

NATIONAL TRANSPORTATION SAFETY BOARD

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



May 18, 2020

MATERIALS LABORATORY FACTUAL REPORT

Report No. 20-019

A. ACCIDENT INFORMATION

Place : Sardis, Georgia
Date : September 17, 2019
Vehicle : Robinson R44, N827JE
NTSB No. : ERA19LA273
Investigator : Robert Gretz, AS-ERA

B. COMPONENTS EXAMINED

Crankshaft idler gear assembly
Crankshaft idler gear shaft
Portions of an attachment bolt and stud
Slotted nut
Safety wire fragments
Crankcase casting fragment

C. DETAILS OF THE EXAMINATION

On September 17, 2019, about 1230 eastern daylight time, a Robinson R44, N827JE, was substantially damaged during a forced landing near Sardis, Georgia. The commercial pilot was seriously injured. The pilot reported that he was flying about 100 feet above ground level, when he heard a "pop," followed by alarms and lights activating in the cockpit. The helicopter then lost engine power and the pilot performed an autorotation. During the autorotation, the helicopter impacted trees and terrain.

Components retained from a teardown of the accident aircraft engine, a Lycoming model O-540-F1B5, were submitted for examination and are shown in figure 1. The engine teardown was performed by a representative from Lycoming, under the supervision of a Federal Aviation Administration inspector. An exploded view of the engine crankcase and crankshaft idler gear arrangement¹ is shown in figure 2 with the parts received, except for the safety wire fragments, highlighted by red boxes for reference.

The idler gear, shown in figure 3, was a single component and consisted of two concentric gears, one with greater pitch circle diameter and tooth count than the other (36 teeth versus 26 teeth). A copper colored bushing was retained inside the gear hub. The gear hub had an integrated cam feature on the larger gear side. A dark brown-black coating was present over most of the gear surfaces. The web of the smaller gear contained a circumferential wear scar evidenced by a lightly polished surface free of the dark brown-black

¹ Images from Lycoming Engine Parts Catalog O-540-F1B5 Wide Cylinder Flange Crankcase Model Engine (Part Number PC-515-2) dated October 2009 available on Lycoming's website.

coating and partially worn part identification information. The visible part identification information read as below on opposite sides of the gear hub:

71652-ASSY	(GEAR HUB)	71653-DET
7189 18/98		MFR 30620

The assembly part number was consistent with the Lycoming O-540-F1B5 parts catalog for a "GEAR ASSEMBLY, Crankshaft idler." The manufacturer CAGE code for the detail part number corresponded to Kurt Manufacturing Company, Inc. Kurt Gear Division in Minneapolis, Minnesota.

All tooth surfaces of the smaller gear exhibited adhesive wear and pitting over the entire surface as shown in figure 4. The smaller gear also showed evidence of plastic flow of material over the forward ends of the teeth accompanied by local chipping. Approximately 85% of the teeth tips on the smaller gear showed evidence of chipping or deformation. The larger gear tooth surfaces exhibited some adhesive wear, pitting, chipping, and tip deformation but to a much lesser extent relative to the smaller gear. No gear teeth appeared to be completely fractured or missing.

Figure 5a shows an overall view of the crankshaft idler gear shaft flange as viewed from the shaft side. The shaft was smooth and uniform overall with a very fine circumferential scratch directionality except an area at the tip approximately 0.35 inches down the shaft had a slightly brighter and shinier appearance relative to the rest of the shaft. The shaft rotated smoothly and freely when inserted into the gear hub.

The fastener holes have been labeled "A" and "B" for the purposes of this report. Both fastener holes were relatively circular, but the hole "B" edge had an indentation around an approximate 25° segment as viewed from the shaft side. This indentation was at the hole edge only, not all the way through, consistent with impact damage or wear. Both holes contained visible off-center circular haloes of worn and polished metal extending 0.04 – 0.08 inches from the edges of the holes on the shaft side of the flange. The halo around hole "A" was rougher in appearance and had a hazy outer boundary as compared to the halo around hole "B," which was smoother and more uniform in appearance, with a more distinct outer boundary. The inner surface of the holes contained circumferential wear scars which are better observed in figure 5b.

The surface of the flange opposite of the shaft, as shown in figure 5b, was bright, smeared, and battered consistent with mechanical contact against the mating crankcase. There was a visible demarcation line on this surface of the flange at the tab features which exhibited a faint parallel scratch pattern.

Around the edge of the shaft flange were two protruding tab features which contained holes that were oriented transverse to the shaft axis and parallel to the adjacent flange edge. The holes in the tab features were elongated on the side of the tabs facing the shaft, the elongated side oriented away from the shaft, towards the shaft side of the flange.

Figure 6 shows a view of the fractured bolt piece, fractured stud piece, and slotted-nut. The top surface of the bolt-head was black in appearance and had the letters "HAP" stamped on the top surface. The top edge of the bolt-head was worn down to the top of the drilled holes and approximately 50% of the height of the bolt head down the hex-flat edges as evidenced by the absence of black color and a shiny, battered, and rounded profile. The bearing surface of the bolt head was also absent of black color and showed rounding and material loss due to wear with visible circumferential scars. A small stud of material approximately 0.06 inches high and 0.12 inches in diameter remained approximately centered on the hex-head where the fastener separated which indicated the nominal bolt grip diameter had been reduced by approximately 85% prior to separation. The fracture features observed are discussed in more detail later in this report.

The bolt fragment containing the grip area was worn and reduced to a half-hourglass shape. From the end of the bolt grip length, partially worn threads were observed for approximately 0.4 inches as thread roots were still visible. Continuing along the grip towards the point of separation, the fastener was worn below the minor diameter, tapering in a half-hourglass shaped profile to approximately 0.08 inches at the point of separation. The fracture surface on this fragment was deformed and smeared, consistent with post fracture impact damage. There were circumferential wear scars on the reduced diameter sections as well as where the thread crests had been worn down.

The outer edges of the tops of the slotted nut and the tip of the drilled end of the stud were shiny, battered, rounded, and worn similarly to the top edge of the hex-head bolt. The bearing surface of the nut was shiny, battered, and had some areas of smeared and flaking metal consistent with adhesive wear.

The fractured stud was worn to an hourglass shaped profile with two to three thread roots still visible at both ends. The threads on the drilled end of the stud fragment were more intact relative to the crankcase fragment, but visibly deformed and somewhat flaky in appearance, consistent with adhesive wear and impact damage. A length of approximately 0.19 inches of the stud fragment (drilled/nut end) had been worn to below the minor diameter and length of approximately 0.42 inches had been reduced below the minor diameter on the mating fragment. At the point of separation, the stud had been worn to a diameter of approximately 0.10 inches which indicated the nominal stud diameter had been reduced by approximately 90% prior to separation. There were circumferential wear scars on the reduced diameter sections as well as polishing where the thread crests had been worn on the crankcase fragment.

Figure 7 shows a closer view of the stud piece fracture surface using a digital microscope. The fracture surface was flat and multiple fracture origins were present around the entire circumference of the worn stud piece as evidenced by numerous radial ratchet marks.² Beach mark³ features were visible and indicated inward crack propagation. A small

² Ratchet marks are 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.

³ Beach marks are macroscopic progression marks on a fatigue fracture surface that indicate successive positions of the advancing crack front. The classic appearance is of irregular elliptical or semielliptical rings, radiating outward from one or more origins. Beach marks (also known as clamshell marks or arrest marks) are typically found on

elliptical area of rough morphology was present at the approximate center of the fracture surface consistent with overstress separation. Fatigue cracking traversed approximately 95% of the fracture surface prior to overstress separation. Features present on the fracture surface were consistent with multiple origin rotating bending fatigue at relatively low nominal stress.

The bolt piece fracture surface, as viewed in figure 8, resembled the stud piece fracture surface; however, features were smoother, somewhat smeared, and less discernible. The circumferential scars were consistent with rotational wear.

There was a total of 5 fragments of safety wire submitted as shown in figure 9. The fragments shown in the left and center images of this figure contained a single wire that followed a partial hexagonal path consistent with the profile of the slotted-nut and bolt followed by a helical path immediately before and after. The ends of the fragment in the left image each contained an additional fragment of wire twisted together forming a double helix. The fractured ends of wire are highlighted with unlabeled arrows. The red arrows indicate relatively flat fracture surfaces observed using a stereomicroscope. The black arrow indicates an end where both strands of wire terminate in a sharp point at the same location and orientation, consistent with being mechanically cut. The fragment of safety wire in the center image had witness marks consistent with hard contact or rubbing which are highlighted with green arrows. The fractured ends of this fragment appeared more necked down⁴, consistent with tensile stretching and overstress. The smaller fragments are shown grouped together in the right image of figure 9. The fragment indicated with the yellow bracket was of comparable dimension to parallel sides of the slotted-nut and bolt head. Witness marks consistent with hard contact or rubbing are highlighted with green arrows, and the red arrow indicates a relatively flat fracture with no obvious necking observed using a stereomicroscope. The unlabeled fragment ends in the right image were smeared and deformed, consistent with post fracture damage.

The casting fragment shown in figure 10 was fractured through a circular bore feature that appeared to originate near the unlabeled red arrow. The yellow arrows show the approximate direction of fracture. The as-cast surface exhibited a golden-straw colored appearance. The flat surface oriented normal to the bore surface showed evidence of polished, smeared, and battered metal, consistent with impact wear. On the bore surface, there was a shiny circumferential gouge approximately 0.10 inches from the flat surface and between this gouge and the flat surface was a circumferential band of polished and smeared metal absent of the golden-straw color. An alternating striped pattern was observed on the bore surface that consisted of circumferential bands of smeared/polished metal followed by bands of golden-straw color. There were small pits present on the bore surface as indicated in the photograph.

Michael Meadows
Materials Engineer

service fractures where the part is loaded randomly, intermittently, or with periodic variations in mean stress or alternating stress.

⁴ Necking down refers to the localized reduction in area of a specimen during tensile deformation.

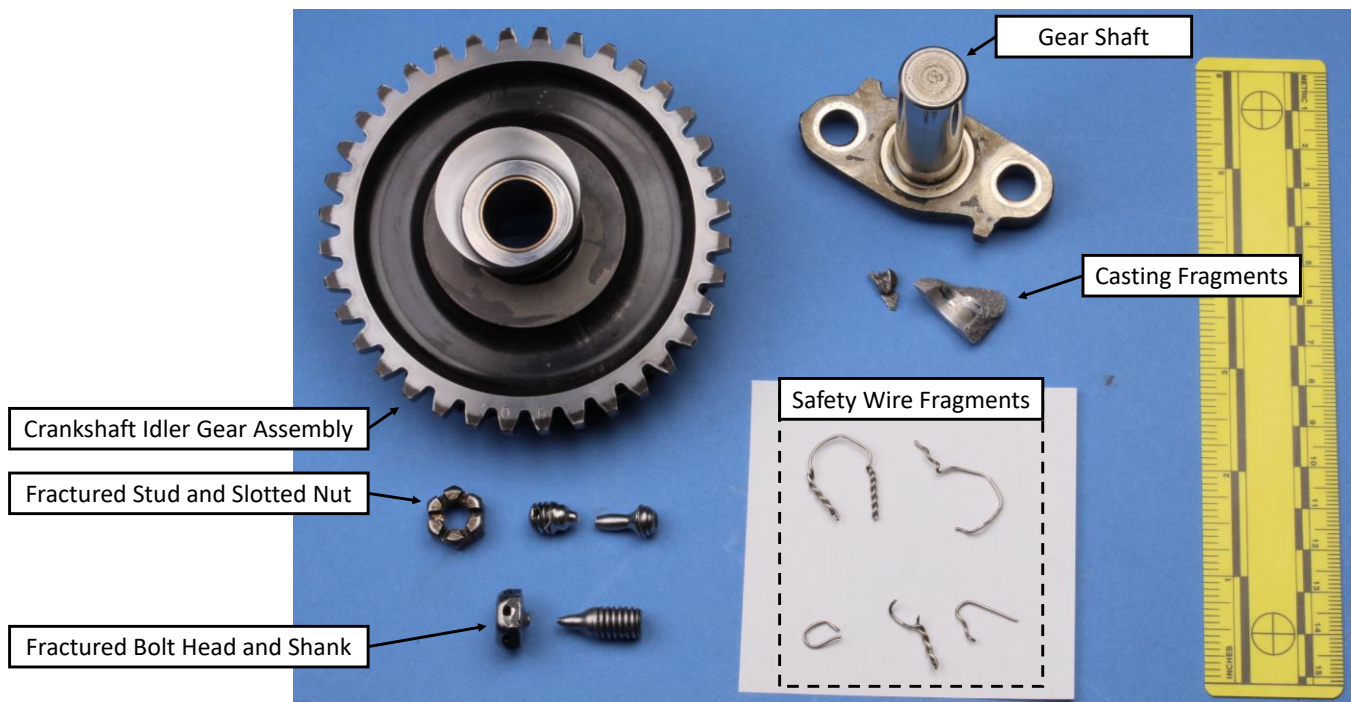


Figure 1: Photograph of components as-received. The smaller gear of the crankshaft idler gear assembly is obscured by the larger gear in this photo.

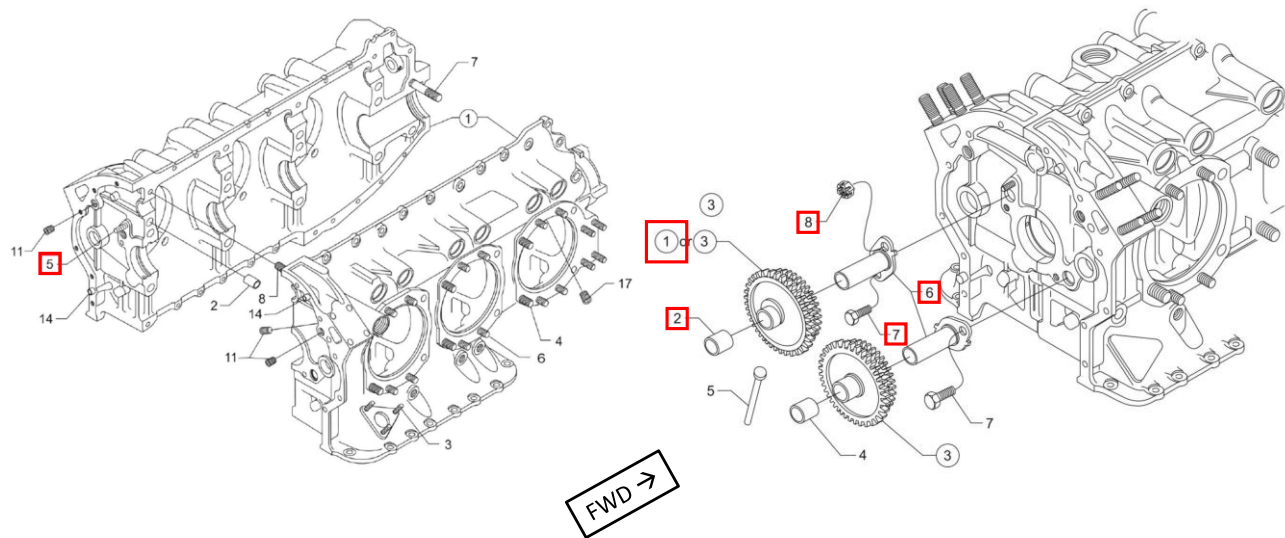


Figure 2: The left image is an exploded view of the aft side of the crankcase showing the location of the stud (item 5) which was received fractured. The right image is the aft side of the assembled crankcase with an exploded view of the crankshaft idler gear arrangement. Item 1 is the crankshaft idler gear assembly received which contained item 2 (a bushing), item 6 is the idler gear shaft, item 7 is a bolt which was received fractured, and item 8 is a slotted nut.

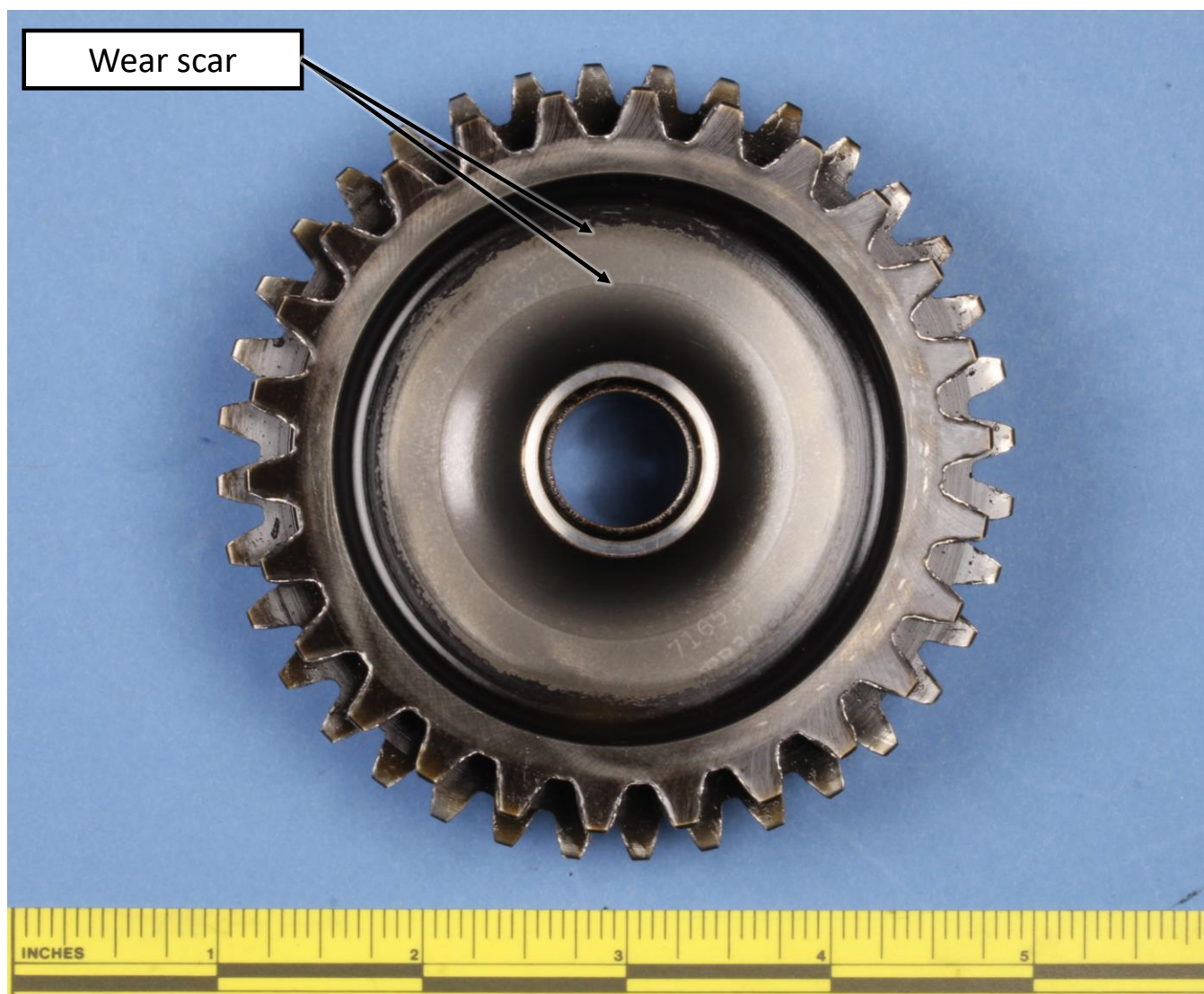


Figure 3: A photograph of the crankshaft idler gear assembly as viewed from the forward side of the engine looking at the smaller gear. The inner and outer boundaries of the circumferential wear scar around the gear web are highlighted. Partially worn part identification information is also observed on the web on each side of the hub at approximately the 10 and 5 o'clock positions. The finned appearance of nearly all the smaller gear teeth edges was evidence of plastic flow of material at these locations.

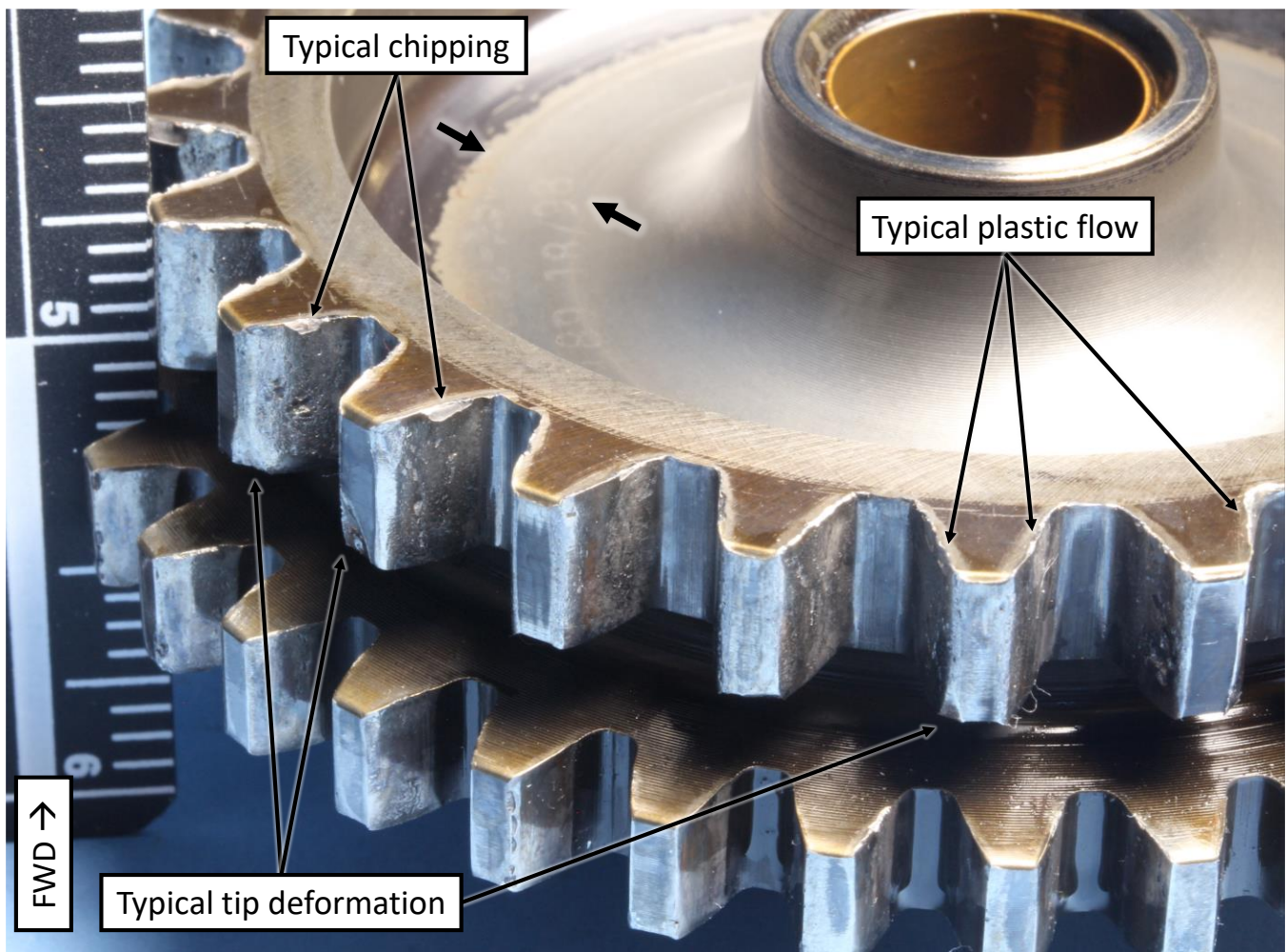


Figure 4: A closer photograph of the gear teeth (smaller gear oriented above the larger gear). Typical observations of plastic flow, chipping, and deformed/impacted teeth are indicated. The teeth surfaces of the smaller gear were polished and pitted. The unlabeled arrows in the gear web indicate the inner and outer boundaries of the circumferential wear scar.

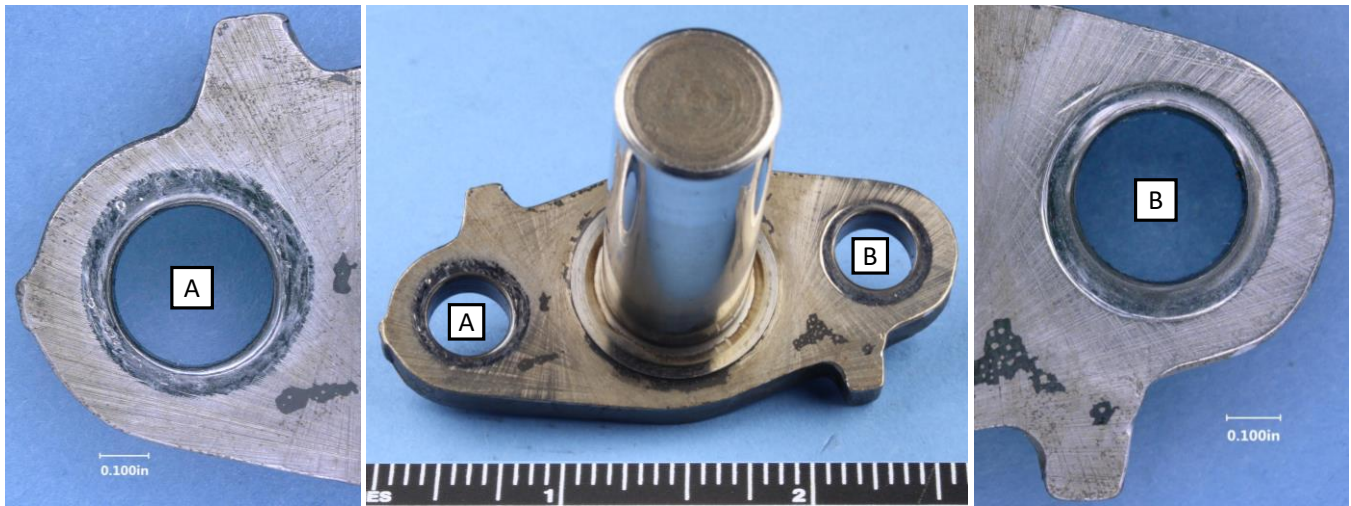


Figure 5a: The central photograph shows an overall view of the of the gear shaft as viewed from the shaft side of the flange. The holes were labeled “A” and “B” arbitrarily for the purposes of this report. To the left and right of this photo are digital microscope images showing closer views of the wear haloes around the holes for holes “A” and “B,” respectively.

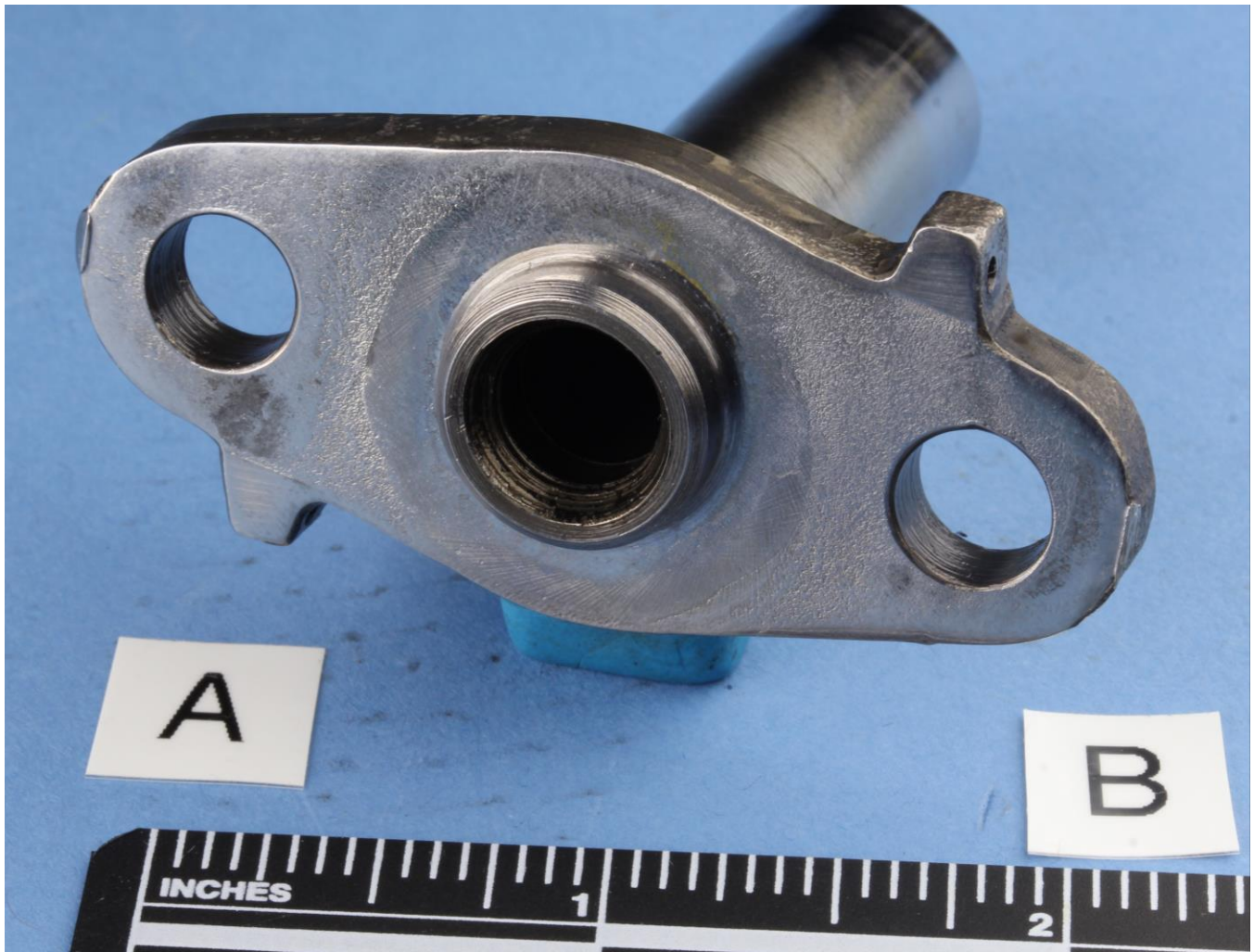


Figure 5b: A photograph of the gear shaft viewing the side of the flange opposite of the shaft. The flange surface was bright/shiny, smeared, and battered, consistent with mechanical wear. The hole locations "A" and "B" are indicated for reference. Circumferential scars were visible on the hole surfaces.

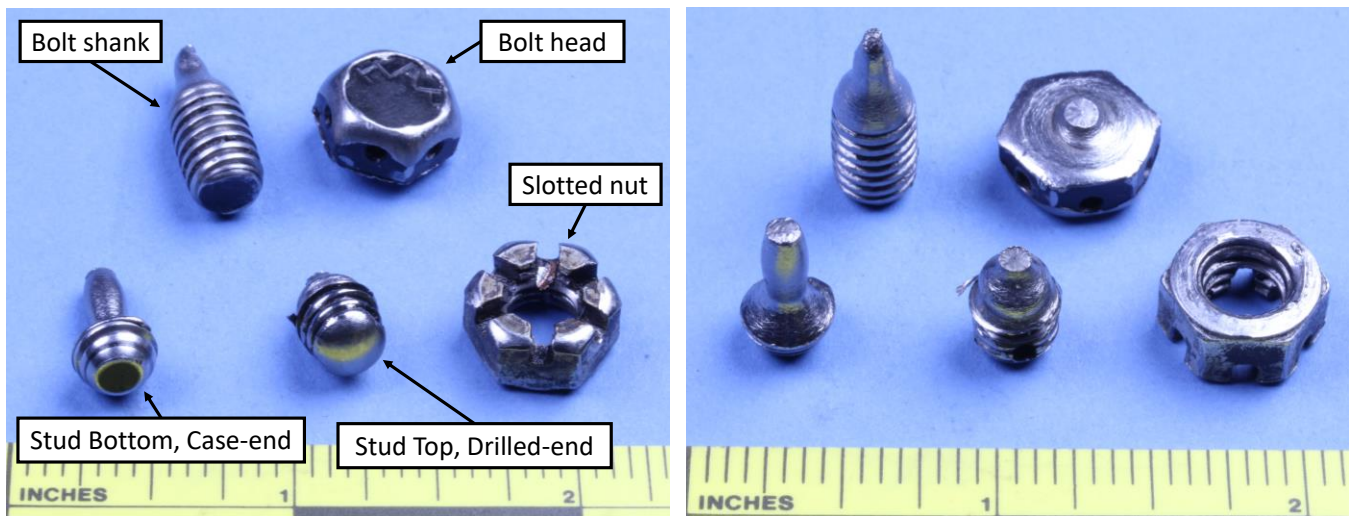


Figure 6: The left photograph shows the top of the bolt head, slotted-nut, and stud with evidence of material loss due to adhesive wear. Also in this photo is a bottom view of the worn stud and bolt shank. The right photograph shows (same relative component locations as the left) the bearing surfaces of the bolt head and nut with evidence of adhesive wear. Also shown are the fractured surfaces of the worn bolt and stud.

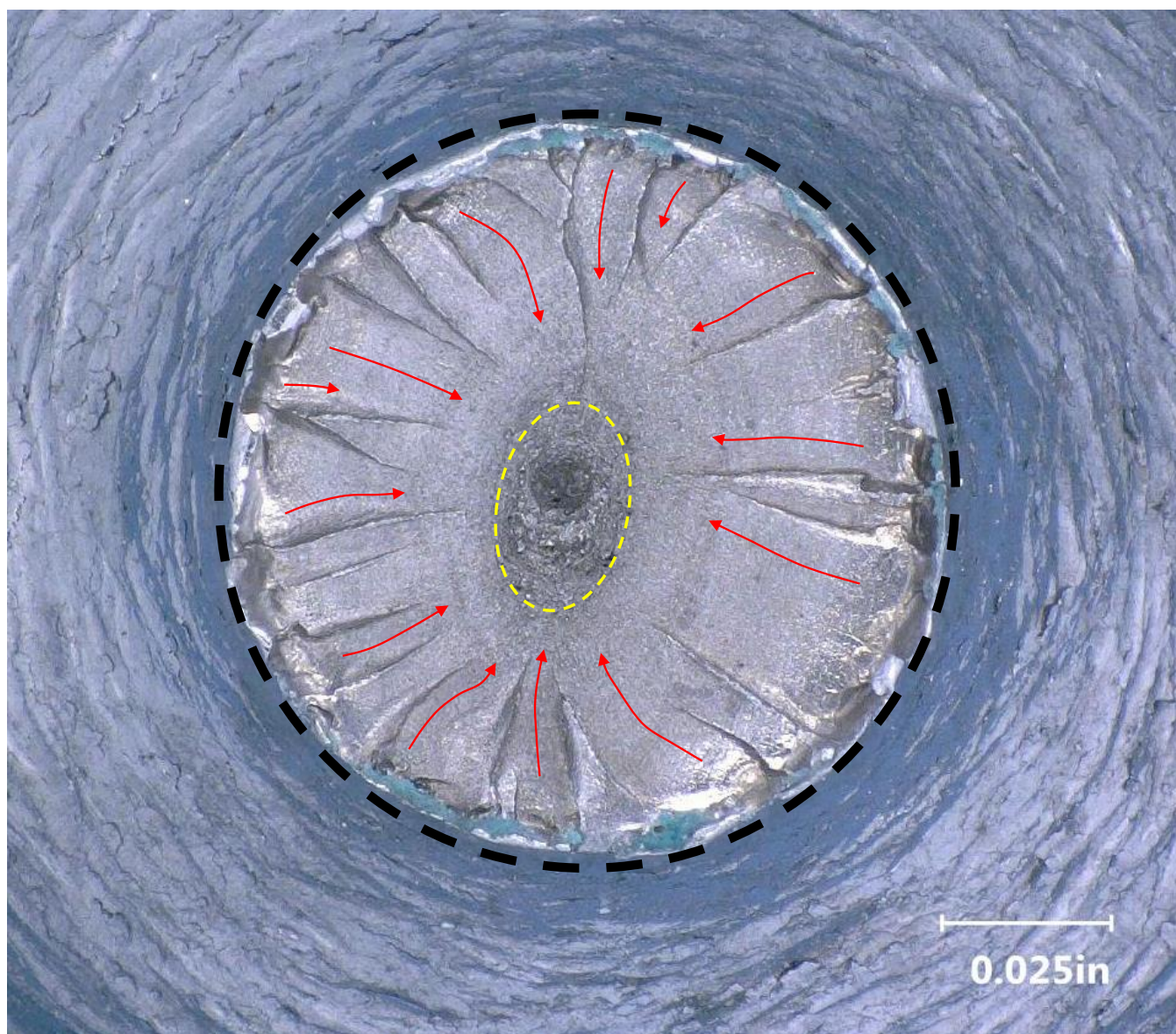


Figure 7: A digital microscope image of the circular stud fracture surface contained within the black dashed circle. Multiple fracture origins were observed around the entire circumference of the fracture surface as evidenced by numerous ratchet marks. The red arrows indicate typical fatigue crack propagation direction following ratchet mark and beach mark features. The area within the yellow dashed ellipse was consistent with final overstress separation. Circumferential wear scars on the reduced diameter section of the stud are visible outside of the black dashed circle (below the plane of focus in this image).

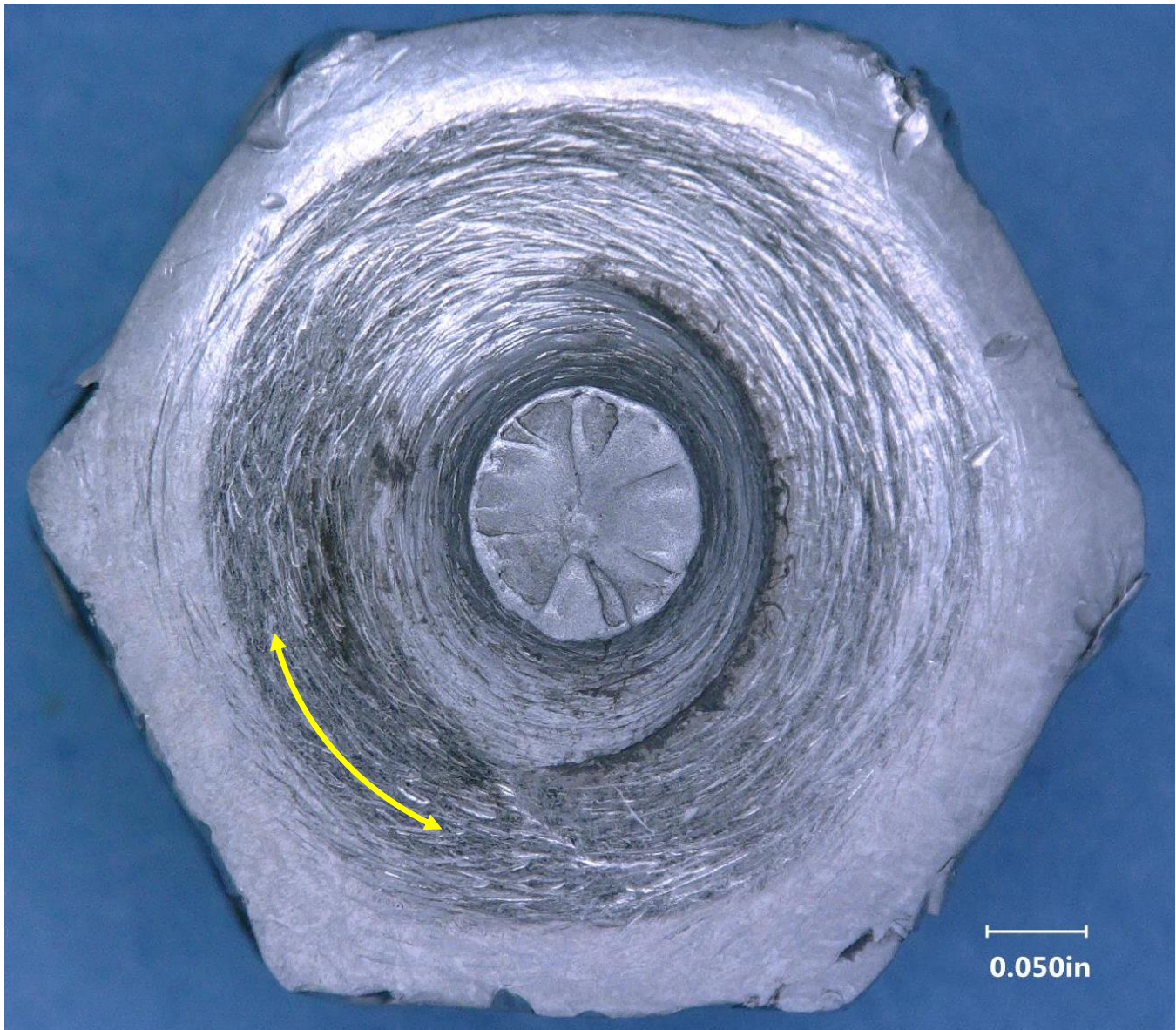


Figure 8: Digital microscope image of the polished and worn bearing surface of the bolt head showing the fracture surface. Features were similar to the stud fracture surface but smoother, more smeared, and less discernible. Circumferential wear scars (with orientation highlighted by the yellow arrows) were observed on the bearing surface of the bolt head and reduced diameter section, consistent with rotational wear.

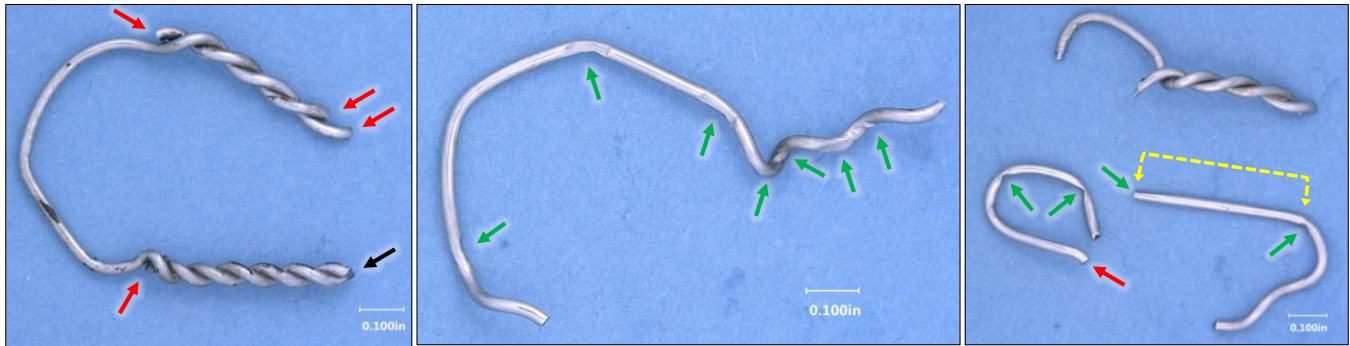


Figure 9: Digital microscope images of the safety wire fragments examined. Red arrows indicate relatively flat fracture locations. The black arrow indicates a wire termination consistent with being mechanically cut. Green arrows indicate witness marks and evidence of contact or wear. The yellow bracket indicates a span of wire consistent with dimensions of parallel sides of the slotted nut and hex-head bolt. Unlabeled wire terminations in the center image were consistent with tensile stretching/overstress. Unlabeled wire terminations in the right image were damaged after separation and were not classified.

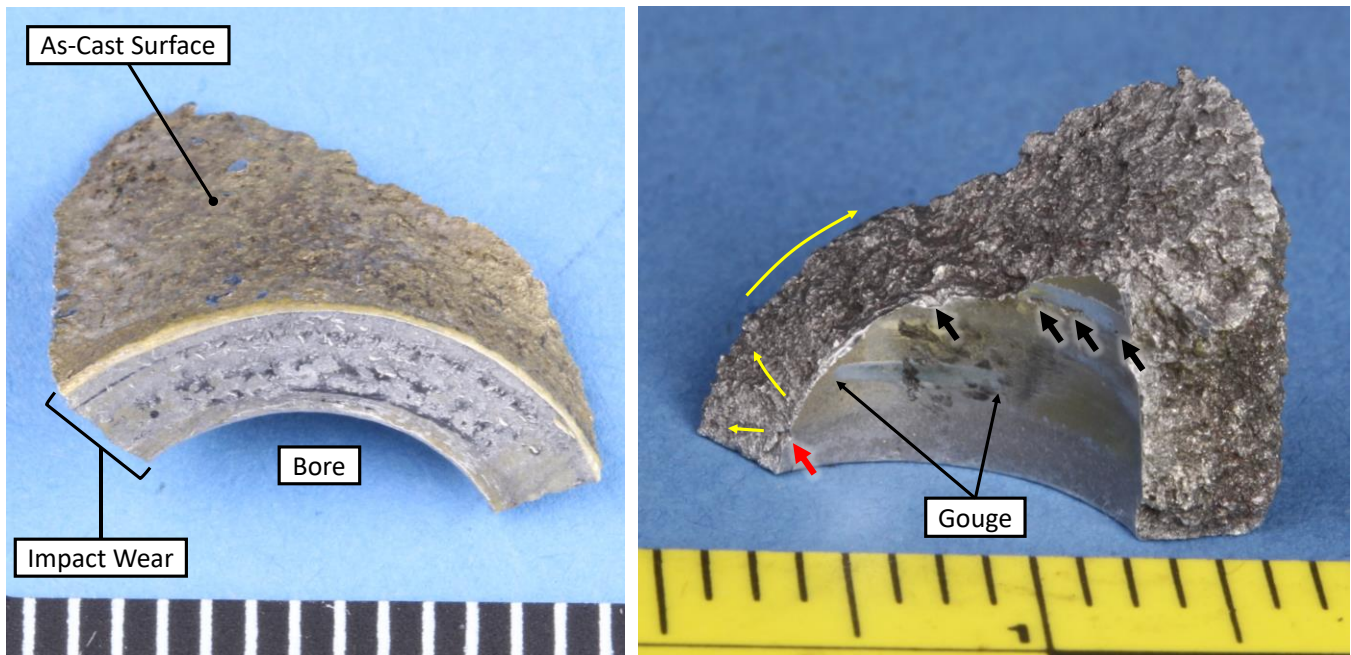


Figure 10: The left photograph shows a fractured piece of casting where the flat, bright-silver colored surface normal to the bore feature is visible. This surface was shiny and battered, consistent with impact wear. The right photograph shows the fracture surface and inside of the bore feature of the same piece of casting on the left. The red arrow highlights a small pit on the border of a wear band near the fracture initiation. The yellow arrows highlight the approximate direction of fracture. The unlabeled black arrows highlight several other pits observed on this surface. Scale markings are 1/16 inch.