The Categorization of Toolmarks and Tool Types

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ABSTRACT

The forensic examination process of comparing two toolmarks to determine if they have a common origin, commonly referred to as pattern matching, begins with a taxonomical study of the most general (class) characteristics, progressing through to the most distinctive (individual) characteristics. During the initial phase of such a study, questioned toolmarks and suspect tools are classified and characterized according to their characteristics.

The development of a more robust tool/toolmark classification system was recommended over thirty years ago. This article proposes a classification delineation system that includes terms and descriptions for toolmarks and tool actions that are intended to augment those found in the pre-existing literature in order to encourage the use of a more standardized format when working on these types of forensic examinations.

The forensic examination of toolmarks, and the tools that produced them, entails an empirical (usually microscopic) comparative analysis of these toolmarks, which are usually of a known and unknown origin, respectively. This comparative process, which is referred to as pattern matching [1], begins with a taxonomical study of these known and questioned toolmarks to ensure that their general (class) characteristics are similar. During this initial study, toolmarks are first classified according to their most general features or types, and then characterized by their more specific (individual) characteristics. These traits will usually reflect the reverse image or profile of the tool's working edge(s) that produced them. This taxonomical study serves as a sorting process where toolmarks that contain different classified or characterized general features (class characteristics) are excluded from the examination process, and toolmarks with the same classified or characterized features (class characteristics) are further analyzed by their distinguishing (individual) characteristics for possible individual association of the questioned toolmark to the known tool [2, 3].

A review of the literature finds limited or scattered information that describes a systematical categorization of toolmarks and tool types. Olsen recommended that a more robust nomenclature scheme of tool characteristics be developed and that "… class and individual characteristics should be more adequately defined…." [4]. While subclass characteristics were later proposed [5] and added to this taxonomy structure in 1992 [6], information defining and further categorizing general toolmarks/tool action type characteristics is limited. Miller first provided a categorization of some tool actions back in 2001 [7]. However, this list was incomplete, as tool classification and characterization were difficult to articulate at that time. This was mainly attributed to tool manufacturers having a different (commercial) view on the categorization of tools that did not comport well with the descriptions for forensic applications.

In practical field applications, Sherlock and Keating developed specialized tool type code descriptors to assist them in categorizing the general tool types of toolmarks produced during the obliteration of firearm serial numbers [8].

To develop tool and toolmark type classifications, the use and harnessing of physical forces should be realized as tools are designed to perform particular tasks by gaining mechanical advantage over a work piece. Additionally, tools are specifically constructed to attain and apply a force, or combination of forces, to achieve their designed tasks. Consequently, understanding the basic forces in physical science is of the utmost importance.

A force is anything that causes an object to move or accelerate. It is also more simply defined as a push or a pull. Forces are measured in Newtons (pound-force). There are five basic types of physical forces that are pertinent to tool design and function. These forces are listed and described below.

1. Compression- Force produced when a structure is squeezed or squashed (**Figure 1**).

2. Tension or tensile- Force produced when a structure is stretched or pulled in opposite directions (**Figure 2**).

3. Bending or flexure- Force produced when a structure is bent; i.e., compression on one side and tension on the opposite side (**Figure 3**).

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4. Shear- A severing force created when two forces act in opposite directions to each other (**Figure 4**). There are three general types (modes) of shear: tensile, in-plane, cross (anti)-plane as depicted in **Figure 5**.

5. Torsion- Force that twists, turns or rotates an object (**Figure 6**).

In developing a tool action type classification system for forensic use, basic tool categories were reviewed and adapted from both the hand and power tool industries. This review noted four general categories of tools: Compression, Cutting, Gripping and Special Function. Using these categories, the following tool classifications were derived:

1. Compression

-Crimping -Stamping -Peening

2. Cutting

-Abrading -Piercing -Shearing

-Chopping -Pinching -Slicing

-Engraving -Sawing

3. Gripping

-Clamping -Squeezing -Grasping

4. Special Function

-Leveraging (Prying) -Torquing or Torsion

From the above listings, along with previously established classifications in the Association of Firearm and Tool Mark Examiners (AFTE) Glossary, the following proposed tool action type classifications were adapted. These tool action names and descriptions represent an additional development, or continuing evolution, in the categorization of tools for the taxonomical labeling and differentiation in the forensic discipline of Firearms and Toolmark Identification.

<u>Tool Action Type Classifications</u>

Abrading- The cutting of an item by rubbing a tool against it to remove material. Examples: cutting discs, chop saw, file, and rasp (**Figures 7A-7C**).

Chopping- Cutting by applying a non-continuous (striking) force opposite the working blade edge to sever or cut a material by compression or removing pieces in bits. Note: Compare with compression and slicing. Examples: axes and hatchets (**Figures 8A-8B**).

Compression- To compact, impress or shape by pressure or striking. Examples: hammers, die stamps and punches (**Figures 9A-9B**).

Crimping- A tool with a pair of interactive blades on same plane, i.e. opposing, that are designed to bend, crease or press together. Examples: wire crimpers and bank seal press (**Figures 10A-10C**).

Engraving- Any single, multi-bladed, or pointed tool that removes material using in-plane shear force. Refer to three shear modes in **Figure 5**. Examples: scribes, vibratory cutters, and firearm bores (**Figures 11A-11D**).

Firing- The ignition, discharge, extraction and/or ejection of an ammunition cartridge component(s) by an explosive from a firearm, which is considered a specialized tool designed with multiple working edges that employ multiple forces (**Figure 12A-12B**).

Gripping- A tool with a pair of interactive jaws on same plane, i.e. opposing, that abut each other and is designed to grasp or squeeze. Examples: vises and pliers (**Figures 13A-13B**).

Leveraging- Force by employing a lever with, generally, a squared or tapered flat blade, usually designed to pry or perform a special function. Examples: tire iron, pry or wrecking bar (**Figures 14A-14E**).

Pinching- A tool with a pair of interactive blades on same plane; i.e., opposing, that abut each other and is designed to cut. Examples: boltcutters, diagonal cutters, and nippers (**Figures 15A-15C**).

Piercing- To cut or tear an opening, either penetrating or perforating, in a material with a pointed or sharp bladed tool tip. Examples: awl, knife, or scalpel. Note: synonymous with stabbing & puncturing (**Figures 16A-16B**).

Sawing- A cutting tool composed of a metal band or disc with an aligned series of blades designed to remove material. A saw will employ either a reciprocal or continuous cutting action. Examples: band, rotary, and jig saws (**Figures 17A-17C**).

Shearing- A tool with a pair of interactive blades on adjacent planes that pass by each other; where one cuts and other acts as an anvil to stabilize the workpiece. Blade action applies anti-plane shear force (**Figures 4 & 5**). Examples: scissors, snips, and pruners (**Figures 18A-18C**).

Slicing- A tool with at least one sharp (tapered) blade designed to cut by moving the blade in the direction of the cut by applying a continuous force on backside (opposite) of the working edge. Examples: knives, razors, and scalpels (**Figures 19A-19C**).

Torquing- A tool designed to apply torsion by turning or rotating a work piece. Examples: screwdriver, wrench, and ratchet socket (**Figures 20A-20C**).

As mentioned, these tool types and their descriptions were primarily developed from the study of basic physical forces and previous classifications from the tool industry. However, the final classification criterion for adaptation to forensic use was by the general type of toolmark impression or configuration left by a particular tool type.

This was necessary as there were some conflicting or overlapping terms, such as shear, which is described as a basic force, yet in the description of shear modes it also encompassed tensile and even compression forces (See **Figure 5**). Additionally, in describing a shear cutting action, tools with a designated anvil were sometimes classified as a pinching tool with a single bevel configuration. In this instance, it was classified as a shearing action as it conformed more to tools that utilized a shear rather than compressive force in their fundamental design, as well as the toolmark configuration it imparted on a work piece. Cutting tool classifications could also be expanded to cover the innumerable single and multi-blade type cutting tool configurations. Examples of these would be basic single-blade cutting tools such as chisels and planes, circular multi-blade tools such as drill and milling bits, as well as rotating single-blade tools such as pipe and tube cutters, etc.

Also, while these classifications are for designation of original tool designs, it is well-known that many people do not use tools the way they were designed or intended to be used (e.g., a slotted-tip screwdriver, designed to turn a screw, could be used as a leveraging tool to pry a paint can). In these types of toolmark examinations, initial documentation along the lines of: "torsion type tool used as leveraging tool" will begin to provide clarity for that particular case.

These listed tool types will hopefully provide toolmark examiners with a standard, fundamental delineation of basic tool types that will enable them to better articulate generic tool actions and the toolmark configuration classifications they produce. Subsequent development of tool/toolmark characterization and even additional subclass delineations should be worthy goals for future study.

References

[1] "SWGGUN Summary of Examination Method". AFTE Website. <https://www.afte.org/resources/swggun-ark/summary-of-the-examination-method>.
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[3] "Fundamentals of Firearms Identification". Firearms ID.com Website. <http://www.firearmsid.com/A_FirearmsID.htm>.
[4] Olsen, R.D., "Defining Nomenclature of Characteristics", Association of Firearm and Tool Mark Examiners (AFTE) Journal, Volume 17, No. 2, April 1985, p. 32.
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[7] Miller J., "An Introduction to the Forensic Examination of Toolmarks, AFTE Journal, Volume 33, No. 3, Summer 2001, pp. 240-248.
[8] Sherlock, W.E., and Keating, D.M., "Obliterated Serial Number Tracking", AFTE Journal, Volume 27, No. 4, 1995, pp. 264-280.

(Figures begin on next page)

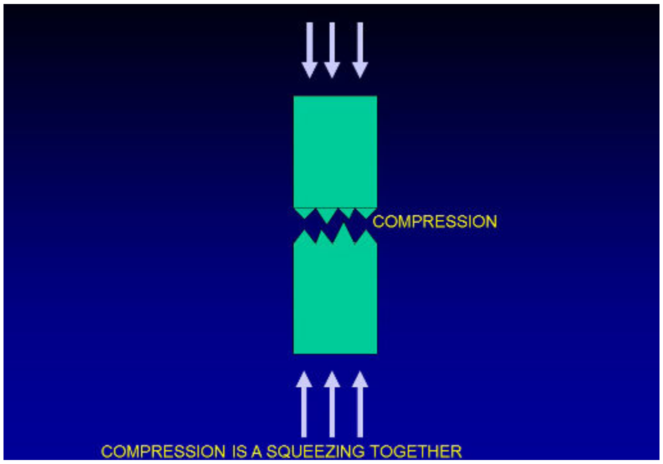

Figure 1: Compression force

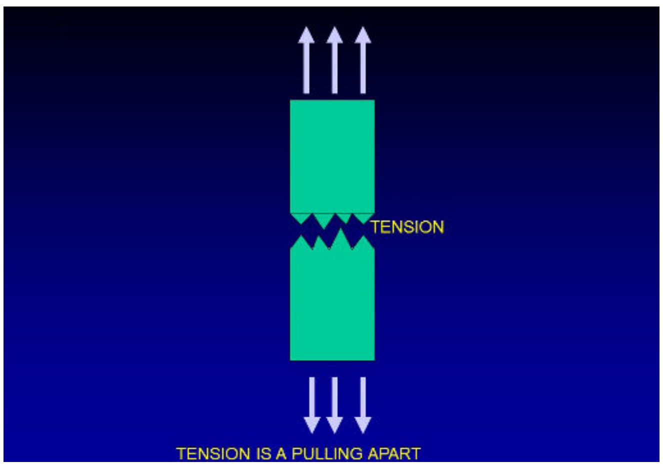

Figure 2: Tension or tensile force

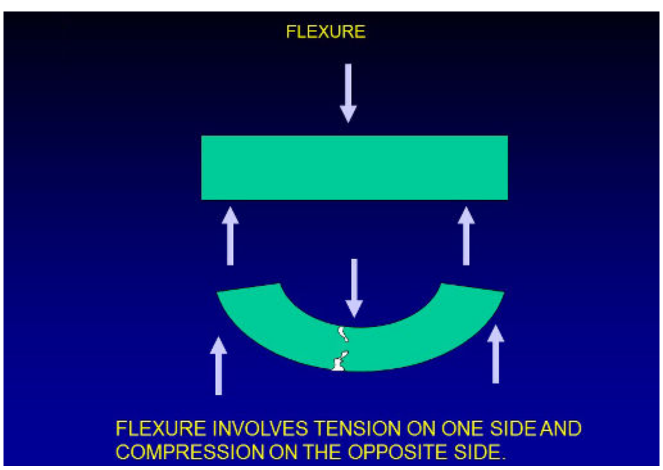

Figure 3: Bending or flexure force

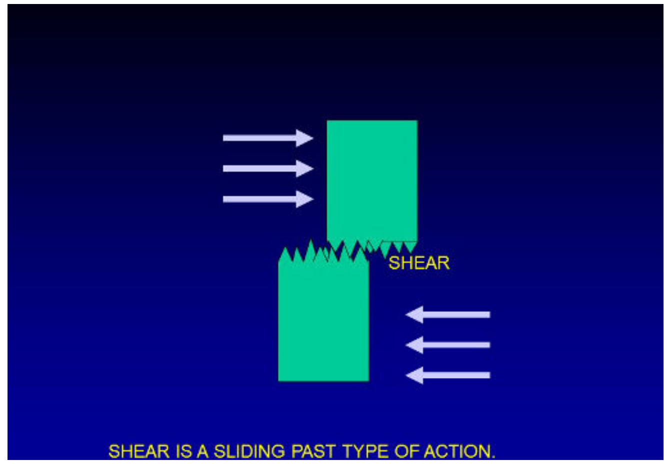

Figure 4: Illustration of anti-plane shear force usually associated with interactive bladed cutting tools

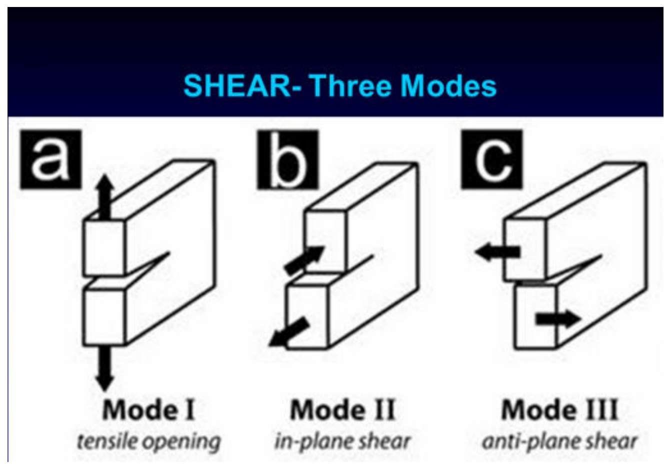

Figure 5: Three common shear force modes

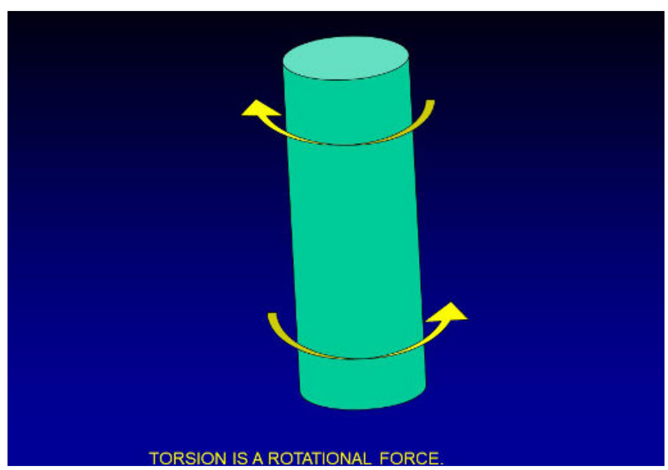

Figure 6: Torsion force

Figure 7A-1: Right angle grinder with medium grinding wheel (courtesy: logfurniturehowto.com)

Figure 7A-2: Abrading toolmarks from a medium grit grinding wheel

Figure 7B-1: Abrasive wheel cutter or chop saw (courtesy: truckinweb.com)

Figure 7B-2: Abrading toolmarks from coarse grit grinding or cutting disc. Note metal flow is even but striae are non-uniform

Figure 7C-1: Right angle grinder with coarse grit grinding disc

Figure 7C-2: Abrading toolmarks from coarse grit grinding disc. Note even metal flow is even but striae are non-uniform

Figure 8A: Hatchet

Figure 8B: Chopping impressions produced by hatchet in Figure 8A

Figure 9A: Pin stamping a serial number. (courtesy: columbiamt.com)

Figure 9B: Hand stamps with stamped samples

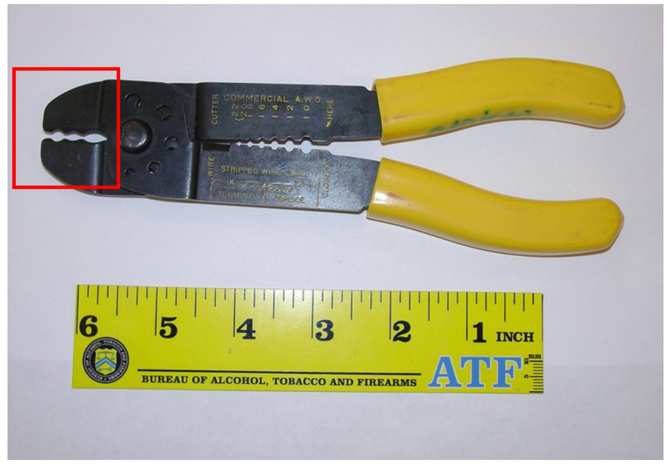

Figure 10A: Crimping jaws on a multipurpose electrician's tool

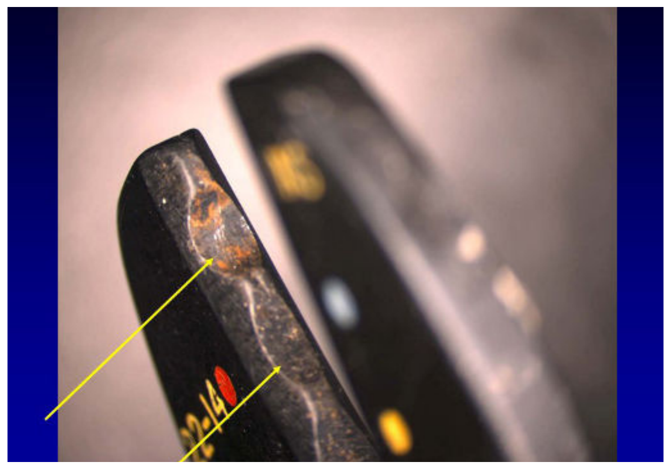

Figure 10B: Close-up of crimping jaws on a multipurpose electrician's tool

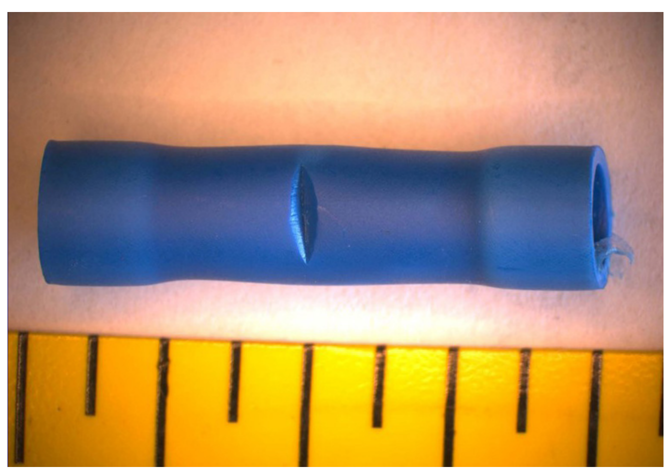

Figure 10C: Crimped impression on electrical butt connector

Figure 11A: Letters cut by single point engraving machine where workpiece moves and tool is stationary (courtesy: gtschmidt.com)

Figure 11B: Single point engraver where tool moves and workpiece is stationary (corporategifts4you.com)

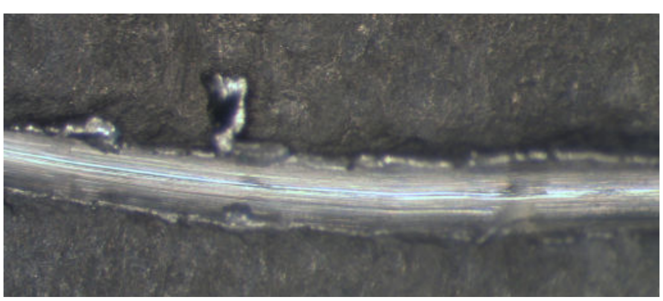

Figure 11C: Toolmarks produced from single point engraver at 30X magnification

Figure 11D-1: Bullet being discharged and engraved by the lands of a firearm barrel where engraving tool (rifling in barrel) is stationary and workpiece (bullet) moves (courtesy: strangemilitary.com)

Figure 11D-2: Fired bullets with engraved impressions from firearm barrel lands

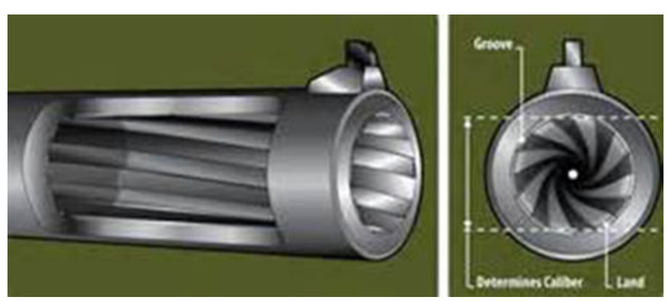

Figure 11D-3: Close-up of firearm barrel engraving lands. (courtesy: greyops.net)

Figure 12A: Firing ammunition cartridge components (artist's representation) (courtesy: stag-bratislava.com)

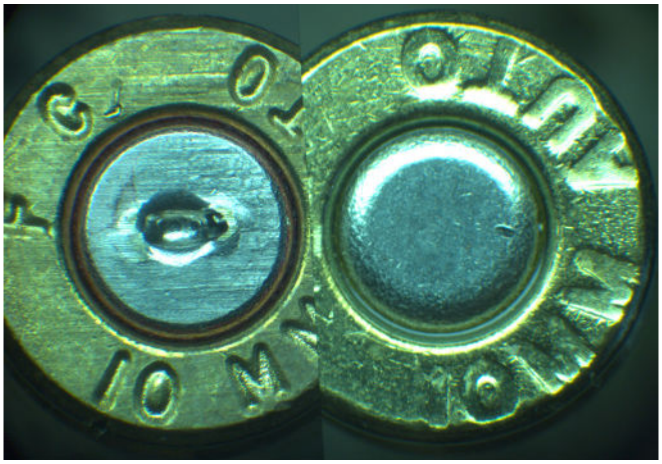

Figure 12B: Fired and unfired ammunition cartridge case

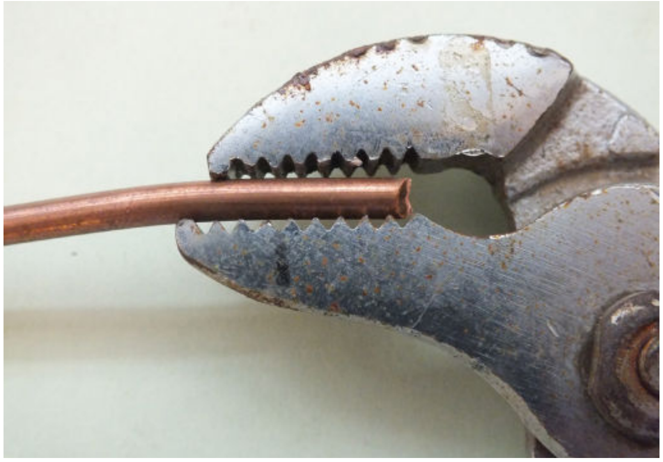

Figure 13A: Adjustable groove pliers with serrated jaws gripping copper wire strand

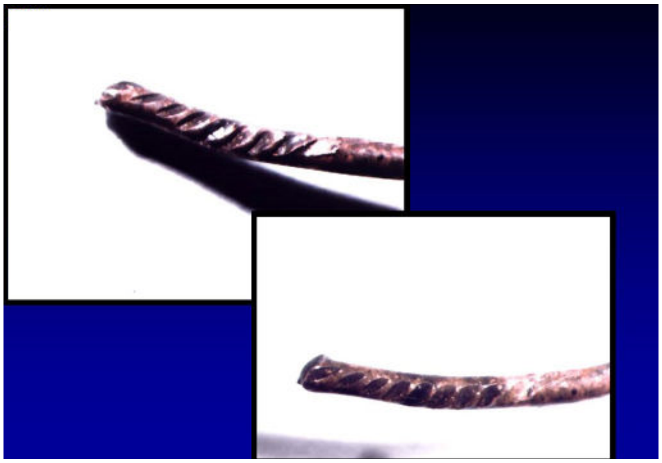

Figure 13B: Toolmark impressions from serrated jaw pliers

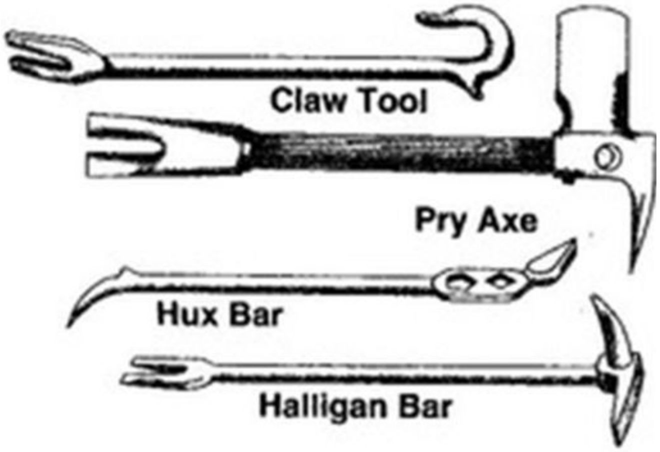

Figure 14A: General types of leveraging tools with designs to pry (push or pull) (courtesy:quizlet.com)

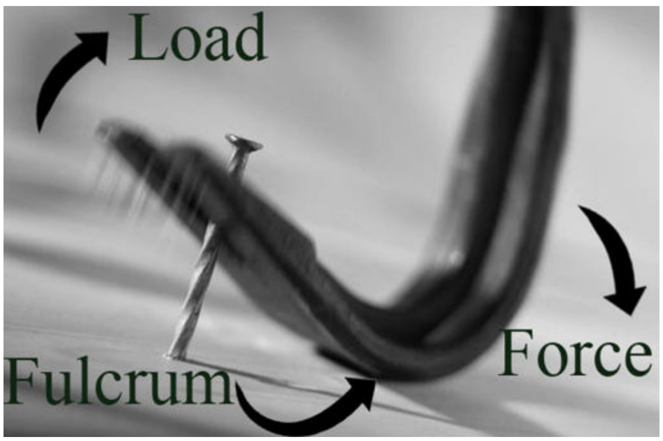

Figure 14B: Leveraging claw tool (pull) mechanics in removing nail (courtesy: republicanhour.com)

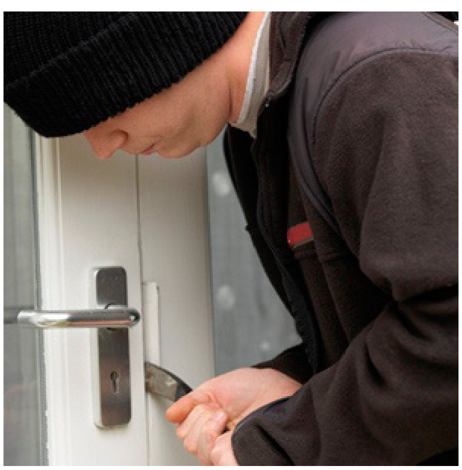

Figure 14C: Prying a door open with leveraging tool (courtesy: mcneillifestories.com)

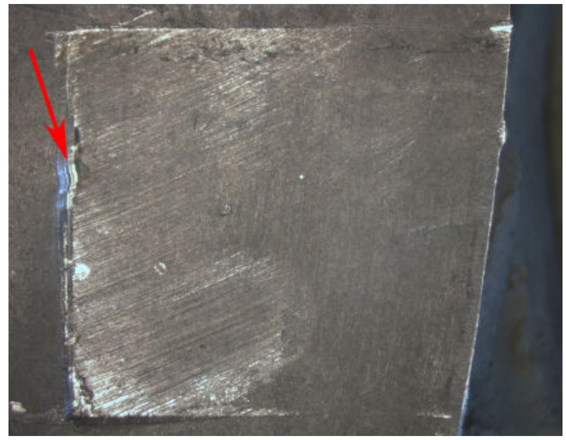

Figure 14D: Impressed type toolmarks produced by a flat leveraging pry tool blade. Note the striated sliding toolmarks produced by the pry end tip near middle of left edge

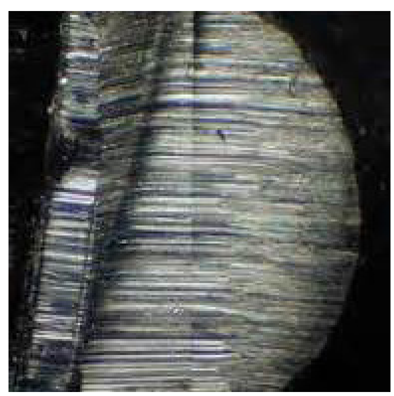

Figure 14E: Microscopic comparison of striated toolmarks produced by a sliding pry tool end (courtesy: forensic.net.in)

Figure 15A: Diagonal cutter with abutting blades employing pinching action (courtesy: wire2craft.com)

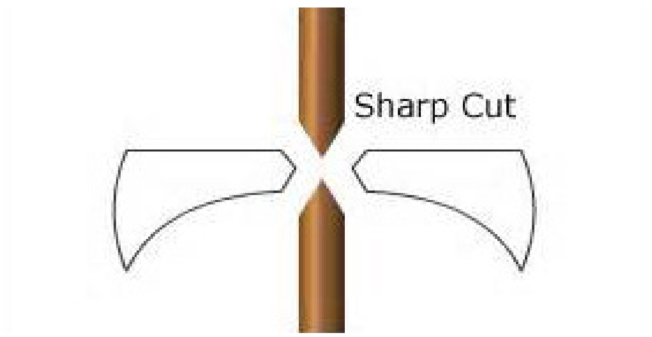

Figure 15B: Side view of diagonal cutter with abutting blades employing pinching action (courtesy: wire2craft.com)

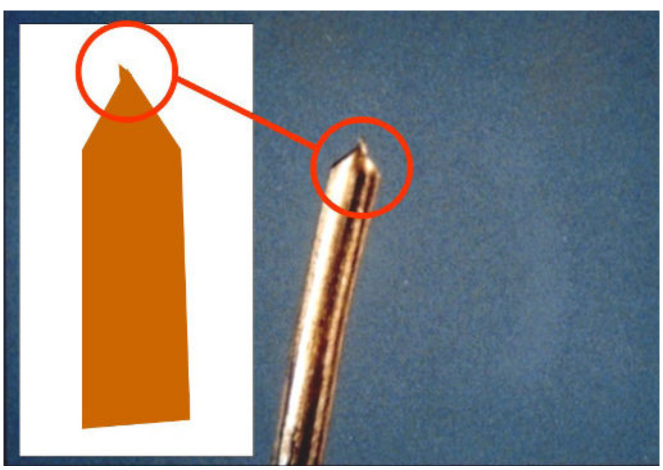

Figure 15C: Toolmark impressions on a single strand wire end cut by a diagonal cutter, employing a pinching action, depicted by a drawing and actual wire photograph. Note that the abutting tool blade bevels impart a reverse profile that resembles a gable roof or spire

Figure 16A: Wire insulation pierced with a scalpel tip

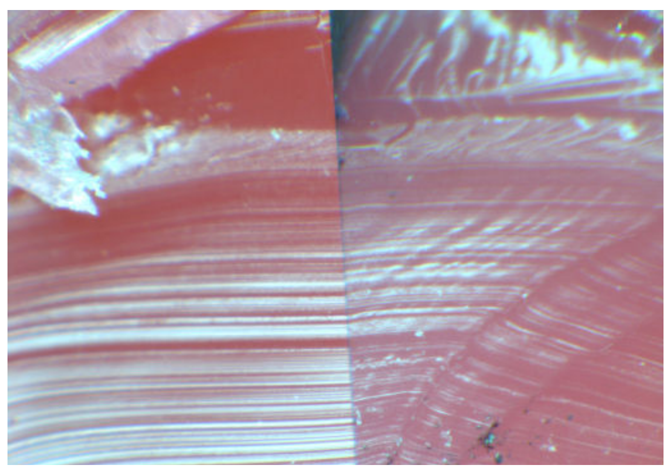

Figure 16B: Microscopic comparison of pierced wire insulation with test samples from scalpel tip at 40X

Figure 17A-1: Copper tube being cut by reciprocating hacksaw (Courtesy: diyadvice.com)

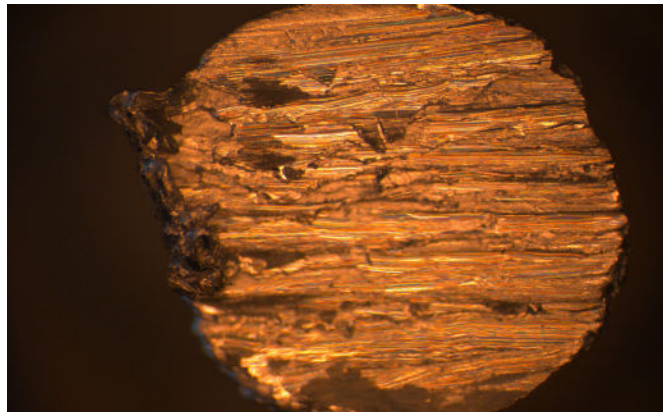

Figure 17A-2: Toolmarks produced by a reciprocating hacksaw. Note non-uniformly spaced striae, uneven metal flow, and jagged surface roughness appearance

Figure 17B-1: Cutting by reciprocating power saw (Courtesy: csunitec.com)

Figure 17B-2: Toolmarks produced by a reciprocating power saw

Figure 17C-1: Cutting pipe using a continuous cutting band saw (Courtesy: csunitec.com)

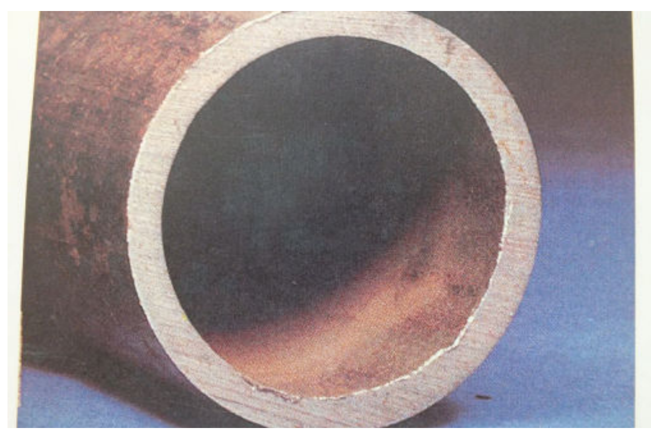

Figure 17C-2: Toolmarks produced by a continuous cutting band saw. Note uniformly spaced striae, even metal flow, and smooth surface roughness appearance, relative to reciprocating saw cut

Figure 18A: Shearing blades, with bypass blade type on left and shear with designated anvil shear type on right (Courtesy: smallkitchengarden.net)

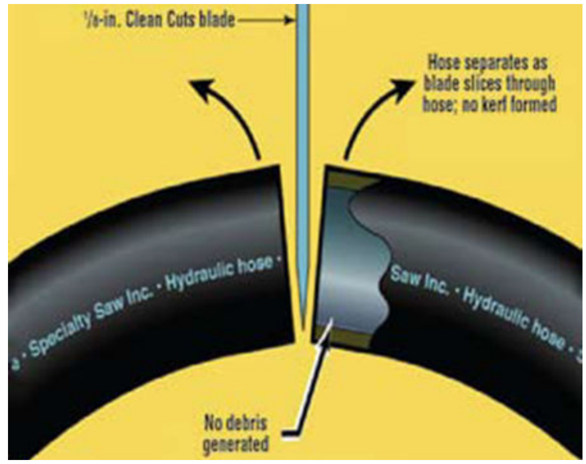

Figure 19A: Hose sliced by knife blade (courtesy: hydraulicspnuematics.com)

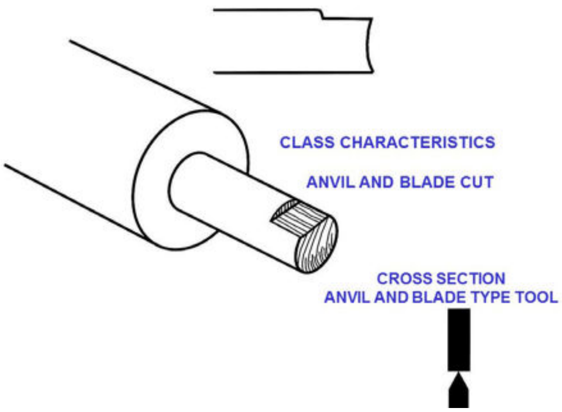

Figure 18B: Toolmark impression profiles produced on wire end by a shear cutter. Anvil impression on side of wire with cut impression on the end of the wire. Note that the anvil size could be a significant characterizing feature

Figure 19B: Slicing tire with razor knife (courtesy: whatdidshedotoday.com)

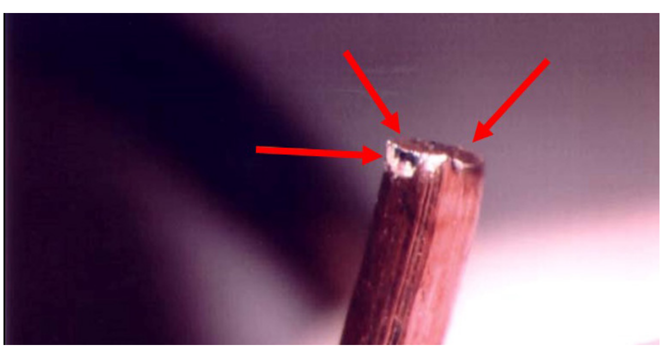

Figure 18C: Copper wire cut by stripper/cutter (bypass) shear tool. Arrows point to anvil, fracture, and shear cutting zones (L to R)

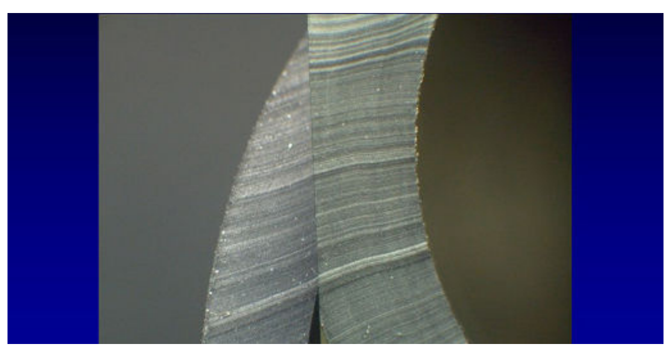

Figure 19C: Side view of two hose ends cut by razor knife compared at 15X magnification

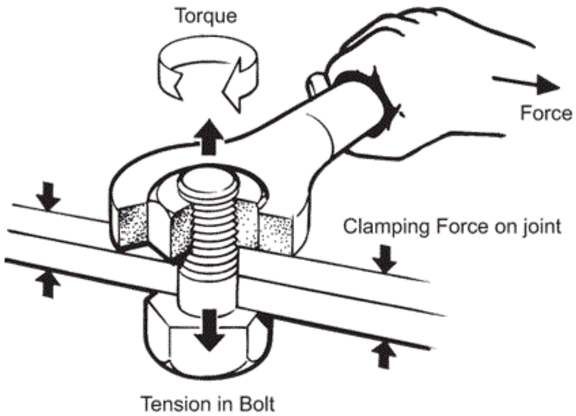

Figure 20A: Tightening a nut by torque (Courtesy: m5carblog.blogspot.com)

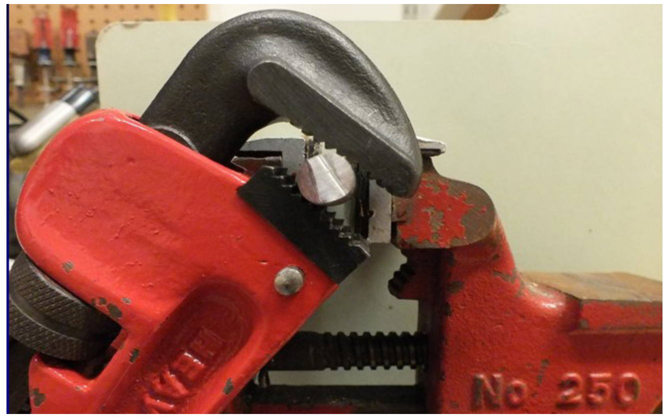

Figure 20C-2: Pipe wrench jaws are designed to grip by virtue of the top, adjustable jaw squeezing down on a work piece as torsion is applied by forcing down the handle

Figure 20B: Turning a screw by torque (Courtesy: guitargirlmag.com)

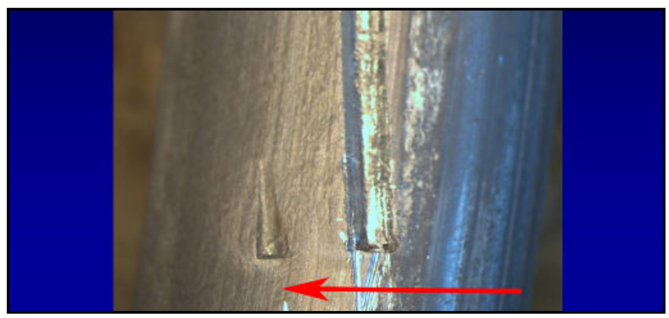

Figure 20C-3: Pipe wrenches produce serrated impressions usually with material build-up, referred to as "snowplow effect" or "snowplowing," in direction of applied torsion (Arrow indicates direction of applied force)

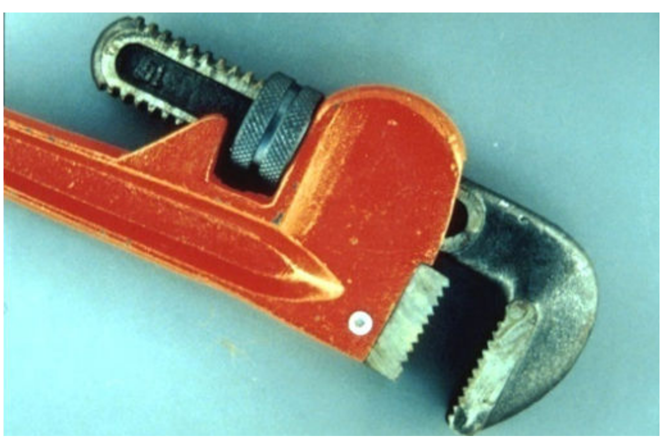

Figure 20C-1: The pipe wrench is primarily a torquing tool with secondary gripping component

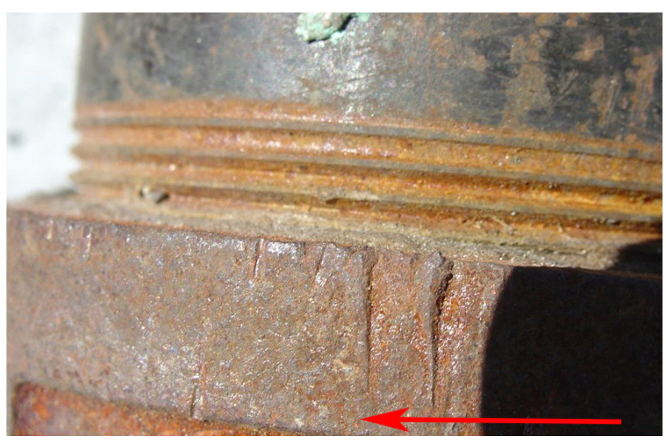

Figure 20C-4: Pipe wrench serrated jaw impressions with "snowplowing" on the last two impressions on the right of end cap band indicating counter-clockwise torsion