Toolmarks: Examining The Possibility of Subclass Characteristics

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ABSTRACT

The identification of toolmarks to the tool working surface that produced them is dependent upon the significant reproducibility of individual characteristics. Subclass characteristics produced incidental to the manufacturing process can occur on several tool working surfaces. While some types of manufacturing processes impart individual characteristics exclusively, others may produce subclass characteristics on numerous tools. In this study, consecutively manufactured tools including pliers, cutters, punches, and chisels were examined for the presence of subclass characteristics and any possible effect on toolmarks produced by the tool. The manufacturing method used to produce the tool working surface is discussed as well as the effect of different manufacturing methods used to produce the same tool type.

Introduction

There has been a significant amount of published research discussing the toolmarks produced using consecutively rifled barrels on fired bullets and consecutively manufactured breech or bolt faces on fired cartridge casings. These areas of firearms are simply specialized tools creating toolmarks on very specific surfaces. Previous published research specifically applied to hand tools includes screwdrivers, bolt cutters, drill bits, knives, crimping dies, tongue and groove pliers, and chisels[1,2,3,4,5,6,7,8,9,10,11,12,13]. In most of this research, the tools used have been consecutively manufactured, with toolmarks generated on a variety of surfaces. The consecutively manufactured tools are used because they offer the best possibility of observing tool working surfaces that produce the possibility of subclass characteristics and similar individual characteristics. As the tools that are being used to manufacture these tool working surfaces wear and change, so to do the resulting toolmarks that they produce. Tools that are not consecutively manufactured have the least occurrence or potential for similar subclass characteristics or a similarity in individual characteristics.

A general over-view of manufacturing processes and toolmark examination has been previously published[14]. The working surface of a tool refers to the actual part of a tool that comes in contact with another surface and produces a toolmark. If the tool is cutting pliers for example, then the working surface is the actual cutting surface of the tool. The AFTE Theory of Identification defines subclass characteristics as "discernable surface features of an object which are more restrictive than class characteristics in that they are produced incidental to manufacture; are significant in that they relate to a smaller group source, and can arise from a source which changes over time"[15]. These subclass characteristics are sometimes referred to as "family characteristics", or "carry over". It is very important to be able to distinguish between subclass characteristics and individual characteristics when comparing and evaluating toolmarks (See Photo 1).

There are two ways in which subclass characteristics can affect a toolmark examination. The first involves a single manufacturing tool, whose working surface changes over time, producing toolmarks on individual objects. For example, in the production of cut nails, one cutter will produce thousands of nails. The toolmark produced by the cutter will be observed on these nails, but as the tool working surface of the cutter begins to dull and change, the resulting toolmarks on the nails will exhibit these changes. In this way, nails that exhibit similar toolmarks will be a smaller group, or subclass, of the toolmarks observed on the entire production run of nails manufactured with the cutter[16].

When producing objects using molds, any toolmarks present on the molds will be imparted to the objects made using those molds. If a master object is used to produce hundreds of molds, then each of those molds will exhibit the toolmarks or characteristics of the master. Any objects then made using those molds will exhibit the same characteristics of the master as well as any other accidental characteristics that may have

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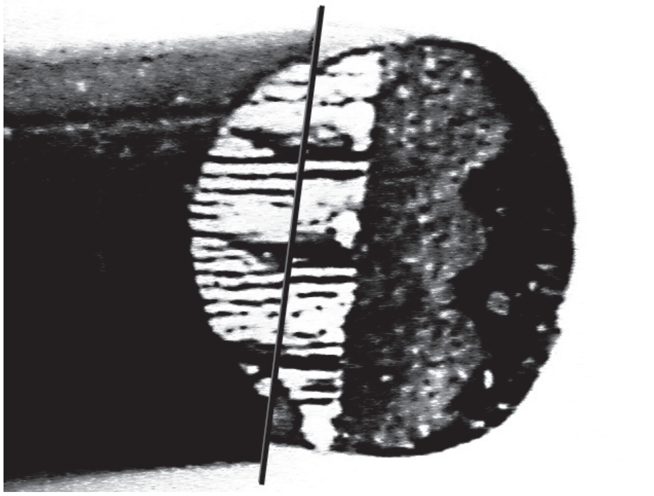

Photo 1: Striated Subclass Toolmarks From Two Different Tools From a Broach Cut Serrated Blade

occured to the molds during their manufacture. In this way, although the objects are produced by a single mold, they are actually just a subclass of the master, with the addition of any accidental features that may have appeared on the mold.

The second way in which subclass characteristics can affect a toolmark includes toolmarks produced during manufacturing on a tool working surface that can also be produced on other tool working surfaces. For example, if a milling process is used to create a tool working surface, the toolmarks produced will be parallel, evenly spaced, and exhibit the same width and depth. The tool working surface will exhibit these same toolmarks on the one produced before it and after it. They are subclass characteristics. There may also be individual characteristics present, and it is important to be able to distinguish between the two types. Subclass characteristics may be recognized by an examination of the toolmark when the examiner has a working knowledge of various types of manufacturing processes and the types of toolmarks they produce. It may then also be possible to differentiate between the subclass characteristics and individual characteristics; however, it may be necessary to have the actual tool working surface to examine in order to do this. It may also be necessary to obtain similar examples of the tool working surface from other similar tools to determine the subclass potential and its influence on toolmarks that are produced.

Manufacturing Methods

The tool working surfaces used to produce the toolmarks evaluated in this research were manufactured using a variety of methods. Although, in general, many different types of manufacturing methods are used in the production of a tool, the primary interest of a toolmark examination is in the area of the tool that is creating the toolmark, the *tool working surface*.

For the tools used in this study, manufacturing methods include forging, milling, broach cutting, grinding, and hand filing. The actions of these methods on the tool working surface will affect the type of toolmarks created on that surface and will affect the resulting toolmarks that are produced. These processes may impart subclass characteristics and individual characteristics.

In the drop forging process, metal is shaped by heating it and rapidly impacting it between a punch and die to form the desired shape. Several cavities within the same die can be used to obtain the final shape, or a series of punch and die operations can be used. The toolmarks produced on the workpiece result from the surface of the die and can be found on many samples made with that die (See Photo 2). These are subclass characteristics.

Milling is a cutting operation that shapes the workpiece by removing material in the form of chips using a cutter with multiple teeth. The milling process can be done using a variety of methods including arbor milling and end milling. In arbor milling, the cutting occurs parallel to the axis of tool rotation. It is basically a circular wheel with the teeth around it's circumference. In end milling, material is removed by the end of the cutter and the sides. It can be thought of as a reamer that rotates on an axis perpendicular to the surface being cut. Milling toolmarks can appear circular or parallel depending upon tool rotation, and are evenly spaced with an evenly appearing height and width (See Photo 3). These are generally subclass characteristics.

In a broaching operation, material is removed using a multipoint cutter with a single pass of the tool. The tool itself

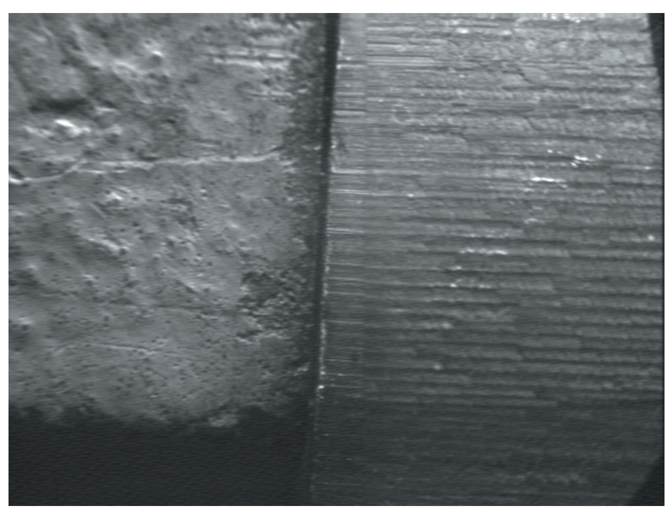

Photo: 2 Two Examples of Forging Toolmarks

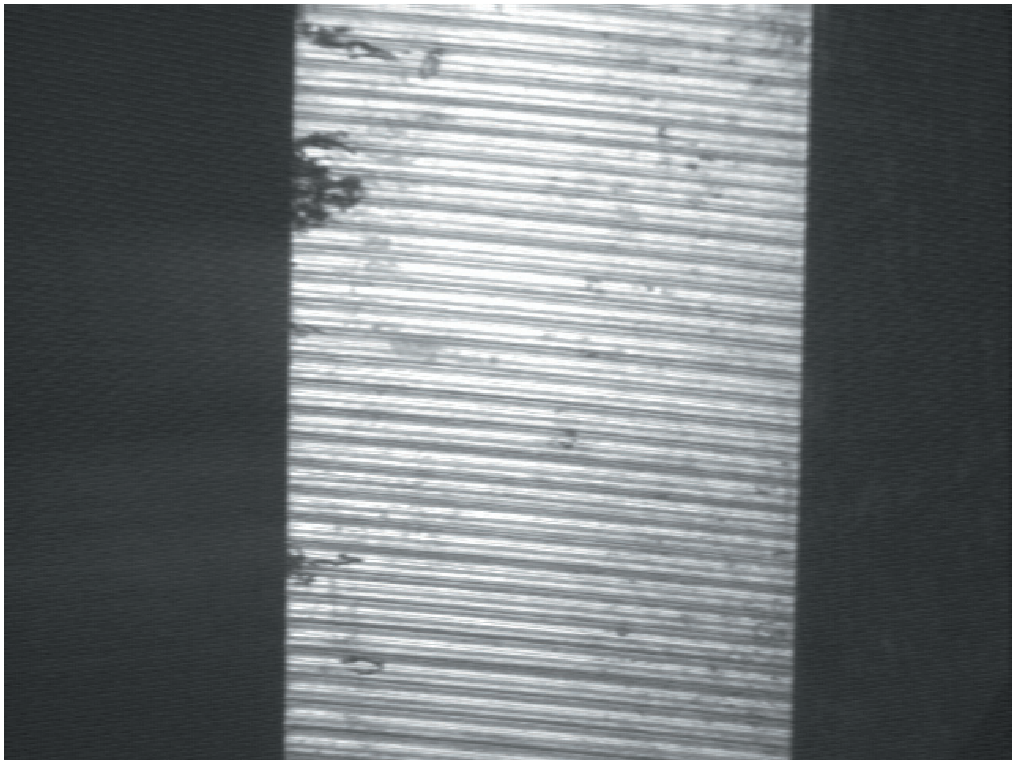

Photo 3: Milling Toolmarks

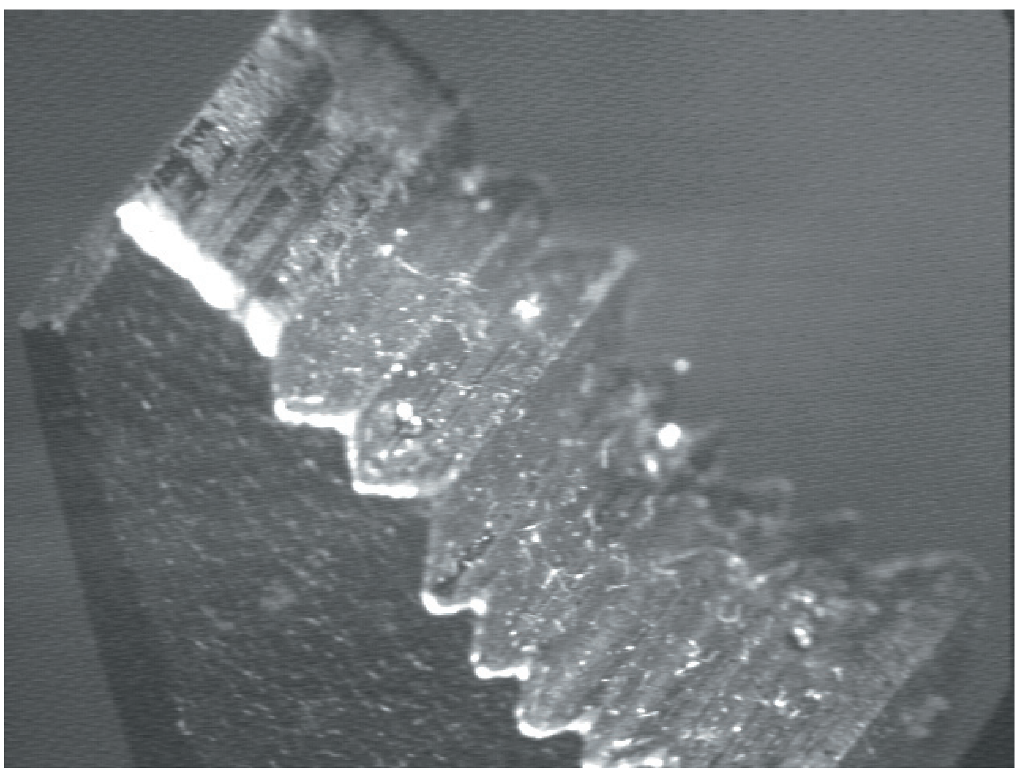

Photo 4: Broaching Toolmarks

contains successive teeth that each cut successively deeper into the material as it progresses through. A variety of shapes can be cut using this method, and the rough and finish cuts can be done in a single operation. Toolmarks appear as relatively evenly spaced parallel peaks and furrows with relatively the same height and width (See Photo 4). These are generally subclass characteristics.

Grinding is an abrasive machine process that uses abrasive materials bonded in an aggregate on a rotating wheel. The abrasives within the aggregate cut material from the surface it comes into contact with. Cylindrical grinding uses the flat outside circumference of the wheel. Surface grinding uses the sides of the wheel, and belt grinding has the abrasive materials bonded to a belt. The grinding wheel can be manipulated to produce a variety of shapes in a workpiece. The toolmarks appear as irregular striae of varying depth, width, and position (See Photo 5). These are generally individual characteristics.

Hand filing uses a file containing a pattern of teeth that can be pushed or pulled across the surface to remove material. The toolmarks produced are irregular in height, width, depth, and spatial relationship, and are generally individual characteristics.

Subclass Characteristics and Individual Characteristics

The presence of subclass characteristics does not preclude the presence of individual characteristics. The presence of subclass characteristics may also not be an influence in an identification due to the action of the tool when creating the toolmarks.

Consecutively Manufactured Tools

The tools examined in this study include diagonal cutters, slip-joint pliers, center punches, cold chisels, and beveled wood chisels (See Photos 6-10). Two sets of test toolmarks for each tool were made in lead. The cutting surfaces were designated with a letter corresponding to the toolmark that it produced.

The working surfaces of the tools were examined to determine their potential for subclass characteristics and individual characteristics. The known test toolmarks for each tool and each cutting surface of the tool were microscopically compared. Test toolmarks for the same tool type from different tools were microscopically inter-compared to determine the degree of any random correspondence of individual characteristics or any influence of subclass characteristics. In all of the toolmark examinations, a description of the type of characteristic observed and its significance was noted.

In the case of the two types of chisels, a discussion concerning the type of toolmarks observed from the different manufacturing processes is included. This best illustrates the differences as a result of the manufacturing process used, the influence that those processes have in the generation of toolmarks, and the significance of subclass characteristics.

Diagonal Cutting Pliers

Diagonal cutting pliers are also called diagonal cutting nippers or side cutting nippers. These are designed to cut metal wire close to a surface. The flat section of the jaws allows for a cut close to the workpiece while the shape of the jaws and handles provide sufficient hand clearance. The three pliers used for this study are 6-5/8" long with a 1" long cutting blade made of steel. The width of the cutting bevel on the blade is 3/16". The pliers are forged. The surface area by the pivot is rough ground to make the pivot flush with the cutter body. The inside surface of the cutting blade is milled using a circular movement. The outside cutting edges are also milled using a circular milling movement. One edge of one blade is hand filed. No additional tool finishing process is conducted (See Photos 11 and 12).

The milled surfaces of the cutting blades produce circular toolmarks perpendicular to the cutting blades. The toolmarks are irregularly spaced and have varying degrees of width and depth. The position of these toolmarks is very uniform between the same cutting location of the blade between different tools. For example, a comparison of these toolmarks on the right and left inside surface of the tool between cutter #1 and cutter #2 illustrates agreement of these toolmarks (See Photos 13 and 14). The position of these toolmarks and their reproducibility on the tools cause them to be subclass characteristics. The same can be seen on the cutting surface of the outside of the blades (See Photos 15 and 16).

The cutting edge of each blade of the cutters consists of two sides. One side is milled at a more acute angle to the apex. The other side is the rough surface resulting from the hand filing process. The milled side of the cutting edge exhibits irregular striae of varying width and depth positioned at a slight angle to the blade edge. These too are subclass characteristics and have been reproduced on all three cutters (See Photos 17 and 18). The hand filed side of the cutting edge exhibits occasional random individual characteristics and striae agreement within the toolmarks of different tools, but nothing that would support a conclusion of same source (See Photos 19 and 20).

A comparison of test toolmarks made in lead shows that each side of the blades create reproducing striae that can be identified to the tool working surface that produced it (See Photos 21 – 32). The circular milling toolmarks that are semi-parallel to the cutting edge, although subclass, do not affect

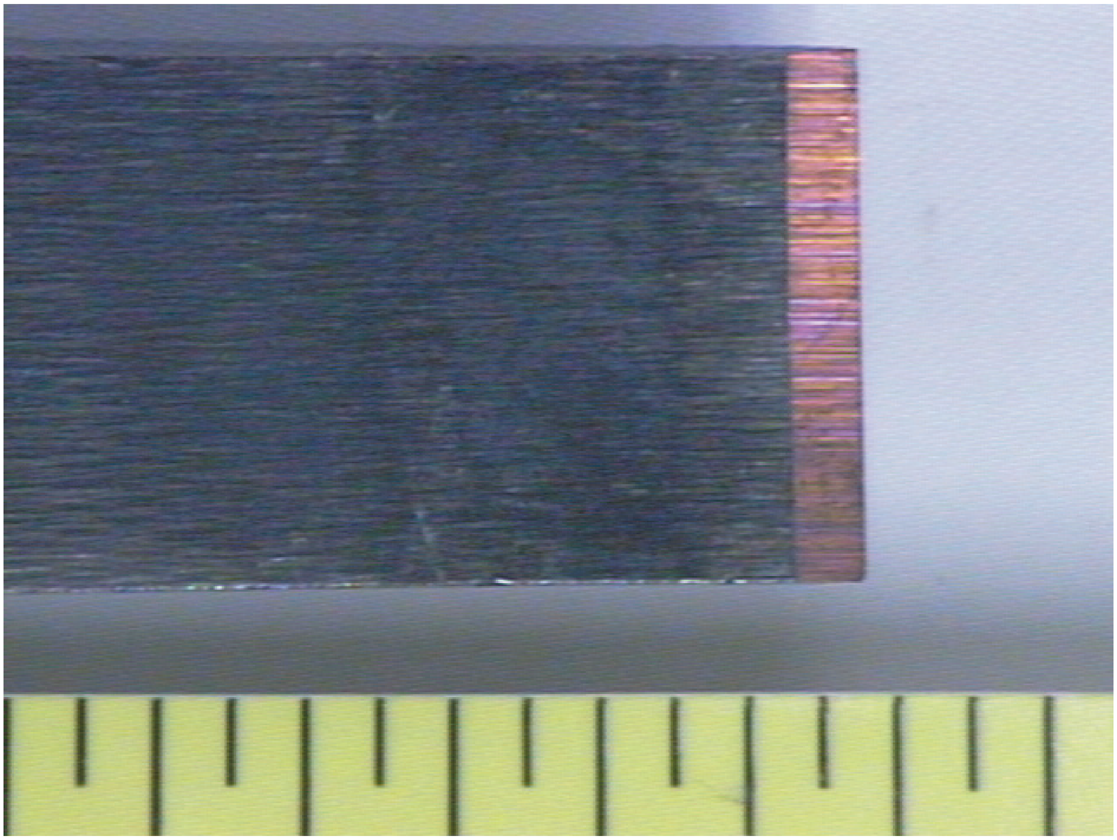

Photo 5: Grinding Toolmarks

Photo 6: Consecutively Made Cutters

Photo 7: Consecutively Made Pliers

Photo 8: Consecutively Made Punches

Photo 9: Consecutively Made Cold Chisels

Photo 10: Consecutively Made Wood Chisels

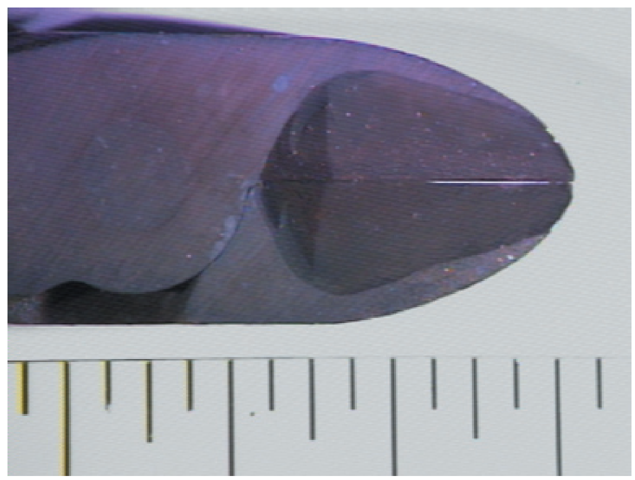

Photo 11: In side Jaw of Cutter

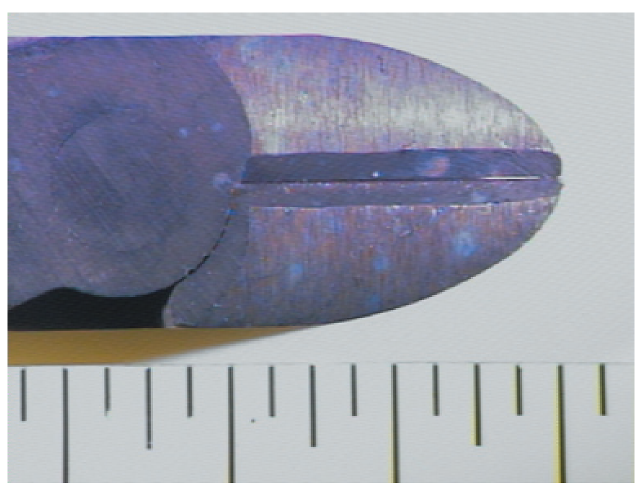

Photo 12: Outside Jaw of Cutter

the generation of reproducible striae due to the cutting action of the tool. This is because the milling toolmarks do not extend to the apex of the cutting edge. If they did, then they could possibly reproduce as subclass characteristics in the resulting toolmarks. These circular toolmarks do impress themselves into the soft lead at an angle to the striae and can be observed in the photographs. By repositioning the toolmark and changing the angle of the lighting, the agreement of these characteristics can be observed (See Photo 33). This does not influence the identification of the toolmark. An inter-comparison of the test toolmarks for each cutting surface between the three cutters exhibits random agreement of striae that is insufficient to support a conclusion of identity (See Photos 34-37).

Comparison of the impressed area from the cutting blade edges were made between the tests produced using the same tool, as well as an inter-comparison between tools. The milled edge reproduced striae with significant agreement between tests made using the same tool (See Photos 38-40). This same level of agreement however, can also be observed in the inter-comparison of these edges between different tools, and are subclass characteristics (See Photos 41 and 42). An examination of the other hand filed edge shows sufficient agreement of characteristics to conclude that they were produced using the same tool (See Photos 43-45). An inter-comparison of these hand filed edges between the three cutters only exhibits random striae agreement, with no subclass carry over (See Photos 46 and 47).

Due to the manufacturing process used in producing these cutters, toolmarks can consist of subclass characteristics and individual characteristics that are reproduced in toolmarks made using them. Although the milled blades display subclass characteristics on the tool working surfaces, these do not affect the toolmarks produced in cuts from these areas due to the tool action. The cutting blade edges themselves exhibit subclass toolmarks on one edge/surface that reproduce in toolmarks, but exhibits individual characteristics on the other edge/surface that are reproducible and identifiable to the tool that produced it.

Slip-Joint Pliers

Slip-joint pliers have a wider jaw capacity than standard pliers because of the pivot point that allows two widths of the jaw opening. The jaws have a serrated flat section and a wider curved section with coarse teeth. The three pliers used for this study include only the slip-joint half from each tool. They are forged steel 6-3/4” long with a 7/16” wide jaw. There are 14 broach-cut teeth. The curved section has seven teeth of a larger set than the front teeth (See Photo 48).

All of the teeth have fine striae parallel to each other along the width of the jaw. These striae are similar in width, height, and spacing and is what is normally observed from a broaching process (See Photos 49-52). These are subclass characteristics.

The normal action of this type of tool is perpendicular to the orientation of the subclass characteristics. This tool movement negates any influence that they would have on any toolmarks that are produced. In addition, normal tool to surface contact would primarily occur on the upper portion of the teeth, preventing any significant reproduction of subclass characteristics. It may be possible to move the jaw sideways in an unnatural tool movement, but to register significant duplication of subclass toolmarks would require a large amount of pressure.

The toolmarks produced by these jaws are individual (See Photos 53-55). Although the manufacturing process imparts subclass characteristics to the tool working surface of the pliers, the action of the tool precludes any subclass influence on the toolmark produced.

Center Punch

A center punch is used to mark hole center positions and to create a starting point for a drill bit. The point of the punch is ground to an acute angle. The three punches used in this study are 3/8” diameter and 4 ½” long (See Photo 56).

The tool working surfaces of the punches are ground and have a torn appearance (See Photo 57). They are placed into a jig and moved against a rotating abrasive disc to grind the surface at the same angle. Each punch is ground at the same position on the disc. These working surface toolmarks are irregular in width, depth, position, and are not reproduced on sequentially manufactured punches. They are individual characteristics.

The difficulty with the toolmarks observed on the tool working surfaces of the punches is in reproducing these toolmarks in tests. A comparison of test toolmarks made in lead from the same punch does not provide sufficient correspondence of toolmarks to support a conclusion of identity (See Photos 58-60). An inter-comparison of test toolmarks between the punches provides no useful correspondence of toolmarks (See Photos 61 and 62). It may be possible to observe these individual characteristics sufficiently to support a conclusion of identification by casting the actual tool working surface. This was not done for this research.

The conclusion in the examination of these tools is that the manufacturing process does not produce subclass characteristics, and that the individual characteristics on these newly manufactured punches are insufficient to support a conclusion of identity. Further use of the punches would begin

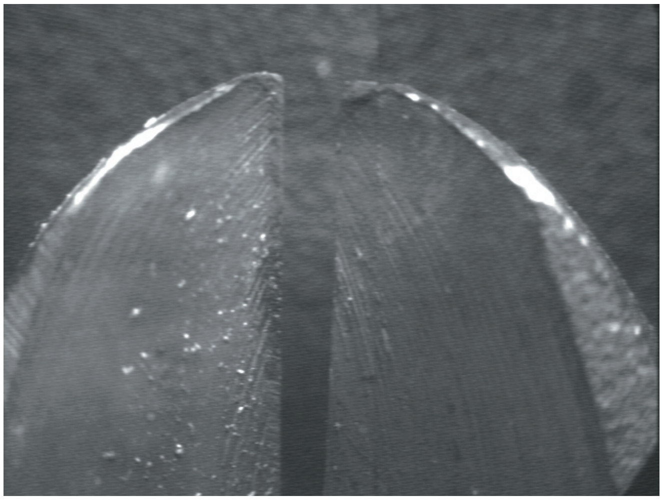

Photo 13: Comparison of milled toolmarks on right inside of jaw between cutter #1 and cutter #2

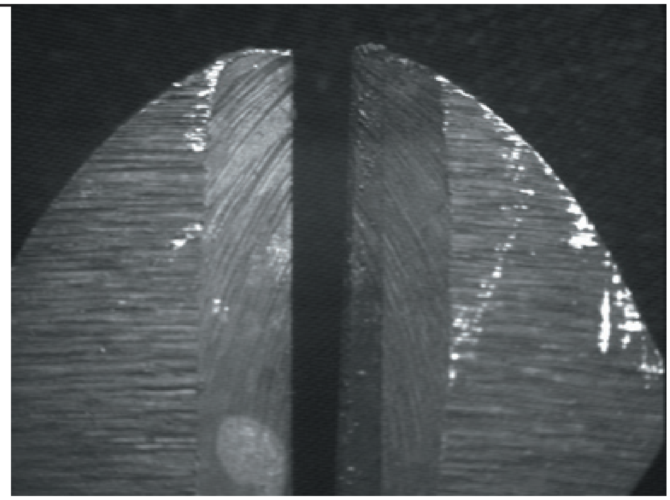

Photo 15: Comparison of milled toolmarks on right outside of jaw between cutter #1 and cutter #2

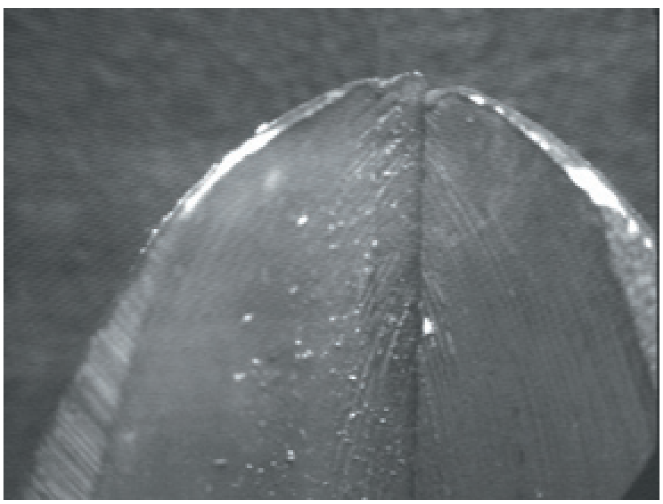

Photo 14: Comparison of milled toolmarks on left inside of jaw between cutter #1 and cutter #2

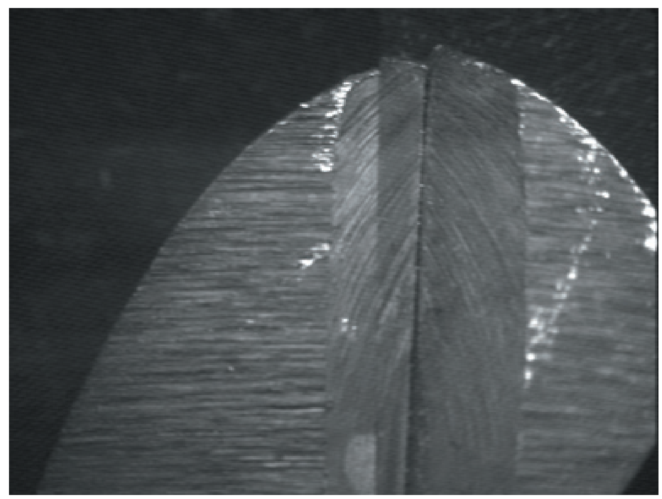

Photo 16: Comparison of milled toolmarks on left outside of jaw between cutter #1 and cutter #2

to impart more individual characteristics to the tool working surface, and may become more readily identifiable.

Chisel Toolmarks

The chisels used for this research included two different sets of consecutively manufactured chisels. The tool working surfaces of the first set was manufactured using a method different from the second set. The chisels include cold chisels and beveled wood chisels. Although they are both chisels and employ the same basic tool action, each has its own specific use and manufacturing process. Toolmarks produced by chisels can be striated and impressed, and consist of subclass and individual characteristics.

Cold Chisels

A cold chisel, or flat chisel, is primarily used to cut metal. It is made from a forged hexagonal shaped steel stock with a wedge-shaped bit tapering to an included angle of about ten degrees. The cutting surface is ground on both sides at an included angle of 60 degrees (see Photo 63). The three cold chisels used in this study were each 11 ½" long with a 7/8" wide cutting edge. Test toolmarks were produced in lead with the chisel held at 90 degrees using one strike from a hammer. The extreme apex of the cutting edge precluded any reproduction of impressed toolmarks from this area, but may be cast to record this surface (See Photo 64). The cutting surfaces of the chisel were designated by a letter corresponding to the test toolmark that it produced.

An examination of the toolmarks produced by the chisel cutting surfaces shows relatively parallel striae of varying width and depth, and is what is commonly observed in toolmarks produced by a grinding process. A microscopic comparison of tests toolmarks from each chisel exhibits reproducible individual characteristics that can be identified to the tool working surface (See Photos 65-70). An inter-comparison of test toolmarks between the three cold chisels exhibits only random agreement of striae that would not be sufficient to support an identification (See Photos 71-74). Additional uniqueness of individual characteristics will develop as the chisels are used.

Beveled Wood Chisels

The beveled edge chisel, or butt chisel, is designed for woodworking. The blade of the chisel is beveled approximately 30 degrees on one face only (the top), and along the long sides (See Photo 75). These bevels are milled, and the resulting striae are evenly spaced with equal width and depth. Further, the striae are 90 degrees to the tool edge and parallel with normal tool cutting action. The back edge/surface of the chisel is milled with a slight curvature to the milling toolmarks and are generally parallel to the tool edge (90 degrees to normal tool cutting action, See Photo 76). The chisels used for this study are forged 1" wide and 5-3/8" long without handles. Test toolmarks were produced in lead with the chisel held at 90 degrees using one strike from a hammer. The blade cutting surface is milled to a very fine edge and did not reproduce any impressed toolmarks from this area but may be cast to record this surface (See Photo 77).

An examination of the beveled edge tool working surface exhibits the parallel, evenly spaced, milling toolmarks that are the same width and depth, and are subclass characteristics. A microscopic comparison of these areas between the three chisels shows the level of agreement that can be produced (See Photos 78 and 79). The milled toolmarks on the back edge of the tool working surface are shallower than the beveled edge, but they still exhibit the evenly spaced parallel toolmarks from manufacturing and are also subclass characteristics (See Photos 80 and 81). An examination of the tool working surfaces of the chisels do not exhibit obvious individual characteristics.

The beveled top edge test toolmarks made with the chisels were microscopically compared and the toolmarks observed reproduced well with significant agreement (See Photos 82-84). An inter-comparison of the beveled top edge test toolmarks showed the same level of agreement (See Photos 85 and 86). When examined under higher magnification (40 times), the level of agreement still appears to be significant (See Photos 87 and 88). The subclass characteristics observed on the top beveled tool working surfaces of the chisels reproduce significantly in the test toolmarks.

The test toolmarks from the back edges of the chisels were microscopically compared. The toolmarks reproduced well with significant agreement (See Photos 89-91). An inter-comparison of these toolmarks showed only random correspondence of agreement (See Photo 92 and 93). These are individual characteristics and are identifiable to the tool working surfaces that produced them.

Even though the milled surface leading up to the back edge of the chisel possesses subclass characteristics from the manufacturing process, these characteristics do not influence the resulting toolmark. This is because the subclass characteristics are parallel to the cutting edge and the tool action is perpendicular to these characteristics. In this way, the surface area of the raised points along the subclass milling toolmarks right at the apex of the cutting edge is reproducing individual toolmarks. The subclass characteristics did not vanish, and by positioning the light perpendicular to the striae in the test toolmark, the impression of the subclass characteristics can be seen (See Photo 92). This had no influence in the reproduction of the toolmark because of the tool action.

The manufacturing processes and tool action in the production of toolmarks using these two types of chisels has a significant effect on the production of subclass characteristics, individual characteristics, and their potential for an identification. They are both the same general category of tool and employ the same tool action, yet the cold chisel tool working surface will produce individual characteristics exclusively, and the beveled wood chisel will only produce individual characteristics from the back side of the tool working surface. It is quite possible that after wear and use, the subclass characteristics may begin to show individual characteristics that can be identified to that area of the tool working surface. This can only be determined by an examination of the actual tool, and caution should be exercised when examining these types of toolmarks.

Summary

A toolmark identification is an opinion by a qualified expert that the questioned toolmark was made using the same tool working surface as the test toolmark used in the examination. The toolmark under examination must possess reproducible individual characteristics that are significant and sufficient to support a conclusion of identity. The toolmarks are significant when individual features as represented by their height, width, depth, curvature, and spatial relationship are in sufficient agreement. Sufficient agreement is achieved when the agreement of the pattern of features between two toolmarks meet the level of agreement observed in known matching toolmarks, and exceeds the level of agreement observed in known non-matching toolmarks.

The first priority in the examination of these features is to determine that they are individual characteristics and not subclass characteristics. To conclude an identification based upon subclass characteristics is a wrong conclusion. This determination can be made by an examination of the features observed in the toolmark if the examiner is familiar with tool manufacturing processes and the toolmarks that they produce onto a tool working surface. It can also be determined by an examination of the tools working surface and a comparison with similar tools. It can then be determined if any subclass characteristics that are present influence the toolmark produced based upon tool action.

Subclass characteristics were observed in the diagonal cutters from a milling process on the cutting surface. However, due to their position and the cutting action of the tool, they did not influence the toolmarks produced, which were individual. In the area of the tool cutting edge, one side exhibits subclass characteristics while the other side reproduces individual characteristics.

In the process of grinding the center punches, no subclass characteristics were created. The individual characteristics were shallow and failed to reproduce sufficiently to support a conclusion of identity.

The broach cut pliers jaws exhibited subclass characteristics on every surface examined except at the apex of each tooth. The subclass characteristics are parallel to the jaw width, and where normal tool action was used, had no influence on the toolmarks produced. The features observed in the test toolmarks are individual.

The ground tool working surfaces of the cold chisels reproduced individual characteristics that could be identified to the surface that produced it. The beveled wood chisel exhibited dramatic subclass characteristics that reproduced well between chisels. They also exhibited subclass characteristics that did not reproduce in test toolmarks because of the tool action.

When examining toolmarks, look for subclass characteristics and determine if they will influence the toolmark produced by that tool working surface. Acquire a basic knowledge of manufacturing processes and the appearance of the toolmarks that are produced by them. It is not necessary to know how every tool was made, but it is important to have knowledge about the process that was used to finish the tool working surface. This can be done from an examination of the surface combined with the knowledge of these processes. It can then be determined if subclass characteristics are a possibility.

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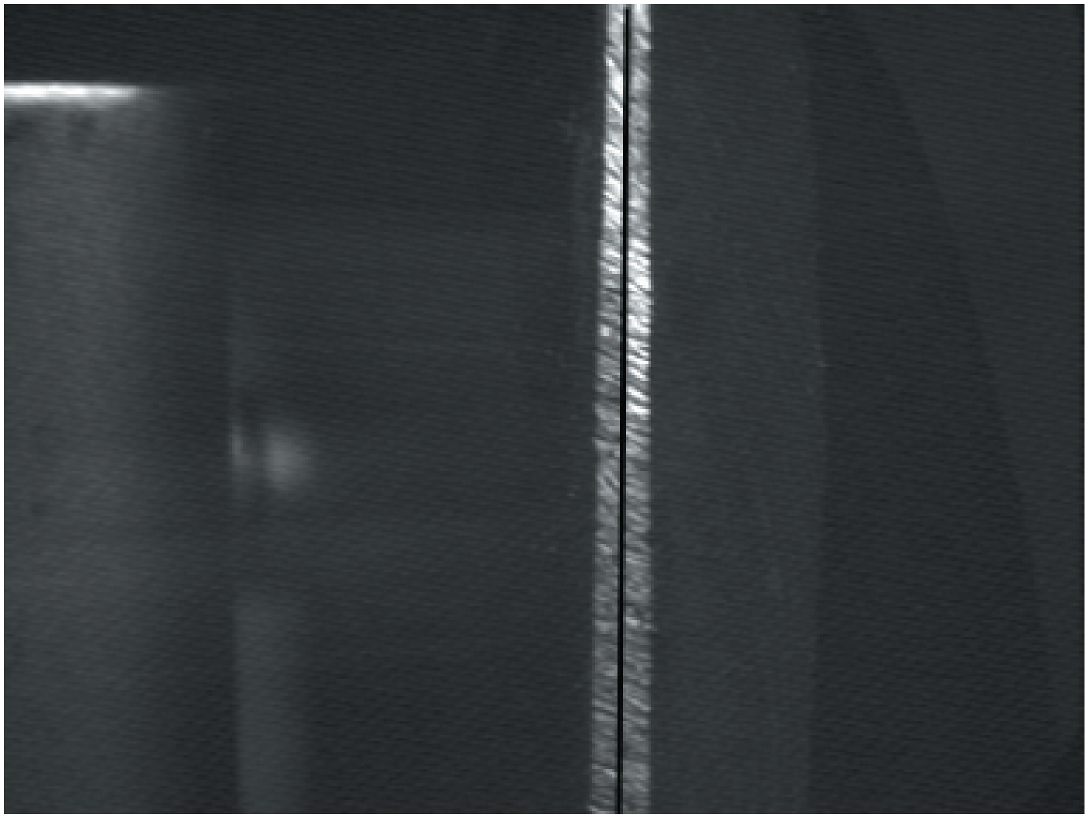


Photo 17: Milled Blade Edge of Cutter #1 and Cutter #2

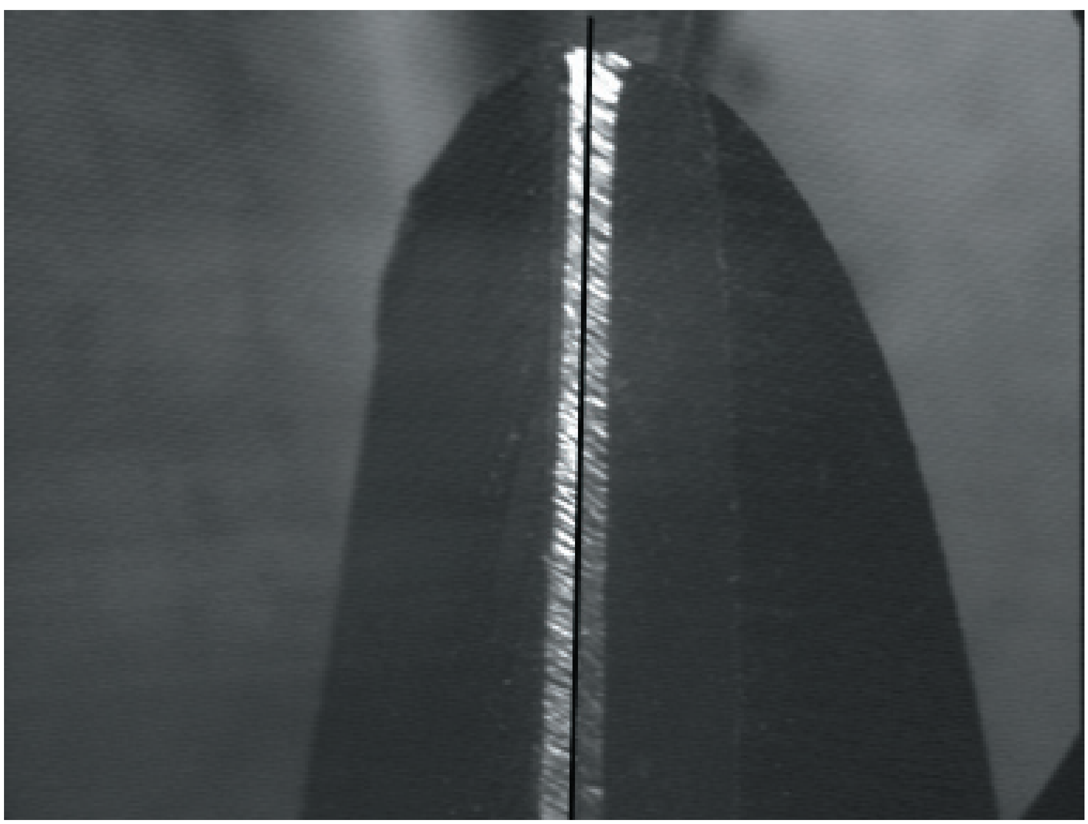


Photo 18: Milled Blade Edge of Cutter #2 and Cutter #3

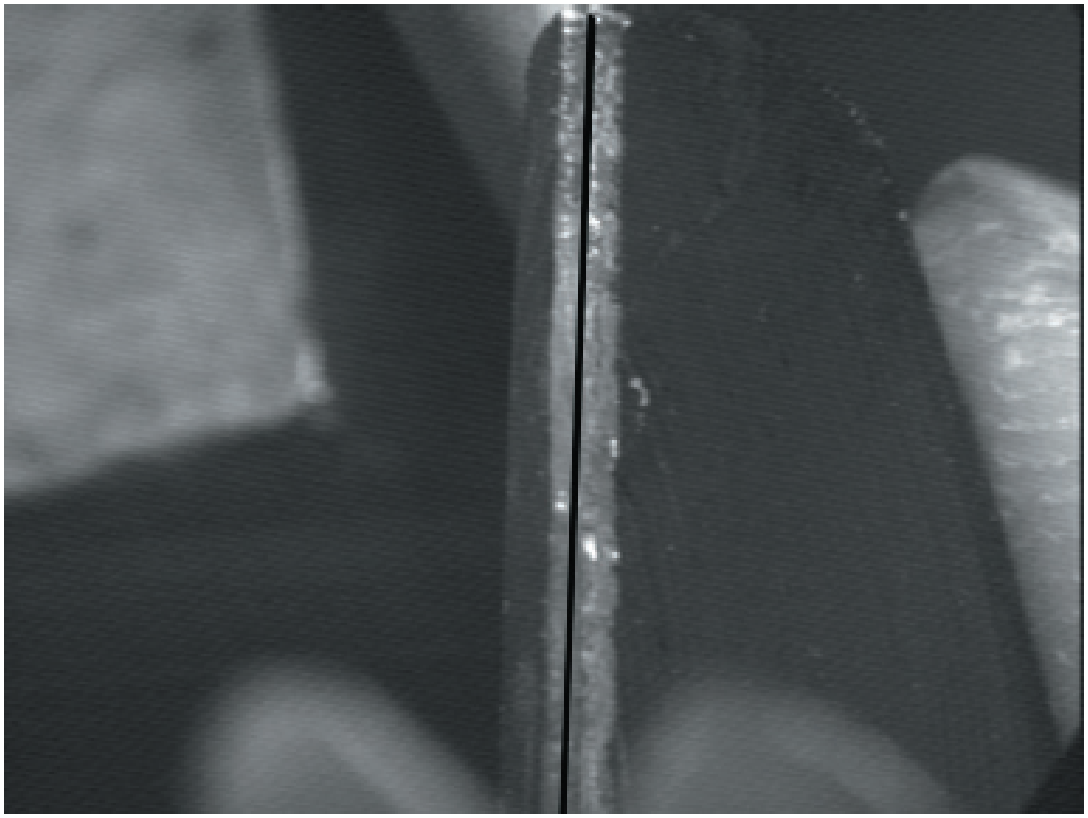


Photo 19: Hand Filed Blade Edge of Cutter #1 and Cutter #2

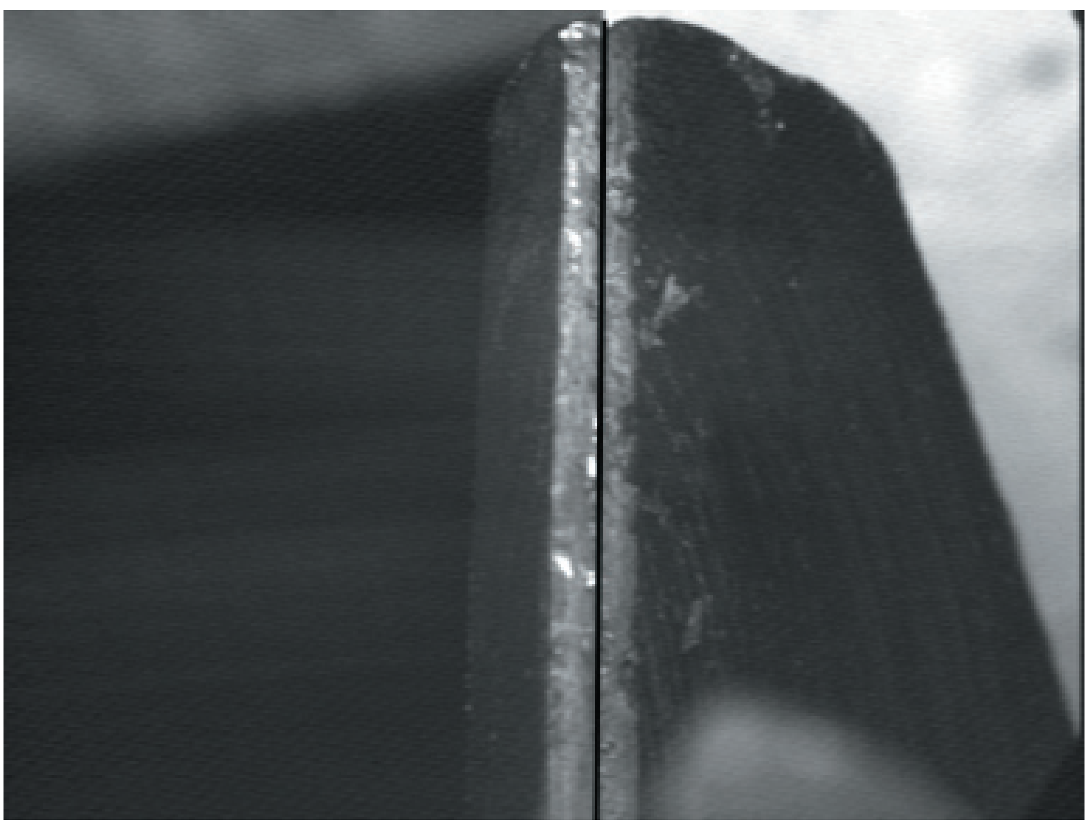


Photo 20: Hand Filed Blade Edge of Cutter #2 and Cutter #3

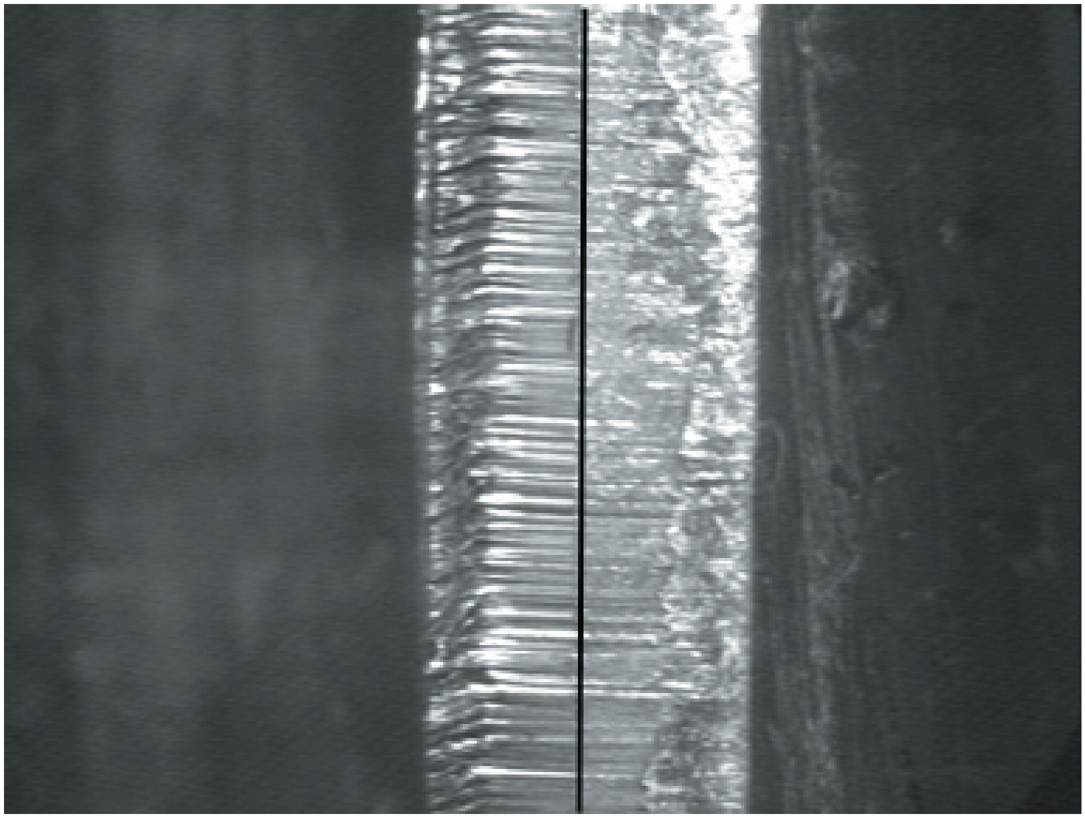


Photo 21: Comparison of Side A of Cutter #1

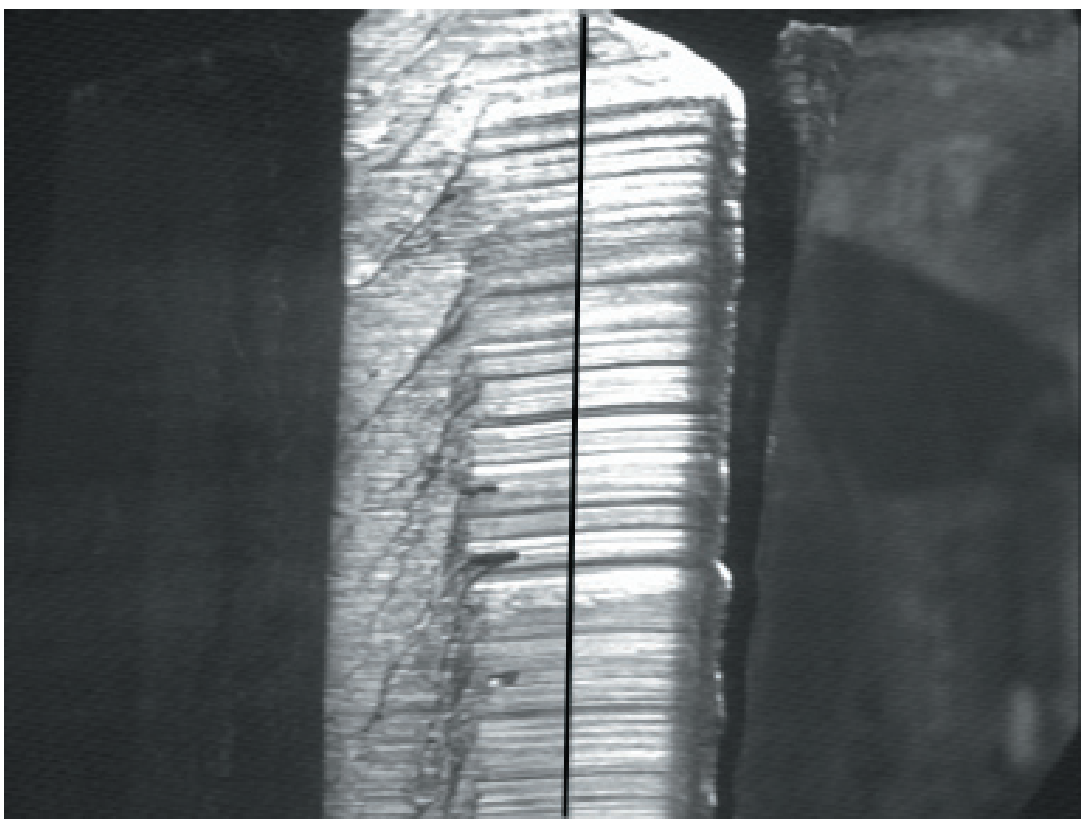


Photo 22: Comparison of Side B of Cutter #1

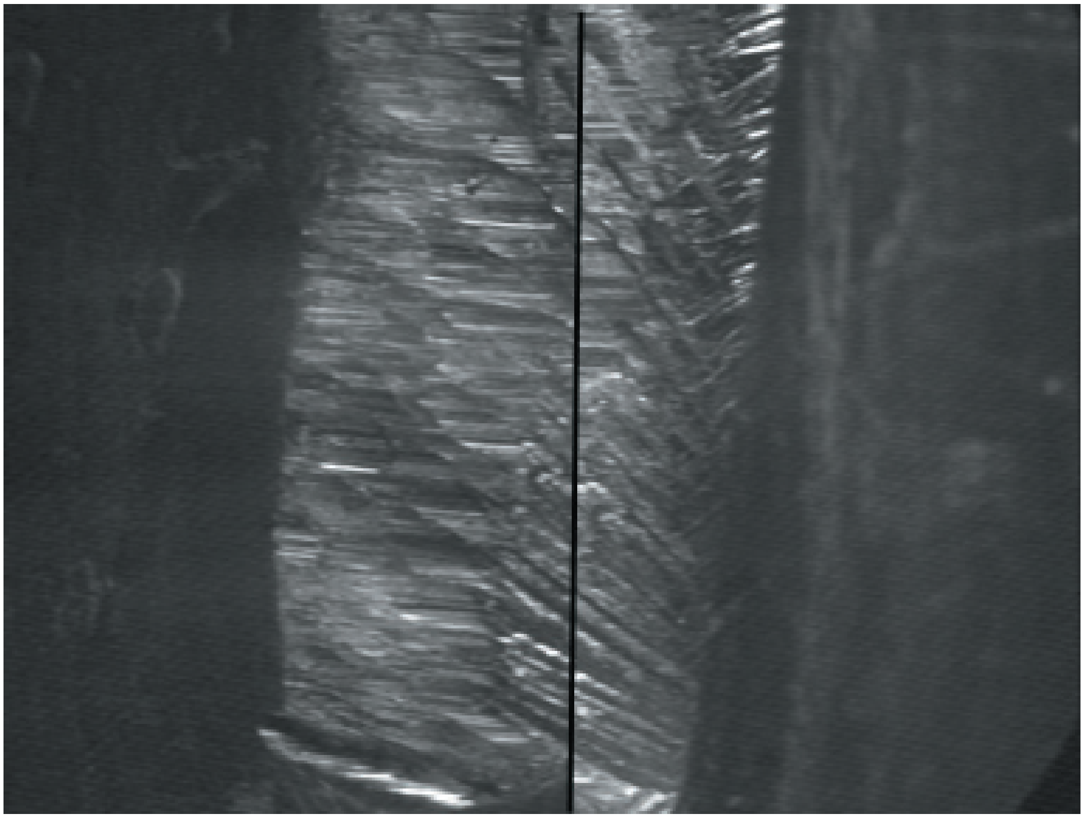


Photo 23: Comparison of Side C of Cutter #1

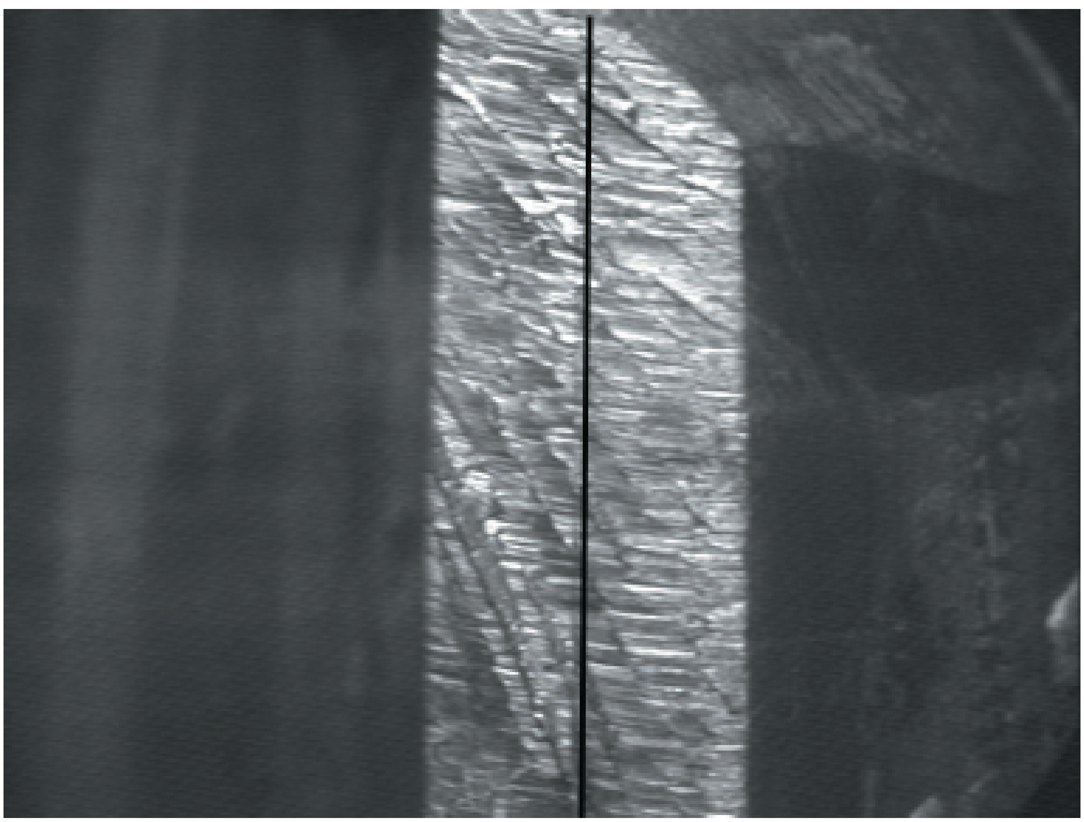


Photo 24: Comparison of Side D of Cutter #1

Photo 25: Comparison of Side A of Cutter #2

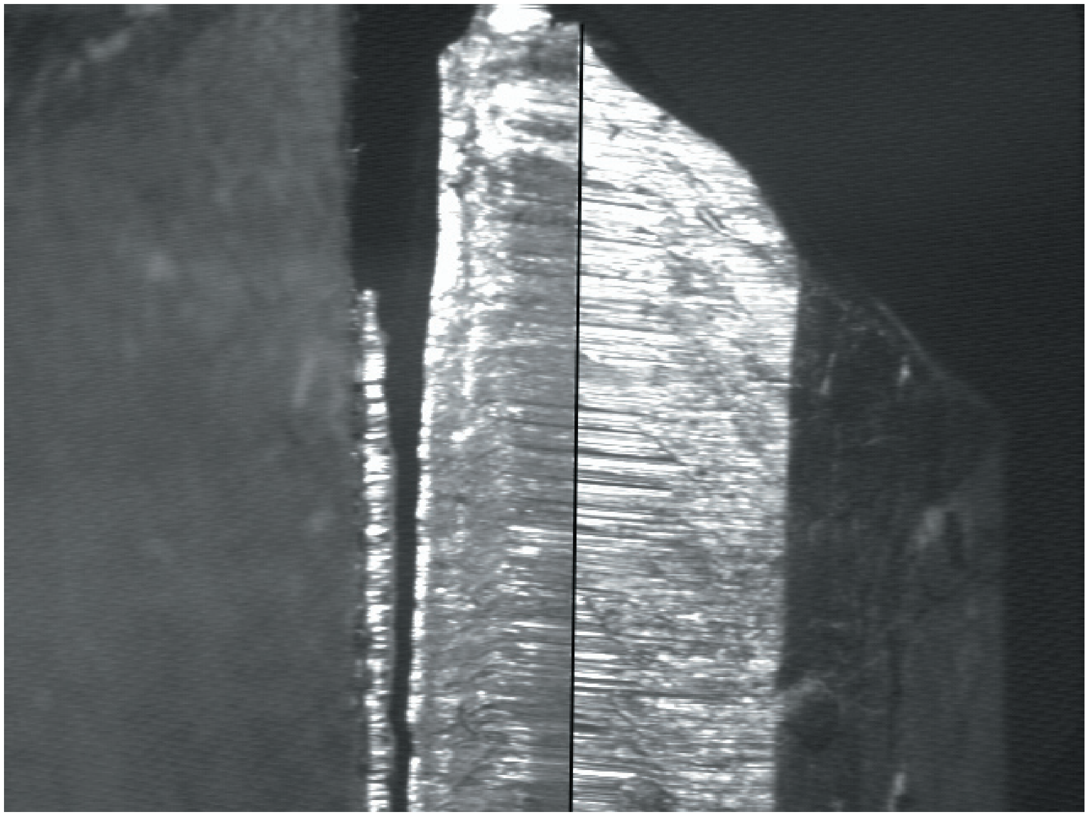
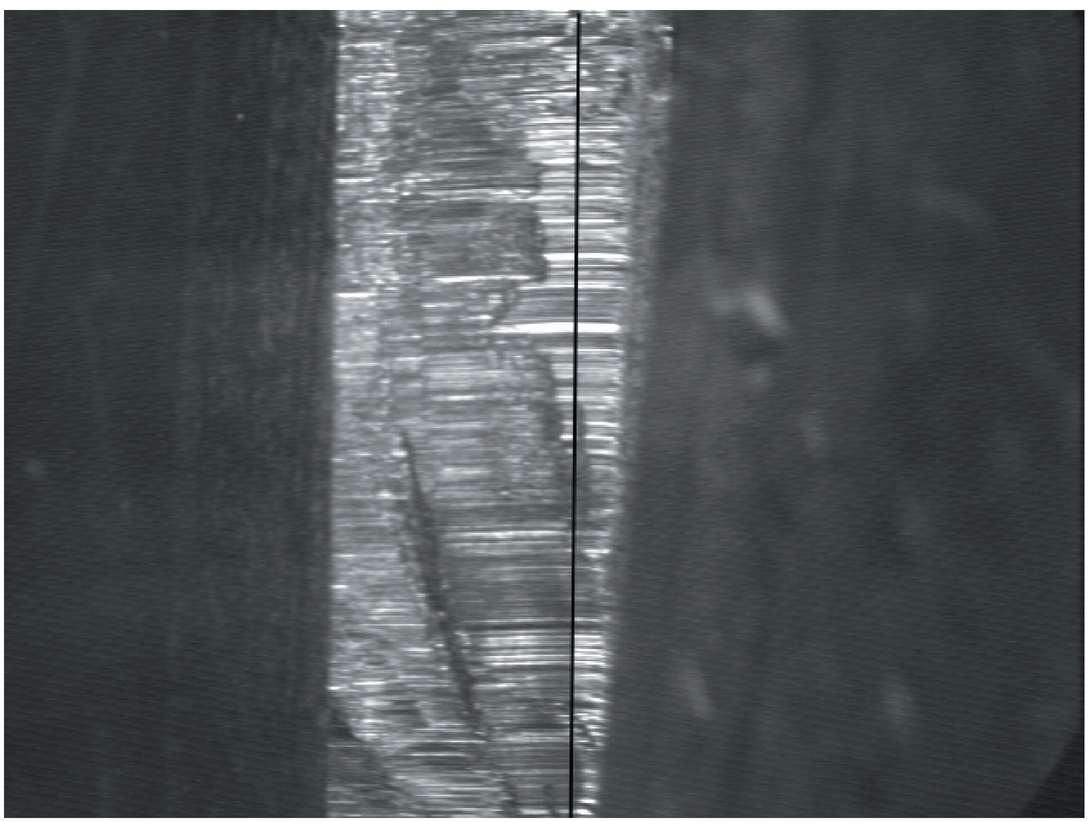


Photo 26: Comparison of Side B of Cutter #2



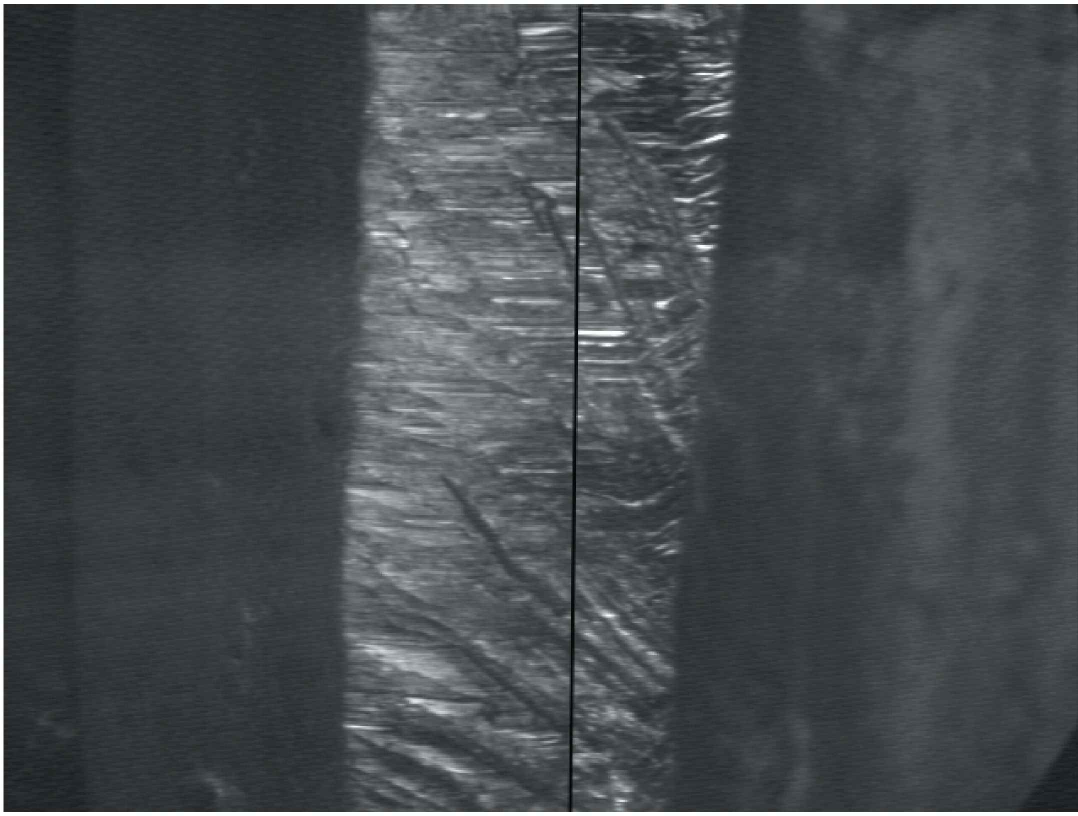


Photo 27: Comparison of Side C of Cutter #2

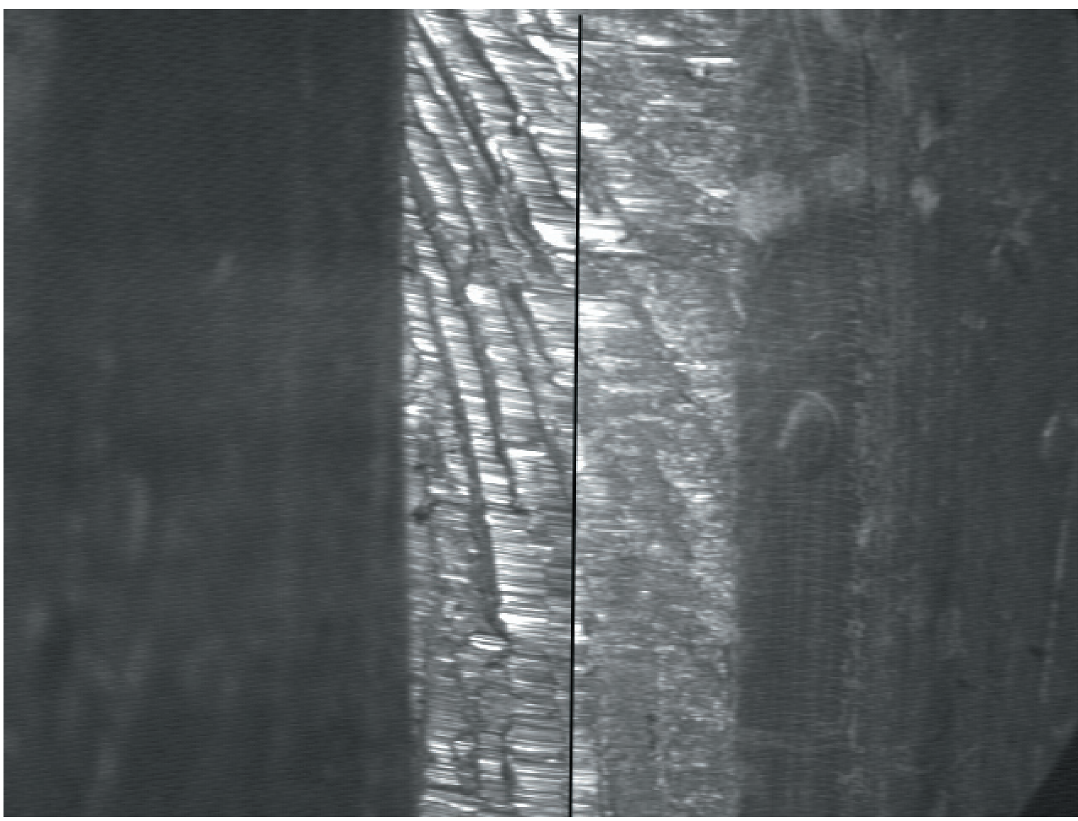


Photo 28: Comparison of Side D of Cutter #2

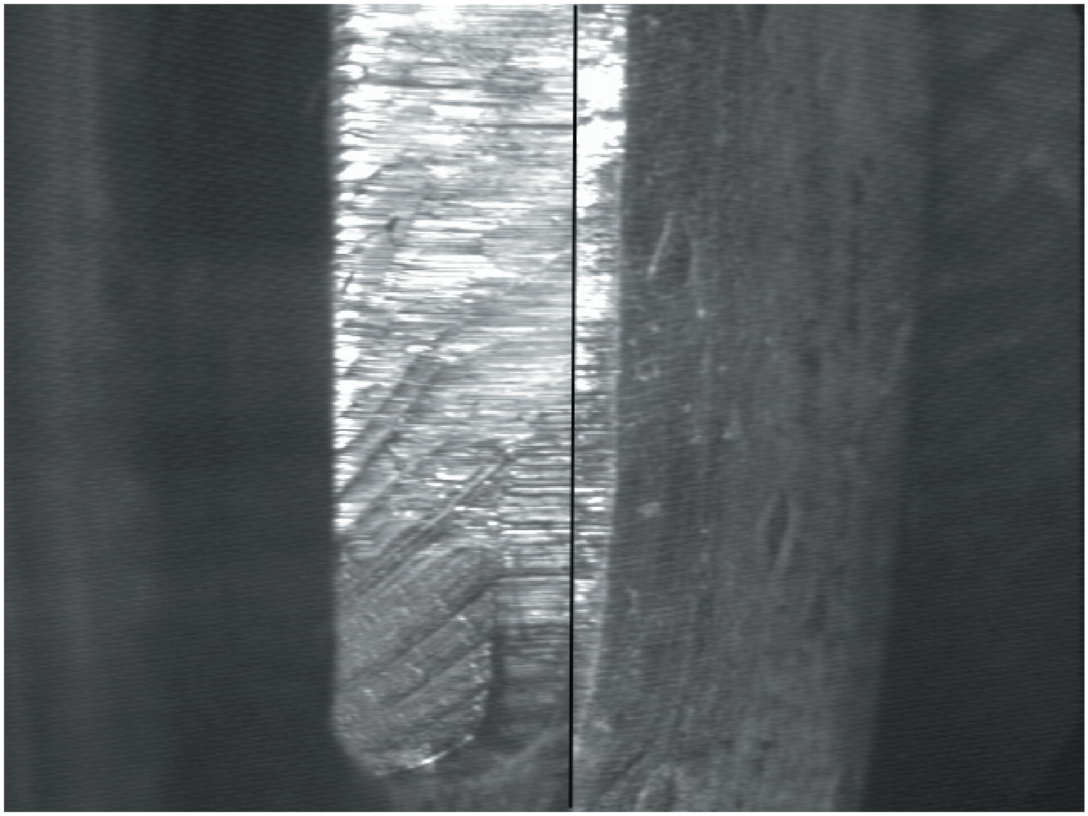


Photo 29: Comparison of Side A of Cutter #3

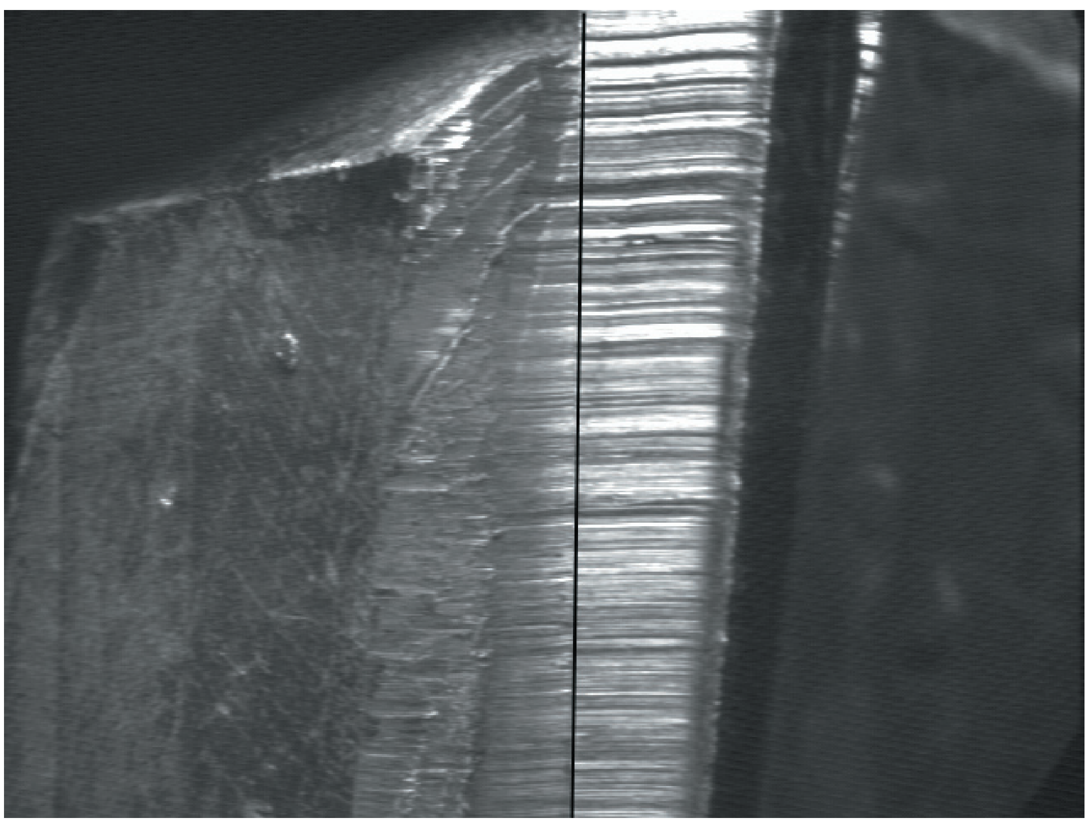


Photo 30: Comparison of Side B of Cutter #3

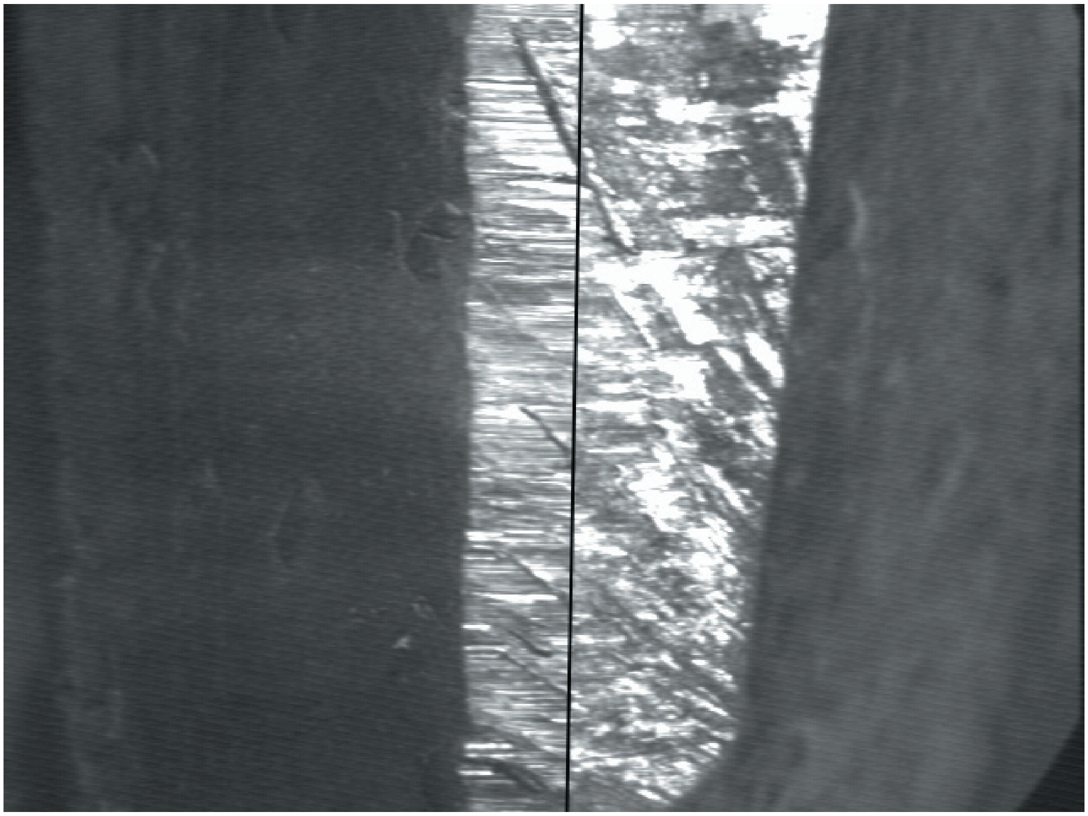


Photo 31: Comparison of Side C of Cutter #3

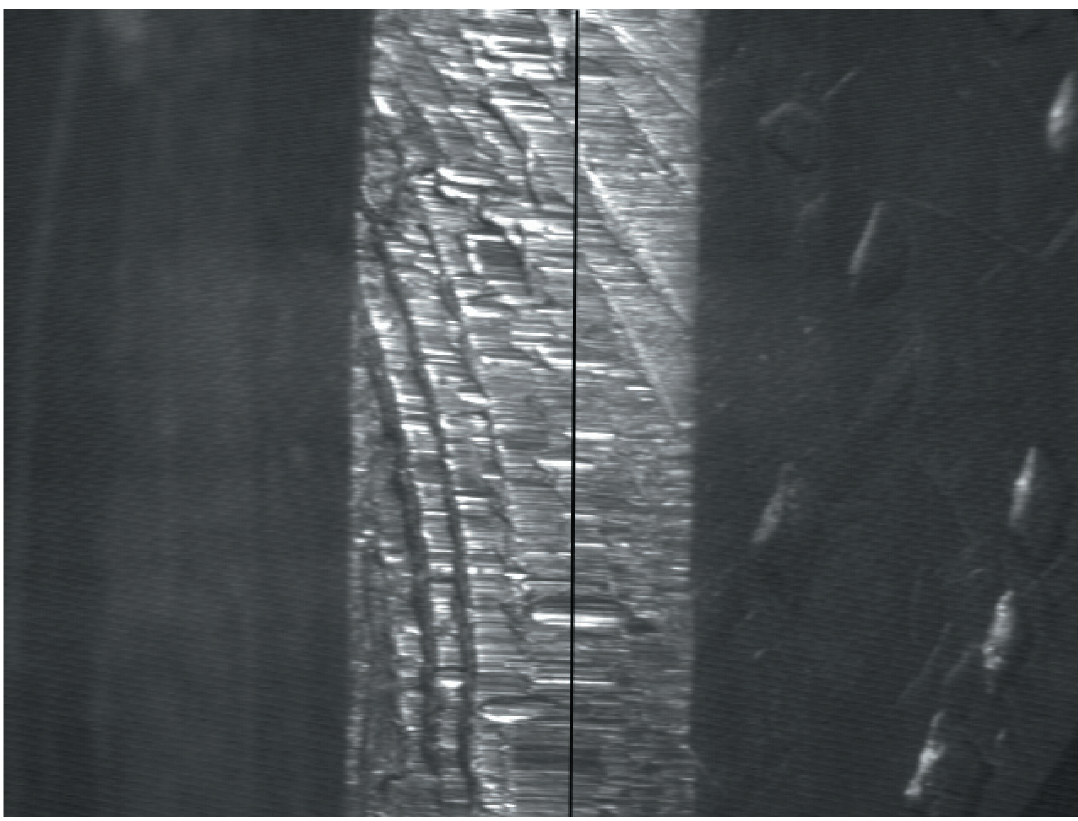


Photo 32: Comparison of Side D of Cutter #3

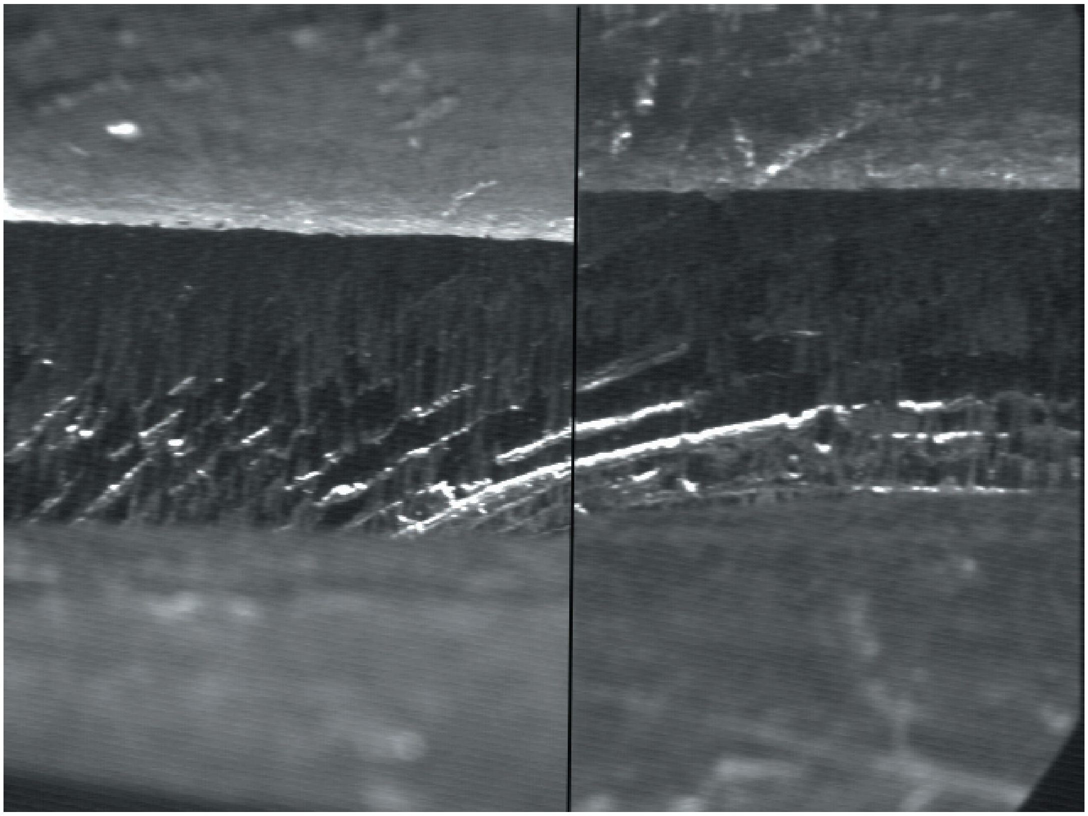


Photo 33: Milled Circular Subclass Characteristics Side D Cutter #1 and Cutter #2.

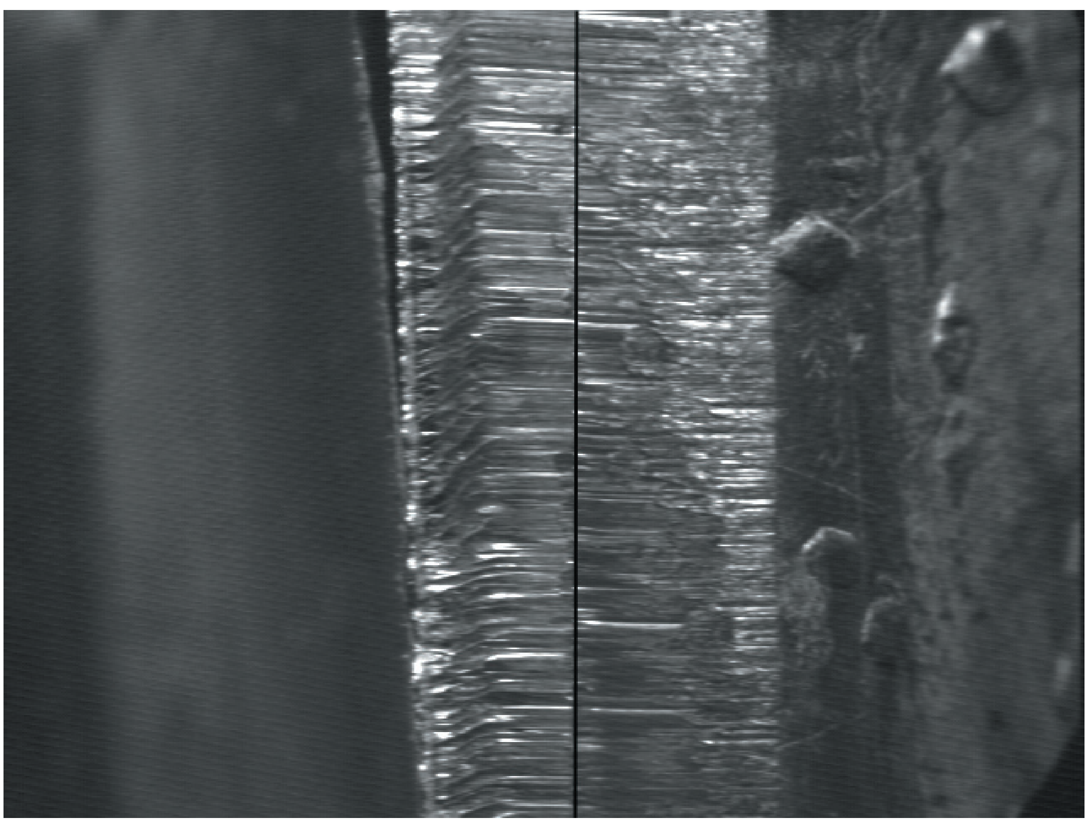


Photo 34: Side A Test Toolmarks Cutter #1 and Cutter #2

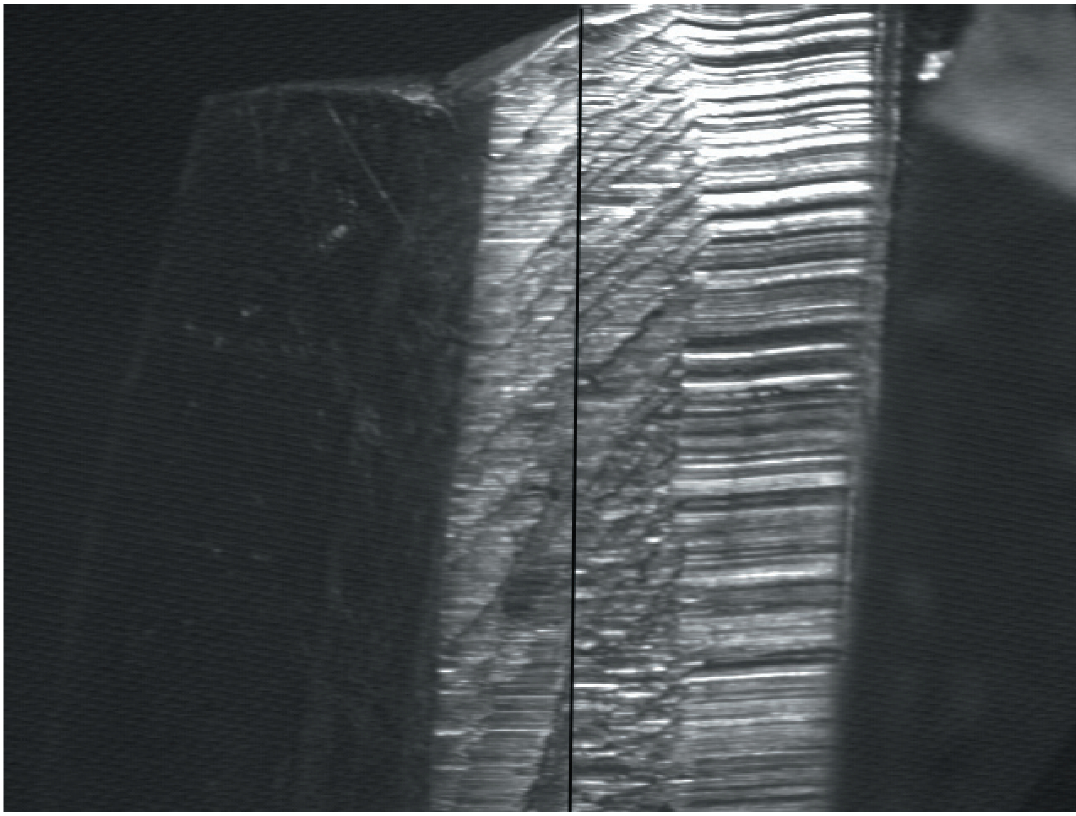


Photo 35: Side B Test Toolmarks Cutter #2 and Cutter #3

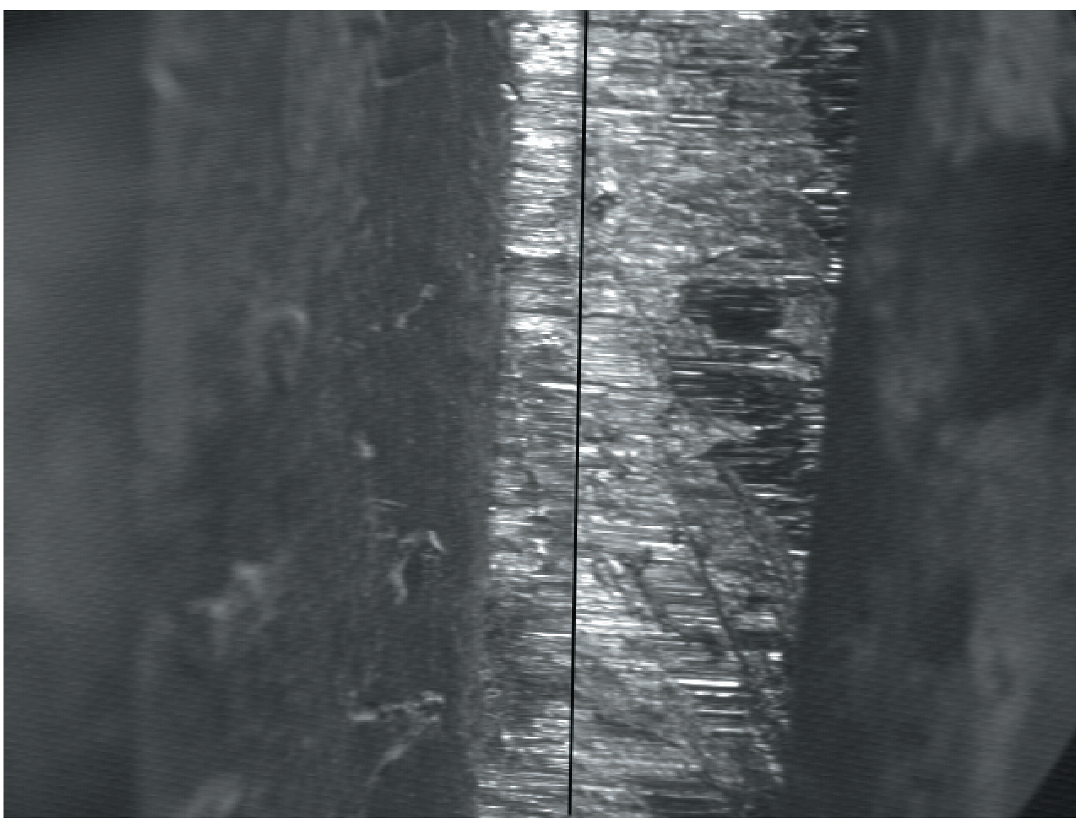


Photo 36: Side C Test Toolmarks Cutter #1 and Cutter #2

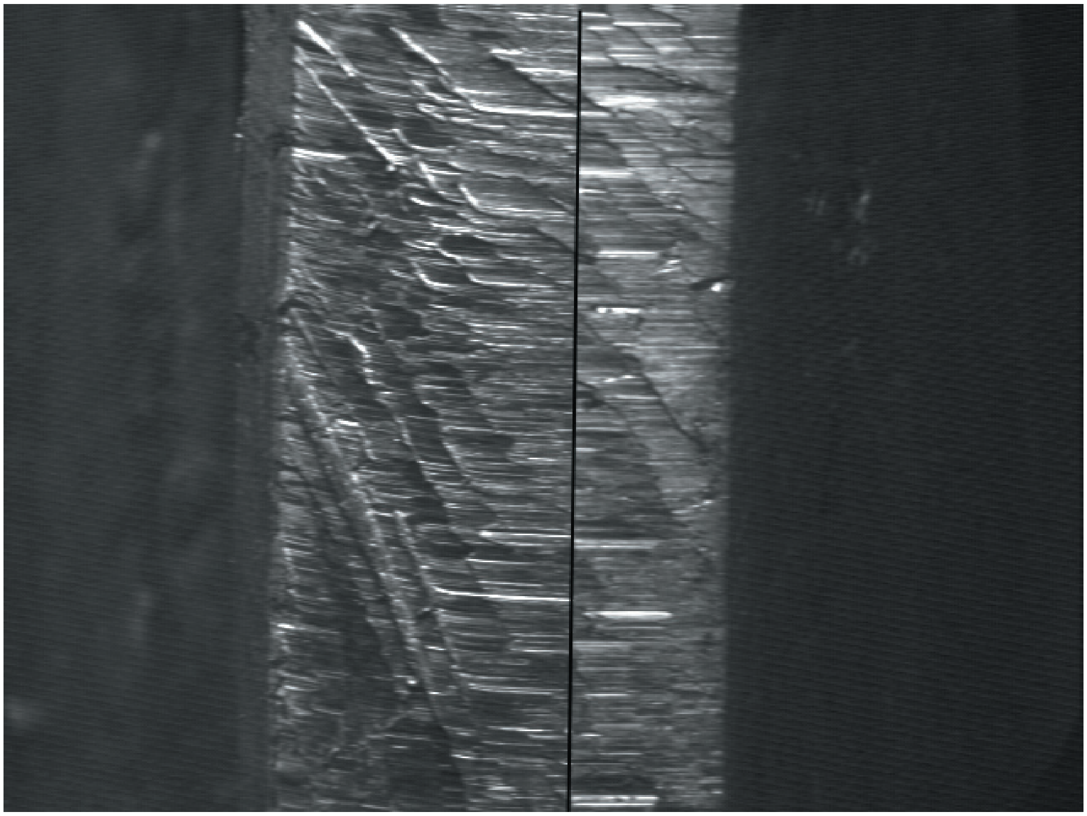


Photo 37: Side D Test Toolmarks Cutter #1 and Cutter #3

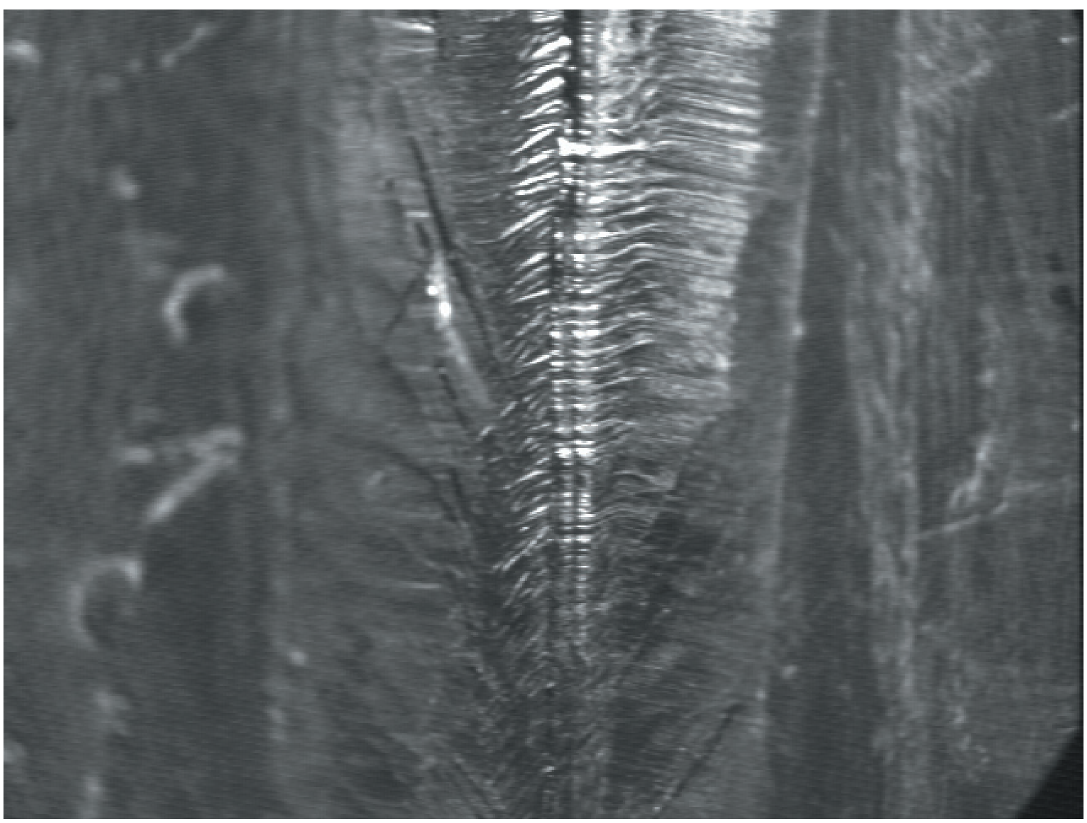


Photo 38: Cutter #1 Impressed Toolmarks Milled Edge

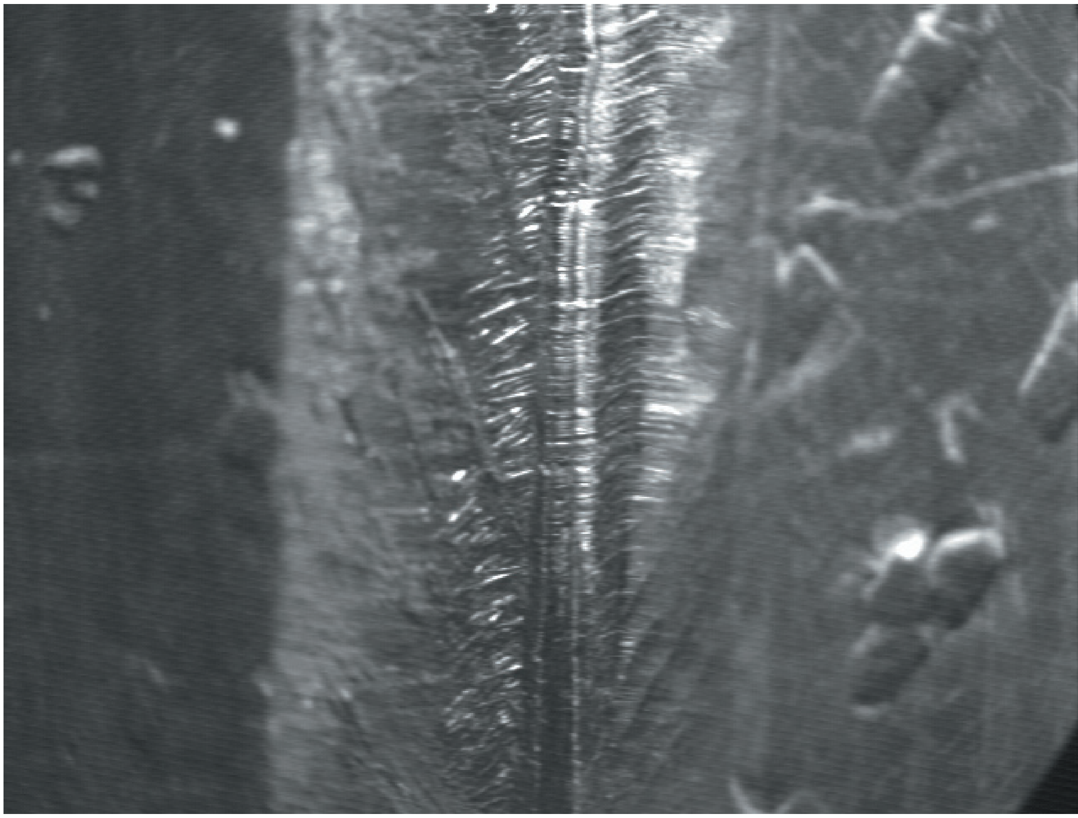


Photo 39: Cutter #2
Impressed Toolmarks
Milled Edge

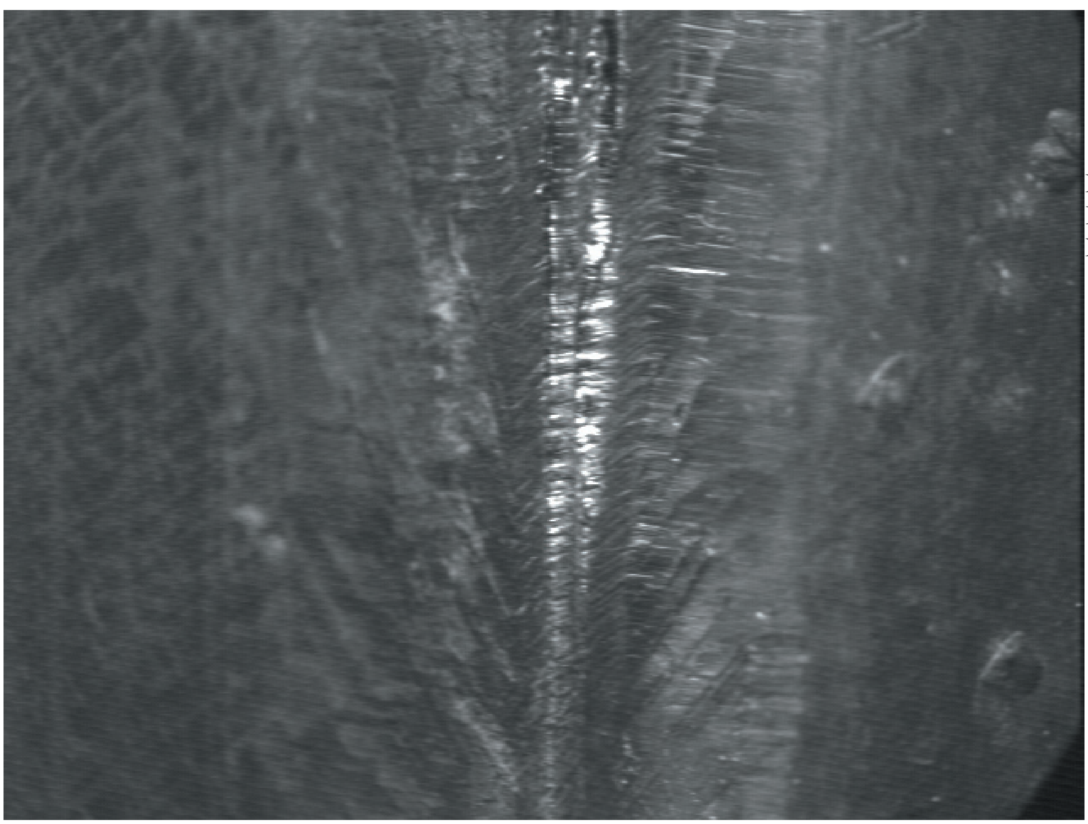


Photo 40: Cutter #3
Impressed Toolmarks
Milled Edge

Photo 41: Cutter #1 and Cutter #2 Impressed Toolmarks Milled Edge

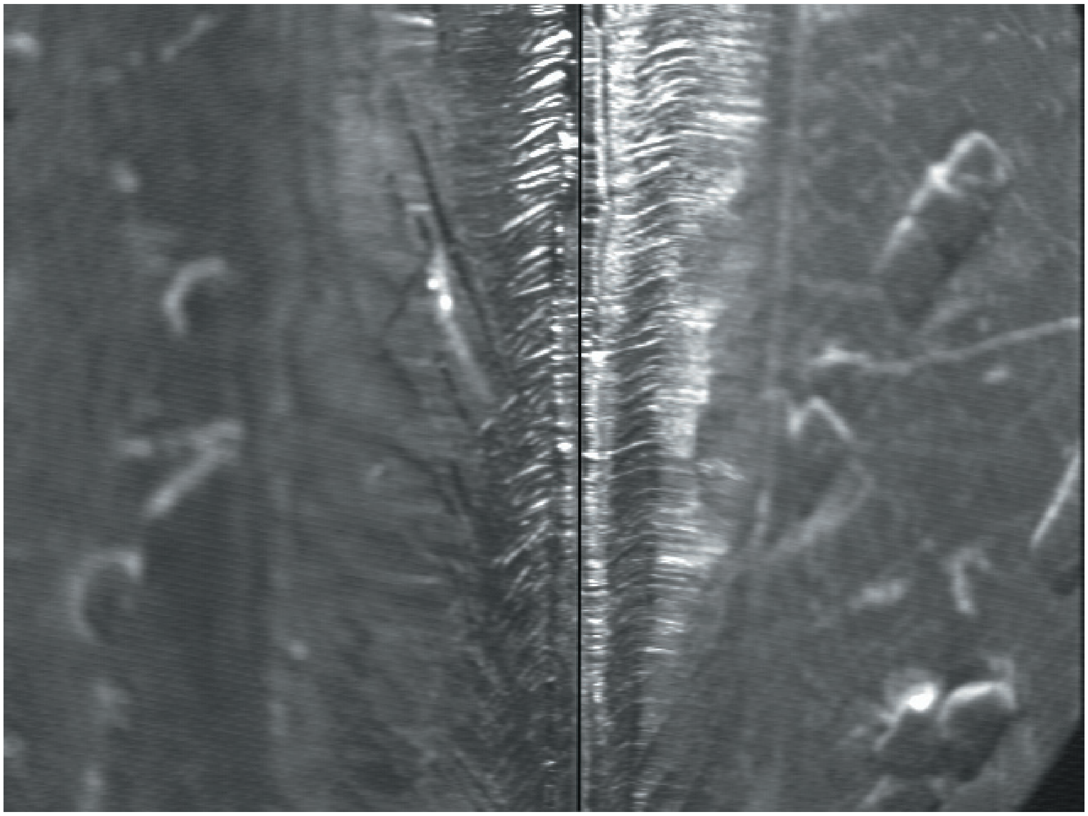
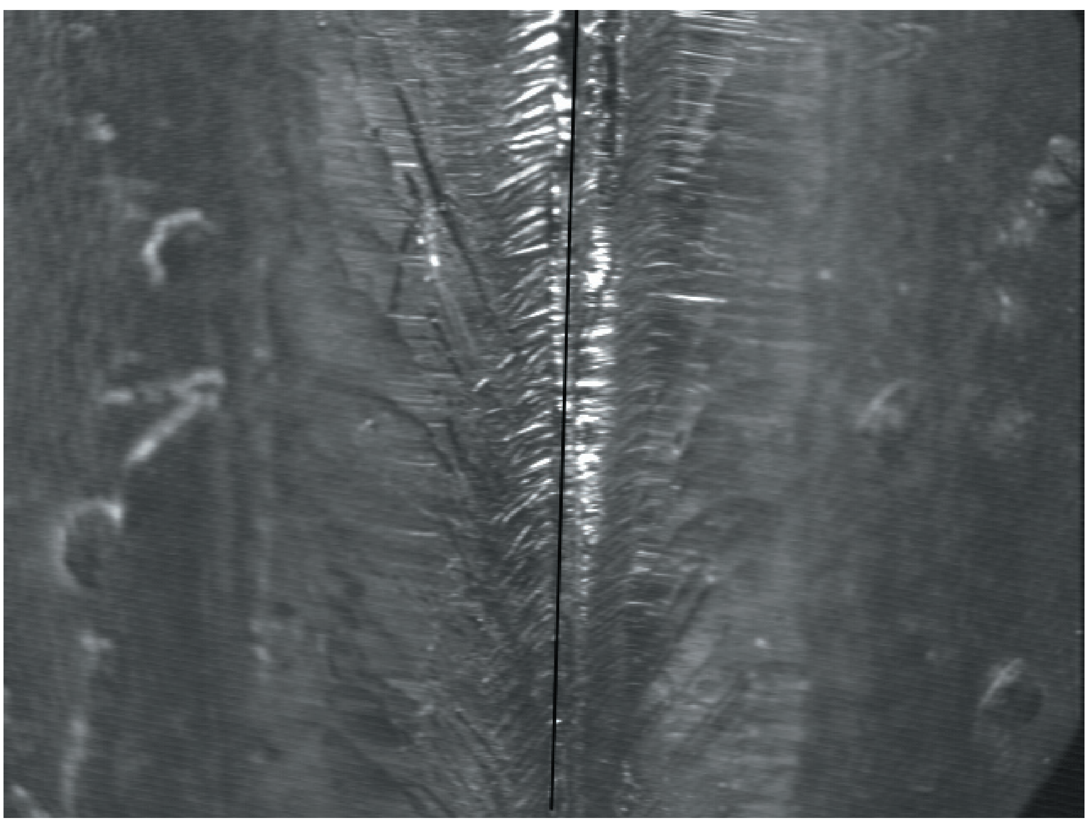


Photo 42: Cutter #1 and Cutter #3 Impressed Toolmarks Milled Edge



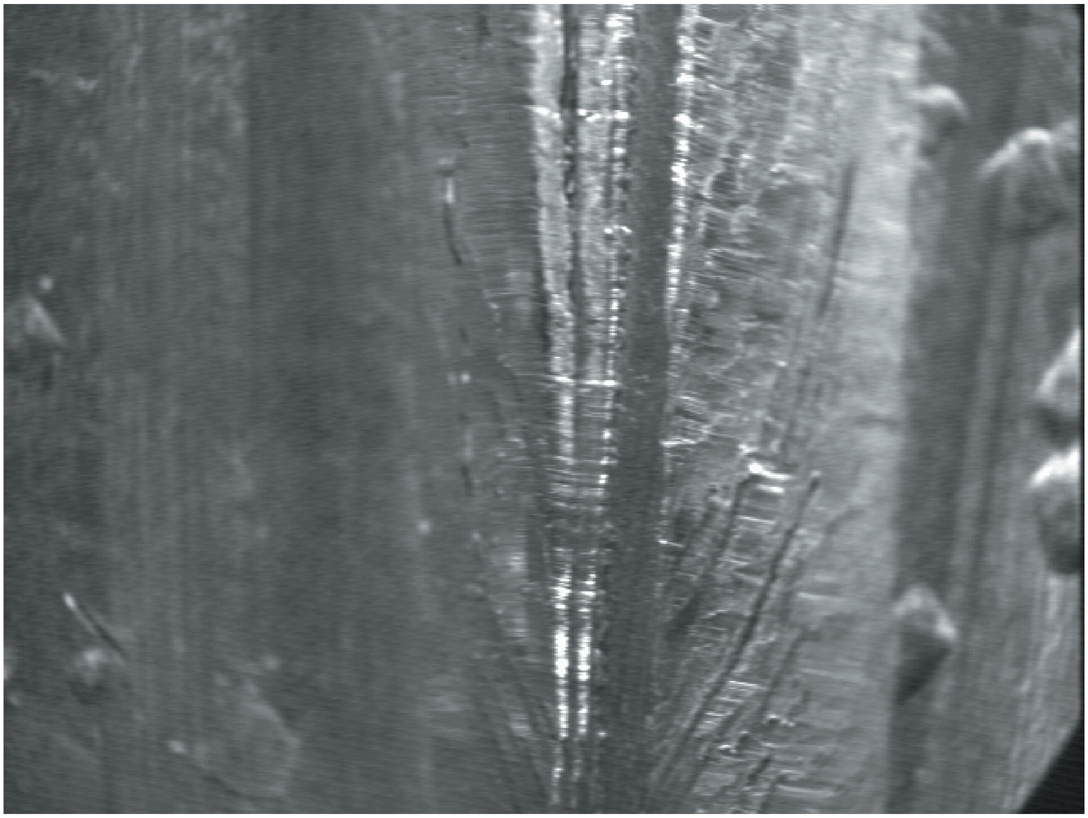


Photo 43: Cutter #1
Impressed Toolmarks
Hand Filed Edge

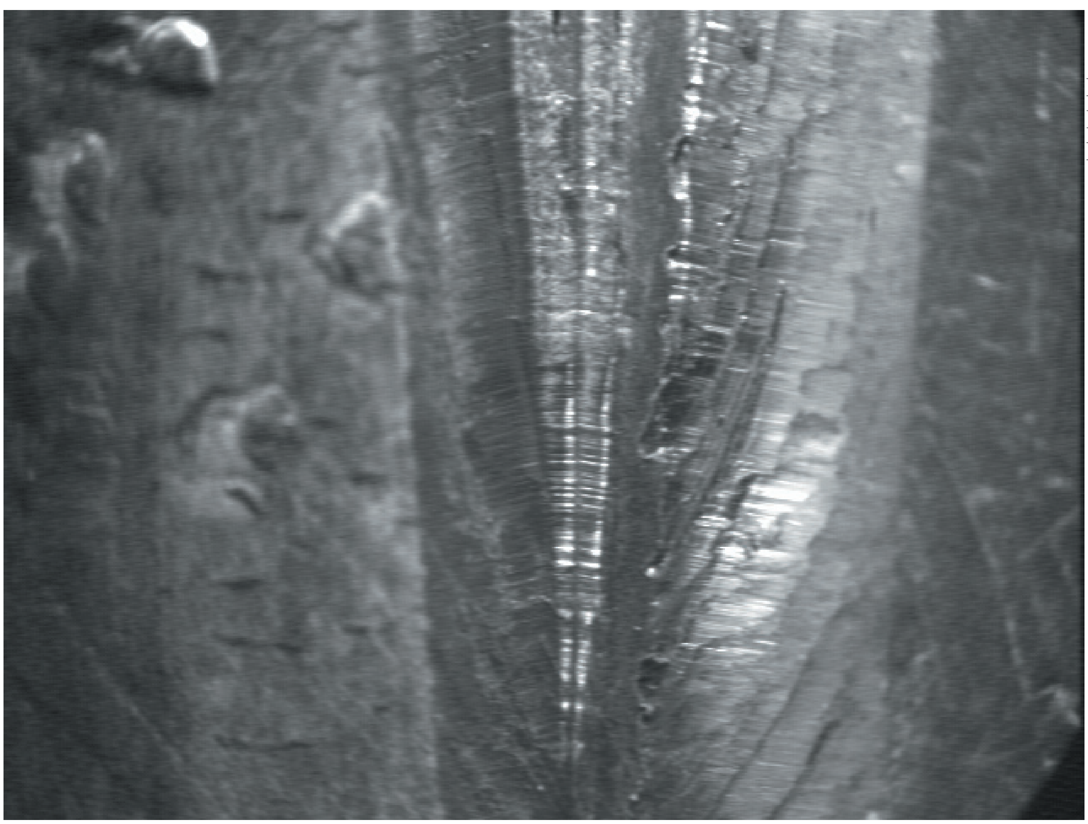


Photo 44: Cutter #2
Impressed Toolmarks
Hand Filed Edge

Photo 45: Cutter #3 Impressed Toolmarks Hand Filed Edge

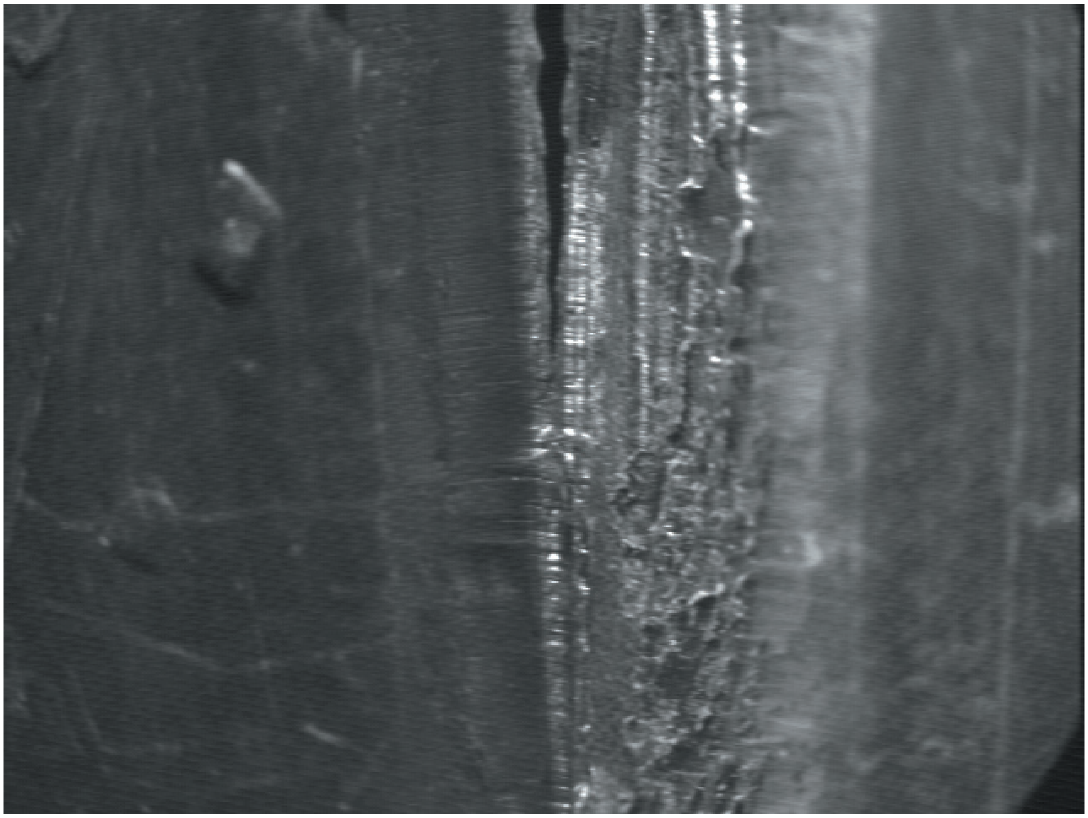
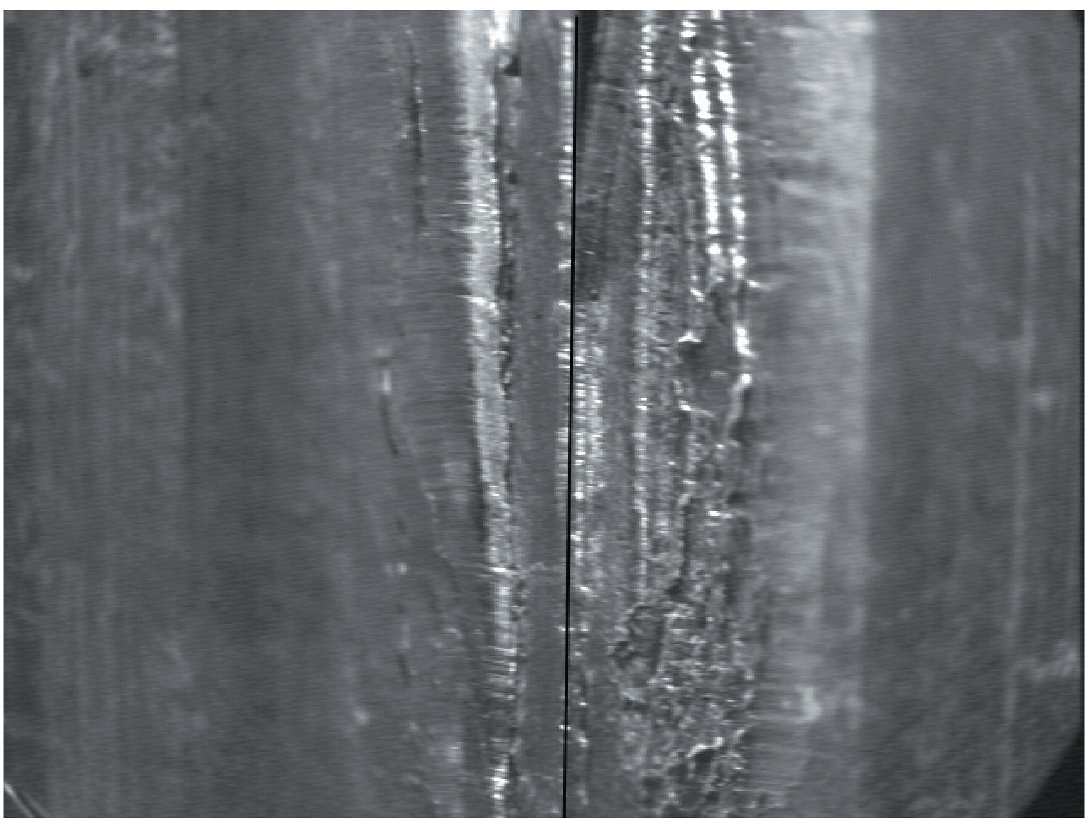


Photo 46: Cutter #1 and Cutter #3 Impressed Toolmarks Hand Filed Edge



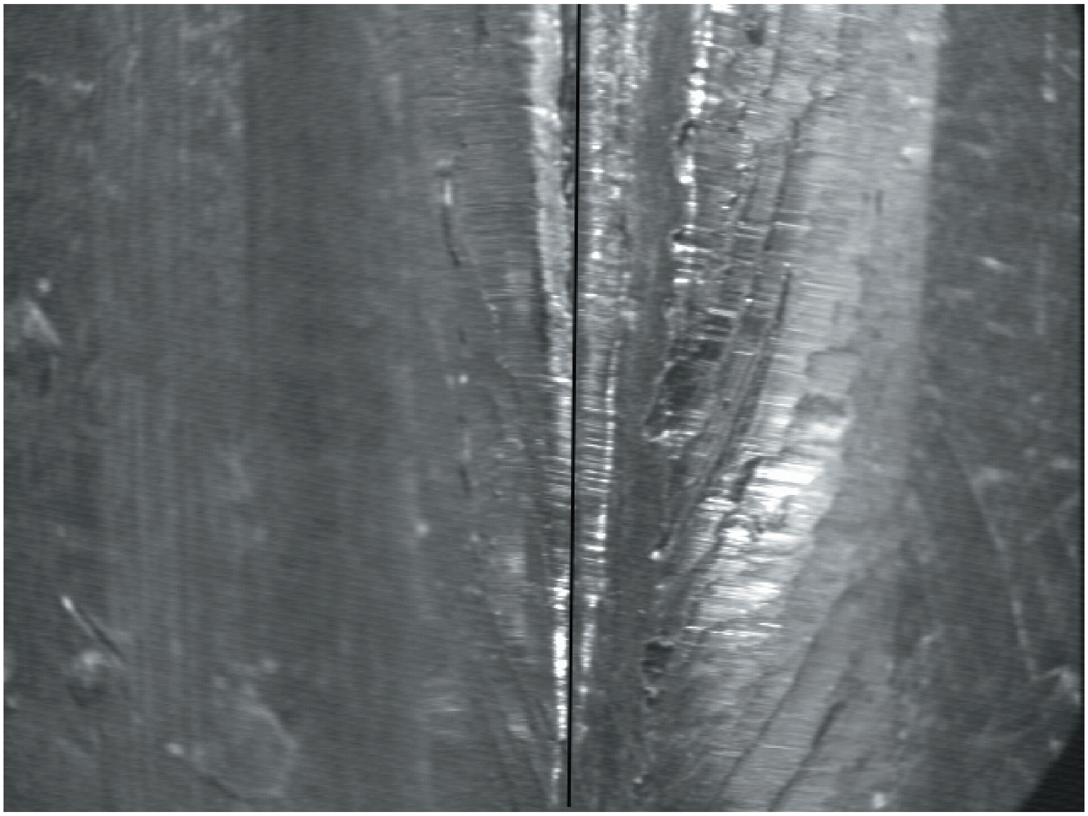


Photo 47: Cutter #1 and Cutter #2 Impressed Toolmarks Hand Filed Edge

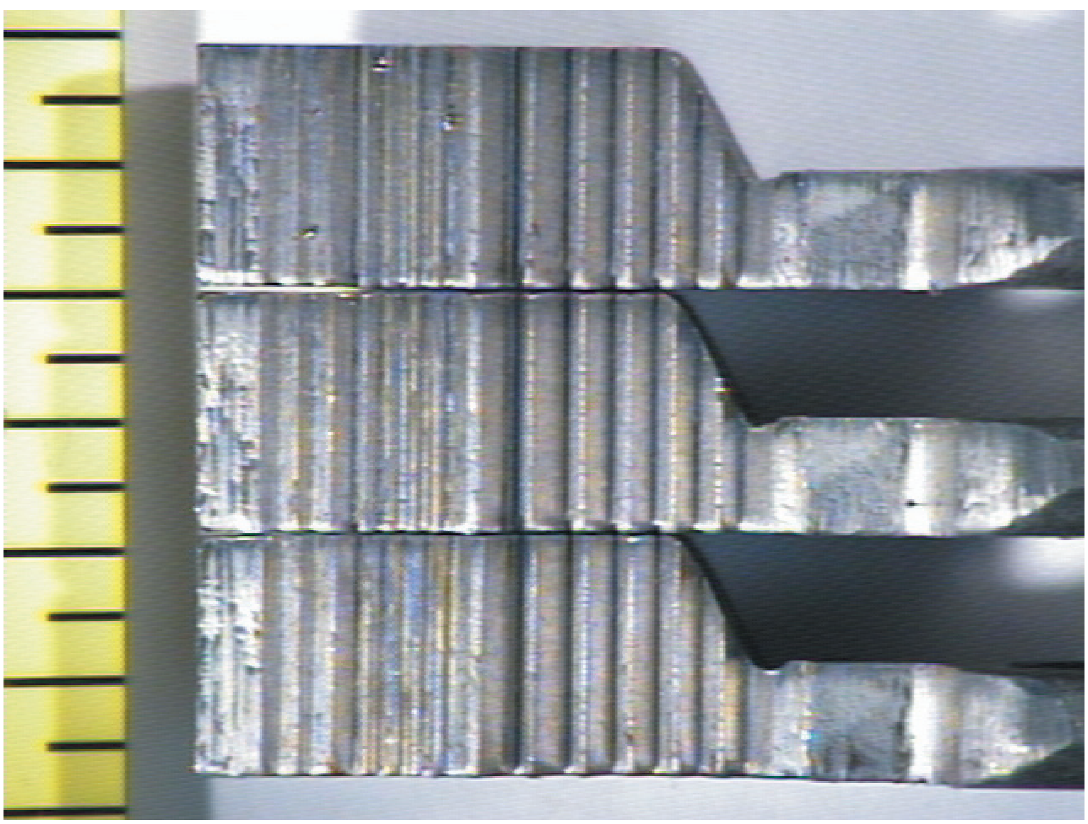


Photo 48: Slip-Joint Pliers Class and Subclass Characteristics

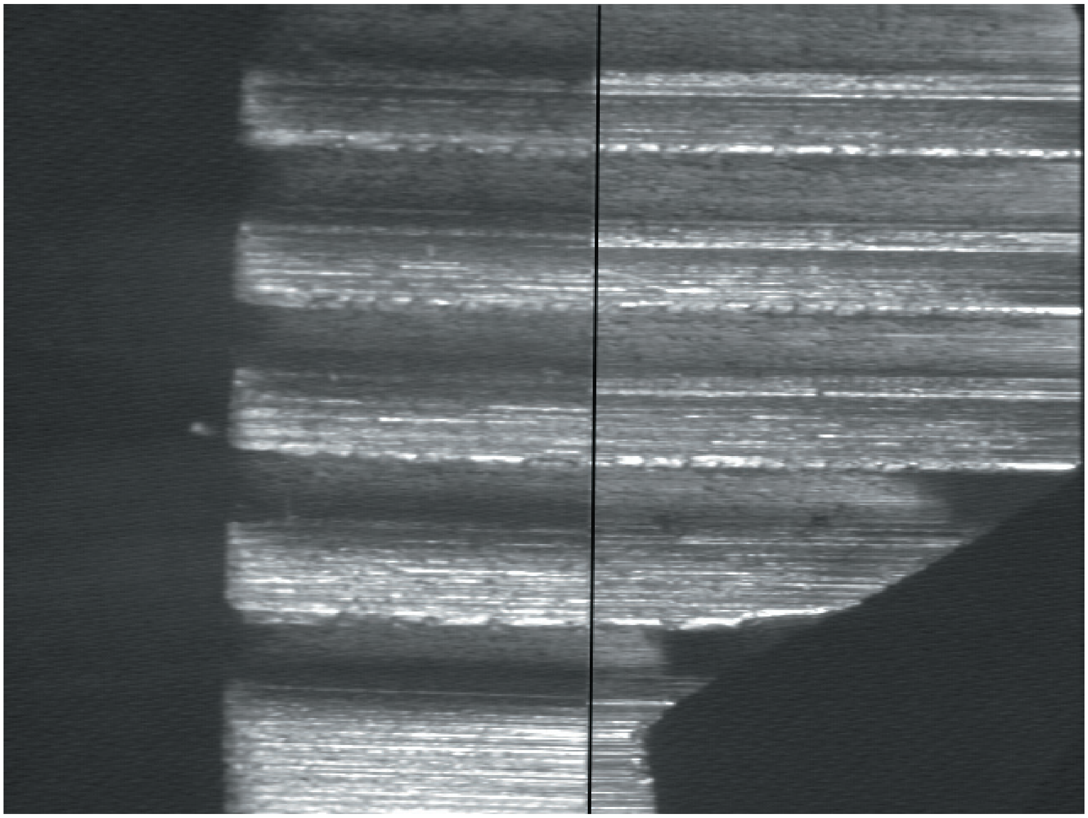


Photo 49: Comparison of Manufacturing Toolmarks on Back Teeth of Pliers #1 and #2.

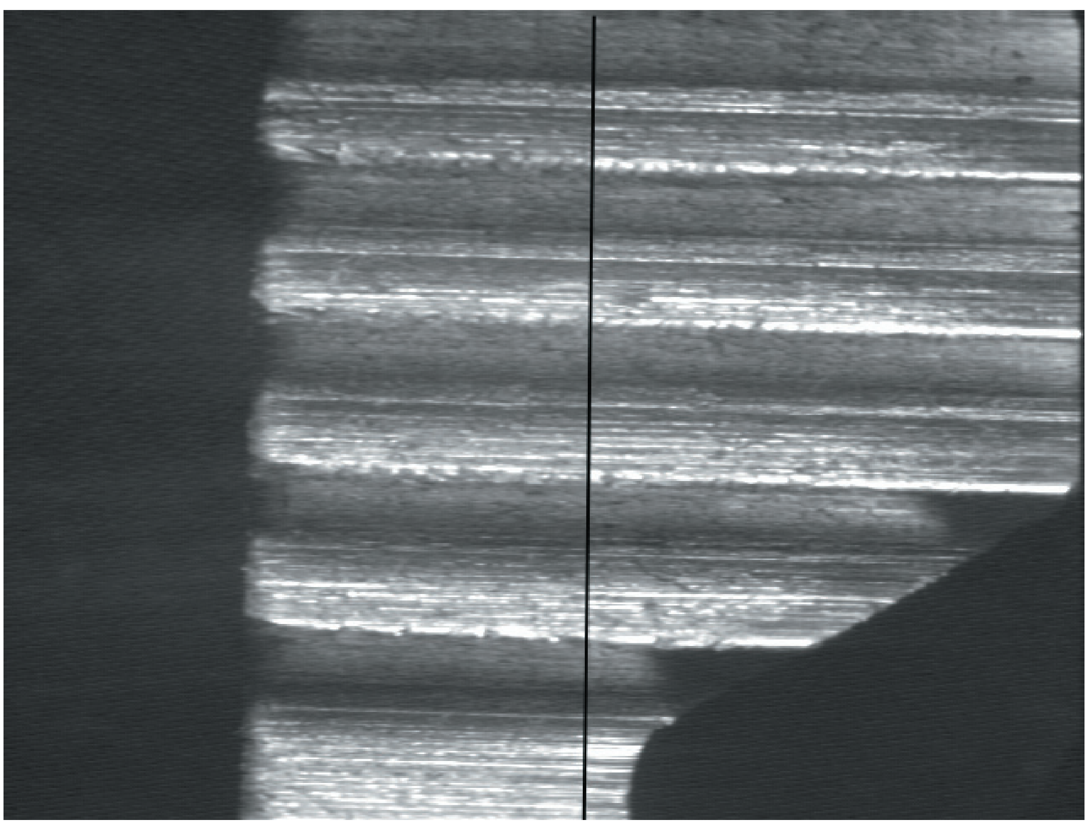


Photo 50: Comparison of Manufacturing Toolmarks on Back Teeth of Pliers #2 and #3.

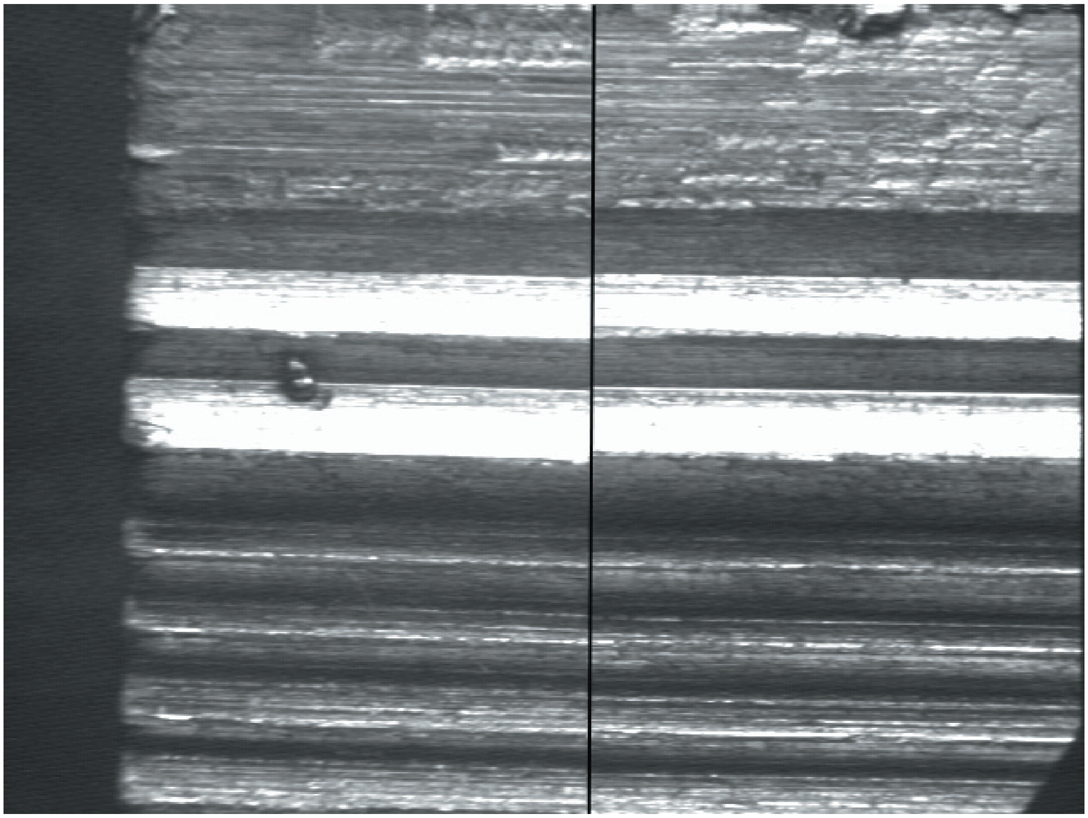


Photo 51: Comparison of Manufacturing Toolmarks on Front Teeth of Pliers #1 and #2.

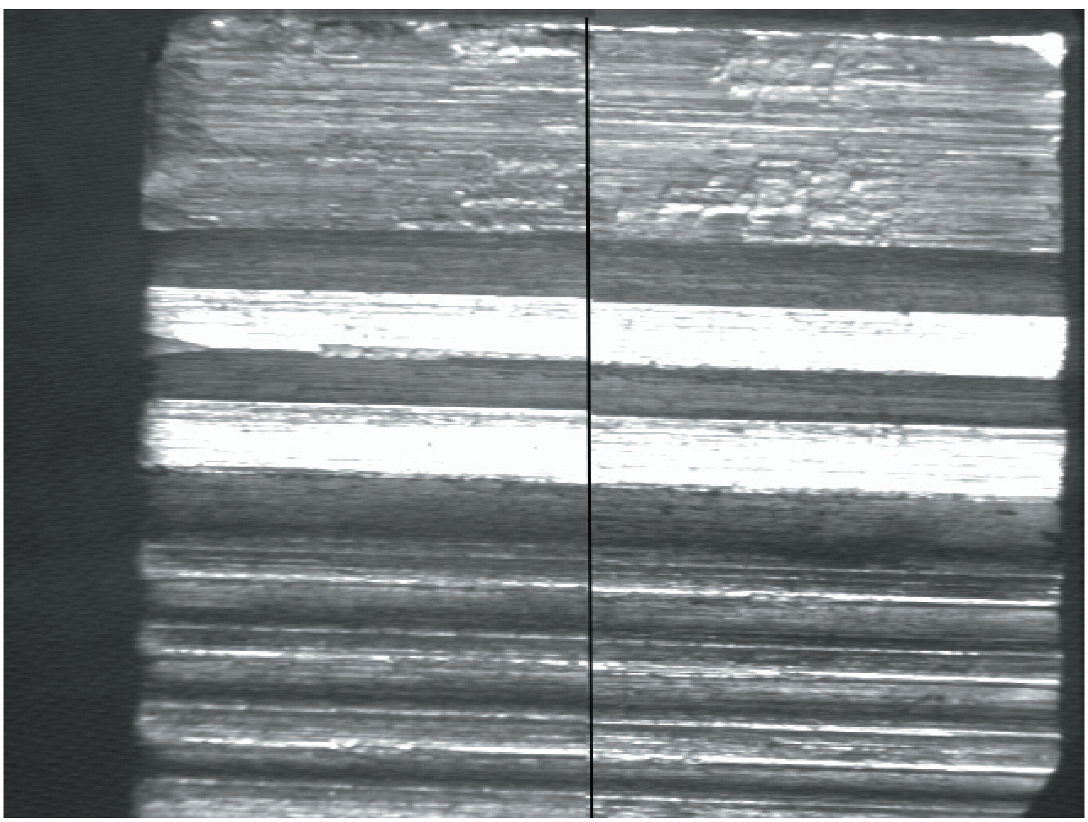


Photo 52: Comparison of Manufacturing Toolmarks on Front Teeth of Pliers #2 and #3.

Photo 53: Pliers #1 Test Toolmark Comparison

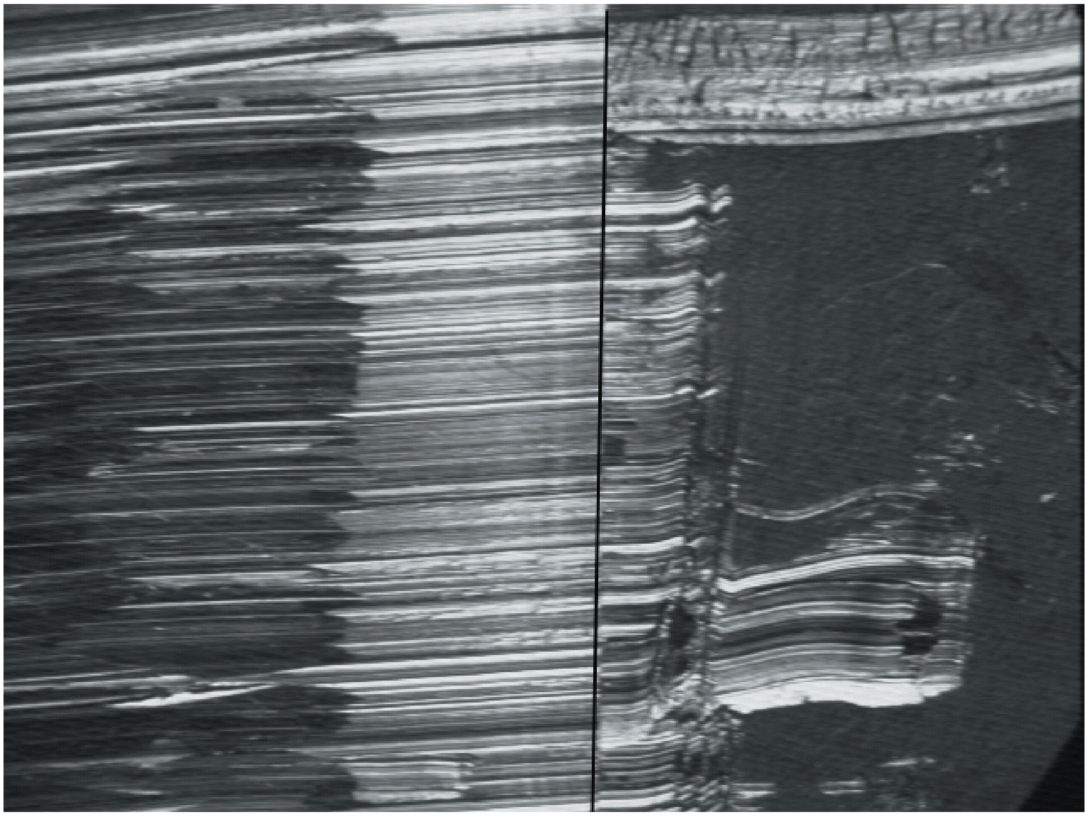
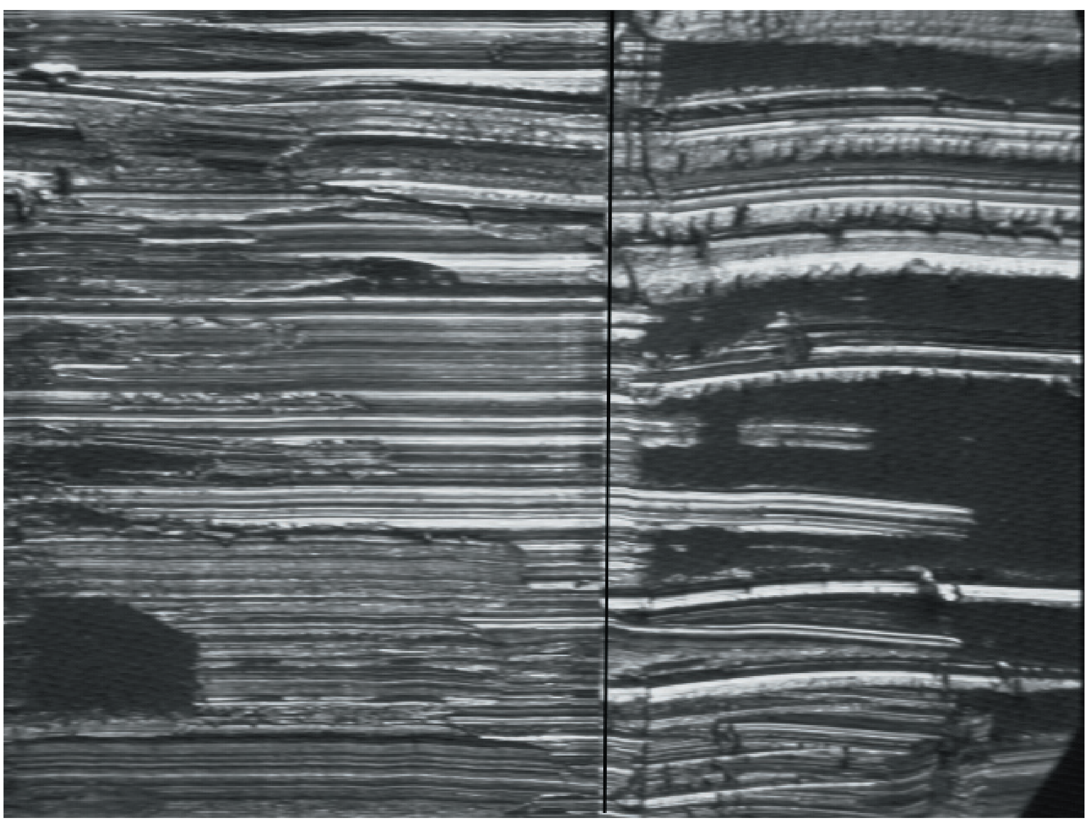


Photo 54: Pliers #2 Test Toolmark Comparison



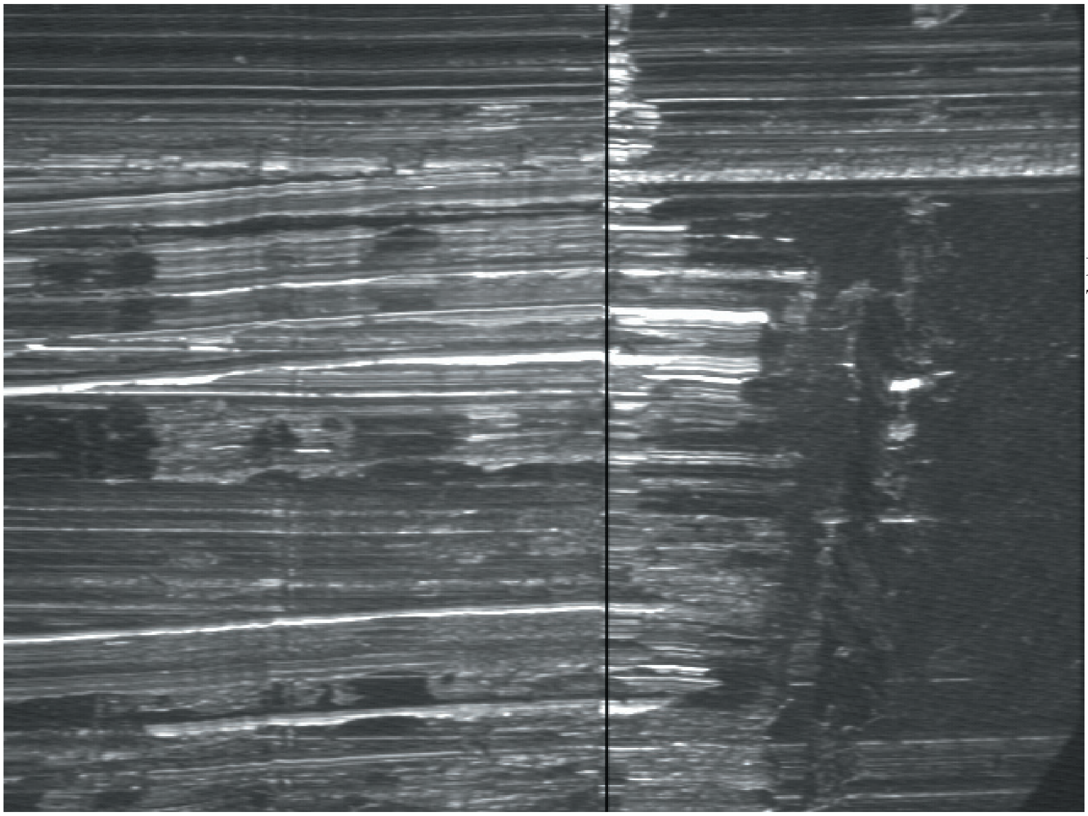


Photo 55: Pliers #3 Test Toolmark Comparison

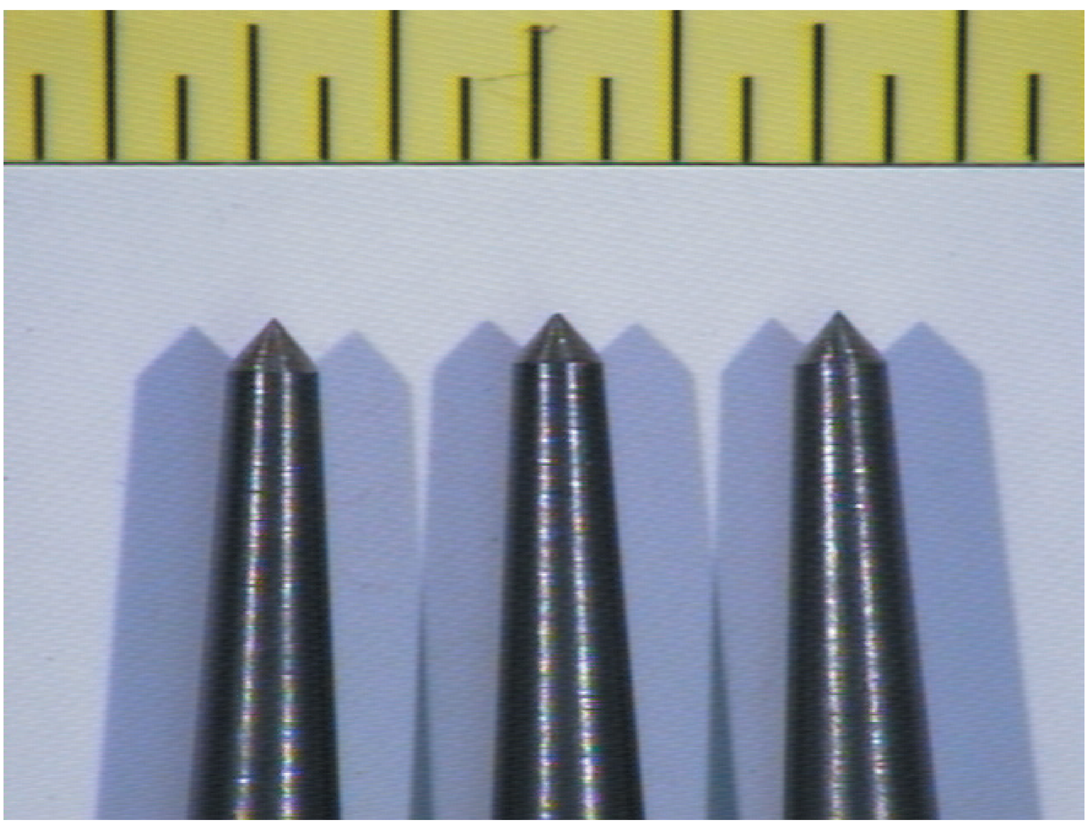


Photo 56: Punches

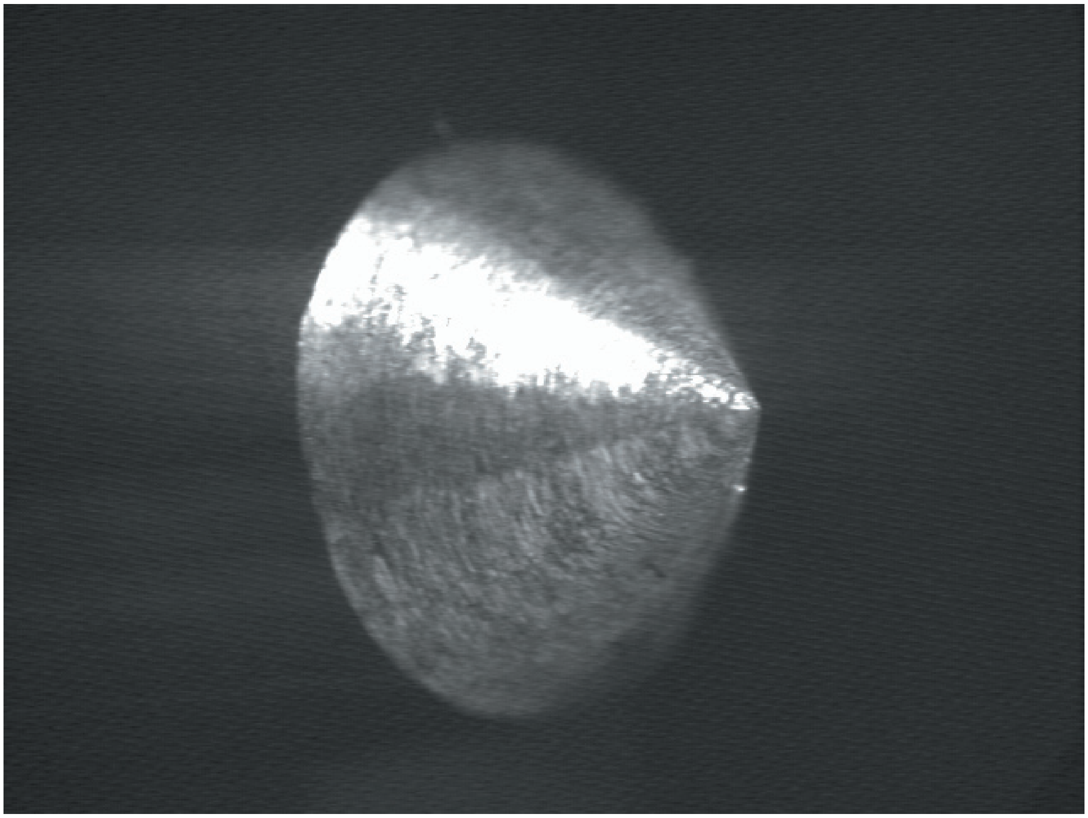


Photo 57: Tool Working Surface of Punch

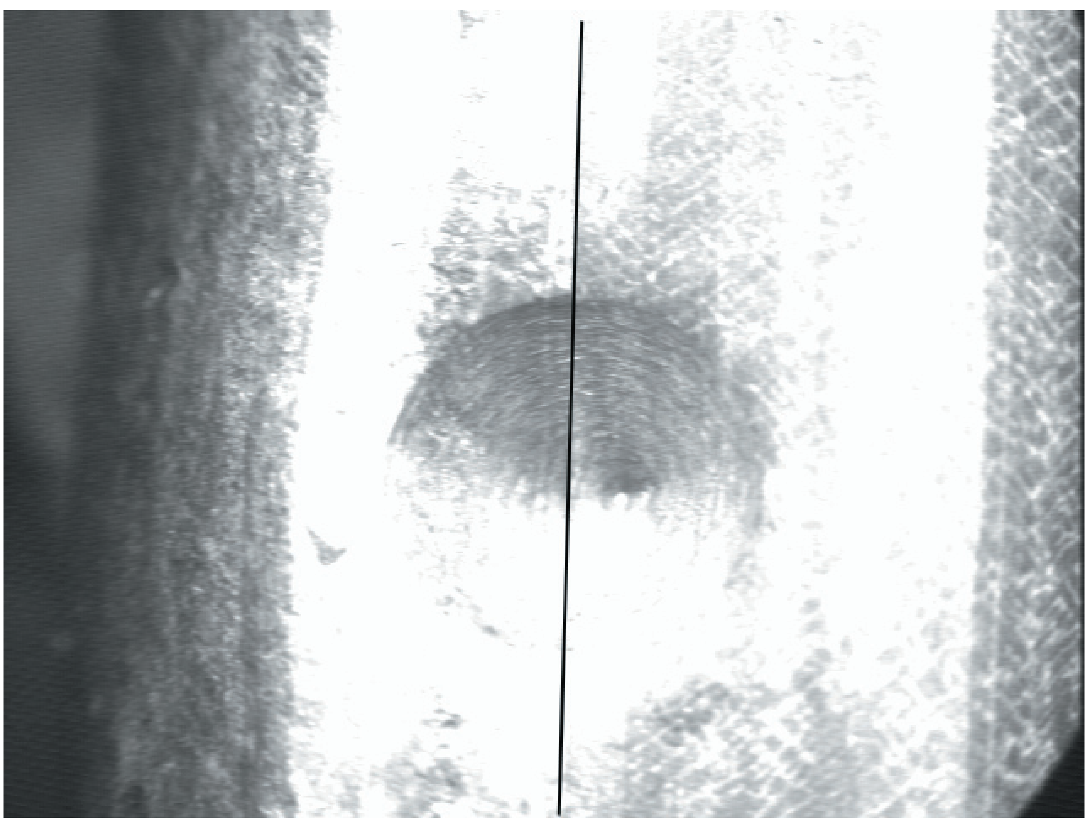


Photo 58: Punch #1 Test Comparison

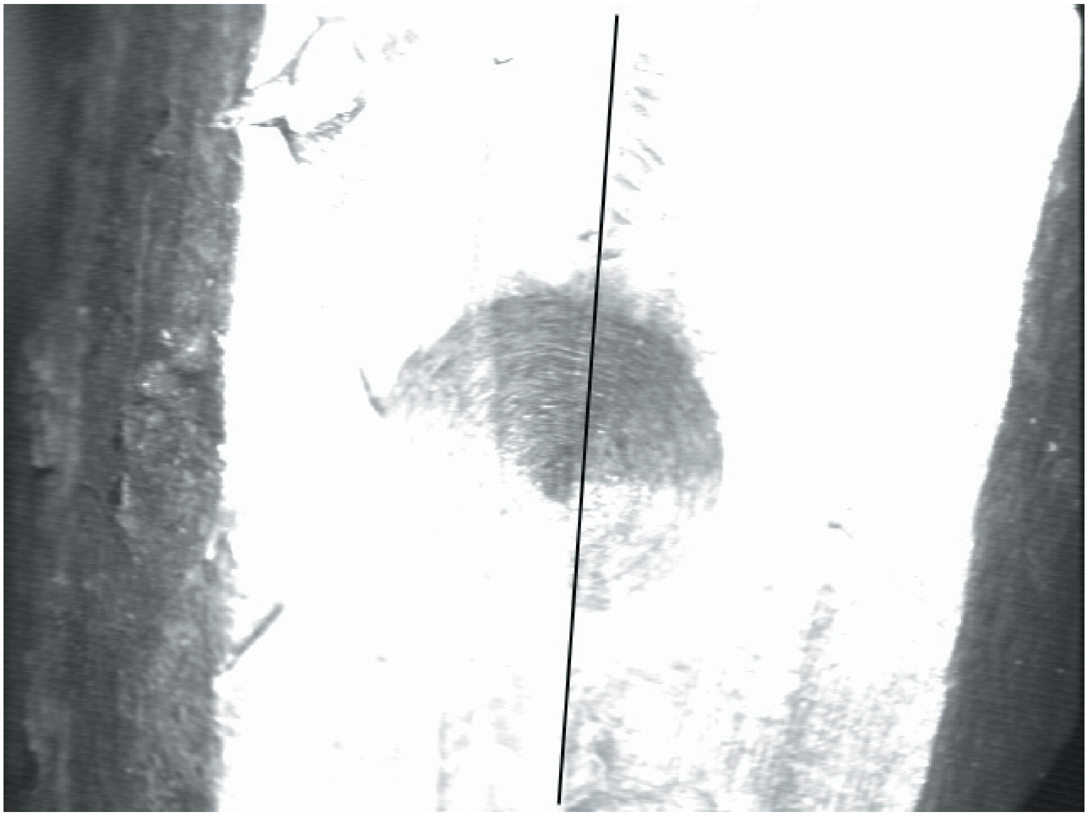


Photo 59: Punch #2 Test Comparison

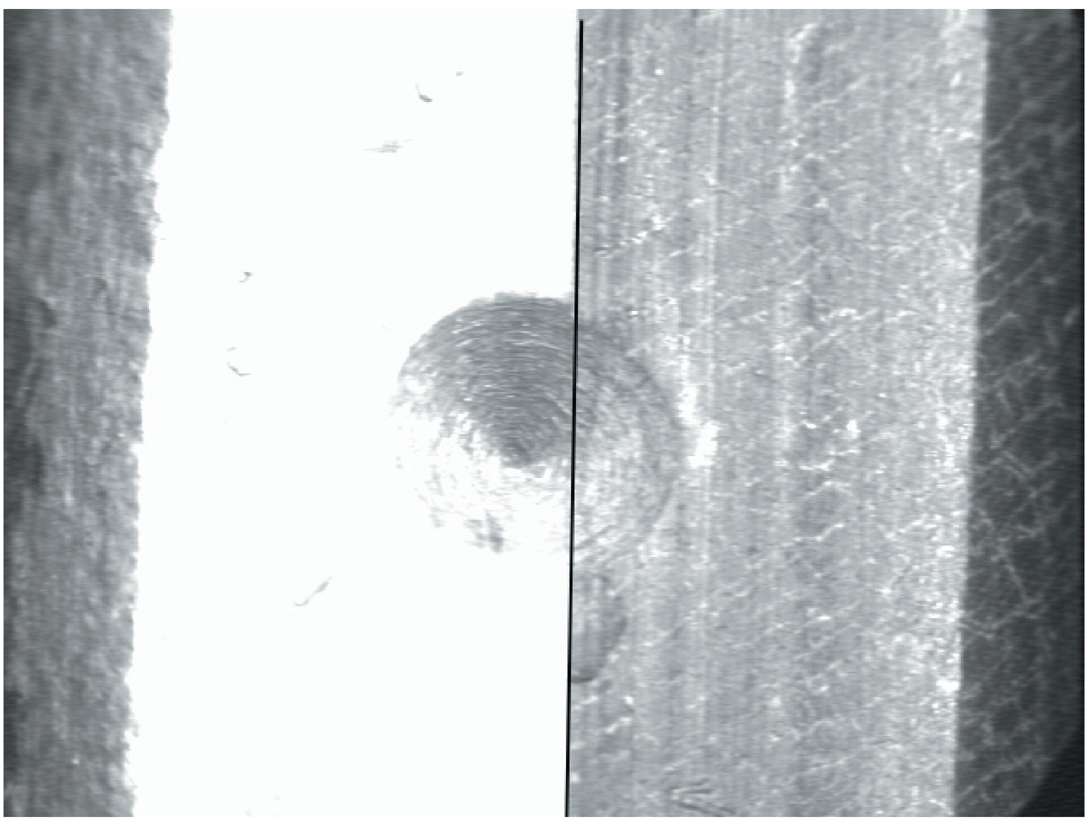


Photo 60: Punch #3 Test Comparison

Photo 61: Test Comparison Punch #1 and Punch #2

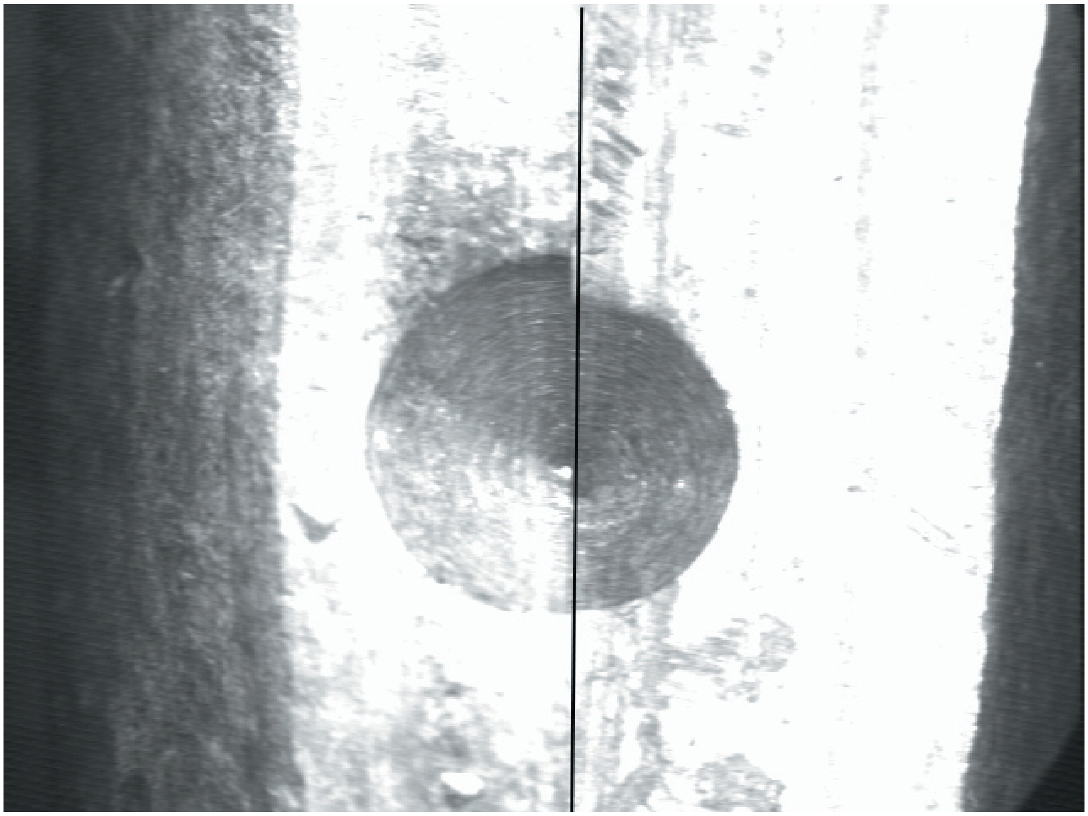
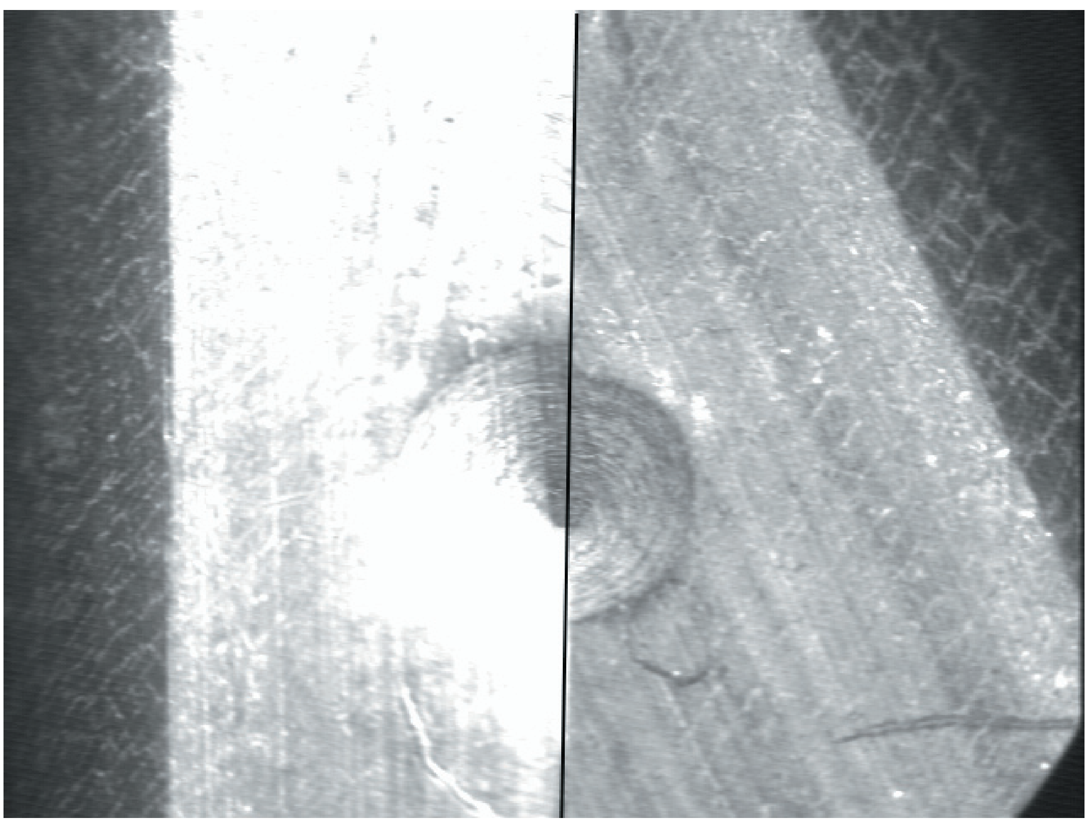


Photo 62: Test Comparison Punch #2 and Punch #3



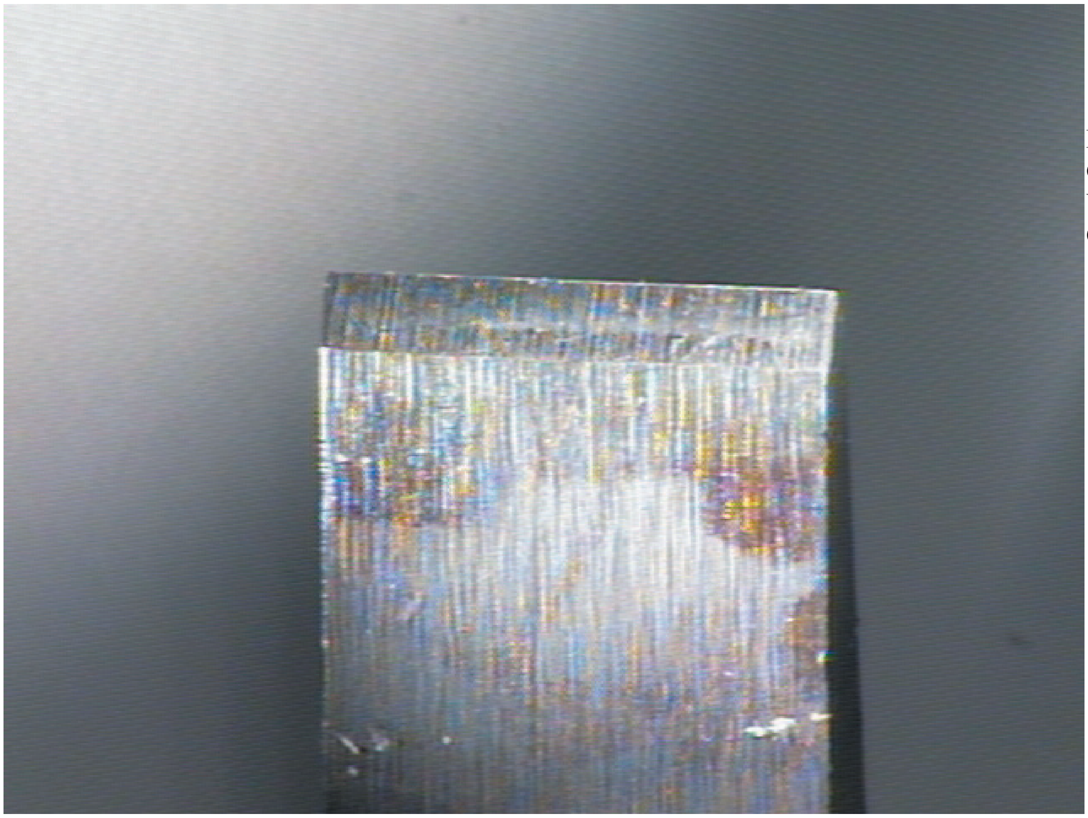


Photo 63: Bevel and Ground Cutting Tool Working Surface of Cold Chisel

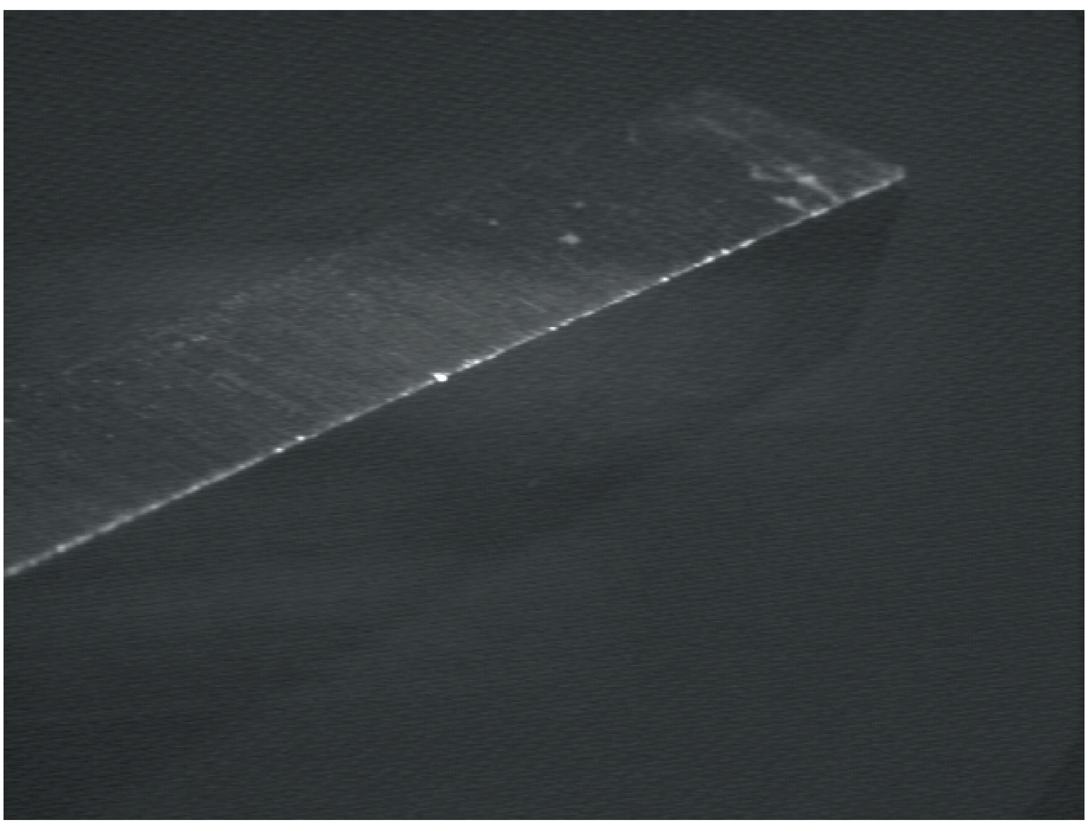


Photo 64: Apex of Cutting Edge of Cold Chisel

Photo 65: Chisel #1
Side A Test Comparison

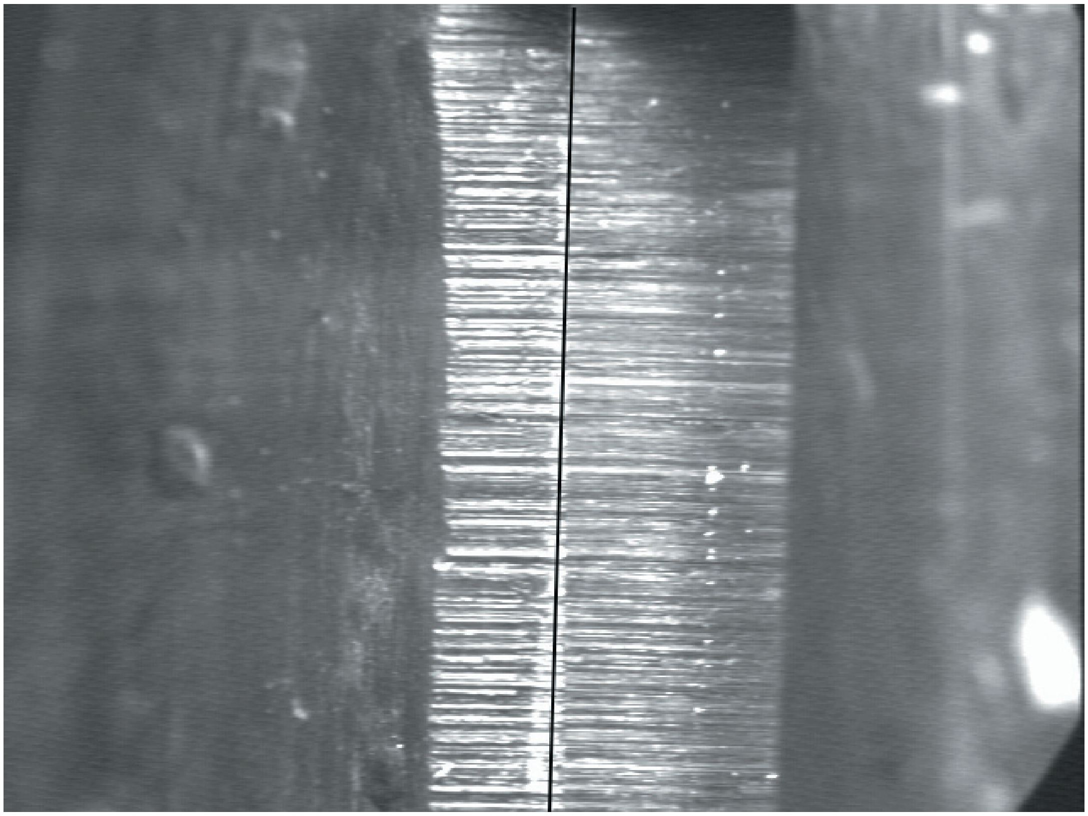
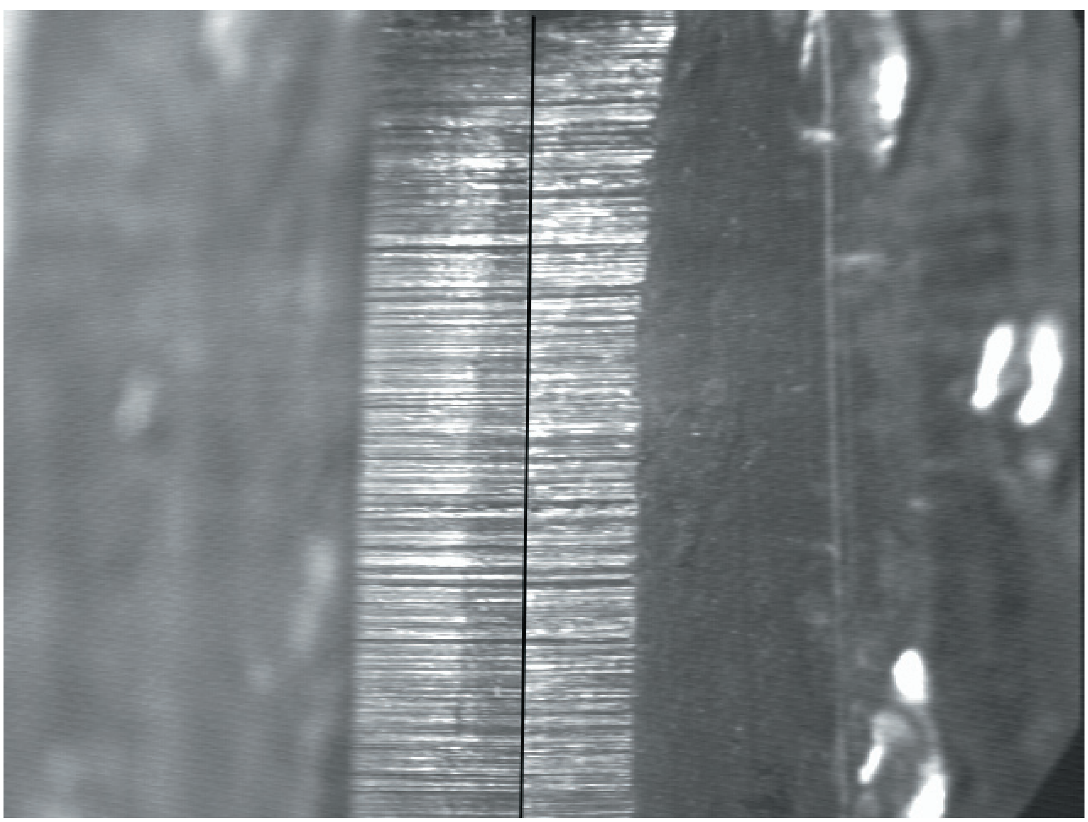


Photo 66: Chisel #1
Side B Test Comparison



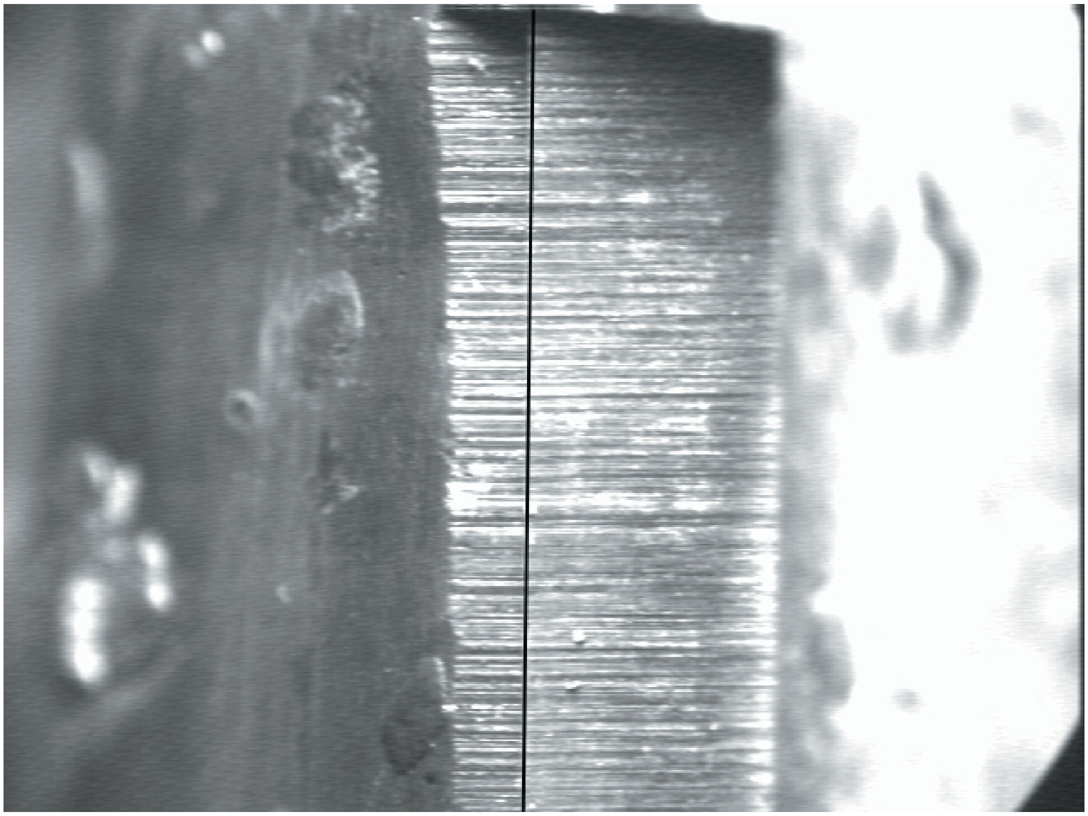


Photo 67: Chisel #2 Side A Test Comparison

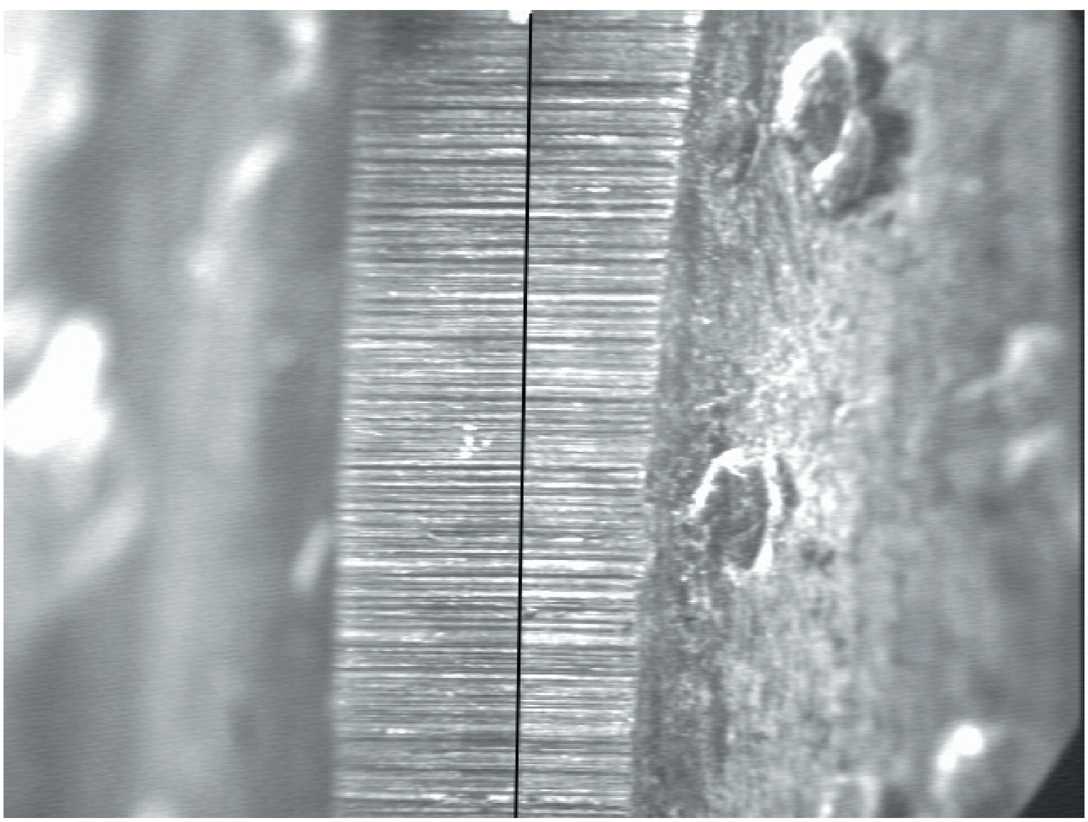


Photo 68: Chisel #2 Side B Test Comparison

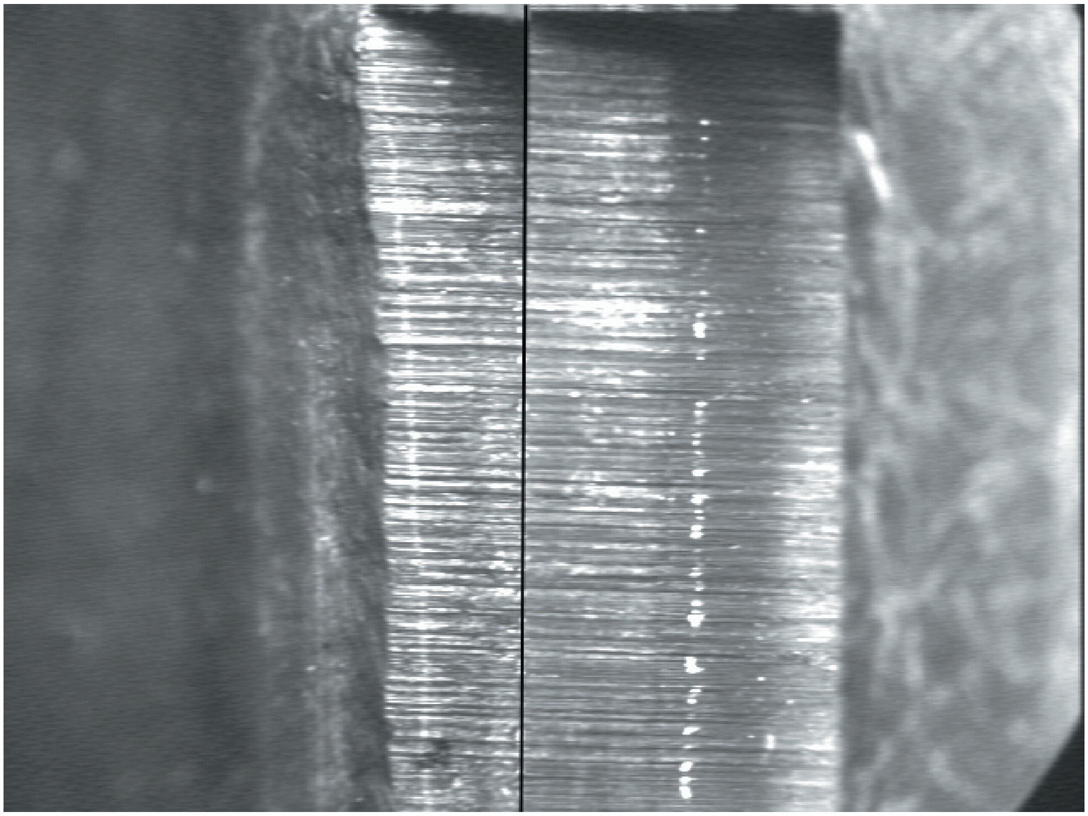


Photo 69: Chisel #3 Side A Test Comparison

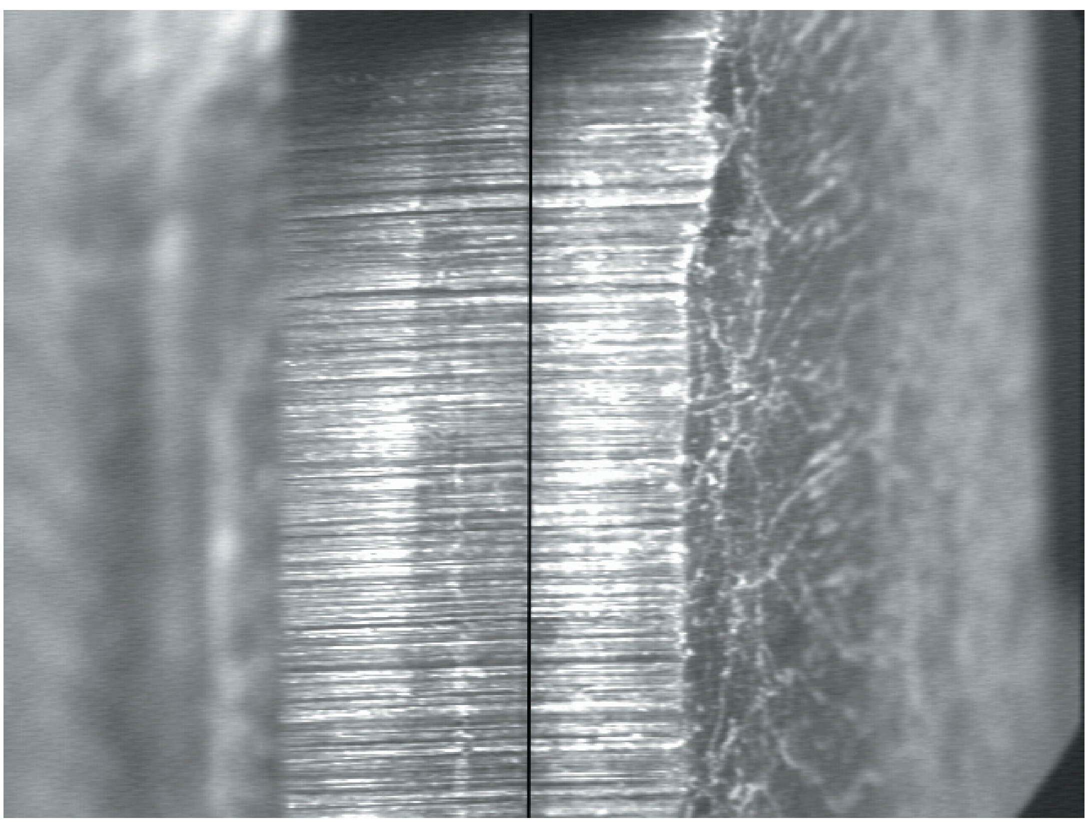


Photo 70: Chisel #3 Side B Test Comparison

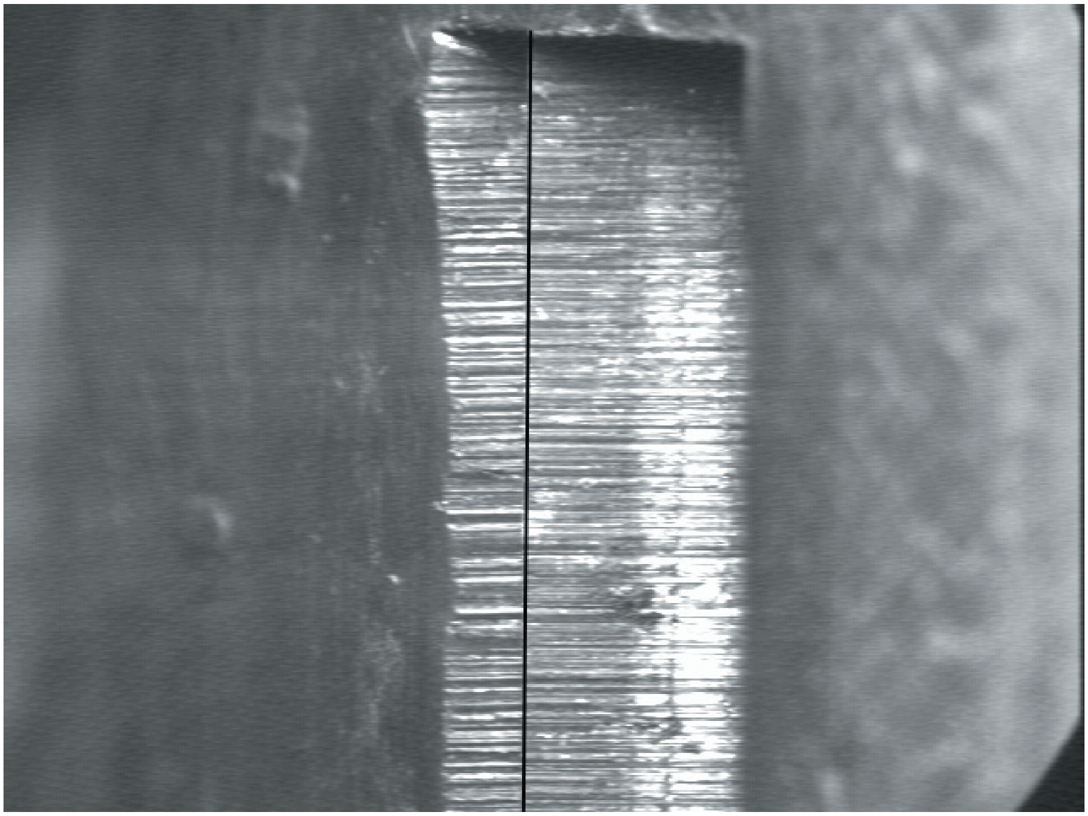


Photo 71: Side A Comparison of Chisel #1 and Chisel #2

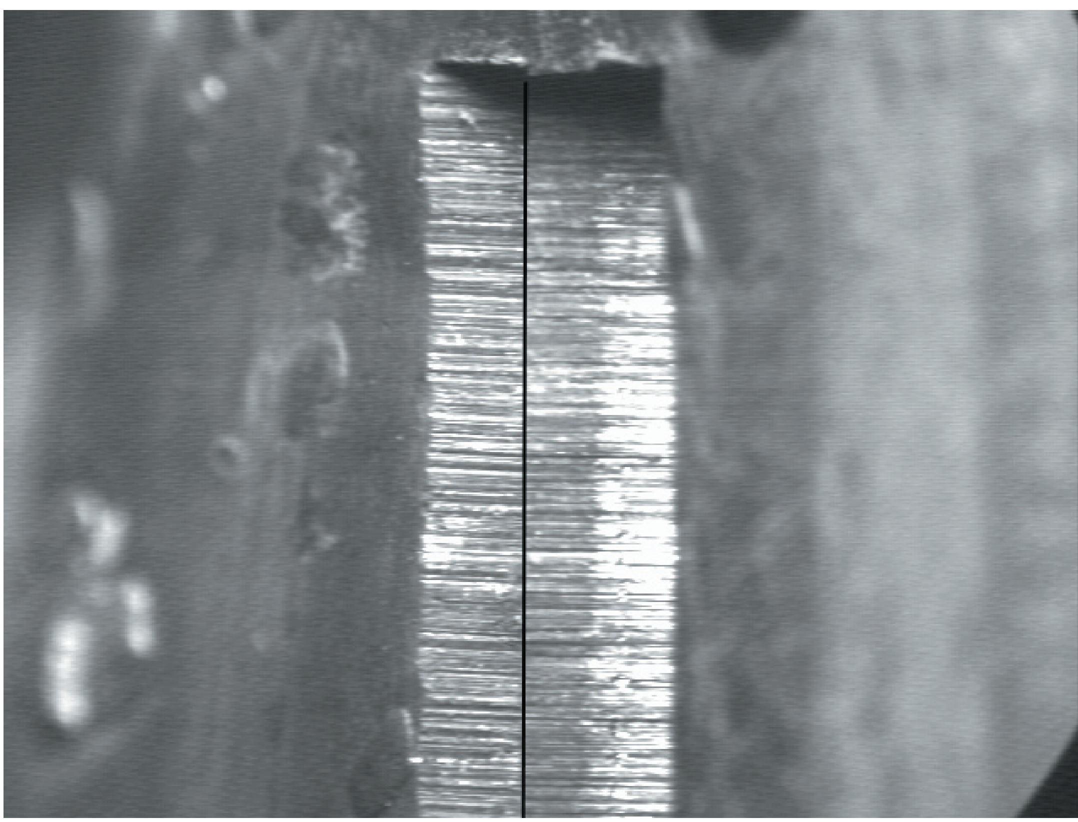


Photo 72: Side A Comparison of Chisel #2 and Chisel #3

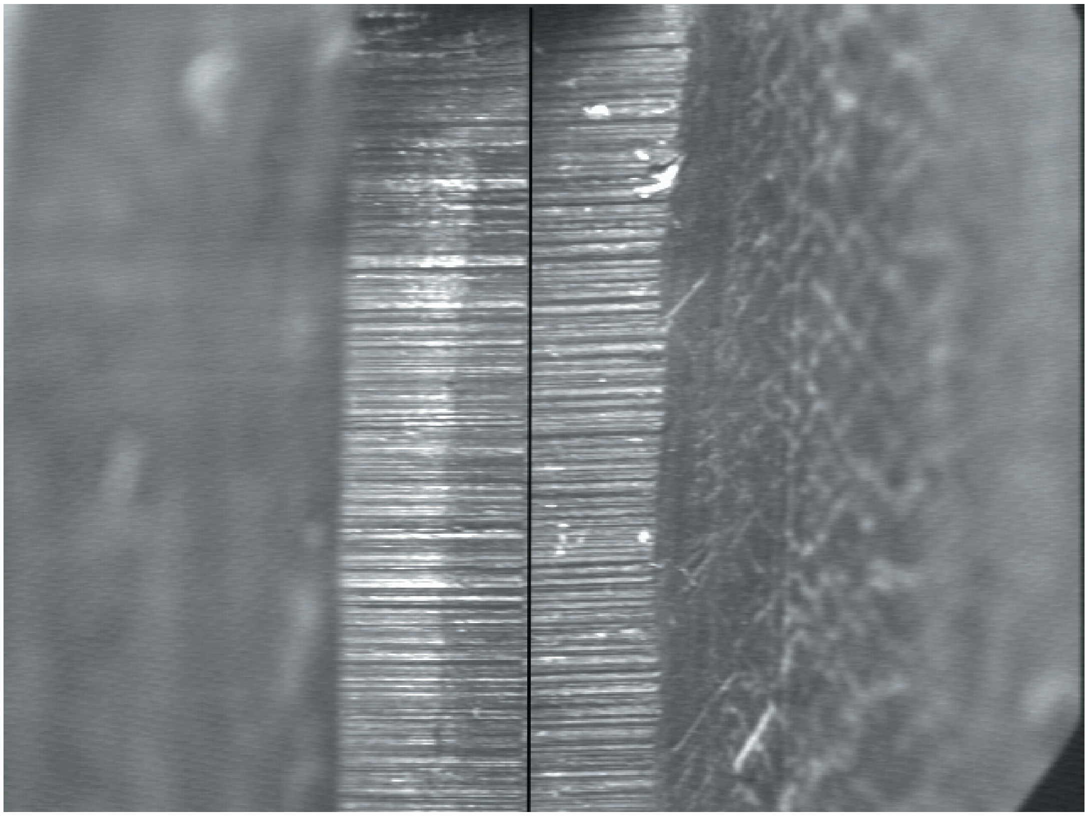


Photo 73: Side B Comparison of Chisel #1 and Chisel #2

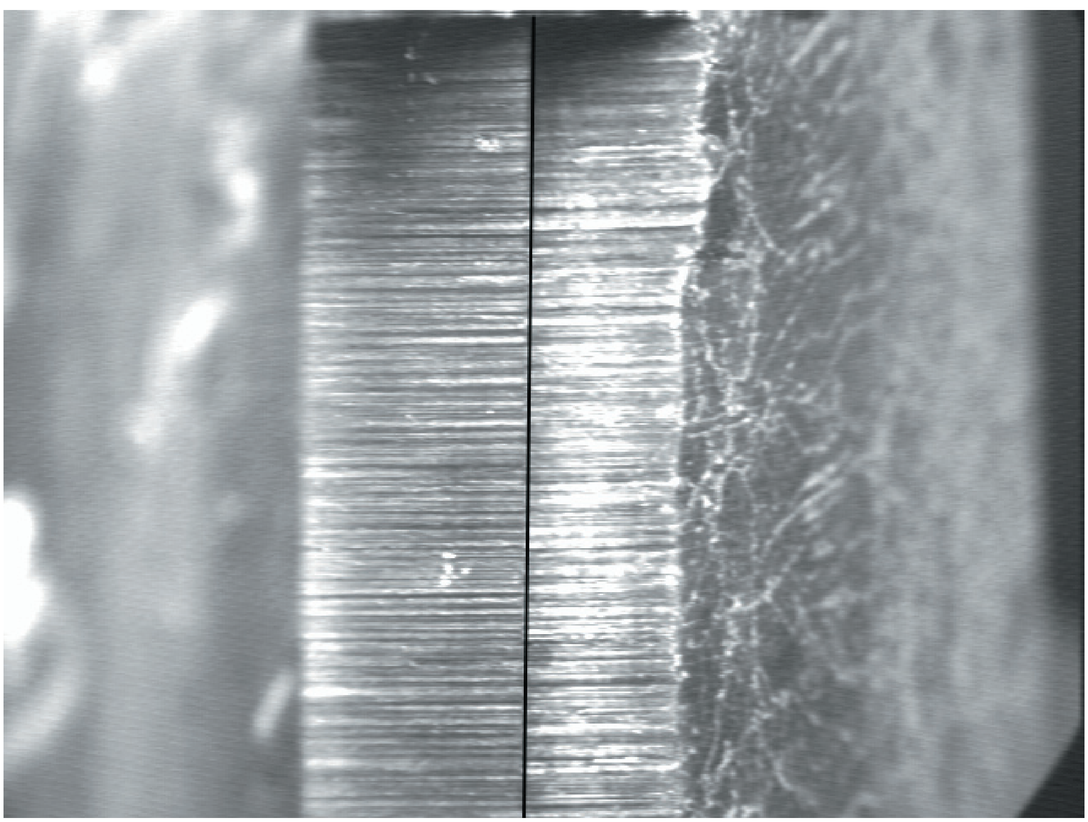


Photo 74: Side B Comparison of Chisel #2 and Chisel #3

Photo 75: Beveled Edges/Surface of Chisel

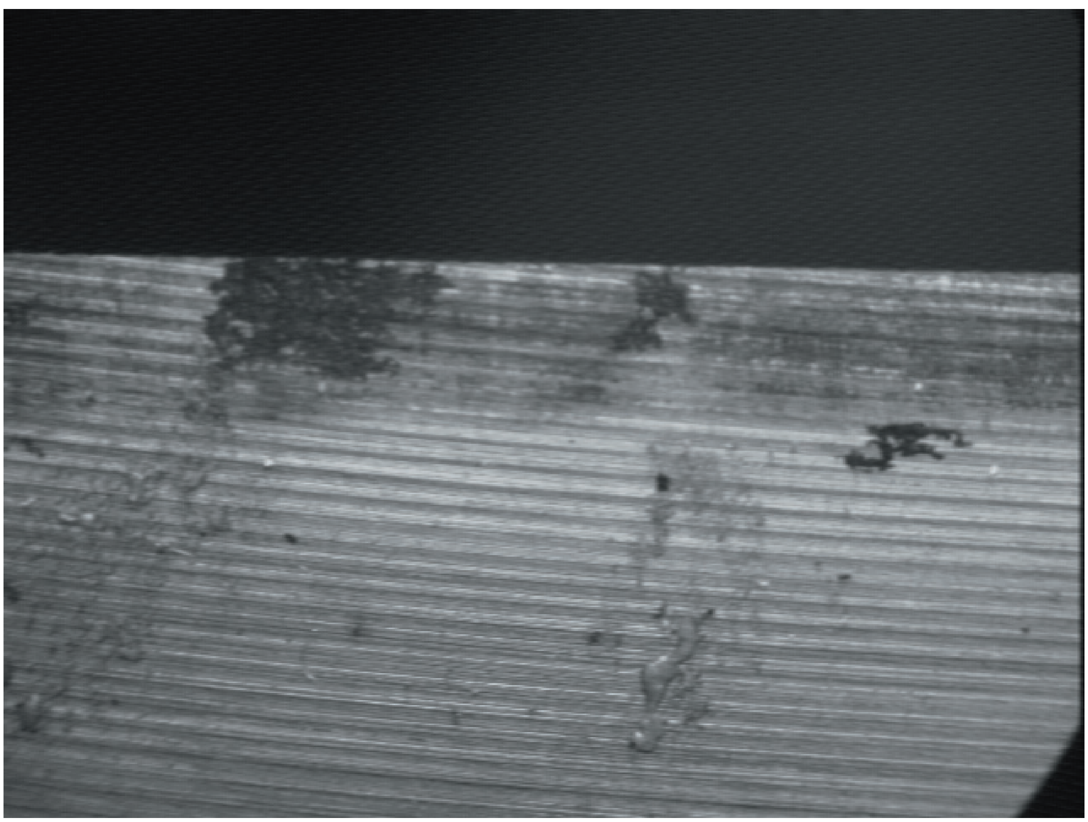


Photo 76: Back Edge/ Surface of Chisel With Cutting Edge at Top

Photo 77: Cutting Edges/Surface of Chisels

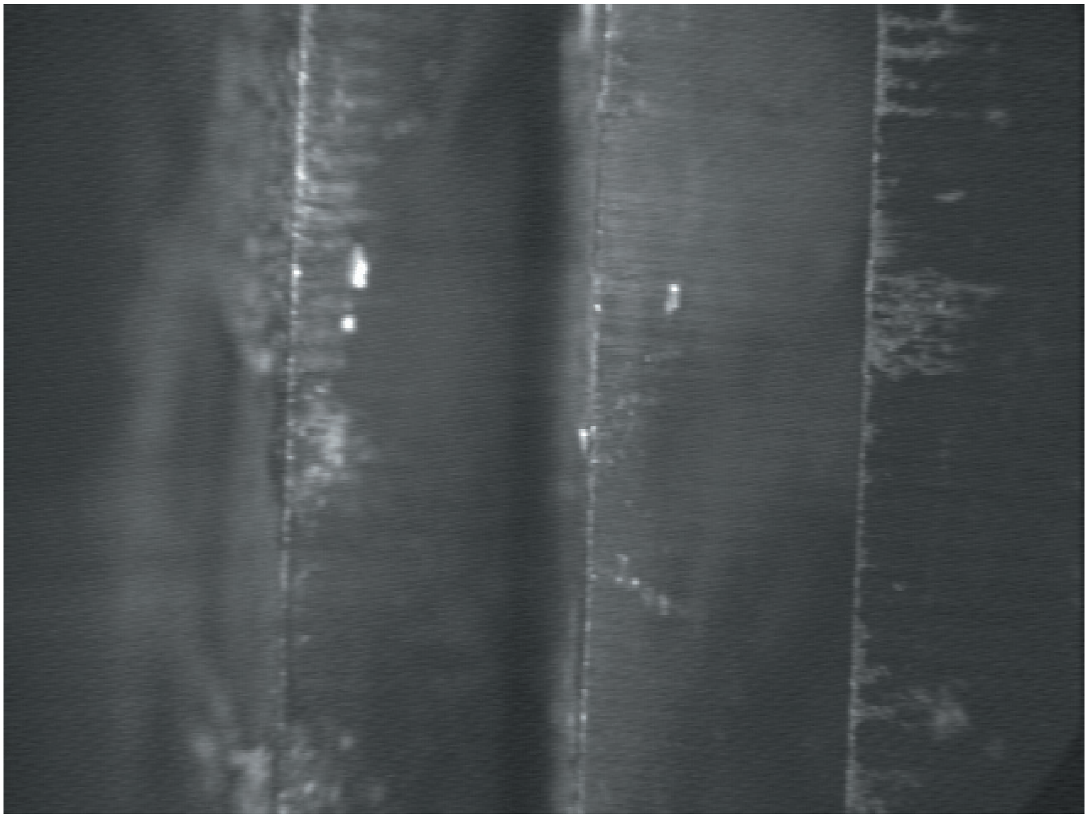
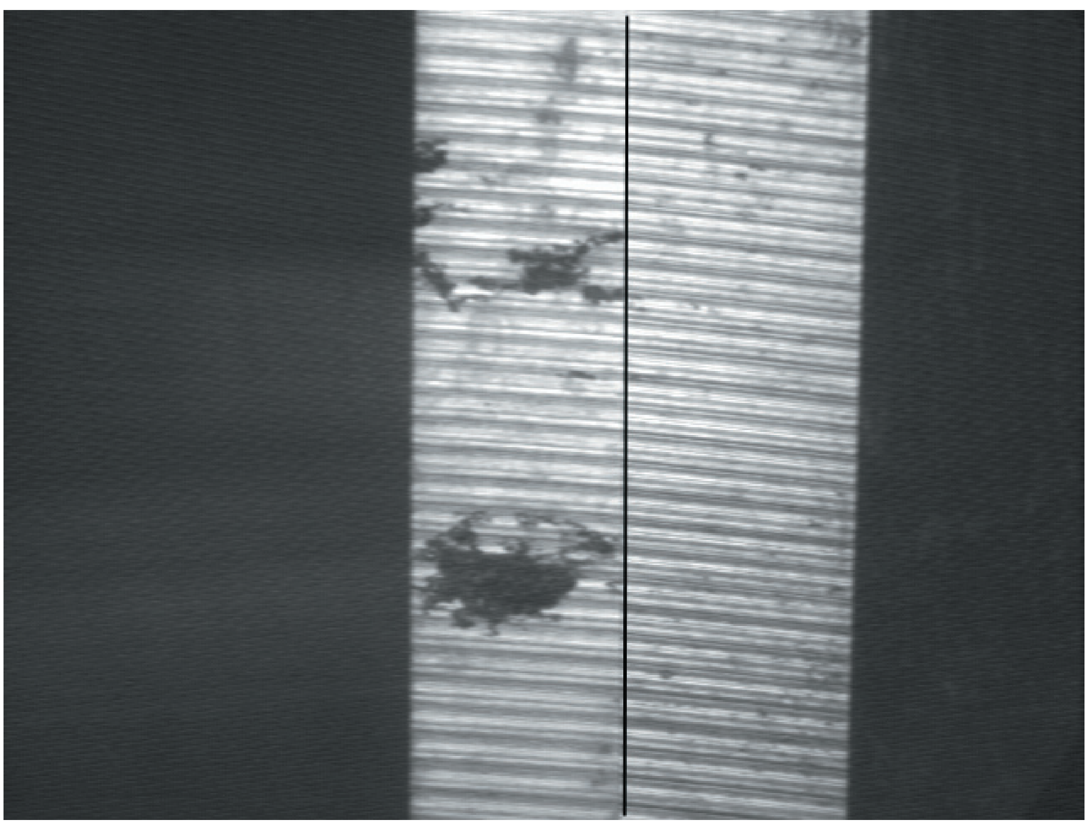


Photo 78: Beveled Edge/Surface Chisel #1 and Chisel #2



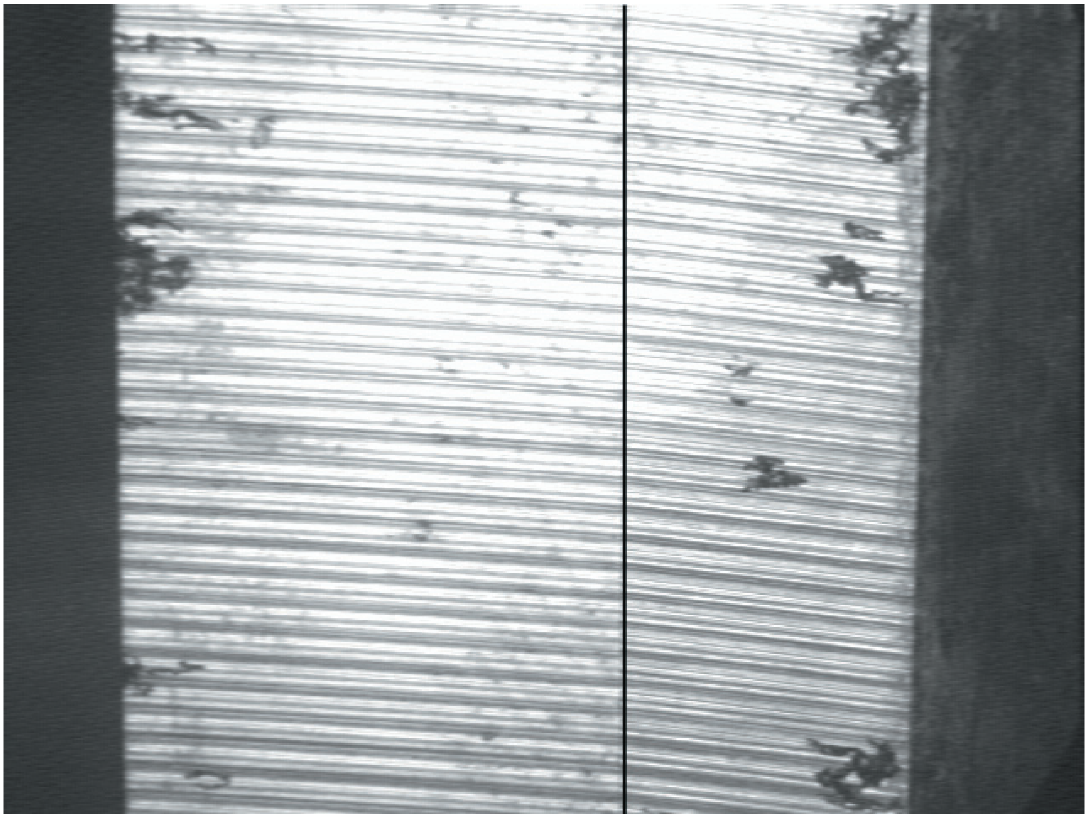


Photo 79: Beveled Edge/Surface Chisel #2 and Chisel #3

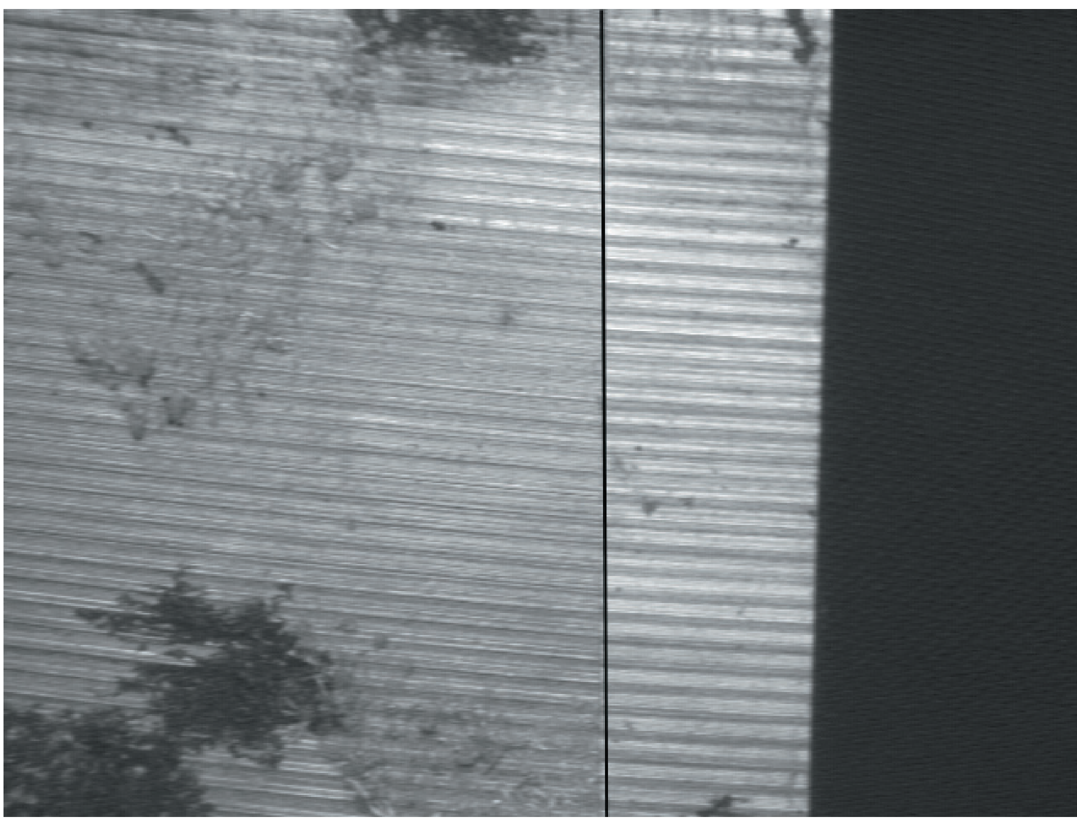


Photo 80: Back Edge/ Surface Chisel #1 and Chisel #2

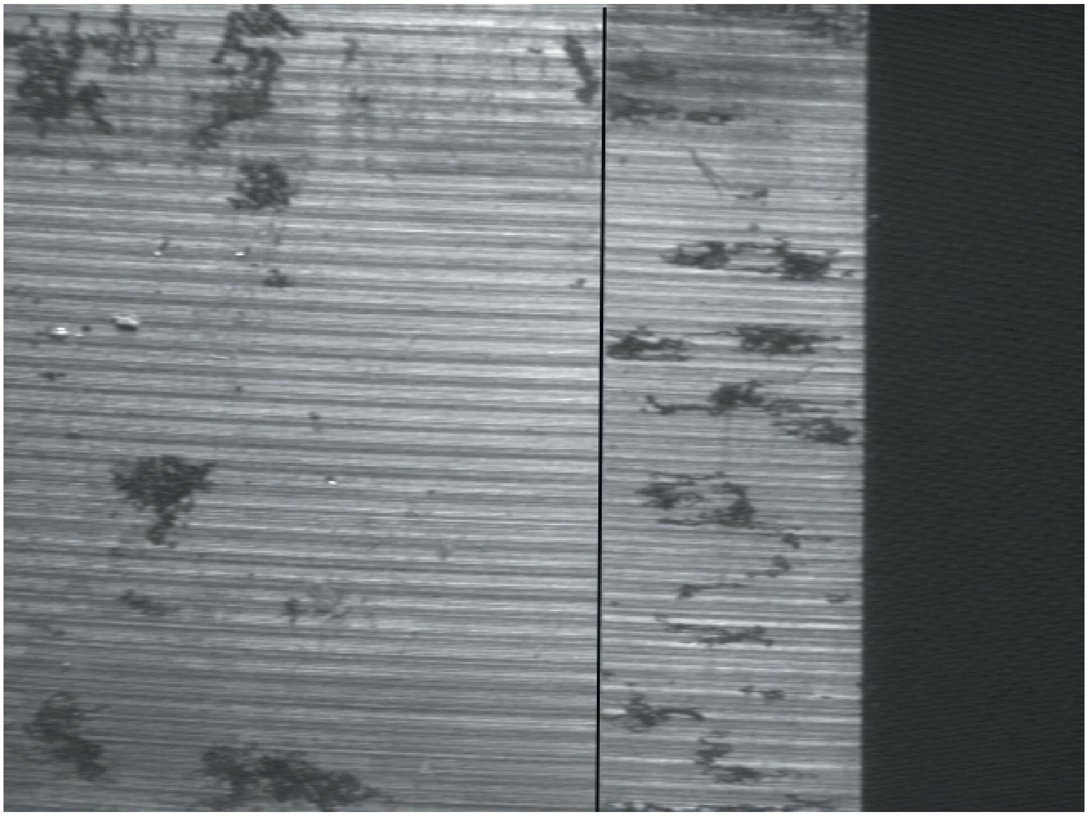


Photo 81: Back Edge/ Surface Chisel #2 and Chisel #3

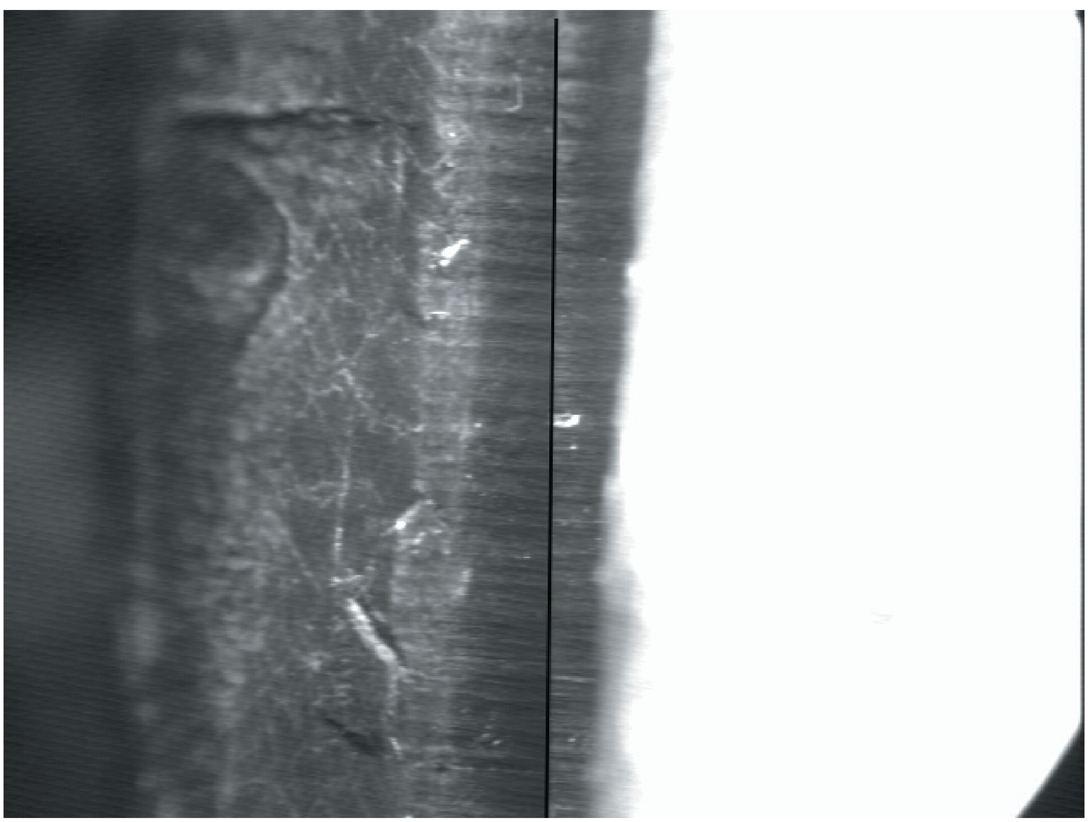


Photo 82: Chisel #1 Beveled Edge/Surface Test toolmarks

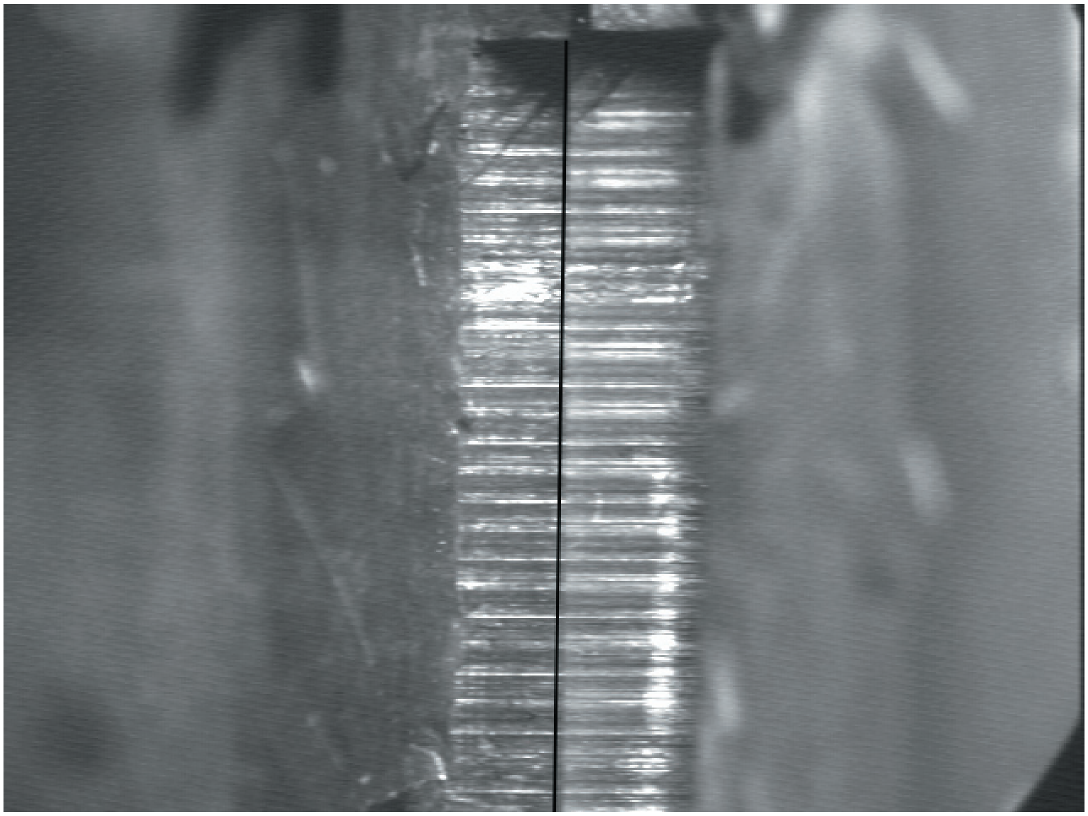


Photo 83: Chisel #2
Beveled Edge/Surface
Test toolmarks

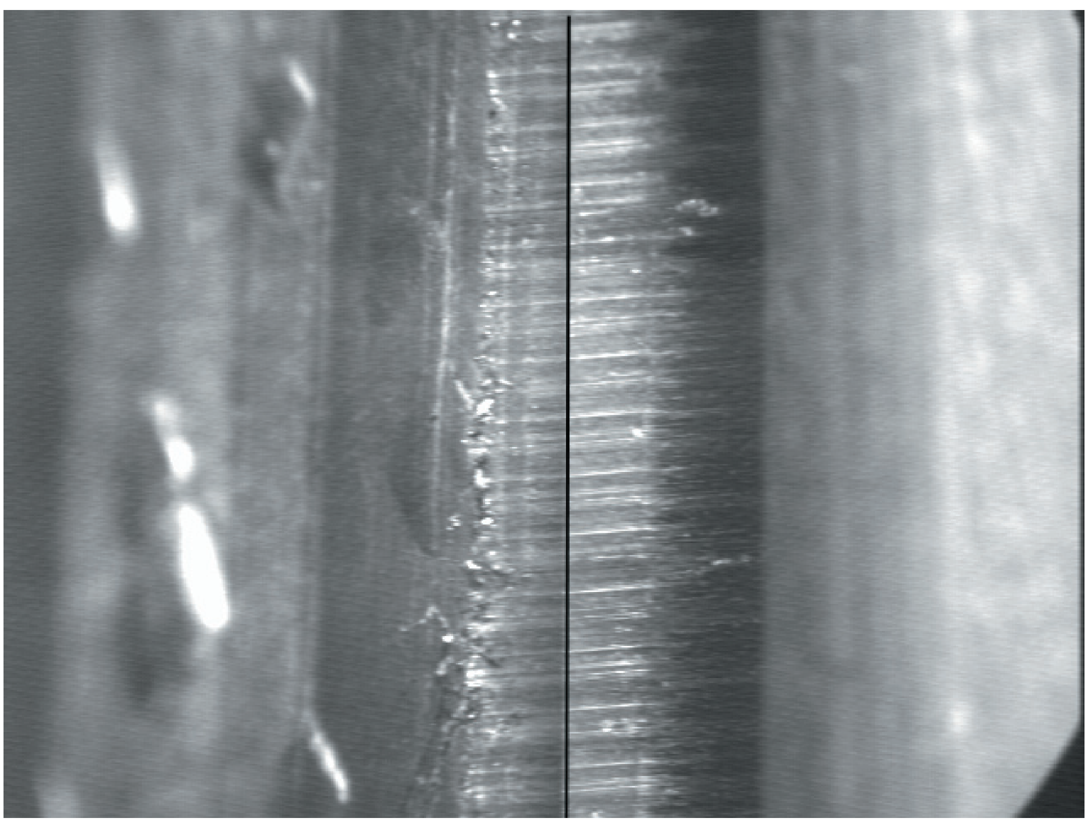


Photo 84: Chisel #3
Beveled Edge/Surface
Test Toolmarks

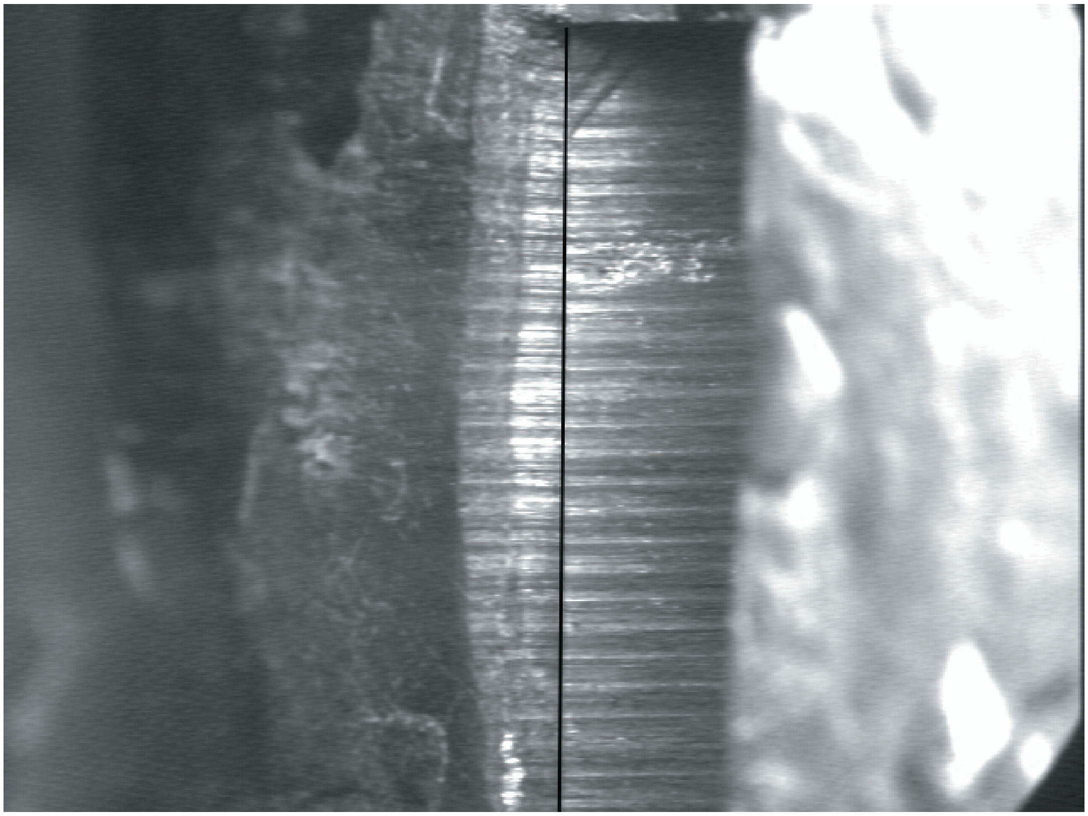


Photo 85: Beveled Edge/Surface Test Toolmarks Chisel #1 and Chisel #2

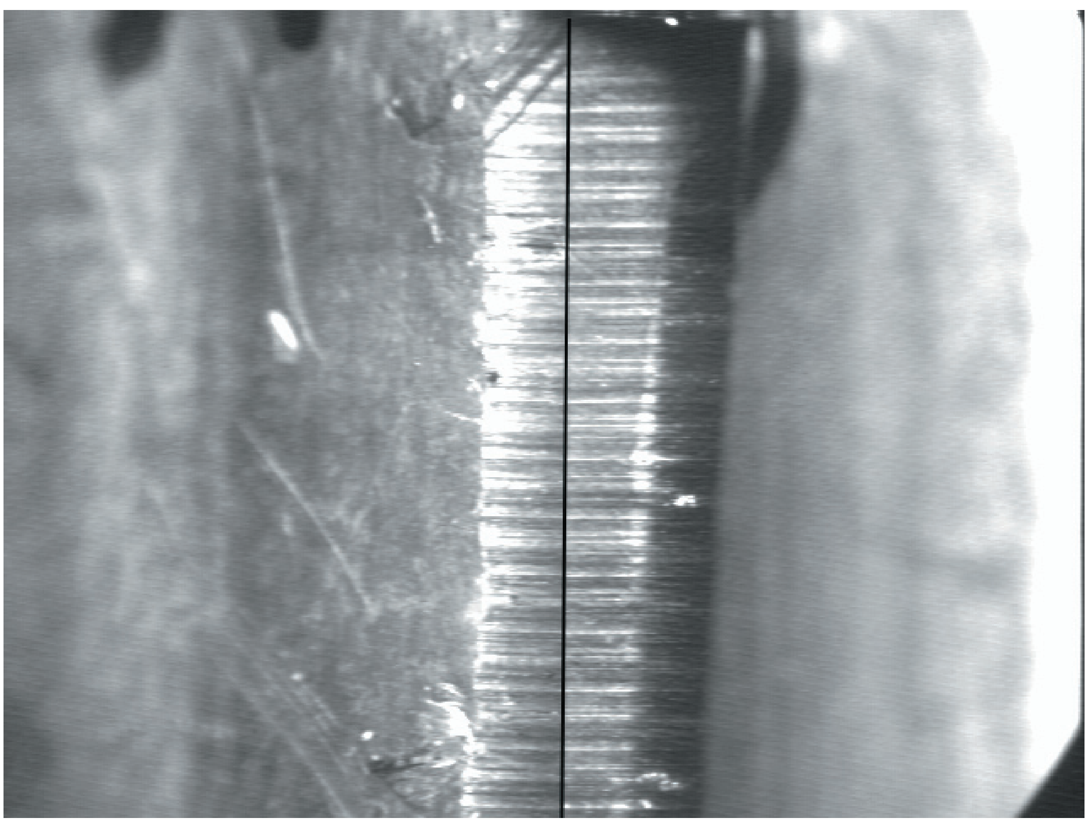


Photo 86: Beveled Edge/Surface Test Toolmarks Chisel #2 and Chisel #3

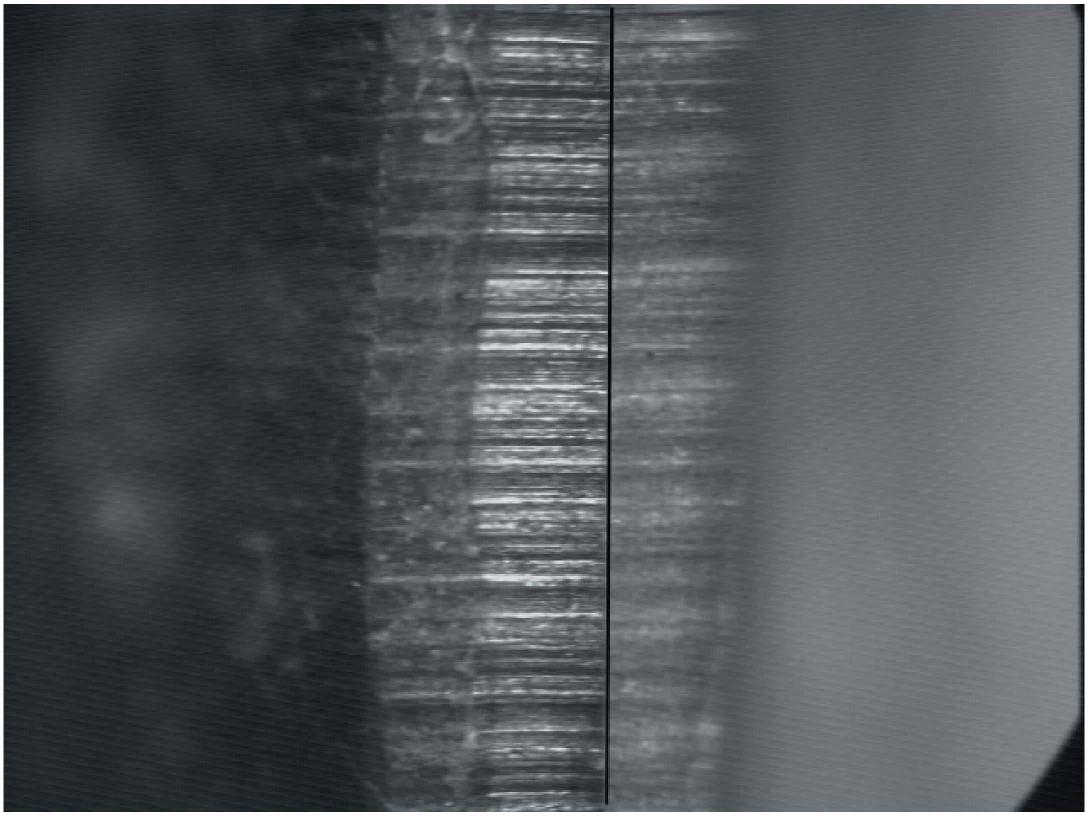


Photo 87: Beveled Edge/Surface Test Toolmarks Chisel #1 40 Times Magnification

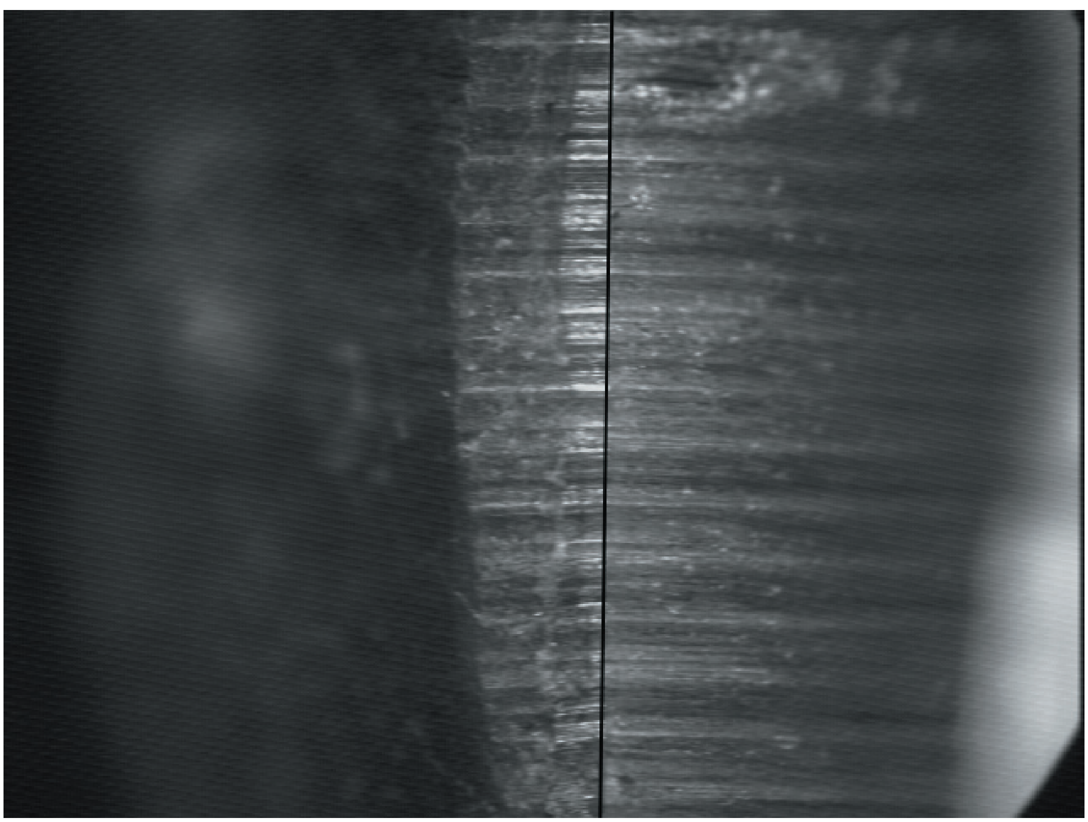


Photo 88: Beveled Edge/Surface Test Toolmarks Chisel #1 and Chisel #2 40 Times Magnification

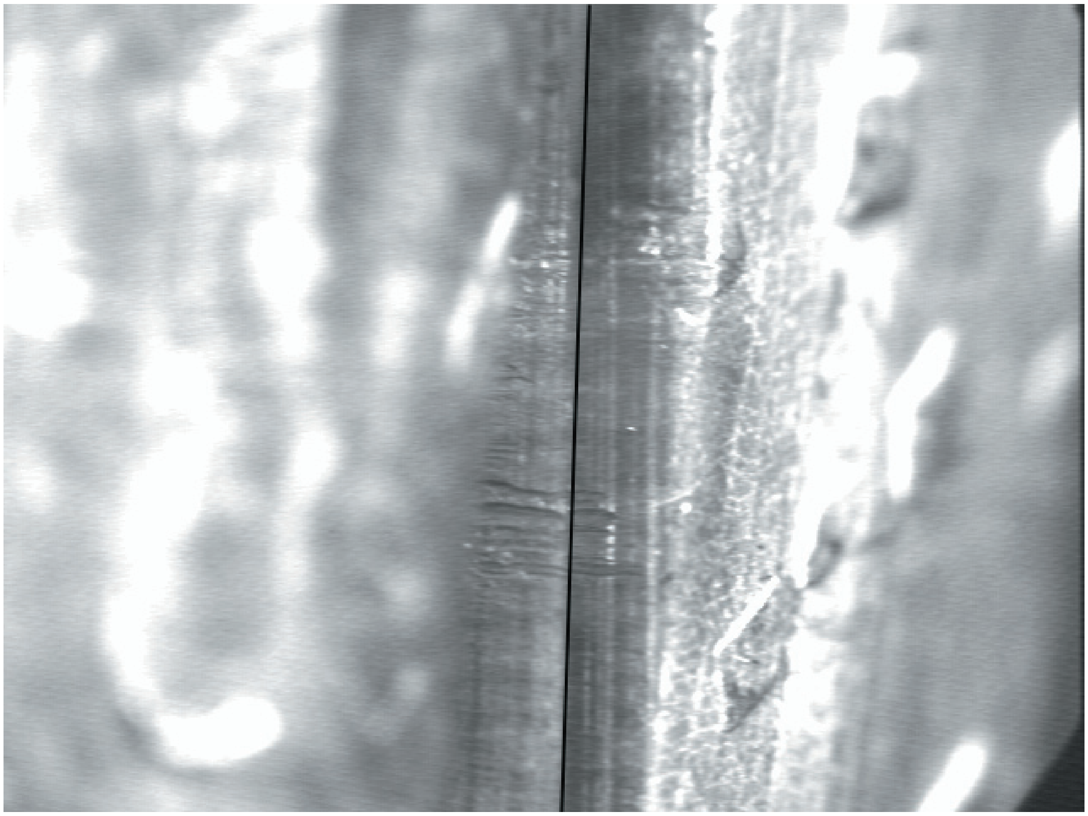


Photo 89: Back Edge/
Surface Test Toolmarks
Chisel #1

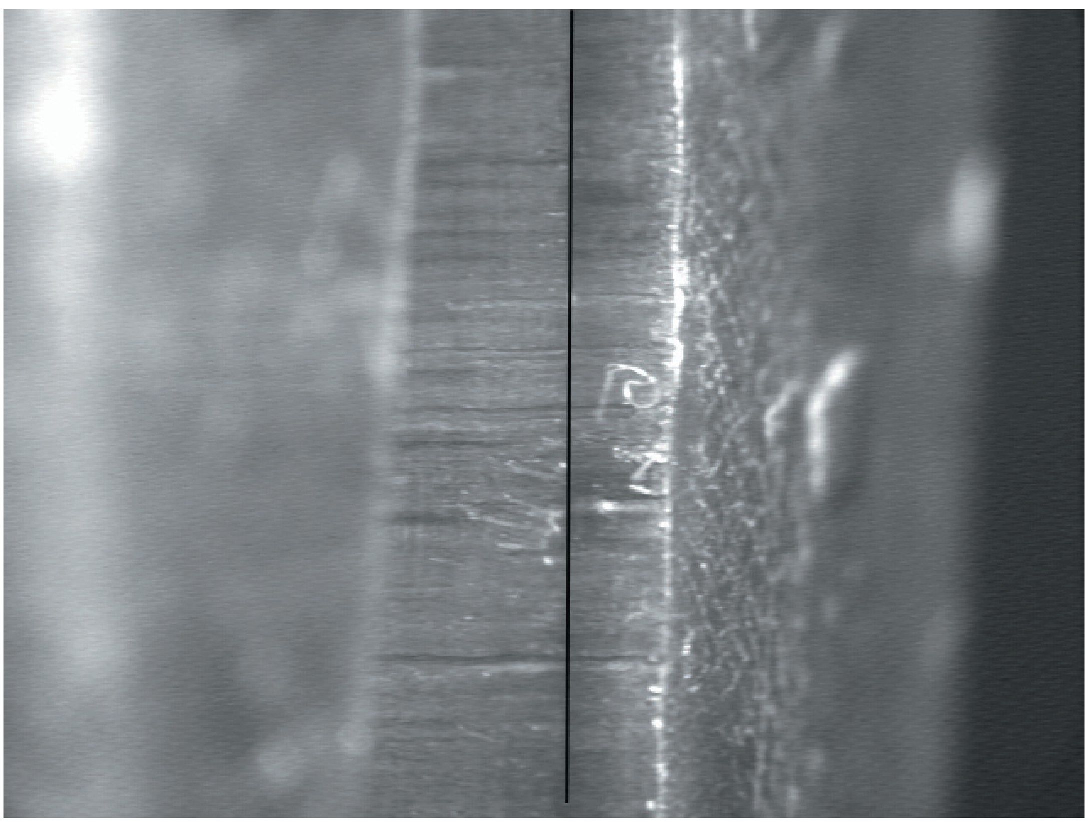


Photo 90: Back Edge/
Surface Test Toolmarks
Chisel #2

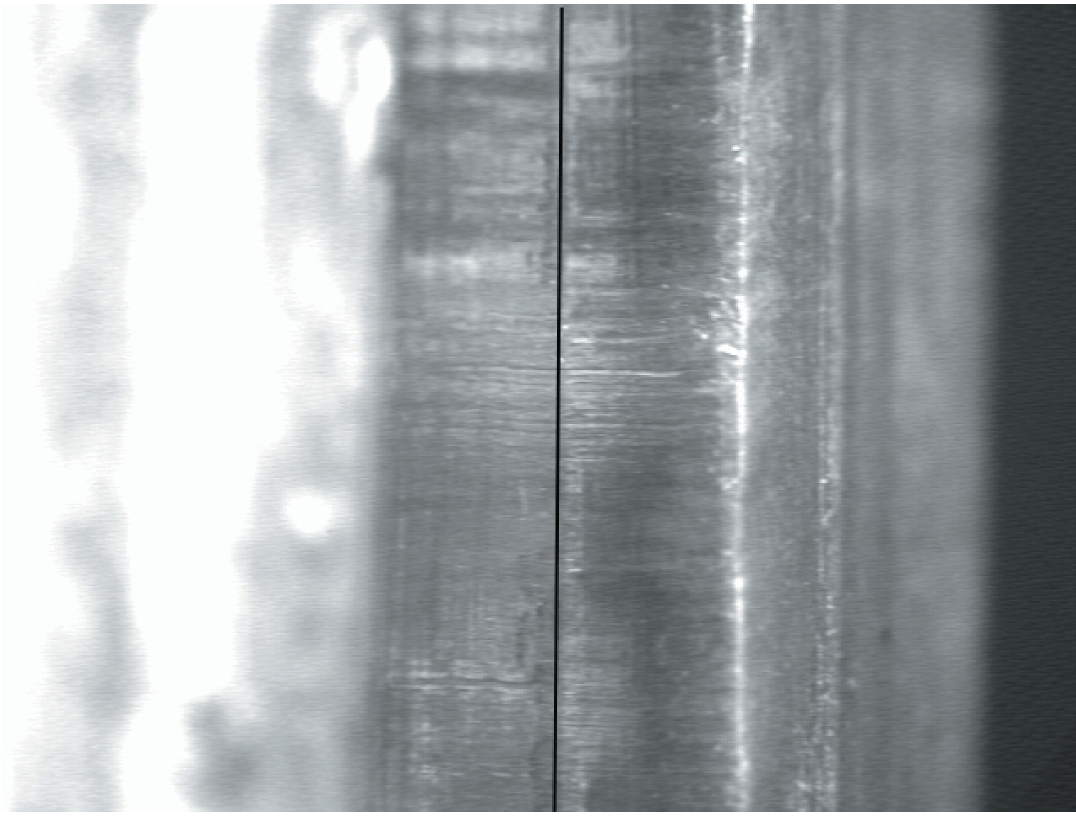


Photo 91: Back Edge/
Surface Test Toolmarks
Chisel #3

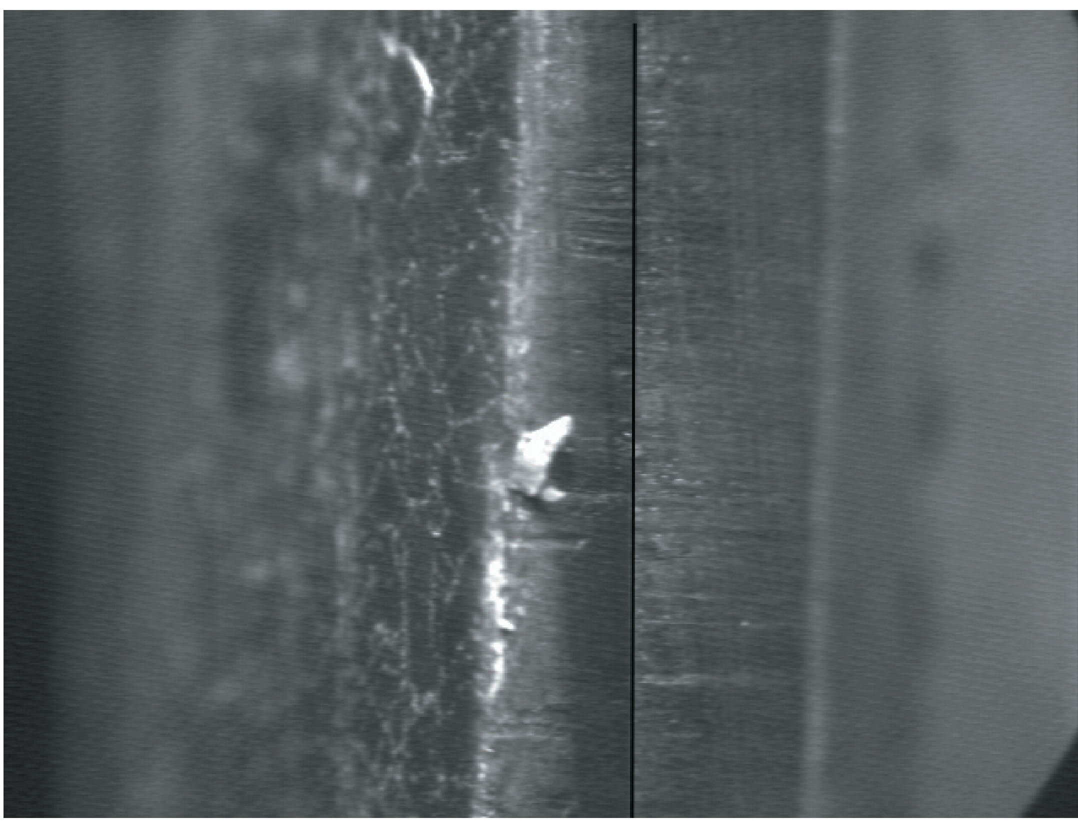


Photo 92: Back Edge/
Surface Test Toolmarks
Chisel #1 and Chisel #2

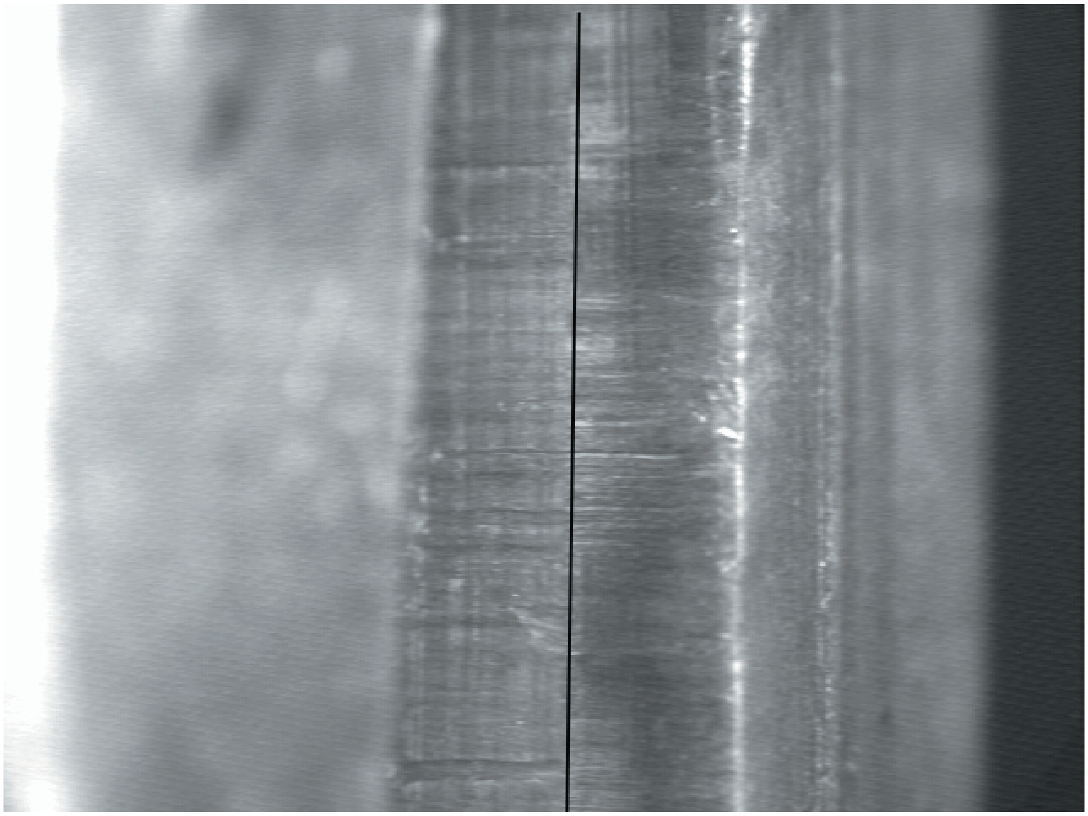


Photo 93: Back Edge/ Surface Test Toolmarks Chisel #2 and Chisel #3

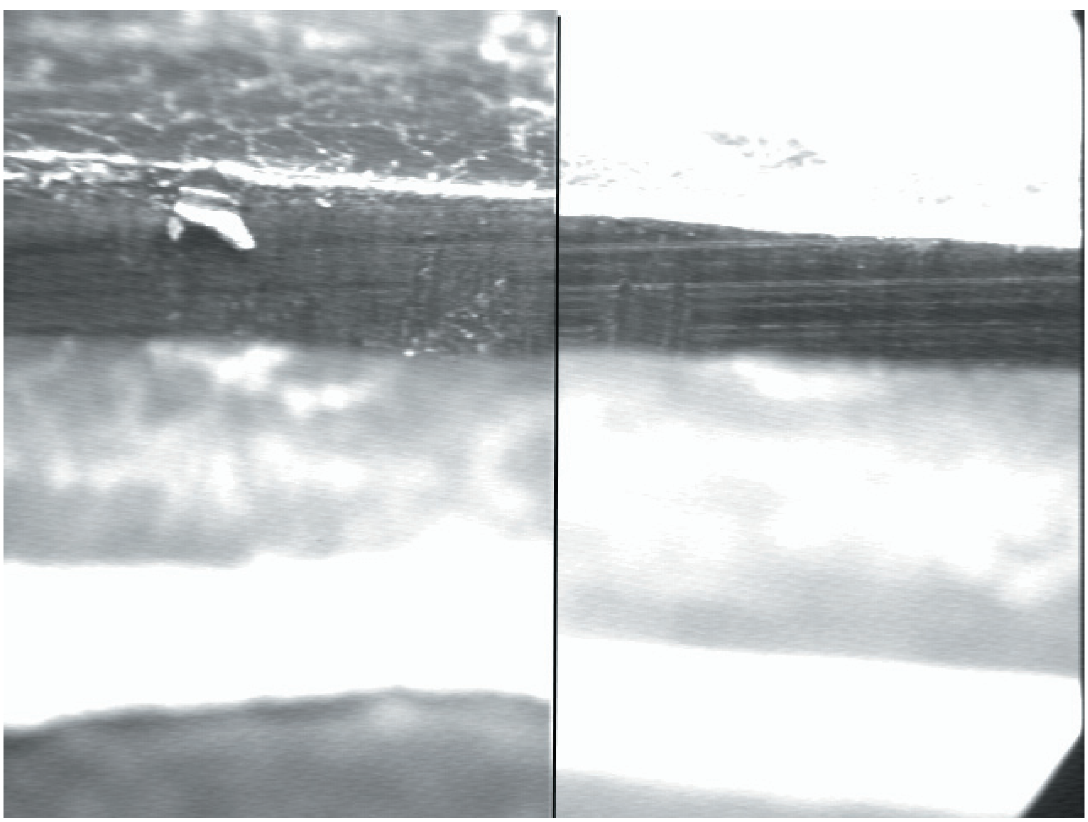


Photo 94: Back Edge/Surface of Chisel Subclass Characteristic Impression