CONSECUTIVELY MACHINED RUGER BOLT FACES

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ABSTRACT

Six consecutively machined Ruger rifle bolts were examined for individual and subclass characteristics resulting from the end mill machining process. Comparisons revealed a startlingly high correspondence of microscopic characteristics among the bolt faces examined. This high level of correspondence resulting from a milling operation recalls previous cautions concerning subclass microscopic "matching." Further examination of these bolts revealed slight individual irregularities such as abrasions and chatter marks. These microscopic flaws differ between the consecutively machined bolts and could be used for identification of these bolt faces if they transfer to a cartridge case.

Introduction

An essential premise of firearm and toolmark identification is that machining processes leave unique marks on cut surfaces rendering even consecutively manufactured objects observably individual (1, 2). The lathe turning process used in the manufacture of hemispherical firing pins (3, 4), and the broach-cutting processes of 38 Special Smith & Wesson revolver barrels (5), however, have both been flagged as creating subclass marks that could easily be mischaracterized as individual. The examiner's ability to distinguish between class, subclass, and individual characteristics created during manufacture is paramount and requires a full and critical evaluation of machining processes. This study focuses on milling operations, specifically end mills.

There are two main categories of milling operations: face milling, of which end milling is one type, and peripheral milling. Face milling operations have the face of the cutter parallel to the surface being machined. Peripheral milling operations use the side or periphery of the cutter, which is held parallel to the work.

Milling operations rotate a toothed cutter into the work to remove metal. A surface machined with a face milling process, such as a bolt face--which at Ruger is cut with an end mill--will have a pattern of concentric circular marks on its surface. Note that a peripherally milled surface will not have concentric circular marks, but will have the familiar parallel striations. However, these parallel marks may be just as susceptible to subclass mark carry-over as are the circular marks, all other things being equal.

Milling cutters are specifically designed to resist abrasion, and to hold a cutting edge in the face of immense heat and heavy loads. Cutters are made of high quality tool steel, often coated with a hardener such as tungsten carbide or chromium, or the teeth may be made of cemented tungsten carbide, which "are excellent for long production runs and for milling materials with a scale-like surface (cast iron, cast steel, bronze, etc.)" (6). Factor in the hard cutting surfaces (Ruger uses cutters rated Rockwell A 91.9) with the relatively soft steel of the bolts (Rockwell C 20-24 before heat treatment) and the small amount of steel actually being machined on the face of the bolt, and the potential exists for subclass marks being created on the bolt face.

Subclass features have thus far often been attributed specifically to machining processes resulting in a surface with concentric circles. We believe that the direction (e.g., circular or straight) of these striated marks is irrelevant; the existence of subclass characteristics is a result of the slow wear of the cutting blades used in a given machining process, not the directionality or angle of the specific cut. The purpose of this paper has been to investigate the extent to which end milling results in unique and identifiable marks by examining consecutively made rifle bolts.

Methods

We obtained six consecutively manufactured M77 Mark II rifle bolts from Ruger, numbered 1 through 6 as they were pulled directly from production. The bolt faces were cut in sets of six by an end mill machining process. At this point the only remaining machining process pertaining to the bolt face was the fixed-blade type ejector cutout--a slot cut by a profiler machine with a downward stroke (Figure 2). The ejector cutout would then be given a one- or two-second polish on a rag wheel with rouge to smooth the residual burrs from the edges. Our bolts, however, did not receive this final machining or polish (Figure 1) because our focus was the end milling process.

Multiple casts were made of the six bolt faces using Mik-

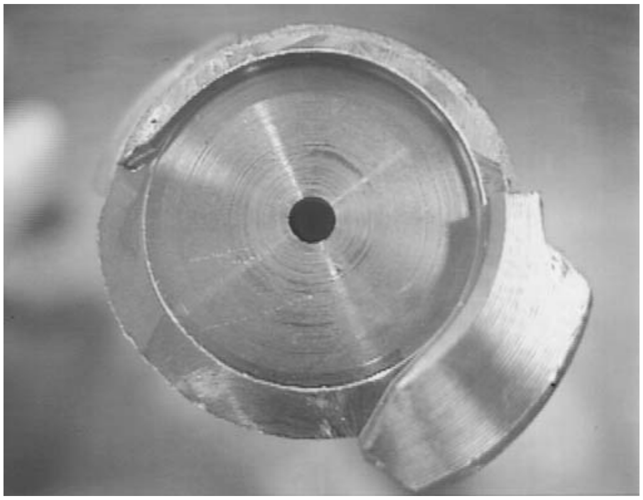


Figure 2

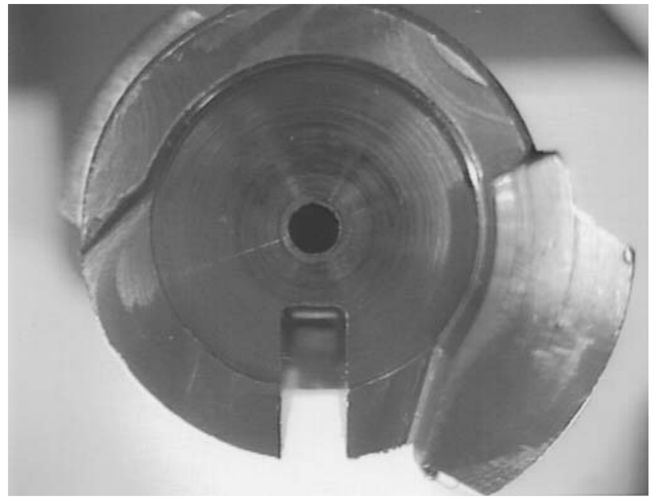


Figure 3

rosil and Theftingate casting material--both media captured the microscopic marks well. We compared the known match bolt face casts to each other under the Leica comparison microscope, noting the degree of correspondence. Next, casts of each consecutive bolt were compared to the casts of the first bolt in the series (bolt #1) in order to observe the correspondence of known non-matching bolts. Where apparent individual characteristics were found (e.g., scratches), we confirmed their individuality by comparing the bolt casts with one another. The comparisons were conducted at various magnifications, and all photomicrographs were taken at 30x.

Results

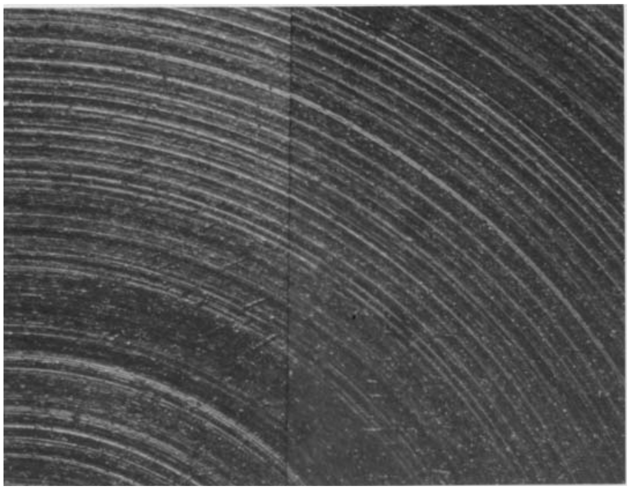
Once a level of correspondence between known matches had been established (Figure 3) we compared the casts of each consecutively machined bolt face to the first in the series, bolt #1. To our surprise we found an alarmingly high level of correspondence between the milled striae of bolts #1 and #2 (Figure 4), #1 and #3 (Figure 5), #1 and #4 (Figure 6), and #1 and #6 (Figure 8).

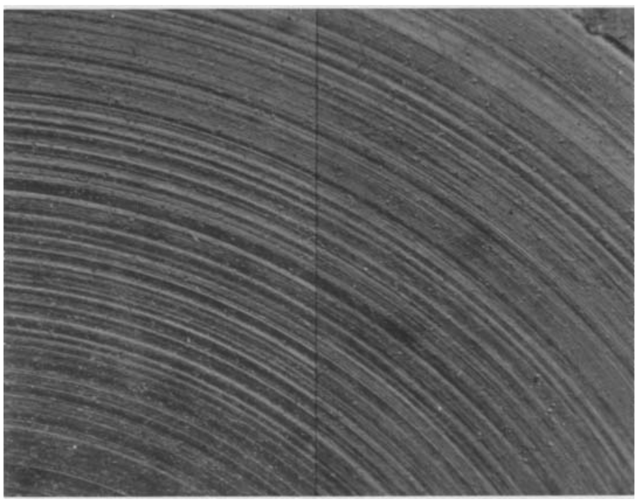
Interestingly, bolt #5 showed the greatest level of divergence from bolt #1 (Figure 7). It is unknown precisely why; possibly that bolt was slightly harder or softer than the others, or was not perfectly aligned in the milling machine. However, even bolt #5 showed a noteworthy level of similarity to bolt #1.

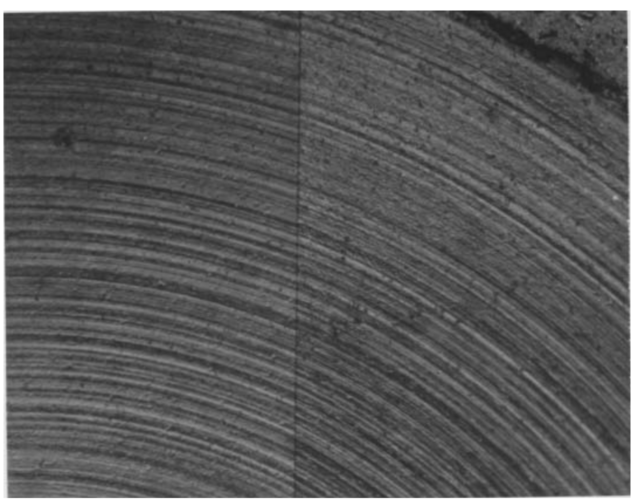
After observing the high degree of correspondence between the sequential bolts, we examined them for identifiable characteristics. A radial scratch was observed on bolt #1, allowing all the casts from this bolt to be identified with one another to the exclusion of all other casts made. Bolts #2 through #6 lacked such a readily identifiable characteristic. With further examination, however, we discovered irregular abrasion marks along the circumference of the firing pin hole on all six bolt faces (Figures 9 - 14). According to the machinists at Sturm, Ruger & Co., this abrasion, or tearing, is caused by a combination of factors: cutter speed, cutter sharpness, and the hardness of the work being milled. A cutter that is rotating too slowly will tear rather than produce a clean cut. Tearing is consistently found near the center of the bolt face because of the difference in surface linear speed between the outer edge of the bolt face and the center. If a milling cutter is rotating at a given number of revolutions per minute, the speed at the cutting surface will be greater at the outer edge than near the center. If the ideal surface speed is set for the outer edge, the cutter will be too slow near the center. If the ideal speed is set for the center, the tool will be going too fast at the outer edge. The mill operator compromises by setting a speed somewhere between the two extremes. The consequence of this compromise is a small amount of tearing near the center. The surface speed issue is further complicated by variations in tool sharpness and workpiece hardness. With a sharp tool and a work product in the ideal hardness range, the major source of tearing will be the slow cutter speed. However, as the cutting edges wear down, they will begin to tear the surface. Additionally, if a given batch of steel is softer than the optimum range for that tool, even a sharp cutter will cause tears. In any case, we found these abrasion marks to be unique and individual for each of the six bolt faces.

In addition, we observed chatter marks in the same relative orientation and spatial relationship on each of the bolt faces (Figures 15 - 20). The marks differed in length and number, but lacked substantial detail. Moreover, their orientation (counter to the direction of the concentric milling marks) raises the question of precisely how they were produced.

Chatter marks are generally caused by an improperly secured workpiece, or by a sharp cutter rotating too quickly. From subsequent discussions with the mill operator at







(Top) Figure 3: Known match standard showing a side by side comparison of casts of bolt face #1.

(Middle) Figure 4: Known non-match.. This photo shows a comparison of casts for bolt #1 vs bolt #2.

(Bottom) Figure 5: Known non-match. Bolt #1 vs bolt #3 casts.

Sturm, Ruger & Co., we were unable to firmly establish the cause of these particular marks, and they were not observed on bolts being produced at the time of our meeting. As a result, the value of chatter marks for identification purposes is limited.

Discussion

An accepted standard for identification is when an examiner observes a quality and quantity of microscopic agreement that exceeds the best known non-match ever observed (7). This standard may be more difficult to determine considering the quality and quantity of agreement observed among the consecutively machined bolt faces in this study.

Essentially, we found that the end milling operation--when performed on cast steel surfaces--produces individual characteristics, but not in the traditional form. The sharpened surfaces of the milling cutter do not appear to be wearing quickly enough to create striated marks that are readily distinguishable from one another on consecutive workpieces. Therefore, the striations produced by the cutting blades should not be used to make an identification; rather, other accidental marks such as tearing, chatter, and scratches provide the unique signature for this type of machined item. Further research with finished bolts will provide us with more information regarding other sources of accidental marks, the persistence of subclass marks through a longer run of bolt faces, and the transfer of marks to fired cartridge cases.

Acknowledgements

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References

1. Thompson, E., "Phoenix Arms (Raven) Breech Face Toolmarks," AFTE Journal, Vol. 26, No. 2, April 1994, p. 134.

2. Matty, W., "Raven 25 Automatic Pistol Breech Face Tool Marks," AFTE Journal, Vol. 16, No. 3, July 1984, p. 57.

3. Matty, W. and Johnson, T., "A Comparison of Manufacturing Marks on Smith & Wesson Firing Pins," AFTE Journal, Vol. 16, No. 3, 1984, p. 51.

4. Biasotti, A.A., and Murdock, J., "Criteria for Identification or State of the Art of Firearm and Toolmark Identification," AFTE Journal, Vol. 16, No. 4, Oct. 1984, p. 16

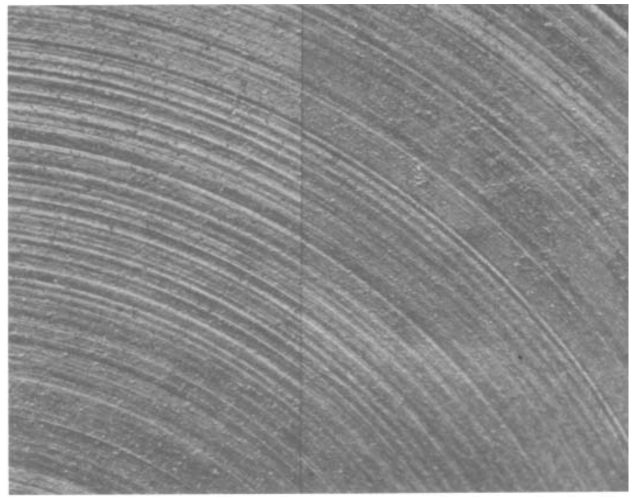
5. Tulleners, F.A., and Hamiel, J.S., "Sub Class Charac-

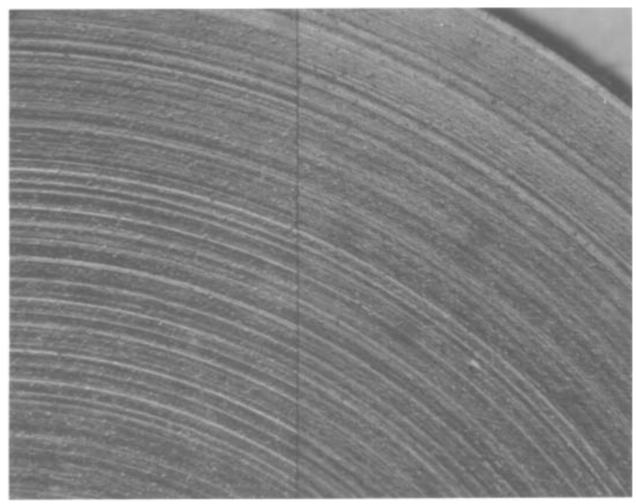
teristics of Sequentially Rifled 38 Special S&W Revolver Barrels," AFTE Journal, Vol. 31, No. 2, Spring 1999, p. 117.

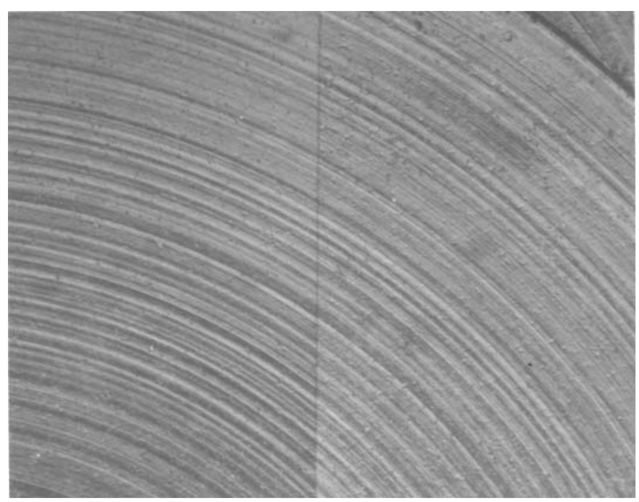
6. Walker, J.R. Machining Fundamentals, Goodheart-Willcox Company, Inc., South Holland, Illinois, 1993, p. 253.

7. "Theory of Identification as it Relates to Toolmarks," AFTE Journal, Vol 30, No. 1, Winter 1998, p. 86.

Please see photomicrographs on the following pages.







(Top) Figure 6 Known Non-Match: Bolt #1and Bolt #4 casts

(Middle) Figure 7 Known Non-Match: Bolt #1 and Bolt #5 casts

(Bottom) Figure 8 Known Non-Match: Bolt #1 and Bolt #6 casts

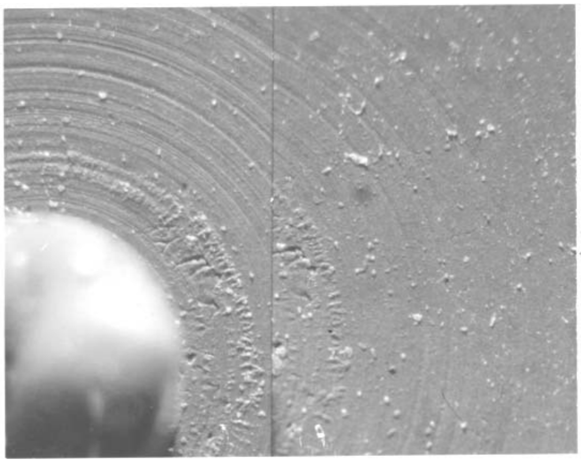


Figure 9 Abrasion Mark Identification: Bolt #1 casts

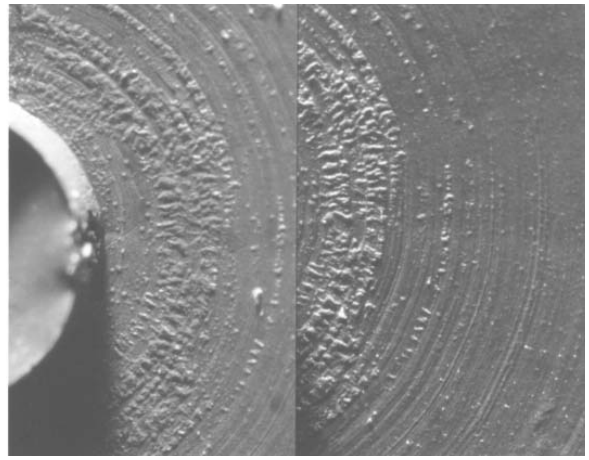


Figure 10 Abrasion Mark Identification: Bolt #2 casts

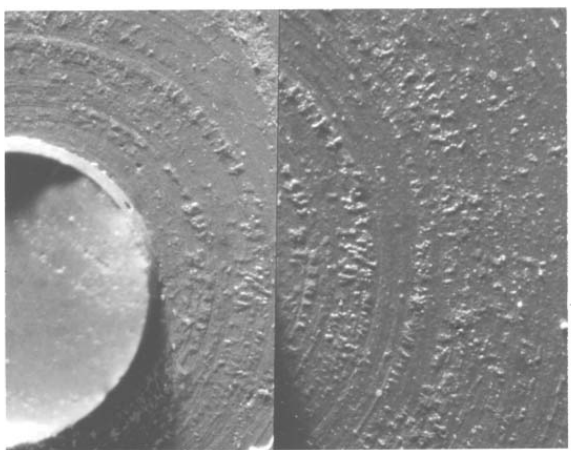


Figure 11 Abrasion Mark Identification: Bolt #3 casts

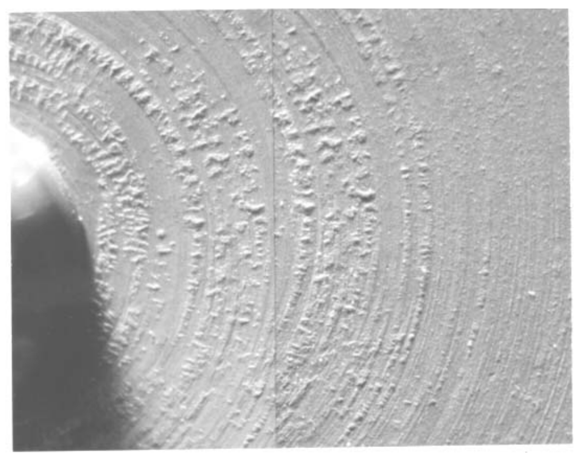


Figure 12 Abrasion Mark Identification: Bolt #4 casts

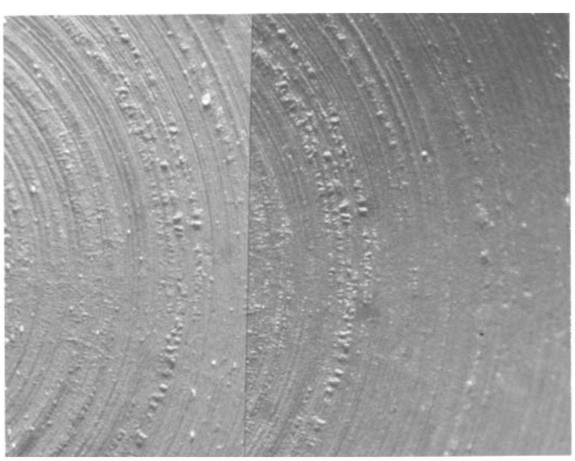


Figure 13 Abrasion Mark Identification: Bolt #5 casts

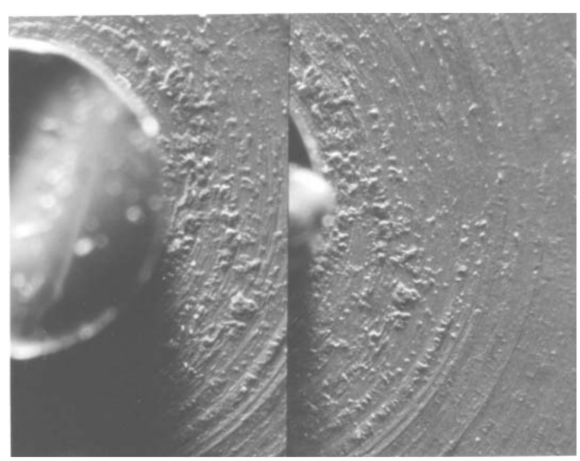


Figure 14 Abrasion Mark Identification: Bolt #6 casts

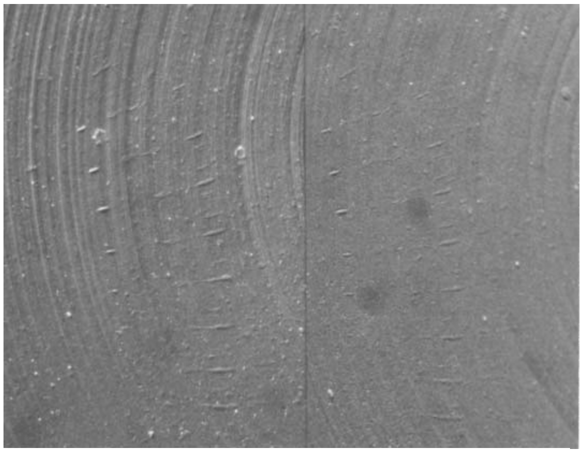


Figure 15 Chatter Mark Identification: Bolt #1 casts

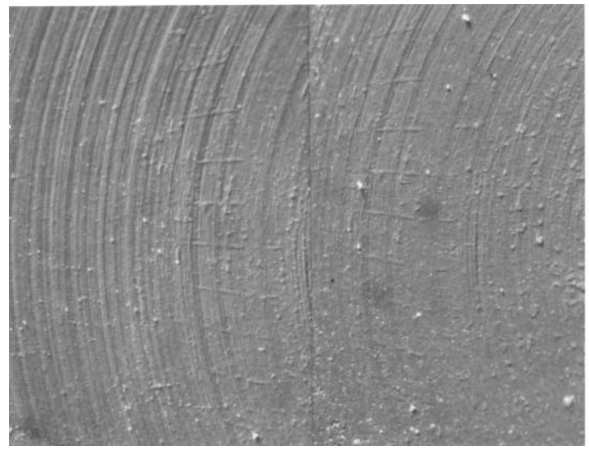


Figure 16 Chatter Mark Identification: Bolt #2 casts

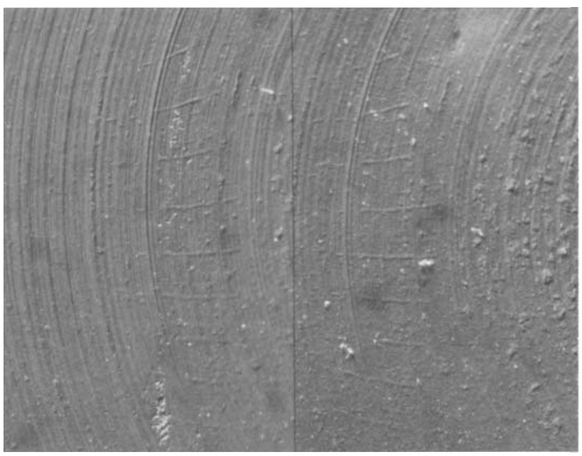


Figure 17 Chatter Mark Identification: Bolt #3 casts

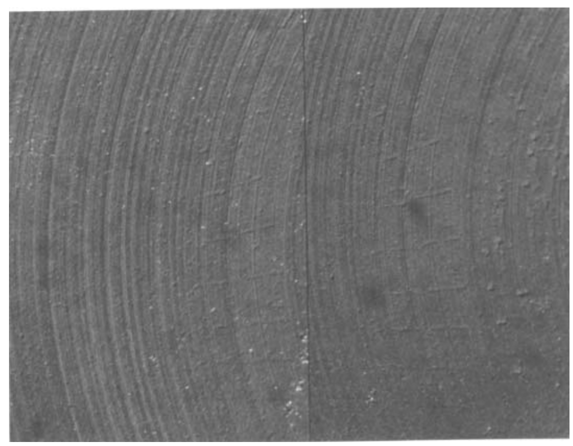


Figure 18 Chatter Mark Identification: Bolt #4 casts

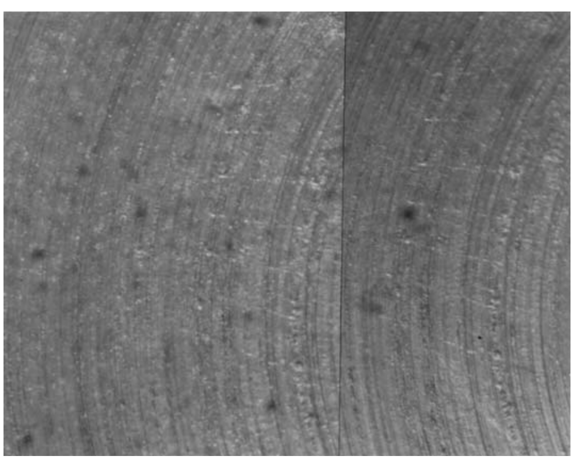


Figure 19 Chatter Mark Identification: Bolt #5 casts

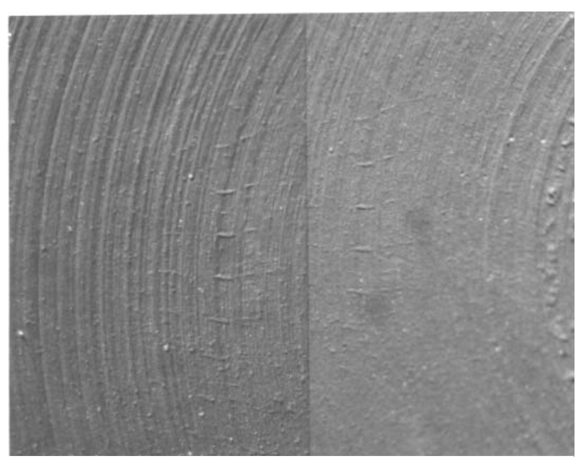


Figure 20 Chatter Mark Identification: Bolt #6 casts