

NATIONAL TRANSPORTATION SAFETY BOARD

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



June 1, 2022

MATERIALS LABORATORY FACTUAL REPORT

Report No. 22-040

A. ACCIDENT INFORMATION

Place : Sacramento, CA
Date : February 15, 2020
Vehicle : Airbus A319-132, N521NK
NTSB No. : ENG20LA016
Investigator : Michael Hauf (AS-10)

B. COMPONENTS EXAMINED

IDG fixed cylinder blocks

C. DETAILS OF THE EXAMINATION

While on approach for landing, the subject Airbus A319-132 aircraft lost all electronics, automatically deployed the ram air turbine and entered the emergency electrical configuration, and the crew landed uneventfully. During inspection of the aircraft, both integrated drive generators (IDG), which incorporate cylinder blocks in their internal hydraulic subsystem, were identified as a possible incident root cause and removed. Subsequently, the fixed cylinder blocks and mating piston assemblies from each IDG were submitted to the NTSB Materials Laboratory for examination.

The parts were removed from engines with serial numbers (S/N) 1266 and 1157; S/N 1266 was the left engine and S/N 1157 was the right engine. The fixed cylinder blocks were identified as part number 764635; the fixed cylinder block removed from engine S/N 1266 was vibro-peen marked with S/N Y10-245-19 and the fixed cylinder block removed from engine S/N 1157 was vibro-peen marked with S/N Y04-232-49. The piston assemblies were identified as part number 768241 and were matched to the fixed cylinder blocks.

Both fixed cylinder blocks were also vibro-peen marked with 'CB-31773', which was reported as the process number for rework performed by an aftermarket company. The part numbers and serial numbers listed above were assigned by the original equipment manufacturer (OEM) of the fixed cylinder blocks. The bores were numbered 1 thru 9 on the outer surface of the fixed cylinder blocks via permanent marker.

Figures 1 and 2 show the fixed cylinder block S/N Y10-245-19 and mating piston assembly. Figures 27 and 28 show the fixed cylinder block S/N Y04-232-49 and mating piston assembly.

NON-DESTRUCTIVE EXAMINATION OF FIXED BLOCK CYLINDER Y10-245-19

The fixed cylinder block S/N Y10-245-19 was visually examined and photo documented. Bands of circumferential wear marks were visible on the outer diameter (OD) of the pistons. A few pistons had heavier bands of wear than others, and the bands occurred along most of the length of the pistons.

Wear was observed in the gold-colored liners assembled inside the bores of the fixed cylinder block. The wear was uneven around the circumference and occurred close to either end of the bores, with the heaviest wear extending up from the bottom of the bores. The gold-colored liners were worn through in some areas in several bores, and silver-colored base metal was visible (encircled by red dotted lines in Figures 3–5). Areas on bores 3, 5, and 6 were missing segments of gold-colored liner; the areas with missing liner ranged in size from very small to almost half the liner length.

In areas where the gold-colored liner was beginning to wear through, thin circumferential rings became visible (yellow arrows, Figure 4). In areas where the gold-colored liner was missing, thicker circumferential rings consistent with machining were visible (yellow arrows, Figure 5). Piece of gold-colored debris was present in the bottom of at least one of the bores (Figure 6).

LINER REMOVAL FROM FIXED BLOCK CYLINDER Y10-245-19

Bore 5 was one with the heaviest wear, as shown in Figure 7. The liner was removed from the bore by chiseling an axial line through its length. The bore with the liner removed is shown in Figure 8. Seven parallel circumferential grooves were revealed on the bore inner diameter (ID) once the sleeve was removed. The grooves were evenly spaced along the bore length and were consistent with a machining operation. There was a substance adhering to the ID surface of the bore between the machined grooves (yellow arrows, Figure 9).

The removed liner is shown in Figures 10–12. The chiseled axial line created in the lab to facilitate liner removal is indicated by the black arrows in Figure 10. A segment of liner around about half the circumference and extending approximately 0.5 inches up from the bottom of the bore was missing. Seven raised rings of material were observed in parallel lines around the OD circumference of the liner; the rings likely mated with the machined grooves in the ID of the block bore. The edges of the liner adjacent to the missing portion are shown in Figure 11. One edge (green dashed line) had thinned down to a knife edge. The other edge (black dashed line) was thicker and had features consistent with the liner separating in pieces.

The black dashed lines in Figure 12 encircle dents on the OD of the liner that mated with the ID of the bore. The dents likely resulted from contact with the substance observed on the ID of the bore. Pieces of flattened gold-colored debris were also visible on the OD of the liner (red arrows).

DESTRUCTIVE EXAMINATION OF FIXED BLOCK CYLINDER Y10-245-19

The two additional bores with heavy liner wear, bores 3 and 6, and one bore with a lesser amount of wear, bore 8, were destructively examined. Cuts were made through the OD side wall of the block and the mating liner from each bore, as shown for bore 3 in Figure 13. After sectioning, the liners were not attached to the block pieces and the mating parts could be easily separated.

The ID of the block piece and the ID and OD of the liner piece from bore 3 are shown in Figure 14. The sectioned piece of liner was whole and intact. The ID surface of the block piece had a translucent substance on it (indicated by yellow arrows in Figure 15) consistent with the substance observed on the ID surface of bore 5 after the liner was removed. A few sections of the machined rings were entirely filled with the substance (indicated by yellow brackets in Figure 15). The raised rings on the mating OD of the liner had flat sections where the material was flush with the rest of the OD surface that likely mated to the sections of ID grooves in the bore filled with substance. The flat sections on the liner OD piece are encircled by black dashed lines in Figure 16.

The remaining portion of block with the liner still installed in bore 3 is shown in Figures 17–19. A segment of the liner at the bottom of the bore was missing, as indicated by the red dotted line in Figure 17. The edges of the missing piece were thinned, and a machined groove was visible in the exposed block ID surface. A curved wear pattern was visible on the liner adjacent to the missing portion (black dashed line in Figure 18). Further along the axis from the bottom of the bore there were areas where the liner had begun to wear through the thickness, as indicated by the yellow arrows in Figure 19. The areas aligned circumferentially and likely coincided with machined grooves in the ID of the mating block.

The ID of the block piece and the ID and OD of the liner piece from bore 6 are shown in Figure 20. The sectioned piece of liner was whole and intact. Both the OD of the liner and the ID of the block had had the same substance on it as the other bores. While there were thicker sections of substance visible on some of the raised rings of the liner OD, no areas of the machined grooves in the block ID were completely filled with it.

The remaining portion of block with the liner still installed in bore 6 is shown in Figures 21–23. A segment of the liner at the bottom of the bore was missing (red dotted line, Figure 21), and again a curved wear pattern was visible on the liner adjacent to the missing portion (black dashed line, Figure 21). The edges of the liner along one side of the missing segment were thinned, as shown in Figure 22. In other locations along the missing segment the edges were thick and had features consistent with pieces of the liner separating (black dotted circle, Figure 23).

The ID of the block piece and the ID and OD of the liner piece from bore 8 are shown in Figure 24. The sectioned piece of liner was whole and intact. Both the OD of the liner and the ID of the block had had the same substance on it as the other bores, and the OD of the liner also had the raised rings from being pressed inside the mating machined grooves in the ID of the block. Debris was visible inside some of the machined

grooves in the ID of the block, as indicated by the yellow arrows in Figure 25. The debris was adhered with substance that had darkened in color in some areas and appeared to consist of gold-colored shavings.

The remaining portion of block with the liner still installed in bore 8 is shown in Figure 26. The remaining liner was intact along the entire axial length. Circumferential wear was observed in the middle of the liner ID surface. The wear closer to the bottom of the bore had a curved pattern. A few locations where pieces of liner were missing were observed in the worn area (black arrows, Figure 26).

DESTRUCTIVE EXAMINATION OF FIXED BLOCK CYLINDER Y04-232-49

Uneven wear was observed around the circumference of the gold-colored liners. In only bore 3 had the gold-colored liner worn through. The heavily worn bore 3 and another bore with a lesser amount of wear (bore 7) were destructively examined.

Bore 3 after sectioning is shown in Figure 29. The ID of the block piece and the ID and OD of the liner piece are shown in Figure 30. The bottom 0.1 inches of the sectioned piece of liner was missing, and the edge of the liner adjacent to the missing portion had thinned. The ID surface of the block piece and OD surface of the liner had a substance on it consistent with the bores examined from the other fixed block. The substance along the bottom half of the liner OD had darkened in color, along with several areas on the ID of the block piece. Debris was visible adhering to the substance inside some of the machined grooves in the ID of the block.

The remaining portion of block with the liner still installed in bore 3 is shown in Figure 31. A segment of the liner near but not immediately adjacent to the bottom of the bore was missing, as indicated by the red dotted line. The edges of the missing segment were a mix of thinned and thick with features consistent with pieces of the liner separating. The yellow arrow in Figure 31 points to a large piece from the top half of the liner thickness that had separated near the missing liner segment. Machined grooves were visible in the exposed block ID surface, and one area within a groove had darkened substance adhering to it. A curved wear pattern was visible on the liner away from the missing portion (black dashed line, Figure 31).

Bore 7 after sectioning is shown in Figure 32. The sectioned piece of liner was whole and intact. The ID of the block piece and the ID and OD of the liner piece are shown in Figure 33. The ID surface of the block piece and OD surface of the liner had a substance on it consistent with the bores examined from the other fixed block, and a few areas of substance within the grooves in the block ID had darkened in color.

The remaining portion of block with the liner still installed in bore 7 is shown in Figure 34. The remaining liner was intact along the entire axial length. A curved wear pattern was visible on the liner (black dashed line). A few small areas where the liner had begun to wear through the thickness were observed (yellow arrows).

COMPOSITION OF LINERS FROM FIXED BLOCK CYLINDERS Y10-245-19 AND Y04-232-49

The composition of the one removed liner from fixed block cylinder Y10-245-19 and the sectioned liners from both fixed block cylinders were analyzed using an Olympus Vanta x-ray fluorescence (XRF) alloy analyzer. The liners were all identified as Cu 932, which is a high-leaded tin bronze alloy that also goes by the designations SAE 660 and C93200. The measured compositions met the material specifications for liners used by the aftermarket company.

NON-DESTRUCTIVE EXAMINATION OF EXEMPLAR FIXED BLOCK CYLINDER

An exemplar fixed block cylinder from an IDG with similar flight hours as those of the IDGs in the incident aircraft was provided by the OEM for comparison purposes. The exemplar fixed block had not been reworked by an aftermarket company.

The exemplar fixed block is shown in Figure 35. The exemplar fixed block was visually examined photo documented. Images of two representative bores are shown in Figures 36 and 37.

Wear was observed in the gold-colored liners assembled inside the bores of the fixed cylinder block. The wear was uneven around the circumference and typically occurred close to the top end the bores. The heaviest wear around the circumference were in areas diametrically opposite each other. No areas of silver-colored base metal were visible and no discrete pieces where the liner had separated due to wear through were observed.

Adrienne V. Lamm
Materials Engineer



Figure 1: Overall photo showing the packaging with identifying information and the components from the IDG from engine S/N 1266.



Figure 2: Close up photos of the pistons (top) and fixed cylinder block from engine S/N 1266. The fixed cylinder block was labeled S/N Y10-245-19.

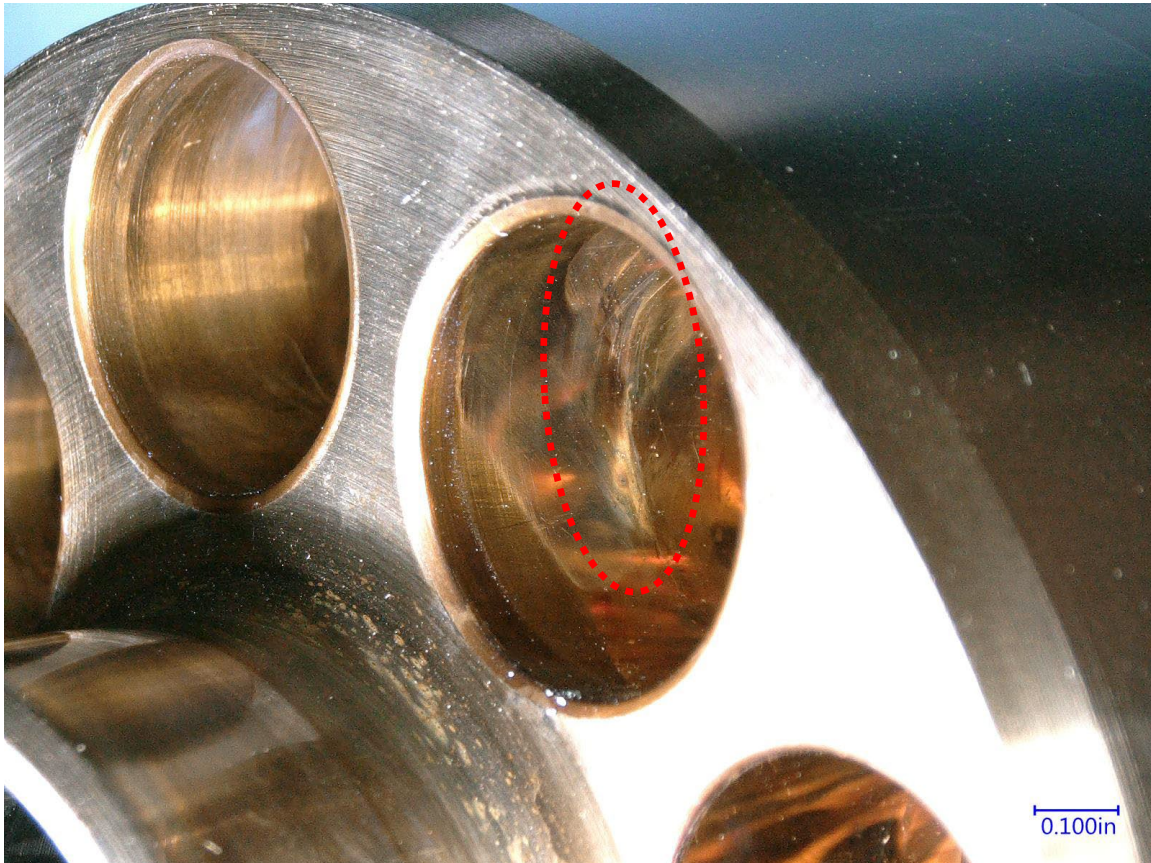


Figure 3: Digital microscope image showing bore 2 in fixed cylinder block S/N Y10-245-19. The red dotted line encircles wear on the gold-colored liner and silver-colored base metal visible underneath.

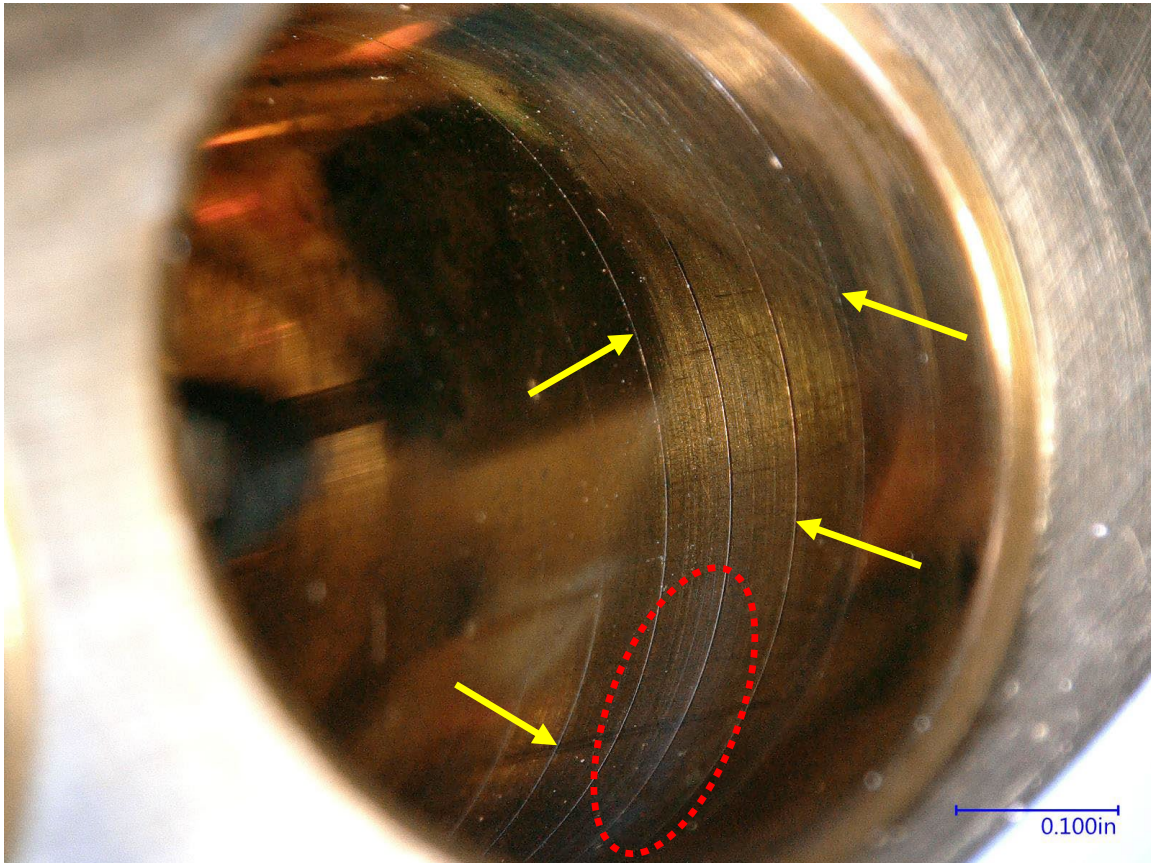


Figure 4: Digital microscope image showing bore 1 in fixed cylinder block S/N Y10-245-19. The red dotted line encircles wear on the gold-colored liner and silver-colored base metal visible underneath. The yellow arrows point to circumferential rings visible under the liner.

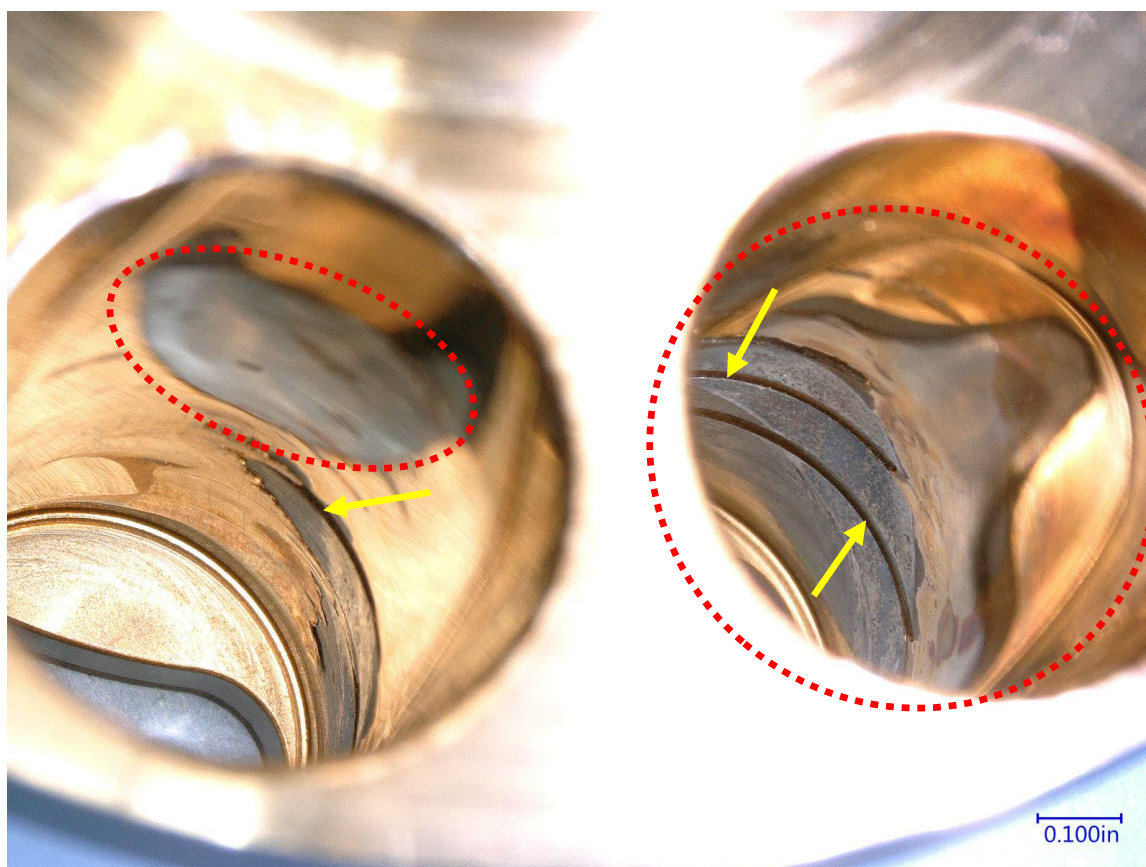


Figure 5: Digital microscope image showing bores 5 (left) and 6 (right) in fixed cylinder block S/N Y10-245-19. The red dotted lines encircle wear on the gold-colored liners and silver-colored base metal visible underneath. The yellow arrows point to machined circumferential rings visible in the base metal under the liner.

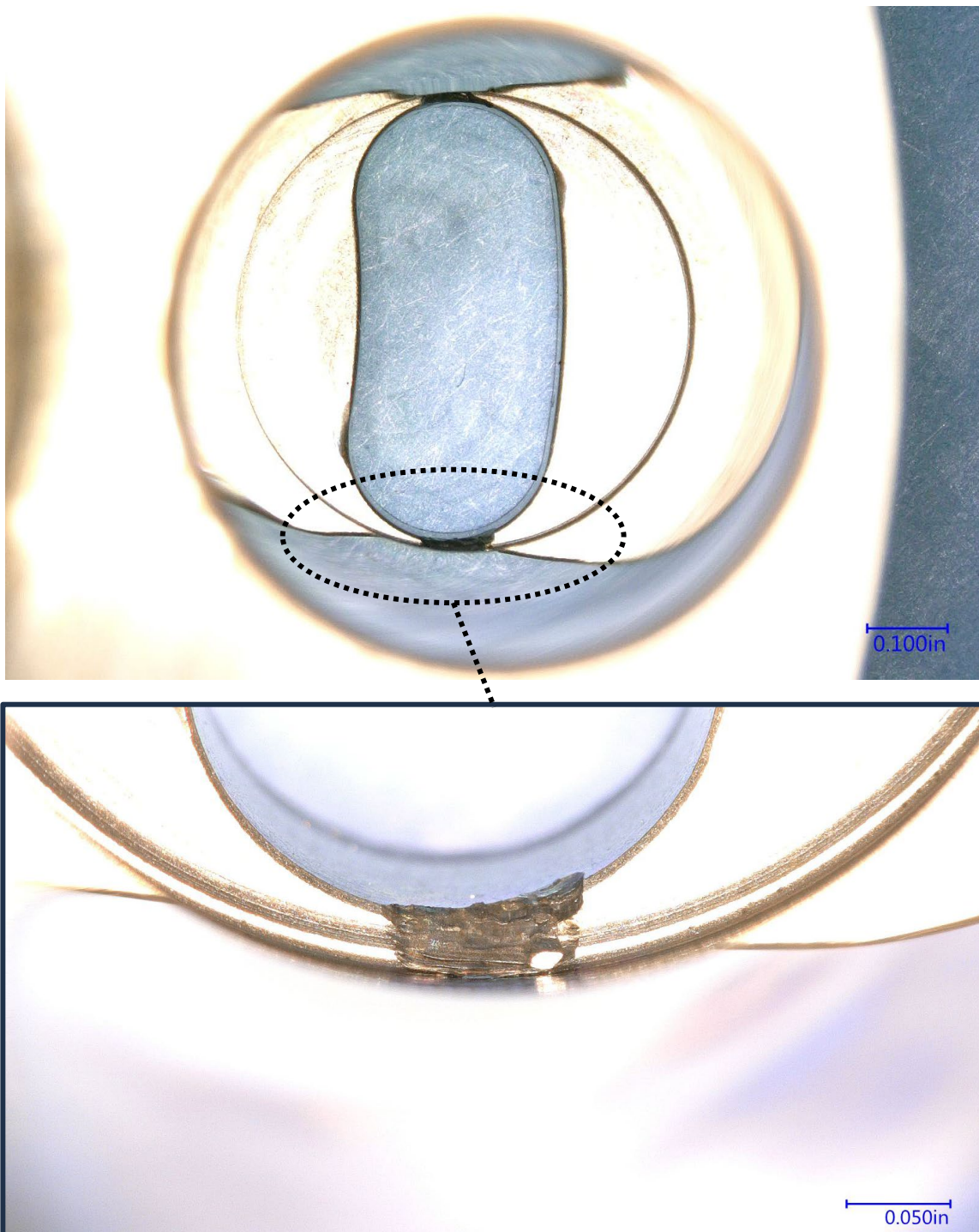


Figure 6: Digital microscope images showing a piece of gold-colored debris in the bottom of bore 9 in fixed cylinder block S/N Y10-245-19.

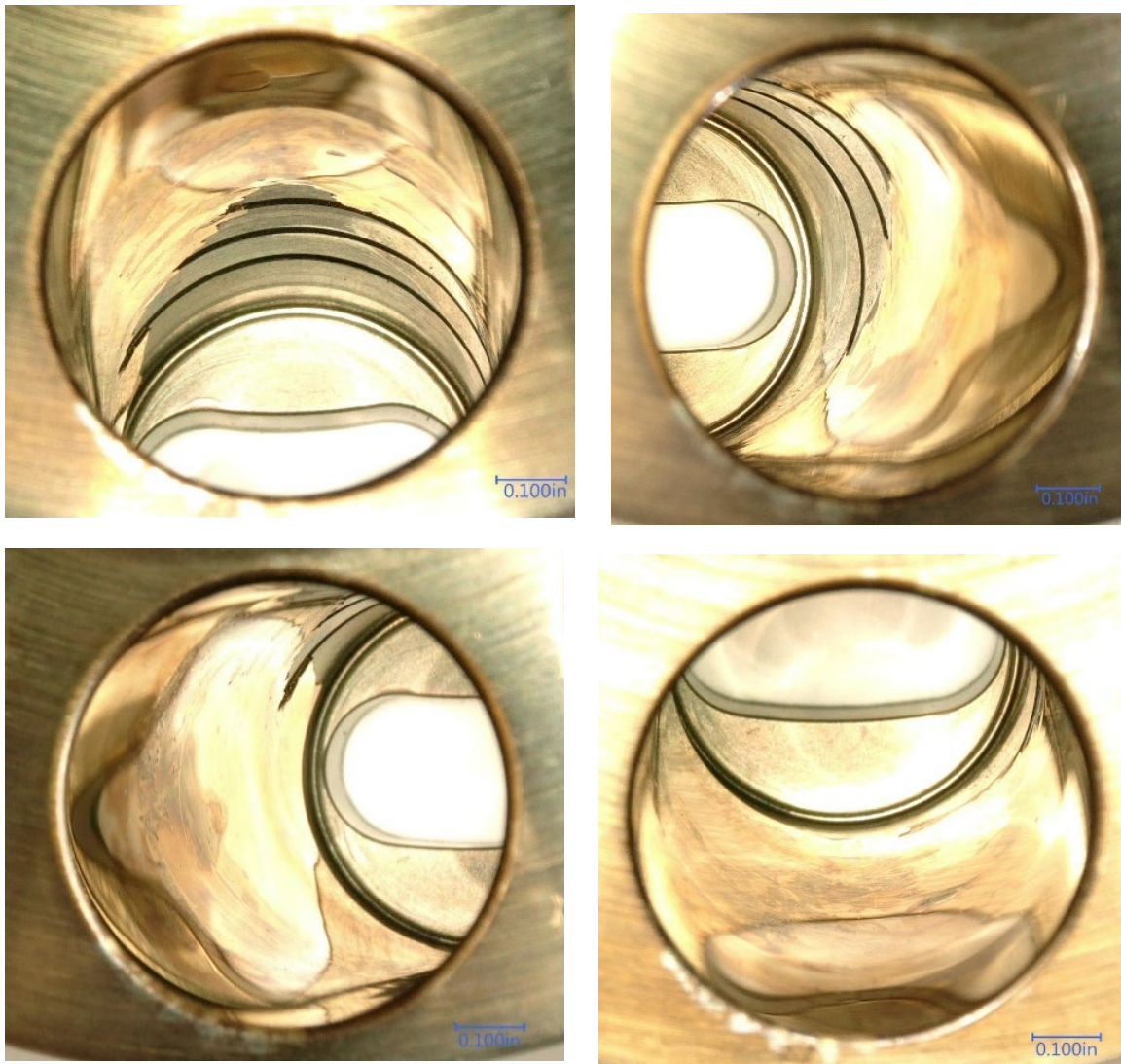


Figure 7: Digital microscope images showing around the entire circumference of bore 5 in fixed cylinder block S/N Y10-245-19.

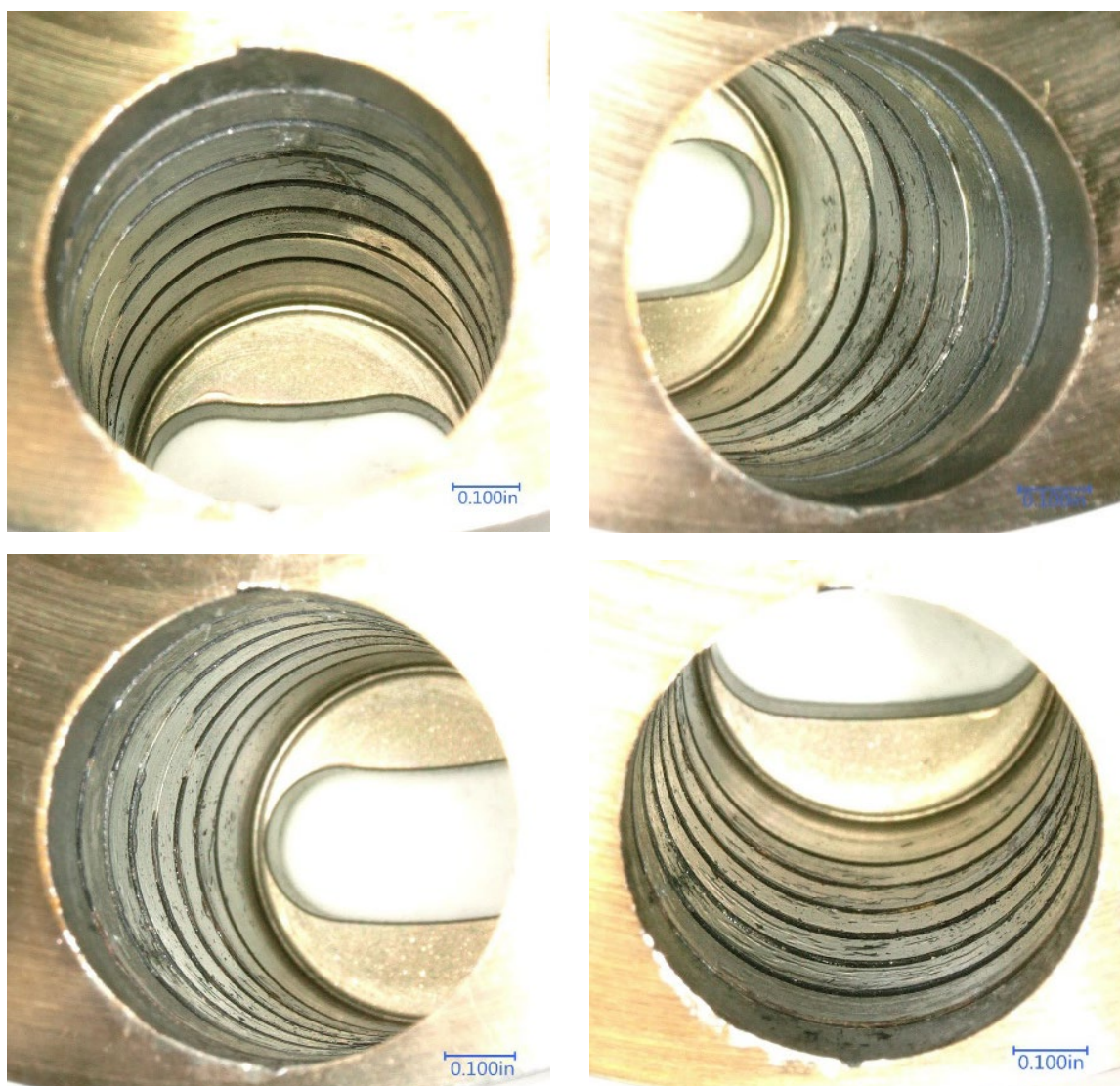


Figure 8: Digital microscope images showing around the entire circumference of bore 5 in fixed cylinder block S/N Y10-245-19 after the gold-colored liner had been removed.

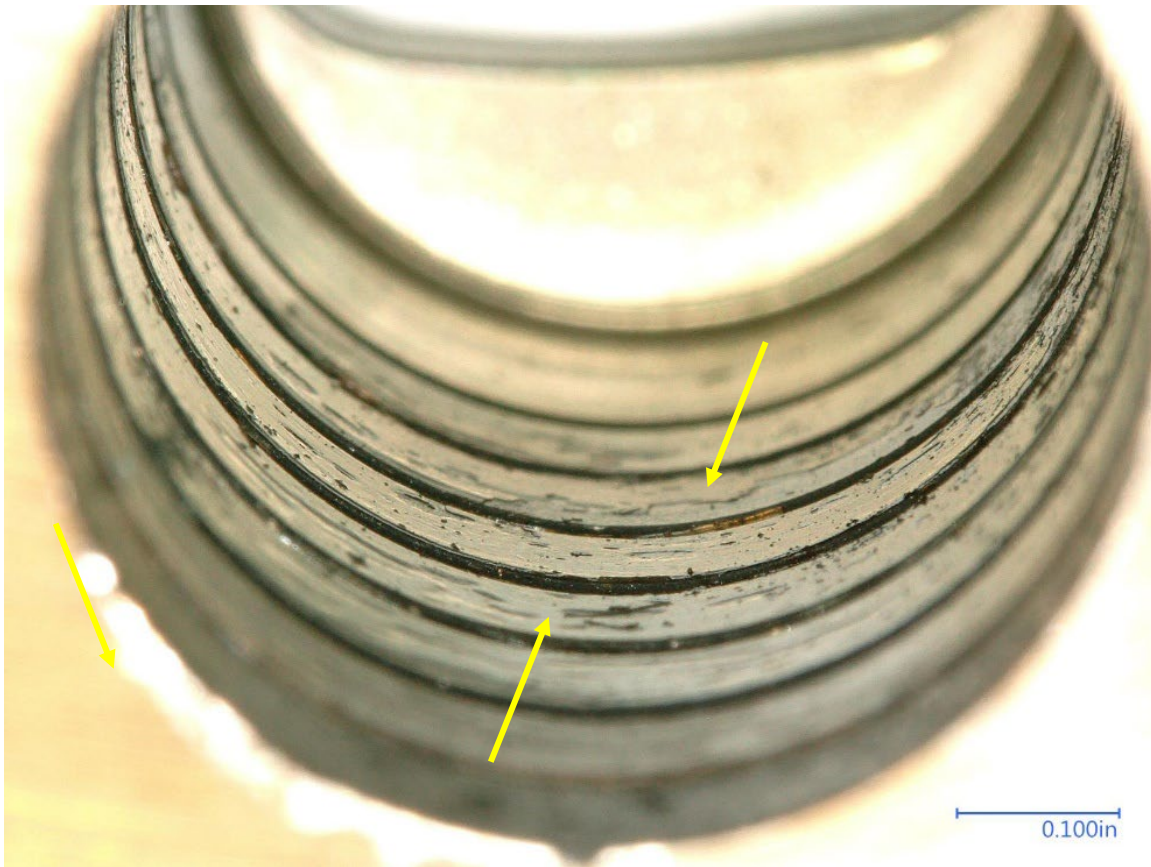


Figure 9: Digital microscope image showing a substance (yellow arrows) adhering to the ID surface of bore 5 in fixed cylinder block S/N Y10-245-19 after the gold-colored liner had been removed.

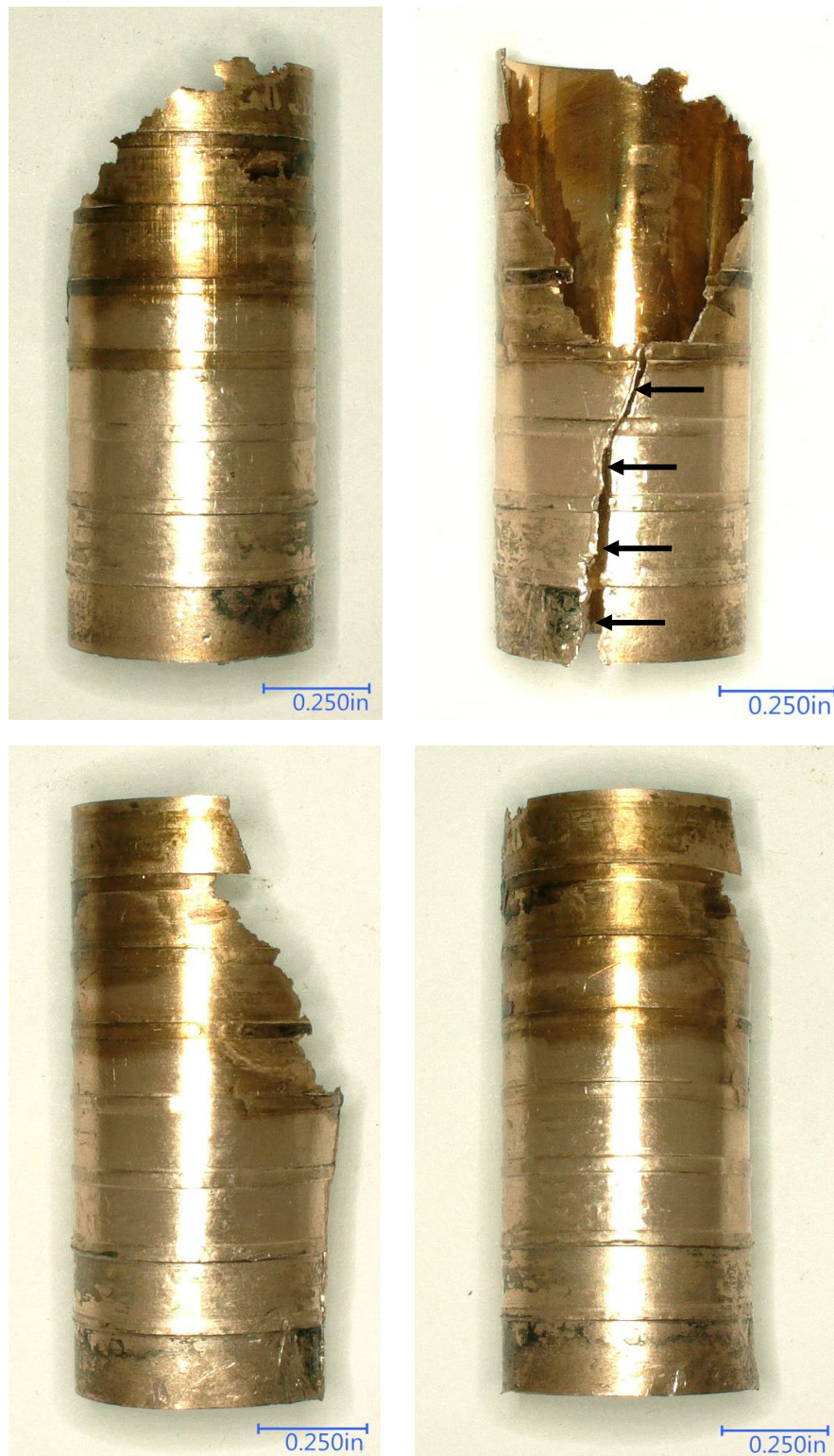


Figure 10: Digital microscope images showing the entire circumference of the gold-colored liner removed from bore 5 in fixed cylinder block S/N Y10-245-19. The black arrows point to the chiseled axial line that facilitated removal of the liner from the bore.



Figure 11: Digital microscope image showing the edges along the missing segment in the liner removed from bore 5 in fixed cylinder block S/N Y10-245-19. One edge (green dashed line) had thinned down to a knife edge. The other edge (black dashed line) was thicker and had features consistent with the liner separating in pieces.

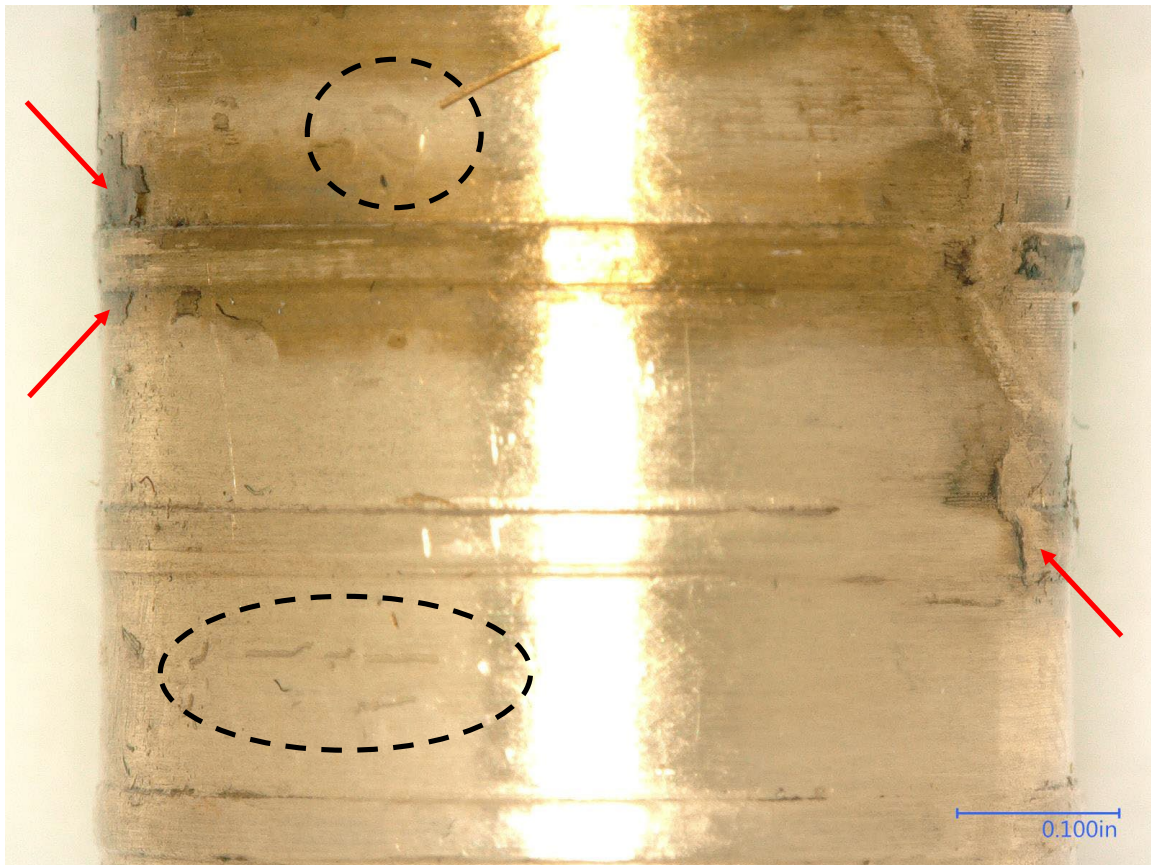


Figure 12: Digital microscope image showing OD surface of the gold-colored liner removed from bore 5 in fixed cylinder block S/N Y10-245-19. The black dashed lines encircle dents. The red arrows point to pieces of flattened gold-colored debris.

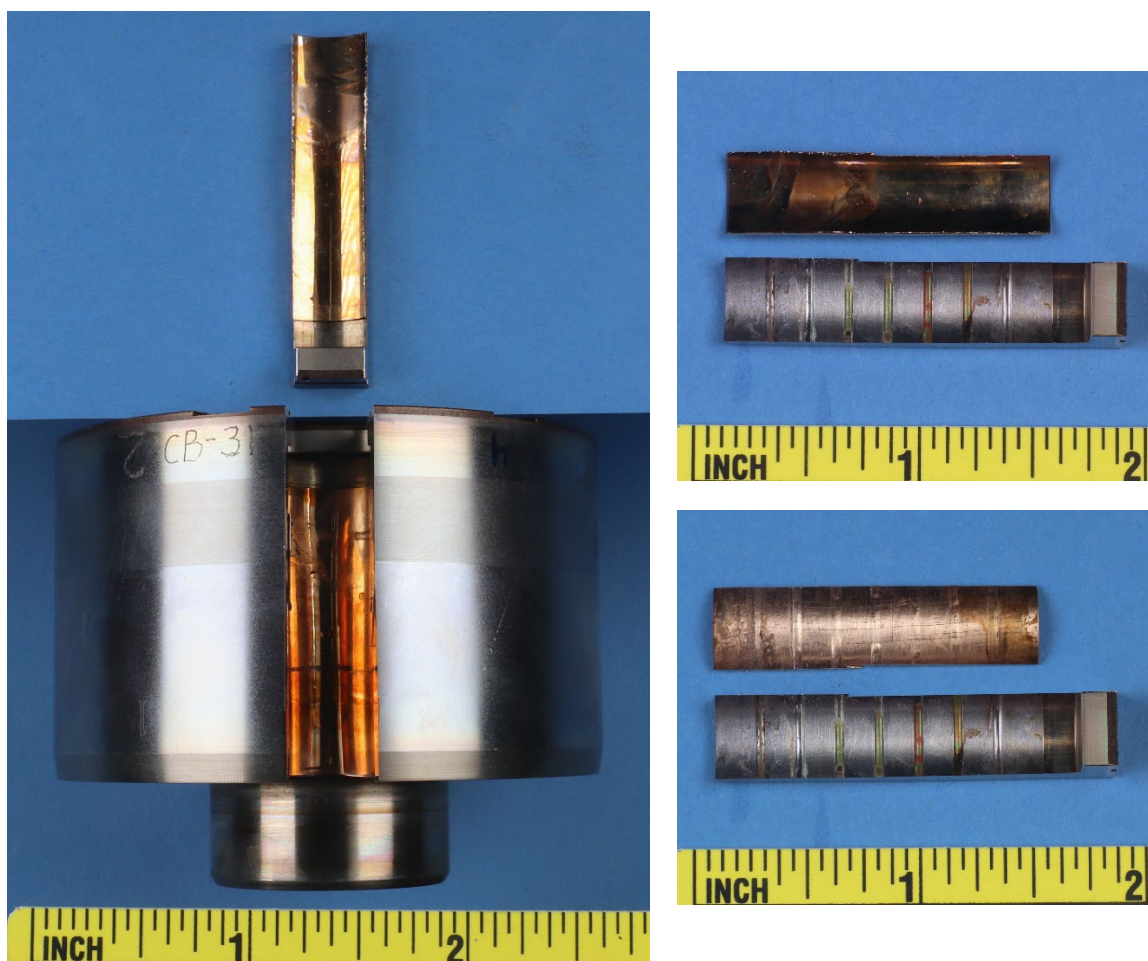


Figure 13: Overall and close-up photos of the pieces of liner and OD block side wall sectioned from bore 3 in fixed cylinder block S/N Y10-245-19.

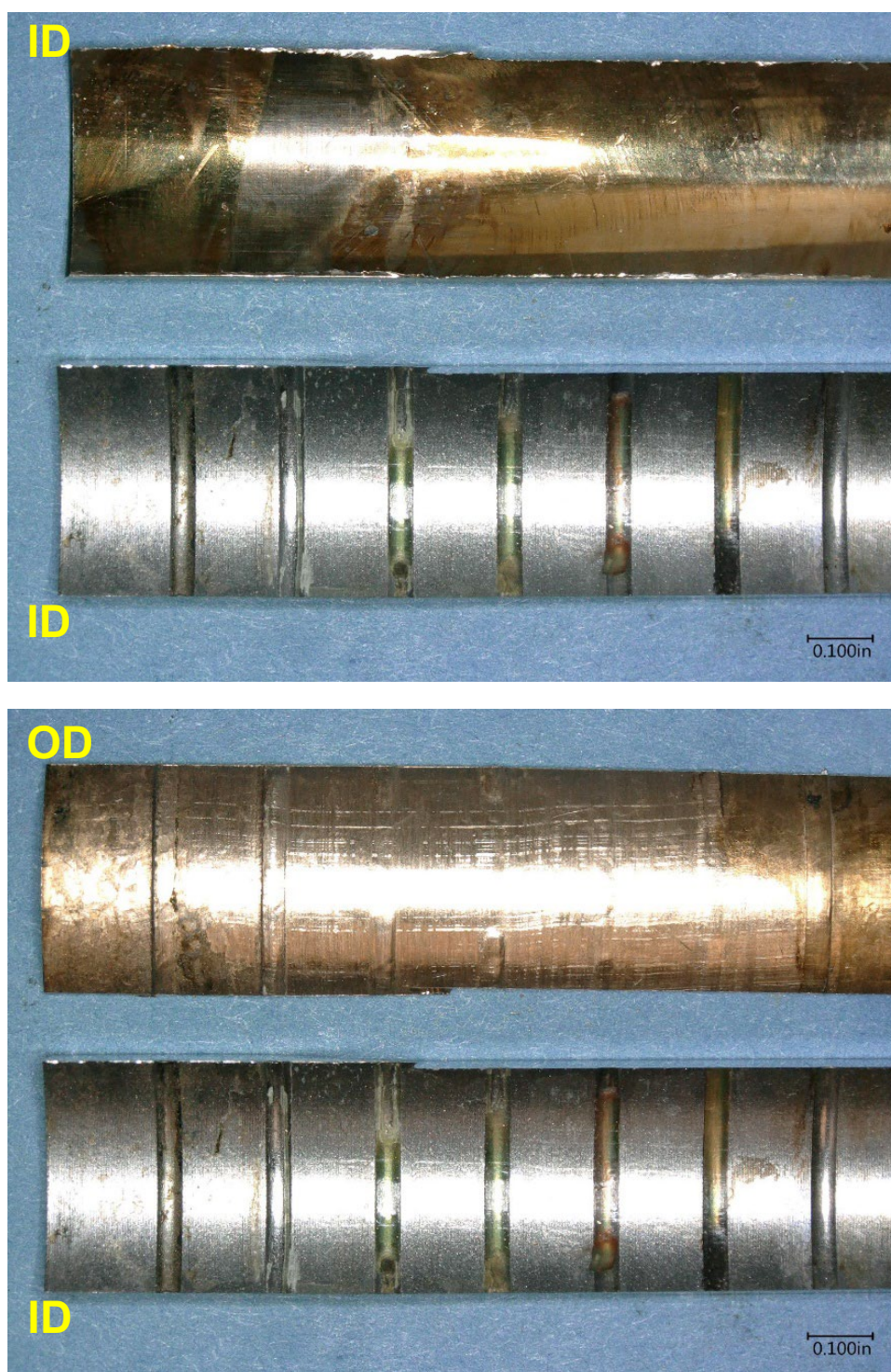


Figure 14: Digital microscope images showing the ID of the block piece and the ID and OD of the liner piece sectioned from bore 3 in fixed cylinder block S/N Y10-245-19.

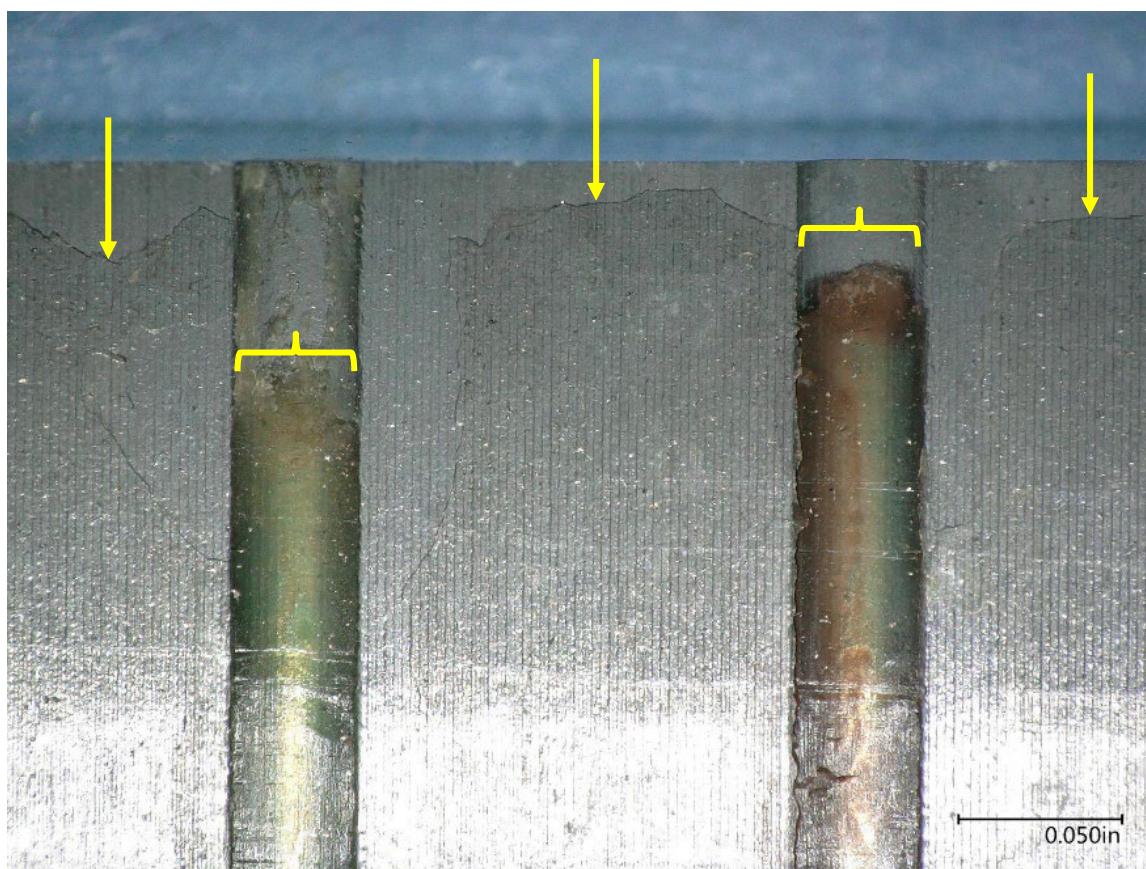


Figure 15: Digital microscope image showing the ID of the block piece sectioned from bore 3 in fixed cylinder block S/N Y10-245-19. The yellow arrows point to a translucent substance adhering to the ID surface of the bore. The yellow brackets indicate the substance also completely filling the machined grooves.

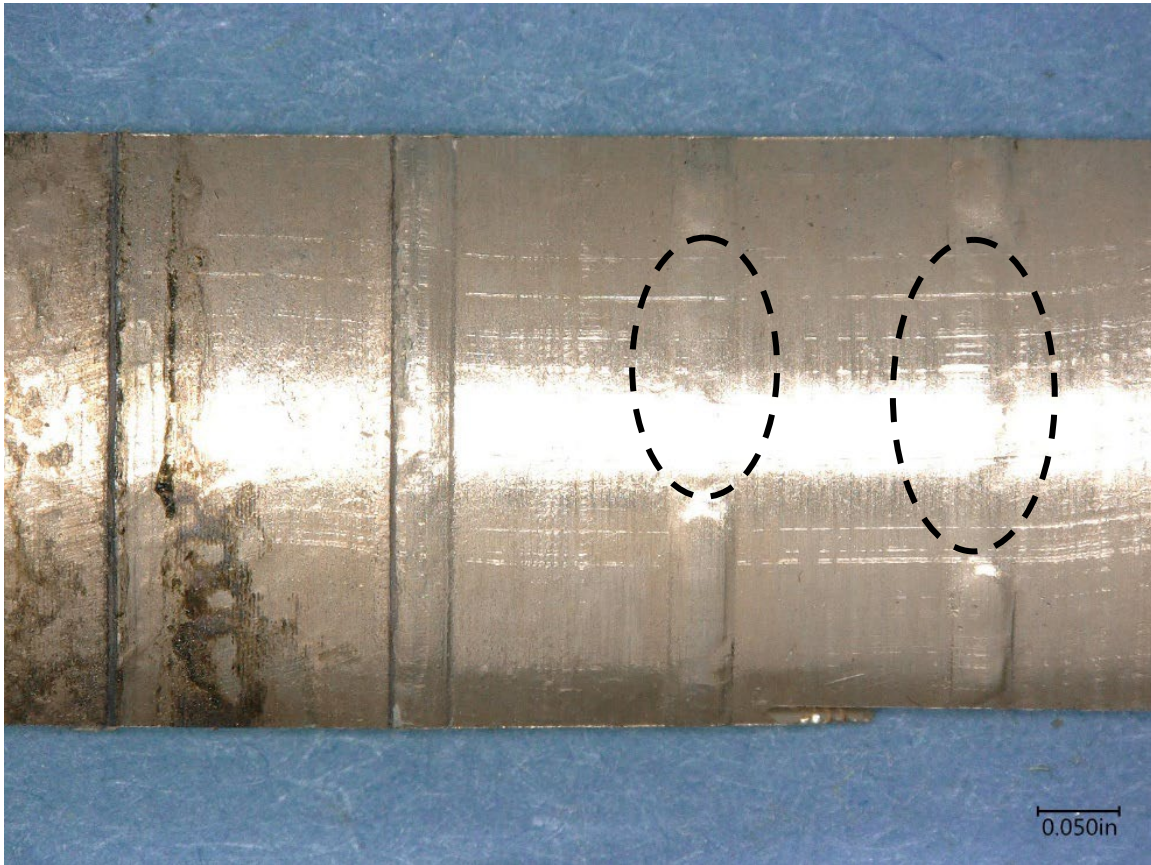


Figure 16: Digital microscope image showing the OD of the liner piece sectioned from bore 3 in fixed cylinder block S/N Y10-245-19. The black dashed lines encircle flat sections that mated with the machined grooves in the block piece filled with substance.

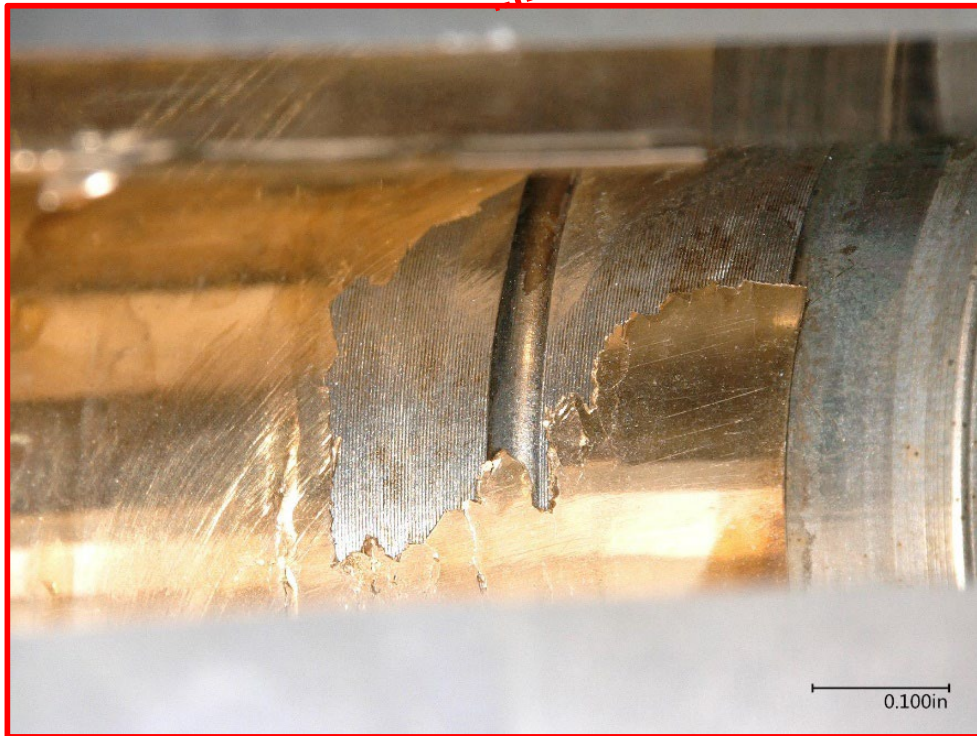
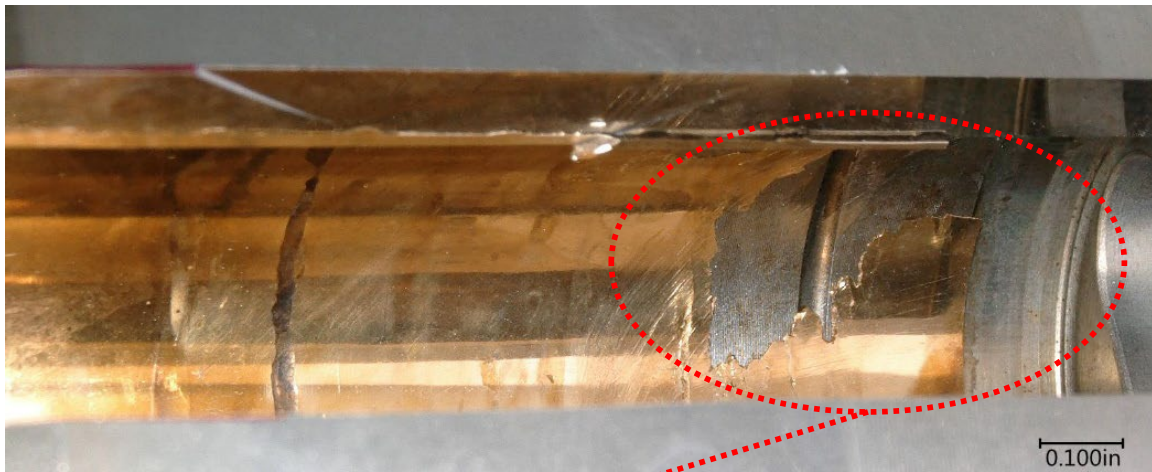


Figure 17: Digital microscope images showing the ID liner still installed inside bore 3 in fixed cylinder block S/N Y10-245-19.

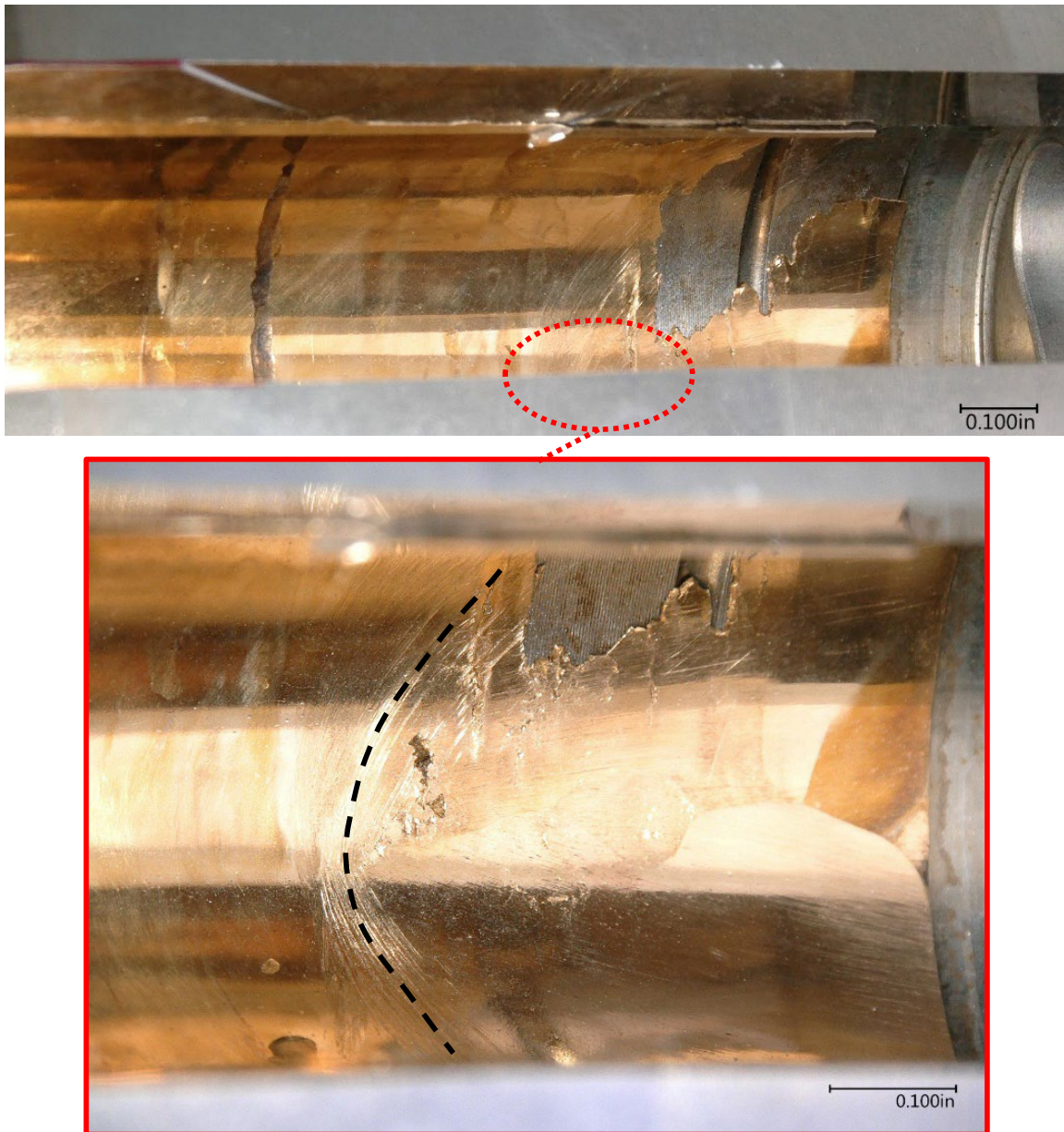


Figure 18: Digital microscope images showing the ID liner still installed inside bore 3 in fixed cylinder block S/N Y10-245-19. The black dashed line highlights a curved wear pattern visible on the liner ID surface.

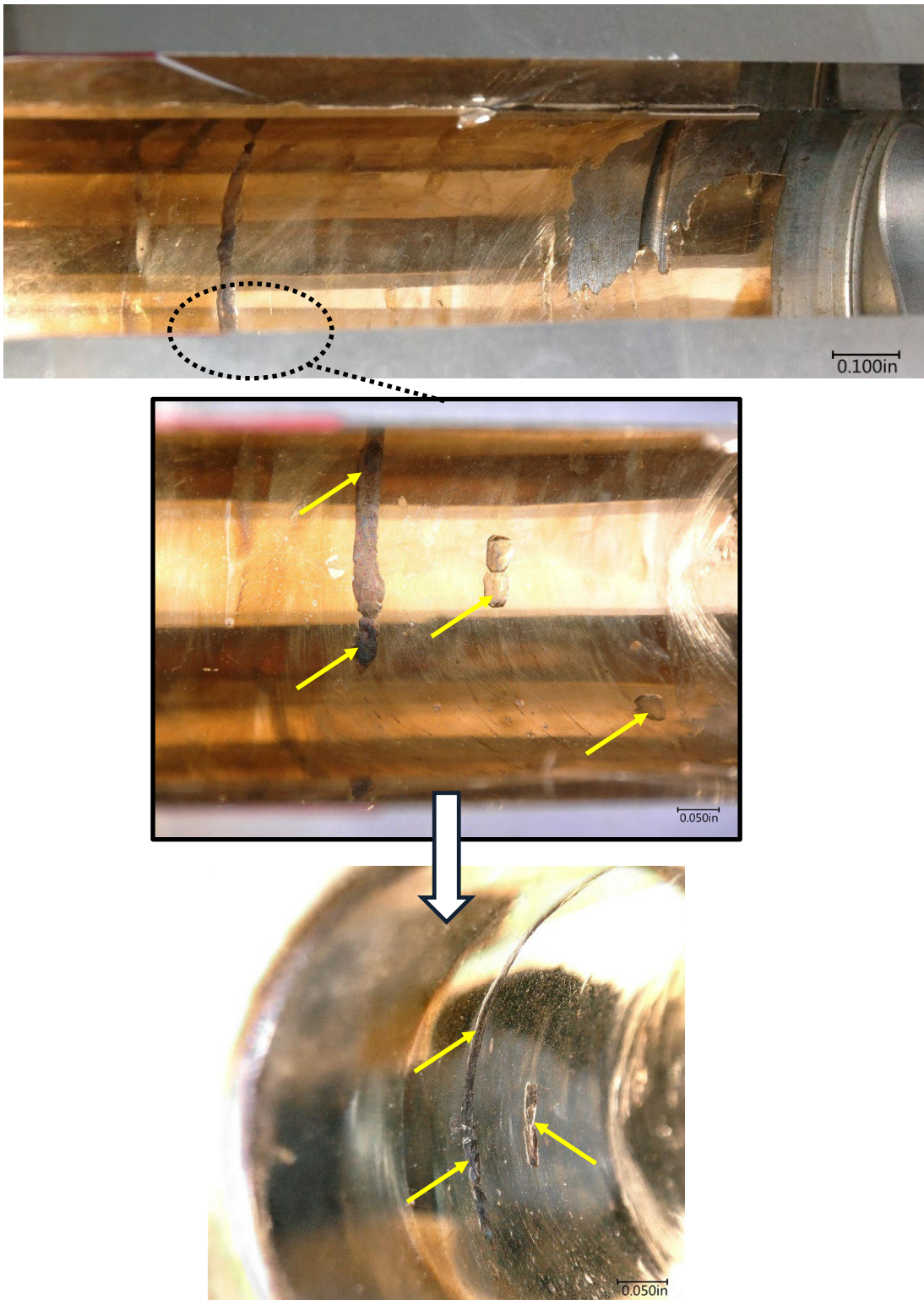


Figure 19: Digital microscope images showing the ID liner still installed inside bore 3 in fixed cylinder block S/N Y10-245-19. The yellow arrows point to areas where the liner had begun to wear through the thickness.

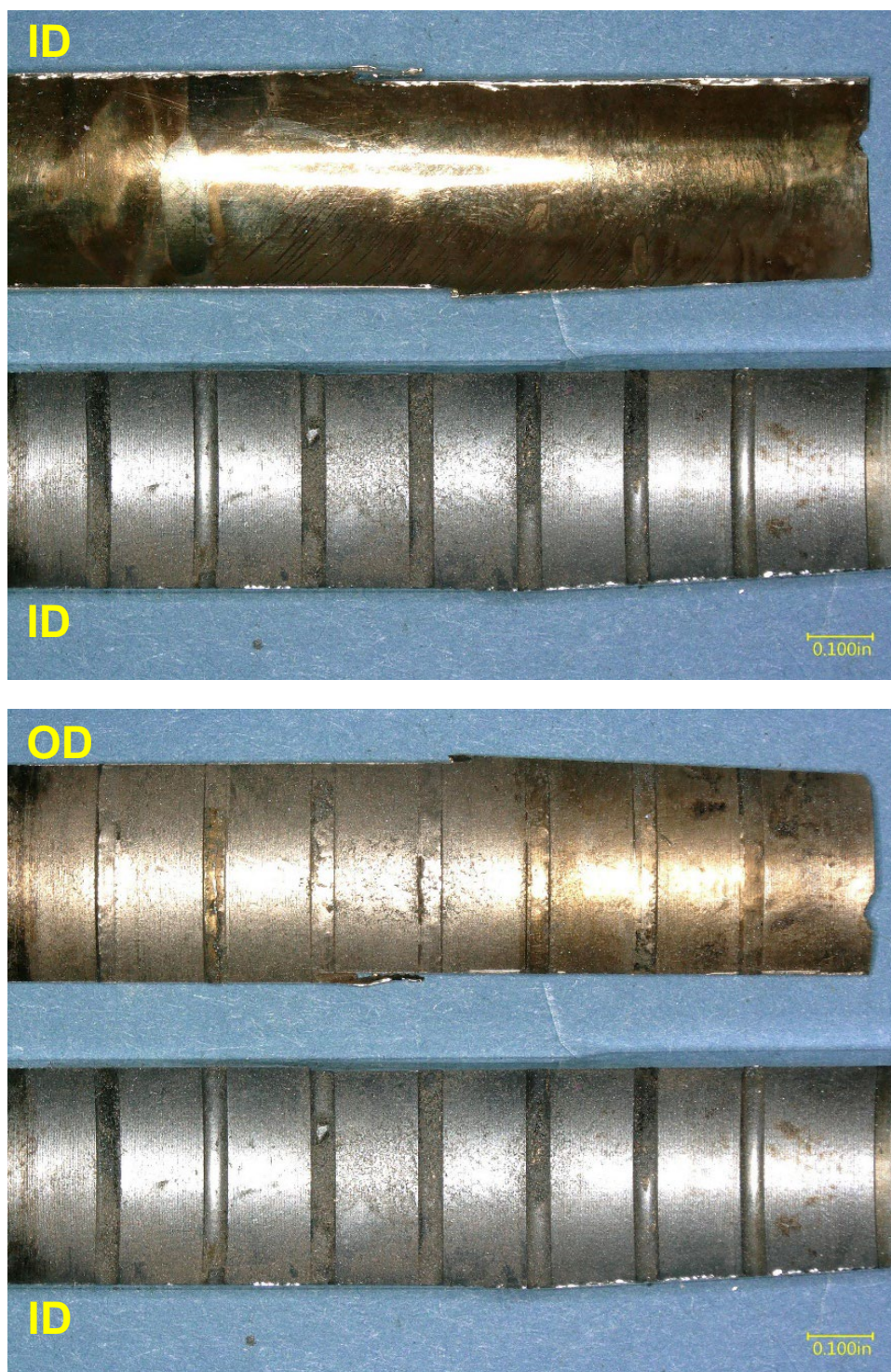


Figure 20: Digital microscope images showing the ID of the block piece and the ID and OD of the liner piece sectioned from bore 6 in fixed cylinder block S/N Y10-245-19.

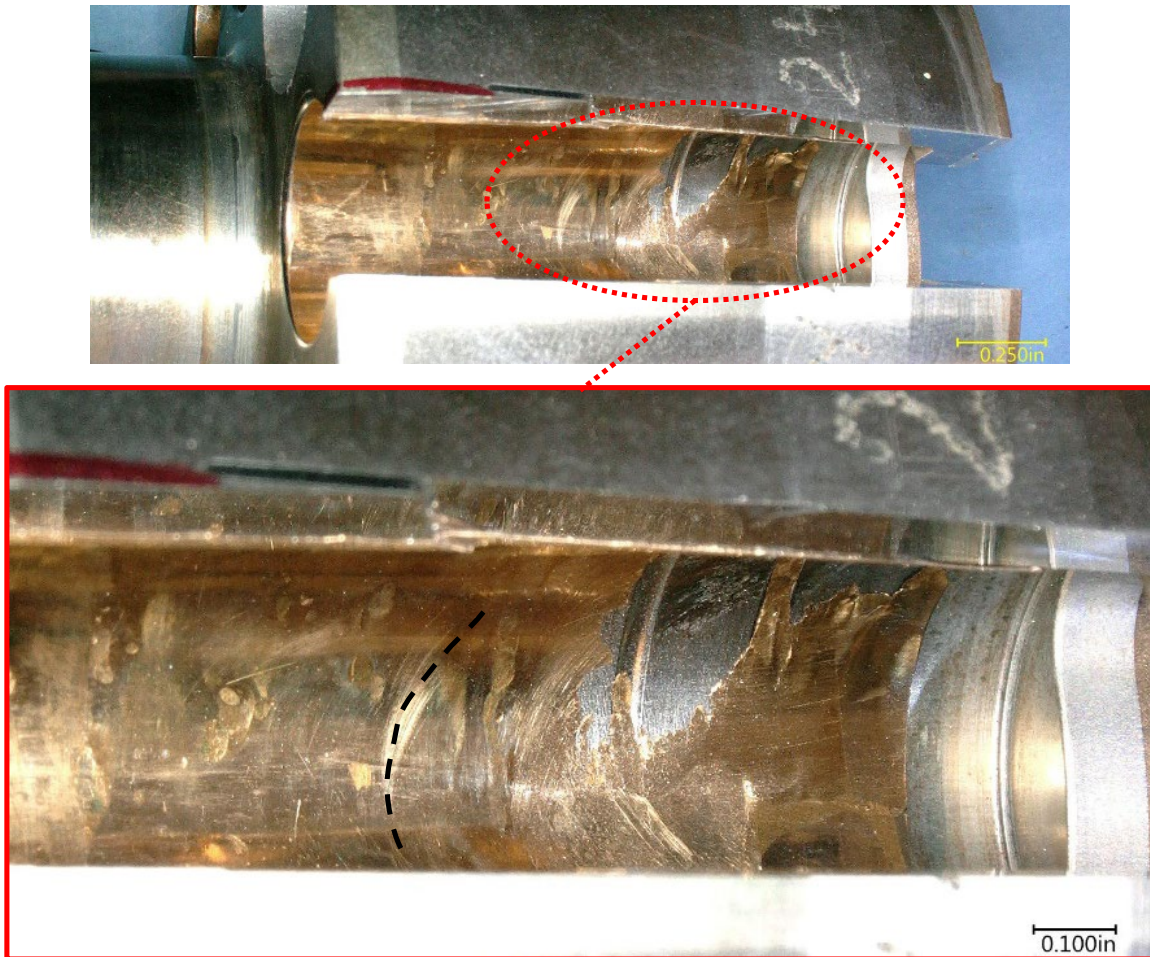


Figure 21: Digital microscope images showing the ID liner still installed inside bore 6 in fixed cylinder block S/N Y10-245-19. The black dashed line highlights a curved wear pattern visible on the liner ID surface.

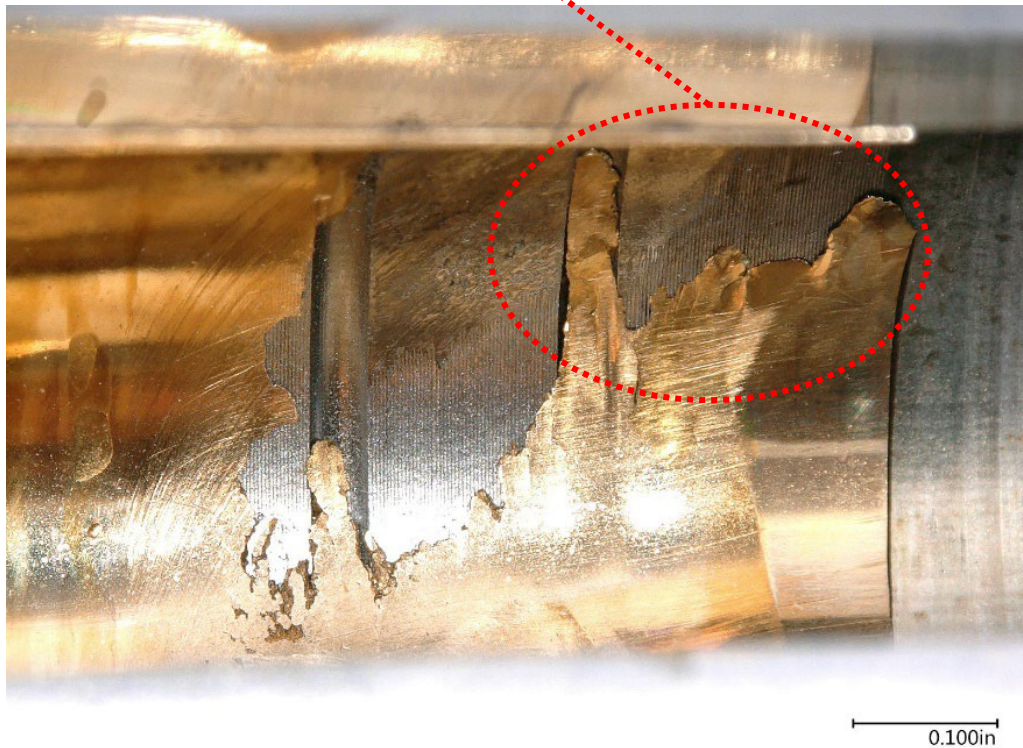


Figure 22: Digital microscope images showing the ID liner still installed inside bore 6 in fixed cylinder block S/N Y10-245-19.

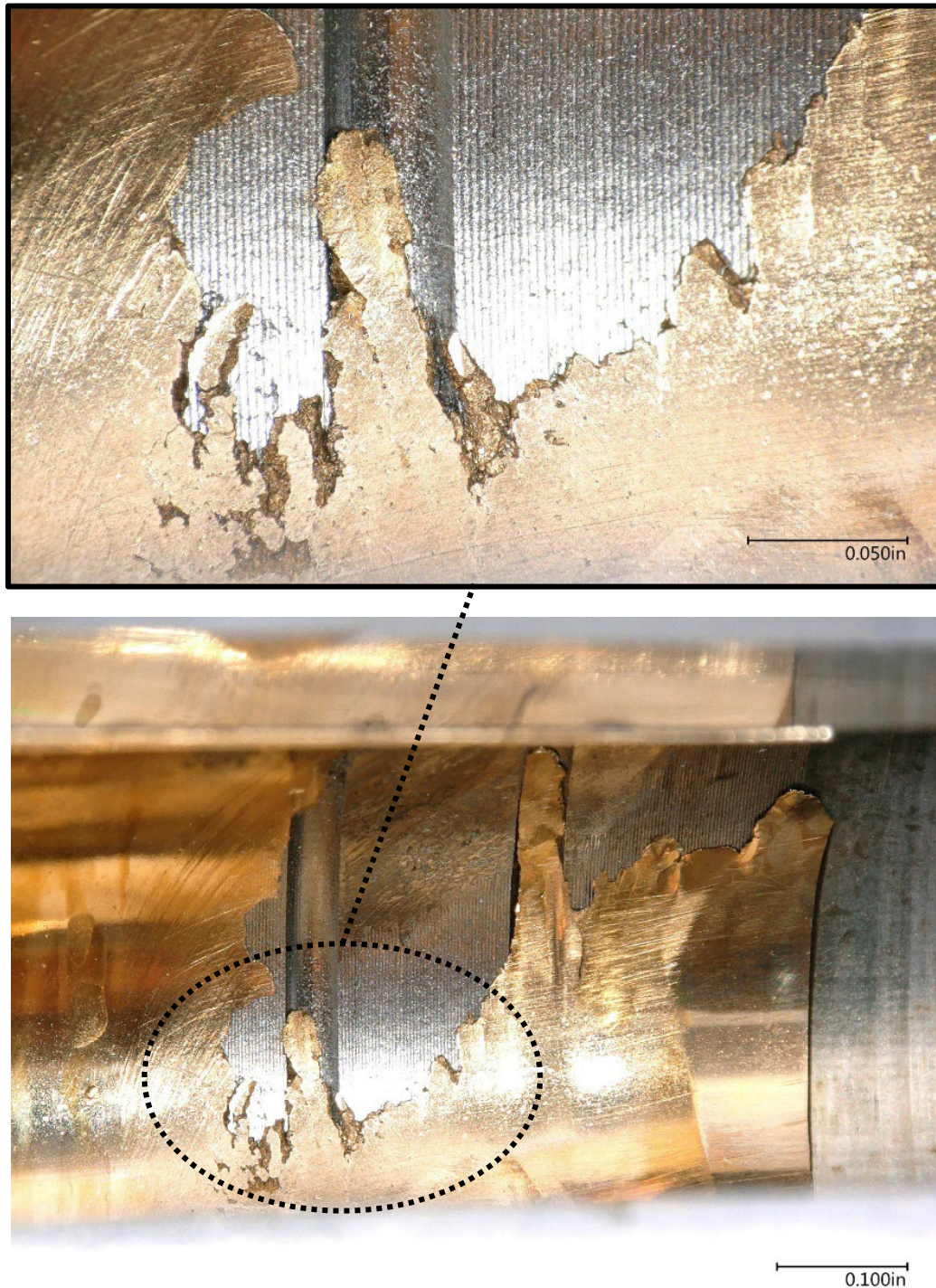


Figure 23: Digital microscope images showing the ID liner still installed inside bore 6 in fixed cylinder block S/N Y10-245-19.

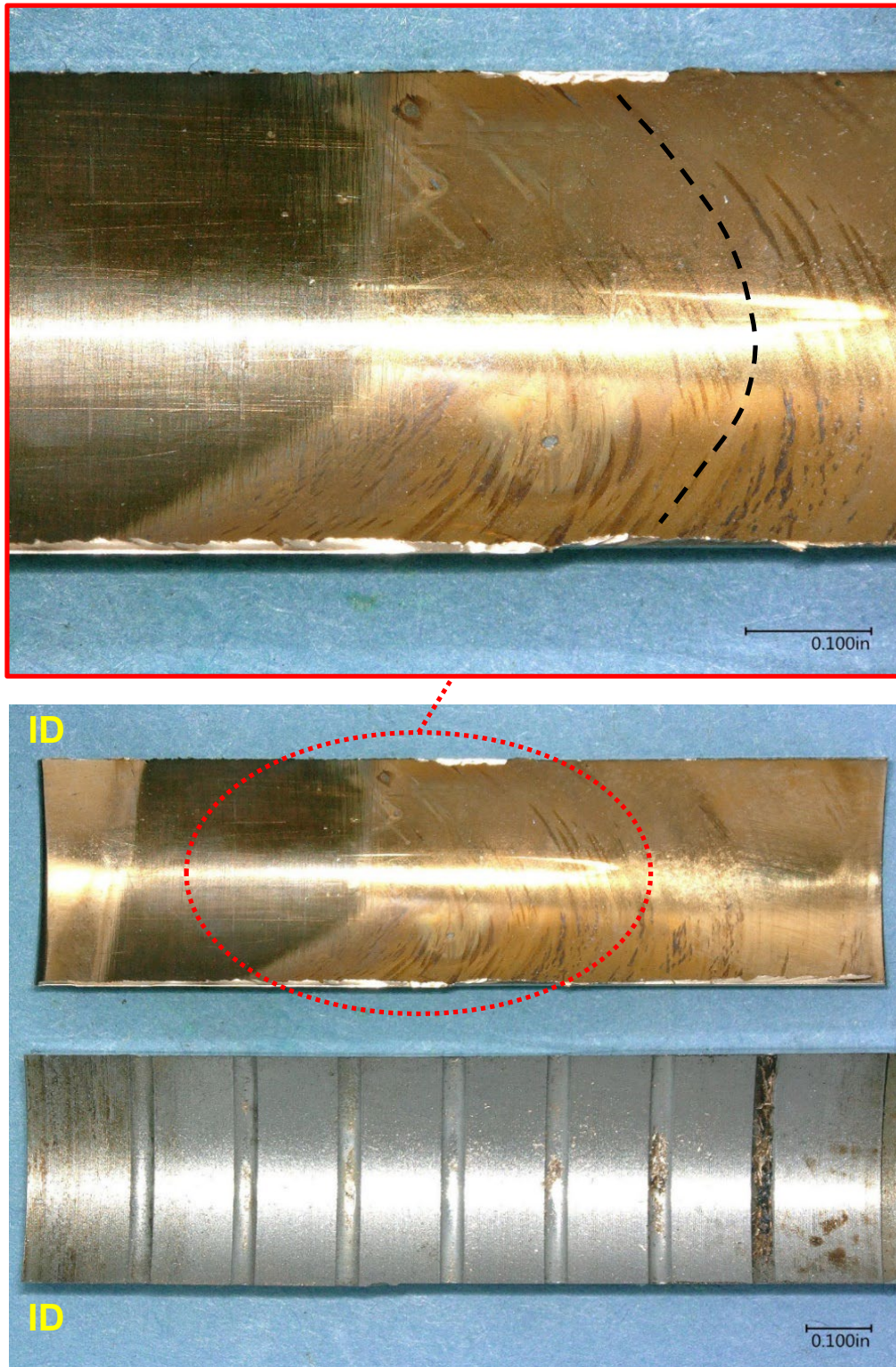


Figure 24: Digital microscope images showing the IDs of the block and liner pieces sectioned from bore 8 in fixed cylinder block S/N Y10-245-19. The black dashed line highlights a curved wear pattern visible on the liner ID surface.

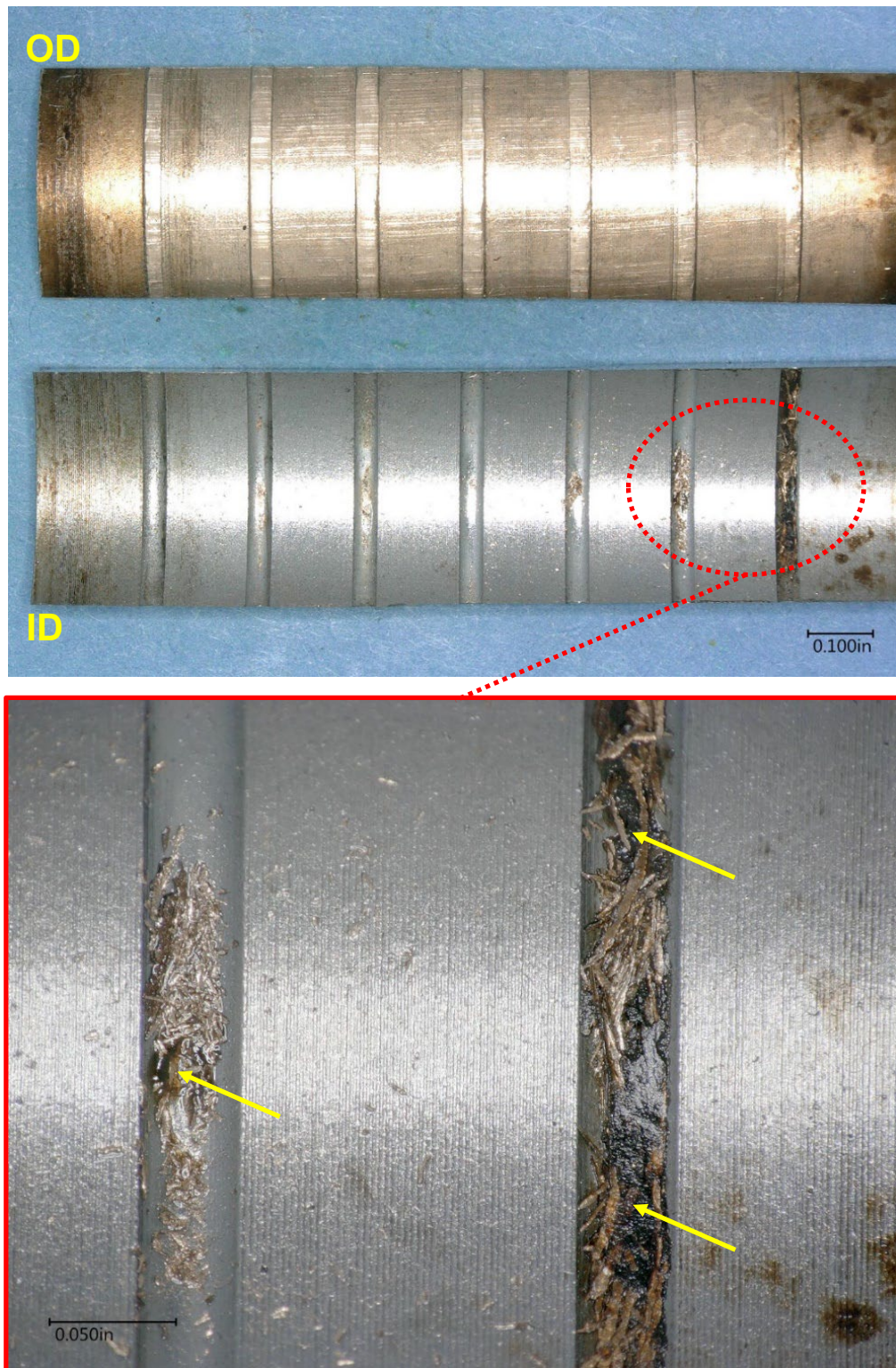


Figure 25: Digital microscope images showing the ID of the block piece and the OD of the liner piece sectioned from bore 8 in fixed cylinder block S/N Y10-245-19. The yellow arrows point to debris inside some of the machined grooves in the ID of the block.

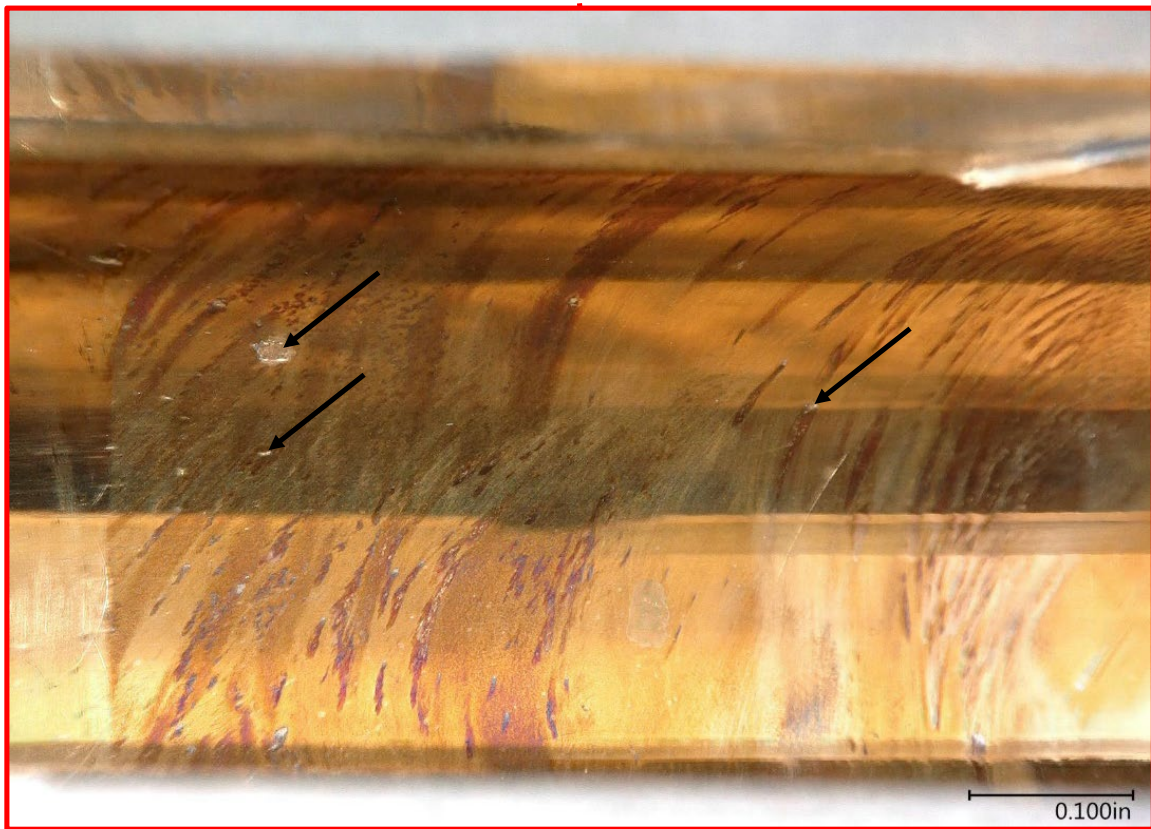
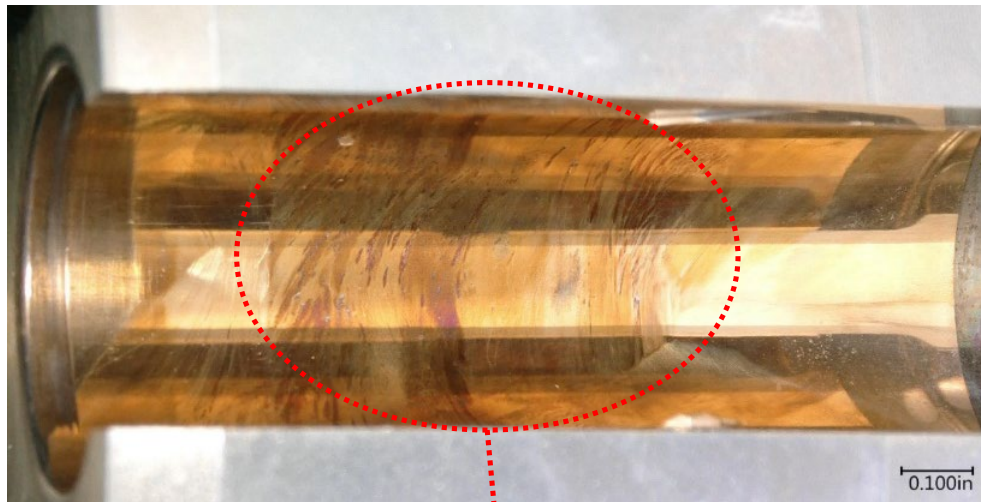


Figure 26: Digital microscope images showing the ID liner still installed inside bore 8 in fixed cylinder block S/N Y10-245-19. The black arrows point to areas where pieces of liner were missing.



Figure 27: Overall photo showing the packaging with identifying information and the components from the IDG from engine S/N 1157.



Figure 28: Close up photos of the pistons (top) and fixed cylinder block from engine S/N 1157. The fixed cylinder block was labeled S/N Y04-232-49.

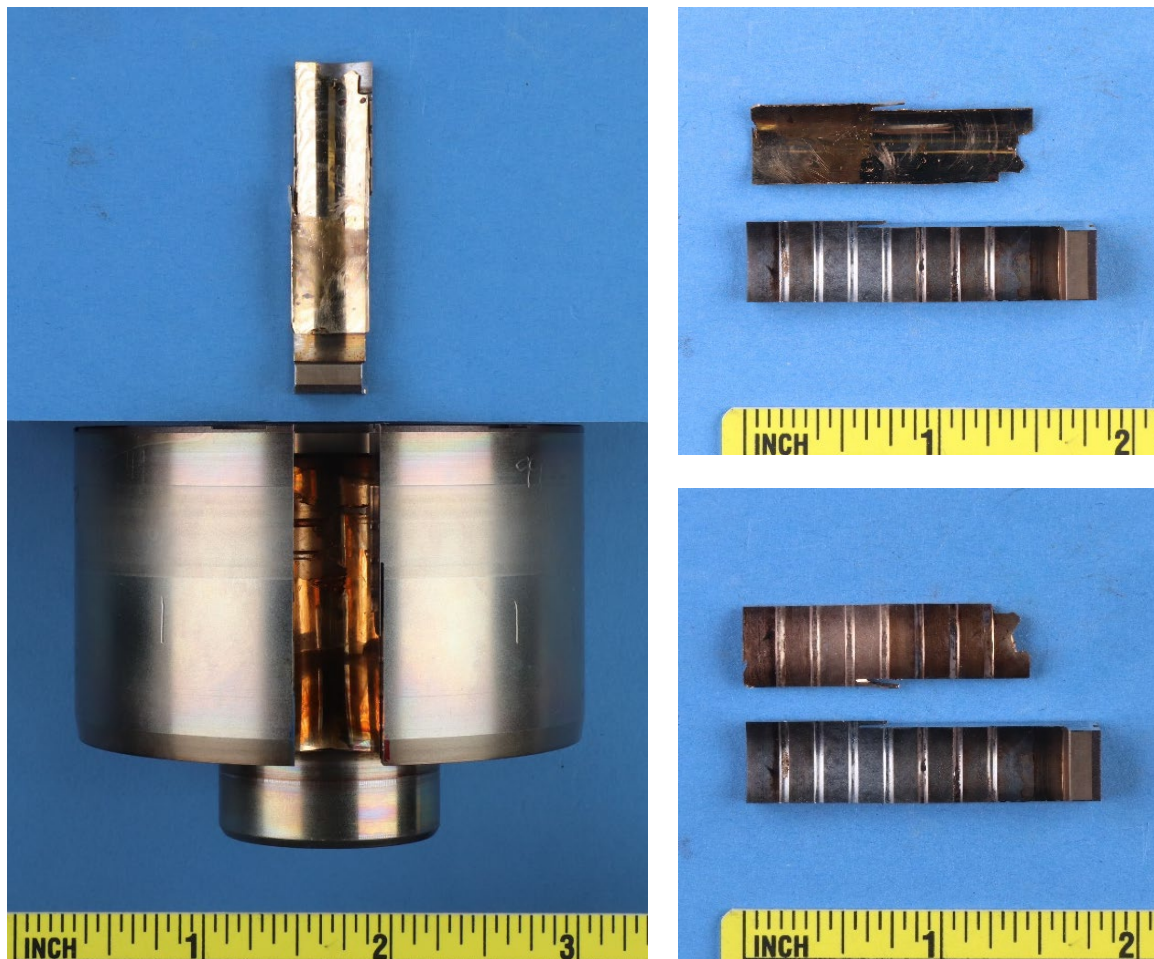


Figure 29: Overall and close-up photos of the pieces of liner and OD block side wall sectioned from bore 3 in fixed cylinder block S/N Y04-232-49.

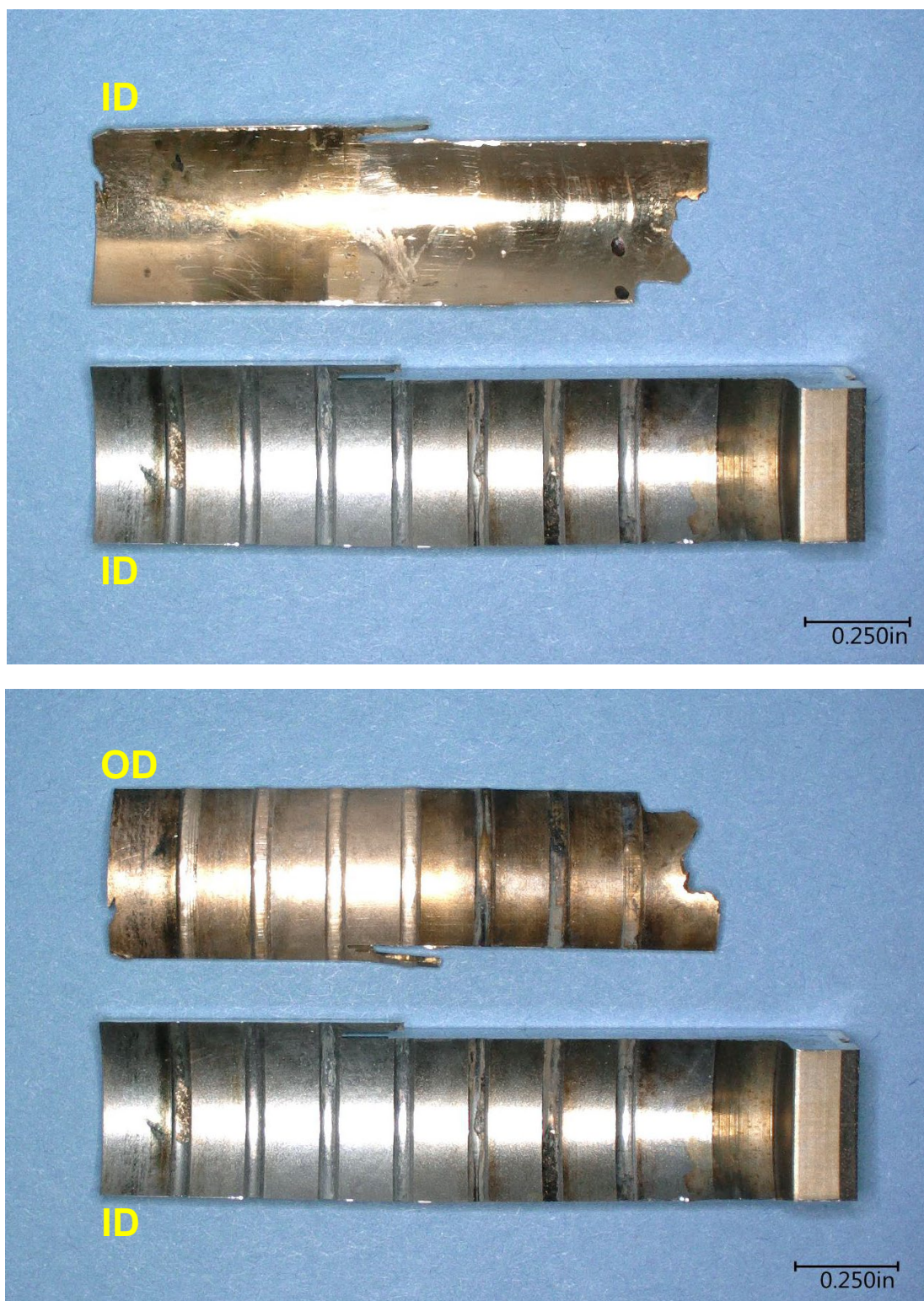


Figure 30: Digital microscope images showing the ID of the block piece and the ID and OD of the liner piece sectioned from bore 3 in fixed cylinder block S/N Y04-232-49.

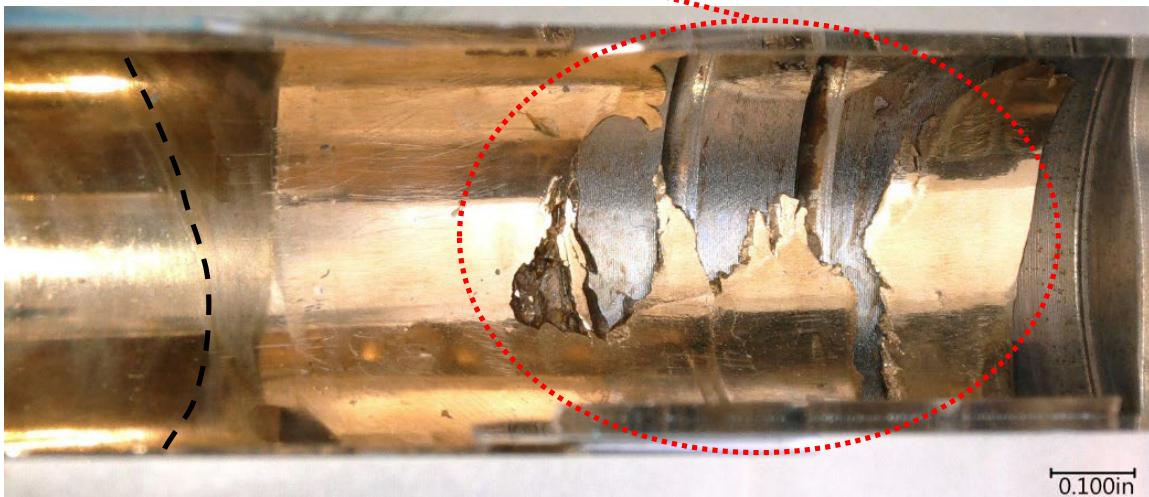
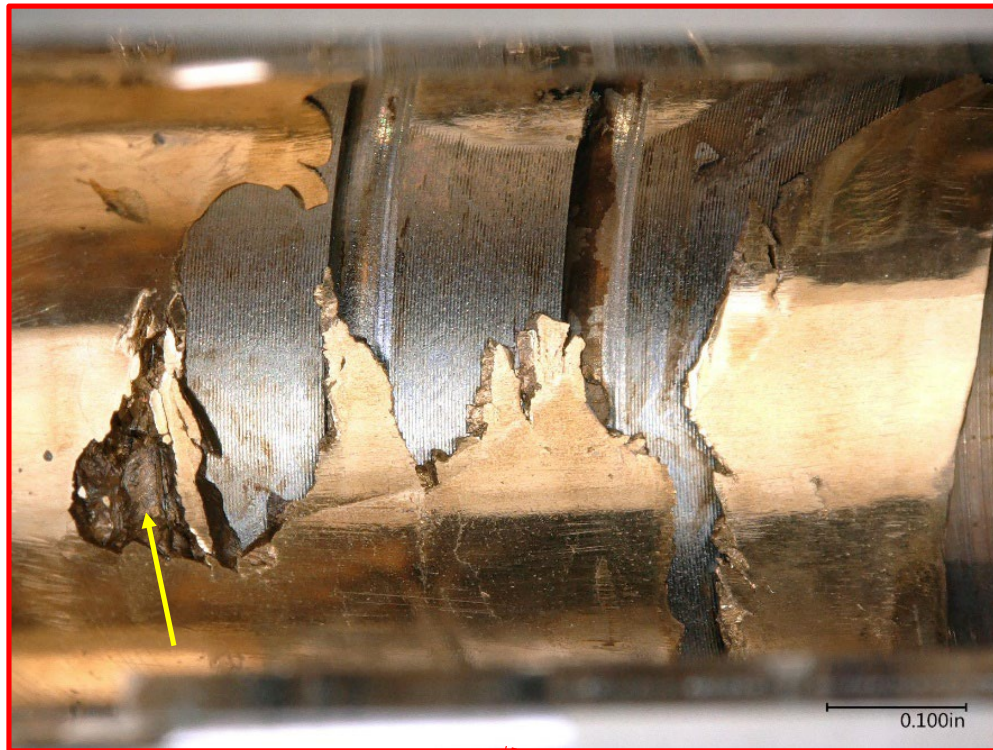


Figure 31: Digital microscope images showing the ID liner still installed inside bore 3 in fixed cylinder block S/N Y04-232-49. The black dashed line highlights a curved wear pattern visible on the liner ID surface. The yellow arrow points to a large piece from the top half of the liner thickness that had separated.



Figure 32: Overall and close-up photos of the pieces of liner and OD block side wall sectioned from bore 7 in fixed cylinder block S/N Y04-232-49.

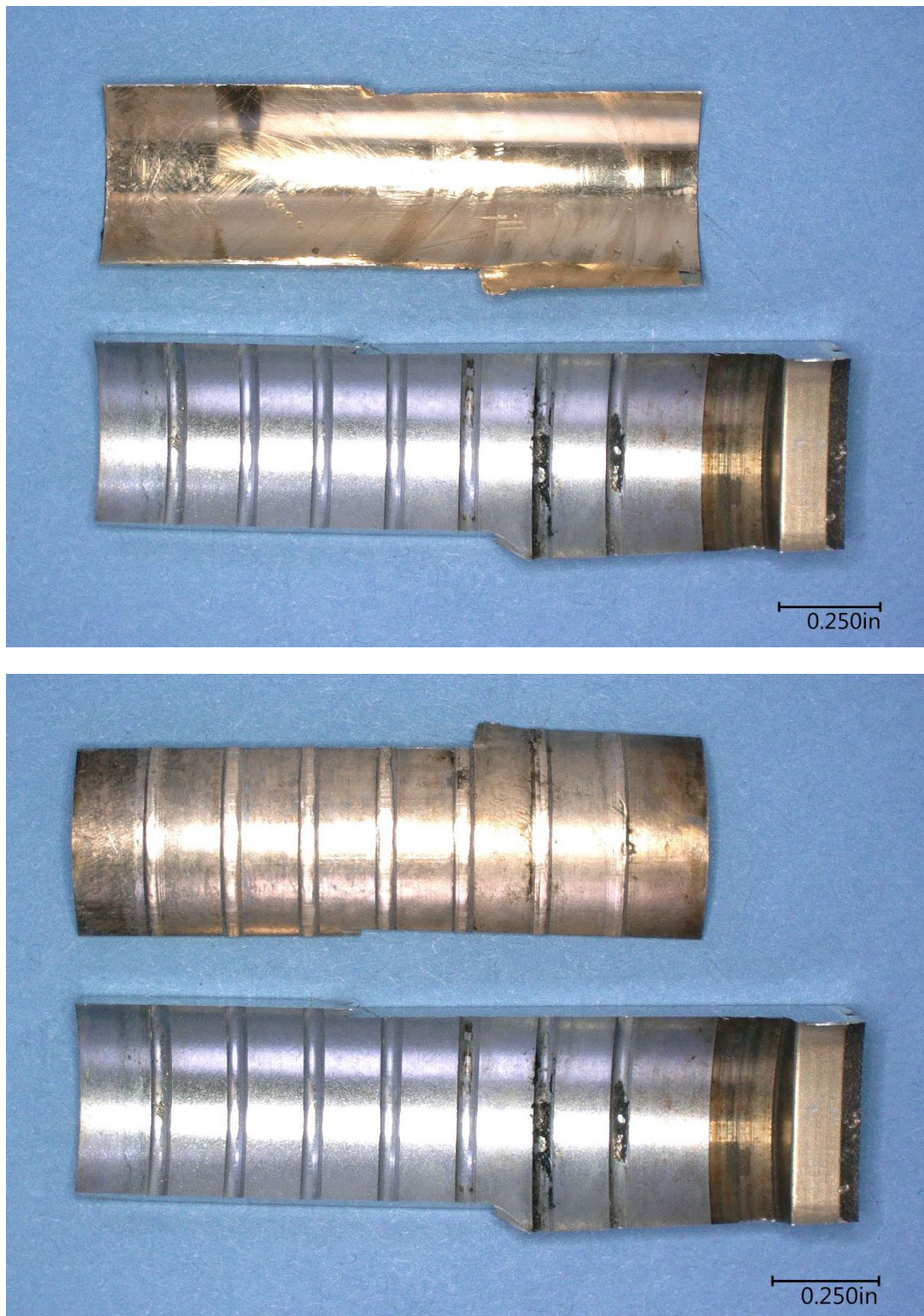


Figure 33: Digital microscope images showing the ID of the block piece and the ID and OD of the liner piece sectioned from bore 8 in fixed cylinder block S/N Y04-232-49.

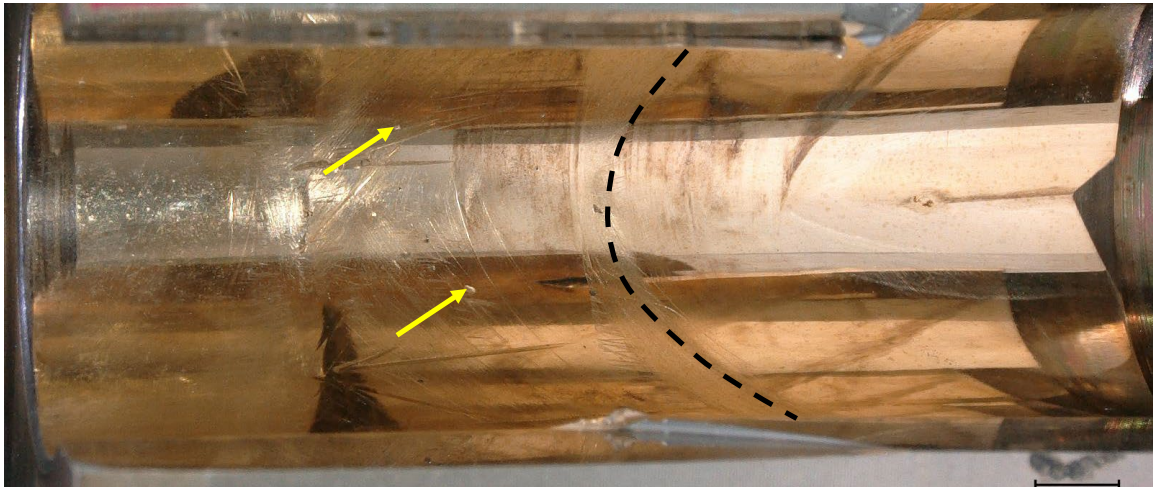


Figure 34: Digital microscope images showing the ID liner still installed inside bore 7 in fixed cylinder block S/N Y04-232-49. The black dashed line highlights a curved wear pattern visible on the liner ID surface. The yellow arrows point to areas where pieces of liner were missing.



Figure 35: Overall photo of the exemplar fixed cylinder block submitted by the OEM.

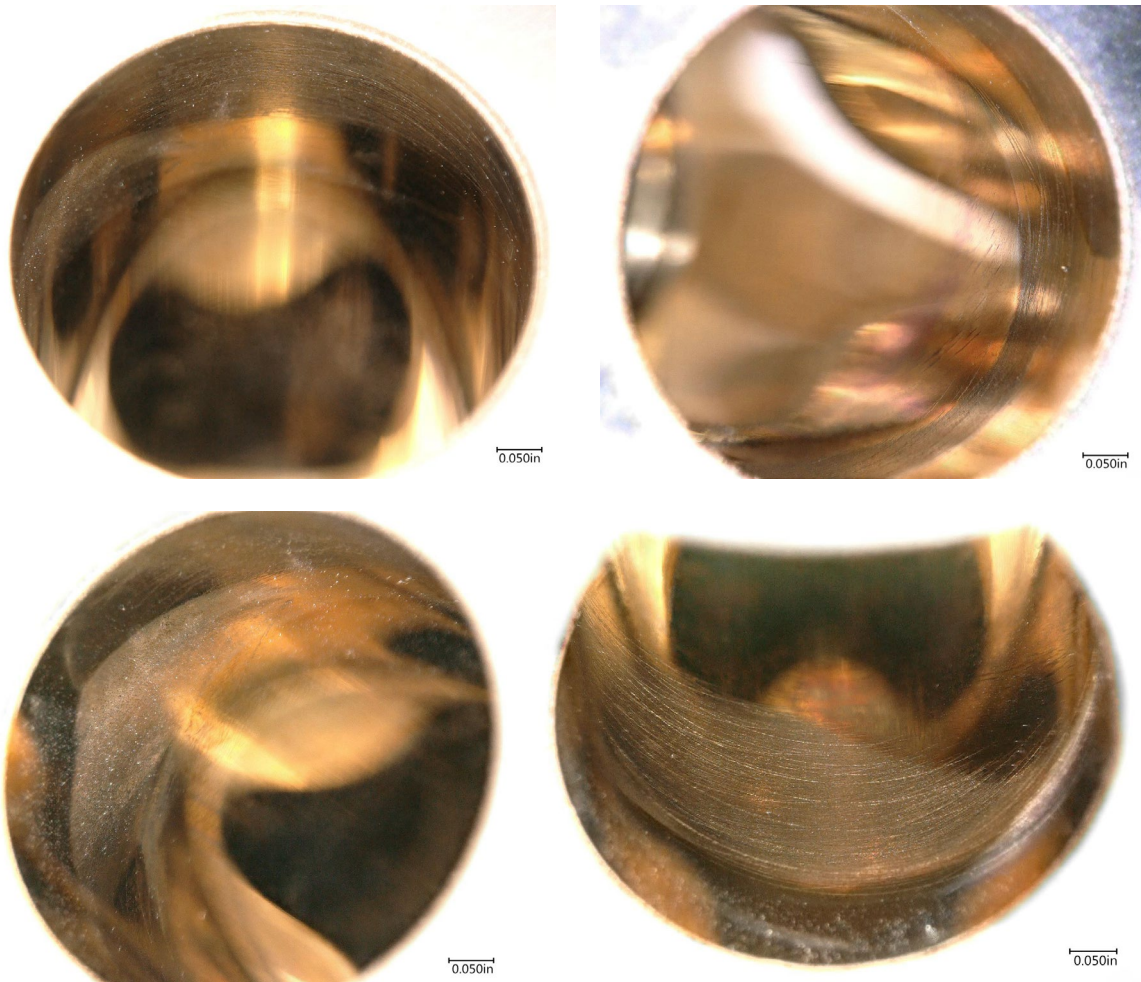


Figure 36: Digital microscope images showing around the entire circumference of a representative bore in the exemplar fixed cylinder block submitted by the OEM.

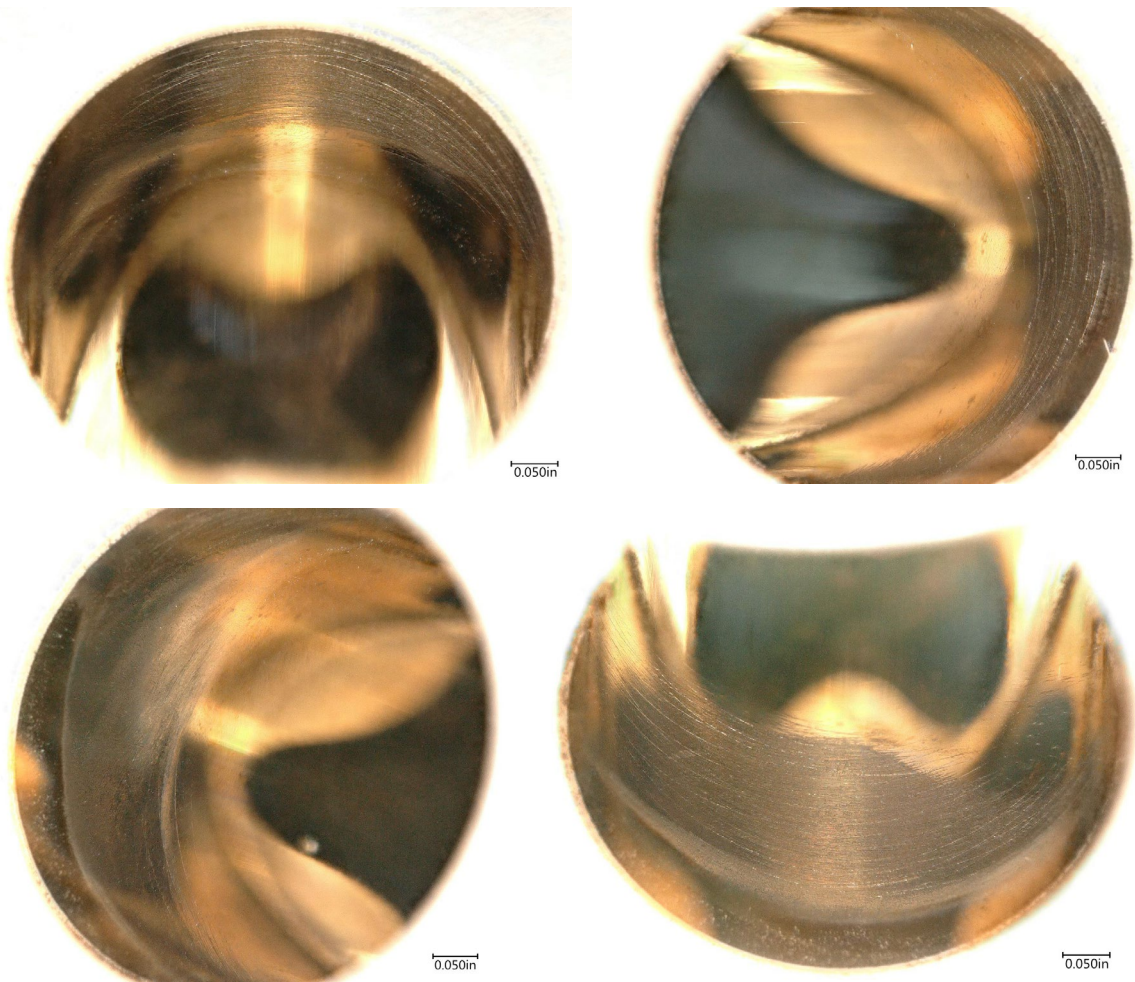


Figure 37: Digital microscope images showing around the entire circumference of a second representative bore in the exemplar fixed cylinder block submitted by the OEM.