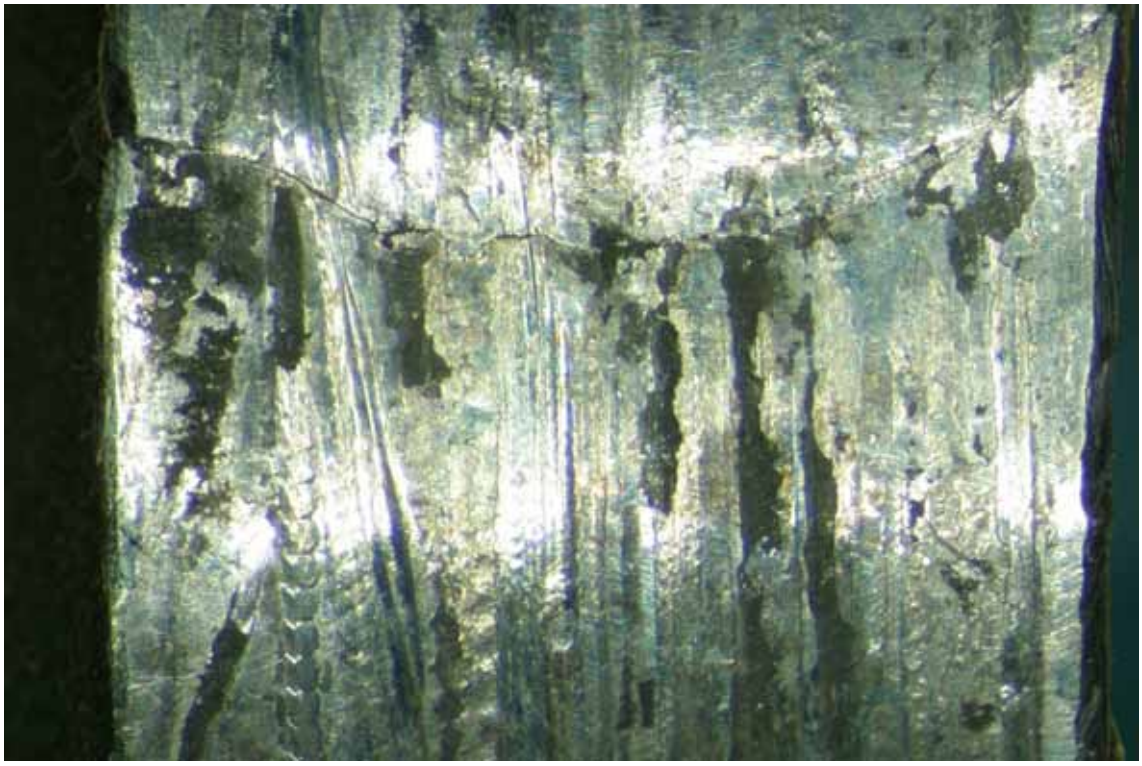


FIGURE 7: Secondary cracking visible from the inside surface of the strut tubular section



Note also the rough machining and flash around the hole periphery

FIGURE 8: Oxide (corrosion product) evident within the cracked drag brace hole



Rear strut bushing
A cylindrical steel bushing had been fitted to the rear strut drag brace attachment point (through which fracture occurred) and served to transmit forward and aft landing gear loads into the drag link (see Figure 9).

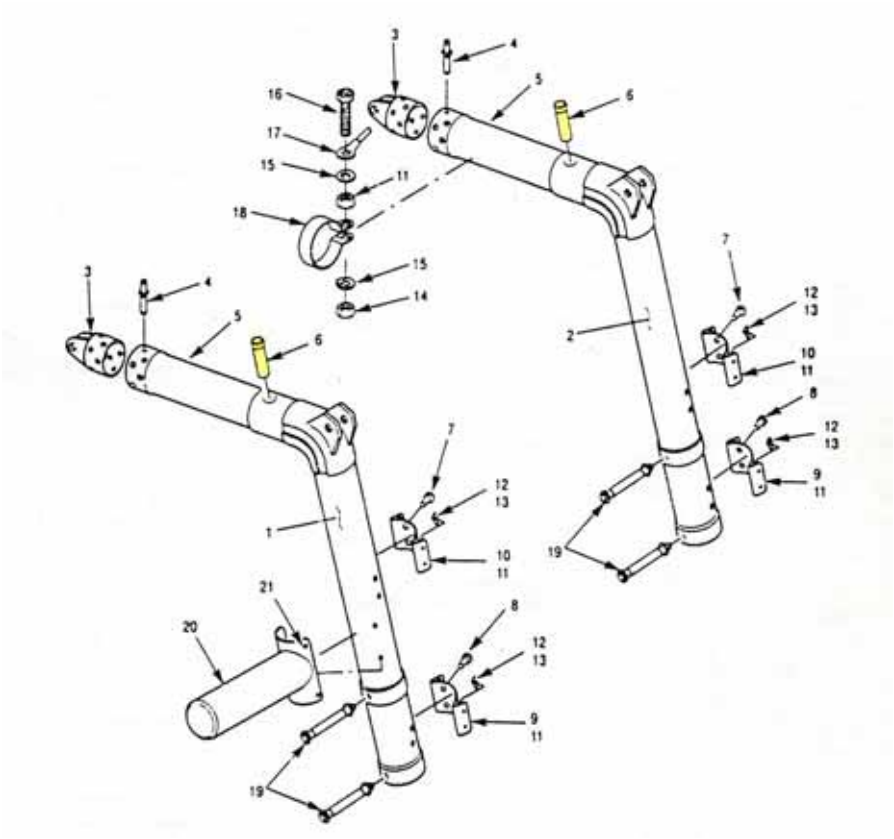
Basic dimensions of the bushing were as follows:

Outer diameter:	0.655” uniform along length
Inner diameter:	0.444”
Length:	2.507”

The helicopter manufacturer indicated that several bushing parts were available to suit the strut-brace connection, however the outer diameters of all were less than the bushing fitted to the rear strut from VH-MPI. The manufacturer also indicated that all original equipment bushings were supplied with a larger diameter flanged upper end (see Figure 10) and were manufactured from an AISI/SAE 4130 alloy steel, or a 17-4PH stainless steel as an alternative.

FIGURE 9: Drag brace connection bushing and fractured rear strut

FIGURE 10: Drawing from the illustrated parts catalogue showing the use of bushings (item 6) at the drag brace connection points



Reference MD Helicopters Inc. *Illustrated Parts Catalogue*, CSP-IPC-4, Page 18, Revision 6
NOT TO BE USED FOR MAINTENANCE PURPOSES

1.2.2 Fractography

The small area of prior cracking identified within the rear strut drag link hole was cleaned and studied under the scanning electron microscope (SEM). That work identified features typical of progressive fatigue cracking, initiated at multiple locations within the hole bore (see Figure 11). Regular crack progression markings characterised the fracture path to the limit of the prior cracking (see Figure 12), before the morphology changed to the typical dimpled appearance of ductile tensile overload (see Figure 13).

FIGURE 11: Scanning electron fractograph showing the extension of cracking from the hole bore (upper surface)

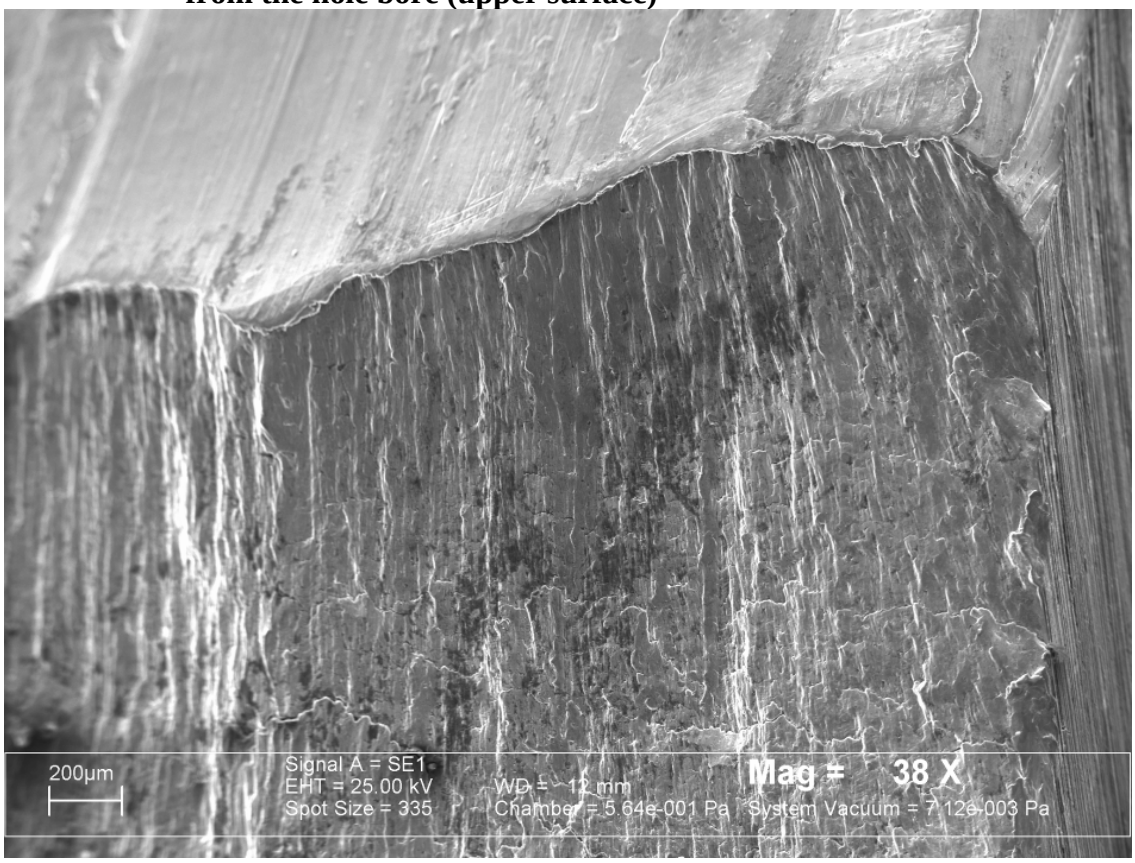


FIGURE 12. Striated fracture surface typical of a fatigue cracking mechanism

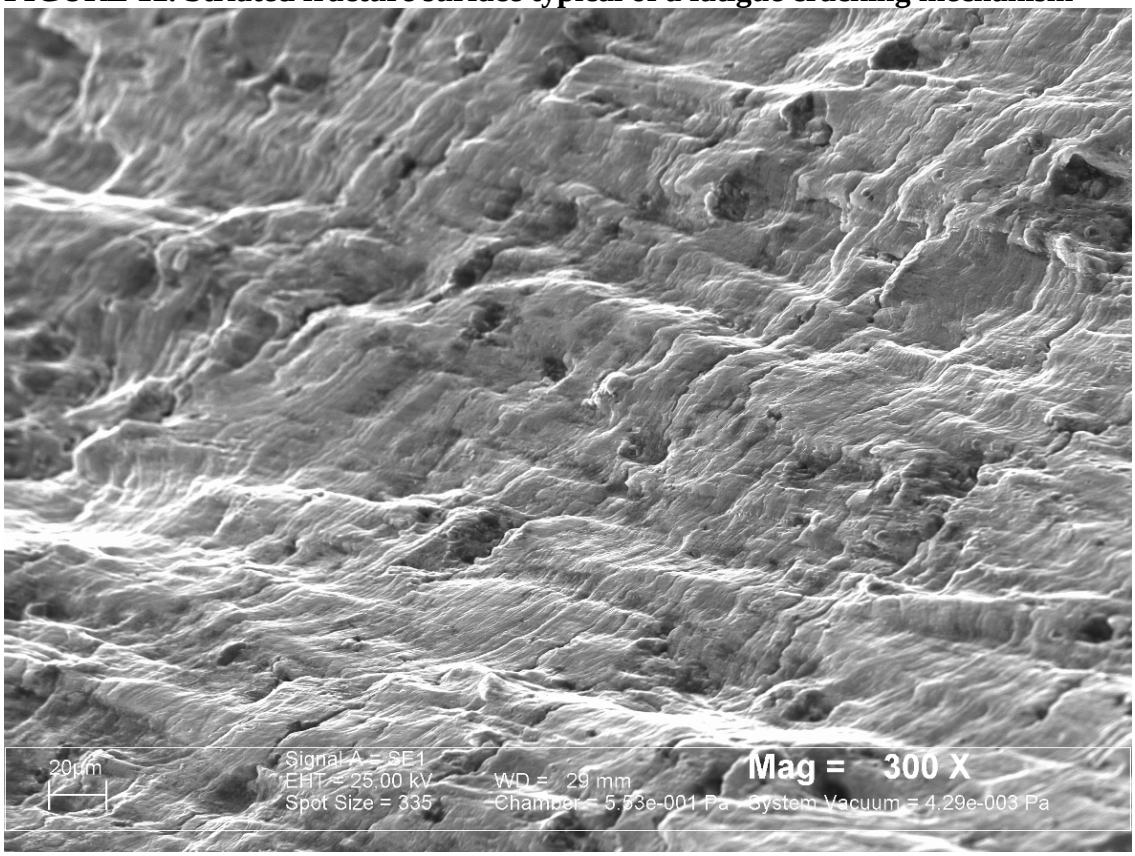
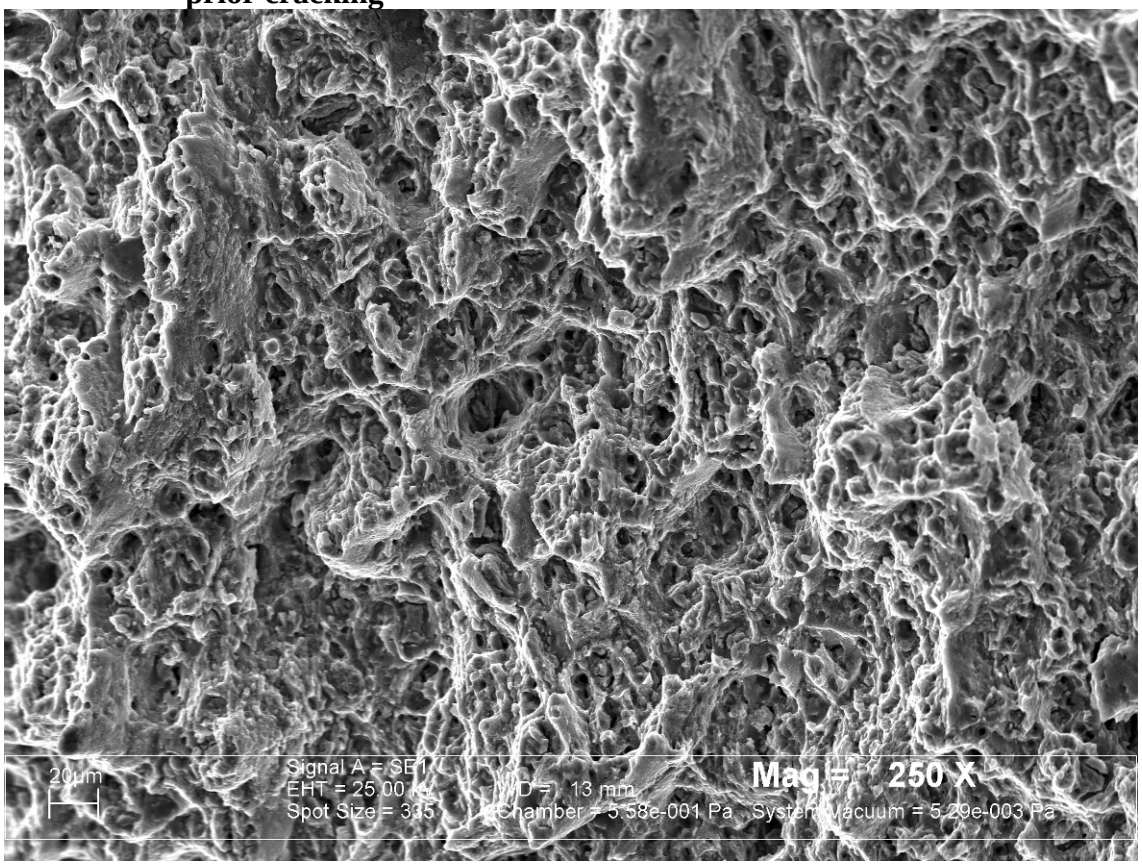


FIGURE 13: Ductile fracture morphology as evident away from the areas of prior cracking



1.2.3 Chemical analysis

Spectrographic analysis of samples taken from the strut and bushing materials of the rear strut assembly returned the following results (as elemental weight percentage).

	C	**Mn**	**Si**	**S**	**P**	**Ni**	**Cr**	**Mo**	**Cu**	**Nb**	**Ti**
Bushing	.02	.74	.45	.006	.028	12.3	16.9	2.2	.24	<.05	<.05

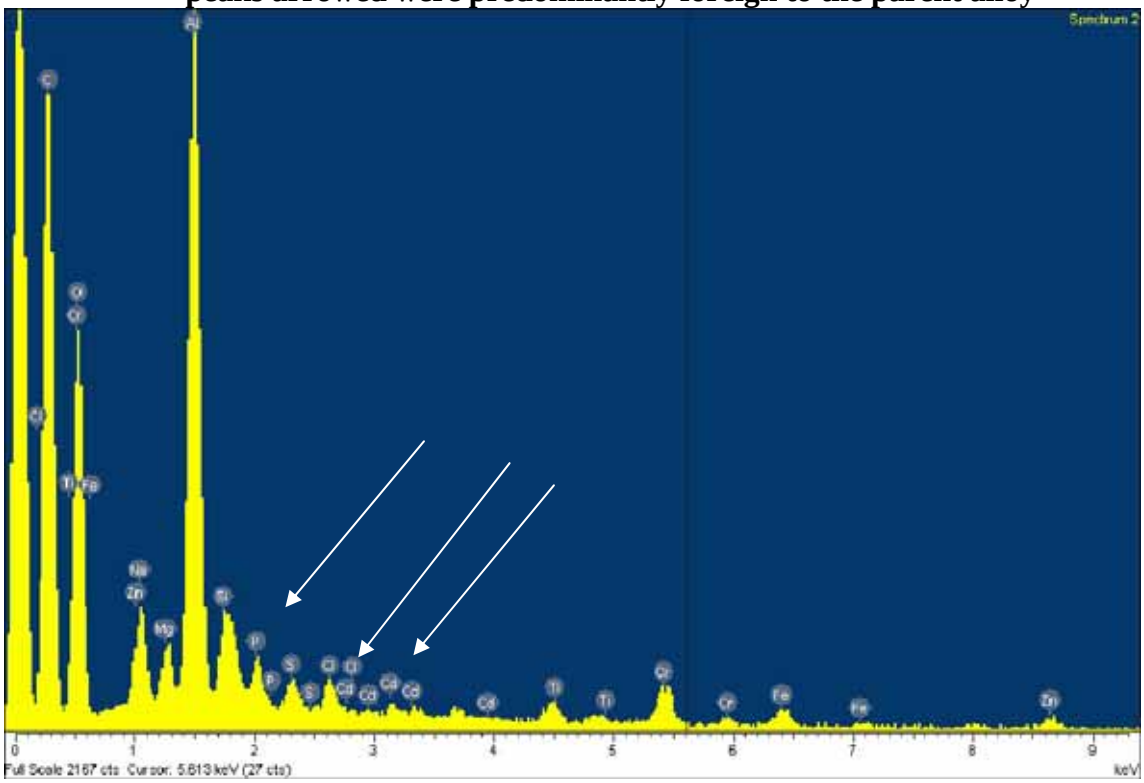
	Al	**Si**	**Cu**	**Fe**	**Mg**	**Zn**	**Cr**	**Ni**	**Mn**	**Ti**	**Sr**	**Zr**
Strut	~bal	.11	1.72	.25	2.59	5.47	.20	<.01	.05	.03	<.001	.013

The bushing was identified as a corrosion resistant austenitic stainless steel meeting the general chemical composition of a 316L (UNS S31603) grade. The strut alloy was a typical age hardening aluminium alloy of the 7075 (UNS A97075) type.

1.2.4 Surface product analysis

Energy-dispersive x-ray spectroscopy (EDS) was used to qualitatively characterise the dark product observed on the rear strut hole bore and crack surfaces. As such, the material was identified as a mixed aluminium oxide corrosion product, with traces of chloride, sulphide and silicate compounds (see Figure 14). The marine operating environment of the helicopter was a rich source of chloride products.

FIGURE 14: EDS spectrum taken from the crack surface product. Elemental peaks arrowed were predominantly foreign to the parent alloy



1.2.5 Hardness tests

Vickers hardness tests were employed to further characterise the strut and bushing materials.

Strut 170 – 173 HV_{10} (approximately 145 HB[1])
Bushing 163 – 177 HV_{10}

The strut hardness level was typical of the 7075 alloy in the T6 or T651 temper condition. In that and similar solution treated and artificially aged conditions, the alloy exhibits good mechanical strength levels, however toughness can be limited and the material susceptible to fracture in the presence of stress concentrations and applied tensile loads. The hardness of the strut bushing suggested its production from material in the mill or solution annealed condition, which is typical for most austenitic stainless steel alloys.

[1] Converted from the native Vickers hardness values in accordance with ASTM E140.

2 ANALYSIS

2.1 Strut failure

Both front and rear right landing gear strut legs had failed in gross outward bending overload, in a manner consistent with the loads imposed during the helicopter landing. The strut fracture features pointed to the initiation of failure at an area of pre-existing fatigue cracking within rear strut drag brace lower connection hole. That cracking originated at the roughly machined inner surface of the hole and showed evidence of propagation under high-cycle (vibratory) loading conditions. A second crack of similar dimensions to the first showed a similar orientation and was also suspected as having initiated from the hole surface.

The high strength 7075 alloy used for the struts has an inherent sensitivity to the presence of notch like cracks and defects, rendering the components susceptible to unstable fracture when exposed to elevated tensile loads. In the case in question, the evidence suggests that the strut failure was a product of the combined influence of the fatigue cracks with the loads sustained during a firm deck landing.

2.2 Drag brace bushing

The bushing component installed at the connection of the drag brace to the rear strut leg was a non-standard item that did not resemble any of the approved parts for the application. The use of an oversize bushing implies the need to ream out or otherwise enlarge the strut hole to suit, with this activity having produced a rough, poorly finished hole surface. The stress raising influence of the rough machining, in combination with the elevated hoop stresses from the (prescribed) interference fit bushing installation were suspected as being prime factors contributing to the initiation of fatigue cracking. The synergistic action of a corrosion mechanism must also be considered, given the presence of a chloride bearing product within the crack confines.