NATIONAL TRANSPORTATION SAFETY BOARD

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

October 12, 2011.

MATERIALS LABORATORY FACTUAL REPORT Report No. 11-100

A. ACCIDENT INFORMATION

Place	:	Denver, Colorado.
Date	:	May 17, 2011.
Vehicle	:	Beech 1900D, N218YV.
NTSB No.	:	CEN11IA341.
Investigator	:	Clint Crookshanks, AS-40.

B. COMPONENT EXAMINED

1. Nose gear locking actuator from N218YV.
2. Nose gear actuator end cap provided for comparison.

C. DOCUMENTS REVIEWED

1. Airight Inc. drawing 25703 revision P. End cap (shuttle housing).
2. APPH CMM (draft) for actuator assembly-nose gear locking, P/N 25700-22.
3. Airight Inc. drawing 25704, revision M. Piston.
4. Airight Inc. drawing 25726. Spacer-nose gear actuator.

D. DETAILS OF THE EXAMINATION

The nose landing gear locking actuator supplied for examination is illustrated in Figure 1 with the major components indicated and identified. The end cap consisted of the two pieces illustrated, each piece displaying a fracture face. For descriptive purposes the forward (FWD) direction is designated. Reportedly, the actuator had operated for 24,948 cycles on a different aircraft before being removed and overhauled. At the time of the accident the actuator had accumulated 29,553 cycles, 4,605 cycles since overhaul. Representatives from the NTSB, the FAA, Hawker Beechcraft (the aircraft manufacturer), and Great Lakes Aviation (the aircraft operator) were present for the examination.

A preliminary examination revealed an identification plate at the location indicated by the black arrow in Figure 1. The identification plate displayed “MFG BY”, APPH WICHITA, INC.”, WICHITA, KANSAS”, APPH P/N 25700-22”, HBC P/N 112-380022-23”, “SER. NO. 583”, and “MFG DATE 8/08”. The examination also revealed that the piston rod was locked in the extended position. A review of the draft component maintenance manual revealed that the actuator has a mechanical locking mechanism in the housing, which also activates the lock engaged switch. The lock can only be released by the application of hydraulic pressure in the retract port, which is located in the trunnion on the other side of the housing illustrated in Figure 1. The end cap houses the primary extend port, the secondary extend port and a shuttle valve which is located between the ports. In the event that primary pressure is lost, hydraulic pressure from an emergency source is applied to the secondary port, moving the shuttle to block the primary port and extending the actuator.

Examination of the fracture faces on the end cap revealed two distinct zones that extended from the inside diameter of the housing to the porting for the shuttle valve. A review of drawing 25705 (document 1 in section C) revealed that the inside diameter is the flat portion of a groove, with 0.08-inch radii at each end, machined into the rear of the housing. The two zones were located almost equally on both sides of the port from the shuttle valve to the inner diameter of the housing. The zones displayed ratchet marks[1] and an arced crack arrest mark, features consistent with fatigue. The rear portion of the housing is illustrated in the right of Figure 2 with yellow arrows indicating the fatigue zones. The front portion of the housing is illustrated in the left of Figure 2 with the extend ports and the shuttle valve components identified. The purple arrow indicates the intact locking wire which extended across the housing, appropriately locking shuttle fitting to shuttle fitting.

The rear portion of the housing is illustrated in Figure 3 with yellow arrows indicating the fatigue zones similarly indicated in Figure 2 and blue arrows indicating some of the smaller fatigue zones that had initiated around the inside diameter of the end cap. The rear face of the end cap consisted of the smooth surface indicated by the black arrow, and the machined surface indicated by the white arrow. The red arrows indicate the ends of a circumferential mark impressed into the smooth surface on the rear face of the end cap and measurement of the arc on an OGP Smartscope[2] revealed a diameter of 2.00-inch. The green arrow indicates a similar, shorter circumferential mark in the smooth surface which was measured at 2.02-inch diameter.

A closer view of the fatigue zones illustrated by the yellow arrows in Figure 3 is illustrated in Figure 4. The red arrows indicate ratchet marks initiating on the inner diameter of the end cap and the yellow arrows indicate the unified crack fronts of the fatigue zones. The blue arrows indicate arced crack arrest marks located between ratchet marks, where the individual fatigue zones had not propagated into a unified crack front. The green arrow indicates an arced crack arrest mark where the fatigue zone had almost unified with the crack arrest mark indicated by the yellow arrow.

Examination of the annular rear face of the end cap revealed that it consisted of a smooth surface adjacent to the inner diameter and a surface of exposed bare metal

[1] Slight vertical steps in the fracture that link slightly offset planes of fatigue cracking at a fatigue origin area. Ratchet marks generally are aligned in the direction of cracking and taper off as distance from the origin is increased and a unified crack front is produced.
[2] A noncontact video based digital measuring microscope.

displaying circumferential marks consistent with a machining operation. A review of drawing 25703 revealed that the end cap was originally anodized after machining but revision C, dated April 7, 1979, changed the surface treatment to IRIDITE®[3], which imparts a yellow color to the surface. The examination also revealed dark intermittent lines with a lateral orientation in the smooth area, suggestive of a grain orientation. The area within the yellow box in Figure 4 is illustrated in Figure 5 with the lateral orientation in the smooth area indicated by the red arrows. The green arrows indicate the circumferential impression indicated by the green arrow in Figure 3 and the white arrow indicates the machined surface. Drawing 25703 specifies a 32[4] finish for the machining operations in the end cap. The smooth area extended into the radius where the fracture initiated and was found to satisfy the 32 finish on a standard surface comparator plate.

The radius adjacent to the fracture face is illustrated in Figure 6 with red arrows indicating some of the ratchet marks similarly identified in Figure 4 and yellow arrows indicating the fatigue zones also as in Figure 4. The blue arrows indicate the radius and the black arrows indicate the flat portion of the groove. The black dashed line indicates the transition between the flat portion and the radius which coincided with the edge of the fatigue zone.

As the piston was locked in the extended position the piston face was examined using a boroscope. The boroscope revealed that the spacer identified in the illustrated parts break down in the component maintenance manual (document 2 in section C) was installed on the piston, as required. The spacer was deemed a possible source of the circumferential impressions on the rear face of the end cap but was inaccessible for measuring. APPH supplied drawing 25704 (document 3 in section C) and drawing 25726 (document 4 in section C) which verified that the spaced did fit in the piston and indicated that the outside diameter of the spacer would be in the vicinity of 1.75-inches and the inside diameter would be in the vicinity of 1.32-inches.

To verify the lateral grain orientation suggested by the dark intermittent lines illustrated in Figure 5, metallurgical samples were removed from the rear portion of the end cap by cutting along the red dashed lines in Figure 7. The samples identified as "H" for the horizontal axis, "V" for the vertical axis, and "L" for the longitudinal axis, were metallurgically mounted in order to display the orientation indicated by their identification, polished and etched with Keller's reagent[5]. The etchant revealed grain orientation in the horizontal sample and laterally in the vertical sample, confirming the orientation illustrated in Figure 5 and indicated by the red arrows in Figure 7. A review of drawing 25703 revealed that revision N, dated February 19, 2010 added the grain orientation which was required to be in the longitudinal axis of the end cap.

[3] A brand of protective chromate conversion coating from MacDermid Inc of Denver, CO. commonly used on aluminum parts in the aircraft industry.
[4] The center line average of the surface roughness measured in microinches (millionths of an inch).
[5] A solution of distilled water, hydrochloric acid, nitric acid and hydrofluoric acid.

To confirm that the machined surface indicated by the white arrow in Figure 3 had been machined, the end cap was cut at the yellow dashed lines in Figure 7 and the removed sample metallurgically mounted in order to examine it in the direction indicated by the yellow arrows. The mounted sample was polished and etched with Keller's reagent and the area between the yellow arrows in Figure 7 is illustrated in Figure 8. The green arrow indicates the machined surface indicated by the green arrow in Figure 7, the yellow arrow indicates the as-cast surface, and the blue arrow indicates the smaller fatigue zone indicated by the blue arrow in Figure 7. A closer view of the radiused area within the yellow box is illustrated in the left image in Figure 9 with a green arrow indicating the machined surface and a red arrow indicating a bur of material typically displaced by a cutting tool. A closer view of the area within the red box in Figure 8 is illustrated in the right image in Figure 9 with a yellow arrow indicating the as-cast surface, a green arrow indicating the machined surface and a red arrow indicating raised material at the intersection of the two surfaces, consistent with use of a cutting tool. Measurements revealed that the raised material was 0.0025-inch above the machined surface and the machined surface was 0.0007-inch below the as-cast surface, as illustrated.

The remaining rear portion of the end cap was installed in an SEM[6] for an examination of the fatigue zones illustrated in Figure 4. The examination revealed multiple areas containing fatigue striations[7]. The fatigue striations illustrated in the SEM micrograph in Figure 10 were observed at the location indicated by the white arrow in Figure 4 while scanning along the black line. The white line in Figure 10 represents 20 µm[8] when drawn to the micrograph scale and contained 40 individual striations, a striation spacing of 0.5 µm. The fatigue striations illustrated in the SEM micrograph in Figure 11 were observed at the location indicated by the black arrow in Figure 4 while scanning along the black line. The black line in Figure 11 represents 5 µm when drawn to the micrograph scale and contained 28 individual striations, a striation spacing of 0.18 µm. The striation spacing of 0.5 µm and 0.18 µm were added together and divided by two to produce an average spacing of 0.34 µm. The distance along the black line in Figure 4 was measured at 0.223-inch which converts to 5,575 µm. By dividing the line length of 5,575 µm by the average striation spacing of 0.34 µm the number of striations along the black line was calculated at 16,397. It should be noted that the count was performed at the maximum propagated length available and is considered an approximate and a minimum. An accurate count could not be performed due to the fatigue zone propagating into the shuttle holes.

Comparison end cap examination.

The Hawker Beechcraft representative provided a second end cap for comparison with the accident end cap but there was no cycle or overhaul information

[6] Scanning Electron Microscope.

[7] An individual crack arrest feature that is left on a fracture face as a result of the application of one cycle of stress (crack open and closure).

[8] A micrometer (µm) is one thousandth of a millimeter (or 0.00004-inch).

made available. The second end cap had fractured at a similar location and the fracture faces are illustrated in Figure 12 with black arrows indicating where the end cap had been cut to separate the two portions. The red arrows indicate ratchet marks initiating on the inner diameter and the red dashed lines indicate the terminus of the fatigue zone. It was noted that the fatigue zone had propagated further than the fatigue zone on the accident end cap especially into the uniformly thick wall portion of the end cap. The yellow arrows indicate locations where the fatigue had propagated through the uniform wall portion. The blue arrows indicate shear lips initiating where the fatigue zone terminated.

Examination of the rear face of the end cap revealed a machining mark and circumferential marks. The area within the red box in Figure 12 is illustrated in Figure 13 for comparison with Figure 5. A portion of a standard comparator plate with turned, ground and milled surfaces of a 63 finish (coarser than the 32 finish required by drawing 25703) is also illustrated in the figure. The yellow arrows indicate the surface finish on the end cap and the similar turned surface on the comparator plate. The green and black arrows indicate circumferential marks and the blue arrow indicates a circumferential band where a machining process had removed the coating to expose the underlying aluminum. Close examination of the surface revealed what appeared to be undulations on the coated surface displaying a vertical orientation. The orientation is indicated by the red arrows placed adjacent to some undulations.

A closer view of the surface within the yellow box in Figure 12 is illustrated in Figure 14 with the circumferential band indicated by the blue arrow in Figure 13 similarly indicated. The circumferential marks indicated by the green and black arrows in Figure 13 are also similarly identified and were found to measure 1.96-inch diameter and 1.58-inch diameter respectively. The red arrows indicate the orientation of the adjacent dark intermittent lines that appeared to be similar to the grain orientation illustrated in Figure 5 but obscured by the distinct circumferential machining marks.

The groove radius contained within the yellow box in Figure 12 is illustrated in Figure 15 with a white arrow indicating the ratchet mark indicated by the white arrow in Figure 14. The radius exhibited a finish similar to that illustrated in Figure 14 and some of the more distinct machining marks are indicated by the red arrows. Examination revealed that although the edge of the fatigue fracture did not follow any particular machining mark, it was contained in the radius. The black arrow indicates the rear surface illustrated in Figure 14 and the blue arrow indicates the transition point from the rear surface to the radius.

To verify the vertical grain orientation suggested by the dark intermittent lines illustrated in Figure 14, metallurgical samples were removed from the rear portion of the end cap by cutting along the red dashed lines in Figure 16. The samples identified as “H” for the horizontal axis, “V” for the vertical axis, and “L” for the longitudinal axis, were metallurgically mounted in order to display the orientation indicated by their identification, polished and etched with Keller’s reagent. The etchant revealed grain orientation in the vertical sample and vertically in the longitudinal sample, confirming the orientation illustrated in Figures 13 and 14 and indicated by the red arrows in Figure 15.

On the raised center portion at the rear of the housing the green arrow indicates a cut made by the tip of the abrasive blade used to separate the two portions of the end cap. The blue arrow indicates an area of mechanical damage with a hard dark brown deposit on most of its surface. The black arrows indicate areas of mechanical damage where the surface had been smeared in the direction indicated by the black arrows to produce the lip at the tip of the arrows. The orange arrow indicates a mechanically smeared surface. A review of drawings 25707, 25704 and 25726 revealed that the center portion would not be contacted by the piston even if the spacer was in contact with the rear face of the housing around the raised portion.

Derek Nash
Mechanical Engineer

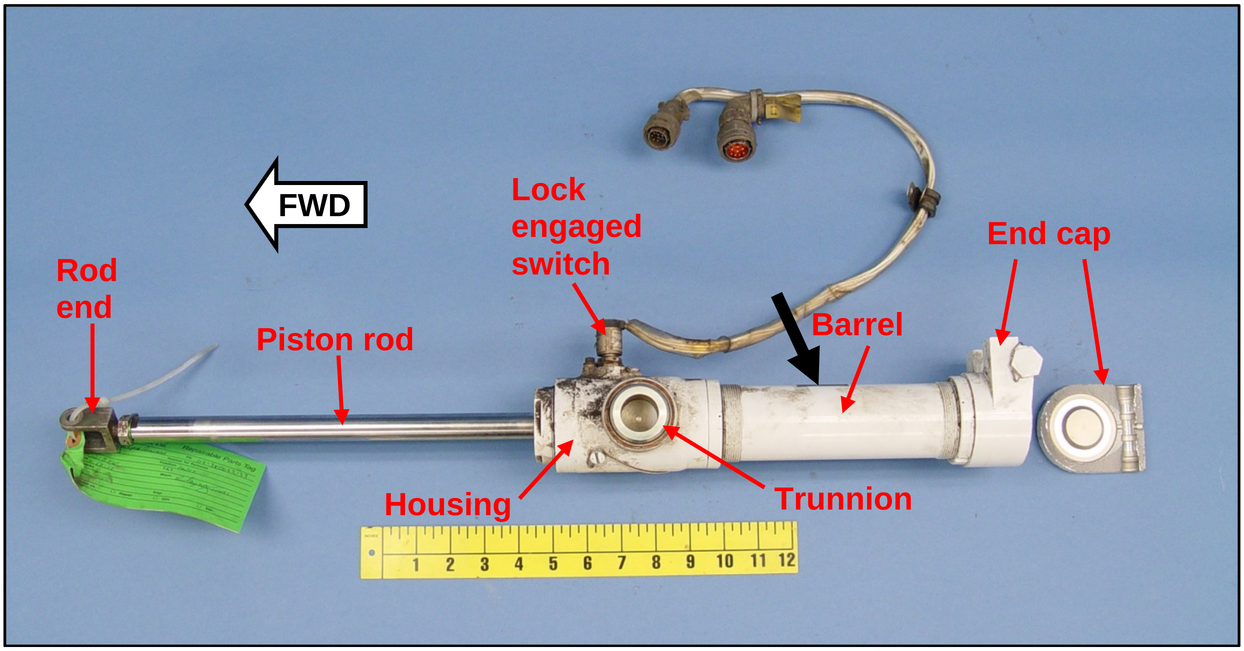

Figure 1. The nose landing gear actuator received for examination.

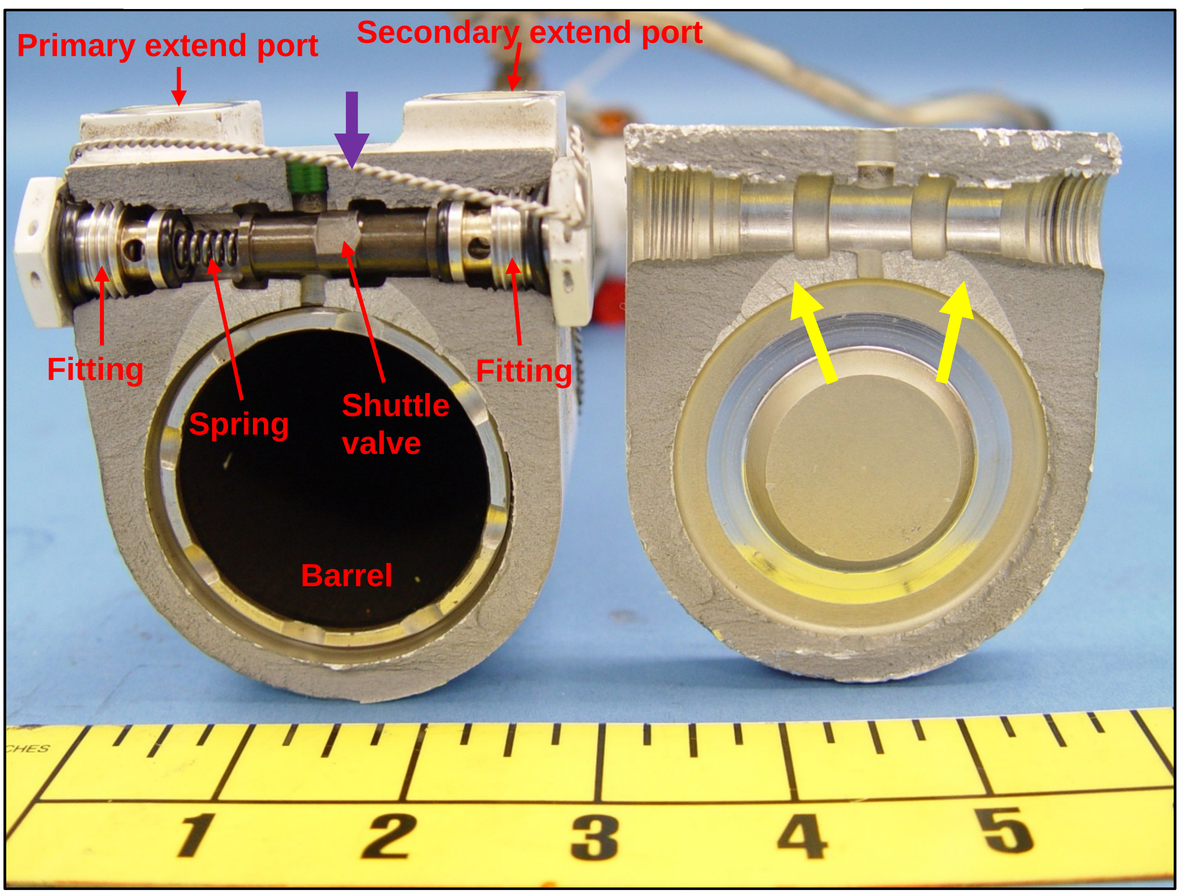

Figure 2. The fracture faces on the forward portion of the end cap (left) and the rear portion (right).

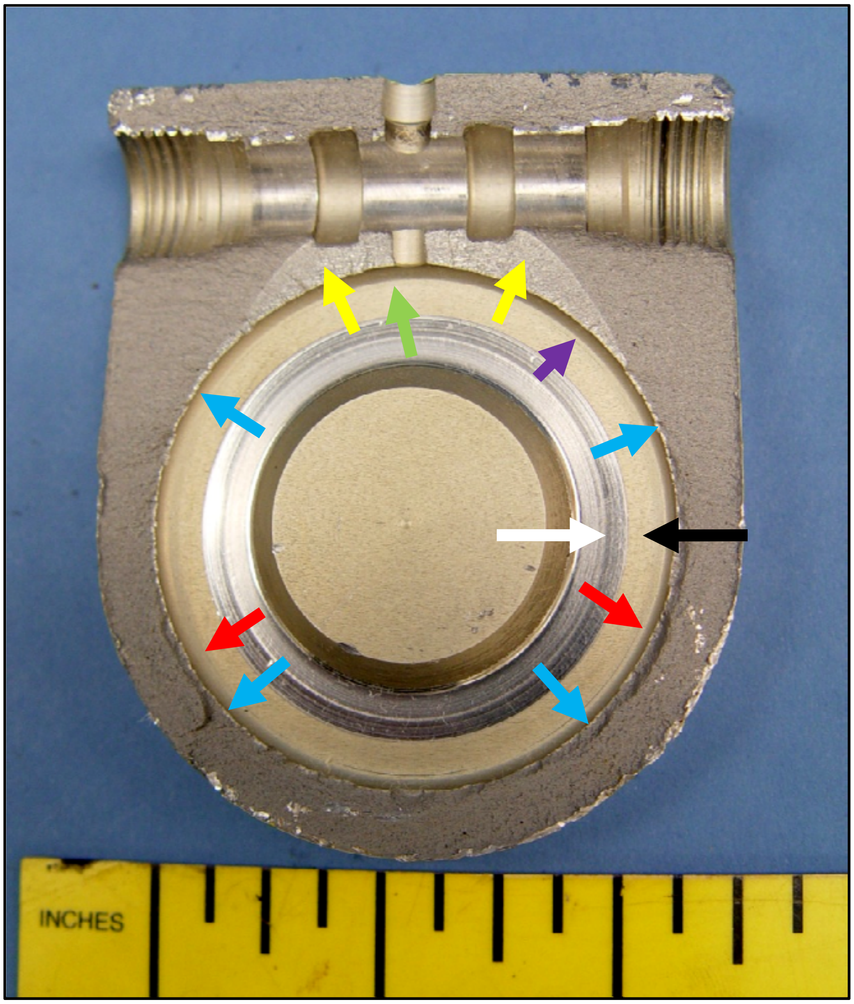

Figure 3. The fracture face on the rear portion of the end cap.

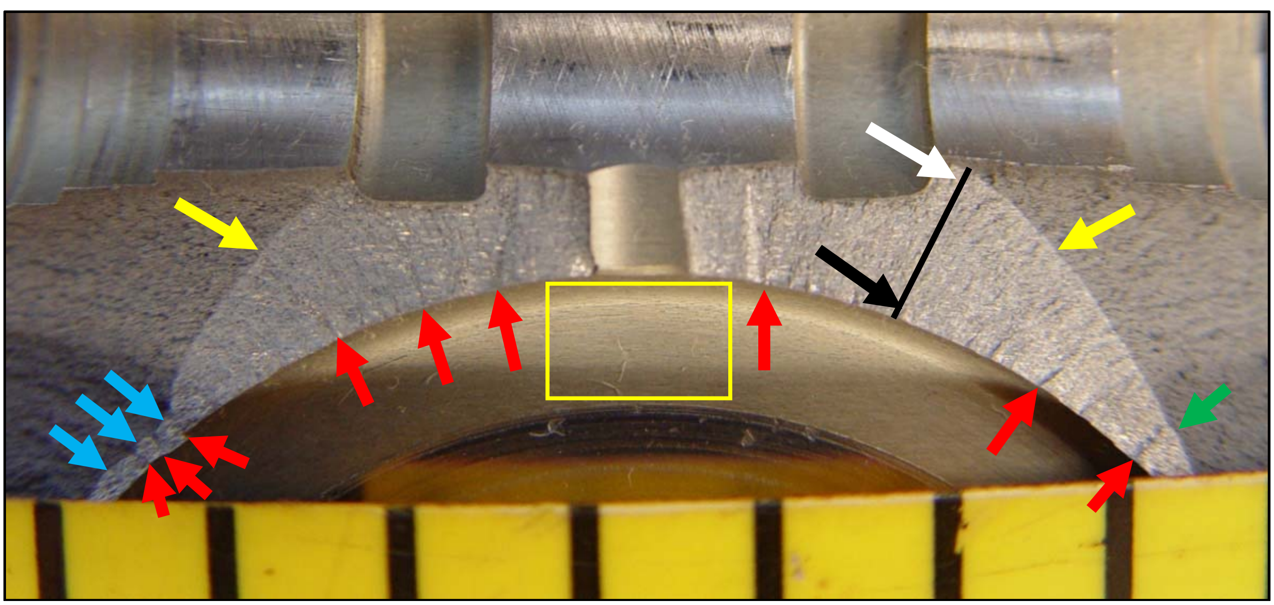

Figure 4. The fatigue zones indicated by the yellow arrows in Figure 3.

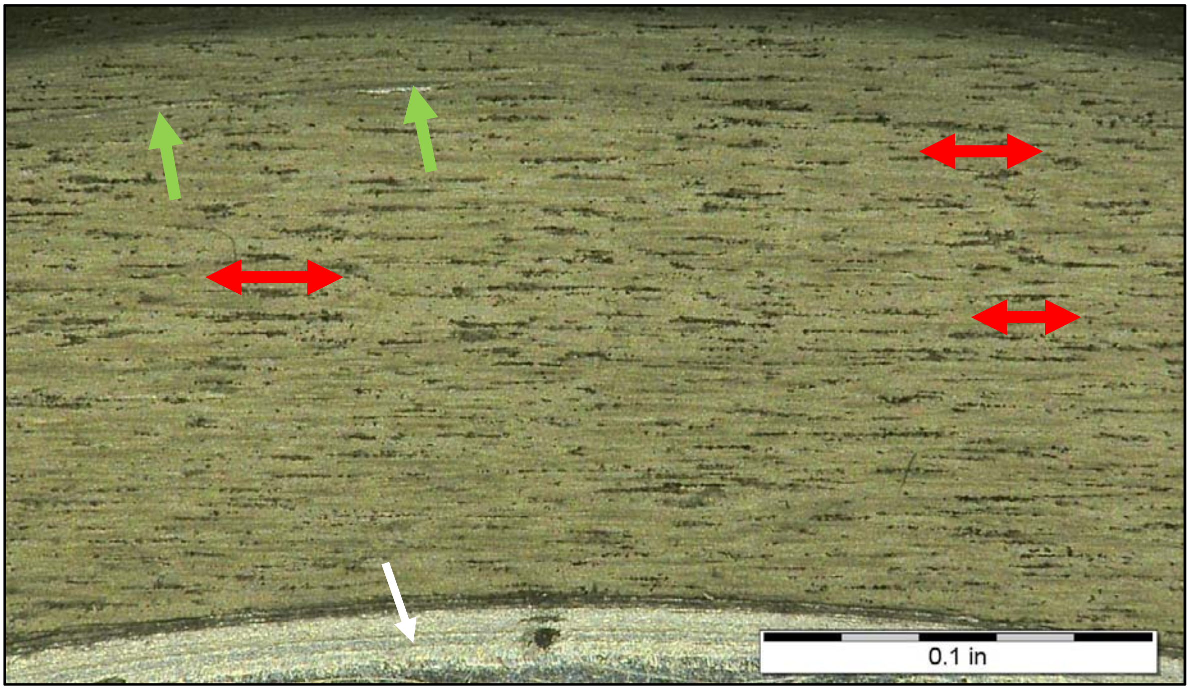

Figure 5. The inner edge of the fatigue zone illustrated in Figure 4.

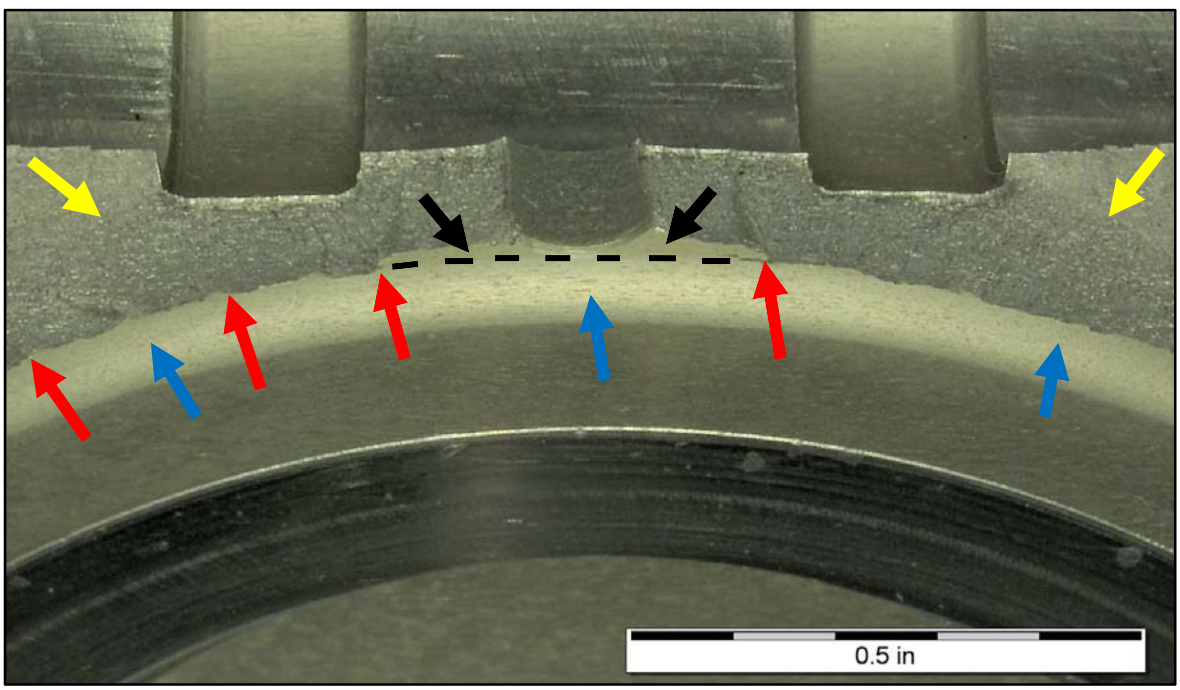

Figure 6. The surface contained within the yellow box in Figure 4.

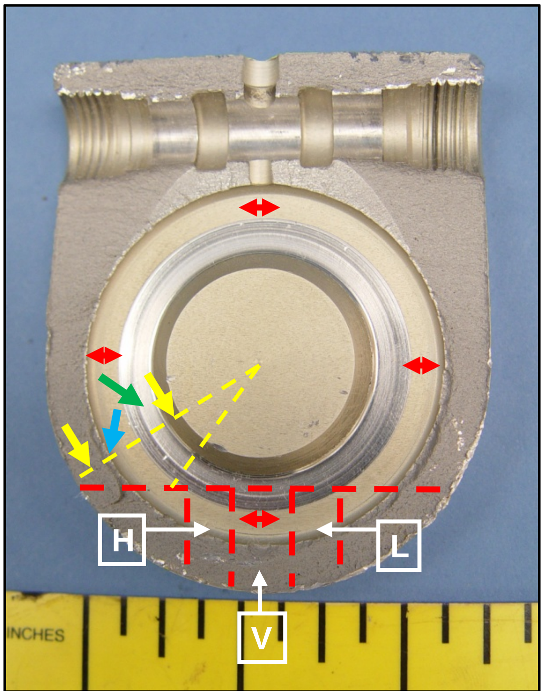

Figure 7. Samples removed from the fractured rear portion of the end cap.

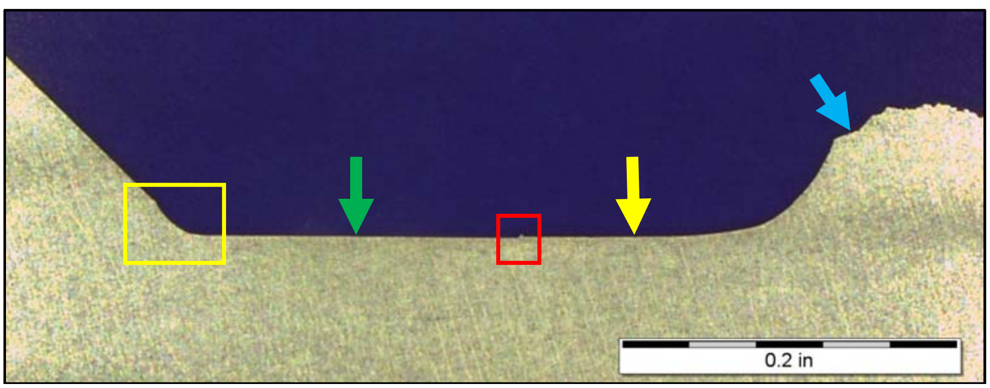

Figure 8. A sectional view between, and in the direction indicated by the yellow arrows in Figure 7.

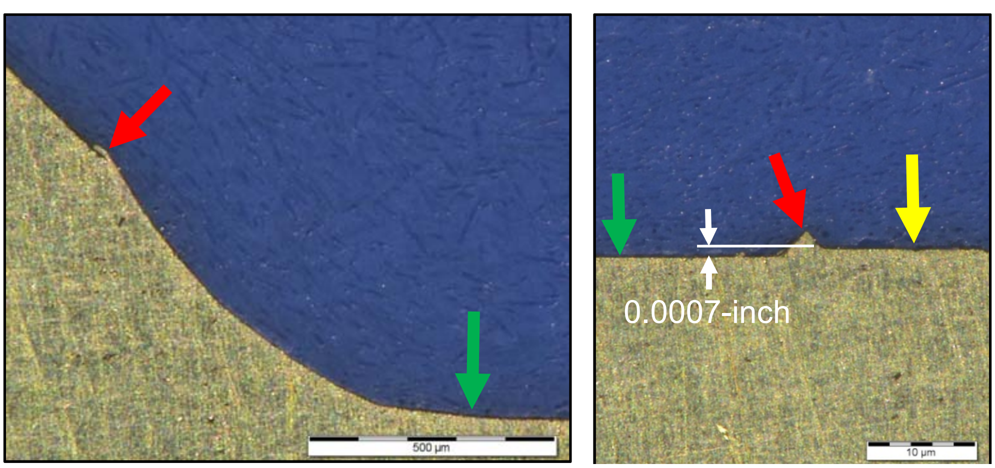

Figure 9. The area within the yellow box in Figure 8 (left) and the area within the red box (right).

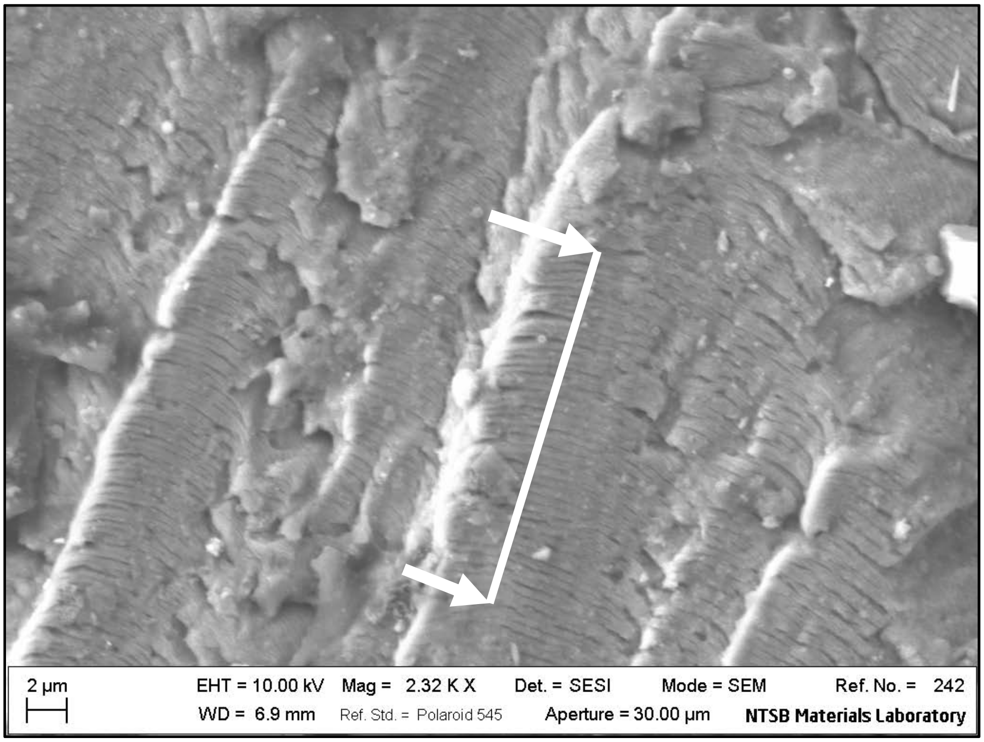

Figure 10. SEM micrograph of fatigue striations at the location indicated by the white arrow in Figure 4.

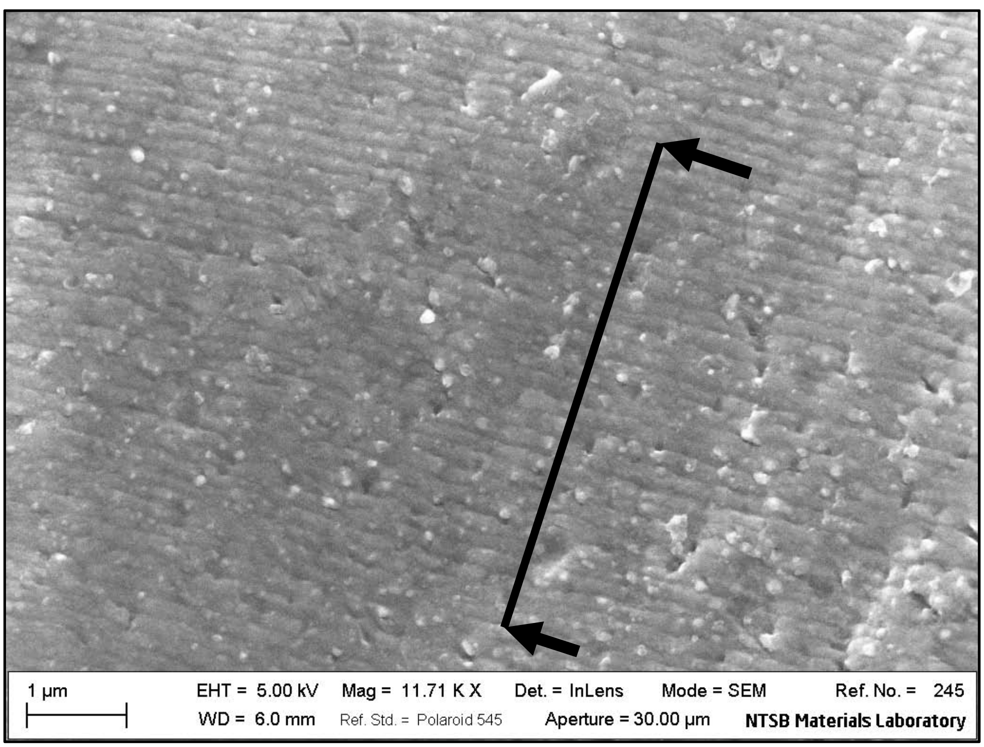

Figure 11. SEM micrograph of fatigue striations at the location indicated by the black arrow in Figure 4.

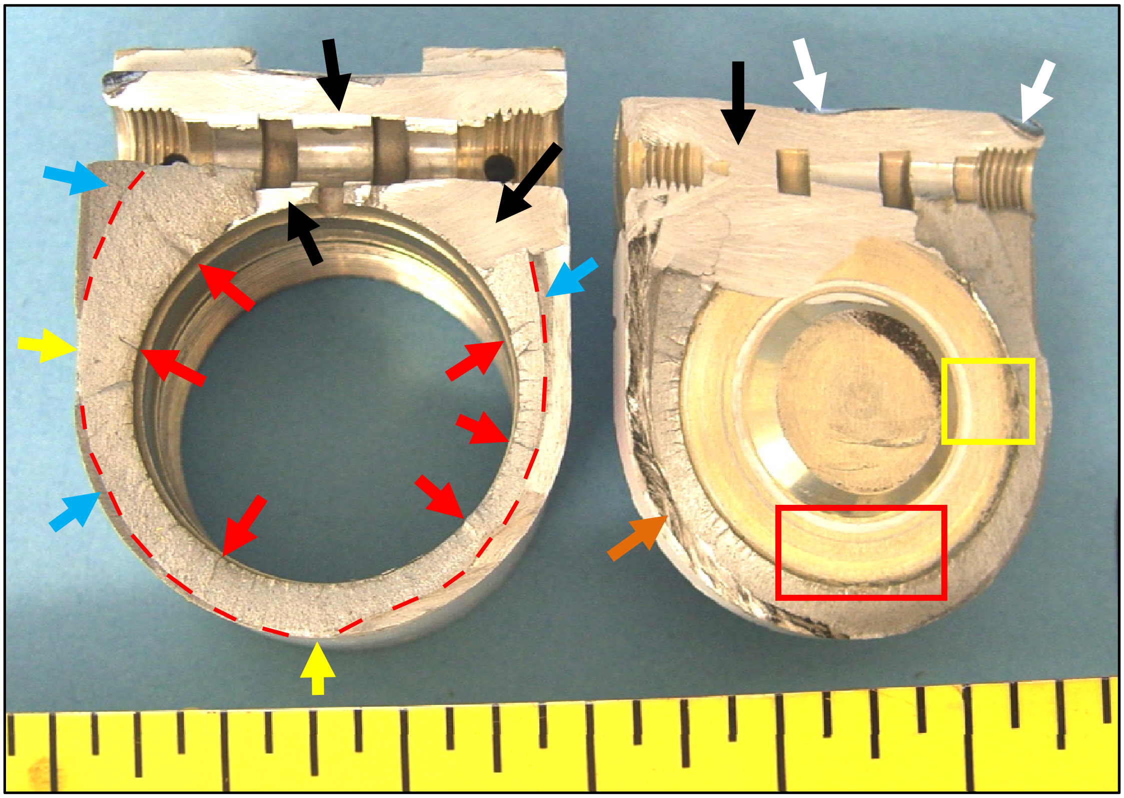

Figure 12. The fracture faces on the comparison end cap.

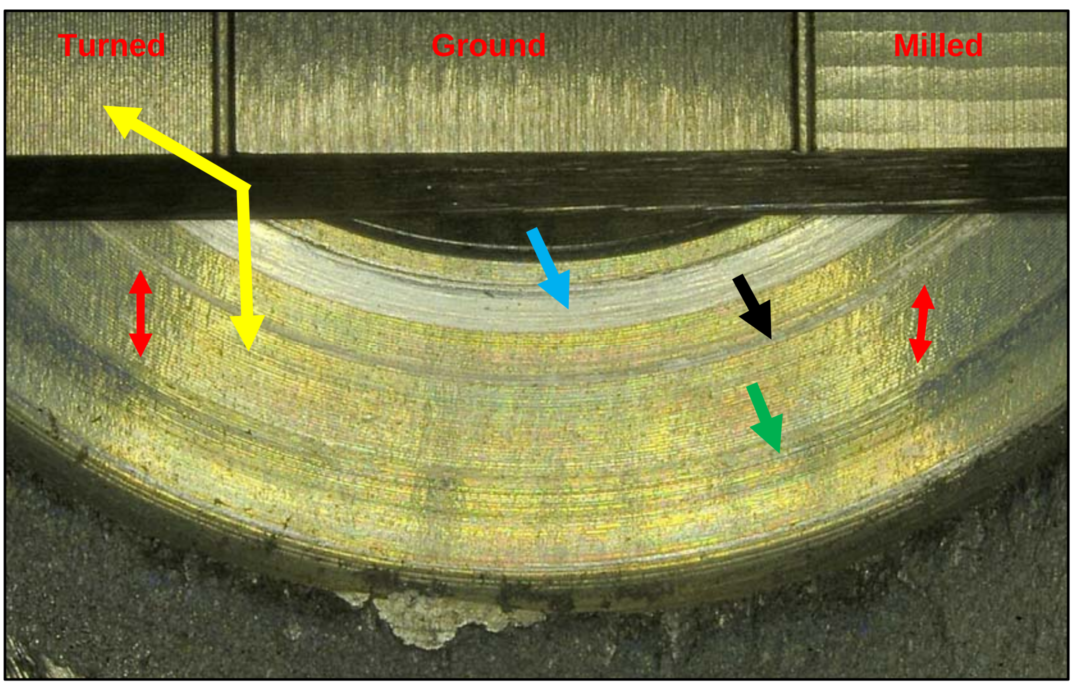

Figure 13. The area within the red box in Figure 12.

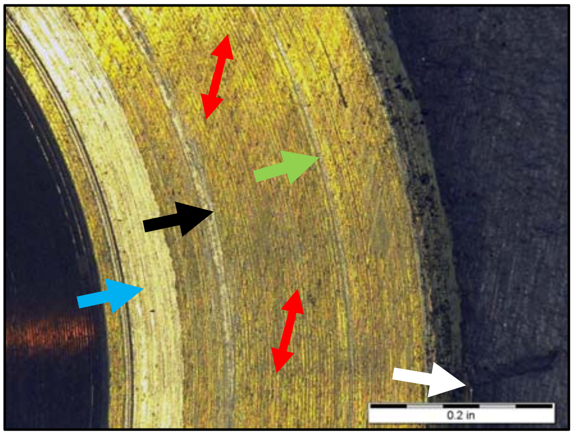

Figure 14. The area within the yellow box in Figure 12.

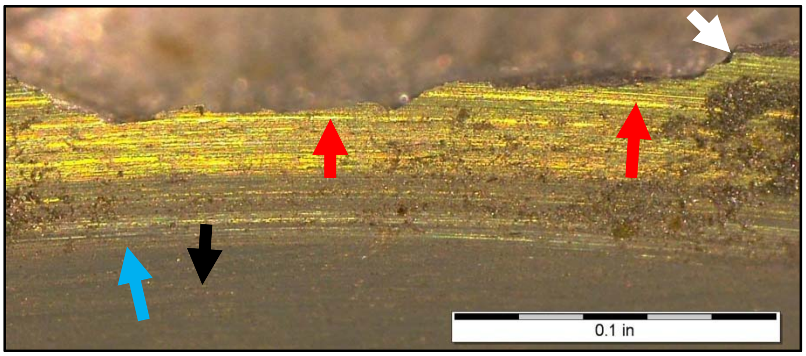

Figure 15. The radius within the yellow box in Figure 12.

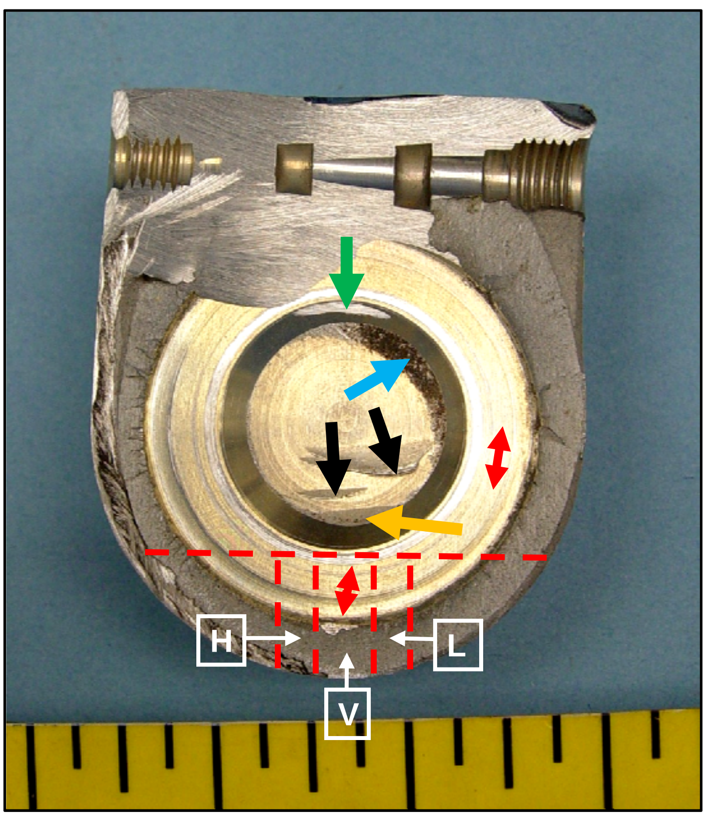

Figure 16. The fractured rear portion of the comparison end cap.