LYCOMING
A Textron Company

Air Safety Investigation

652 Oliver Street
Williamsport, PA 17701

Tel 570-323-6181
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August 16, 2002

RECEIVED
F.A.A.
AUG 19 2002
FLIGHT STANDARDS
DIST. OFFICE 07
JACKSON, MS

FAA Jackson FSDO, SO07
Suite C
100 West Cross Street
Jackson, MS 39208-2307

Attention: Gerald W Dozier

NTSB Report#: MIA02LA108

Registration:	N697MA
Date of Accident:	06/07/02
A/C:	Piper PA32R-301
Location:	Meridian, MS

Enclosed please find Lycoming's Materials Laboratory Technical Report No. 13463 pertaining to the above referenced accident investigation.

Please feel free to contact me if I can be any further help.

Lycoming Engines
A Textron Company

[redacted]

Aaron Spotts
Air Safety Investigator

Enclosure

TECHNICAL REPORT

by

Doug Bailey

Metallurgist

Materials Laboratory

August 6, 2002

Report No. 13463

INVESTIGATION OF BROKEN CRANKSHAFT GEAR BOLT, P/N STD-2209, FROM IO-540-K1G5 ENGINE, S/N L-25968-48A

LYCOMING
A Textron Company

652 Oliver Street
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570/323-6181

SUBJECT: Investigation of Broken Crankshaft Gear Bolt, P/N STD-2209, from IO-540- K1G5 Engine, S/N L-25968-48A

Engine Type:	IO-540-K1G5
S/N:	L-25968-48A
Time:	447.7 hours since new
Build Date:	December 19, 1996

Component:	Crankshaft Gear Bolt
P/N:	STD-2209
Time:	same

The subject crankshaft gear bolt, P/N STD-2209, dowel, P/N STD-1065, lockplate, P/N LW-18638, crankshaft gear, P/N 13S19647, and crankshaft, P/N 13F27727, were forwarded to the Materials Laboratory following a FAA teardown inspection at Lycoming. The as-received components are shown in Figure 1 and 2.

Visual examination revealed the crankshaft gear bolt fractured through the 2nd to 5th threads from the shank, see Figure 3. Two overlapping cracks extending through approximately 270° of the circumference were also observed in the 12th and 13th threads from the shank, see Figure 4. A possible crack was observed in the radius under the head, see Figure 5, and was confirmed by fluorescent magnetic particle inspection. The marking on the head indicated the bolt had been manufactured by Rebco Fasteners, Inc., and had a Grade 8 bolt identification marking. For reference purposes, the fracture in the 2nd to 5th threads will be referred to as crack X, the crack in the 12th and 13th threads as crack Y, and the crack under the head as crack Z.

Fractographic examination revealed that crack X initiated from along an approximate 140° portion of the second thread, see Figure 6. Scanning electron microscope (SEM) examination of the fracture revealed intergranular separation, see Figure 7, along the origin area and throughout area A in Figure 6. Area A propagated perpendicular to the axial direction of the bolt to a maximum depth of approximately 0.06 inch. Area B propagated approximately 45° to the axial direction then perpendicular at the root of the fifth thread and at a slightly adjusted radial direction across the bolt compared to Area A. SEM examination of area B revealed predominantly intergranular separation with very small localized areas of transgranular separation, see Figure 8. A small area of a rather high stress low cycle fatigue, as indicated by the beach marks and rough transgranular topography, was also observed within area B, see Figures 6 and 9. Area C was perpendicular to the axial direction at the root of the fifth thread, angled through the fourth and fifth threads, propagated through the root of the fifth thread, and at a slightly more adjusted radial direction across the bolt compared to Area B. Area C exhibited beach marks, see Figure 10, and a rough transgranular topography, see Figure 11, indicating a rather high stress low cycle fatigue. A narrow shear lip at the back of area C revealed dimple rupture indicating overload. The direction of crack propagation indicates bending loading.

Crack Y corresponds to the first partial and first full thread engaged with the threads in the crankshaft. The crack was mechanically opened and fractographically examined. Examination of the fracture revealed crack initiation throughout 330° of the fracture along the root of the thread, see Figure 12. The remaining 30° is laboratory produced overload. The fracture also revealed intergranular separation throughout the fracture, see Figure 13, with the exception of two small areas of fatigue similar to that seen in crack X.

It was also observed that the relative position of the fatigue on crack X and the laboratory produced overload on crack Y is 180° apart. The laboratory produced overload is then also approximately 30° from the origin area of crack X.

Crack Z was located in the radius under the head. The crack was mechanically opened and fractographically examined. Examination of the as-opened fracture, see Figure 14, revealed a darkened area, the extent of crack propagation, and a lighter central portion, the laboratory produced overload. The darkened area extended along the entire outer circumference of the fracture and varied in depth. Examination in the SEM revealed predominantly intergranular separation, see Figure 15, throughout the darkened area in Figure 14. The depth of intergranular separation varied from only a few grains to approximately 0.1 inch

SEM-EDAX (energy dispersive x-ray analysis) examination revealed the plating was zinc. Zinc plating per AMS 2402 was allowed as an approved variant to the engineering drawing requirement of cadmium under Textron Lycoming SDMR 78347 approved July 19, 1995.

The hardness of the bolt was 36-37 HRC, which conforms to the engineering drawing requirement of 33-39 HRC. The zinc plating thickness was 0.00025 – 0.00030 inch which conforms to the specification requirement of 0.0001-0.0004 inch. The chemistry of the bolt conformed to SAE J429 Grade 8. A metallographic cross-section was made through the shank side fracture surface of crack X. The microstructure of the bolt consisted of tempered martensite, see Figure 16, which is typical for properly heat treated SAE J429 steel. The metallographic cross-section also revealed small cracks in thread roots adjacent to the crack X, see Figure 17.

The dowel broke at the interface between the crankshaft gear and the crankshaft. Fractographic examination revealed a smooth transgranular topography with beach marks and ratchet marks indicating fatigue propagation from multiple origins, see Figures 18 and 19. The more central portion exhibited a slightly rougher transgranular topography and the remaining one third was overload as indicated by the dimple rupture. These results indicate the dowel fractured in rotational bending fatigue as a result of high overloading. The hardness of the dowel was 28 HRC, which conforms to the engineering drawing requirement of 28-32 HRC. The microstructure consisted of tempered martensite which is typical for properly heat treated AMS 6322 steel. It is considered that the dowel most likely fractured secondary to the crankshaft gear bolt.

The lockplate tangs did not exhibit deformation, indicating they had not come unlocked. The mating surface between the crankshaft and crankshaft gear exhibited very minor fretting and wear.

It is concluded that the crankshaft gear bolt is the primary cause of engine failure. Intergranular separation on cracks X, Y, and Z indicate all were caused by hydrogen assisted cracking. Based upon the observations of the fatigue on crack X, the location of laboratory produced overload on crack Y, and the varying depth of intergranular separation on crack Z, it is considered that the source of the induced hydrogen is not likely from insufficient or the absence of post-plate baking. It is considered that if post-plate baking were a possible source the fractures would have exhibit intergranular separation throughout the fracture surfaces or at least more evenly along the entire circumferential outer surface areas.

The other possible source for the induced hydrogen is from the dissolution of the zinc plating during service. A higher loading condition and/or corrosive environment may accelerate the dissolution of zinc and the generation of hydrogen. However, this cannot be determined as sufficient oil samples for testing were not available nor was any evidence of an atypical load condition available.

Prepared by: [redacted]

Doug Bailey
Metallurgist

Approved by: [redacted]

Yoon S. Kim
Manager, Materials Laboratory
Lycoming

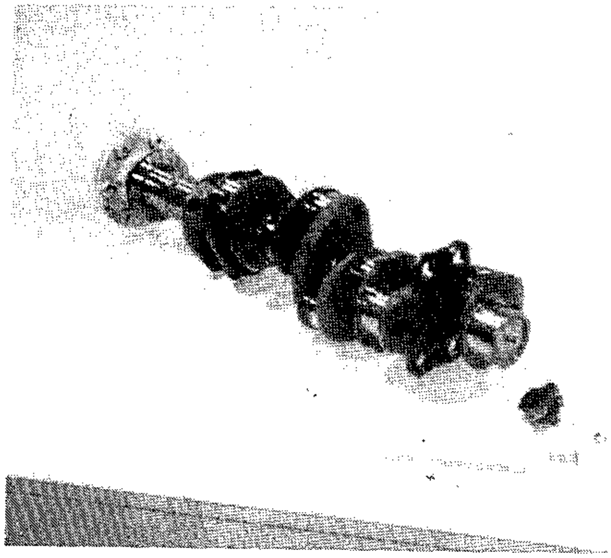

Figure 1 0.12X

The as-received components.

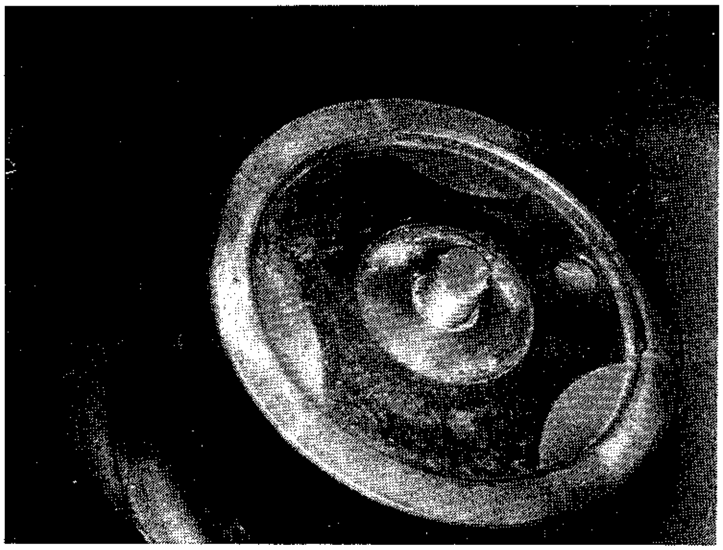

Figure 2 1X

The bolt fractured through the unengaged threaded area of the bolt and the dowel fractured at the gear/crankshaft interface.

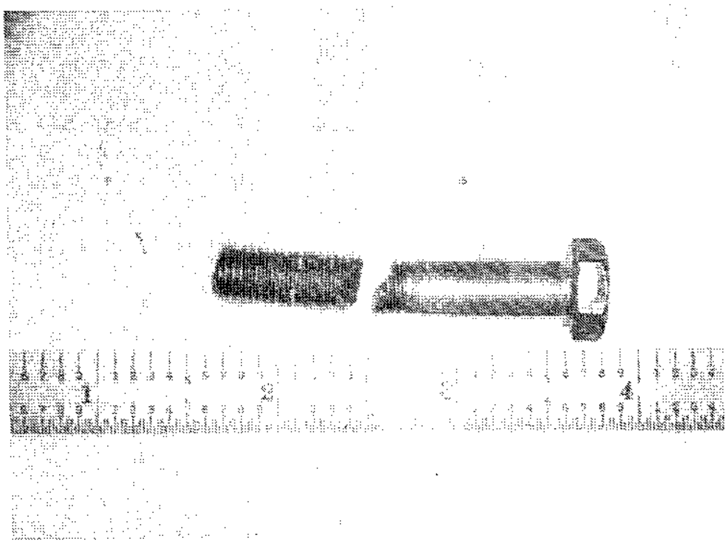

Figure 3 0.95X

The bolt fractured through the 2nd to 5th threads from the shank of the bolt.

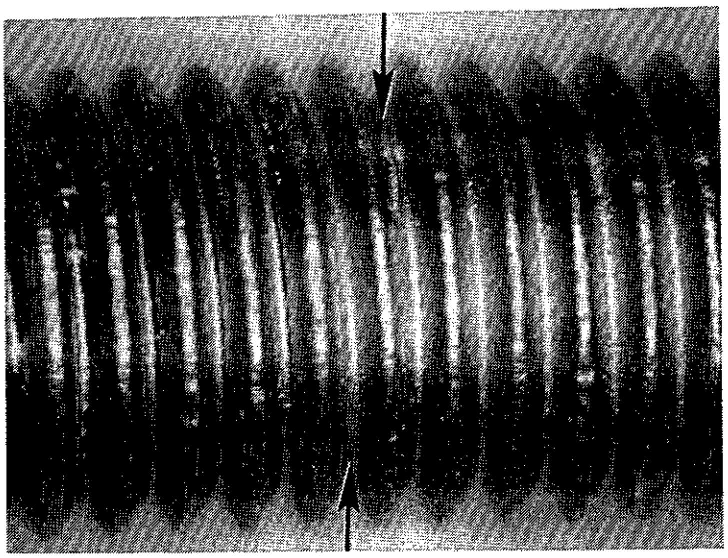

Figure 4 8X

Two overlapping cracks were also observed in the roots of the 12th and 13th treads from the shank, which corresponded to the first partial and full thread engaged in the crankshaft.

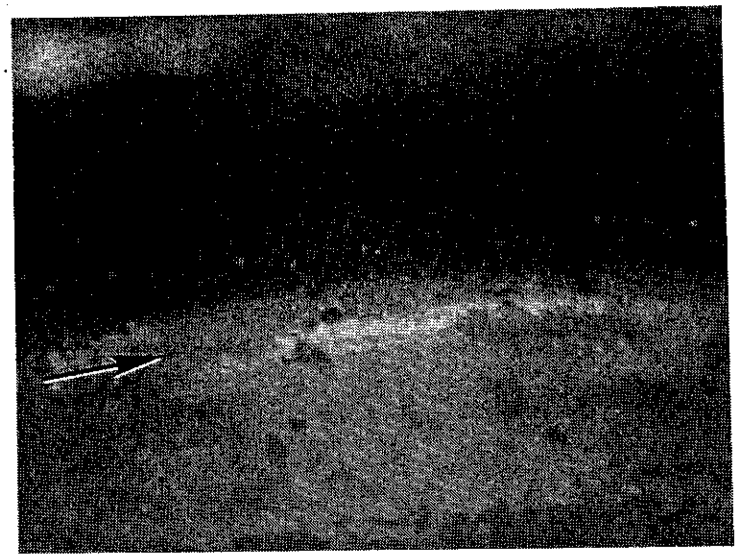

Figure 5 32X

A crack was also observed in the radius under the bolt head.

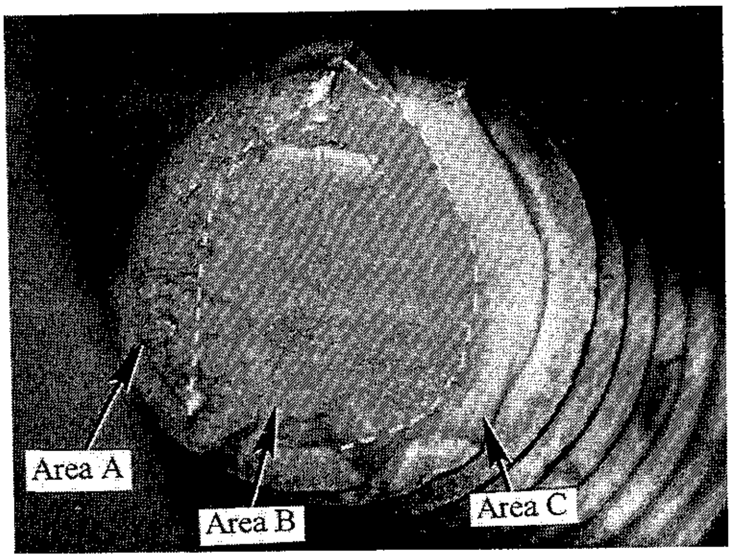

Figure 6 8X

Crack X initiated along the root of the second thread and exhibited three areas of propagation.

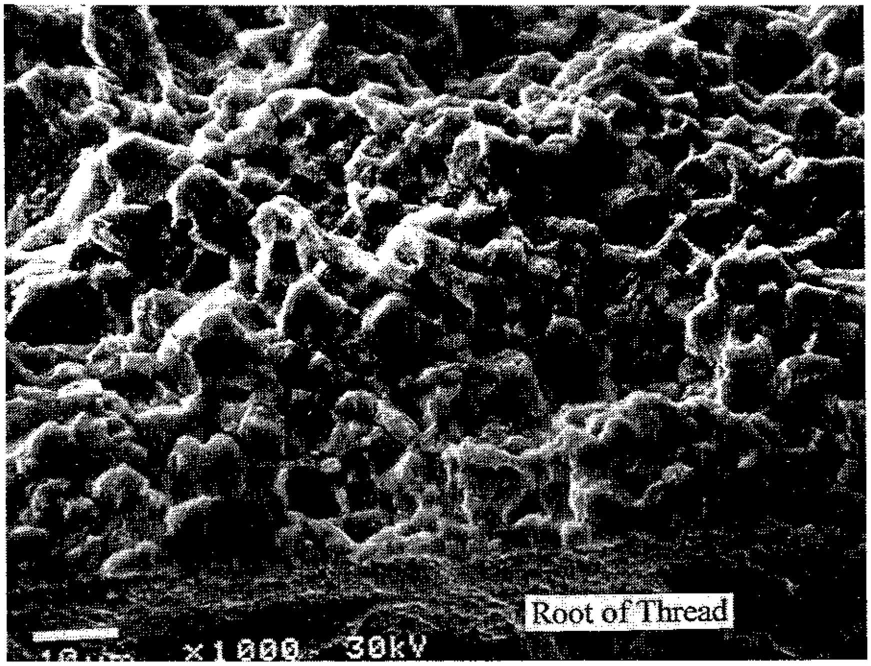

Figure 7 1000X

Area A exhibited intergranular separation.

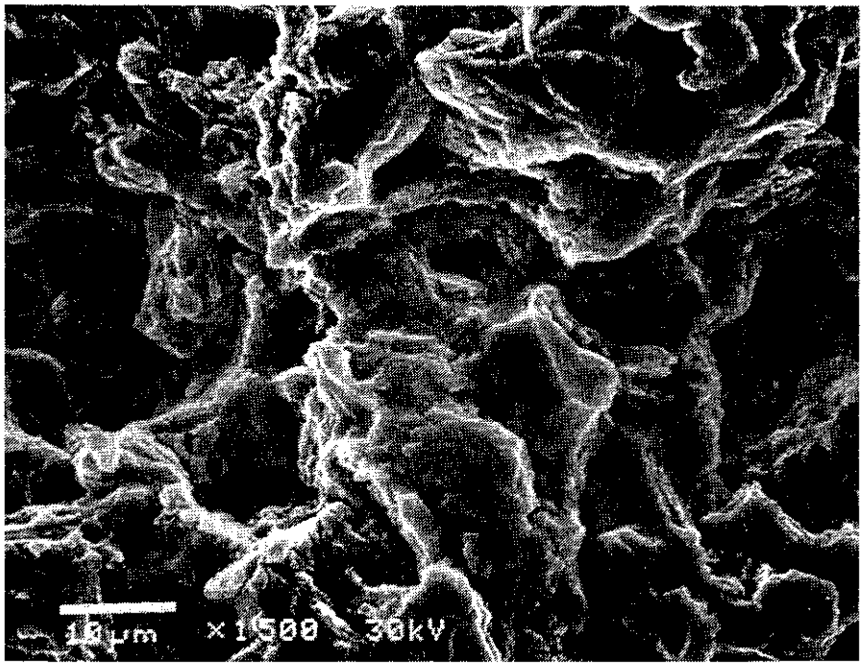

Figure 8 1500X

Area B was predominantly intergranular separation, however, small localized areas of transgranular separation were also observed.

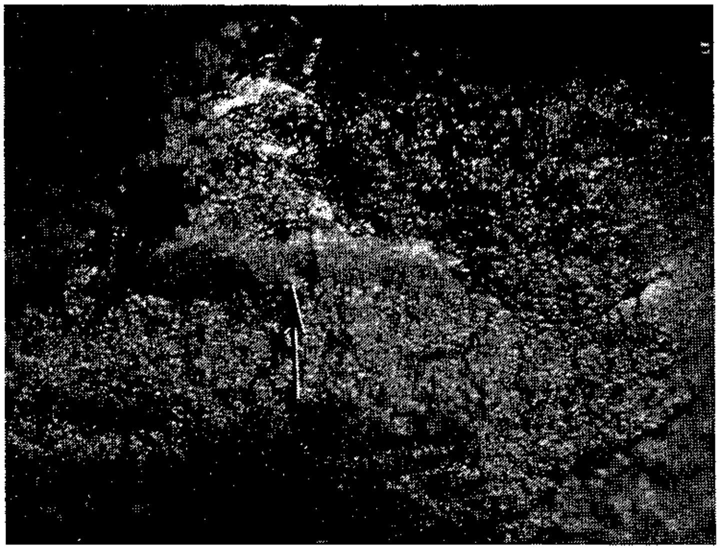

Figure 9 24X

An area of fatigue was also observed within area B as indicated by the transgranular topography and beach marks.

Figure 10 24X

Area C exhibited a transgranular topography and beach marks and a narrow shear lip at the end of propagation.

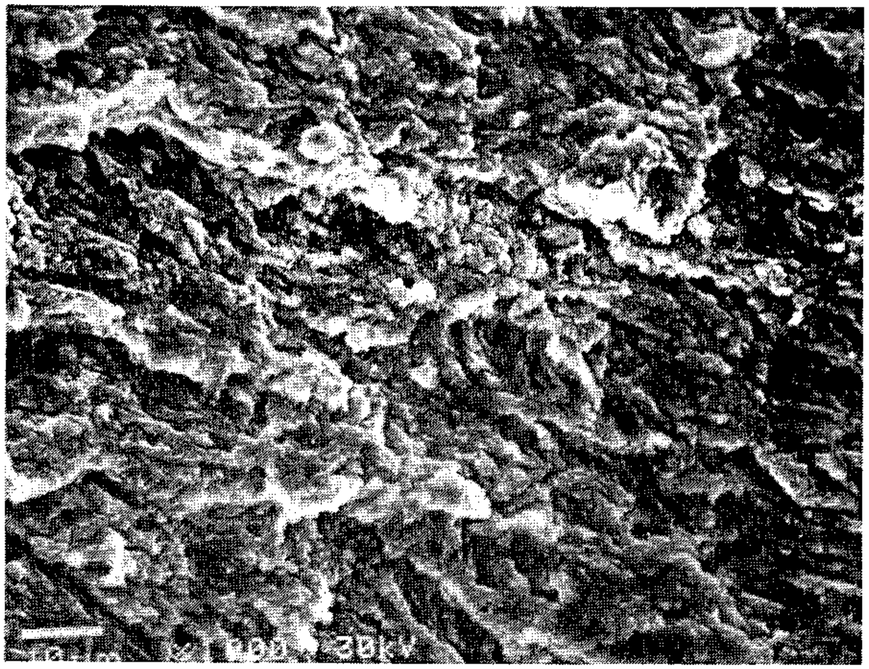

Figure 11 1000X

Area C exhibited a somewhat rough transgranular topography.

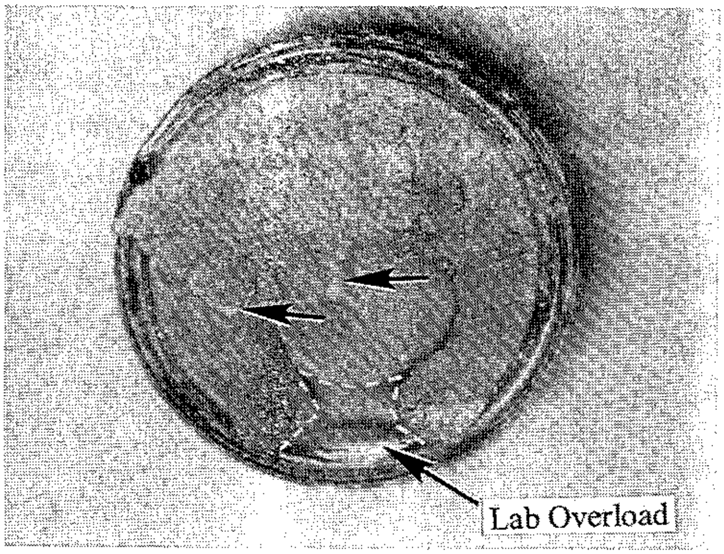

Figure 12 8X

Crack Y exhibited an intergranular topography throughout the fracture with the exception of two small areas of HSLC fatigue, see arrows. The laboratory produced overload is indicated at the bottom of the picture.

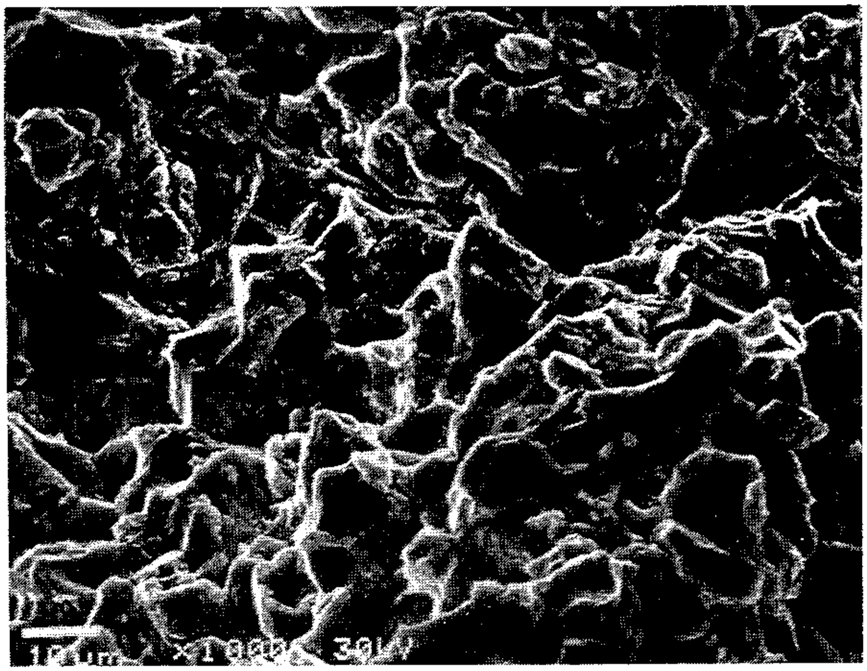

Figure 13 1000X

Crack Y exhibited predominantly intergranular separation throughout the fracture.

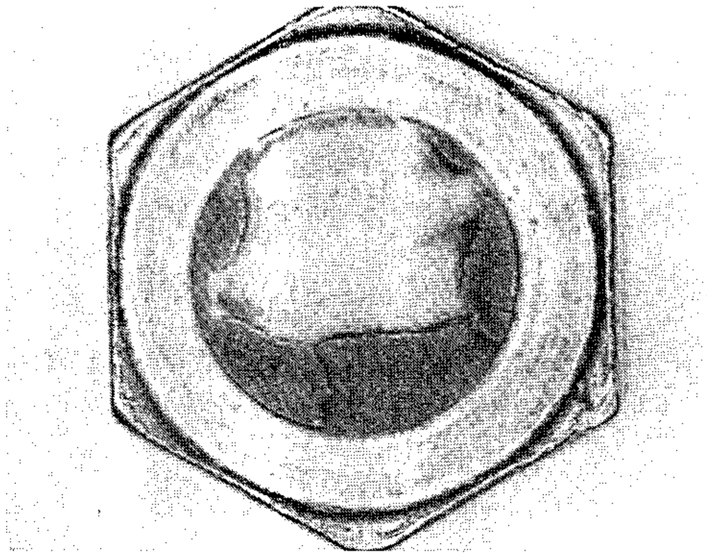

Figure 14 5X

Prior to cleaning, crack Z exhibited a darkened area indicating the crack propagation. The darkened area extended along the entire outer circumference of the crack with varying depth. The lighter central area is the laboratory produced overload.

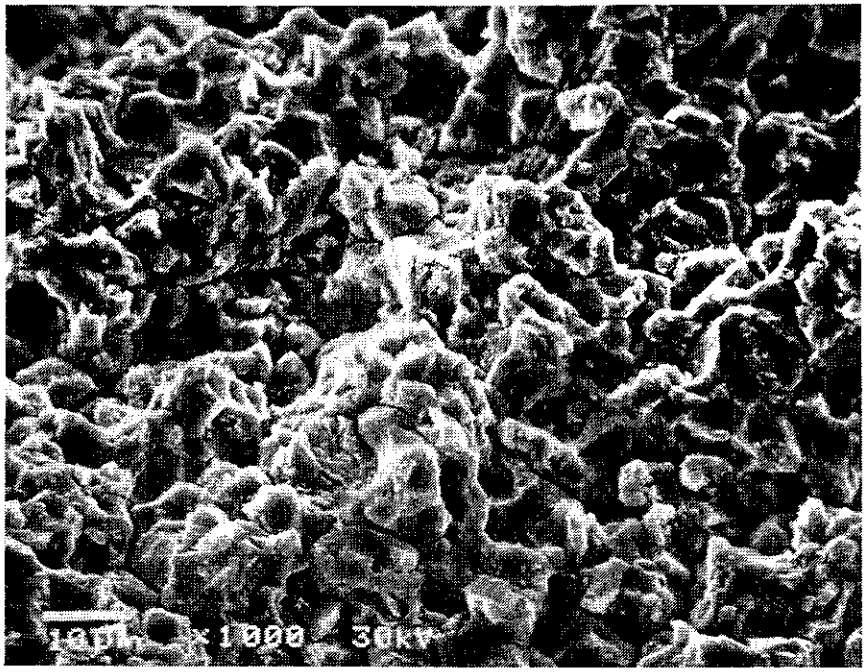

Figure 15 1000X

Crack Z exhibited intergranular separation throughout the propagation area.

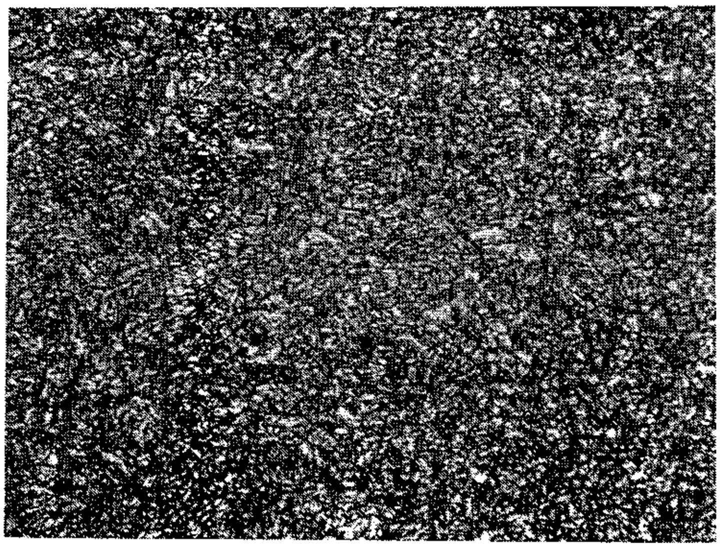

Figure 16 500X

The microstructure of the bolt was tempered martensite which is typical for properly heat treated SAE J423 steel.

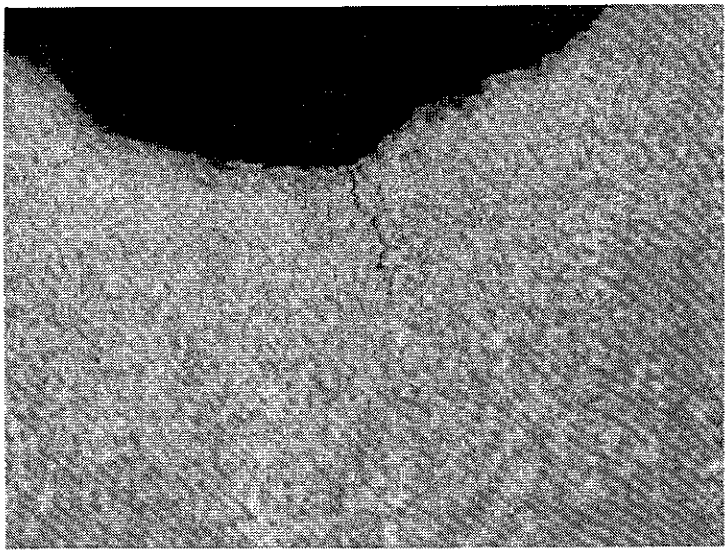

Figure 17 650X

The metallographic cross-section revealed shallow cracks in the thread roots adjacent to crack X.

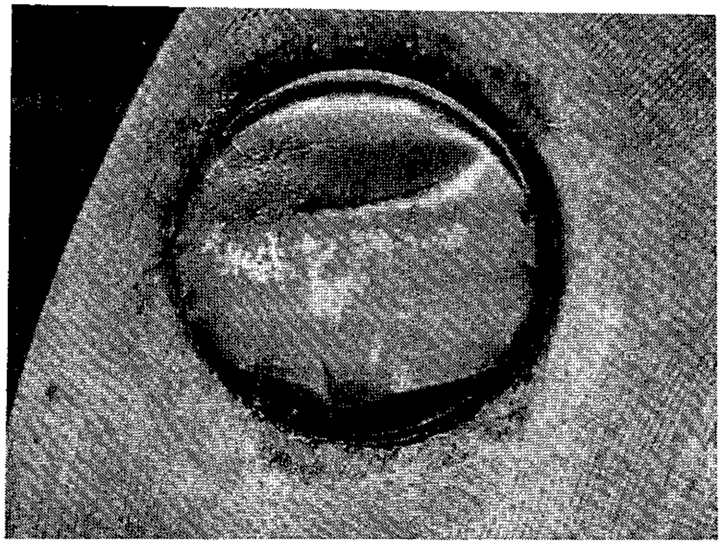

Figure 18 8X

The dowel fracture exhibited beach marks and ratchet marks along the circumference and an off-centered area of overload.

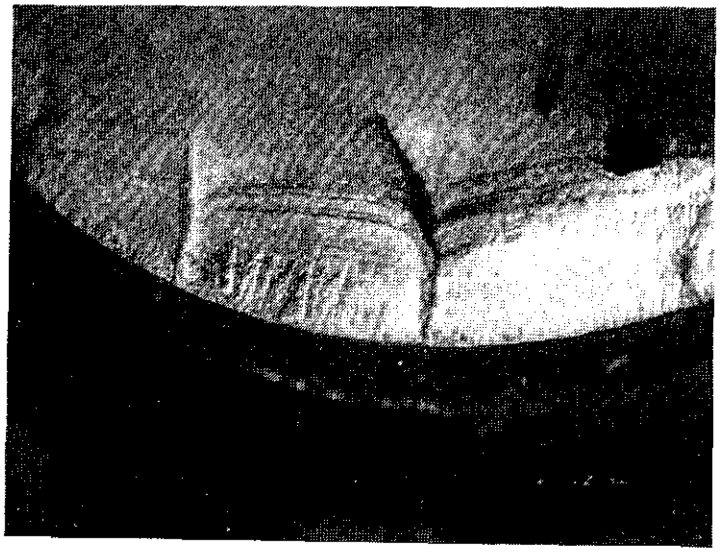

Figure 19 24X

Numerous ratchet marks and beach marks were observed along the circumference of the dowel.