F. H. Cassidy,[1] *B.S.*

Examination of Toolmarks from Sequentially Manufactured Tongue-and-Groove Pliers

REFERENCE: Cassidy, F. H., "**Examination of Toolmarks from Sequentially Manufactured Tongue-and Groove Pliers,**" *Journal of Forensic Sciences,* JFSCA, Vol. 25, No. 4, Oct. 1980, pp. 796-809.

ABSTRACT: Tongue-and-groove pliers are often used in burglaries to twist off doorknobs (to gain entrance) and it was deemed necessary to determine if new, sequentially manufactured pliers would each produce similar toolmarks that would be indistinguishable. Evaluation of the toolmarks from three sets of sequentially broached Craftsman® pliers, together with an analysis of the manufacturing processes, verified that individual and not repetitive structural characteristics are generated.

KEY WORDS: criminalistics, toolmarks, pliers, class characteristics, individual characteristics, manufacturing processes, nodules, repetitive structural details, broaching, striations

One common method used for breaking into locked homes and businesses is to twist off doorknobs with tongue-and-groove pliers. Tools of this type are readily available at hardware stores and can be easily hidden in the clothes of the thief. If a suspect is apprehended who possesses such a tool, the tool and the broken doorknob(s) are usually submitted to a laboratory for toolmark comparison.

The analysis of tools by comparison of the marks they leave has been well-established for many years. Numerous manuscripts and books have been published concerning the various areas of toolmark identification. In 1930, May [*1*] pointed out that his exhaustive research for 18 years had "developed the fact that it is possible, under favorable circumstances to identify the particular instrument, knife or tool making a cut in metal, wood or other stable substance in over 90% of the cases." In 1942, Burd and Kirk [*2*] published a study "concerned with the determination of the effect of variations in the method of application of a tool to the resulting mark; the question of what degree of identity is necessary in a comparison; what degree of similarity is to be expected from two tools which are identical in manufacture and appearance, or from two edges of the same tool; and to a partial classification of the type of marks encountered." Davis [*3*] covered basic identification characteristics of toolmarks and firearms and described a mechanical-optical surface analyzer he designed. Burd and Greene [*4*] documented certain helpful procedures for toolmark examination they had developed during numerous comparisons.

Tools that are extensively used may have considerable wear and damaged areas on their working surfaces. When this occurs, the tool will leave marks that only that tool

Received for publication 22 Jan. 1980; revised manuscript received 4 April 1980; accepted for publication 11 April 1980.

[1] Criminalist, State of California Department of Justice, Santa Barbara Regional Laboratory, Goleta, Calif.

can produce. But new tools may present problems. Burd and Gilmore [5] found that some mass-produced screwdrivers had class characteristics that could be misconstrued as individual characteristics. Modern mass-production methods for tools dictate the necessity of minimizing the manufacturing steps in order to make tool production as economical as possible. When this occurs, the manufacturing processes could turn out consecutively manufactured parts that would have similar surface conditions. These could potentially leave class characteristic toolmarks that might be accepted as individual characteristics.

Some studies have been performed with specific tools that are sequentially produced. Butcher and Pugh [6] examined consecutively manufactured bolt cutters and by virtue of the manufacturing processes and testing found that the toolmarks from each jaw were unique. Similarly, Watson [7,8] examined toolmarks from consecutively manufactured crimping dies and consecutively manufactured knife blades and concluded that unique toolmarks were produced by both types of tools.

No information was found in the forensic science literature concerning toolmark evaluations of consecutively manufactured tongue-and-groove pliers. The desirability of knowing whether toolmarks produced by sequentially manufactured pliers of this type were unique became necessary when an essentially new Craftsman® pliers and broken doorknobs were submitted to the California Department of Justice Regional Criminalistics Laboratory in Santa Barbara. One of the doorknobs had small, dimpled impressions where it had been gripped. Examination of the pliers with a stereomicroscope revealed numerous nodules on the teeth of the pliers. Some of the nodules appeared to be mirror images of the dimpled area of the doorknob (Fig. 1). By using these nodules as an index, the striations produced by the pliers could be matched to the doorknob striations. Subsequently, Sears, Roebuck and Co. were contacted to request the essential manufacturing data from their supplier to clarify whether the same nodule orientation could be produced on consecutively manufactured pliers.

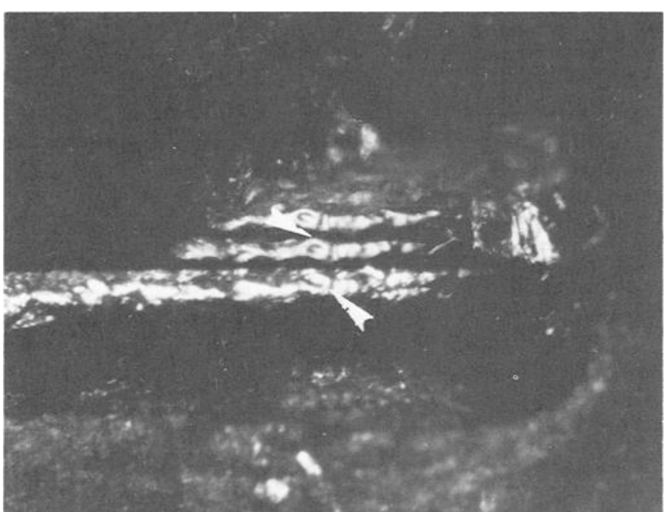

FIG. 1—*Comparison of nodular impressions from the Craftsman tongue-and-groove pliers with those found on the doorknob. The lower arrow points to the impression made at the laboratory; the top arrow points to a double impression found on the doorknob. The double impression appears to have been caused by the same nodule but by a slight repositioning of the pliers.*

Manufacturing Sequence

The questioned model of Craftsman tongue-and-groove pliers was manufactured by Western Forge Corp., Canon City, Colo. The manufacturing sequence steps —that is, those processes that would affect the teeth—according to Western Forge are as follows:

1. The parts are formed by forging, followed by annealing.
2. The teeth in the jaw are simultaneously form-broached by using a tool with stepped inserts of all the teeth. Each jaw is done individually. The upper jaws are processed with a different broach than the bottom jaws. (NOTE: Broaching is one of the methods used for grooving the interior of gun barrels, except that striations in the gun barrel are aligned in the same direction that the bullet travels. The broaching of the pliers' teeth is an external process and the tool moves perpendicular to the direction that causes striations on items such as doorknobs.)
3. Several thousand parts are collected in bins after broaching to await heat-treating.
4. Hardening is performed in a carburizing gas furnace at 815°C (1500°F) for 1 h followed by an oil-quench to result in a hardness (Rockwell C scale) of 62.
5. The parts are tempered in an air furnace at 425°C (800°F) for 1 h to achieve a hardness of Rockwell C 45. (Further information on heat treating can be found in Ref *9*.)
6. De-scaling is performed by a "Wheelabrator" that tumbles the numerous pliers' jaws with abrading material for from 5 to 10 min.
7. The parts are mounted on a plating rack and progressively go through (a) acid pickle with necessary rinses; (b) electrodeposited nickel bath with necessary rinses; (c) chromium electrodeposition (decorative), with no subsequent buffing (the nickel is used as an undercoat to enhance the adhesion of the chromium plating and for corrosion resistance); and (d) assembly.

The only portions of the manufacturing sequence that might possibly produce family characteristics are the forging and the step-broaching, but the forging surface of the tool's gripping area is removed by the broaching. After the broaching, the parts are handled in batches and it is impossible to follow individual parts through the process. To aid the evaluation of the pliers in the laboratory, Western Forge supplied the Santa Barbara Regional Laboratory with three sets of upper and lower jaws that were sequentially broached after forging with no other manufacturing steps as well as three sets of upper jaws that had gone through the complete manufacturing process at approximately the same time as the as-broached jaws. Figure 2 is a photograph of one of the pliers. The upper and lower jaws are designated.

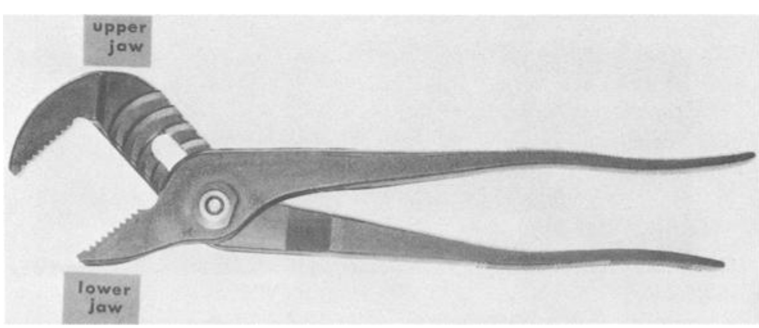

FIG. 2—*One of the as-broached tongue-and-groove pliers received from Western Forge Corp.*

Experimental Procedure

Davis [*3*, p. 26] states "the striated mark is produced by a relatively sliding contact. It is a mark made up of minute parallel striae (ridges and valleys) scratched upon a surface by irregularities along the edge, or upon the surface, of an acting tool. The mark is typically a 'scratch mark' representing a shearing or abrasion of one material by another. ... The 'tool' is the harder of the two materials." These striations are often unique and thus can be used to identify unequivocally the item that caused them. Repetitive structural details are those microscopic characteristics that often result from modern mass-production methods such as molding, die stamping, or die forging [*5*], and striated marks from them may be class characteristics of the tool. If the sequentially as-broached pliers' jaws could produce striations that were not completely different from each other, the possibility existed that the finished jaw would retain some repetitive structural details. But if repetitive structural details were completely removed during the manufacturing process, any striations produced would be individual and each pair of pliers could produce unique markings.

Striations from the three sets of as-broached jaws and the three plated upper jaws were produced on lead by using the cylindrical mandrel shown in Fig. 3. The mandrel consists of an inner piece of steel pipe approximately 38 mm (1½ in.) in diameter. A piece of lead is wrapped around it and secured by adjustable hose clamps. The composite diameter is approximately that of many doorknobs.

Selected teeth were used to make the striations in both clockwise and counterclockwise directions. A minimum of four sets of toolmark striations were made by each pliers' jaw in each direction with the same teeth. The striations were compared as follows: (a) each as-broached tooth to itself; (b) each as-broached jaw to the other as-broached jaws (upper jaws were compared to upper jaws and lower jaws were compared to lower jaws); (c) the teeth marks of each completely finished upper jaw were compared to themselves; (d) each completely finished jaw was compared to the other two finished jaws; and (e) the as-broached upper jaws were compared to the completely finished upper jaws. Selected photomicrographs of the results are included in this paper.

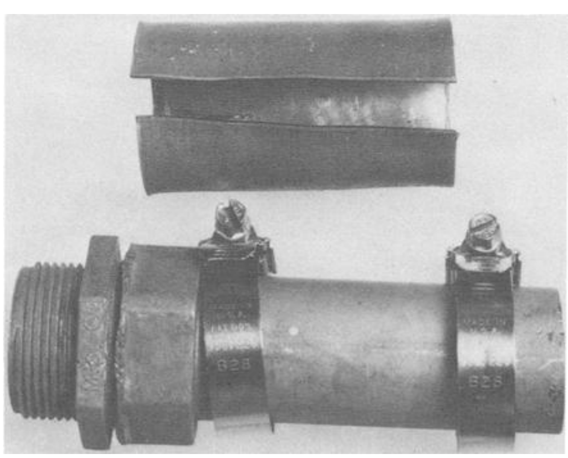

FIG. 3—*Cylindrical mandrel for holding lead sheet while the toolmark impressions were made.*

Results and Discussion

Figures 4 and 5 are photomacrographs comparing the surface conditions of the three as-broached and the three completely finished upper jaws. Figures 6 and 7 are photomicrographs that compare the surface condition at the front of the jaw of one of the as-broached with one of the completely processed jaws. The as-broached surface shows a "shingled" appearance, probably related to (a) the grain structure that occurs when the molten iron alloy solidifies, (b) plastic deformation during forging, and (c) the anneal-

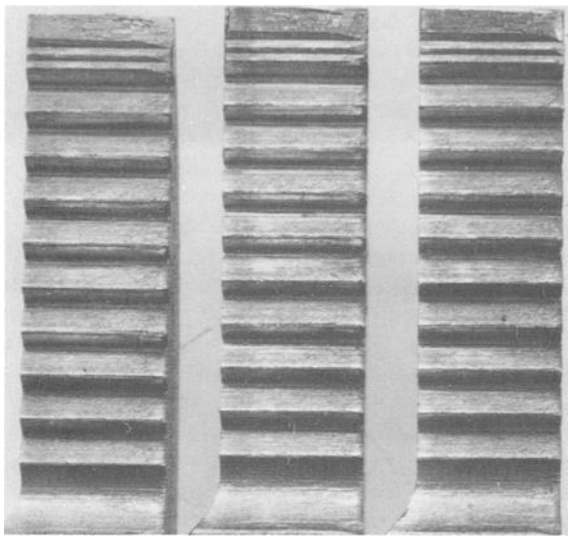

FIG. 4—*Macroscopic surface condition on the three sequentially as-broached pliers' jaws that would eventually become Craftsman pliers.*

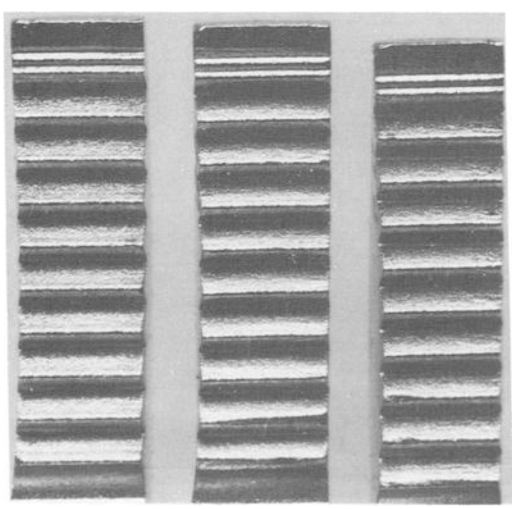

FIG. 5—*Macroscopic surface condition on three completely processed Craftsman tongue-and-groove pliers.*

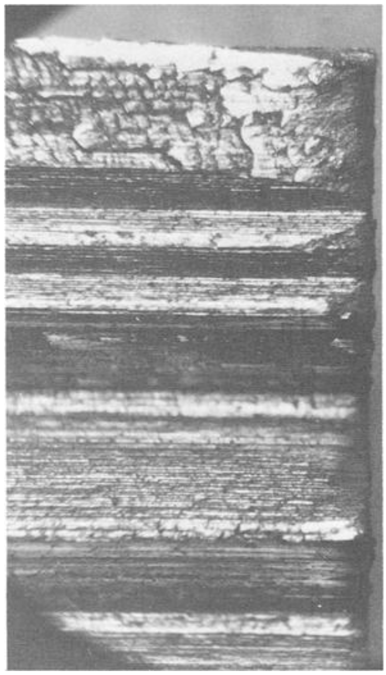

FIG. 6—*Microscopic surface condition of one of the as-broached pliers' jaws that would eventually become part of a pair of Craftsman pliers.*

ing after forging.[2] The finished jaws do not have the same type of surface but rather have one of small dimples and would be expected to produce abrasion patterns different from those of the as-broached jaws. It is shown below that they did.

Figures 8a, 8b, and 8c are photomicrographs comparing the same teeth of the three upper jaws of the as-broached pliers, that is, the same teeth that were processed by one specific area of the step-broach. Figure 8a compares Jaw 2 with Jaw 1, 8b compares Jaw 2 with Jaw 3, and 8c compares Jaw 1 with Jaw 3. The common areas contacted by the step-broach do not have repetitive structural details. Each jaw will produce an individual striation pattern.

Replicate samples of the individual striation patterns of the upper jaw of as-broached Pliers 1 and 2 are compared in Figs. 9a and 9b. Similar patterns for two of the finished jaws (the chromium-plated jaws) are shown in Figs. 10a and 10b. Each photomicrograph shows striations produced by the same tooth area when it is twisted in the same direction (as previously described). These figures demonstrate that the toolmark striations caused by the imperfection of the as-broached jaws and of the finished jaw can readily be compared to themselves when the striations are produced at different times.

When toolmark striation patterns of similar tooth locations of one jaw are compared to the next consecutively broached jaw, there is no identical pattern of striations. Figures 11a, 11b, 11c compare the same tooth of, respectively, the upper as-broached jaw of Jaw 1 to Jaw 2; 1 to 3; and 2 to 3. Each jaw produces unique striations that do not match

[2] The annealing step "softens" the iron alloy to aid in the ease of broaching. This softness is conducive to metal tearing, which is manifested by the shingled appearance.

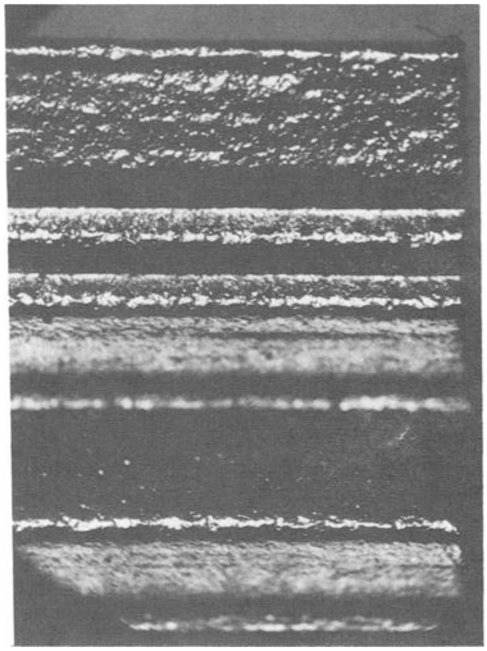

FIG. 7—*Microscopic surface condition of a completely processed pair of Craftsman tongue-and-groove pliers.*

the other jaw striations. Similarly, Figs. 12a, 12b, and 12c likewise compare the same tooth areas on the as-finished jaws with the other as-finished jaws and no identifying matches exist here, either.

Conclusions

After the analysis of the manufacturing procedures for Sears Craftsman tongue-and-groove pliers and after the examination of toolmarks made by the sequentially broached pliers, the following conclusion was reached. If every company that manufactures tongue-and-groove pliers uses a procedure similar to that of Western Forge Corp., this study demonstrates that no two consecutively broached pliers will produce similar striations caused by the manufacturing process steps for these reasons:

1. The individual metal in a particular pliers' jaw will have unique characteristics because of the grain structure crystallinity resulting from the solidification when the molten metal was initially cast, from subsequent plastic deformation during forging and broaching, and from the recrystallization during heat-treating.
2. Although the outside of an item may take on exact repetitive structural details from a permanent-type mold, stamping (for example, as seen on some screwdrivers' surfaces), die-forging, or similar processing tools, the surfaces will become individualistic if those surfaces are processed by tools such as grinders, broaches, or milling machines.
3. The heat-treat scale and its removal will be individualistic, that is, it will not be the same on any two parts. Scale formation on the pliers' jaws is a function of surface metal reactivity, which is related to such things as the grain structure, the furnace atmosphere, and temperature.

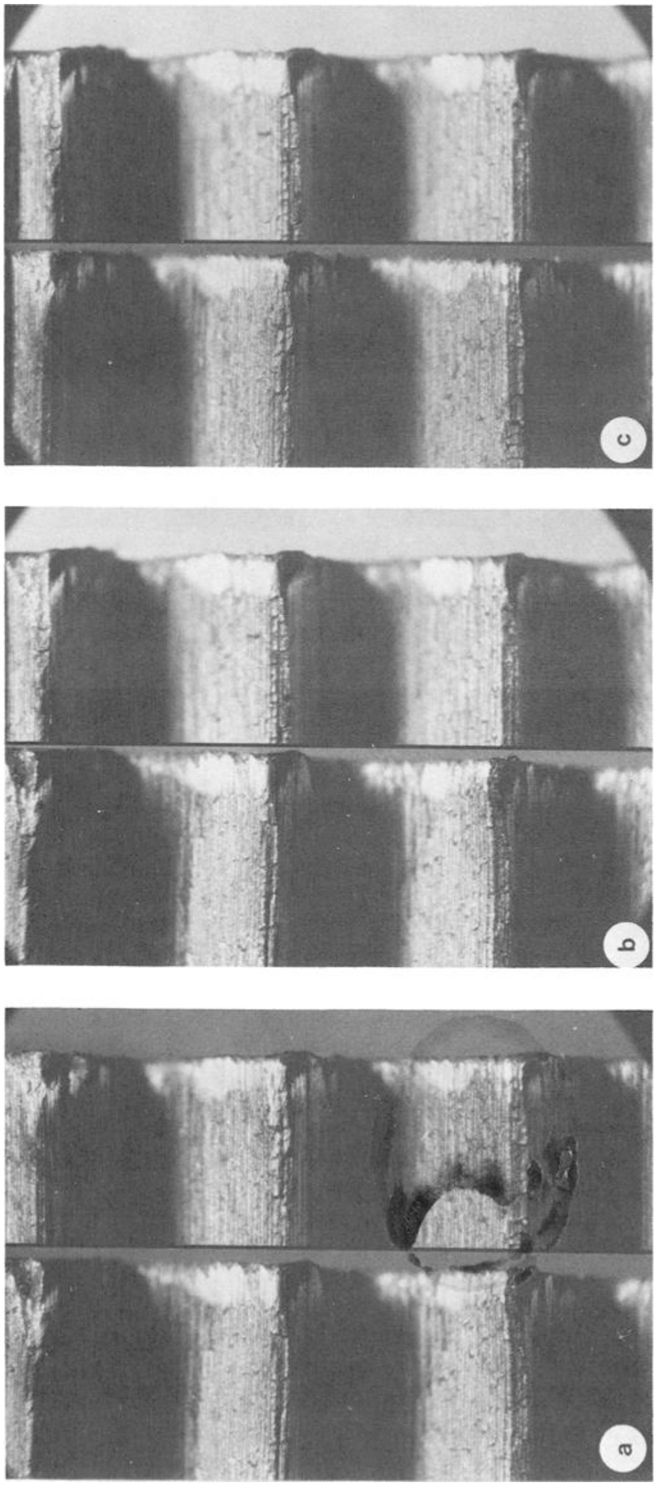

FIG. 8—*Photomicrographs showing the same teeth of the three sequentially broached upper pliers' jaws:* (a) *Pliers 2 and 1;* (b) *Pliers 2 and 3; and* (c) *Pliers 1 and 3.*

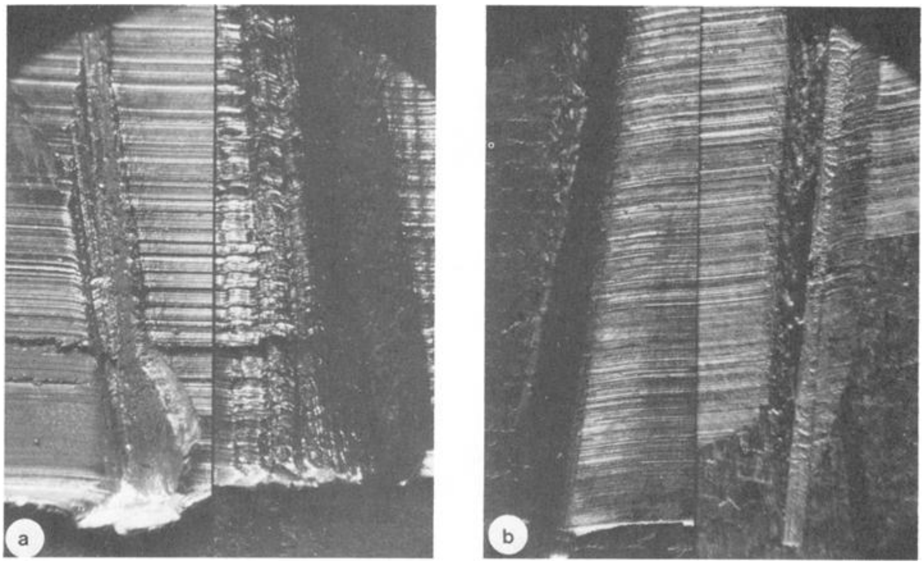

FIG. 9—*Photomicrographs of toolmark striations from the as-broached jaws, demonstrating reproducibility:* (a) *Pliers 1, top jaws and* (b) *Pliers 2, top jaws.*

4. During de-scaling, the individual parts are placed with others into a tumbling tank. The "Wheelabrator" grit granules used for de-scaling may impart different impressions on the individual parts.

5. Several thousand jaws are handled together for additional processing after the broaching. During this operation and during the de-scaling tumbling, it is possible that some of the parts themselves strike one another, thus leaving individualistic dents. It is thought that the imperfection on the tooth edge shown in Fig. 13 is such a dent. (This imperfection is on a tooth apex of one of three electroplated jaws received from Western Forge Corp.)

6. The acid etch prior to the plating can preferentially remove some of the metal surface, depending on its surface reactivity and the length of the etching time. Normally, etching is done for only a short time to remove surface oxides and to reactivate the base metal so that the plating bonds cohesively to the base metal.

7. The electrodeposited nickel and chromium will produce varying degrees of roughness because the plating is deposited on a mechanically de-scaled surface having varying surface irregularities. Electrodeposited coatings will preferentially plate on high points—such as a tooth apex—exaggerating the surfaces they are deposited on [*9*, pp. 432–443]. This buildup tends to produce microscopic nodules as can be observed in Figs. 7 and 13. These nodules will produce unique striations when the plated teeth deform a softer surface.

8. If the broaching tool could produce repetitive structural characteristics they would be produced along the direction of travel of the tool. But striations caused by tool usage are 90 deg from that direction. Figure 14 is a diagrammatic representation of this phenomenon.

Summary

The steps in the manufacturing process for Sears Craftsman tongue-and-groove pliers were reviewed and several sequentially broached pliers as well as completely manufactured pliers' jaws were evaluated to ascertain whether toolmarks from these pliers would be

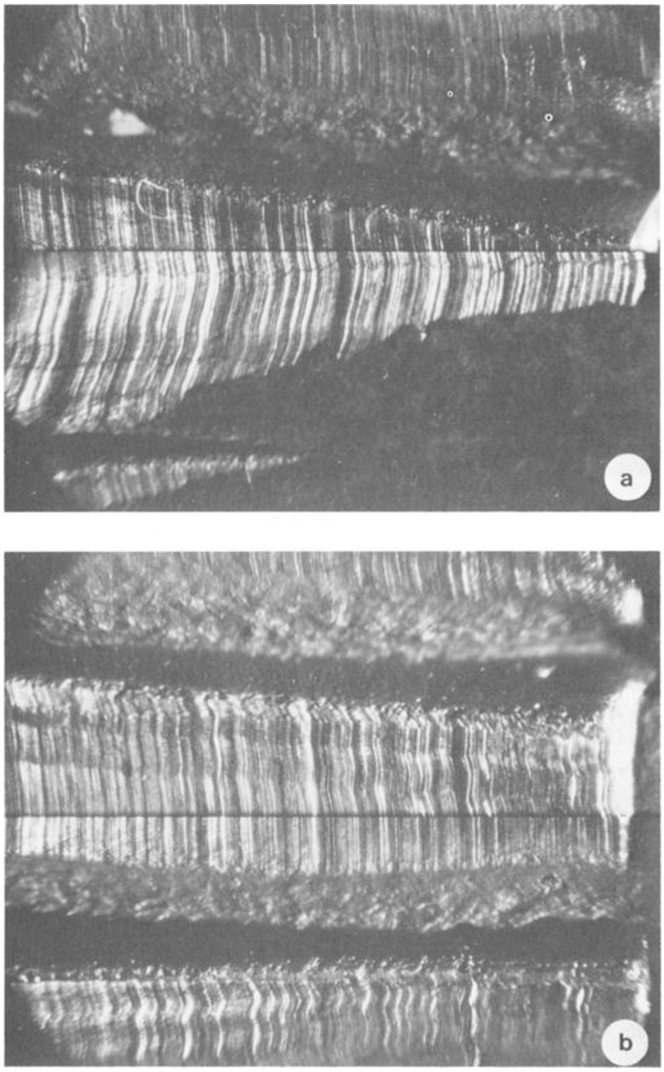

FIG. 10—*Photomicrographs of toolmark striations from the chromium-plated jaws, demonstrating reproducibility:* (a) *Pliers 1, top jaws and* (b) *Pliers 2, top jaws.*

unique. Microscopic examination of the toolmarks from these pliers verified that imperfections do produce individual characteristics. The report also explains why specific manufacturing steps aid in causing the unique surface imperfections on each tool that are responsible for the individuality of its toolmarks.

Acknowledgments

I would like to thank the staff at the Santa Barbara Regional Laboratory for their encouragement, help, and suggestions. Also, I want to express my appreciation to Mr. Howard E. Bleil, registered metallurgical engineer of Azusa, Calif., and Mr. Neil Butler,

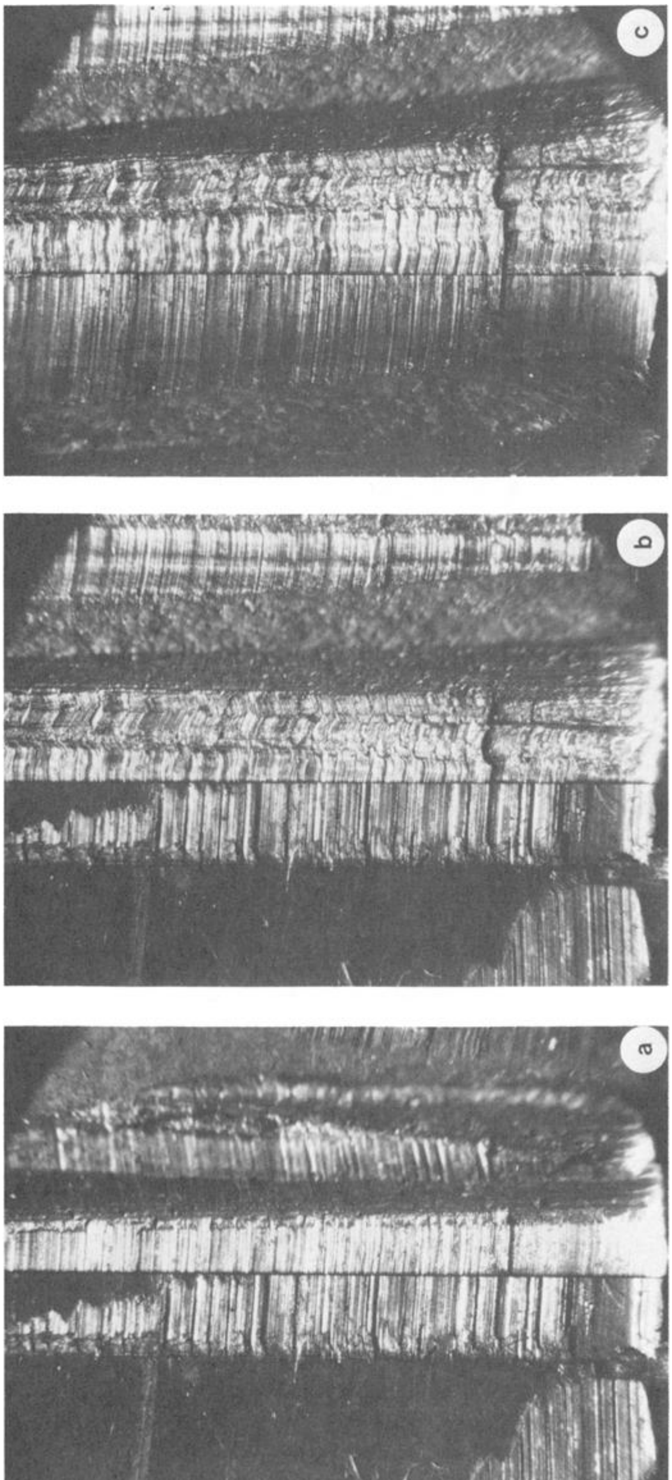

FIG. 11—*Photomicrographs of toolmark striations from the as-broached jaws showing individuality of specific teeth:* (a) *Pliers 1 and 2,* (b) *Pliers 1 and 3, and* (c) *Pliers 2 and 3.*

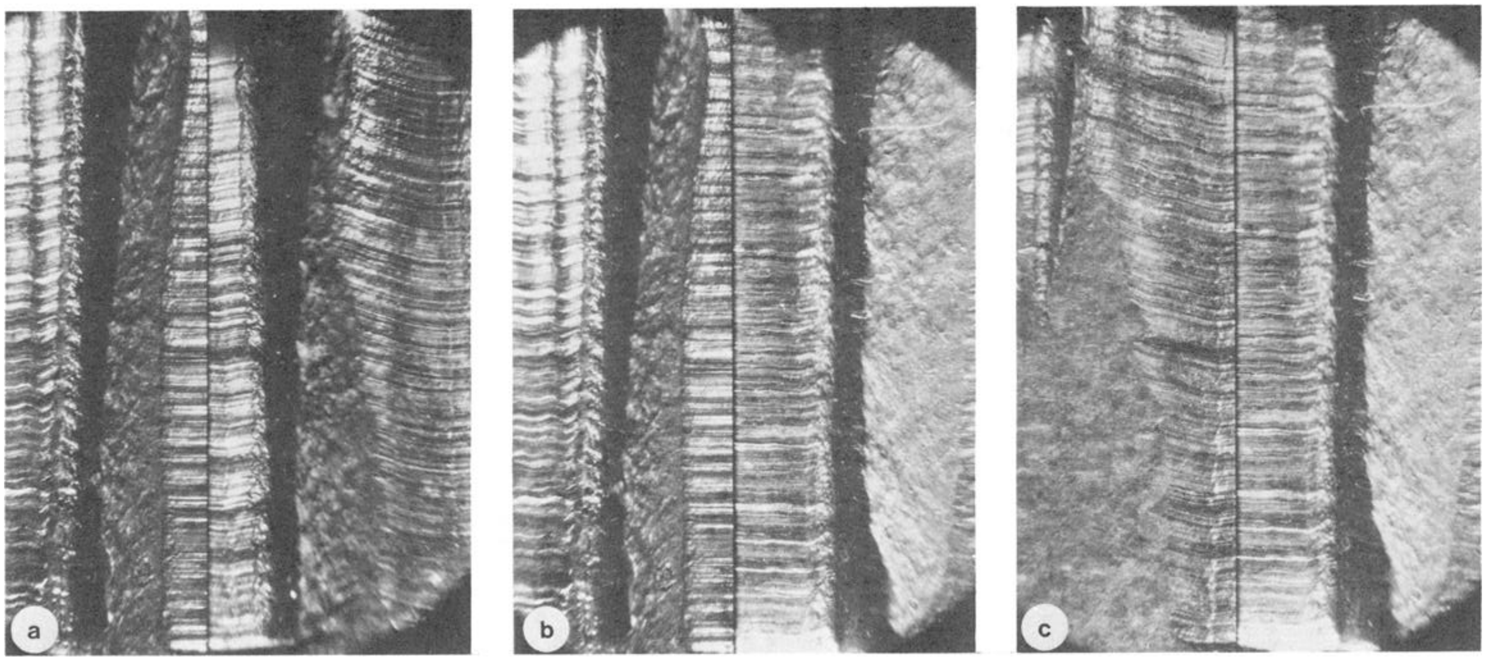

FIG. 12—*Photomicrographs of toolmark striations from the chromium-plated jaws showing individuality of specific teeth:* (a) *Pliers 1 and 2,* (b) *Pliers 1 and 3, and* (c) *Pliers 2 and 3.*

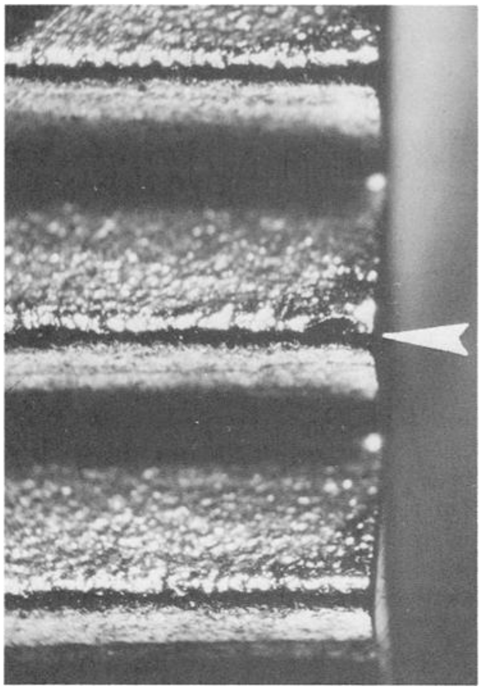

FIG. 13—*Damaged tooth area on one of the completely processed jaws. This dent was probably caused by striking another jaw during processing subsequent to broaching.*

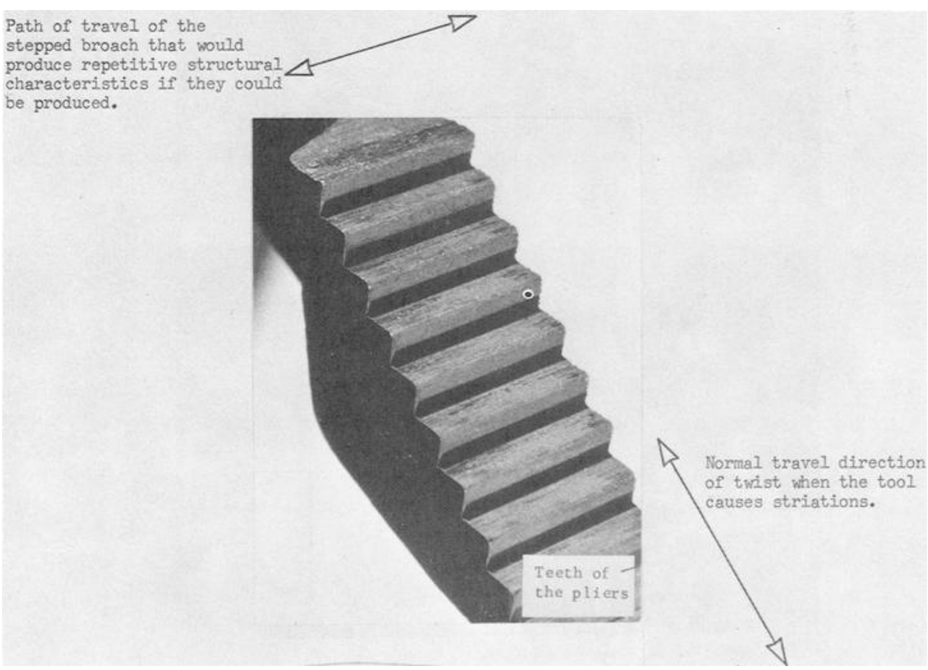

FIG. 14—*The striations caused by using the tool are 90 deg from the direction of the potential repetitive structural characteristics that would be produced, if possible, by the broaching tool. The photograph shows one of the as-broached jaws.*

senior manufacturing engineer, Western Forge Corp. at Canon City, Colo., for their review of this manuscript and helpful suggestions. I am very grateful to Mr. John E. Fisher, vice-president, Sales, Western Forge Corp., for supplying the pliers, and to Mr. E. C. Jordon, buyer, Hardware Department 609, Sears, Roebuck and Co., Chicago, Ill., who referred my inquiry (concerning the manufacturing of Craftsman pliers) to Western Forge Corp.

References

[1] May, L. S., "The Identification of Knives, Tools and Instruments. A Positive Science," *American Journal of Police Science*, Vol. 1, No. 3, 1930, pp. 246-259.

[2] Burd, D. Q. and Kirk, P. L., "Tool Marks: Factors Involved in Their Comparison and Use as Evidence," *Journal of Criminal Law and Criminology*, March-April 1942, pp. 679-686.

[3] Davis, J. E., *An Introduction to Tool Marks, Firearms and the Striagraph*. Charles C Thomas, Springfield, Ill., 1958.

[4] Burd, D. Q. and Greene, R. S., "Tool Mark Examination Techniques," *Journal of Forensic Sciences*, Vol. 2, No. 3, July 1957, pp. 297-306.

[5] Burd, D. Q. and Gilmore, A. E., "Individual and Class Characteristics of Tools," *Journal of Forensic Sciences*, Vol. 13, No. 3, July 1968, pp. 380-396.

[6] Butcher, S. J. and Pugh, P. D., "A Study of Marks Made by Bolt Cutters," *Journal of the Forensic Science Society*, Vol. 15, No. 2, April 1975, pp. 115-126.

[7] Watson, D. J., "The Identification of Consecutively Manufactured Crimping Die," *AFTE Journal*, Vol. 10, No. 3, Sept. 1978, pp. 19-21.

[8] Watson, D. J., "The Identification of Tool Marks Produced from Consecutively Manufactured Knife Blades in Soft Plastic," *AFTE Journal*, Vol. 10, No. 3, Sept. 1978, pp. 43-45.

[9] *Metals Handbook. Volume 2: Heat Treating, Cleaning and Finishing*, 8th ed., American Society for Metals, Metals Park, Ohio, 1964.

Address requests for reprints or additional information to
F. H. Cassidy
Dept. of Justice, State of California
Santa Barbara Regional Laboratory
820 Frances Botello Rd.
Goleta, Calif. 93017