

SAMPLE REPORT No. 5



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TEST ITEM:

NOSE LANDING GEAR (NLG) SPIN BRAKE SPRING FROM A LARGE PASSENGER AIRCRAFT

TEST PERFORMED:

FAILURE ANALYSIS

1. INTRODUCTION

- A. On many large passenger aircraft, the construction of the nose landing gear (NLG) does not include a braking system. Consequently, the nose wheels continue to spin for a period after takeoff and during retraction of the NLG. To arrest the spinning, the NLG bay is fitted with a spin brake, consisting of an aluminium alloy spring plate, fitted with aluminium wear bars (figure 1). When the NLG reaches the fully retracted position, the nose wheels rub on the wear bars, thereby arresting any remaining spinning.

- B. The subject aircraft had suffered a history of noise on retraction of the NLG. In order to identify the source of the noise, the NLG bay was inspected. It was found that the LH spin brake spring had fractured approximately 115mm (4.5in) from the forward attachment bolts (see figures 1 and 2). The liberated portion had departed the aircraft and been lost.

- C. The subject spin brake spring was fitted to the aircraft when it first entered service. At the time the failure was detected, it had endured 16,325 flying hours in 11,592 flight cycles
- D. The material of construction and protective finishes specified for the spin brake spring are detailed below:-
- (1) **Material:** 2024-T42 bare aluminium alloy plate per AMS-QQ-A-250/4
 - (2) **Finishes:**
 - (a) Chromic acid anodising MIL-A-8625F, Type I, Class I but seal in dilute chromate solution.
 - (b) One coat of strontium chromate primer
 - (c) One coat of enamel.
- E. This test was requested to determine the cause of failure.

2. WORK CARRIED OUT

A. Visual Examination

- (1) The retained portion of the fractured spring was examined in the as received condition, using hand magnifiers and a stereomicroscope. It was then sectioned as shown in figure 3, in order to reveal crack surfaces which had not previously been visible. The organic coatings were removed from these sections using a mixture of phenol and dichloromethane. They were then ultrasonically cleaned in acetone, before being re-examined using the stereomicroscope.

B. Fractography

- (1) After sectioning, as detailed at 2.A.(1) above, the fracture surfaces were gently cleaned by the repeated application and removal of cellulose acetate sheet, which

had been softened in acetone. They were then inserted into a scanning electron microscope (SEM), where they were examined at magnifications up to x5000.

C. **Metallography**

- (1) A microsection was taken, at a location close to the fracture surface, as shown in figure 3. This section was mounted in epoxy resin and prepared for examination, using contemporary metallographic techniques. The plane XX was then examined, using an optical microscope, at magnifications up to x1000.

D. **Hardness and Electrical Conductivity Testing**

- (1) In order to verify the temper condition of the alloy, hardness and electrical conductivity measurements were made at the location shown in figure 2, after removal of the surface finishes.

3. **RESULTS**

A. **Visual Examination**

- (1) The fracture surface was composed of numerous, individual fatigue crack fronts (figures 2 to 7). The curvature of fatigue arrest markings on their surfaces indicated that each crack front had initiated at the concave surface of the spring. The major direction of crack growth was through the thickness of the spring, towards its convex surface. Ridges on the fracture surface indicated locations where the individual crack fronts had coalesced during propagation.
- (2) The fatigue crack fronts had penetrated almost the entire thickness of the spring. However, along the edge of the fracture surface, coincident with the convex face of the spring, there were very narrow “shear lips”, inclined at 45° to the major axis of the spring. This indicated the region of final, overload failure. The large surface

area of the fatigue regions, compared to that of final overload, indicated that the load spectrum which produced the failure was characterised by low stress, high number of cycles to failure

- (3) The organic coatings applied to the surfaces of the spring were fully adherent and in good condition. However, once these coatings were removed, severe pitting was evident in the alloy surface (figure 8). These pits were not considered to have been produced by in-service corrosion, due to their smooth and rounded morphology and the lack of any corrosion products. The density of the pitting was most severe at changes in section, such as the edges of the spring and along scratches in its surface
- (4) Several secondary cracks were evident, aligned parallel to the fracture surface. In each case, these appeared to have initiated from the pitting detailed above (figure 8).

B. Fractography

- (1) The curvature of fine fatigue striations on the fracture surface confirmed that the individual fatigue crack fronts had initiated from the surface pitting detailed at 3.A.(3) above (figures 9 and 10). The close spacing of the striations indicated that the crack growth mechanism was one of high cycle fatigue

C. Metallography

- (1) The surface pitting detailed at 3.A.(3) above was *estimated* to be up to 0.05mm (0.002in) in depth. The anodised coating was found to be intact and unbroken across the entire surface of the microsection, including within the pits. There was no evidence of in-service corrosion (figure 11).

D. Hardness and Electrical Conductivity Testing

(1) Table 1 shows the measured values of hardness and conductivity of the spring compared to the ranges specified by the aircraft manufacturer.

	MEASURED VALUE	SPECIFIED RANGE
HARDNESS	78HRB	63-83.5HRB
CONDUCTIVITY	28.6%IACS	28.5-32%IACS

Table 1 - Comparison of measured and specified hardness and conductivity.

4. DISCUSSION

A. As the NLG was retracted, contact between the still spinning nosewheel and the wear bars of the spin brake assembly imposed cyclic bending stresses on the spin brake spring, in the forward direction (see figure 1). This, in turn, established cyclic tensile stresses on the concave face of the spring. Since no other failures of similar spin brake springs from the same aircraft type had been reported, it was reasonable to assume that under normal circumstances, the magnitude of these cyclic stresses would be below the threshold value required for fatigue crack initiation. On the subject spring however, the pitting present on the surface acted as sites of stress concentration, raising the magnitude of the cyclic stresses above this threshold. As a result, fatigue cracks initiated from the pits at numerous locations on the concave face of the spring. With continued cycling of the spring, the fatigue cracks grew and coalesced with each other until the remaining, uncracked ligament became unable to withstand the applied stress. At this point, final overload failure occurred.

B. The unbroken anodised coating with the surface pits indicated that they had been formed either before or during anodising. Their morphology was considered to be consistent with that produced by the application of excessive voltage during the anodising process. Under such conditions, the rate of dissolution is locally increased

in regions of point discharge, such as the edges of the component or scratches in its surface. This results in the formation of rounded pits of the type present on the subject spring.

5. CONCLUSIONS

- A. The subject spin brake spring underwent high cycle fatigue fracture, initiated from multiple origins on its concave face. Each of the fatigue crack fronts had initiated from surface pitting. The most likely cause of the pitting was the application of excessive voltage during the anodising process, performed during manufacture of the spring.

- B. There was no evidence to indicate that the cyclic loading exerted on the spring was abnormal

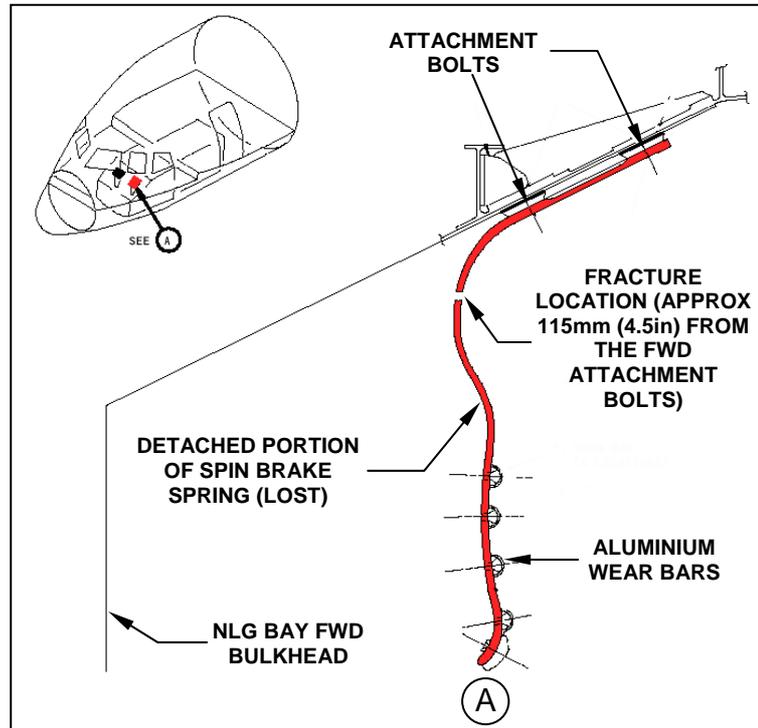


Figure 1 - Schematic of the left hand, nose landing gear spin brake installation.



Figure 2 - General views on both sides of the retained portion of the fractured spring.

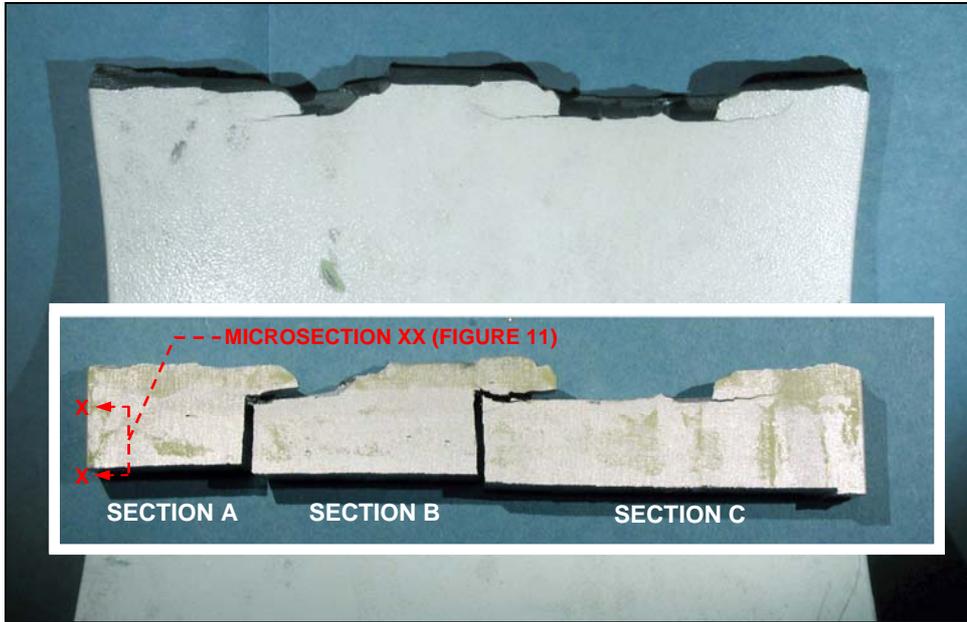


Figure 3 - Close view of the fracture location, from the concave face of the spring. The inset shows locations of sections made, to reveal previously obscured crack surfaces

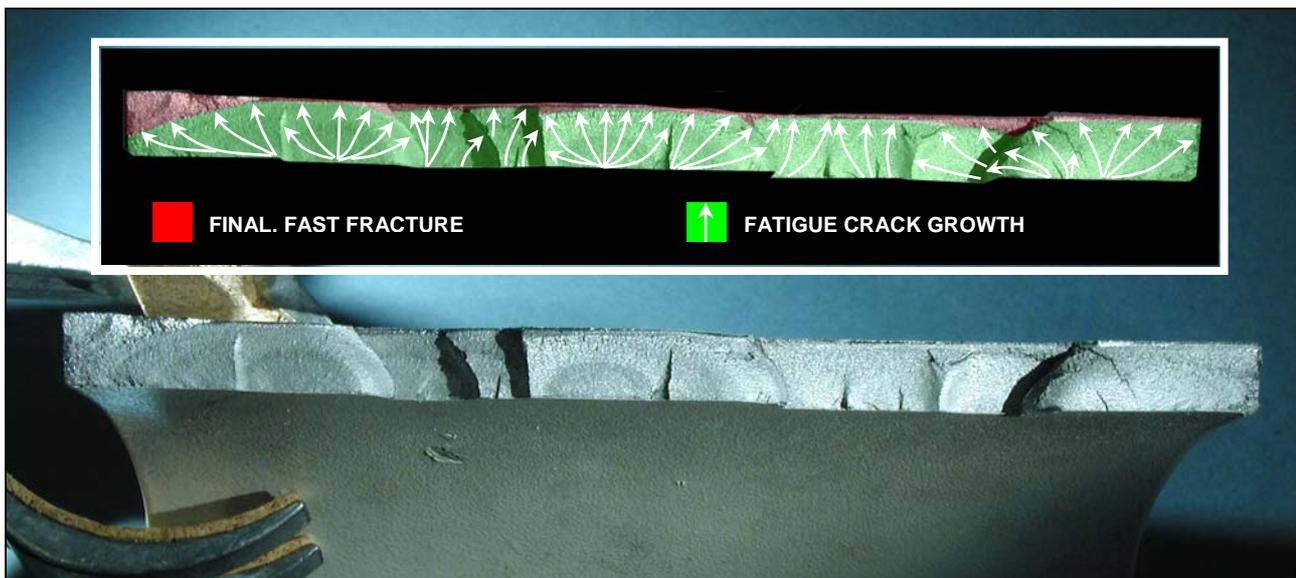


Figure 4 - Close view of the fracture surface, prior to sectioning. Numerous fatigue crack fronts were evident, each of which had initiated on the concave surface of the spring. The inset shows the directions and extent of fatigue crack growth.

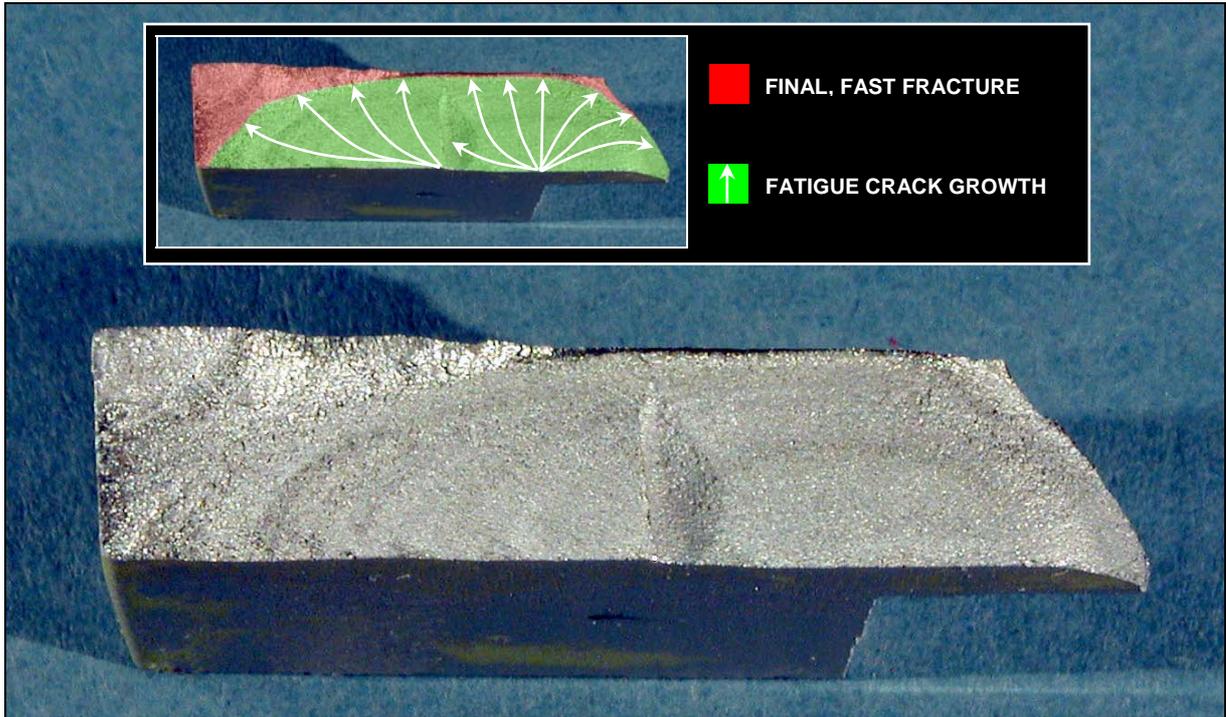


Figure 5 - Close view of the fracture surface of section A, as indicated in figure 3. Fatigue cracks had initiated at the concave surface of the spring and grew primarily in the direction of the convex surface.

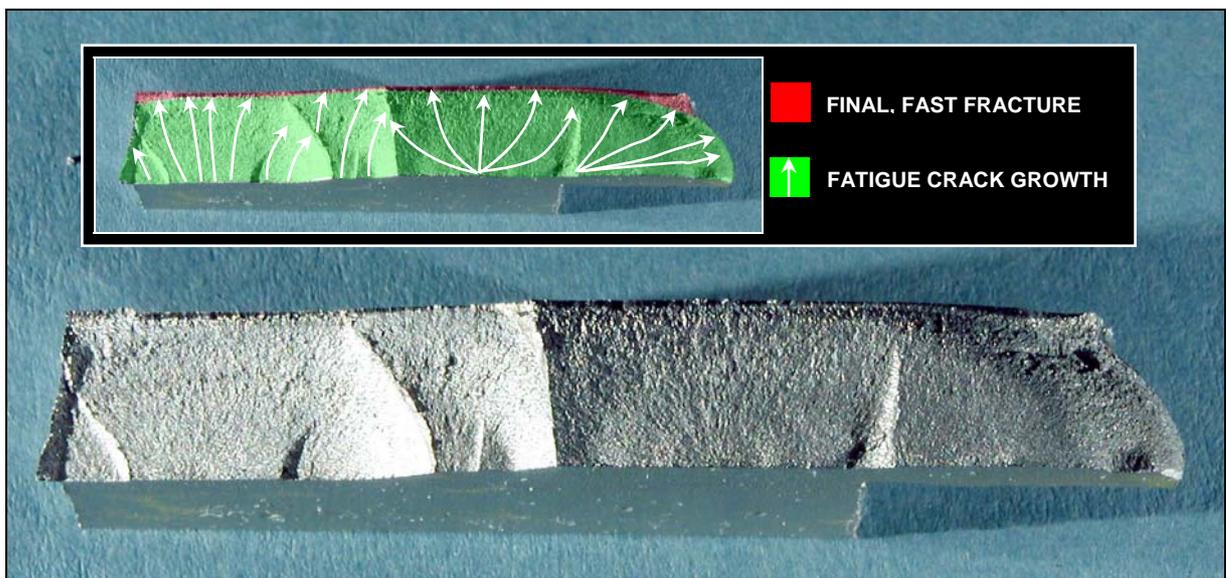


Figure 6 - Close view of the fracture surface of section B, as indicated in figure 3. Fatigue cracks had initiated at the concave surface of the spring and grew primarily in the direction of the convex surface.

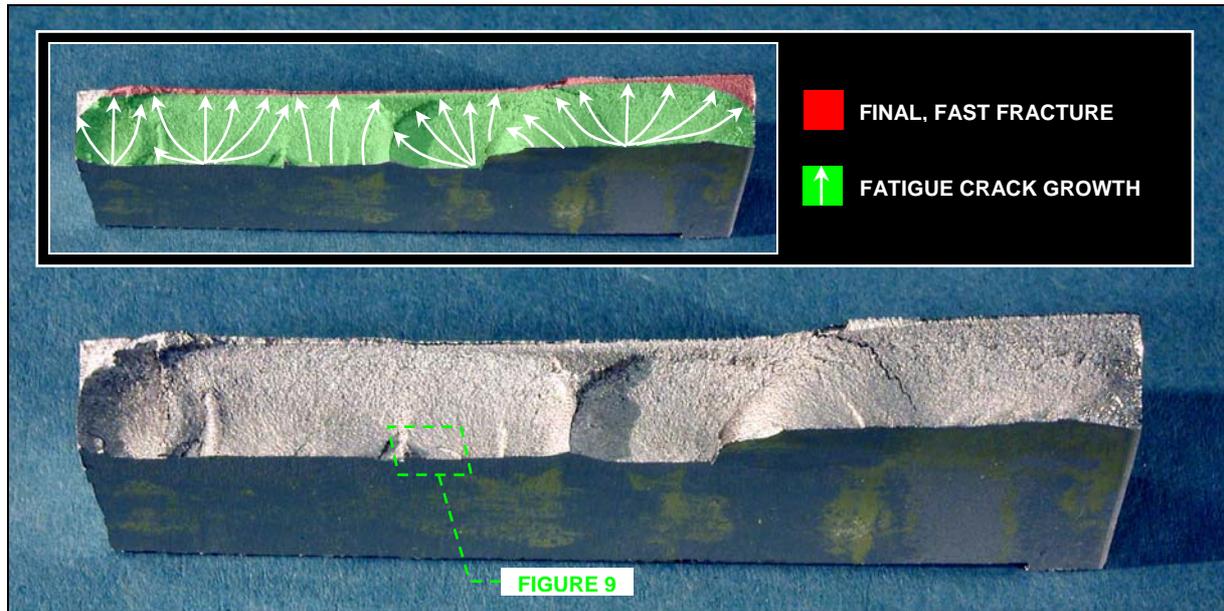


Figure 7 - Close view of the fracture surface of section C, as indicated in figure 3. Fatigue cracks had initiated at the concave surface of the spring and grew primarily in the direction of the convex surface.

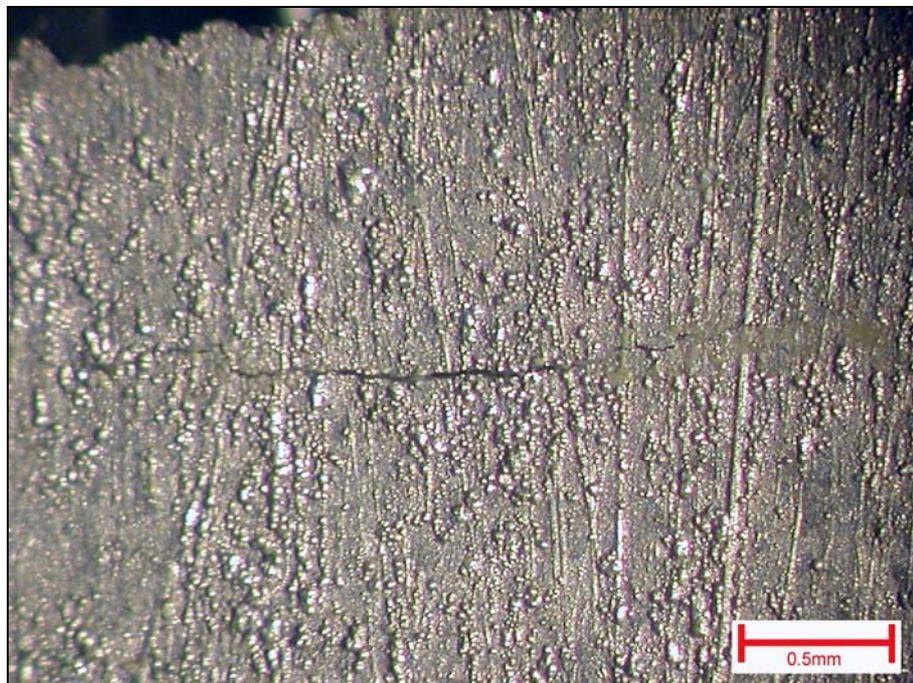


Figure 8 - Close view of the concave face of the spring, adjacent to the fracture surface, after removal of the organic coatings. The surface was heavily pitted, consistent with the application of excessive voltage during anodising. Secondary cracks were present, which had initiated from the surface pitting.

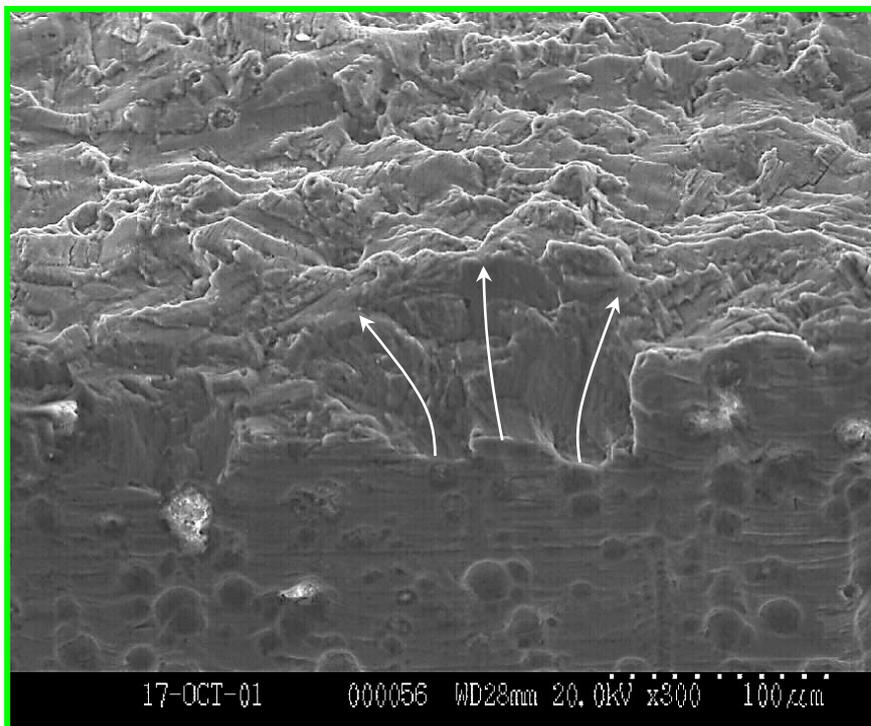
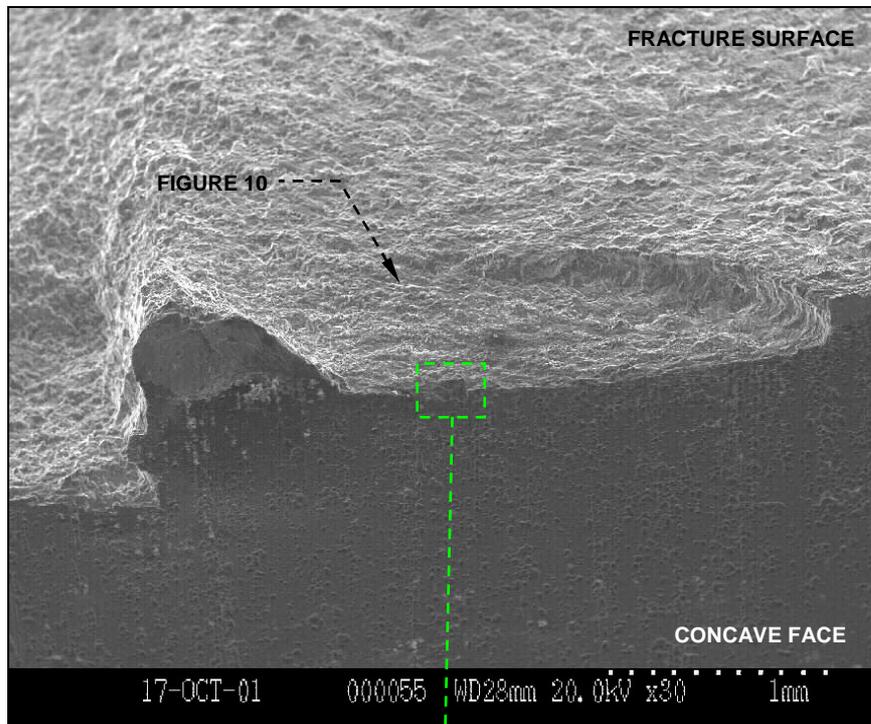


Figure 9 - Close views of the one of the regions of fatigue crack initiation, as indicated in figure 7. Individual fatigue crack fronts had initiated from the pitting in the concave surface of the spring (secondary electron images).

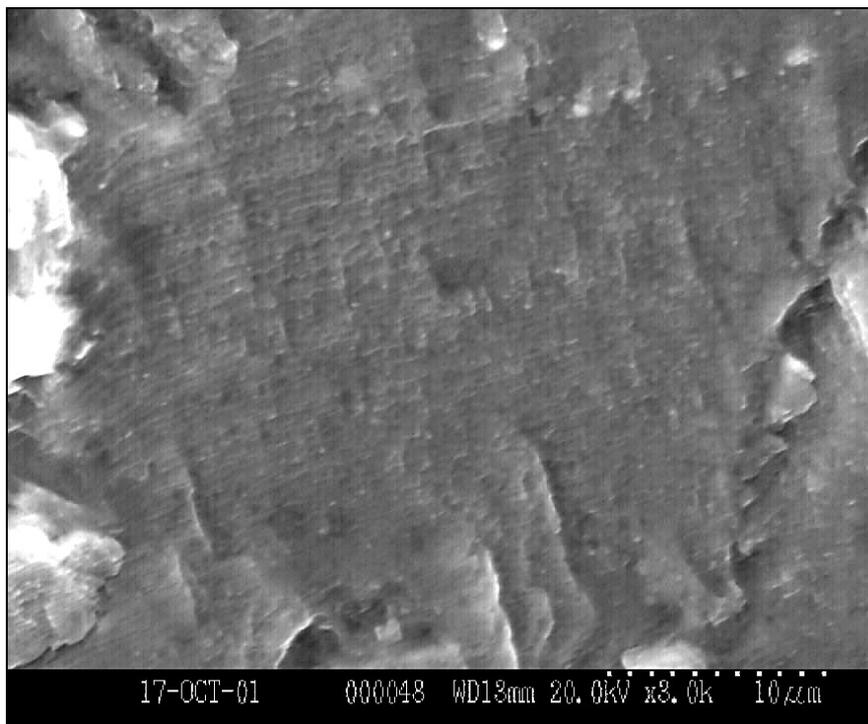


Figure 10 - Close view of the region of fracture surface indicated in figure 9. Fine fatigue striations indicated the directions of crack growth (secondary electron image).

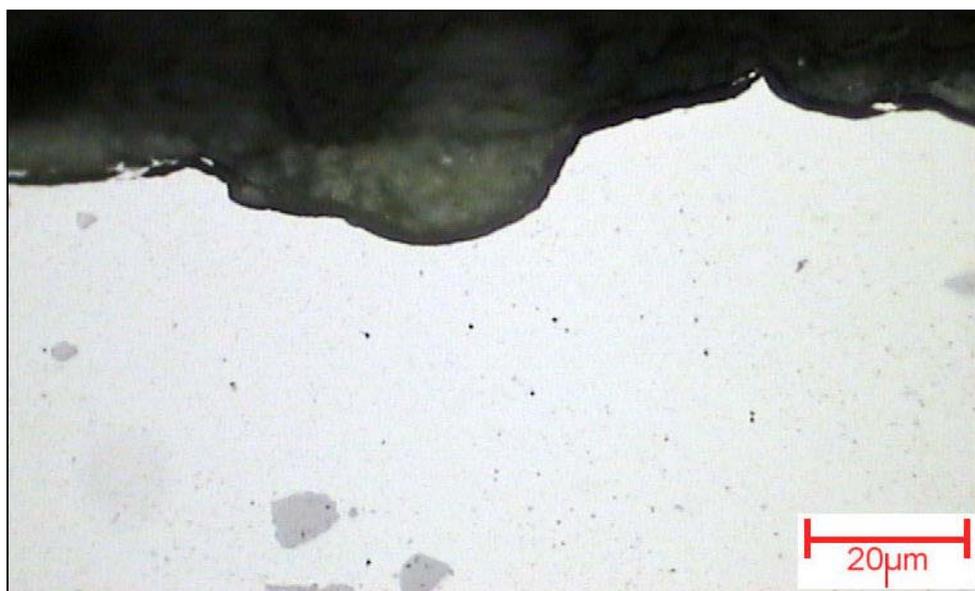


Figure 11 - Microsection XX, taken through the location indicated in figure 3. The pitting was consistent with the application of excessive voltage, during anodising. There was no evidence of in service corrosion.