A Study of Consecutively Manufactured Chisels

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ABSTRACT

Consecutively manufactured (consecutively finished – refer to article) chisels/pry tools were studied to determine whether or not the tools are capable of producing individual and identifying characteristics. Toolmarks were examined from one set of three consecutively ground chisels of one type, and from three sets of three consecutively manufactured or ground chisels of another type, with each set representing a different stage in the manufacturing process. Results showed that each ground chisel produced individual and identifying characteristics, and that there was no carry-over of features due to the finishing process between consecutively finished tools. Consecutively forged and trimmed tools did possess similar features prior to a grinding step.

INTRODUCTION

A number of papers have been published addressing consecutively manufactured firearms and firearm components. However, only a small number of studies have been performed on consecutively manufactured tools. Despite this, firearms examiners come to the same conclusion as they would with a firearm; that is, identifying a tool as having produced a particular toolmark. An extensively used and/or abused tool produces unique marks that can identify that particular tool to a toolmark, but tools possessing similar subclass characteristics can sometimes be mistaken for individual characteristics. As tool manufacturers minimize the steps necessary to produce tools in an effort to become more efficient and economical, the possibility for tools produced with similar characteristics increases. This research project examined toolmarks made by four sets of three consecutively manufactured/finished tools to determine whether or not each tool leaves individual and identifying characteristics.

The AFTE Glossary defines a tool as "an object used to gain mechanical advantage, also thought of as the harder of two objects that when brought into contact with each other, results in the softer one being marked." A toolmark is the result of such contact, and will be discussed in further detail at a later point. Toolmark identification is then defined as "the discipline of forensic science which has as its primary concern to determine if a toolmark was produced by a particular tool." As can be imagined, the idea of consecutively manufactured tools and the subsequent individuality of such toolmarks have the potential to confuse and mislead those unfamiliar with or wary of the field of toolmarks identification.

A basic understanding of the difference between class, subclass, and individual characteristics found in toolmarks is necessary prior to the undertaking of any toolmarks related research project. The AFTE Glossary defines class characteristics as "measurable features of a specimen that indicate a restricted group source. They result from design factors, and are therefore determined prior to manufacture." An example of a class characteristic when concerned with tools and toolmarks is the predetermined number of teeth on a pair of tongue and groove pliers. Another example of a tool class characteristic is the predetermined diameter of the head on a hammer. In the case of the chisels used in this research project, a class characteristic that can be assigned to the chisels is the width of the cutting edge. This is a predetermined design feature of the tool, and all of these tools produced will have a similar size width.

Individual characteristics (also called accidental characteristics) are "imperfections or irregularities produced accidentally during manufacture or caused by use, abuse, corrosion, rust, or damage to an object. They are unique to that object and distinguish it from all other objects." Examples of this are the nicks and gouges found on an extensively used pry bar that will transfer such unique features to the toolmarks it makes. In the case of the tools chosen for this project, individual characteristics are imparted to the tools by means of the finishing steps in the tools' manufacturing process. The tools are ground on a belt sander that results in a linear grind pattern on the tool. As the belt works against the tool held to it, the belt is constantly having its features changed as it is worn down. This constantly changing surface yields a constantly changing tool working surface.

A third type of characteristic encountered in toolmark examinations is subclass characteristics. Subclass characteristics are surface features that are more restrictive than class characteristics, are produced incidental to manufacture, relate to a smaller group source, and can arise from a source that changes over time. An example of such a subclass characteristic can sometimes be found in bunter marks. If a particular bunter used to stamp cartridge heads had a defect or an irregular feature, that feature would be imparted to all of the cartridges stamped with the bunter. Once the bunter was changed out, that feature would no longer be present. Subclass characteristics do appear in the chisels examined in this research project and will be discussed later in the paper. Burd and Gilmore (1) were one of the first to refer to subclass characteristics, although they did not use that exact terminology. A toolmark study conducted by Burd and Gilmore will be discussed at a later point as well.

PREVIOUS RESEARCH

There have been several papers written that discuss tools and the marks they leave, and one of the first papers published that dealt specifically with the study of toolmarks was by David Burd and Paul Kirk (2). Written in 1942, the paper first states that the "comparison of tool marks as an aid in solution of crime is a well known and widely used procedure which is generally considered as yielding valuable court evidence." Burd and Kirk then went on to explain that the individuality of toolmarks and their reproducibility is often in doubt, especially by those not familiar with the science of toolmarks examination. The absence of a careful study of factors influencing the character of toolmarks is one principle reason for such misunderstanding. Burd and Kirk's study was aimed at 1) the determination of the effect of variations in the manner in which a tool is applied to a surface and the resulting toolmark, 2) the issue of what degree of identity is necessary in a comparison, 3) the degree of similarity expected from two tools identical in manufacture and appearance, and 4) a classification of the types of marks encountered in toolmark examinations.

Burd and Kirk classify toolmarks as either being compression marks, friction marks, or cuts. Compression marks, or impressed toolmarks, are commonly encountered in casework. They are defined as microscopic contoured variations on the surface of an object caused by force and perpendicular motion to the plane being marked. In other words, compression marks are created by pressure or a blow to a surface. While the information obtained from such a toolmark can often be limited, it may be very useful. The type of tool used to create the mark is discernible, and the shape and dimensions of the tool surface creating the mark can usually be determined.

Friction marks, also called slippage, striated, or abrasion toolmarks, are defined as microscopic contoured variations on the surface of an object caused by force and parallel motion to the plane being marked. Burd and Kirk characterize these marks as being the "fine, parallel striations left on metal or other surface…when an edge is scraped over it." A scraping or slipping of the tool across a surface causes friction toolmarks. These striated toolmarks are the basis for bullet identifications. While the principle of striated toolmark examinations and bullet examinations are similar, the manner in which a tool is used to create a striated toolmark will greatly affect the comparison. On the other hand, there is only one way for a bullet to travel down the barrel of a firearm.

Cuts, the third of the types of toolmarks, are not encountered as frequently as compression and friction marks according to Burd and Kirk. Despite their infrequency, cut marks are very significant and can often result in a positive identification. The sharp edges of cutting tools tend to be used less than blunt edged prying tools in the commission of crimes.

Of the three types of toolmarks discussed by Burd and Kirk (compression, friction and cuts), the greatest degree of variability occurs in the category of friction marks. The authors list eight factors that influence the character of a friction mark:

1) degree of irregularity of the edge, which will be altered by wear or damage
2) vertical angle of the edge or tool
3) horizontal angle of the edge or tool
4) change of vertical or horizontal angles during application, changing the relations of the various fine lines composing the marks
5) inequalities of pressure
6) change of direction of application giving curves, zigzags, or other irregularities to the impression
7) presence of debris, which may have an abrasive action adding stray lines to the impression
8) type of material receiving the impression

The first factor (degree of irregularity of tool edge) is what imparts uniqueness to the toolmark. While this feature will gradually change over time, in most instances it is not a concern. The only time this factor would become an issue is in the event of a mechanical change to the tool surface, such as grinding, or a chemical change as is encountered in the severe rusting of a tool. The fifth through the eighth factors, while capable of affecting a toolmark, usually do not invalidate an identity.

The second, third and fourth factors (angle and change of angle in application of tool) provide for much greater variability in the comparison of toolmarks. To study these factors, Burd and Kirk obtained a set of screwdrivers with which to produce toolmarks. They were mounted in a framework in such a way as to effect a particular vertical or horizontal angle. Toolmarks produced at angles ranging from 25 degrees to 65 degrees in intervals of 10 degrees were examined. Burd and Kirk found that when the same tool was used to produce two toolmarks at the same angle, as few as 80% of the total lines were found to match photographically.

Adjusting the vertical angle on one of the toolmarks by 10 degrees caused only 60% to 65% of the lines to be matched photographically. A variation of 20 degrees between the vertical angle of the toolmarks resulted in only 40% of the lines matching. According to Burd and Kirk, this information indicates that "two marks made with the same tool must have a correspondence in vertical angle of application to about 10 degrees and not more than 15 degrees if a recognizable match is to be obtained." While Burd and Kirk tended to focus on the percentage of matching lines found in the toolmarks in their study, they do stress that the general character of the mark, or it's contour or cross section, are at least as valuable as the percentage of matching lines.

Burd and Kirk also looked at the effect the horizontal angle of application has on the resulting tool mark. In many instances, a tool is not moved in a straight line across the surface it is traveling. When the tool is advanced at a horizontal angle to the axis of the tool, a foreshortening of the mark is produced, causing the striations in the mark to be placed closer together. In order to examine this effect, Burd and Kirk varied the horizontal angle from the tool axis by 10 degrees and by 20 degrees. They found that for the 10 degree variation foreshortening did occur but no major changes in the toolmarks were observed. Changing the angle by 20 degrees caused the lines to no longer match up but the contour and arrangement of the lines were the same, allowing for an identification. In the case of the 20 degree variation, however, the authors' felt that a photomicrograph would not be helpful to the untrained eye, as often encountered in the courtroom. Burd and Kirk determined that a variation of 20 degrees was as large as could be used to still identify a match.

Since it is nearly impossible to obtain a perfect, 100% match of features in a toolmark comparison, Burd and Kirk state that "it is of crucial importance to determine what degree of identity must be established before it can be stated that two marks were made by the same tool." The contour, including the distribution, width and depth, of a toolmark is the most important factor in a toolmark comparison. When the same contours are noted in a comparison, the actual number or proportion of matching lines becomes less significant. Burd and Kirk's study, however, indicates that if 100 lines are visible in a toolmark comparison and the contour and distribution of the lines are similar, an identification can be made when 60 or more lines match. When the number of matching lines drops below this, the contour of the lines must be dissimilar and, therefore, a match would not occur. The proportion of matching lines will never be high unless the contour of the features is very similar.

Burd and Kirk's study and resulting article was the first to truly experiment with toolmark production and comparisons, and the factors that affect toolmarks. As previously mentioned, many studies concerned with toolmarks since then have been performed, and one in particular carefully analyzed the types of characteristics present on tools, including class, individual, and what was eventually termed subclass characteristics.

In 1968, Burd and Gilmore (1) published a study that examined the types of features present on three randomly selected, mass- produced screwdrivers, all of the same make. The screwdrivers were taken from a bin in a hardware store. Upon examination of the tools, it was determined that the tips of the tools (1/8") were stamped or pressed in a mold or a die. Five different types of characteristics present on the tools were discovered and described:

1. die markings – class characteristics
2. edge cuts – class characteristics
3. depressed broken edge – individual characteristics
4. corner areas with nicks and wear markings – individual characteristics
5. rough folded/squeezed metal at tip – individual characteristics

Both of the types of class characteristics mentioned above might actually be termed today as subclass characteristics. In the instance of the three screwdrivers chosen for this study, all three of the tools possessed these "class characteristics"; however, they do not appear to be an intentional design feature in the tools.

Burd and Gilmore made impression marks with the sides of the blades of the tools where the die markings were evident. They were compared using the comparison microscope and were found to be the same. It can be surmised that these die markings are not unique to each tool but rather a type of class characteristic (subclass characteristic).

Striated, or abrasion, marks were made in lead with the tips of the tools. Upon comparison, there was no correspondence present. The tips possessed the rough areas from the folding and squeezing of the metal due to the die used to form the tool. These features were determined to be individual in nature.

The narrow sides of the screwdriver tips were closely examined as well. Parallel ridges were present on this area of the tool, most likely produced by the die used in manufacture, which partially cut the metal. The tool edges were directly compared, as well as abrasion toolmarks made by the tools. In both cases, correspondence occurred. To a careless examiner or one without knowledge of the manufacturing process of the tools, such a comparison may indicate an identification.

Burd and Gilmore conclude that "as a result of this limited study of just three new screwdrivers, it is therefore apparent that great care must be taken in evaluating tool mark evidence. Distinguishing between certain types of class and individual characteristics of tools can be rather difficult in some instances, and for this reason care must be taken in interpreting laboratory examinations of tool marks."

In addition to the above studies concerning tools, the features they possess, and the toolmarks they leave, a small number of studies have been conducted and published that specifically address a wide variety of consecutively manufactured tools. Several of these articles and studies will be reviewed here.

One of the first documented studies that examined toolmarks produced by such tools was conducted by Butcher and Pugh (3) in 1975. Five pairs of consecutively manufactured bolt cutter blades were obtained. These specially assembled bolt cutters were not subjected to the in-house test cut that all other bolt cutters for public sale receive. Test cuts were made by the bolt cutters in lead rod using the entire length of the blades. Every toolmark was compared against every other toolmark in the four possible orientations for a total of 880 comparisons. Butcher and Pugh determined a match by the percentage of matching lines. A "true match" occurred when 50% or more of the lines were matching, and a "false match" occurred when less than 50% of the lines were matching. Only two geometrically feasible "false matches" occurred out of the 880 comparisons made. However, in neither instance would a trained examiner call the comparison a match in a toolmark examination in the normal sense of the term.

Butcher and Pugh then went on to compare test toolmarks made by five new bolt cutters that were not consecutively manufactured and were used for one test cut in the factory. This process was done to mimic the public's use of the tool and to examine the likelihood of random tools producing similar toolmarks. Again, only two "false matches" were obtained after all of the comparisons were made. The purpose of Butcher and Pugh's research was to determine the degree of match obtained in marks made by different blades and those marks made by the same blade. In the case of the consecutively manufactured, unused blades, 25% matching lines were observed in the false matches, and 89% matching lines were observed in the true matches (known matches). In the case of the new bolt cutters used for one factory test cut, 28% matching lines were observed in the false matches, and 90% matching lines were observed in the true matches (known matches).

Butcher and Pugh determined that for two different cutting edges, as found in bolt cutters, to produce a high percentage of matching lines, identical patterns of grind marks on each of the intersecting faces are needed, as well as grinding of such precision that the intersection was exactly the same in each case. Two concepts were used by Butcher and Pugh in the making of a comparison: definition, which is a measure of the quality of the mark and the level of definition found in the striations, and character, which is a measure of the randomness of the striations.

Sequentially ground drill bits were examined and the results published by Reitz in 1975 (4) in response to an unusual case. Sequentially ground drill bits were obtained from the Gunther Company in Frankfurt, Germany, and an assortment of drill bits were obtained from the Black and Decker Company in Hampstead, Maryland. The drill bits were used to create toolmarks, and it was determined that each drill bit, sequentially ground and non sequentially ground, produced individual circular stria in the test media.

A study of new screwdrivers was conducted by Vandiver (5) and the results published in 1976. Two screwdrivers from the same production lot were provided by seven manufacturers for a total of 14 screwdrivers. The blades were examined to determine if good quality screwdrivers from the same lot possessed similar characteristics that could be used to mistakenly identify a tool. This particular study was a follow-up to a previous study that examined the characteristics of cheaply manufactured, mass produced screwdrivers.

Vandiver reached six conclusions from the examination of the submitted screwdrivers. Several of the conclusions are listed here:

- Crime scene marks bearing striations or detailed impressions could be matched back to the screwdriver even though two blades from a given company are generally alike
- Gross and fine characteristics on screwdriver blades vary from company to company
- A brand and model of screwdriver can possibly be identified based on the characteristics of crime scene marks

- A brand and model of screwdriver can possibly be identified from a fragment of the tool left behind at a crime scene based on the different companies' manufacturing processes.

In 1978, Watson (6,7) published two papers examining toolmarks made by consecutively manufactured knife blades and consecutively manufactured crimping dies. In the first of these studies, Watson obtained two consecutively manufactured Buck knives, model 119 with a 10" blade. A particular area of the blades was selected for making consecutive test cuts in soft extruded plastic similar to the consistency of telephone wire insulation. The toolmarks were then compared with toolmarks produced by both sides of the same blade in successive tests, and with toolmarks produced by both sides of the blade of the other knife. The same side of the blade reproduced its toolmarks for all four blade sides between the two blades. Each side of the blade possessed unique, individual characteristics that identified one from another.

In Watson's study of crimping dies, two sets of consecutively manufactured die sets were obtained. Each die was then used to make two seals in lead using crimping pliers. The resulting seals were then compared to themselves (known matches). Watson determined that there was no carry-over of features between the two die sets, and each possessed unique, identifying features. In this particular study, Watson was examining the die surfaces that have the lettering impressed in the metal by the hand stamping operation as opposed to the surfaces on the die sets in which the metal is removed by the engraver jig.

Consecutively manufactured tongue-and-groove pliers were examined by Cassidy (8) in 1980. Cassidy received three sets of unplated, or as-broached, pliers jaws (for a total of three unplated pliers). Cassidy also received three plated upper jaws. Striated toolmarks were made with the jaws on lead in clockwise and counterclockwise directions. Specific teeth were selected to make the marks, and four sets of toolmarks were made by each jaw in each direction using the same selected teeth. Cassidy then went on to compare the toolmarks produced in the following manner: each as-broached tooth to itself, each as-broached jaw to the other as-broached jaws (upper jaws to upper jaws and lower jaws to lower jaws), the teeth marks of each finished jaw to themselves, each finished jaw to the other finished jaws, and each as-broached upper jaws to each finished upper jaws.

Cassidy determined that individual characteristics were produced by each jaw due to several factors: metal grain structure; grinding, milling, and broaching of metal; heat treat scale and its removal; tumbling in descaling; handling of jaws for additional processing; acid etching; electrodeposited nickel and chromium. These factors are very similar to those encountered in the manufacture of breech faces for firearms. Cassidy stated that even if the broaching process produced class or subclass characteristics, the broaching tool applies marks and characteristics in a 90 degree orientation from how the tool is normally used.

In 1982, sequentially manufactured knives were examined in a second study by Tuira (9). Tuira obtained two consecutively manufactured Buck knives, model 119. The knives were then used to perforate the sidewalls of inflated Goodyear tires. Tuira was able to identify each mark to itself and went on to determine that each knife produced unique and individual toolmarks. The study was performed in response to several tire-stabbing cases received by Tuira's laboratory.

Hall (10) performed another study on bolt cutters in 1992. The bulk of Hall's study focused on consecutive *cuts* made by bolt cutters as opposed to examining consecutively *manufactured* bolt cutters. However, Hall did obtain three consecutively assembled bolt cutters and intercompared the test toolmarks. Hall was able to confirm what was found by Butcher and Pugh: bolt cutters differ microscopically.

MATERIALS AND METHODS

While a variety of consecutively manufactured, finished, and assembled tools have been studied in the past several years, literature is not available concerning the examination of consecutively manufactured (consecutively finished) chisels. It is well known that tools are not often used for their intended purpose in the commission of a crime where toolmarks are evidence of value. In such a situation, chisels can quickly become an effective pry tool. For this reason, chisels were the tools chosen to examine.

On April 18, 2001, four sets of three consecutively manufactured (consecutively finished) tools were received from the manufacturing plant of Enderes Tools located in Albert Lea in southern Minnesota. The tools were numbered 1, 2, and 3 in the order in which they were finished and/or taken from the manufacture line. Following are the types of tools collected and the manufacturing and finishing steps to which they were subjected:

Tool Set #1 - Three brick sets (tool B-26): forged and trimmed (Figure 1)
Tool Set #2 - Three brick sets (tool B-26): forged, trimmed, rehit and ground (Figure 2)
Tool Set #3 - Three brick sets (tool B-26): forged,

trimmed, rehit, ground, heat treated, blasted, sharpened, and waxed (Figure 3)
Tool Set #4 - Three extra long cold chisels (tool A-11): forged, trimmed, rehit, ground, heat treated, blasted, sharpened, and waxed (Figure 4)

Figure 1: Tool Set #1, Tools #1-#3, B-26 chisels

The B-26 brick sets chosen for the project are made from 7/8" stock. They have an overall length of 7" with a cutting edge width of 5". The stock is made of domestic high carbon steel, and is forged and heat treated using Enderes exclusive deep tempering process. The chisel has a hexagonal shaped shaft and the cutting edge has a bevel angle of approximately 45 degrees. The tools are designed for cutting, trimming, and scoring blocks and bricks. Due to their strength and heft, it would be very possible to find tools similar to these used in the commission of a crime as a pry-type tool.

The A-11 extra long cold chisels chosen for the project are made from ¾" stock. They have an overall length of 12" and possess a cutting edge width of ¾". The manufacturing process is similar to that of the B-26
Figure 2: Tool Set #2, Tools #1-#3, B-26 chisels

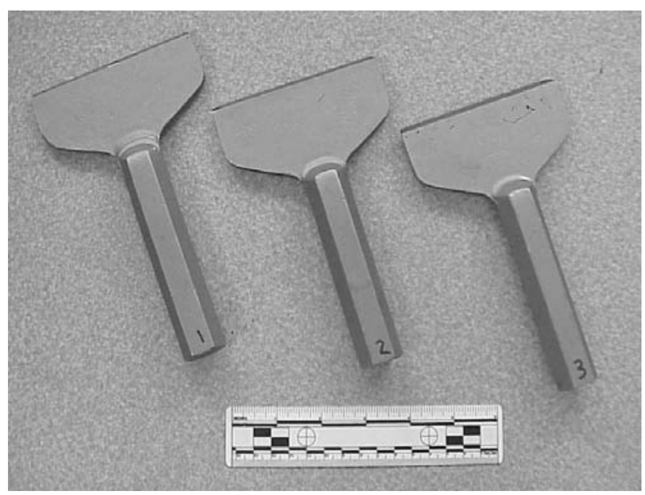
chisels. The cutting edge has a bevel angle of approximately 70 degrees and the Rockwell hardness range for the tools are C57-59. The tools are designed for cutting and removing metal softer than the metal of the cutting edge itself. This tool is long and narrow and could feasibly be used in the commission of a crime where the situation calls for a tool having such design features.

In general, most finished tools from Enderes Tools will be subjected to forging, trimming, rehitting, grinding, heat-treating, blasting, sharpening, and waxing. Each of these steps will be explained in slightly more detail.

Figure 3: Tool Set #3, Tools #1-#3, B-26 chisels

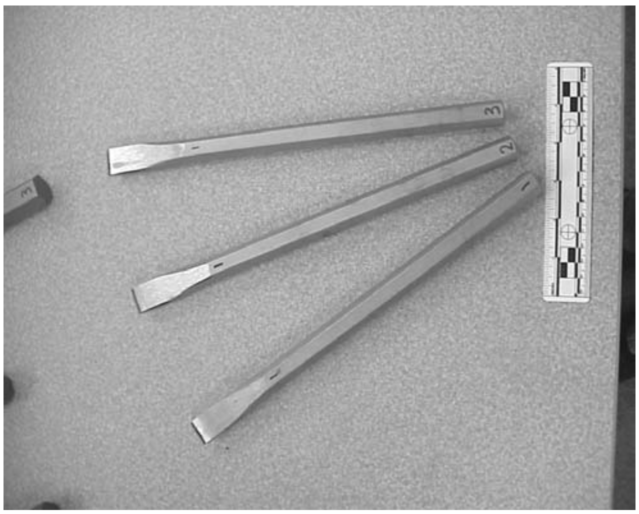
The B-26 brick chisels used in this project start as steel bar stock. The bar stock comes from a variety of suppliers and their exact alloy content will vary from supplier to supplier. The steel bar is cut to the appropriate length segment with a saw, and the non-working end of the tool (handle end) is then beveled by hand on a grinder to eliminate burrs.

The bar is then upsetted, where the tool end of the bar is first heated to red-hot. The bar is then secured in an upright position, and a cup shaped die presses down onto the top of the bar, forming a ball shape on the end of the bar. The tool then moves to the forging and trimming



stage.
Figure 4: Tool Set #4, Tools #1-#3, Edge #1, A-11 chisels

The ball end of the tool is heated again to red-hot, and is placed into the spade form in the drop forge. The forge is dropped several times to rough out the shape of the brick chisel. The tool is then trimmed to take away the curved edge of the spade from the forging step, resulting in a squared off working tool edge. The tool is then touched against a spinning wire brush in order to remove any scale build-up. The tool is then placed in the drop forge for a final time and the forge is dropped just once onto the tool to fill out the tool to the shape of the form in the forge.



The working edges of the B-26 chisels are then subject to grinding on a belt sander. This step is performed by hand, and depending on the operator can be done free form or with the help of a guide. After grinding, the tools are heat-treated. The B-26 chisels undergo an induction heating at a temperature near 1500 degrees Fahrenheit. The heat-treating is followed by a water quench. This process hardens the tools to a stage where they are durable but non-brittle. Other tools in the Enderes Tools line are heat-treated by means of a blast or kiln furnace where similar temperatures are reached. This heat-treatment is followed by an oil quench. Some tools are then placed in a salt bath, followed by a water quench.

Bead blasting is the next step, where tools are first placed in a giant tumbler. As the tools tumble, fine silica sand is blasted at the tools using air jets. This procedure lasts about 15 minutes, and gives the tools an even matte finish. The tool edges are then sharpened and polished by hand on belt sanders. A wax treatment is the final step before the tools are ready to be packaged for retail sale.

While the above description applies directly to the manufacture process of the B-26 brick set chisels in the Enderes Tools product line, many other tools produced by the company undergo similar manufacturing steps, and the A-11 extra long cold chisels are no exception.

All of the dies used in the tool formation are made by hand at Enderes Tools, and no CNC machining (computer numeric controlled machining) is used. The company is now stamping the year of production on the tools; however, no records are kept of the manufacturing procedures for a particular year so it will be difficult to state definitively how a particular tool was manufactured in several years' time.

While the initial intent of the project was to obtain consecutively manufactured tools, it was determined that the tools were actually consecutively finished. After each step in the manufacturing process, the tools at Enderes Tools are placed in collection bins to be transported to the next stage. The tools used in this project were collected consecutively after their respective last manufacturing or finishing step. For example, the second set of chisels listed above was collected one after another following the grinding step. Previous to the grinding step, the order of manufacture of the collected tools was not known.

Enderes Tools was contacted for more detailed information concerning the manufacturing process used for their chisels, especially the method involved in applying the finished, cutting edge to the tools during the grinding and sharpening steps. The information most desired was how often the grinding belts are rotated and replaced. Due to the proprietary nature of the competitive tool manufacturing field, Enderes Tools was unable to supply additional information. Much of the equipment used by Enderes Tools was designed and built by the company itself. Enderes Tools did issue the following statement:

"There are a lot of variables that go into belt usage and there is no magic formula or set number of pieces. In the grinding process, angles of cutting edges, burr removal, reshaping, etc. can make a huge difference on the number of pieces that can be run on one belt. Polishing belt usage is dictated by surface area, angles and how good of a job was done in the grinding process."

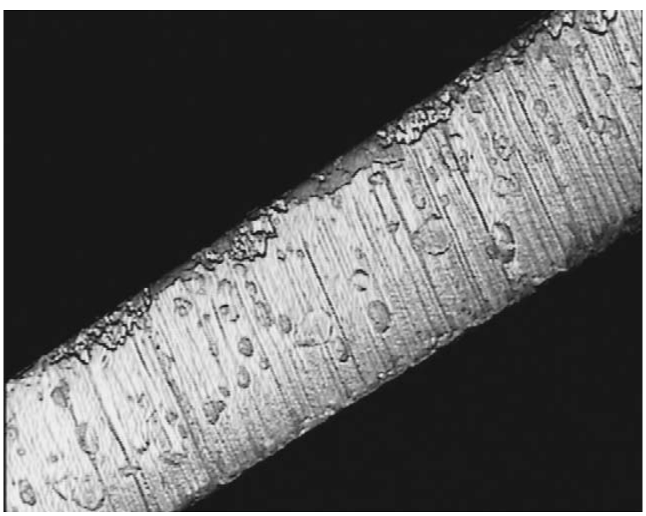
On a successive visit to Enderes Tools in February of 2002, it was stressed that belt usage is also very dependent on the individual operator. The pressure used to grind and sharpen the tools will very from operator to operator; it was stated that some belts last one hour while others will last an entire day. At the time of this following visit, one operator was grinding a set of B-26 brick chisels and this individual stated that he will switch to a new belt about once every 400 tools, or approximately once every two hours. Also, the particular grinder and belt used for the B-26 chisels is narrower than the entire length of the cutting edge by approximately one half inch. The operator must grind the majority of the tool edge, then slightly shift the tool to allow the last part of the edge to be ground. All of the grinding, polishing and sharpening belts used by Enderes Tools are manufactured and supplied by 3M in St. Paul, Minnesota, with manufacture to relocate soon to Mexico.

All of the tools examined were of a chisel-type. Tool Set #3 and Tool Set #4 listed above describe completely finished products. Tools in this state are ready for sale. All of the above tools and their cutting edges were examined macroscopically and microscopically. (Figures 5-8).

Figure 5: Edge of Tool #1 from Tool Set #1. This tool edge is in an unfinished state and has only been forged and trimmed.

Mikrosil casts were made of the ground and finished cutting edges of Tool Set #3 and Tool Set #4. The casts were made to intercompare these finished surfaces. The casts also served to simulate the comparison of impressed toolmarks made by the tools.

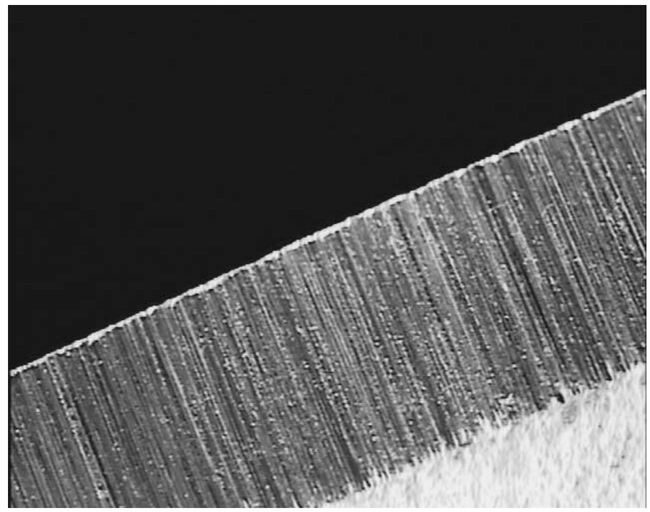
The chisels in Tool Set #3 had only one finished, cutting edge and one cast was made of each edge on every tool for a total of three casts. The edge on chisel #1 was compared to that of chisel #2, and chisels #2 and #3 were compared as well. The entire length of each cutting edge was examined and compared. Each finished cutting edge was determined to be unique as a result of the finishing steps since the compared surfaces did not reveal similar



individual characteristics and could not be identified to each other.

Figure 6: Edge of Tool #1 from Tool Set #2. This tool edge is in a partially finished state and had been forged, trimmed, rehit and ground.

The chisels in Tool Set #4 had two finished cutting edges on each tool. The two edges on every tool were ground consecutively on the same belt grinder. In essence, each of these chisels provided two consecutively manufactured or finished "tools", or cutting edges. Each edge of every tool was cast for a total of six casts. The entire length of each edge of each tool was compared to its "mate". For example, cutting edge #1 and cutting edge #2 of tool #1 were compared. The same was done for tool #2 and for tool #3. In every case, the comparisons showed that each finished cutting edge of the chisels from Tool Set #4 could not be identified to the second edge on the same tool since the presence of matching individual



characteristics were not observed. (Refer to Figure 9).

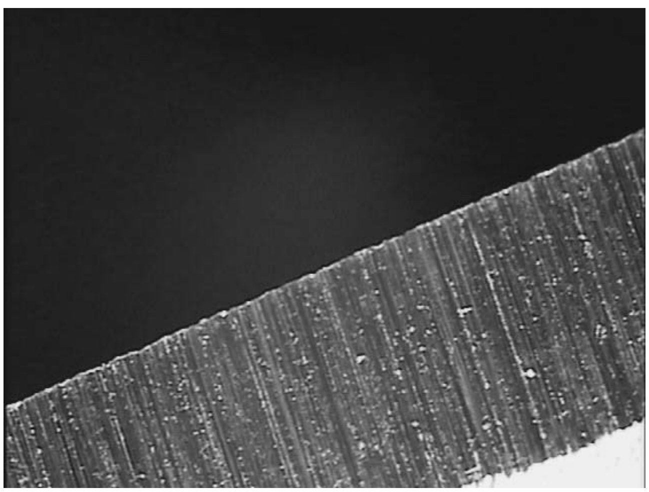
The ground, unfinished cutting edges of the chisels from Tool Set #2 (forged, trimmed, rehit, and ground tools) were cast with Mikrosil and intercompared. The entire length of each edge was examined. Each surface possessed distinct, unique toolmarks and the tools could not be identified to each other.

A second series of Mikrosil casts were made of the cutting edge of the first tool collected from Tool Set #2, Tool Set #3 and Tool Set #4 that were initially cast. The second set of casts was compared to the casts of the same tools made previously. These additional casts were made to reaffirm how a "match" should appear in this case. Each tool could be identified to itself when the casts were compared.

Test toolmarks were made in lead using the finished products A-11 chisels from Tool Set #4. This particular tool set was chosen over the B-26 tools in Tool Set #3 for the tools' shorter cutting edge length and ease of maneuverability of the toolmarks under the microscope. Since the A-11 chisels have a two-sided cutting edge there are more opportunities for comparisons with this model of tool as well. Each cutting edge of each of the three tools in Tool Set #4 were used to make two test toolmarks each for a total of twelve toolmarks produced. All of the toolmarks were produced in soft sheet lead at approximately a 45 degree angle using a consistent manner for each toolmark.

Figure 7: Edge of Tool #1 from Tool Set #3. This tool edge is in a completely finished state and has been forged,trimmed, rehit, ground, heat treated, blasted, sharpened, and waxed.

The test toolmarks were first compared to themselves to ensure that the toolmarks were reproducing and could be identified to each other. The toolmarks were found to be reproducible and were easily identified to each other. The toolmarks were then intercompared to see whether or not there was any carry-over of features between tools due to the manufacturing and/or finishing processes. In the case of the A-11 series of tools, cutting edge #1 of a tool was compared to cutting edge #2 of the same tool so as to compare two consecutively finished cutting edges. In every case, the toolmarks made by one cutting edge were found to be unique and could not be identified to the toolmarks produced by the next, consecutively finished



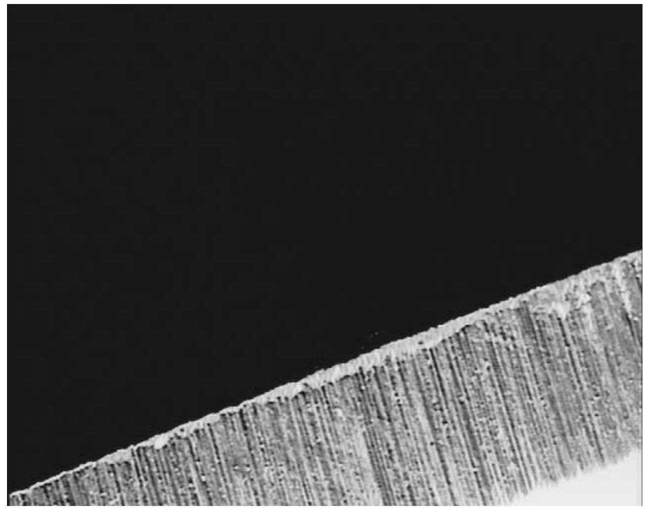
edge.

Figure 8: Edge #1 of Tool #1 from Tool Set #4. This tool edge is in a completely finished state and has been forged, trimmed, rehit, ground, heat treated, blasted, sharpened, and waxed.

Figure 9: Profile of Tool #1 from Tool Set #4. Note the two finished cutting edges on each tool.

RESULTS

While all of the examined tool surfaces and toolmarks showed the presence of unique features, there were two interesting comparisons. At first glance, it appears as if portions of the patterns found in some of the toolmarks made with Tool Set #4 were similar. If such a scenario were encountered in an actual case, additional toolmarks would have been produced. Upon more thorough examination it was determined that the toolmarks did not possess similar individual characteristics. These comparisons were between the two cutting edges of tool



#1 and tool #3 from Tool Set #4 and are demonstrated in the accompanying photographs. (Refer to Figures 10 and 11). These comparisons are examples of best-known non-matches.

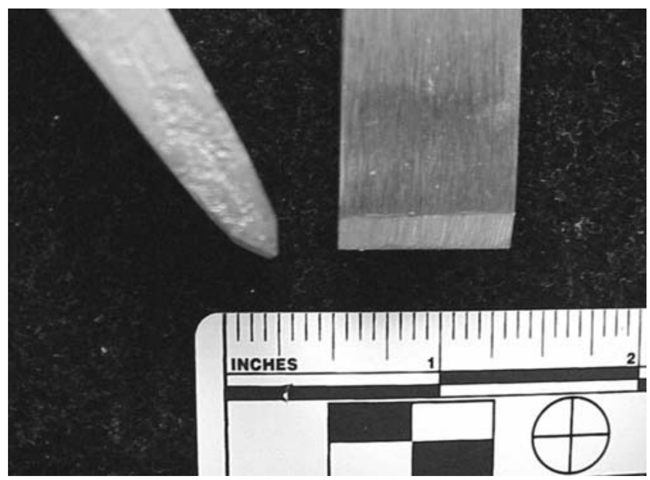
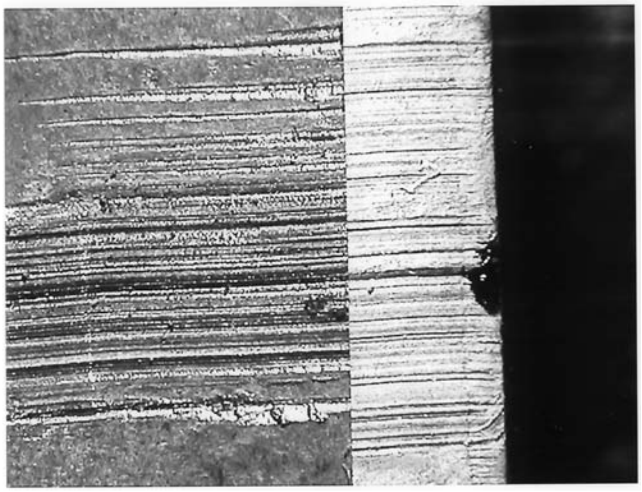


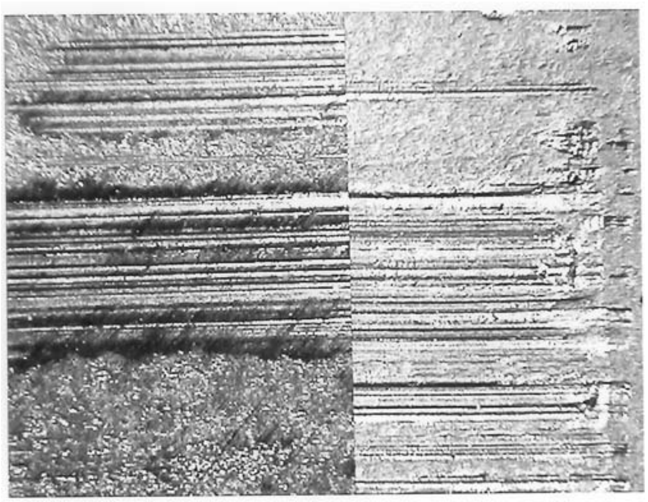
Figure 10: **Comparison of toolmarks from Tool #1 Side #1 from Tool Set #4 (right) and Side #2 of same tool (left) at 20X, example of best-known non-match.**

Figure 11: **Comparison of toolmarks from Tool #3 Side #2 from Tool Set #4 (right) and Side #1 of same tool (left) at 20X, example of best-known non-match.**

An additional series of comparisons were made. Mikrosil casts were made of the tools from Tool Set #1 (a set of three unfinished B-26 brick set chisels). The edges of the tools themselves were cast and compared. This particular series of tools had only been subjected to the forging and cutting steps from the manufacturing process, and had no finishing applications. Comparisons between all three tools cast showed the presence of similar subclass characteristics. These characteristics were in the form of striated marks produced by the cutter used to create a straight edge for what would eventually become the



cutting edge. (Figure 12). This is another example of a best-known non-match. While the presence of similar subclass characteristics were encountered on the tool at



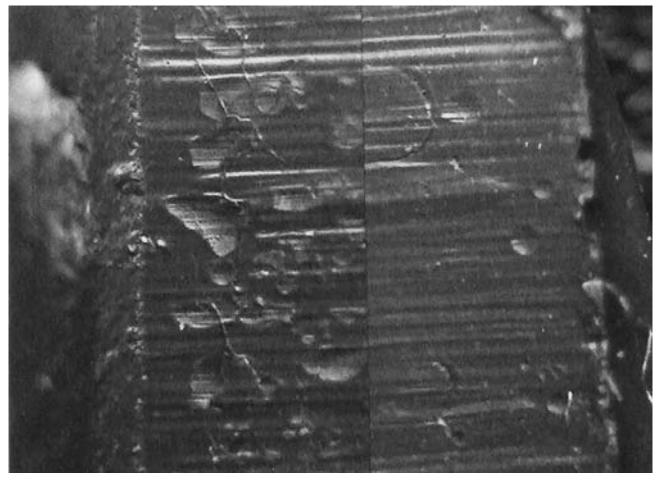
this stage in the manufacture process, these features are completely removed in the later finishing steps of manufacture (grinding and sharpening) and are not present on any final product tools. An example of true agreement of individual characteristics in finished product tools is evident in the comparison photograph of two toolmarks produced by side #2 of tool #2 from Tool Set #4. As evident, this particular tool readily reproduced its marks. (Figure 13). This is an example of a known-match.

Figure 12: Comparison of tool edges of Tool #1 (right) and Tool #2 (left) from Tool Set #1 at 25X, example of best-known non-match.

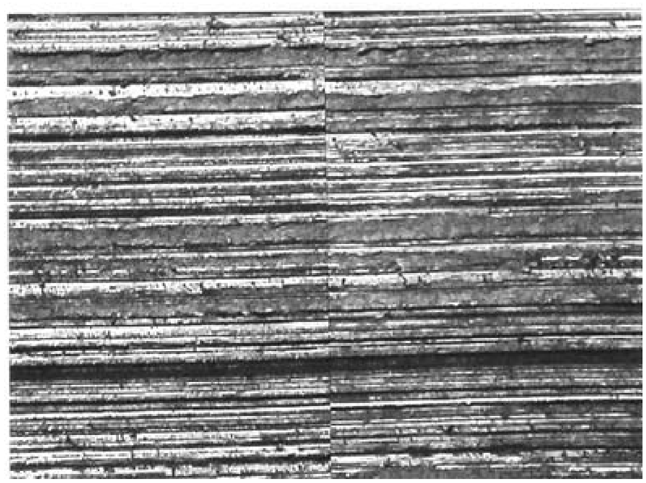
Figure 13: Comparison of toolmarks from Tool #2 Side #2 from Tool Set #4 at 20X, example of known-match.

DISCUSSION AND SUMMARY

While the subclass characteristics are easily discernible in the above comparison of tool surfaces from Tool Set #1, a close inspection would show the presence of individual characteristics. These individual characteristics can be found in the form of bumps on the tools (dimples on the casts of the tool edges) and are most likely a result of the heating process of the metal prior to the forging and cutting steps. One would almost never encounter these subclass characteristics in a finished product tool since the marks are ground away when the finished edge is applied to the tool. Only if the tools were somehow



removed from the manufacturing site by means of an accident, or if they were stolen from the site in an unfinished state, would they ever possess such similar



subclass characteristics. Also, the tools at this stage in the manufacture process are soft and have not yet been subjected to any hardening steps. Tools in this state are not as durable as those in a finished state, and could easily be deformed when worked against a harder object.

In an article by Jerry Miller, he states the following: "To conclude that a specific tool working surface is the source of a toolmark, the individuality of that tool working surface must be determined. The basis for this determination lies in the manufacturing process used to produce the tool working surface, what has occurred to that surface since manufacturing, and how that surface interacted with the material when the toolmark was produced." (11).

The findings of this research indeed support the results of the scientists in earlier studies: consecutively finished tools do not produce toolmarks with matching features. The nature of this particular manufacturing process affords unique and individual characteristics to the tools made. In the case of consecutively manufactured or consecutively finished tools, it is of the utmost importance to determine the manufacturing process used to produce the tool's working surface.

It is important to note that the finished chisels supplied by Enderes Tools have a grind finish to them applied with a sand belt-type grinder. This type of finishing step will give unique and individual characteristics to the tool surface since the surface of the belt itself is constantly changing as it is being used. Also, no two tools are applied to the belt to be ground in the exact same position and in the exact same manner. One can be assured that every chisel manufactured in this manner will posses unique features and will in turn create unique toolmarks, and this research project certainly helped to demonstrate that fact. The fact that the unfinished tools examined from Tool Set #1 did possess similar subclass characteristics should be a warning sign to firearms examiners to be aware of how tools are manufactured; had these particular tools been cheaply manufactured and were only stamped without a ground finish, the possibility for the presence of subclass characteristics would be much greater.

While this project looked specifically at brick set chisels and extra long cold chisels produced by Enderes Tools, other tools in the product line are manufactured in a similar way. Many other types of tools are ground on the exact same belt sanders with the same belts used for the chisels, including pry bars. Tools of this type are often used in the commission of a crime where the subsequent toolmarks are valuable evidence. Knowing this, one could apply the findings from this study to other tools in the Enderes Tools line, such as several of their pry tools.

FUTURE RESEARCH

Many possibilities exist to expand the research conducted in this study. It would be very interesting to witness the manufacture of the grinding belts used by Enderes Tools for the grinding and sharpening of their tools. To know how the belts are produced and the nature of the materials used in belt manufacture would help in understanding the significance of the finished edges of the tools. Another possibility would be to examine other tools in the Enderes Tools line. Enderes Tools produces a variety of tools including screwdrivers, nippers, pry bars, and drill bits. All of these tools have the possibility to be used in the commission of a crime, and leave behind valuable toolmarks as evidence. A final avenue to explore is the manufacture of lower quality tools. After several visits to Enderes Tools, the high quality of their tools and manufacture methods are evident. It would be of interest to examine tools whose production is of less quality and entails fewer steps in the manufacture process. Tools that do not have a ground or polished working surface would fall into this category.

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