Piper PA44-180, Failed Nose Gear Drag Link Bolt, ATA 3222

Chief inspector James Kelly of Embry-Riddle Aeronautical University states “The forward drag link bolt (P/N AN 551) on this aircraft’s nose gear failed during touch and go practice. The aircraft returned to the departure runway and landed with the nose gear stuck in the nose wheel-well.” (With respect to the common good and interest of safety, “hats-off” are again due to the next three participants for making possible the following structural analysis—the very same contributors for the PA44 trunnion failure analysis in September 2006. “Thank-you” James Kelly and Embry-Riddle University for your frequent contributions and help to the Alerts—for sharing this report and many other safety-related concerns. A special thanks again to George A. Morse of Failure Analysis Service Technology for another fascinating dissection of microscopic clues to failure.

Readers should note the following editorial redactions: N-numbers have been eliminated as standard practice, and “conversion battles” between moving from PDF files, to Word, then back to PDF created some difficulty. The first four pages are obvious “scans,” preserving the format of the analysis report. However, scans of PDF files render very poor photo image quality, so these were cut from the original PDF files...converted to Bit-mapped...converted to J-peg...then re-inserted into the Word document with slight horizontal elongation. This process seemed to “truncate” the photo descriptions, requiring their re-typing by this editor. The point of this exercise was to maintain the best photo quality possible as will hopefully be apparent in this limited format. Any mistakes or errors induced by this process are entirely inadvertent and the sole responsibility of this editor.

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24 October 2007

TO: Pat Kelly
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FROM: George A. Morse

SUBJECT: **NOSE LANDING GEAR BOLT FAILURE**

BACKGROUND

This report summarizes the investigation of a nose landing gear (NLG) bolt failure on aircraft N ER. The end of the bolt, which was stuck in the NLG drag link assembly, was submitted along with the drag link assembly to Failure Analysis Service Technology, Inc. (FAST) for evaluation. The following information is applicable:

Type AC: PA44-180 AC Number: AC Total Time: 4146.0

Part Failure: NLG FWD bolt in drag link assembly PN: 400-191

Bolt Specification: AN5-51 FAST Report Number: F5429

The aircraft was performing touch-and-go landings. During the last gear retraction, a noise was heard in the NLG. The nose gear could not be extended for the next landing. Subsequent inspection revealed a sheared bolt in the forward section of the drag link assembly. This report addresses the failure of this bolt in detail.

CONCLUSION

The last gear retraction of N ER was the final event in a continuous fracture history of the NLG bolt. Fracture initiation sites were located roughly 180 degrees apart on the outer circumference of the bolt. Crack growth progressed from the initiation sites at opposite ends towards the center of the bolt by fatigue. The bolt finally failed along a thin band running through the center of the bolt. The landing just prior to the final gear retraction did not result excessive loads to this bolt.

DISCUSSION

The NLG diagram from Piper's Airplane Parts Catalog is shown in Figure 1 for reference. Post failure, the fractured bolt, Figure item #69 was stuck in the NLG drag link assembly, Figure item #20, which is shown "as received" by FAST in Figures 2 & 3. The bolt was stuck in the drag link assembly due to the bending in the bolt shaft. The bolt could not be rotated in the assembly using finger force only. Another view of the fracture surface of the bolt is shown looking through the drag link assembly hole, Figure 4. There are significant fracture features visible at this level of magnification. There is a dark narrow band running through the center of the bolt from the 8 o'clock to 2 o'clock position. There is a semi-circle at the outer edge of the bolt at the 11 o'clock position, and on the opposite edge at the 4 o'clock position is a roughened edge. It was necessary for FAST personnel to cut the bolt so that the fracture surface could be examined in detail under the scanning electron microscope (SEM). The mating surface of the bolt was never found.

A macro photo of the bolt fracture surface after the shaft was cut by FAST personnel is shown in Figure 5. There are numerous fracture origins at both the top and bottom, indicated by the blue arrows, Figure 5. The yellow arrows indicate crack growth direction that progressed by fatigue from the fracture origins. The bolt finally failed instantaneously at the narrow dark zone traveling through the center of the bolt. A number of beach marks, which look like ripples in a pond emanating from the point where a thrown stone enters the water, emanate from the fracture origins at both the top and bottom edges. Each of these fracture features were examined in detail in the SEM.

A 20X SEM photo of the narrow band running through the center of the bolt is shown in Figures 6 & 7. A number of beach marks can be seen in each of these photos. Notice that the marks above the center band are concaved upwards toward the fracture origin at the top. The beach marks below the center band are concaved downward toward the fracture origin at the bottom. Each beach mark represents crack growth stoppage from a landing and taxiing operation. The presence of numerous beach marks is proof that this bolt did not fail in one landing operation, but instead failed over many operations over a long period of time.

Higher SEM magnifications of the narrow center band are shown in the SEM photos, Figures 8 - 10. Each shows the characteristic ductile dimple fracture features of instantaneous overload. In other the words, this narrow center band represents the amount of metal holding the bolt together when it finally failed during the last gear retraction. There wasn't much.

While the bolt finally failed in the narrow center band, the outer edges are where the fracture initiated. Progressive SEM magnification of the top edge shown in Figure 5, is shown in the SEM photos, Figures 11 – 13. The origin is indicated by the arrow in Figure 11. Notice that there is a vertical feature in the metal that also points to the origin. The 1000X SEM photo of the top origin shows a very smooth surface from rubbing of the mating surface of the bolt after the initial crack was formed. This photo also shows wear deformation at the outer edge of the bolt. A 1000X SEM photo of the area just below the origin reveals closely spaced parallel striations that are characteristic of fatigue crack growth, Figure 14. The striations are widened slightly

near the final fracture zone on the top half of the bolt due to less metal being able to sustain a landing and taxiing operation, Figure 15. So crack growth was accelerating.

Similar fracture features are shown in the SEM photos for the bottom of the bolt, Figures 16 - 18. A 20X SEM photo of the bottom edge reveals multiple fracture origins at the outer edge. A 60X SEM photo of the origin at the 6 o'clock position is shown in Figure 17. A 500X SEM photo of the fracture surface just above this origin reveals fatigue crack growth features, Figure 18.

A side profile of the bolt at the 6 o'clock edge shown in Figure 5 is shown in the 30X SEM photo, Figure 19. Progressive SEM magnifications of this area show a crack in the edge and wear, Figures 20 – 22. These photos reveal that the source of the stress concentration from which crack growth proceeded by fatigue is from wear with in the mating NLG bushing. The wear is very close to the edge of the bushing. Notice the gold color is worn from the bolt right at the edge of the fracture, Figure 23.

The bolt was found to be made of a non-corrosion resistant steel in accordance with the AN5-51 bolt specification, Figure 24. The outer surface was plated with cadmium and a chromate conversion coating, Figure 25.

SUMMARY

The evidence is conclusive for this bolt having failed over a long period of time and many landing/taxiing operations. The bolt failed by a fatigue crack growth mechanism. Crack growth proceeded from opposite edges towards the center. The bolt failed during the last gear retraction with very little metal actually holding the bolt together. The crack initiation sites were on the edges and due to wearing of the bolt with the mating NLG bushing. Please contact me if further assistance is required.

George A. Morse
Failure Analysis Service Technology, Inc.

PIPER AIRCRAFT, INC.
PA-44-180 SEMINOLE
AIRPLANE PARTS CATALOG

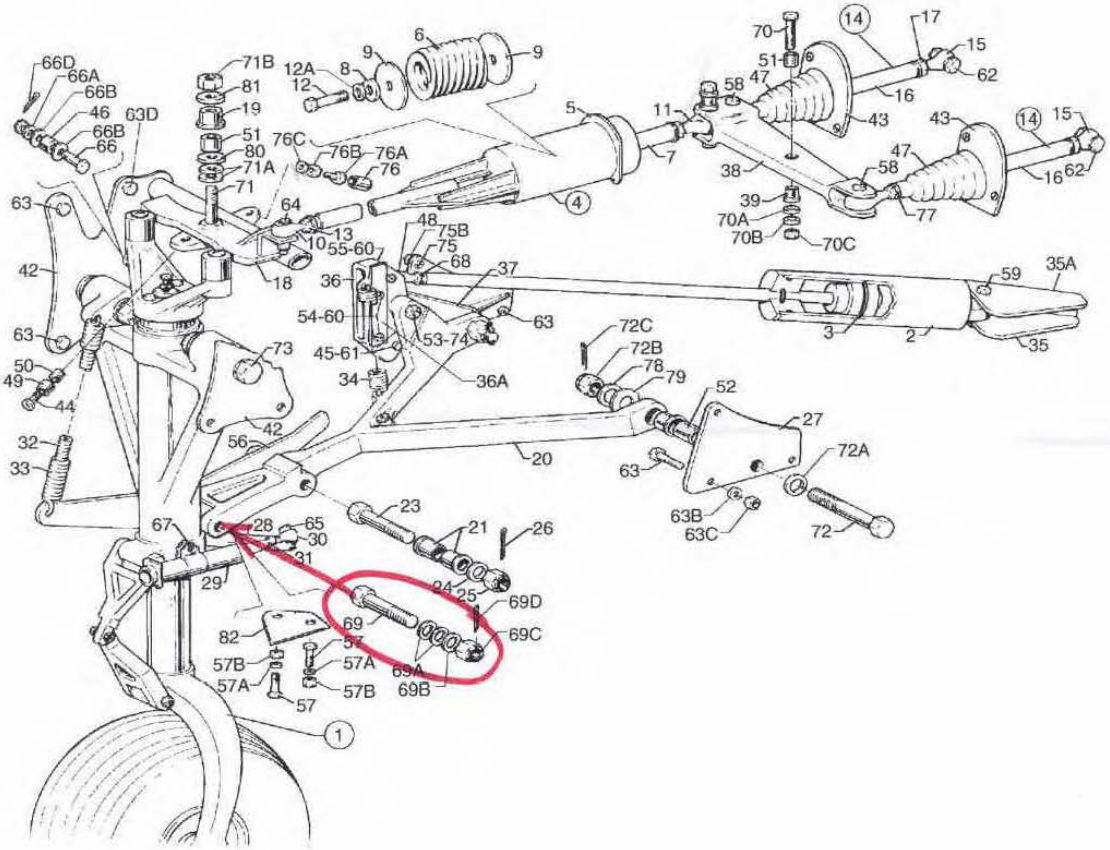

Figure 21. Nose Landing Gear Installation

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Figure 1 Figure item #69 is the bolt that failed. It is PN 400-191, an AN5-51 bolt.

Figure 2 This photo shows the bolt still stuck in the drag link assembly, Figure item 20 in Figure 1.

Figure 3 A side view of the bolt and drag assembly shown as received.

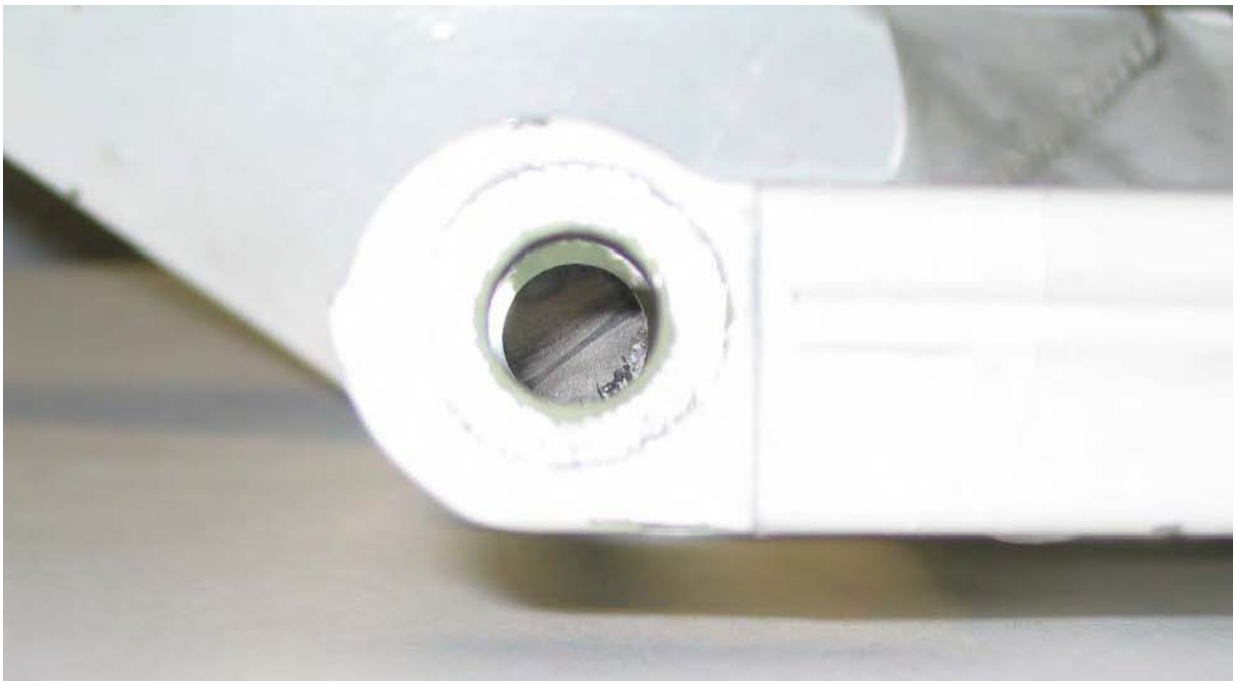

Figure 4 This photo is looking through the drag link assembly hole that reveals a dark narrow band running diagonally through the center of the bolt fracture surface from 8 o'clock to 2 o'clock. There is a semi-circle at the 11 o'clock position and rough edge at the four o'clock

position. These fracture features are shown in detail in subsequent photos.

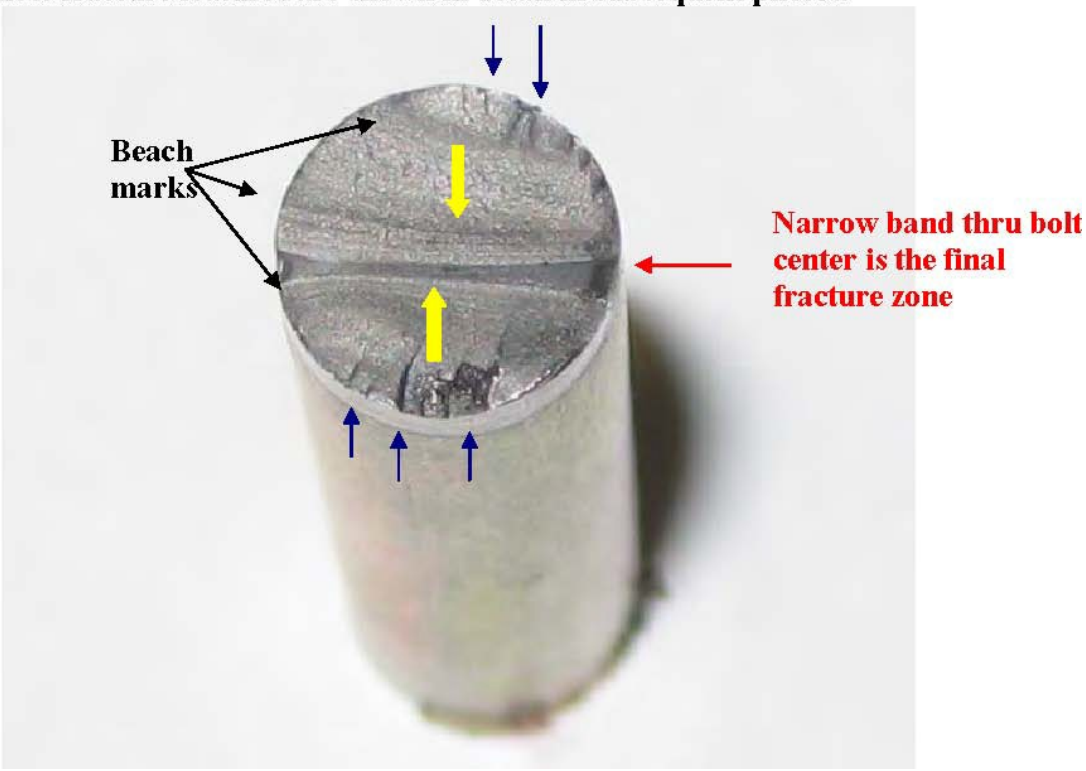

Figure 5 This photo shows the bolt fracture surface with appropriate areas labeled. Blue arrows are fracture origins. Large yellow arrows indicate crack growth direction by fatigue.

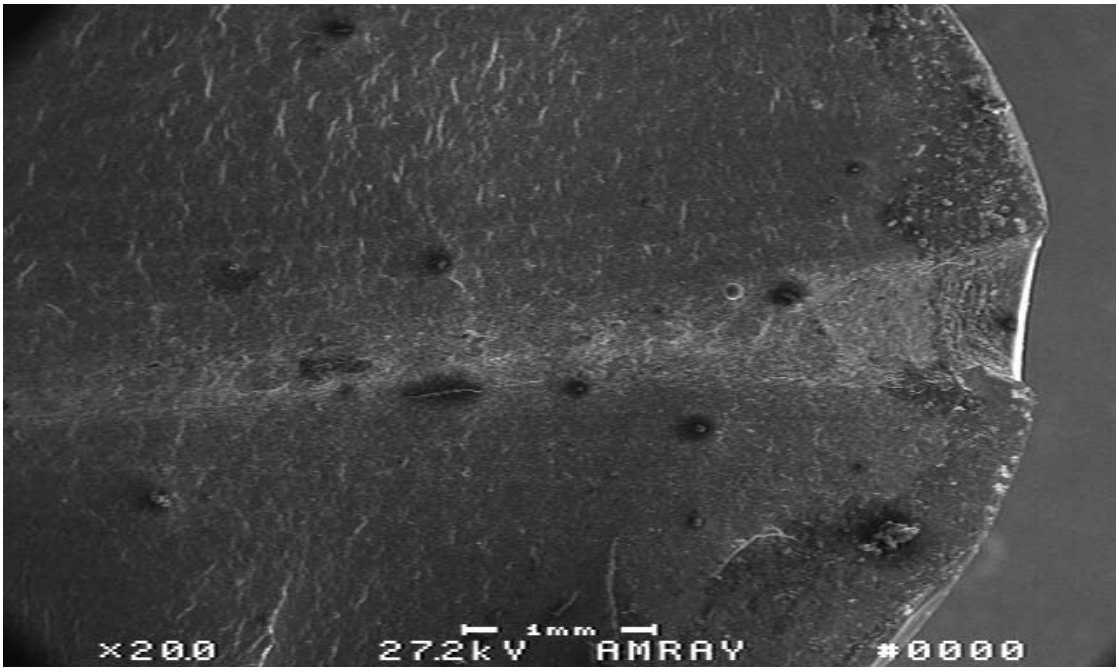

Figure 6 A 20X SEM photo of the right side of the narrow dark band running through the center of the bolt. Notice that the beach marks above the center band are concaved upwards, and those below the center band are concaved downwards.

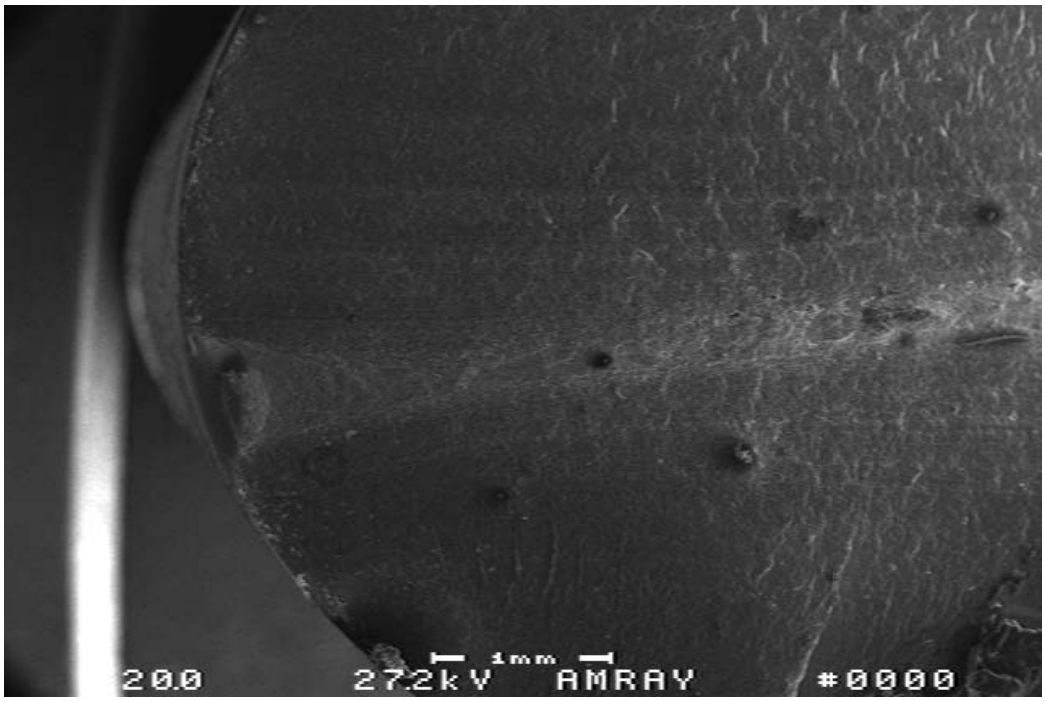

Figure 7 A 20X SEM photo of the left side of the narrow center band. The description of the beach marks discussed in Figure 6 also applies here

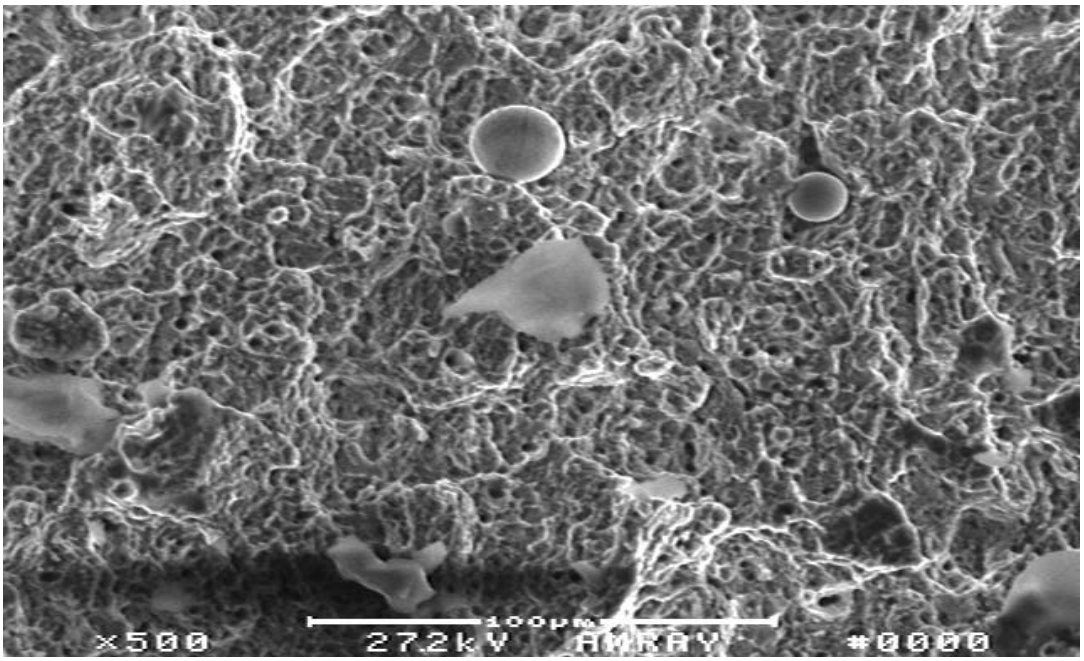

Figure 8 A 500X SEM photo of the right side of the narrow band thru the center of the bolt reveals ductile dimple fracture features characteristic of instantaneous final fracture.

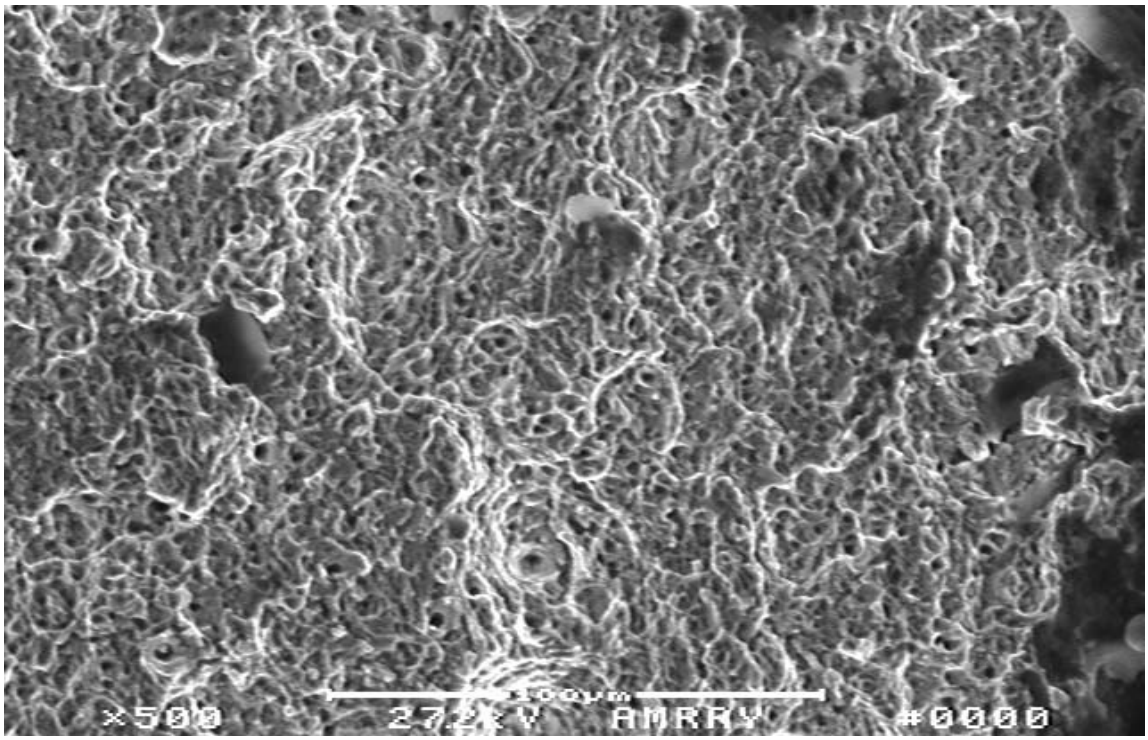

Figure 9 A 500X SEM photo of the center section of the narrow band reveals similar fracture features characteristic of overload.

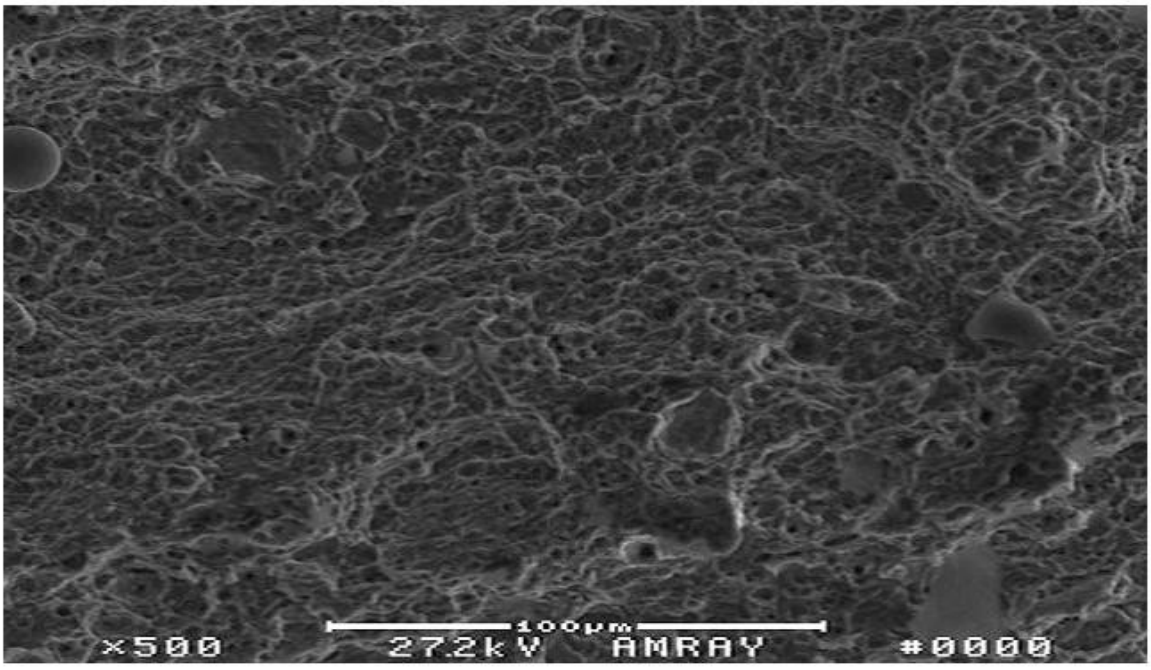

Figure 10 A 500X SEM photo of the left side of the narrow band in the center of the bolt also reveals the ductile dimple fracture features characteristic of instantaneous overload.

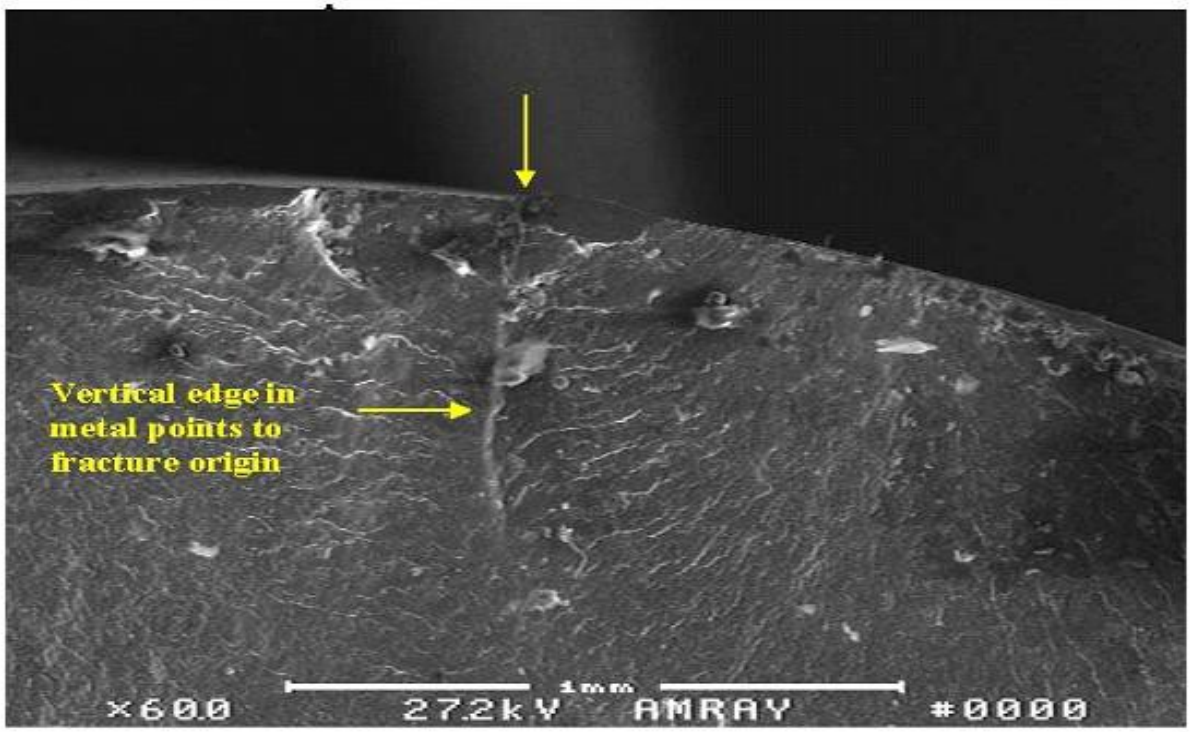

Figure 11 A 60X SEM photo showing the semi-circular shaped area at the bolt's top edge in figure 5. The origin is at the outer surface and indicated by the arrow. Note the vertical feature in the metal that also points to this edge

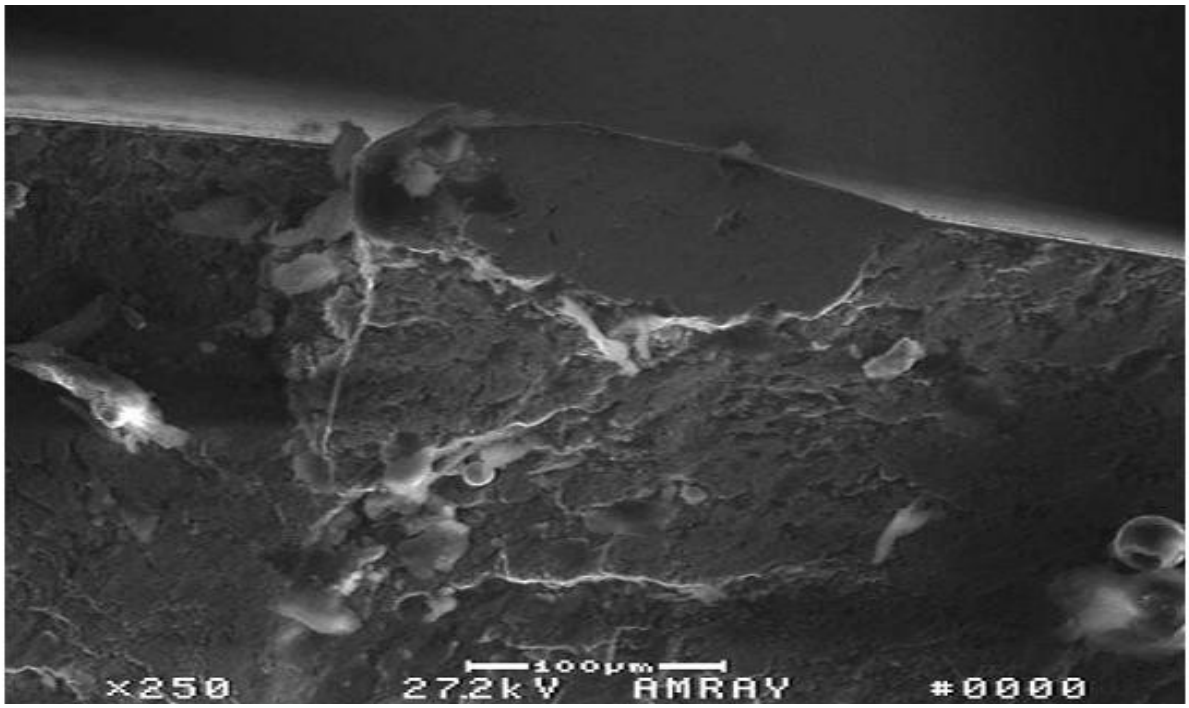

Figure 12 A 250X SEM photo of the origin shown in Figure 11.

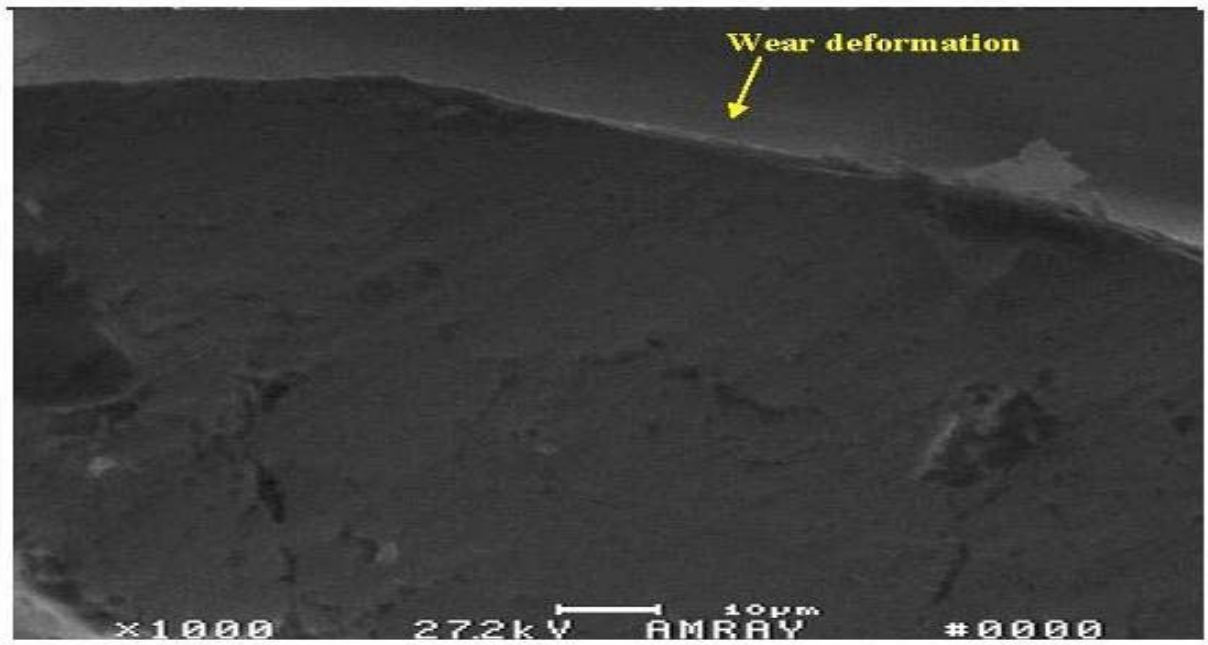

Figure 13 A 1000X SEM photo of the top fracture origin shows wear deformation at the outer edge. Notice the smooth fracture surface from rubbing with the mating surface after initial cracking.

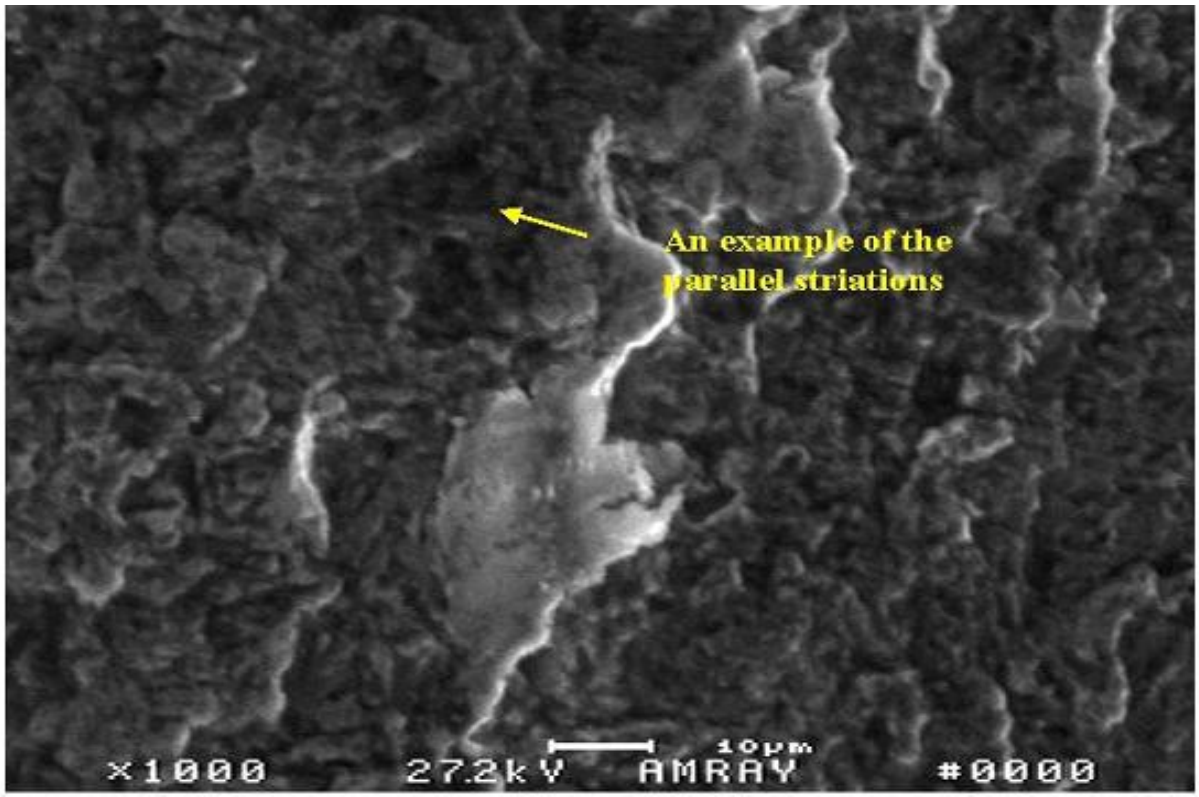

Figure 14 A 1000X SEM photo of an area just below the top origin shows parallel striations characteristic of fatigue crack growth

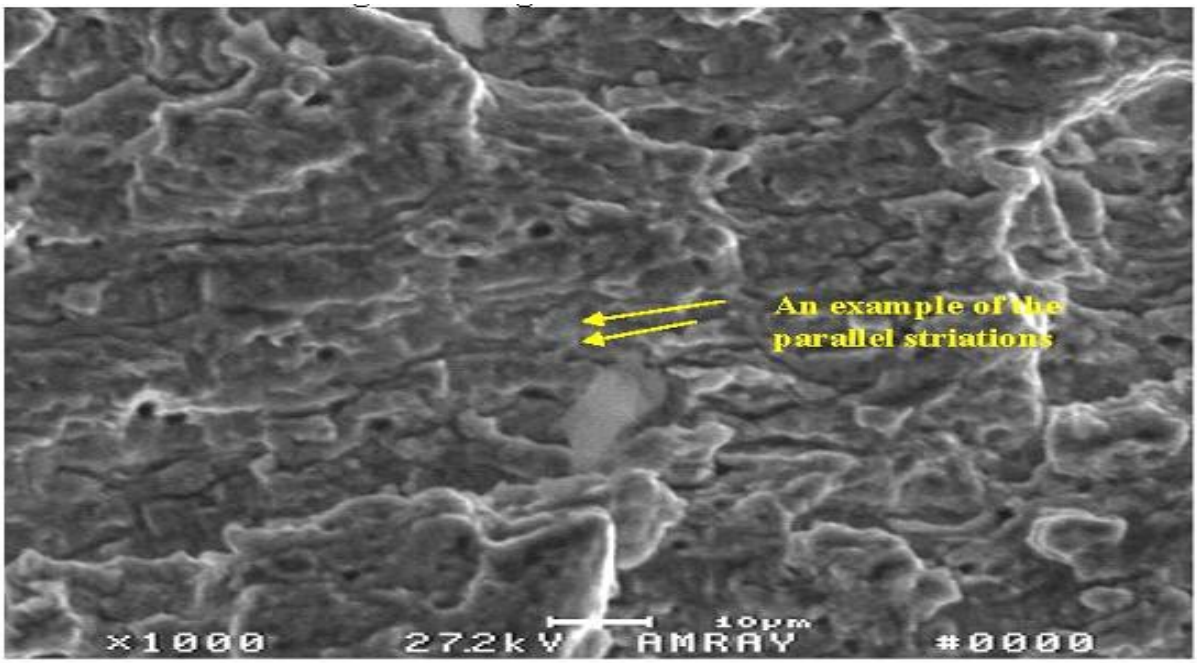

Figure 15 A 1000X SEM photo of an area below the top origin and above the final fracture at the center of the bolt shows parallel striations characteristic of fatigue crack growth. Crack growth direction runs from top to bottom.

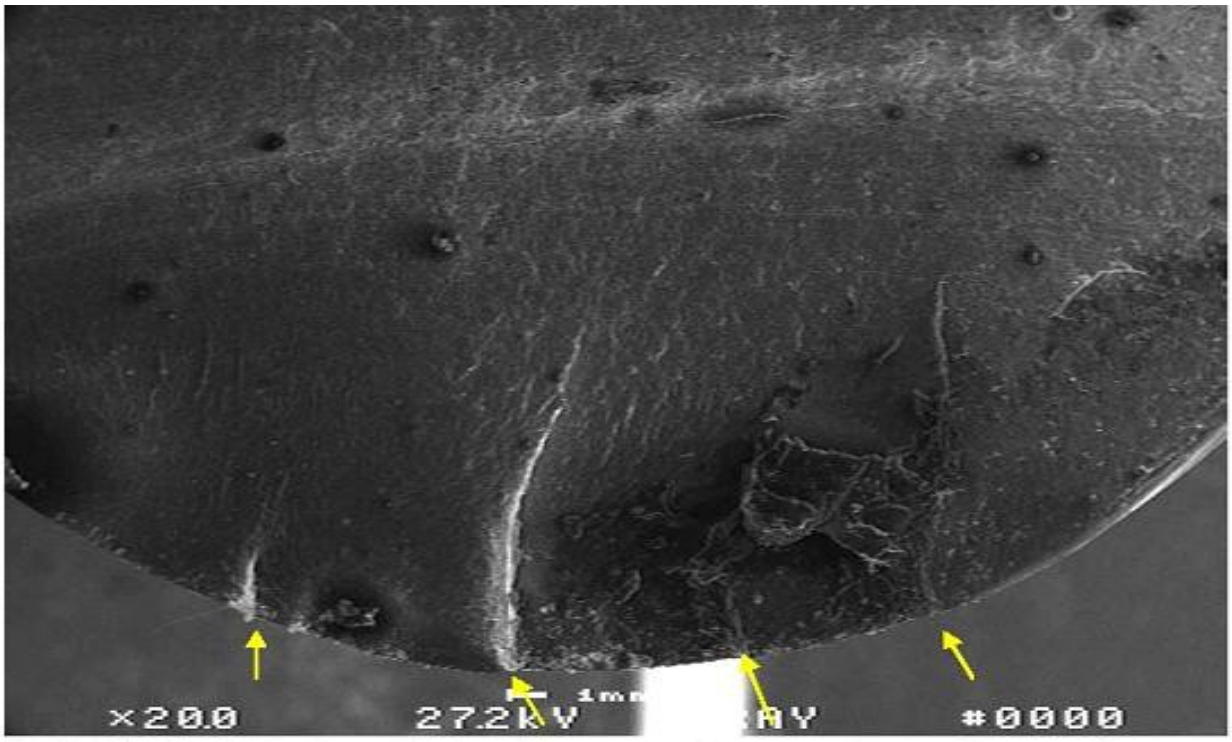

Figure 16 A 20X SEM photo of the bottom edge of the bolt from Figure 5 shows multiple origins (arrows) at the edge

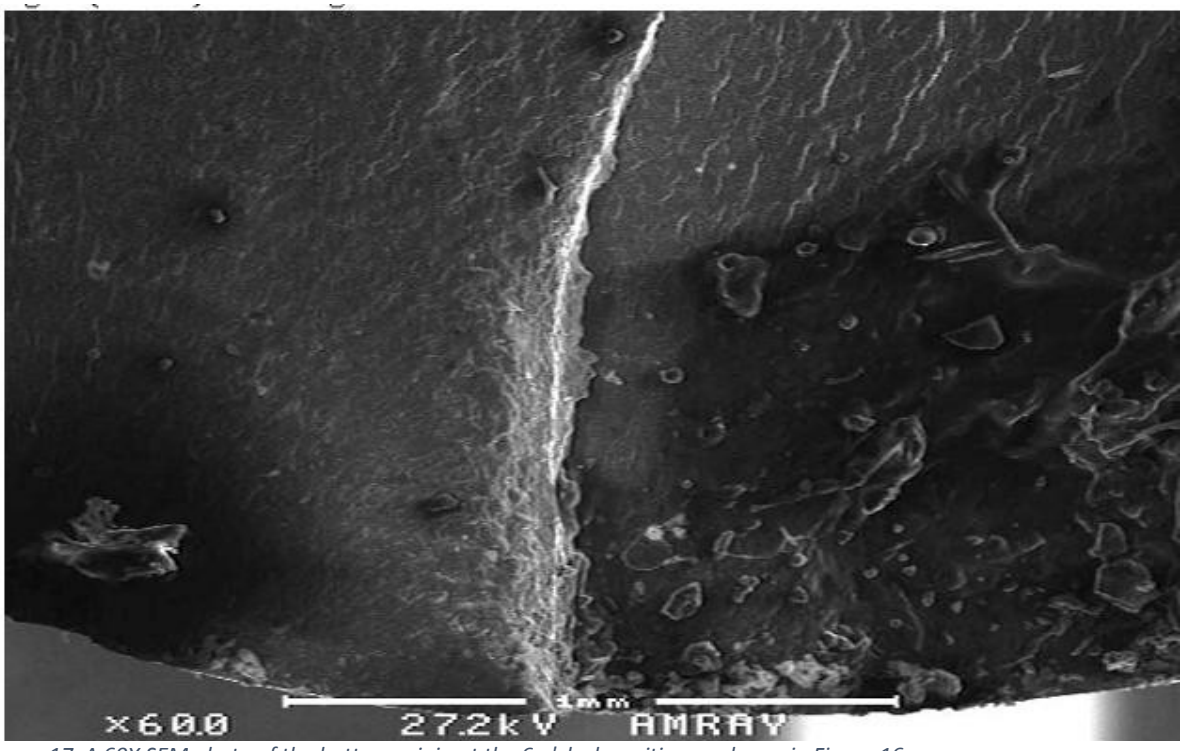

Figure 17 A 60X SEM photo of the bottom origin at the 6 o'clock position as shown in Figure 16.

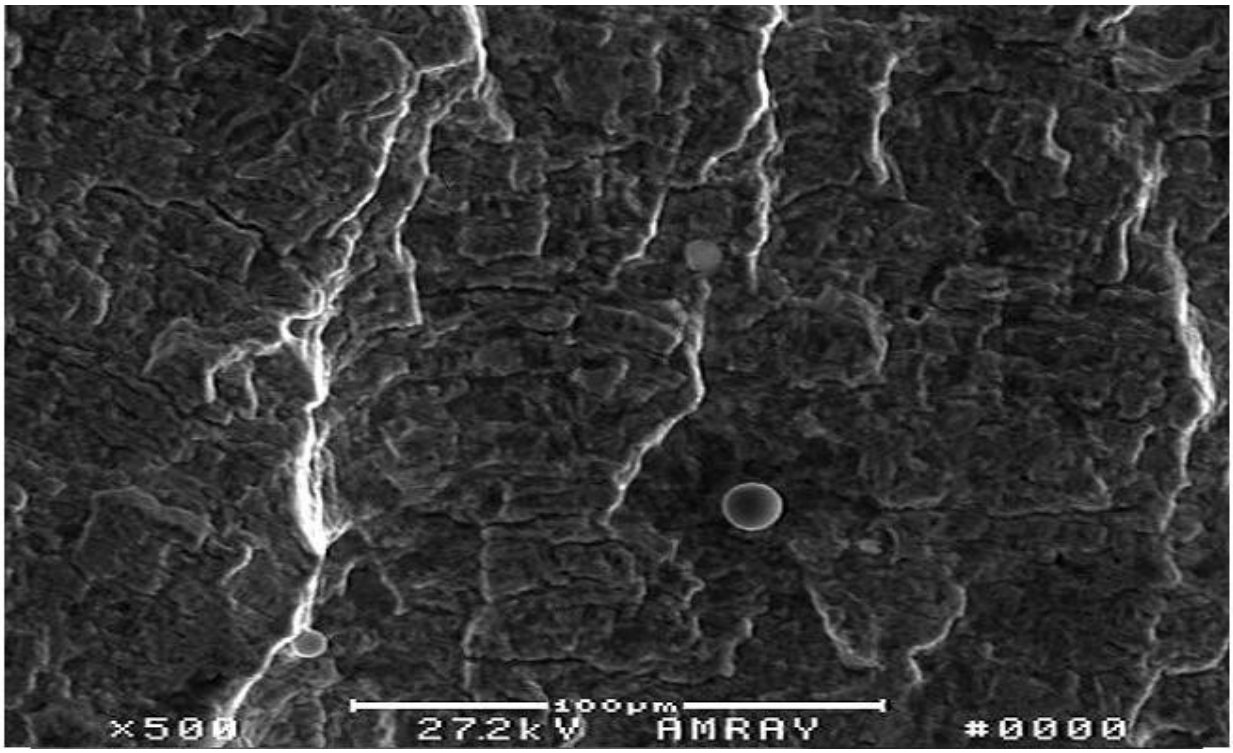

Figure 18 A 500X SEM photo of the area just above the origin shown in Figure 17 reveals fatigue fracture features

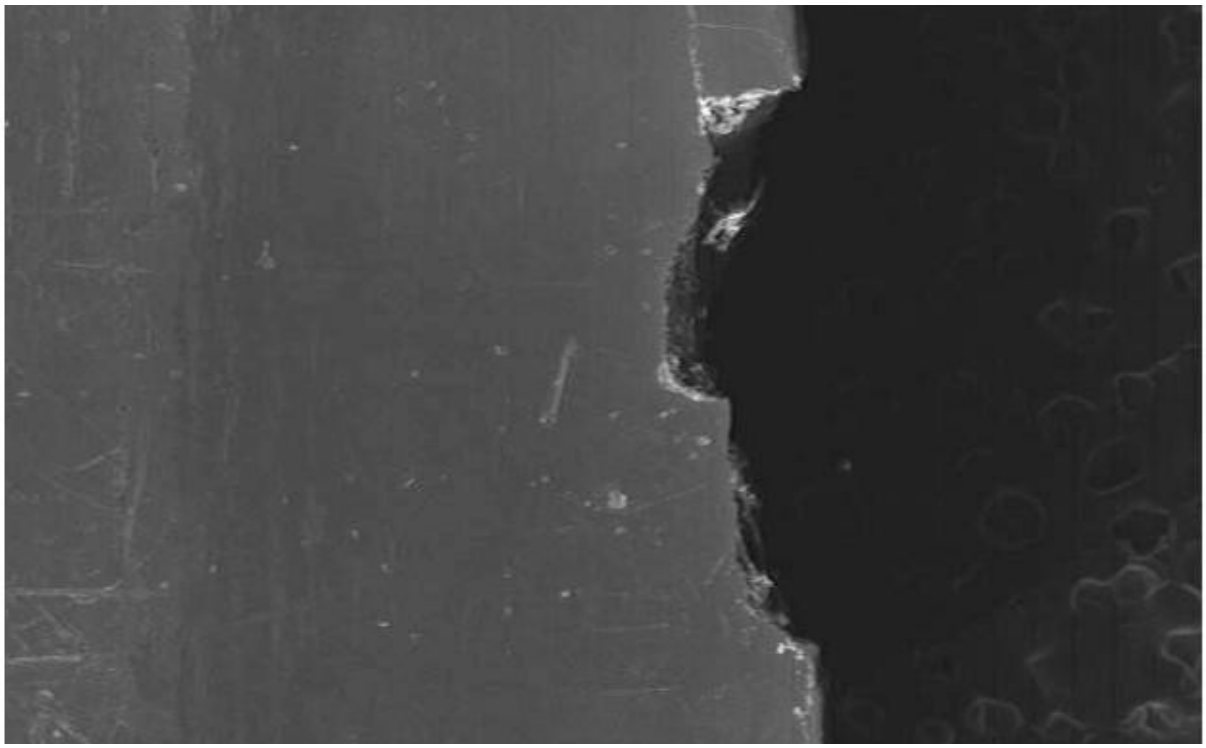

Figure 19 A 30X SEM photo of the side of the bolt at the 6 o'clock area from Figure 5 shows some wear and a crack

Figure 20 A 30X SEM photo of the side at the 6 o'clock fracture origin shows a crack on the surface.

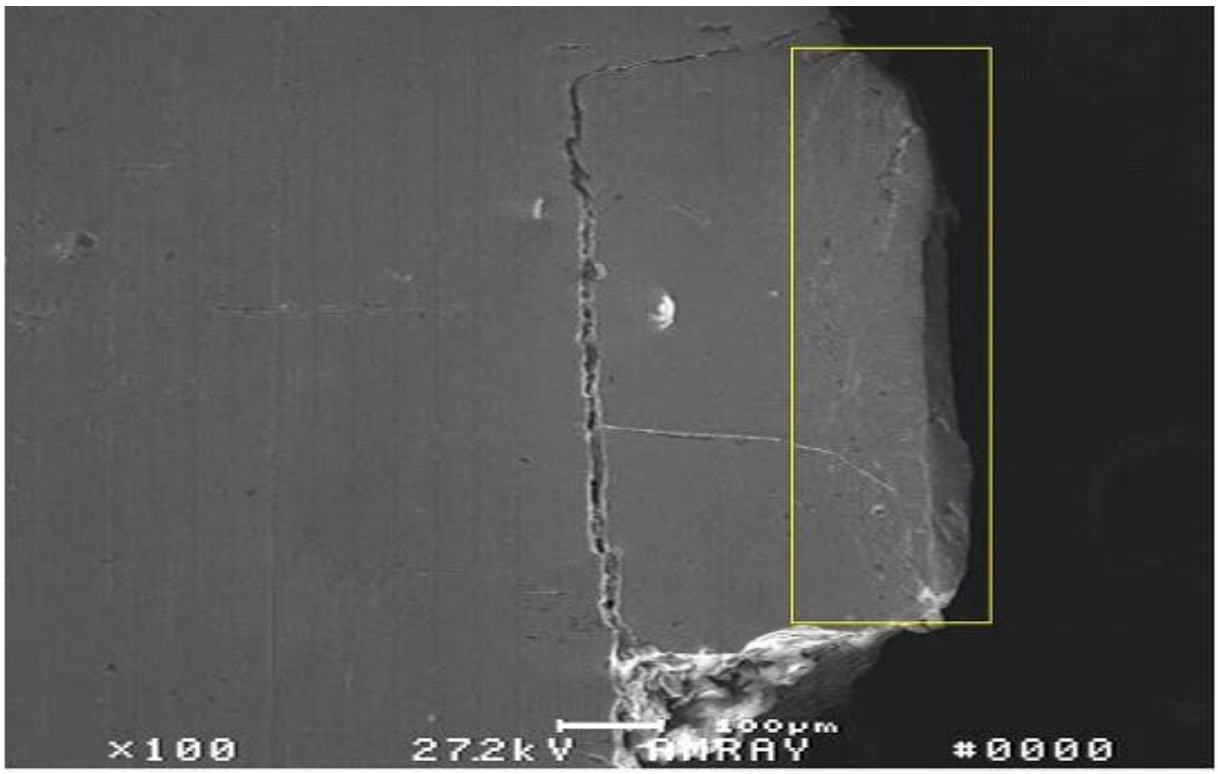

Figure 21 A 100X SEM photo of the cracked area from Figure 20. Notice the wear area outlined by the box

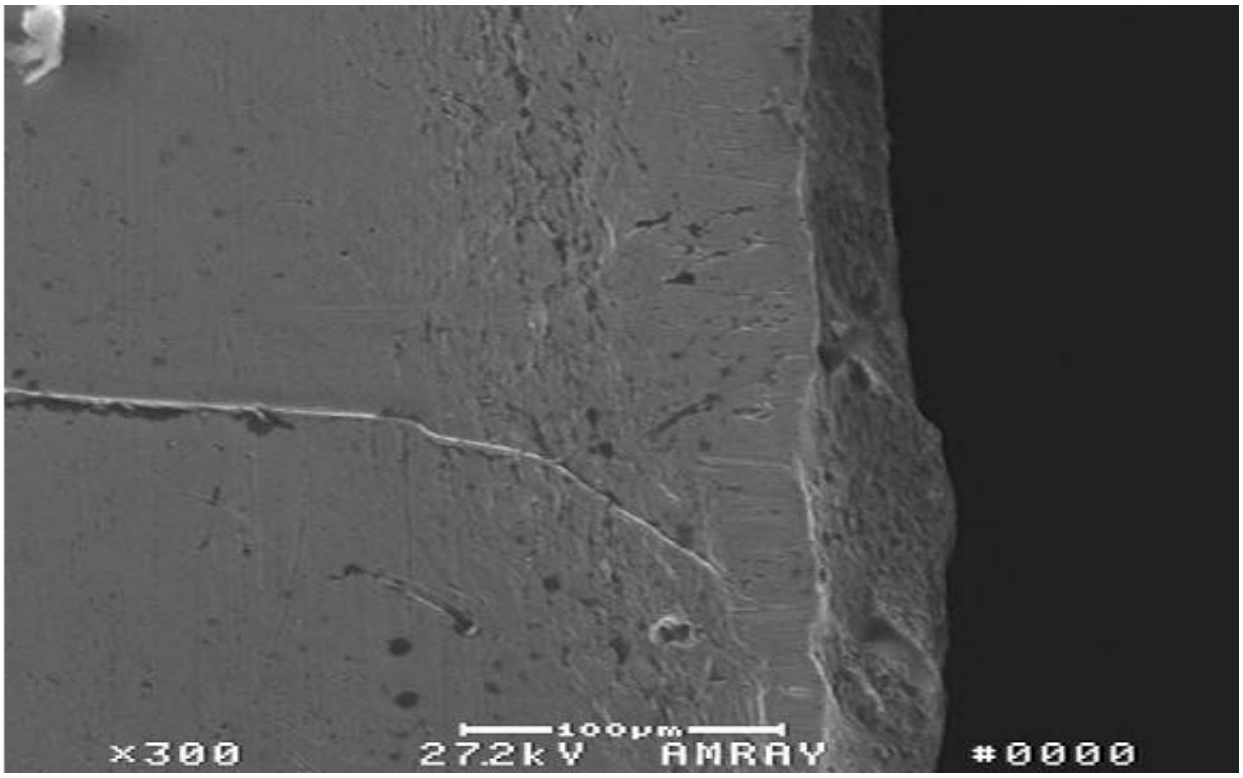

Figure 22 A 300X SEM photo of the outlined area in Figure 21 shows the wear.

Figure 23 The gold color is removed from the bolt very near the fracture zone.

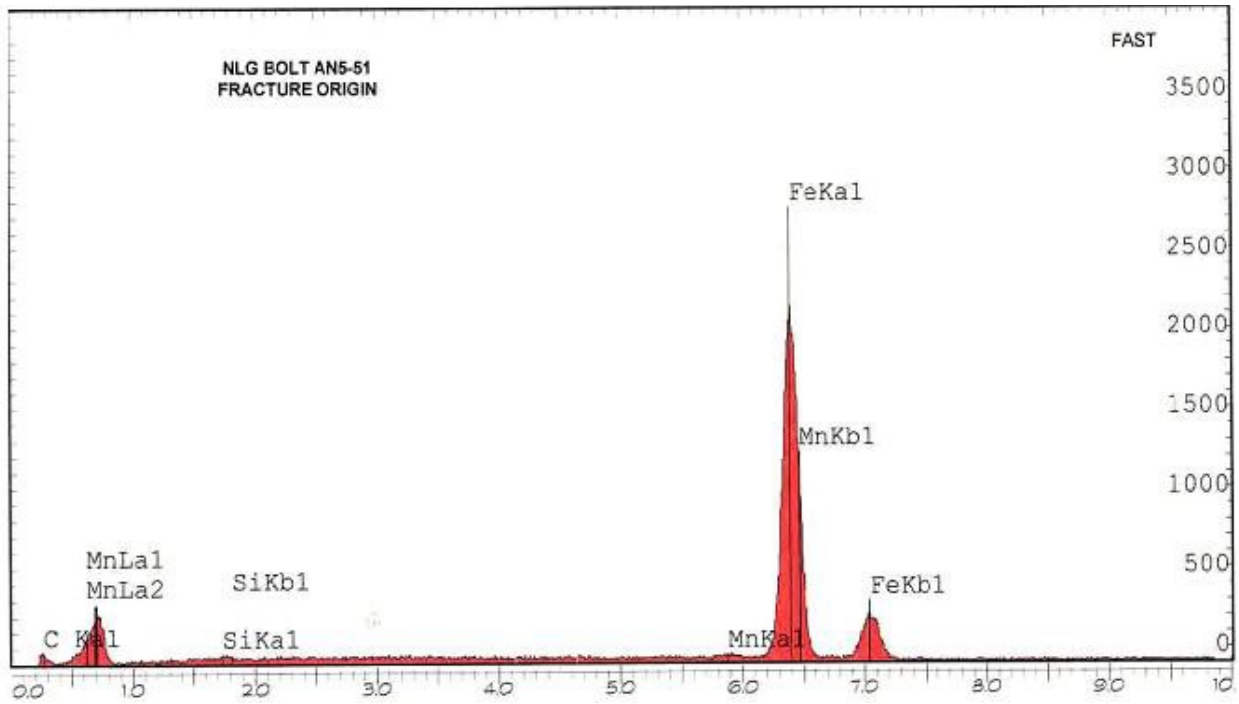

Figure 24 The base metal of the bolt is low alloy carbon steel.

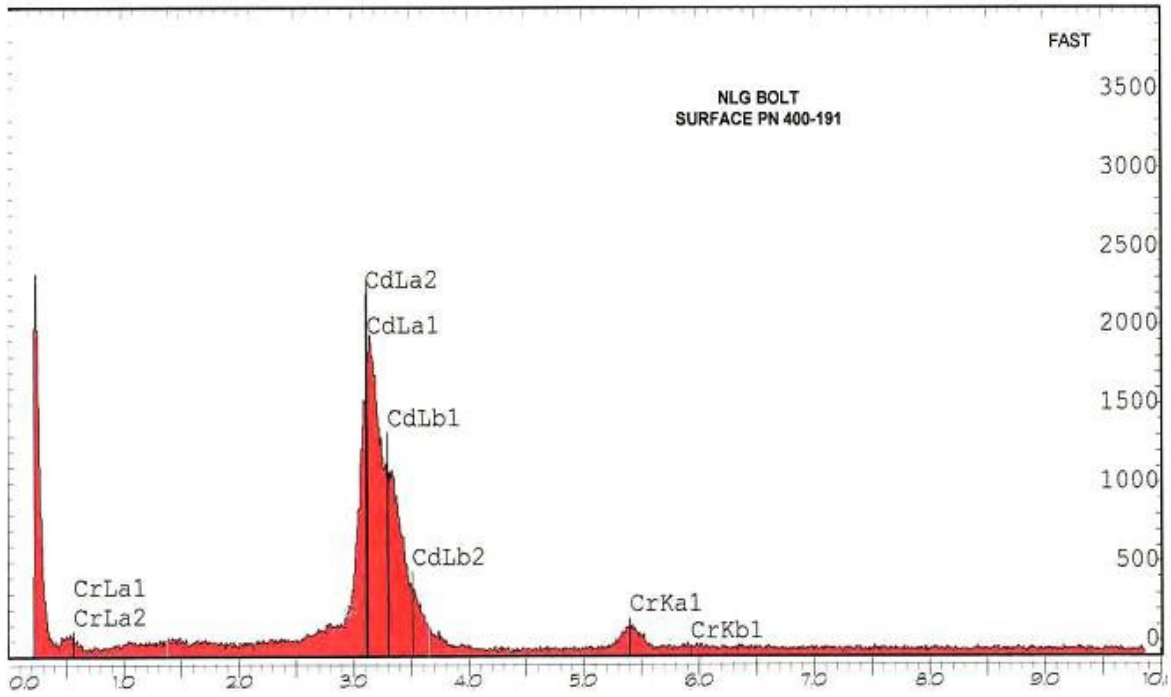

Figure 25 The bolt outer surface is plated with cadmium and a chromate conversion coating.

End Fast Report

Piper PA44-180, Failed Nose Gear Drag Link Bolt, ATA 3222

Part Total Time: 125 Hous