NATIONAL TRANSPORTATION SAFETY BOARD

Office of Research and Engineering
Materials Laboratory Division
Washington, D.C. 20594

January 9, 2002

MATERIALS LABORATORY FACTUAL REPORT Report No. 01-150

A. ACCIDENT

Place : Near Port Hueneme, California
Date : January 31, 2000
Vehicle : MD-83, N963AS
Operator : Alaska Airlines, Flight 261
NTSB No. : DCA00-M-A023

B. COMPONENTS EXAMINED

Test coupons from grease immersion test
Acme nuts from N981AS and N982AS.

C. DETAILS OF THE EXAMINATION

Selected sample coupons were optically and electronically (SEM) examined for evidence of corrosion following grease immersion testing. In addition, sections of used Acme nuts were also examined.

TEST COUPONS

Of the 30 test coupons subjected to accelerated grease exposure tests, four were selected for further examination. An outside laboratory had previously examined these four and others. In addition a control coupon, typical of all other coupons prior to exposure, was examined. These are listed in the following table along with the test parameters.

Table A—Selected Test Coupons

Sample No.	Grease Type	Contamination	Temperature	Time
Control	None	None	Lab	
19	100% Aeroshell 33	Distilled Water	150° F	2 weeks
22	100% Aeroshell 33	None	150° F	2 weeks
27	100% Mobil 28	Distilled Water	150° F	2 weeks
30	100% Mobil 28	None	150° F	2 weeks

Each test coupon was about 0.5 inches wide, 0.1 inch thick and 3 inches long and manufactured from aluminum nickel bronze alloy C95500. All coupons exhibited a fine longitudinally oriented abraded surface finish consistent with fine sand paper. Closer examinations found that all coupons typically displayed a distinct scratch pattern. Fine longitudinal scratches dominated with interspersed individual larger (deeper and wider) scratches also running longitudinally. Individual swirling scratches were visible overlaying the longitudinal scratches. One surface of each coupon was examined optically at low magnification (<50X) and electronically with a scanning electron microscope at low (<100X), medium (~100 to ~500X) and high (>~1000X) magnifications. Both the submerged (below grease line) and upper (above grease line) regions of each coupon were examined with the interface region (grease line) determined by optical examinations. The five examined coupons are displayed in figure 1.

The sections below describe observations for each specimen.

Control Coupon

The surface of the control coupon displayed a fine pattern of mostly longitudinal scratches with intermittent larger longitudinal scratches and a few smaller swirling scratches as shown at lower and medium magnifications in figure 2. The surface was shiny with a uniform yellow gold coloration. At higher magnifications some surface tears were found, generally associated with the larger scratches, shown in figure 3. No indications of pitting were visible at any magnifications used.

Coupon 19

100% Aeroshell 33	Distilled Water

Optically, the region above the grease line on coupon 19 exhibited a gradated greenish gold tarnish. Below the grease line the surface was shiny and yellow gold similar to the control coupon. Although some small areas below the grease line showed slight darkening, no pitting was visible at optical magnifications.

Above the grease line the surface displayed a slightly mottled dark / light pattern (figure 4 top) in the SEM with a few small pits visible at medium magnification (figure 4 middle). The pits were generally less than about 20 micrometers[1] (μm) in their largest dimension and had an estimated depth of only a few micrometers (figure 4 bottom). The surface also displayed a thin surface film that corresponded to the previously noted dark areas and shown in the bottom view of figure 4.

Pitting was also found below the grease line to about the same extent as above. These pits were generally larger than those above the grease line but the largest was still less than 40μm and most were less than about 20μm. No film or surface deposit was visible below the grease line at low and medium magnifications but at high magnifications

[1] A micrometer (micron) is equal to 0.0000394 inch or 100 μm equal 0.003937 mils

small areas of surface film were present. These small areas were similar to those previously noted above the grease line (compare bottom views in figure 4 and 5).

Coupon 22

100% Aeroshell 33	None

Visually the grease line was difficult to perceive on coupon 22. The area above the grease line had only a slight darker tarnish and a faint water line marked the grease interface.

At low SEM magnifications the typical surface above the grease line individual scratches showing dark as in figure 6. A few small, localized bands of disturbed material were also found in this area. A disturbed area is highlighted in the top view of figure 6 and shown at higher magnification in figure 7. The disturbed areas were aligned with the overall direction of the scratch pattern and the one shown measured about 350 μm long (vertical in view) by about 100 μm wide. At higher magnifications these bands of disturbed material appeared as collections of smaller pits as shown in figure 7.

In the two areas examined below the grease line no individual pits were found. However, a single linear area of damage was found in one area examined. The damage line is shown in figure 8.

Coupon 27

100% Mobil 28	Distilled Water

Optically coupon 27 had a prominent dull multicolored discoloration showing reds greens, gold and blue above the grease line. Below the grease line, the surface was shiny yellow gold with some dark brown gray spots.

Medium and high magnification SEM views found an almost continuous film on the surface above the grease line as displayed in figure 9. However, no pitting was observed. Slight dark / light mottling was visible below the grease line but no pitting was detected, see figure 10.

Coupon 30

100% Mobil 28	None

The area above the grease line was slightly darker and more golden in color than that below when viewed optically. The grease interface line was very faint and difficult to see.

A few randomly located pits were visible above the grease line when viewed at medium and high SEM magnifications, as shown in figure 11. The pits were shallow and generally 20 μm or less in size.

Very few pits were found during examinations of the surface below the grease line. Those that were located were generally 20 μm or less in size.

ACME NUTS

Portions of two used Acme nuts s/n D-3141 and D-3145 were examined optically and with an SEM. The examined sections were milled from Acme nuts removed from jackscrew assemblies s/n DCA-3008 and DCA-3000 previously installed on aircraft N981AS and N982AS and are displayed in figure 12. Each section was less than 1 inch wide and contained about 6 thread forms and had been ultrasonically cleaned in both acetone and toluene prior to examinations.

Although all internal surfaces were examined, the thread crests and upper flanks were examined in more detail, because during service these surfaces would have been exposed to the grease the longest with minimal mechanical interaction with the screw.

N981AS

At low optical magnifications, the internal threaded surfaces of the section had a general yellow golden appearance with circumferential[2] scratch patterns except for the thread crests (minor diameter). The thread crests displayed a matte pebble grained finish at low magnifications and areas of dark gray surface deposits. Closer inspection also found thin bands of similar pebble grain finish on the upper thread flanks at the junctions with the major and minor diameter surfaces. The individual surfaces show some variations in reflective quality and hue. The major diameter surfaces had a generally shiny appearance while the upper flank surfaces were slightly dull and darker. The lower flank surfaces were lustrous but darker with a blue hue. Some areas of disturbed surface were noted associated with the minor diameter burr on the lower surfaces. No visible pitting was noted on any surface.

SEM examinations of the thread crest surfaces found deposits overlaying a surface texture composed of randomly oriented generally angular indentations as shown in figure 13. The deposits covered much of the surface and filled most of the indentations.

Low and medium magnification examinations of the upper flanks of the thread profiles found the surface mostly composed of fine parallel scratches running circumferentially with a occasional larger scratch as shown in figure 14. Further inspections found some surface disruptions as displayed in the two views of figure 15. The upper view shows a mechanically induced dent about 50 μm wide while the lower view shows small (<5 μm) shallow globular pit-like features only visible at high magnifications, 1,780X for this view. It was also noted that the pebble grain features seen on the thread crest was present on the upper thread flanks adjacent to major and minor diameters.

The major diameter surfaces also exhibited a small band of pebble grain finish adjacent to the upper flank as shown in figure 16. The remainder of the major diameter surface displayed mostly parallel scratches running circumferentially. However the relative sizes of the scratches varied considerably with position. An area of typical scratches on the

[2] In the context used in this report, circumferential refers to the direction within the nut bore parallel to the threads. As the threads are inclined at a slight angle to the bore of the nut they actually spiral through the bore.

major diameter is shown in figure 17. No demarcations were visible on the major diameters to indicate the original (pre wear) positions of the lower thread flank. At medium magnifications some areas of the major diameter surface displayed small-scale (<50μm) mechanical indentations into the surface as shown in figure 18. These areas were typically in the lower portions of the major diameter near the upper thread flanks. At high magnifications, an occasional pit structure was found like that shown in figure 19. These were generally less than 20 μm in diameter. The central portions of the pit structure in figure 19 measured approximately 18 μm in diameter.

The scratch pattern on the lower flank surfaces was similar to the major diameter with generally smaller scratches intermixed with larger scratches as shown in figure 20. Many of the scratches also contained circumferential surface cracks some of which were closed and some were gapped slightly open and the mating faces displaced as shown in figure 21. Many of these were more than a millimeter in length. Several other short gapping cracks were also noted at medium and high magnifications. A typical one is displayed in figure 22. Further areas of cracking and deformation were found associated with the burrs of the threads at the minor diameters as shown in figure 23.

N982AS

At low optical magnifications the surfaces of the Acme nut sample from N982AS were generally similar to those of N981AS. The surfaces were lustrous and displayed circumferential scratch patterns except for the minor diameter that was matte and had a pebble grain finish, like N981AS. N982AS also exhibited remnants of the matte finish on the lower flank at the major and minor diameters and dark gray surface deposits on the minor diameter. The major diameter surfaces on N982AS appeared more banded than the same areas on N981AS with a slightly darker smoother central band and adjacent rougher and brighter bands. The upper flank surfaces were also slightly darker and less lustrous than other areas and displayed a circumferential scratch pattern composed mostly of fine scratches with some larger gouges. The lower flank surface was bright with some darker bands but was much rougher than the upper flank and showed many large gouges. Several spall-like features were readily apparent in the middle region of two upper flanks. The largest of the spalls measured 0.04 to 0.06 inches long circumferentially.

SEM examinations of the thread crests (minor diameter surfaces) revealed a surface composed of randomly oriented angular indentations as shown in figure 24. The surfaces were very similar to those on N981AS but had fewer deposits.

The major diameter surfaces had fine circumferential scratches and areas of surface deposits as shown in figure 25. The deposits were mostly in the area near the upper flank. High magnification examinations found areas of small shallow surface pitting adjacent to the upper flank as shown in figure 26. Many of these pits appeared to be remnants of the pebble grain finish previously noted at the junction of the upper flank and major diameter. Measurements determined that most of these pits were less than 3 μm in width. A few similar pits were found in the central area of the major diameter surface.

These pits, shown in figure 27, were generally less than 2 μm but a larger one measured up to about 6μm in diameter.

The upper flank surfaces were composed of larger circumferential scratches in a field of finer scratches along with some apparently random surface deposits as shown in figure 28. At high magnifications, some small shallow pits were visible but most were on the upper flank of the top thread as shown in figure 29. These pits were similar in appearance to those noted on the major diameter surfaces. They were generally less than 2μm in width.

The lower thread flank surfaces were, in general, much rougher appearing than upper surfaces and contained fine scratches with interspersed larger gouges and several previously noted spall-like surface depressions, as shown in figure 30. As can be seen in figure 30 some of the large gouges emanated from the spall areas. Close examinations of the surface depressions found fracture features and cracking within the spalls consistent with mechanical formation, as shown in figure 31. Spalling was generally found between the minor diameter and mid flank on most of the threads, see figure 32. In size they ranged from over 1 mm in length to 20μm long. The larger optically apparent spalls were on two threads while other smaller spalls were found on several threads.

High magnification viewing of the lower flank surfaces also uncovered many circumferential cracks running in some of the scratches. Some of the cracks intersected spalled areas while others did not. Figure 33 shows two typical surface cracks, the upper one intersecting a spall in the upper left of the view. Many of these cracks were more than 1 mm in length.

Signature Not Verified
Joe Epperson
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Date: 2002.01.16 08:30:37 -05'00'

Joe Epperson
Senior Metallurgist

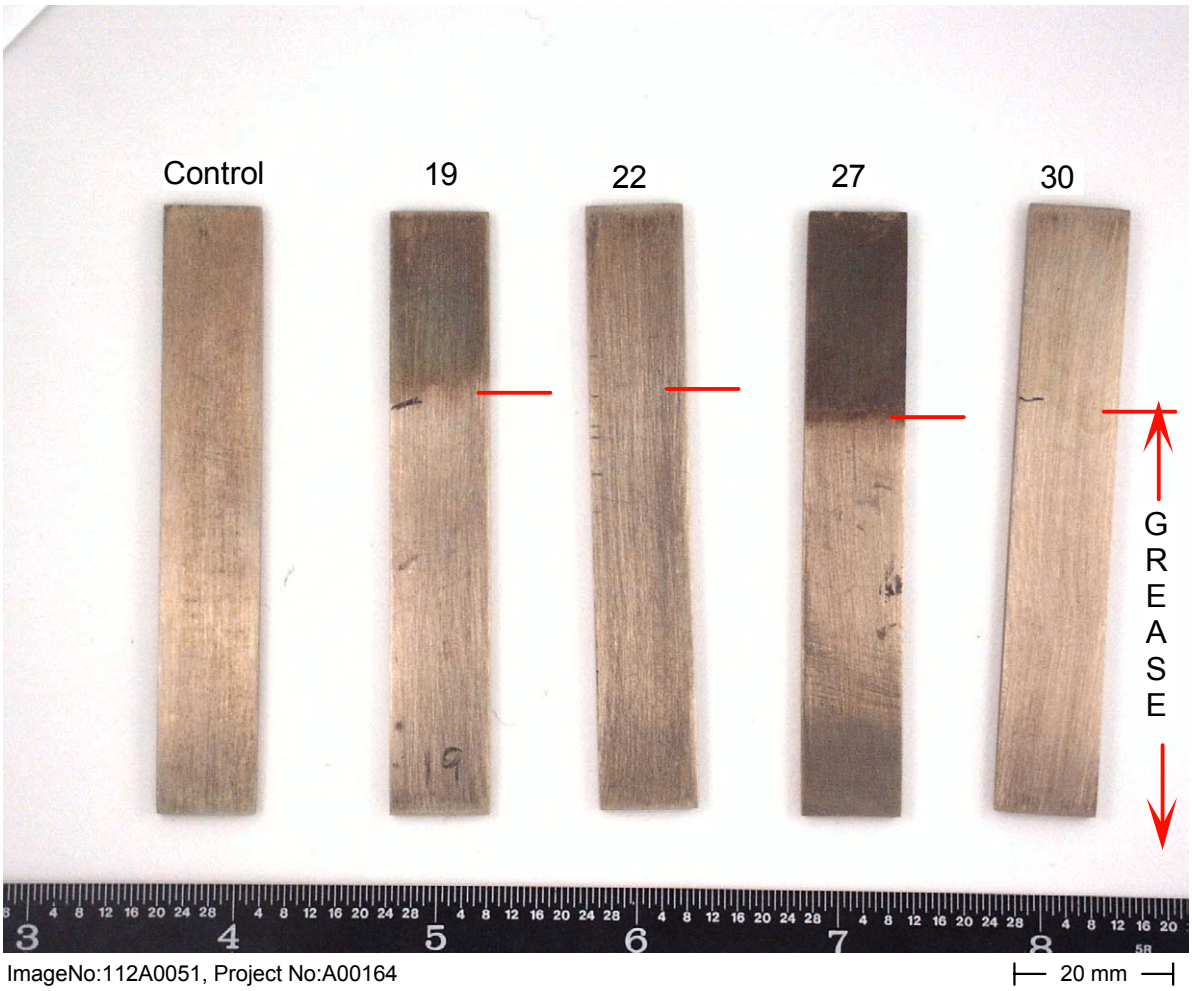
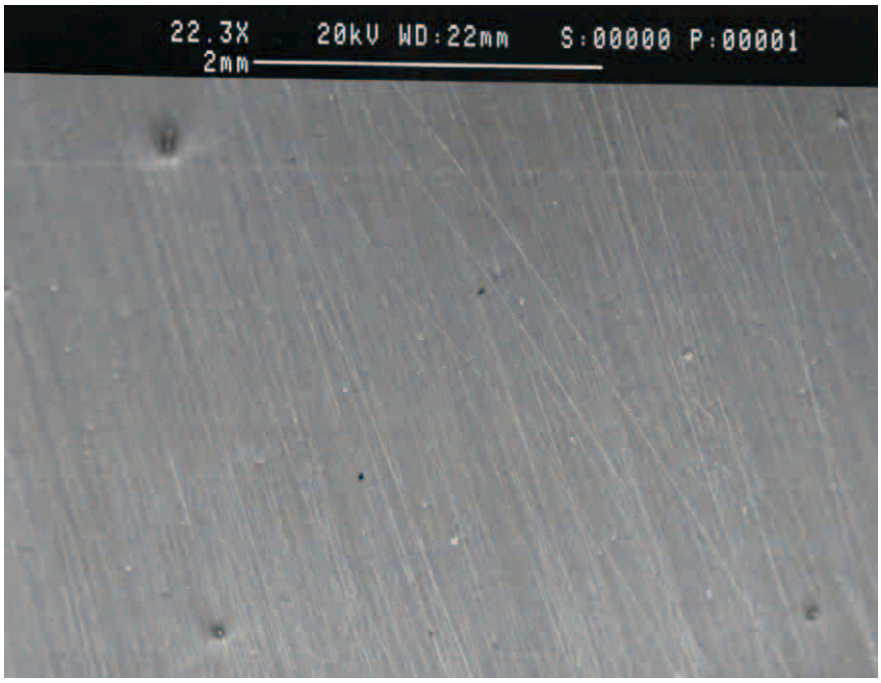


Figure 1--A view of the 5 examined test coupons, from left to right, control, 19, 22, 27 and 30. The red line denote the approximate grease level.



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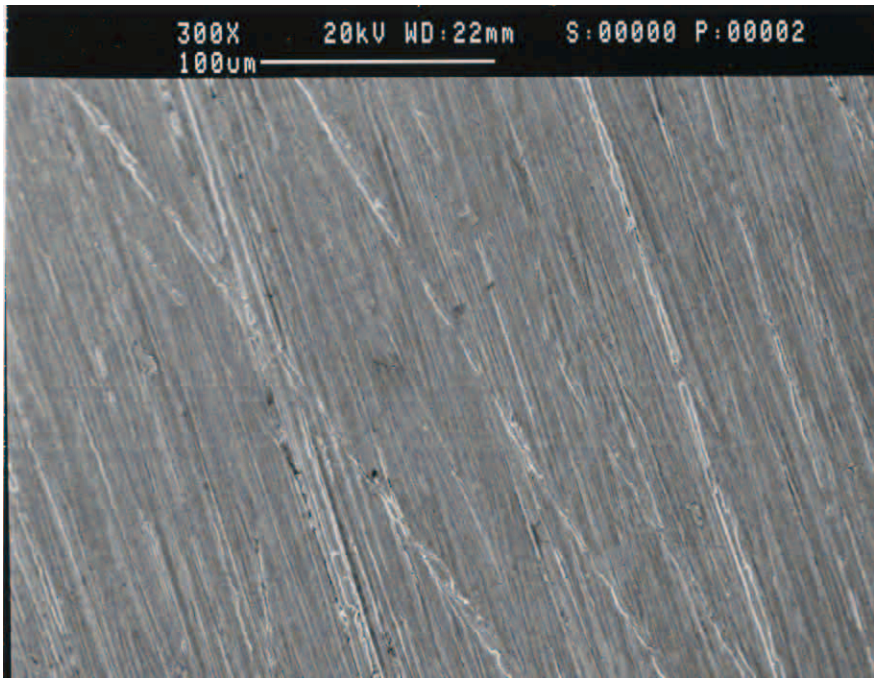

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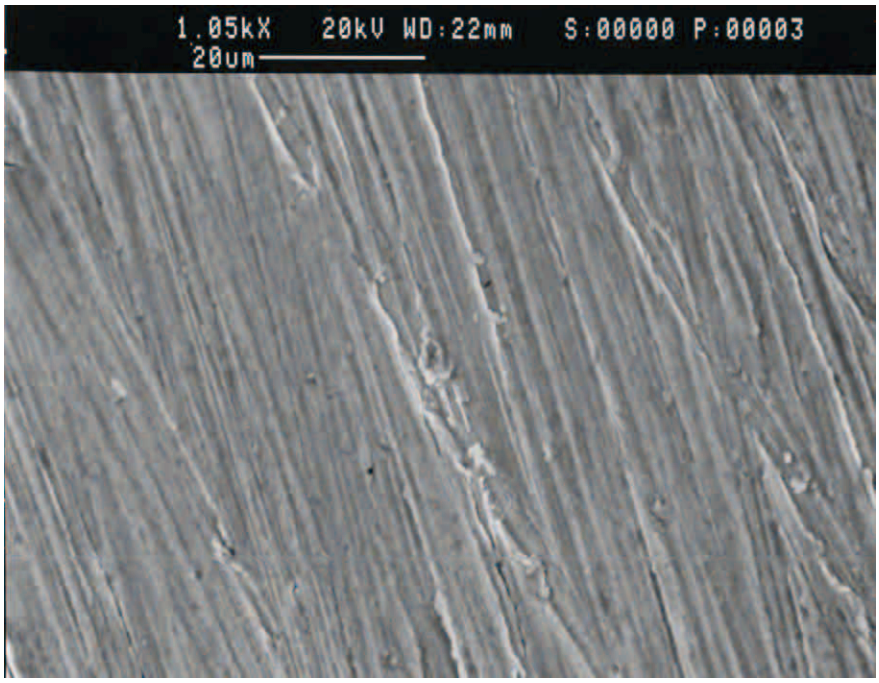
Figure 2--Low and medium magnification views of typical areas of the control coupon.



ImageNo:112A0068, Project No:A00164 — 20 µm

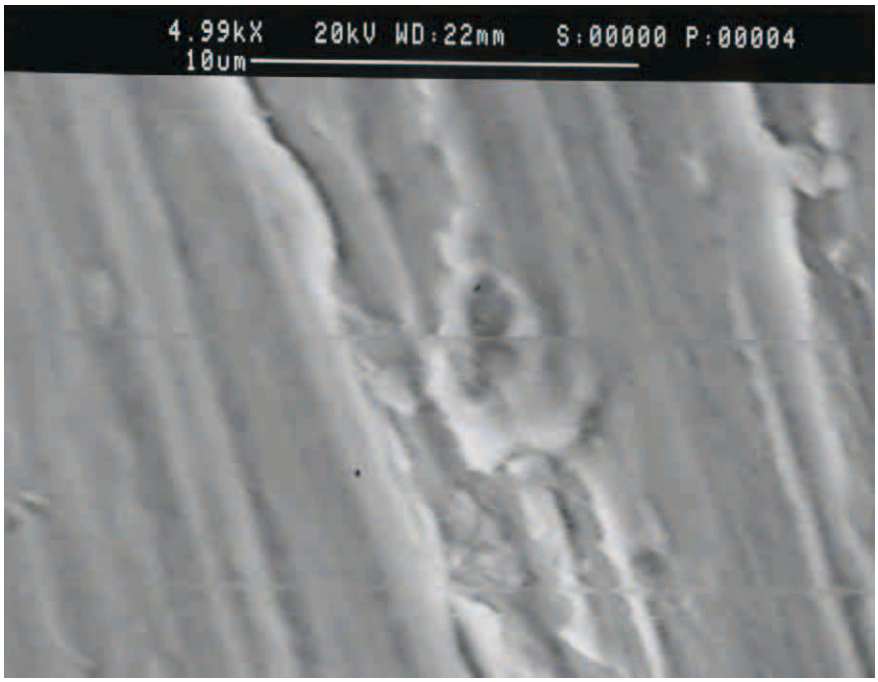


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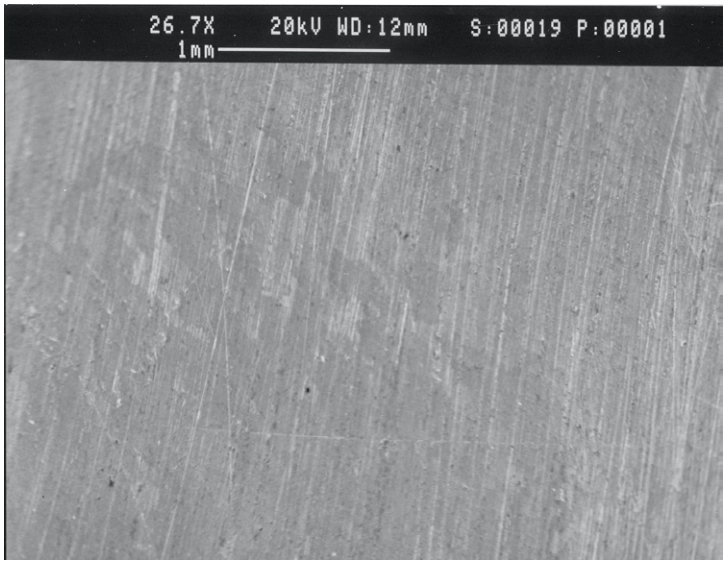
Figure 3--High magnification SEM views showing typical tears associated with scratches.



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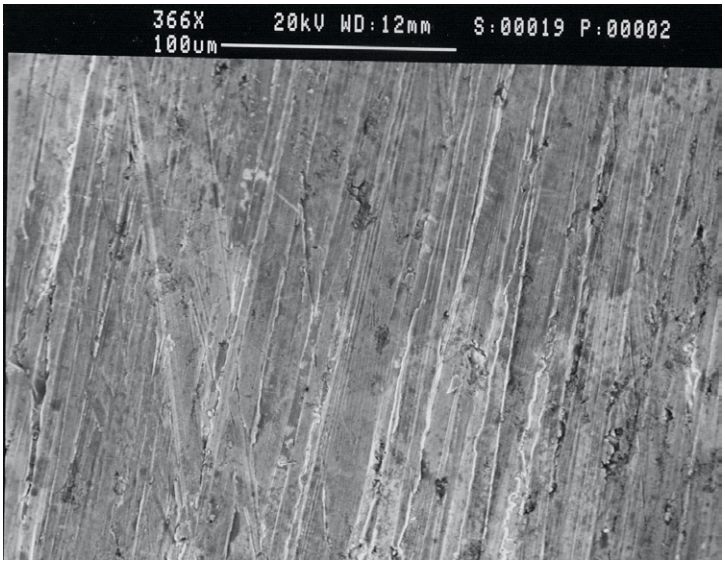
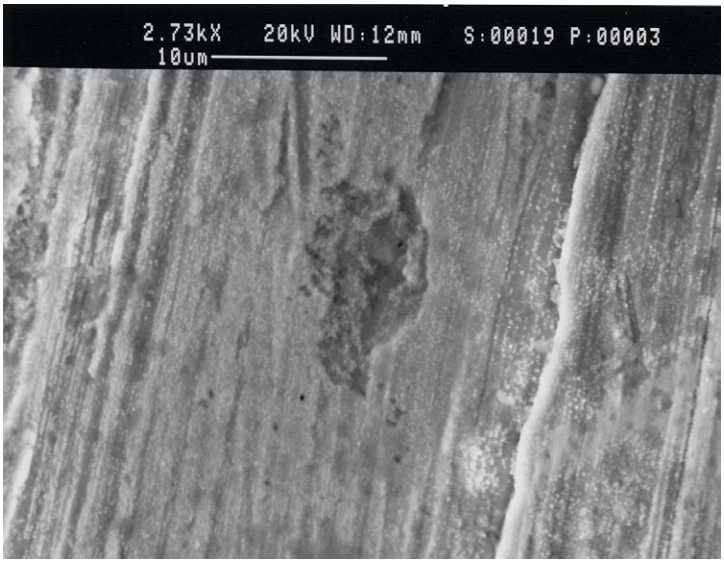


ImageNo: 112A0070, Project No:A00164 ⊢— 100 µm —⊣

Figure 4--Three SEM views above the grease line on coupon 19. Top view at lower magnification showed mottle pattern on surface. Middle and bottom views show shallow pits and surface film.



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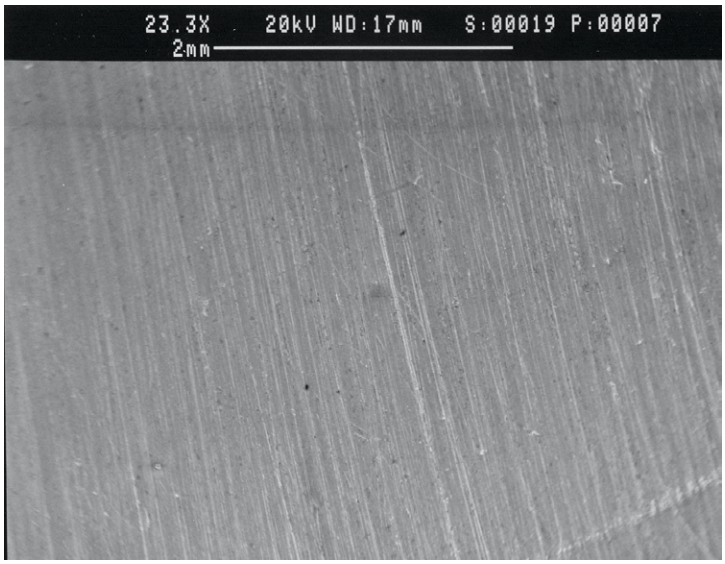

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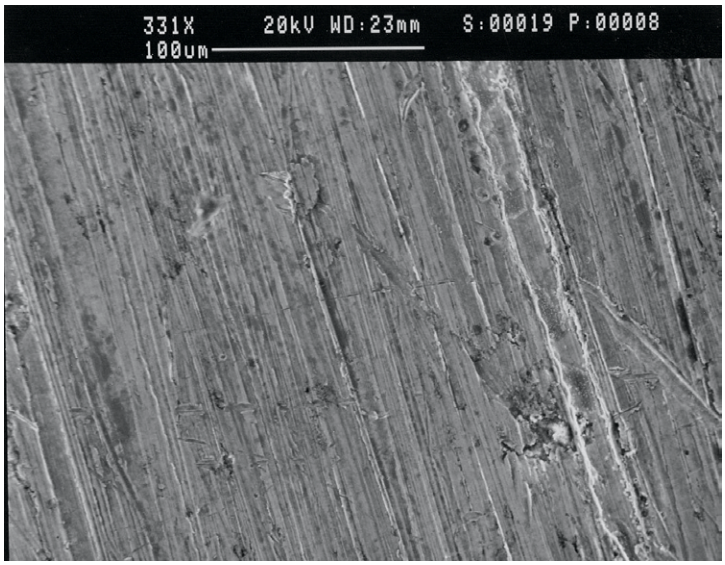
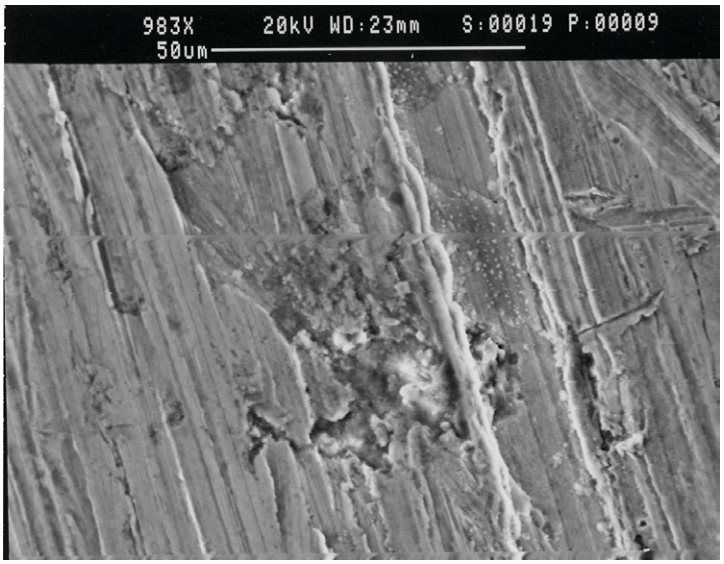
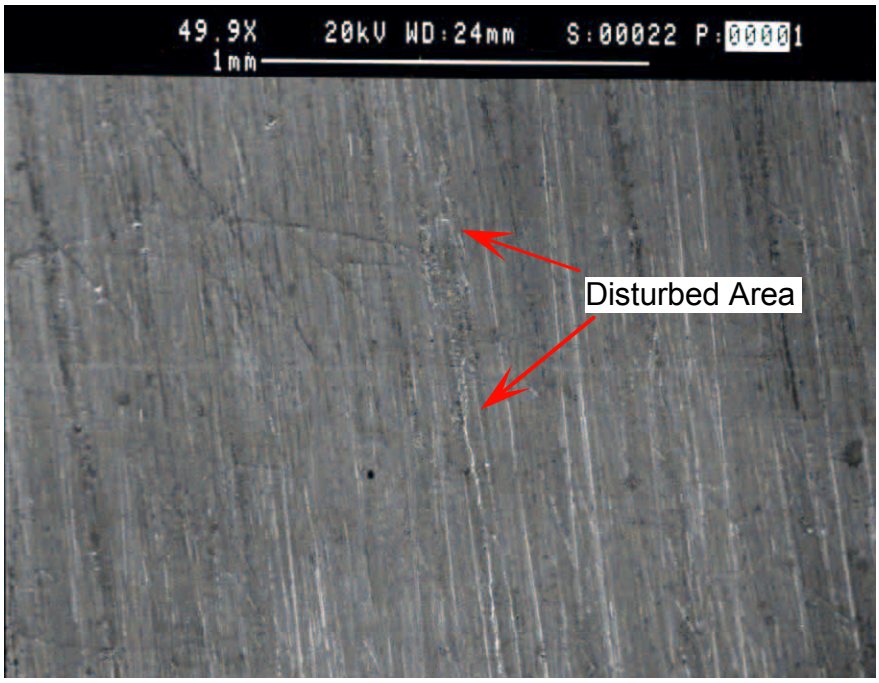


ImageNo: 112A0073, Project No:A00164 ⊢ 100 µm ⊣

Figure 5--Below the grease line on coupon 19. Middle and lower view show pitting.



ImageNo:112A0083 , Project No:A00164 ⊢ 20 µm ⊣



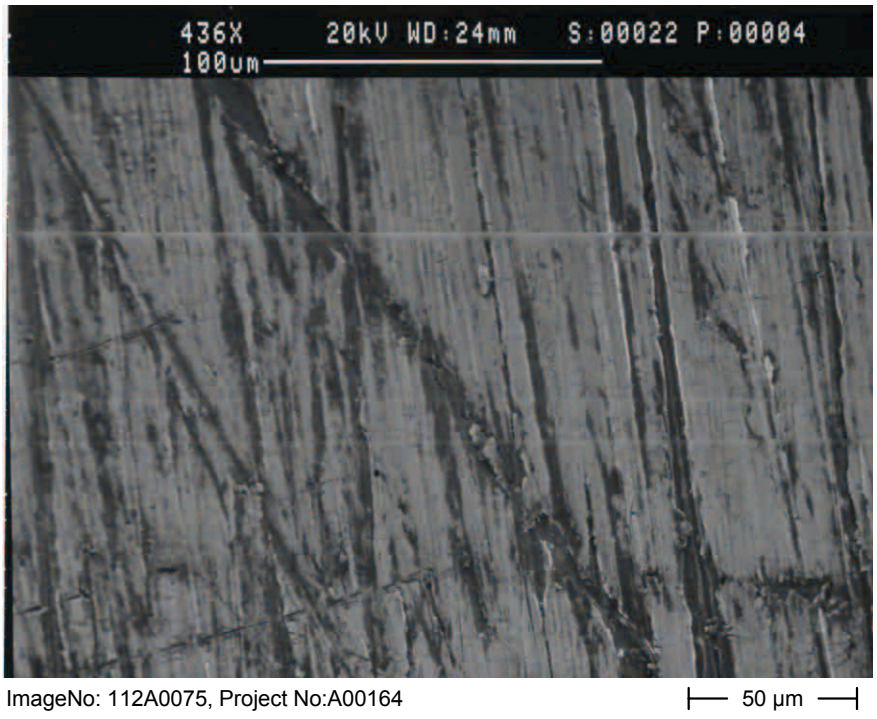
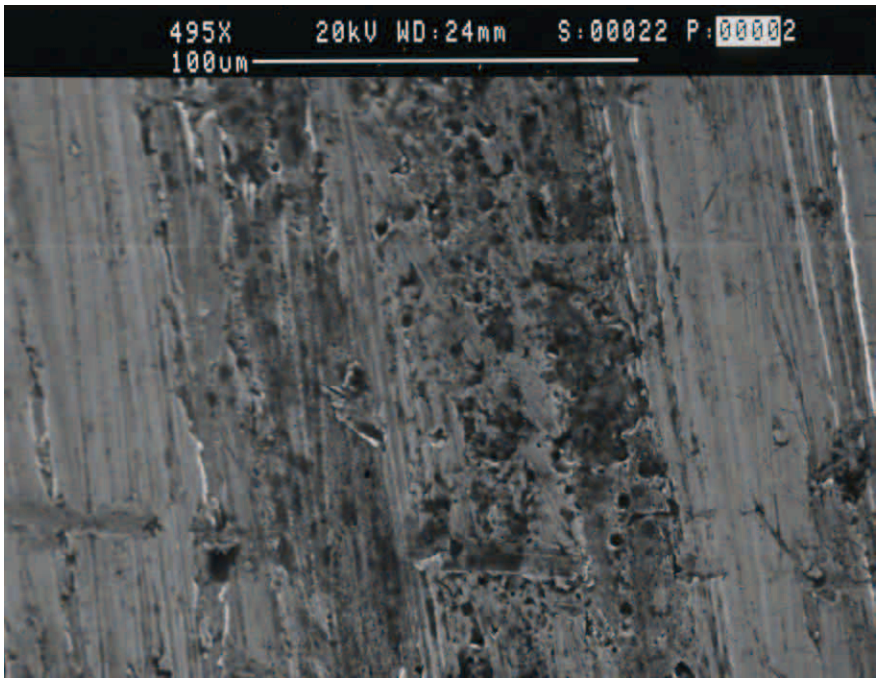


Figure 6--A few disturbed areas were visible above the grease line on coupon 22 as in the top view. Typical features on the majority of the surface appeared as in the lower view.



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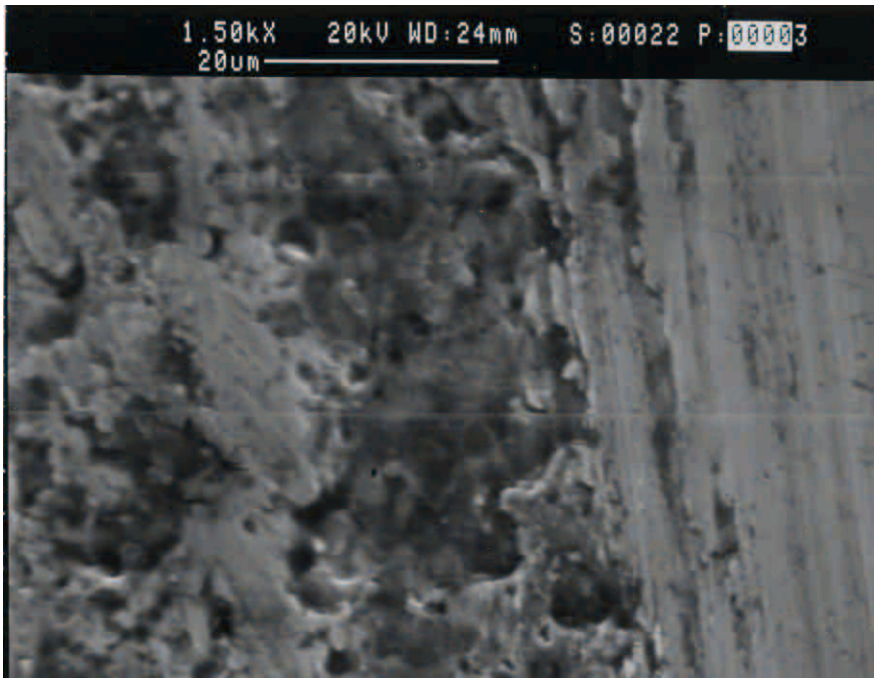

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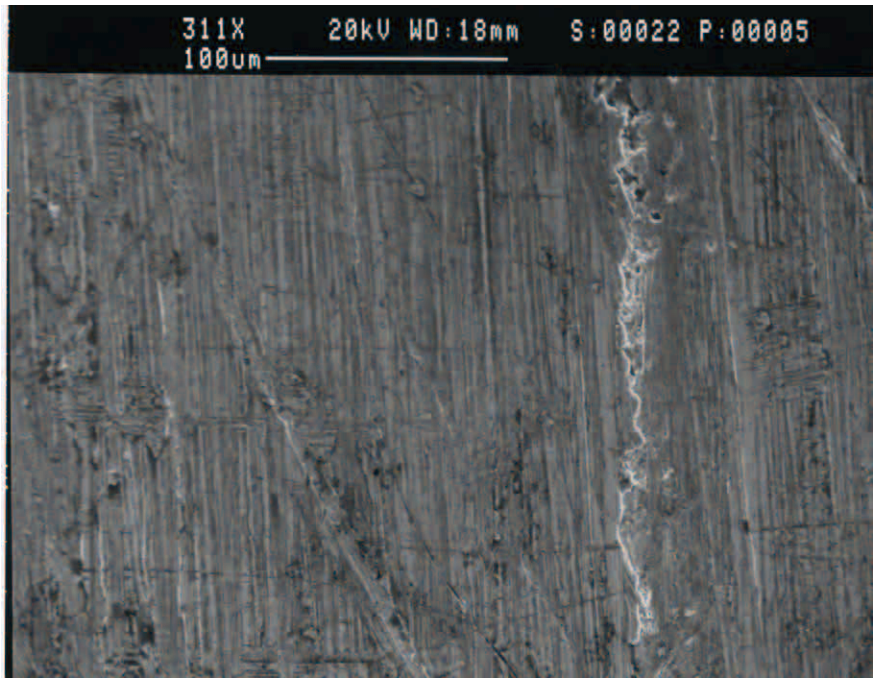
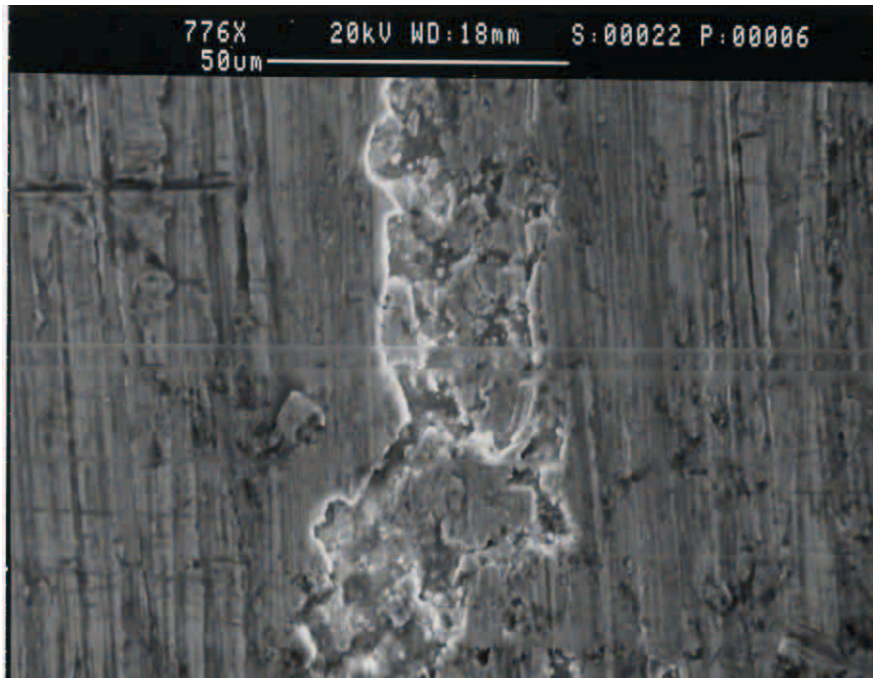
Figure 7--Two SEM views of the disturbed area noted in figure 6 on coupon 22 consisting of collections of pits.

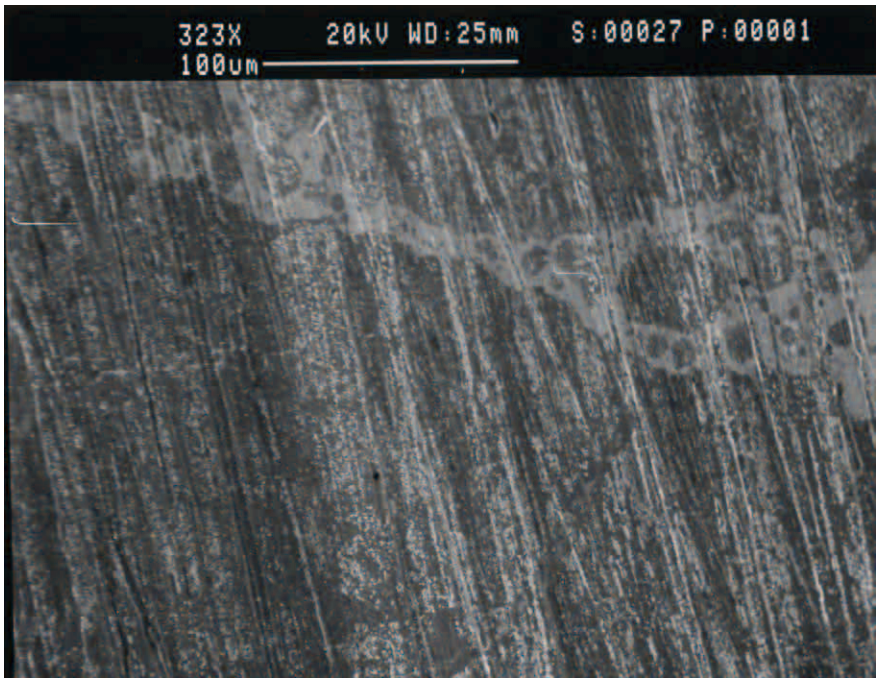


ImageNo:112A0080, Project No:A00164 100 µm



ImageNo: 112A0079, Project No:A00164 20 µm

Figure 8--Two views below the grease line on coupon 22, showing the linear area of damage.



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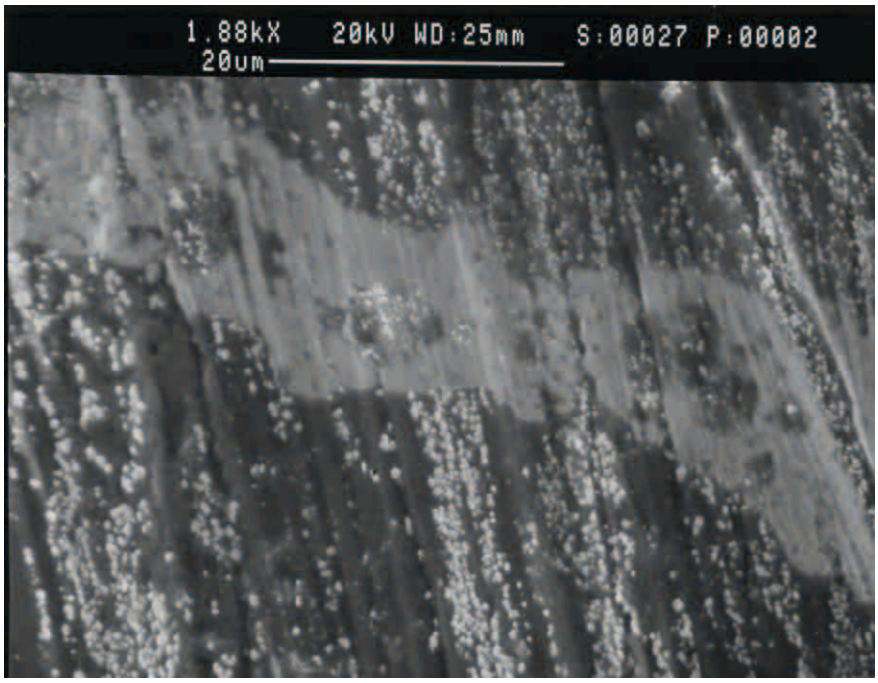
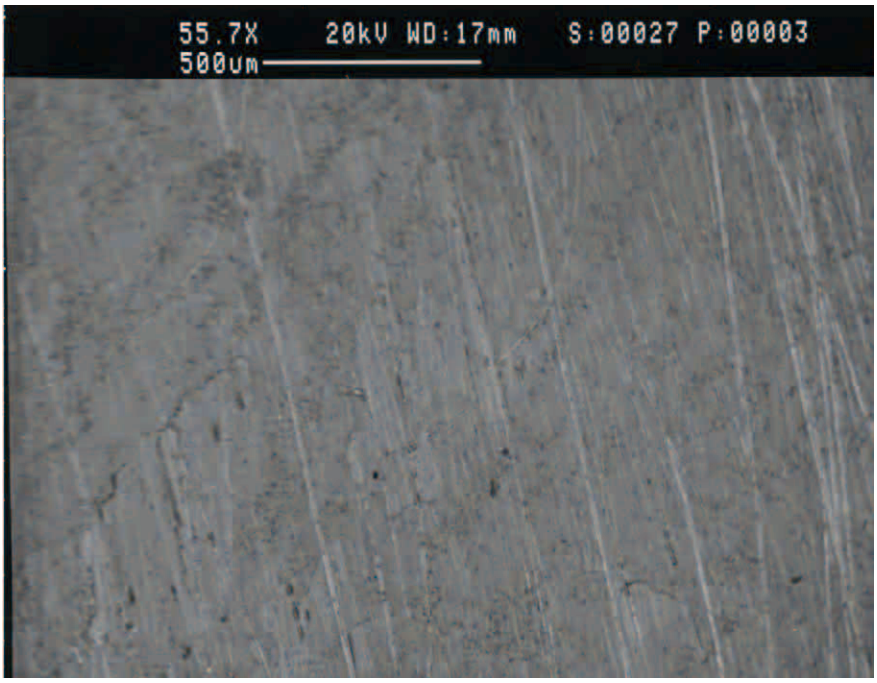
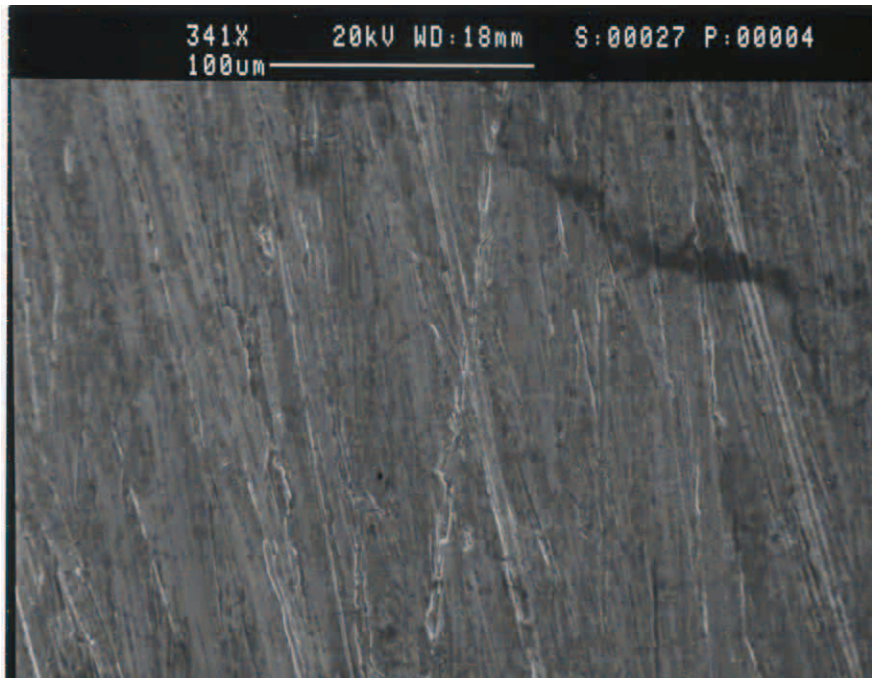


ImageNo: 112A0081, Project No:A00164 10 µm

Figure 9--Two views of the surface film above the grease line on coupon 27.

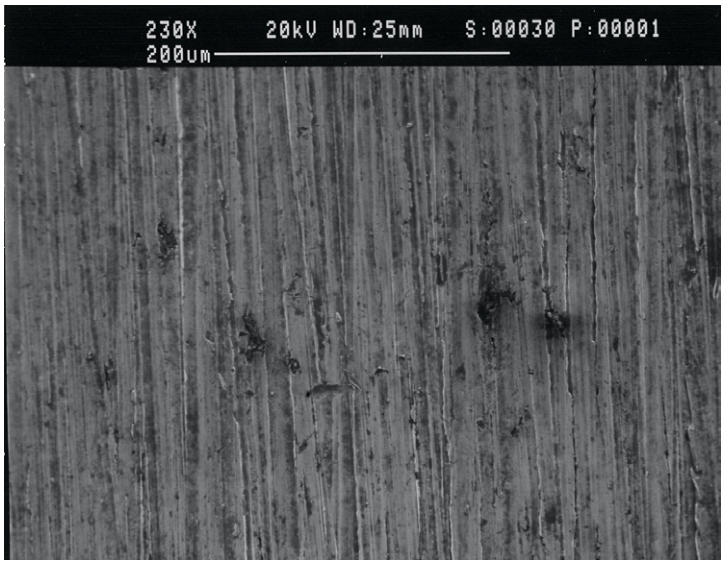


ImageNo:112A0062, Project No:A00164 500 µm

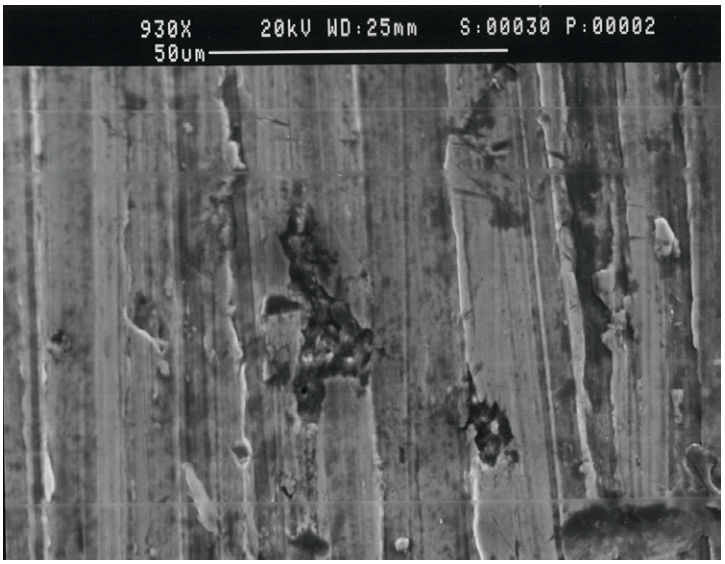


ImageNo: 112A0060, Project No:A00164 100 µm

Figure 10--Typical surface features below the grease line on coupon 27. No pitting was evident.

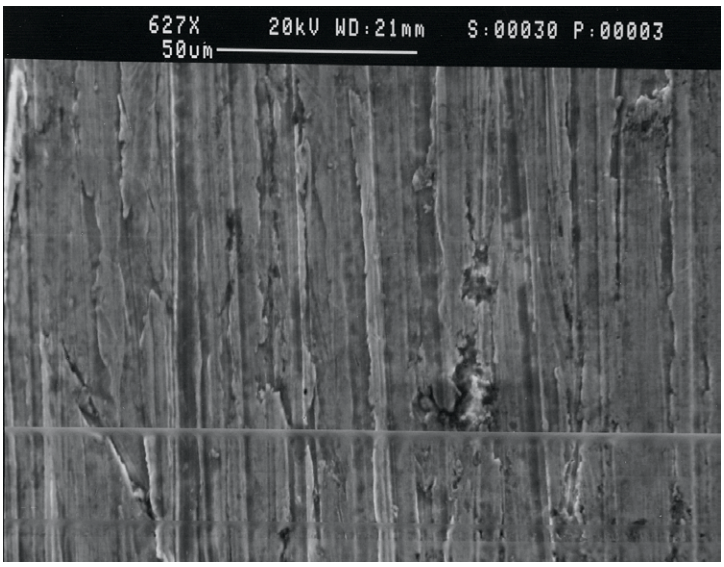


ImageNo:@ImageNo@ , Project No:A00164 ⊢ 100 µm ⊣



ImageNo: 112A0063, Project No:A00164 ⊢ 20 µm ⊣

Figure 11--Views of randomly located pits above the grease line on coupon 30.



ImageNo:112A0065, Project No:A00164 ⊢—— 50 µm ——⊣

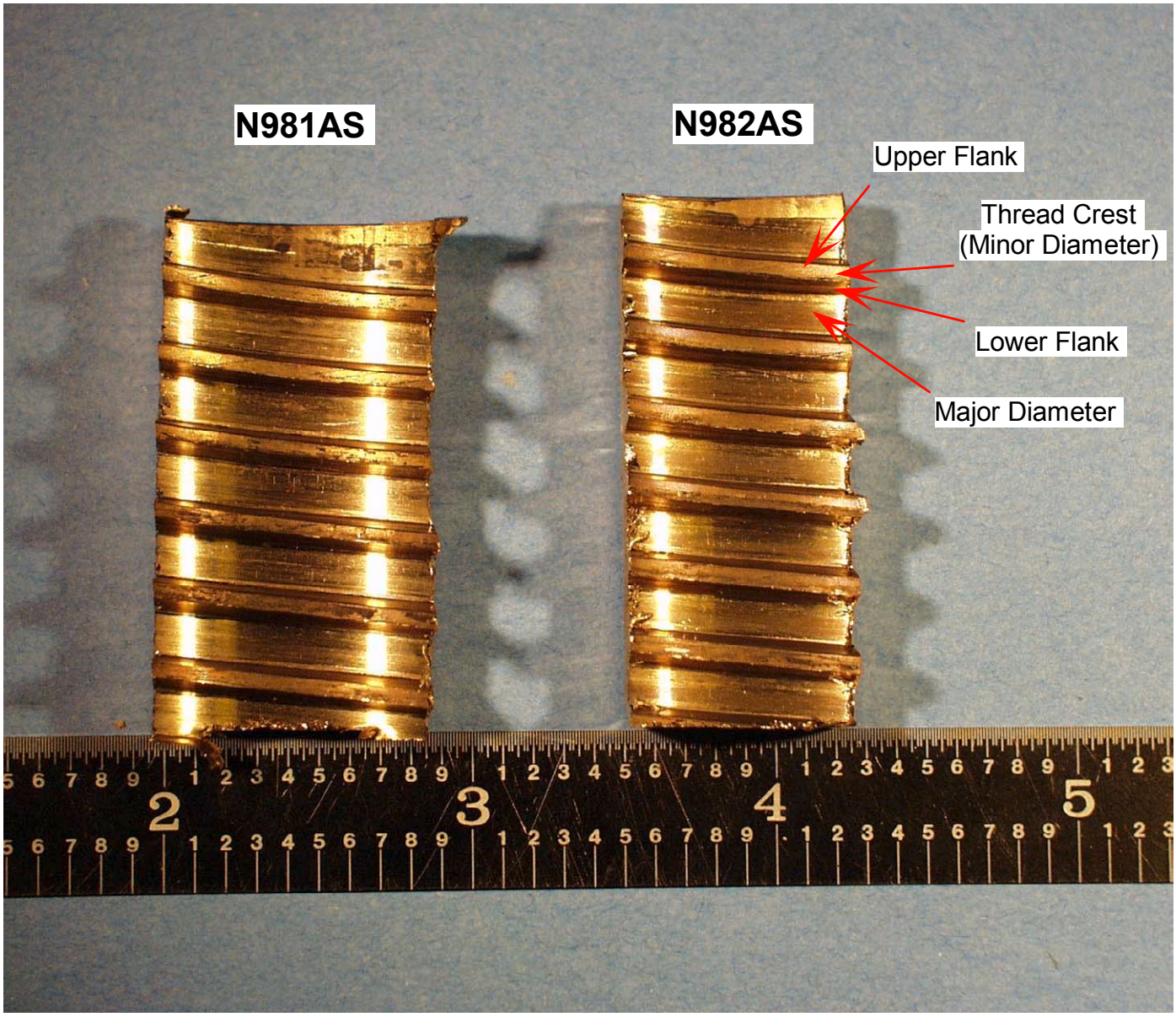
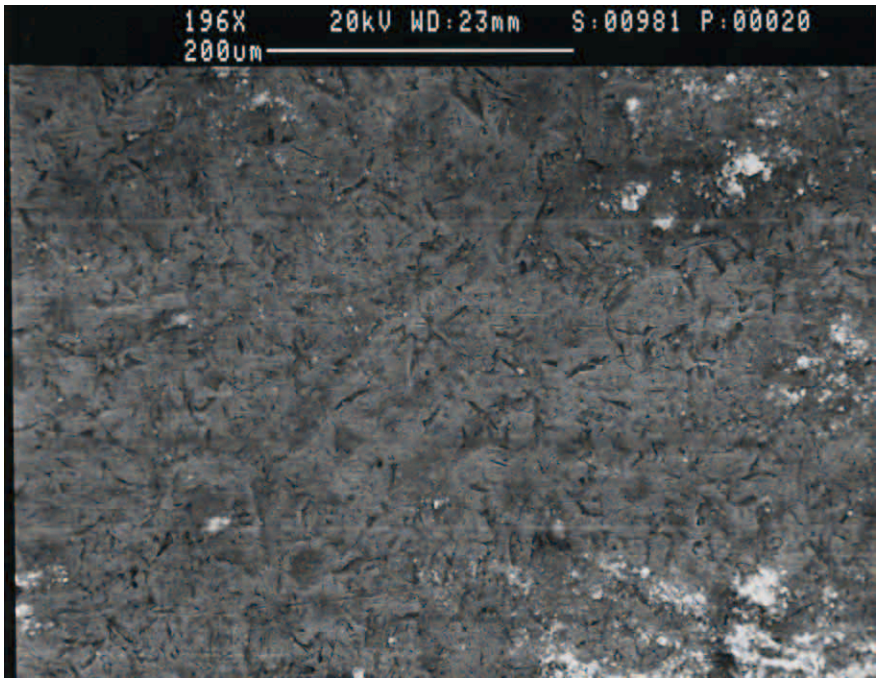
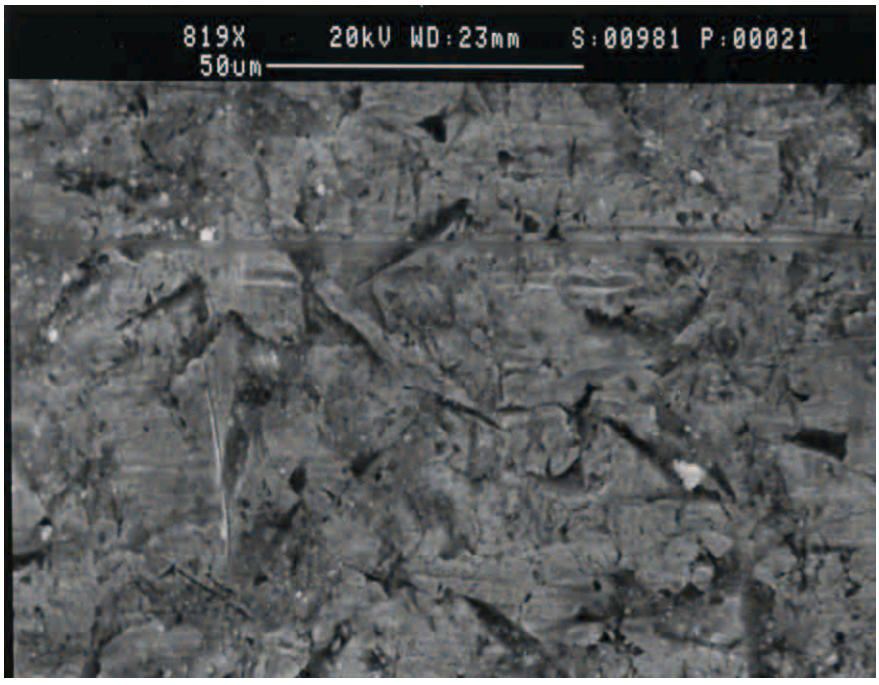


Figure 12--The examined sections of Acme nuts from N981AS (left) and N982AS (right) with the top of the nut at the top of the view.

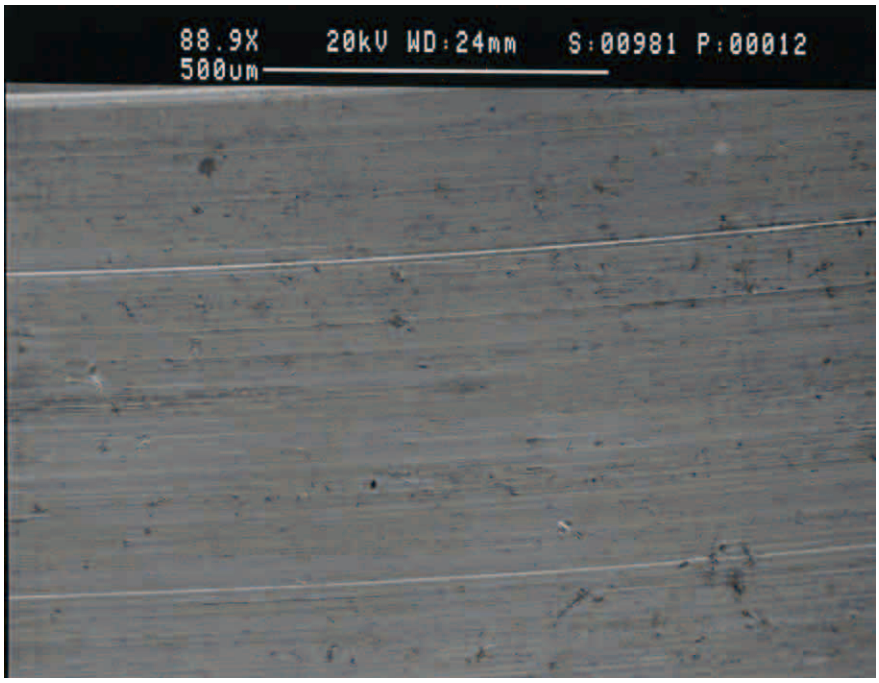


ImageNo:112A0292, Project No:A00164 ⊢ 100 µm ⊣

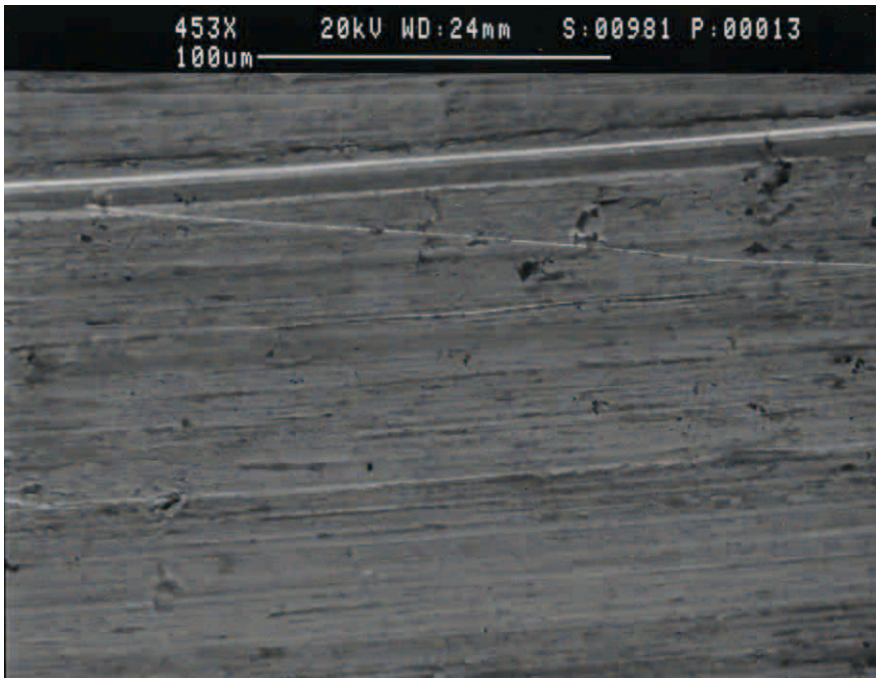


ImageNo: 112A0293, Project No:A00164 ⊢ 20 µm ⊣

Figure 13--Typical surface features on the thread crests (minor diameter) of N981AS.



ImageNo:112A0294, Project No:A00164 ⊢ 200 µm ⊣



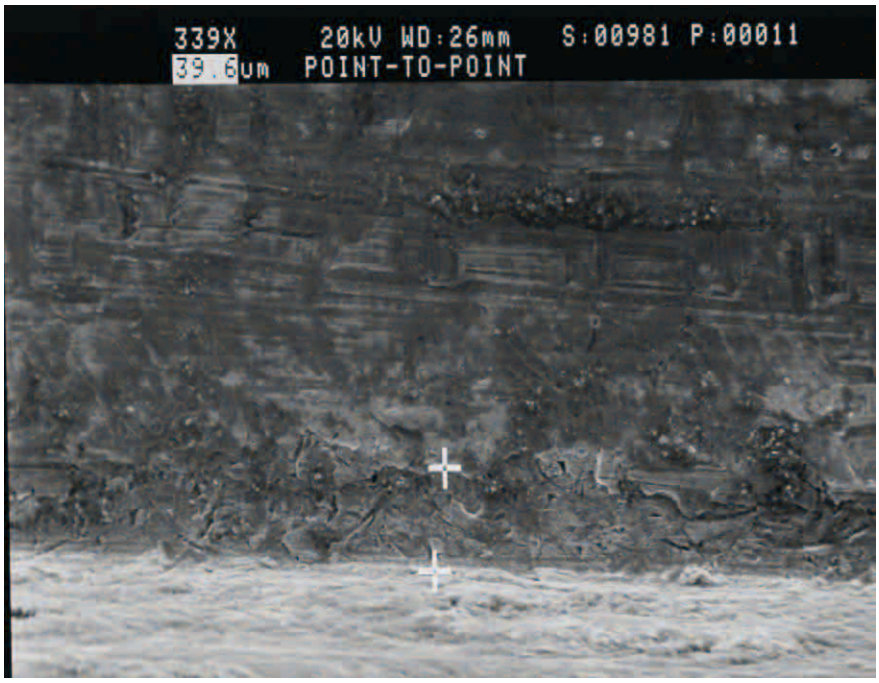
ImageNo: 112A0295, Project No:A00164 ⊢ 50 µm ⊣

Figure 14--Typical surface features on the upper thread flank from N981AS.

ImageNo:112A0296, Project No:A00164 50 µm

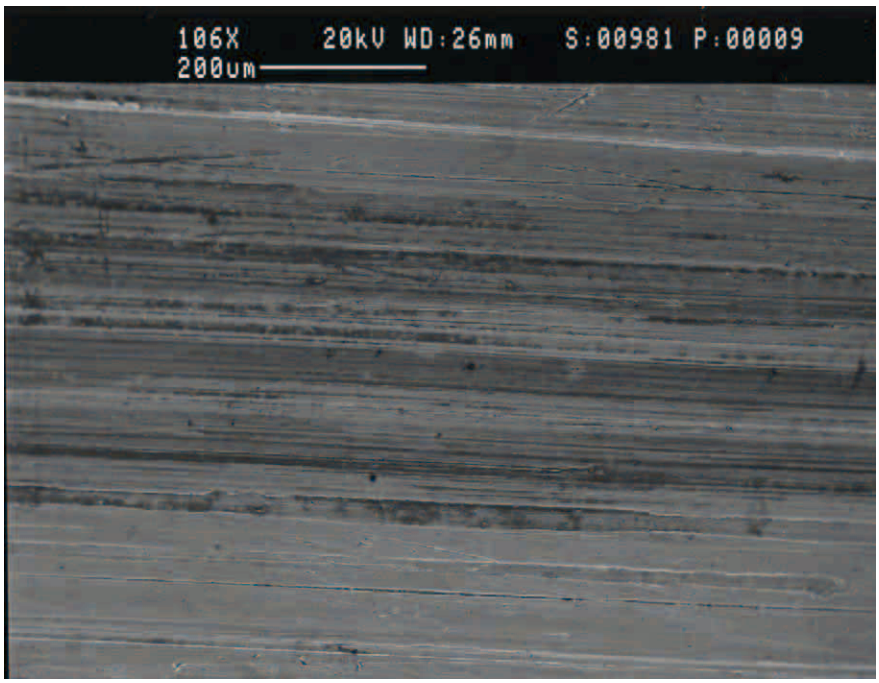
ImageNo: 112A0297, Project No:A00164 20 µm

Figure 15--Surface disruptions on the upper thread flank of N981AS. Upper view of mechanically induced damage; lower view of pit-like features at high magnification.



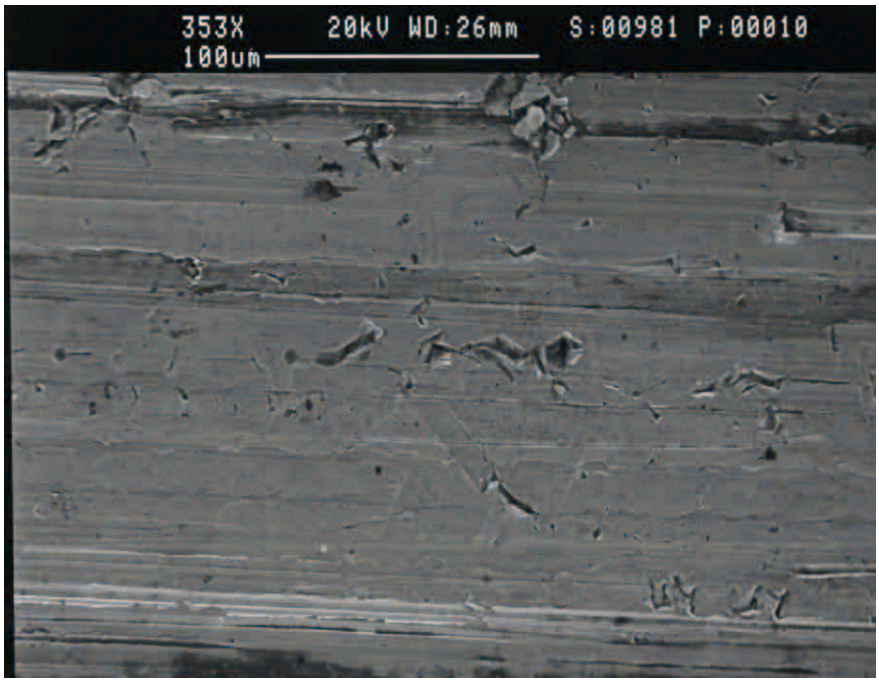
ImageNo:112A0298, Project No:A00164 100 µm

Figure 16--Thin band of pebble grain finish on the major diameter of N981AS adjacent to the upper flank.



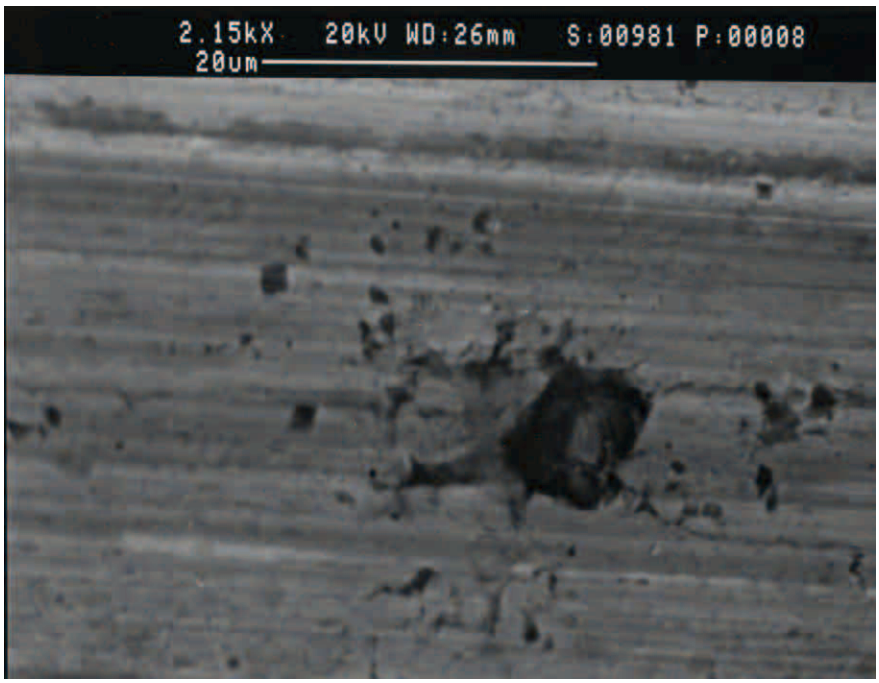
ImageNo: 112A0299, Project No:A00164 200 µm

Figure 17--Typical scratches on the major diameter of N981AS.



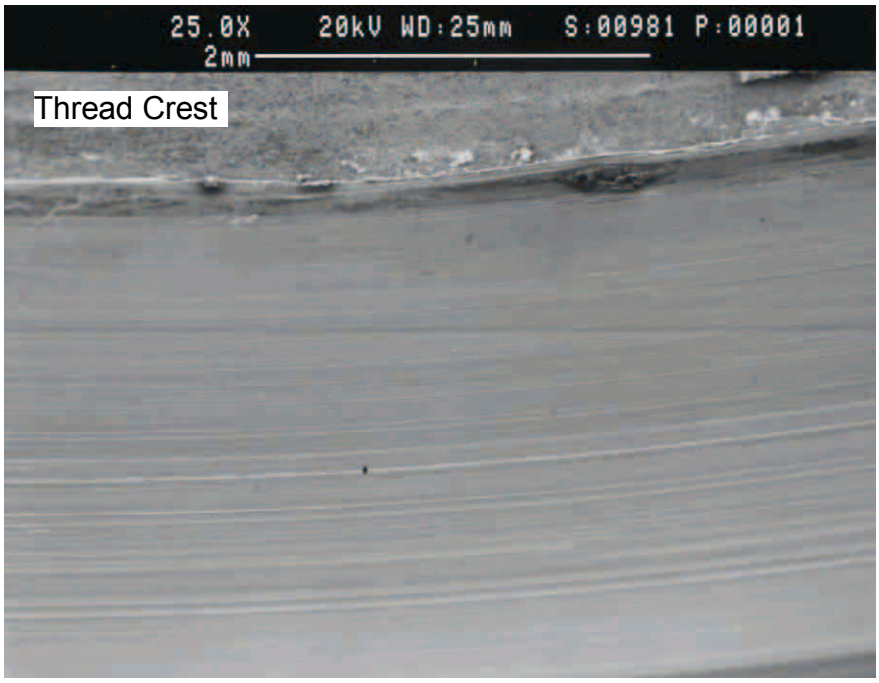
ImageNo:112A0300, Project No:A00164 100 µm

Figure 18--Mechanical indentations into the major diameter of N981AS.



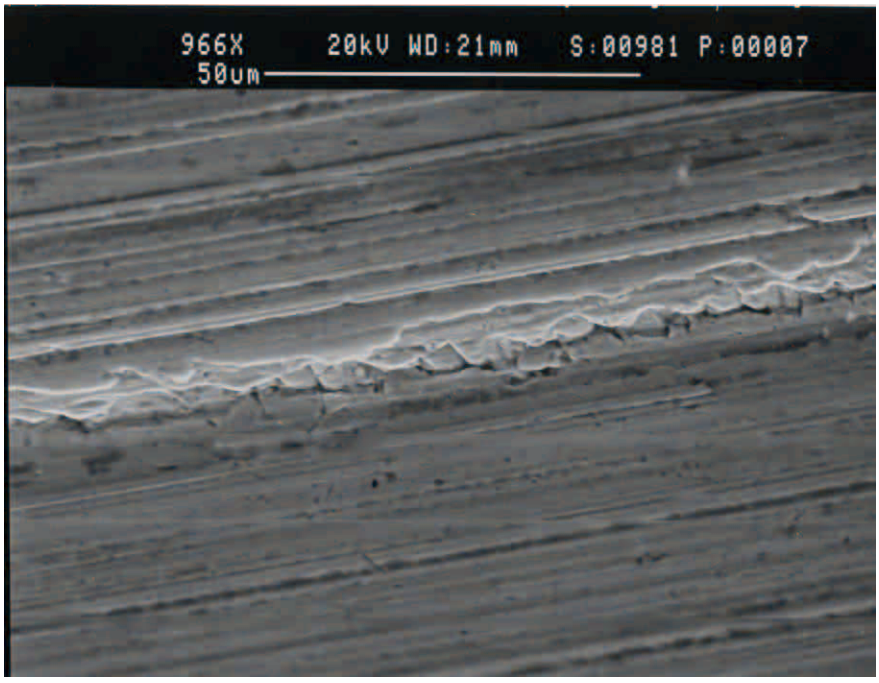
ImageNo: 112A0301, Project No:A00164 10 µm

Figure 19--Pit structure in the major diameter of N981AS.



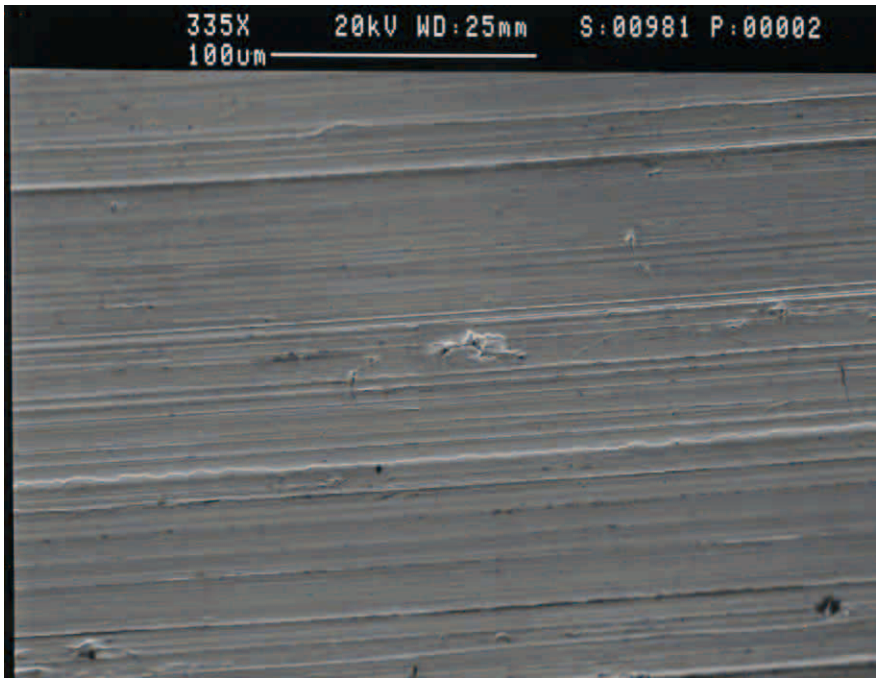
ImageNo:112A0302, Project No:A00164 1 mm

Figure 20--Typical scratch pattern on the lower flank of N981AS.



ImageNo: 112A0303, Project No:A00164 20 µm

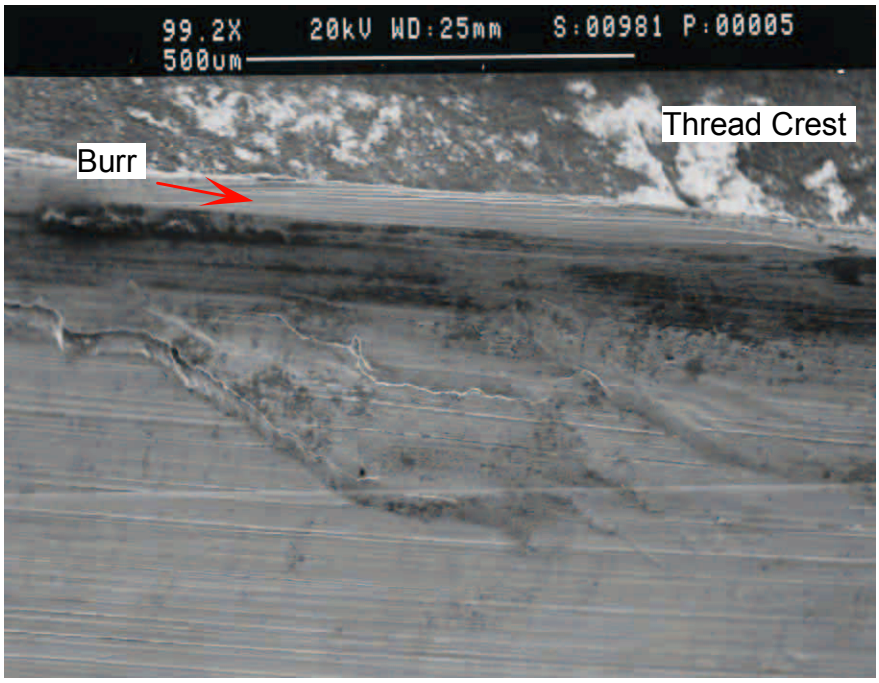
Figure 21--A long gapping crack in the lower flank of N981AS.



ImageNo:112A0305, Project No:A00164 100 µm

ImageNo: 112A0306, Project No:A00164 20 µm

Figure 22--Two views of a typical short crack in the lower flank of N981AS.



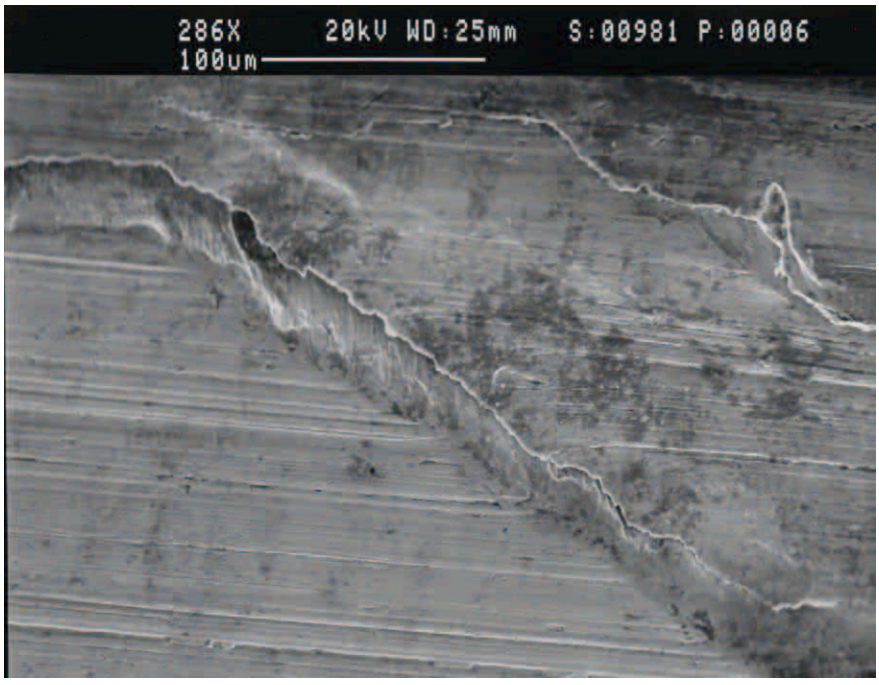
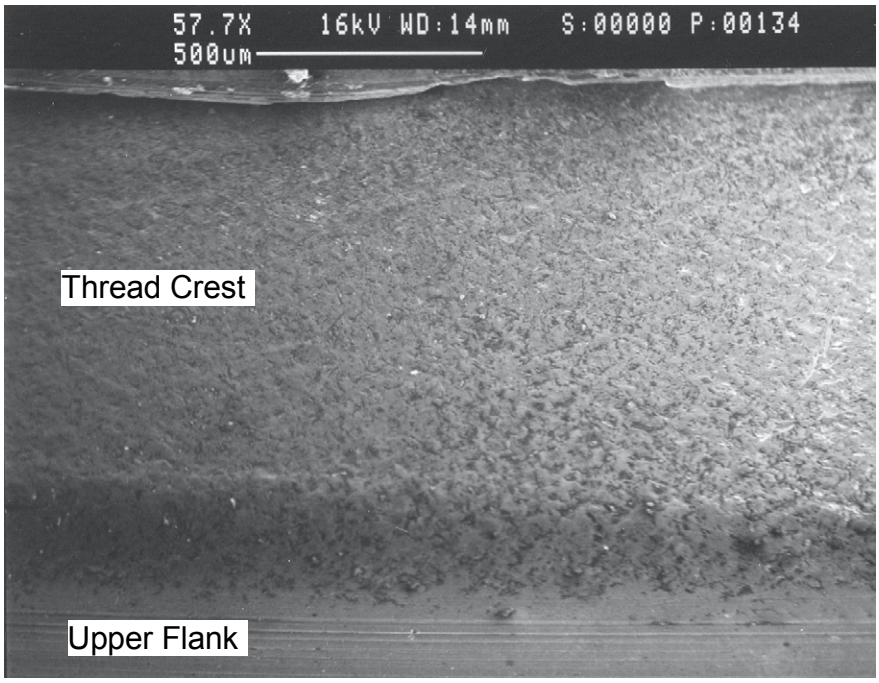
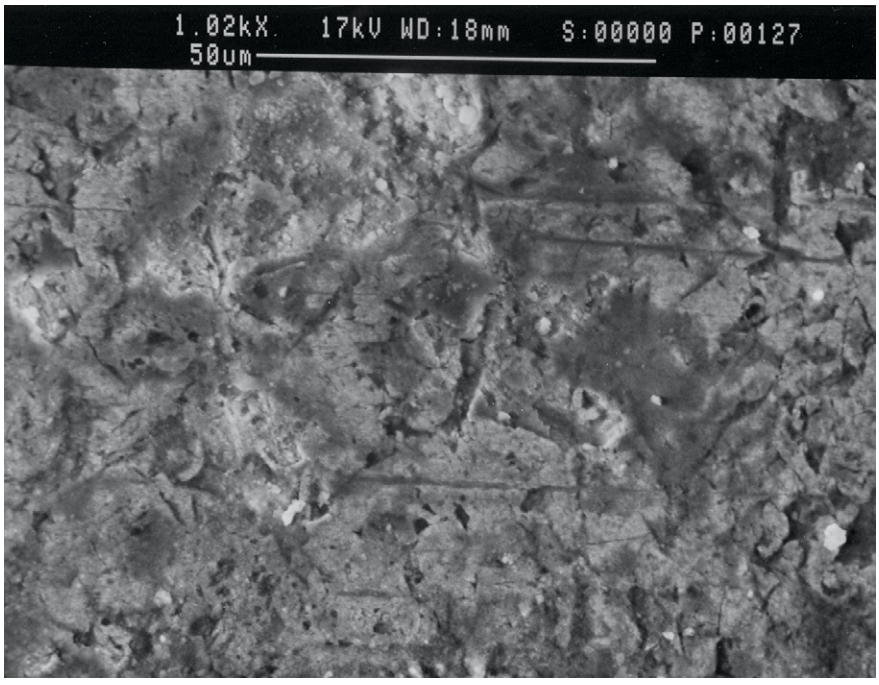


Figure 23--Typical cracking and deformation associated with the burrs protruding from the lower flank of N981AS.

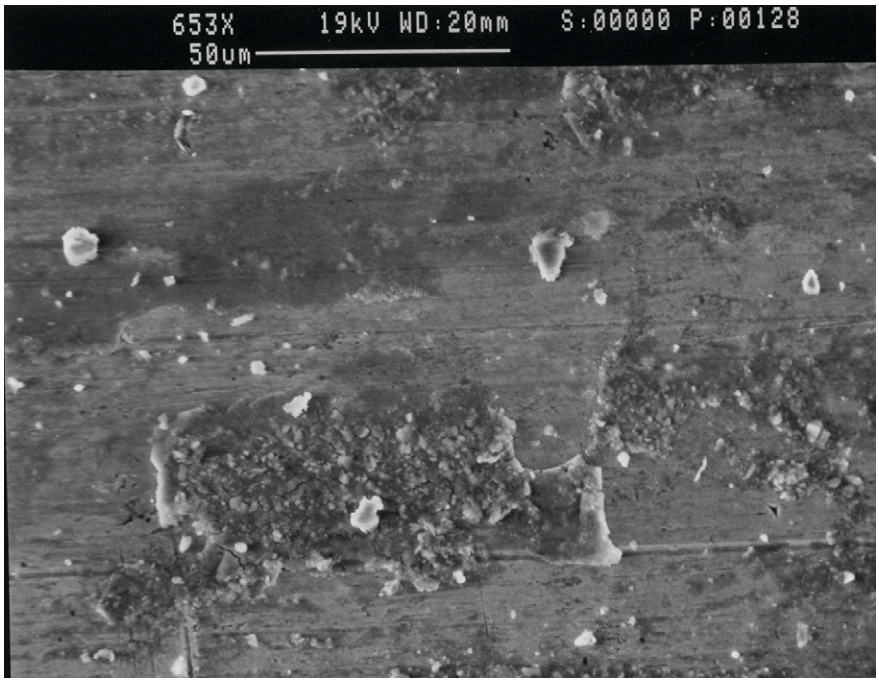


ImageNo:112A0309, Project No:A00164 ⊢—— 500 µm ——⊣



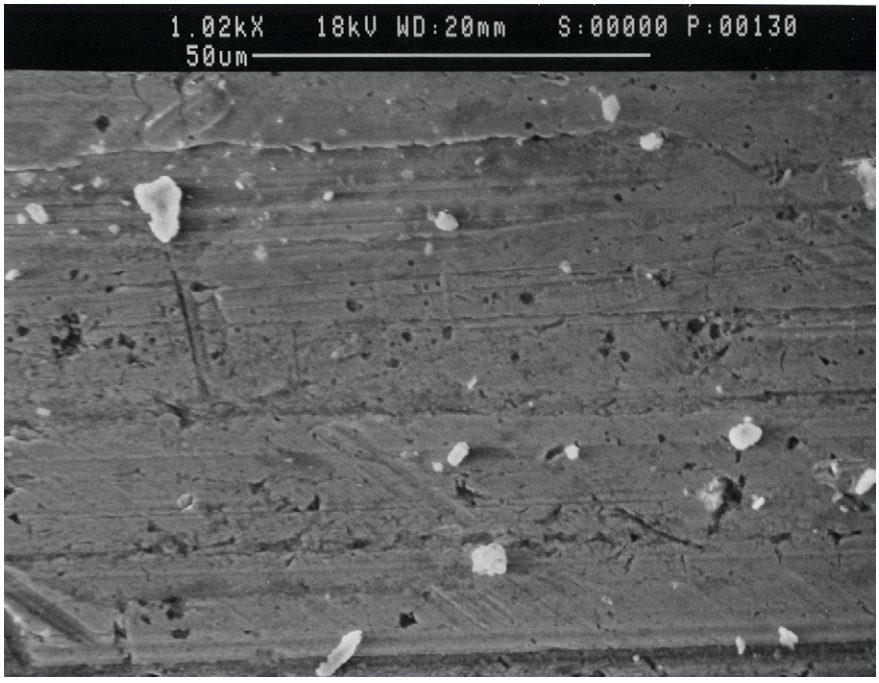
ImageNo: 112A0310, Project No:A00164 ⊢— 20 µm —⊣

Figure 24--Typical pebble grain surface finish of the thread crests of N982AS.



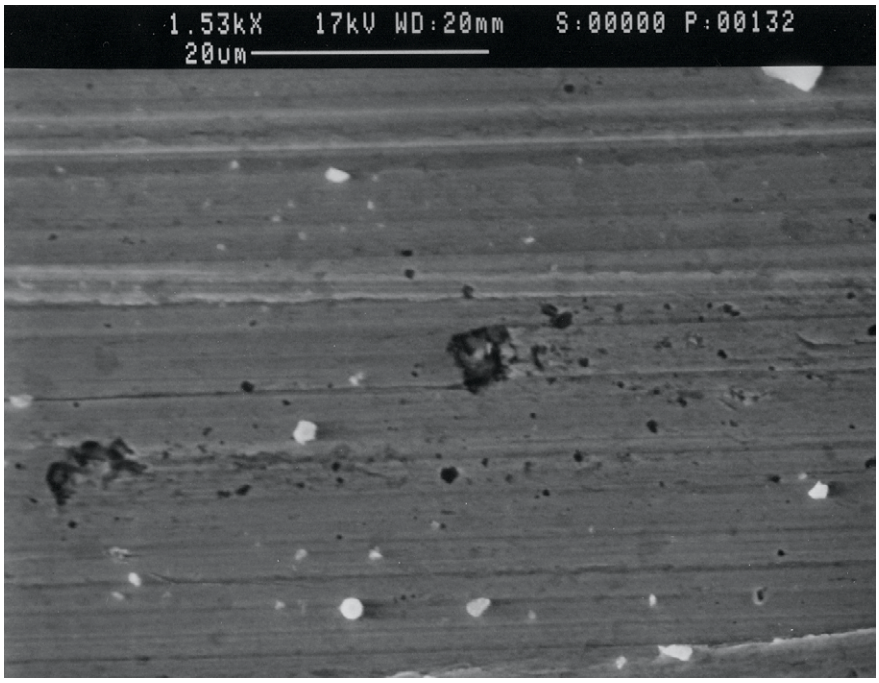
ImageNo:112A0311, Project No:A00164 50 µm

Figure 25--Typical scratch pattern and deposts on the major diameter surface of N982AS. White particles are dust on the surface.



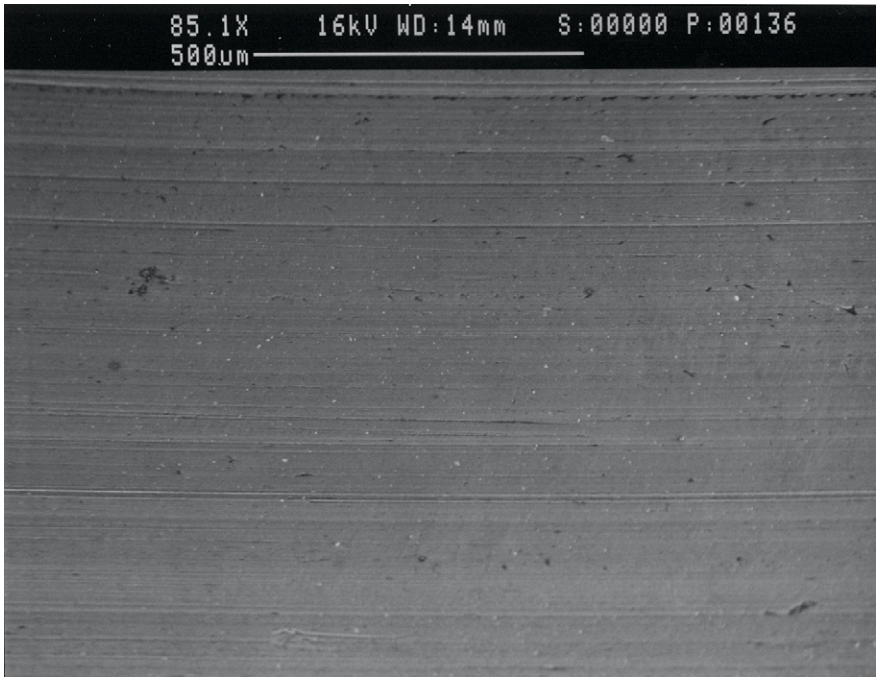
ImageNo: 112A0312, Project No:A00164 20 µm

Figure 26--Shallow pits and other features found on the major diameter near the upper thread flank of N982AS. White particles are dust on the surface.



ImageNo:112A0313, Project No:A00164 ⊢—— 20 µm ——⊣

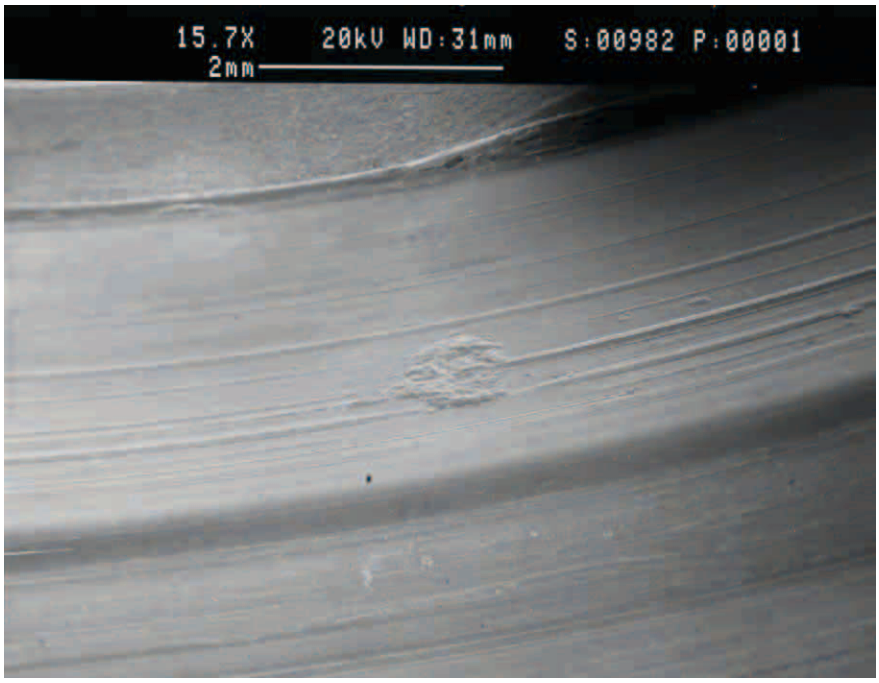
Figure 27--Pits found in the central area of the major diameter of N982AS. White particles are dust on the surface.



ImageNo: 112A0315, Project No:A00164 ⊢ 200 µm ⊣

Figure 28--Typical surface of the upper thread flank on N982AS.

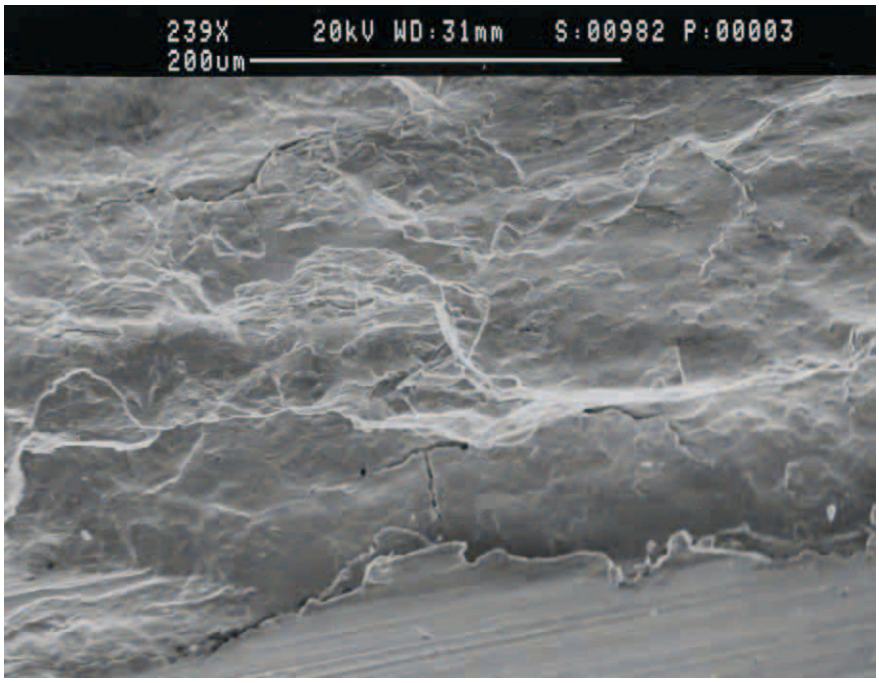
Figure 29--Small shallow pits found on the upper flank of the top thread at high magnification (N982AS).



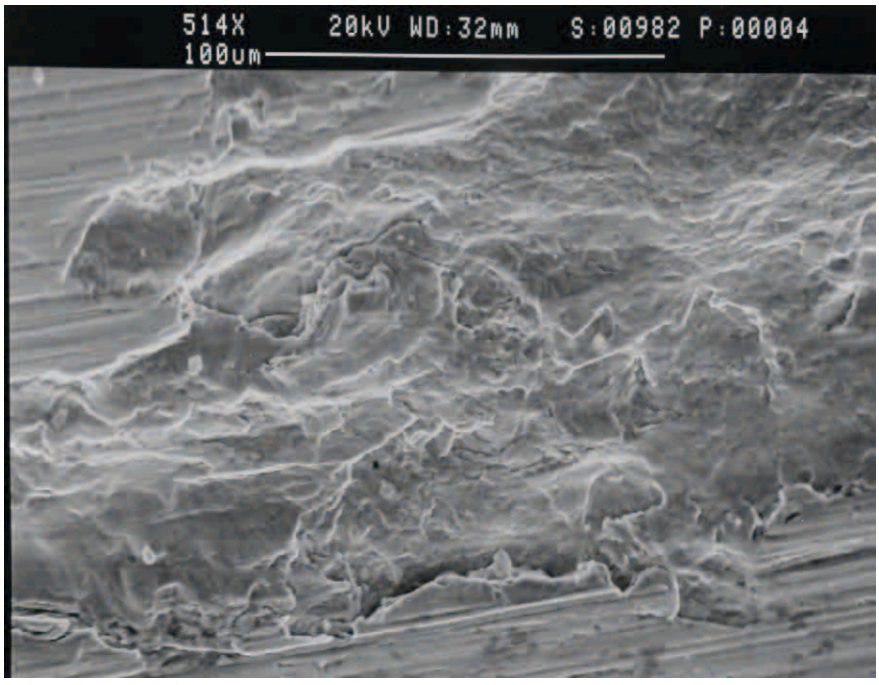
ImageNo:112A0317, Project No:A00164 2 mm

ImageNo: 112A0318, Project No:A00164 500 µm

Figure 30--Lower flank of N982AS showing gouges and spalls.

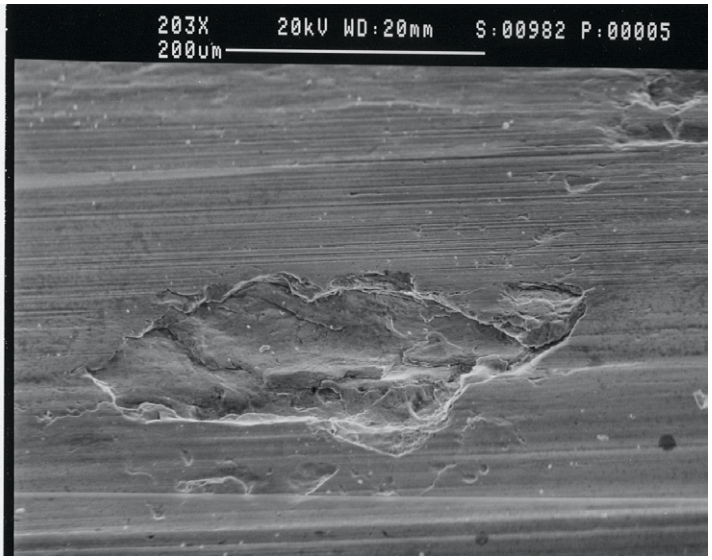


ImageNo:112A0319, Project No:A00164 100 µm

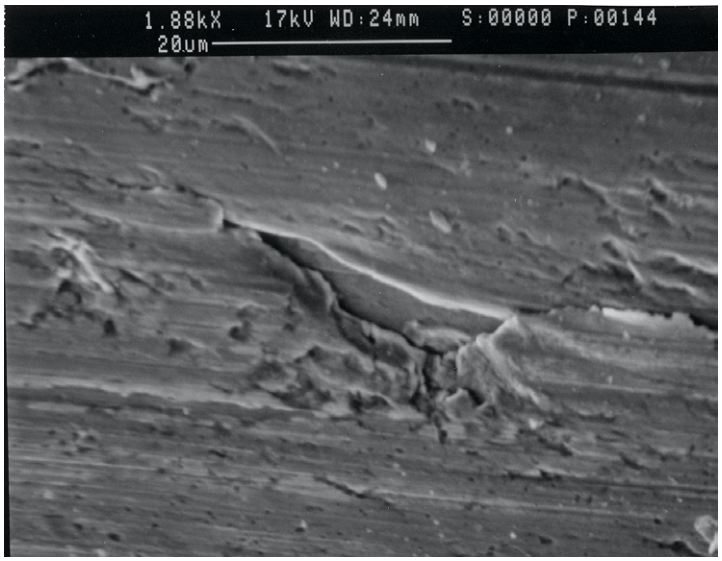


ImageNo: 112A0320, Project No:A00164 50 µm

Figure 31--Two medium magnification views of the spall from figure 30 (N982AS) showing surface cracking and fracturing features.

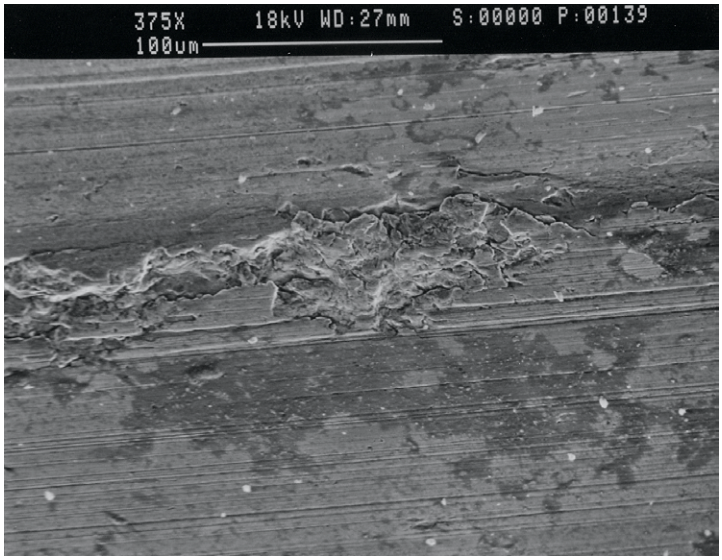


ImageNo:112A0321, Project No:A00164 ⊢ 100 µm ⊣



ImageNo: 112A0322, Project No:A00164 ⊢ 10 µm ⊣

Figure 32--Other spalls on the lower flank of N982AS.



ImageNo:@ImageNo/1@, Project No:A00164 ⊢ 50 µm ⊣

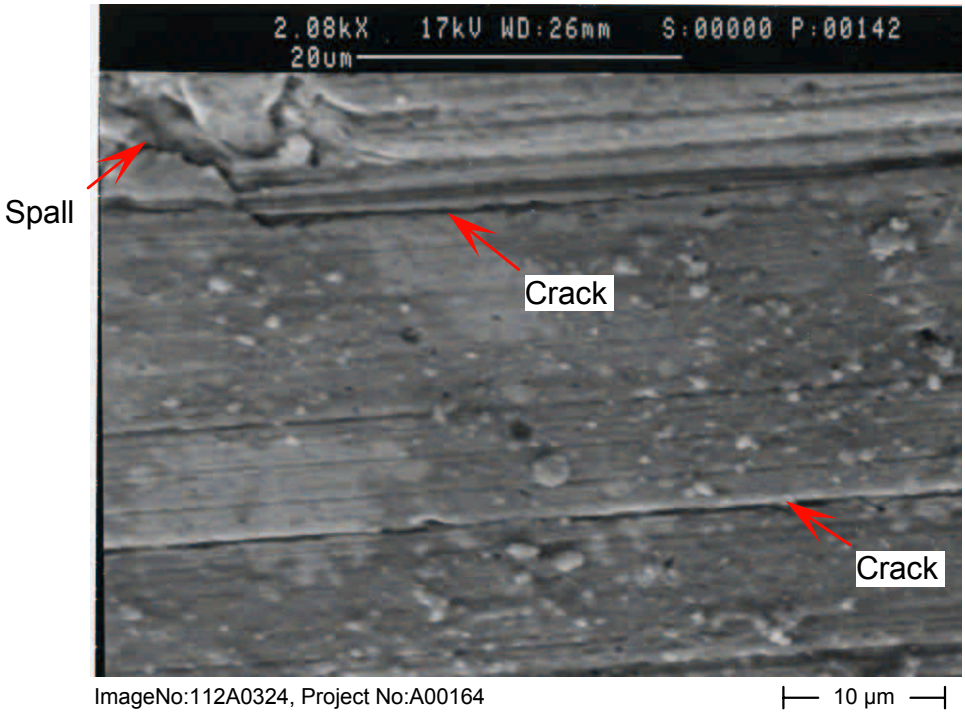


Figure 33--Long circumferential cracks in the lower flank surface of N982AS. The upper crack intersects a spalled area while the lower crack did not.