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TOOL MARKS

Factors Involved in Their Comparison and Use as Evidence

David Q. Burd† and Paul L. Kirk‡

Comparison of tool marks as an aid in the solution of crime is a well known and widely used procedure which is generally considered as yielding valid court evidence. It is true, nevertheless, that much misapprehension exists as to the individuality of such marks and the probability of repetition of a mark by more than one tool. Such misapprehension as exists has undoubtedly arisen in part from a lack of careful study of the factors which influence the character of the marks left by a tool, and which must be considered in the identification of such marks. Although many authors mention and discuss briefly the use of marks in identification of tools, apparently none of them have reported an adequate study of these factors, or if they have, a careful search of the literature of the subject has failed to reveal such a record.

Aside from brief mention of tool marks in such standard works as those by Lucas,¹ and Söderman and O'Connell,² the most publicized account of their employment in criminal investigation seems to be that of May,³ portions of which have been reproduced by Dieckmann⁴ and by others. Details of the matching of marks are given in these accounts, but no comparative study of methods of evaluating the doubtful case is reported. Moreover, the criminal case chiefly concerned in the latter articles involved cutting of the branches of a tree, which is considerably different from the usual type

of marks found in burglaries, etc. Mezgar, Hasslacher, and Frankle⁵ have described a study of axe cuts in trees while Koehler⁶ and Wilson⁷ have both reported fine illustrations of the tracing of industrial machinery and other tools through the use of tool marks. Other brief reports of the use of tool marks in individual cases are available.

The present study is 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 types of marks encountered.

Types of Tool Marks

Compression marks. Perhaps most commonly found of all types of marks are those caused by pressure, a blow or a gouge of a tool on a wooden, metal, or other surface. If lateral movement of the tool does not take place during contact, to produce a friction mark, the information obtainable from such a compression mark is limited in scope, but may be very useful. In the first place, it is usually possible to determine the kind of tool employed (screwdriver, bar, etc.) and to ascertain the dimensions and shape of the portion which left the mark. To the extent that the

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tool is individual in its shape and dimensions, it may be identified from such marks. In one instance, it was possible to identify a bar quite positively from a study of several compression marks left by the side of a bent portion just back of the flattened end. The bar had been hand forged, and the flattened end was flared at very different angles on the two sides of the axial line. The bend in the bar was also characteristically irregular due to wear and error in forging. It is an interesting fact that even superficial identity of appearance of bars is rarely if ever encountered.

A gouge left by the end of a sharp instrument may also be sufficiently characteristic for identification. It is more likely, however, that a tool of standardized manufacture, such as a screwdriver, will be employed in a crime, and in this case, compression marks will rarely serve for positive identification of the tool, but only for its type and dimensions. This kind of mark should always receive very close study for its irregularities and specific characteristics which often occur and may well be overlooked.

Friction marks. The most characteristic marks left by a tool are the fine parallel striations left on a metal or other smooth surface (seldom on unpainted wood) when an edge is scraped over it. Such striations are the common focus of study in the case of bullet comparisons as well as tool mark comparisons, and are well known to investigators. The problem of matching these parallel lines by means of the comparison microscope is fundamentally somewhat different though not necessarily more difficult than the

similar matching of bullets. A tool may be applied to a surface in an almost infinite number of ways, and every such variation will have some effect on the resultant striations. This matter will be considered in some detail in a later section, along with the question of what constitutes proof of identity of two such marks. It may be emphasized that even apparently smooth edges will customarily leave such a series of striations, and an edge which is so polished as to leave a perfectly smooth mark is almost never encountered.

Cuts. Cutting edges are less commonly used in commission of crimes than the more blunt edges of tools used for prying. Consequently, marks of cutting tools will not be found so frequently. In many instances cut marks are highly significant and may serve for positive identification of the tool making them. Due to the fairly adequate studies of such marks already published in the references given above, cuts will not be considered in detail in this paper.

Friction Marks

When a mark results from sliding of an edge over a surface, the factors which will influence the character of the mark are:

- a. Degree of irregularity of the edge, which will be altered by wear or damage;
- b. Vertical angle of the edge (or the tool);
- c. Horizontal angle of the edge (or the tool);
- d. Change of vertical or horizontal angles during application, changing the relations of the various fine lines composing the marks;
- e. Inequalities of pressure;

- f. Change of direction of application giving curves, zigzags, or other irregularities to the impression;
- g. Presence of debris, which may have an abrasive action adding stray lines to the impression; and
- h. Type of material receiving the impression.

Of these factors, only *b*, *c*, and *d* need to be considered in detail. Factor *a* is a characteristic of the tool at a particular time and will usually alter only slowly due to wear unless subjected to mechanical treatment, such as grinding, or chemical alteration, such as corrosion. Factors *e* and *f* merely complicate the problem of obtaining adequate comparisons, but in no way invalidate identities found. Factor *g* is one for which occasional allowance must be made, but in general it appears only as a small number of erratic lines which again do not invalidate an identity. Factor *h* is one which is crucial to the extent that only some surfaces retain fine line striations. Obviously, this factor may not be controlled in an investigation, and the striations, if present, may always be compared. Variations in the material may greatly affect the ease of both visual and photographic comparisons.

In order to study the effects of factors *b* and *c*, a set of screwdrivers was used. They were mounted individually in a framework which was so arranged that the tool was held at any predetermined vertical or horizontal angle as shown in Figure 1. The tool was then scraped over a flat sheet of lead to record a striated mark.

Vertical angle of application. The impressions from one of the screwdrivers were compared under a com-

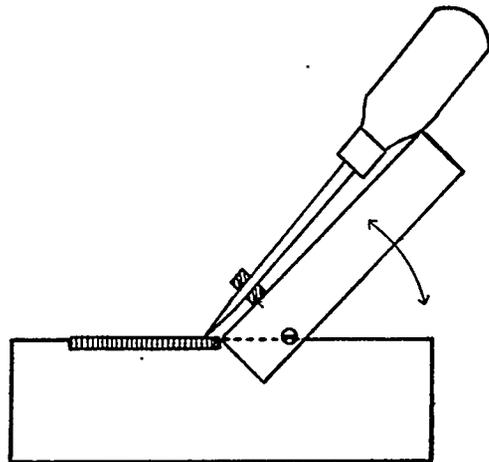


Figure 1

Tool holder with variable vertical and horizontal angles.

parison microscope when the tool was held at vertical angles ranging from 25° to 65° from horizontal at intervals of 10° . This tool, which had been used in a series of burglaries, was used for photographic comparisons because of its great irregularity which had been caused by previous immersion in storage battery acid. The photomicrographs representing these comparisons are shown in Figure 2. They were photographed by means of oblique illumination. Irregularity of the reflective power of various portions of the marks used resulted in obscuring in the photographs, some matching lines which were visible to the eye. Counts of the proportion of total lines which are matched in this and other comparisons demonstrated that two marks made with the same tool held at the same vertical and horizontal angles, and without intermediate alteration might show as few as 80% of the total lines giving accurate matches. Actually, this proportion will usually be appreciably greater when the marks are viewed with the eye and under the best con-

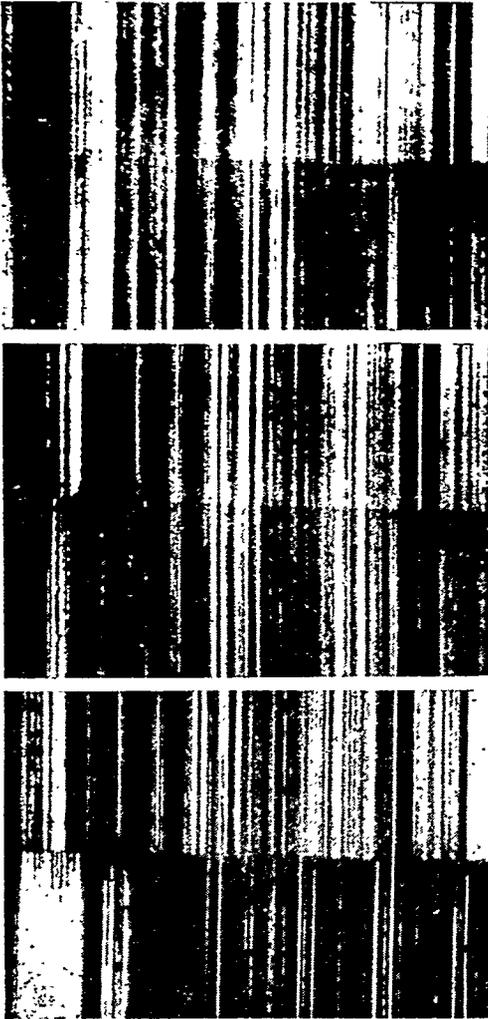


Figure 2

Photomicrographs of friction marks made by moving screw driver across lead sheets with varying vertical angles. Top: Comparison of two markings made with tool inclined at angle of 45°. Middle: Comparison of two markings made with tool inclined at angle of 45° (upper half) and 35° (lower half). Bottom: Comparison of two markings made with tool inclined at angle of 45° (upper half) and 25° (lower half).

ditions, but only rarely will a perfect match of all lines be obtained.

When marks made with the same tool, but differing by 10° in the vertical angle were compared, about 60 to 65% of the lines matched photographically and somewhat more visually. When the vertical angles differed by as much

as 20°, the proportion of matching lines fell to about 40% and the appearance of the mark was noticeably different. It is apparent, therefore, from this series of comparisons, that two marks made with the same tool must have a correspondence in vertical angle of application to about 10° and not more than 15° if a recognizable match is to be obtained.

It should be stressed, that in determining the identity of two marks, it is not merely the number of checking lines or their proportion which is important. The general character of the mark, which may be best defined in terms of its *contour*, or cross section, is at least as valuable as the line matches themselves. That this is true follows from a consideration of the fact that the ridges and hollows making up the mark are of a random nature, depending only on the shape and structure of the edge, varying in height or depth and in thickness, and giving a semi-quantitative aspect to each line compared. It is actually this contour, rather than the lines themselves that is first used to align two marks under the comparison microscope, and it is the appearance of the contour that is essential in determining whether a poor line match is adequate to establish identity.

A consideration of the contour of the marks shown in the photomicrographs of Figure 2, clearly shows that in the comparison of two marks with the same vertical angle and with variations of 10°, the contour is similar or identical, whereas in lines varying by 20°, it is no longer recognizably the same.

Other screwdrivers studied in the same manner as described above,

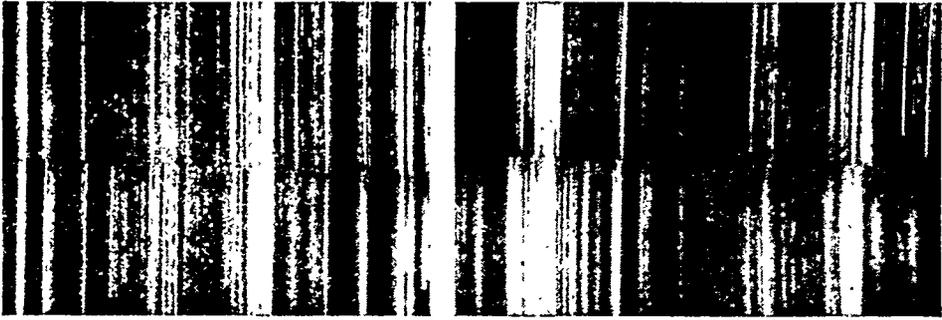


Figure 3

Photomicrographs of friction marks made by moving screw driver across lead sheets with constant vertical angle (45°) but with varying horizontal angles. Left: Comparison of two markings made with tool inclined horizontally at angle of 0° (upper half) and 10° (lower half). Right: Comparison of two markings made with tool inclined at angle of 0° (upper half) and 20° (lower half).

yielded essentially the same results. None of them showed the same degree of irregularity as the one described—hence, the number of visible lines was greater, and they were much finer, as is characteristic of a smoother edge. The proportions of lines which matched was almost identical to those of the first tool, except in the case of 20° variation in vertical angle. In this case, the finer irregularities of the tool edge were more readily eliminated by the angular variation than was the case with the highly irregular edge, and the proportion of matching lines was less. The conclusion as to the allowable change in vertical angle was shown to be valid with a number of different tools, and is presumably applicable to all similar cases, and with new or old tools.

Horizontal angle of application. In applying a tool, it is apparent that in many instances it is not advanced directly along its axis, but at some horizontal angle to the axis of the tool itself. This variation must necessarily produce a foreshortening of the mark with the lines spaced closer together. In order to determine the actual in-

fluence of this factor on the ease of matching marks, the same screwdriver whose marks were shown in Figure 2 was used to prepare marks in which the tool varied horizontally by 10° and 20° from the tool axis. The photographic record of the matches obtained is shown in Figure 3. The predicted foreshortening is clearly apparent, but in the case of a 10° variation between the standard and comparison mark, no serious alteration is produced. When a 20° angle is used, the lines no longer match accurately except in a short section, but their arrangement and the contour are still clearly the same. Thus any reasonable variation in horizontal angle would not make an identification difficult, but might lessen the value of a photomicrograph shown in court to inexperienced jurors. When such foreshortening is shown in a match, it may often be corrected for photographic purposes by changing the horizontal angle of the tool until the exact line match is obtained. This naturally amounts to making a standard under the actual conditions used in the original application of the tool, and in no

respect constitutes tampering with the evidence.

When smoother edged tools were used, it could be shown that the effect of a change in horizontal angle made it slightly more difficult to obtain a match because the smoother the edge, the less important is the apparent contour in relation to the fine line structure which is altered to the greatest extent. For practical purposes, an alteration of 20° from the axis of the tool was as great as could be used and still yield recognizable matches.

Necessary Degree of Identity

In view of the great difficulty of obtaining at any time an absolutely perfect match of the striations making up a tool mark of the friction type, 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. It is, for example, commonplace for a defense attorney to attempt to establish that all mass production tools which are apparently identical will therefore leave identical marks, although exactly the reverse has been established many times in the case of bullet and cartridge case comparison. It is just as certainly true that no two tools will ever be expected to leave identical marks, nor in fact will the same tool ordinarily leave two absolutely identical marks. However, for a considerable period of time, the marks left by a single tool will be so similar as to leave no doubt of their common origin unless some major change is wrought in the edges leaving the marks.

From this study and other observa-

tions, it is apparent that it is the virtual identity of the contour of the mark which is important in an identification. The usual method of illuminating the mark obliquely and photographing the resulting line structure is merely a device to strikingly illustrate the similarity of the contour, though this obvious fact has usually escaped attention or mention in discussion of this subject. Any method by which the exact shape of the mark's surface may be studied will provide evidence which is at least as convincing as any pure line study. However, the technical advantages of the usual method are great, and it seems wise to use it but in conjunction with a careful observation of contour as well. When the latter factor matches, as demonstrated by identity of distribution, width, depth, etc., of lines, it is actually not highly significant to know the exact number or proportion of matching lines. If only a photomicrograph is available for matching, then it may be necessary as well to actually make a line count. In this case, two factors enter, viz., the number of matching lines, and their proportion to the total number of lines. If 100 lines are visible, and the apparent contour and distribution are similar, the data available in this study indicate an identity if approximately 60 or more of the lines match. When the number drops to about 40 the contour is obviously not the same, and a match is not indicated.

To illustrate the differences which will be given by apparently identical tools, such a set of new and unused screwdrivers were obtained. Marks were made under the same conditions on lead plates and the resulting align-

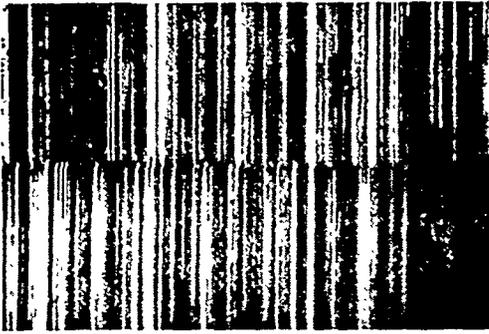


Figure 4

Photomicrographs of friction marks made by the edges of two new, unused tools manufactured under the same conditions.

ments photographed. Figure 4 illustrates how greatly two seemingly smooth edges on two tools of standardized manufacture will differ with respect to the marks they produce. Although in a comparison of two marks made by the same edge more than 80% of the lines matched, in this case the percentage of matches is from 20-25%. It becomes immediately obvious that the number of matching lines, in itself has no significance since in marks made with different tools one can find a very considerable number of chance matches if the total number of lines is high. The proportion of matching lines, on the other hand, will never be high unless the contour is very similar which in turn will not happen except when the same tool has been used. If the total number of lines is small, it is increasingly important that a higher proportion of those lines match, since the probability of chance correspondence becomes much less. In one burglary case, marks were left which showed just five visible lines. Exact correspondence of all five to standards made with the suspected tool could be demonstrated, and this small number of lines constituted irrefutable

proof of identity, but only due to the high proportion of matching lines, not their number.

Unusual Friction Marks

While most friction marks that figure in criminal acts are caused by instruments used in forcing an entry, and are correspondingly found as relatively long, obviously striated marks on surfaces at the scene of the crime, many variants will be found and because of their unusual character may be overlooked by the investigator. For purposes of illustration two of these instances are reproduced here.

In one case, padlocks were forced by striking them with a hammer. While a blow is expected to produce a compression type of mark, it usually will produce also a friction mark from lateral movement at the instant of contact. Such marks were demonstrable in this instance. Some comparisons of hammer marks to illustrate how effectively such marks may be compared are shown in Figure 5. Although their length is greatly restricted, and the angles of application erratic, the identity of contour as demonstrated by line comparison is striking.

Another variant which may be of interest is the case in which the mark

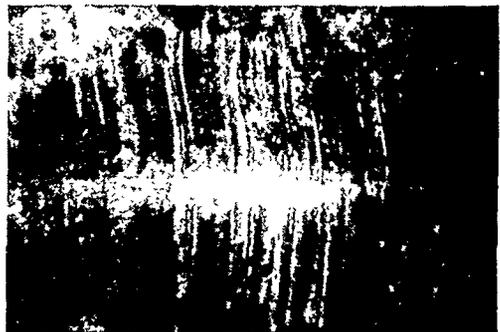


Figure 5

Photomicrographic comparison of hammer marks on brass.

is made on the tool from an edge in the environment rather than the reverse situation. One such case involving burglaries from hotel rooms will be used for illustration. The tool consisted of a strip of galvanized iron which was used to force open the bolts of spring locks by insertion through the crack between the door and the door jam. Two small nails had been driven for the purpose of preventing the insertion of such a strip. While they did not serve this purpose they left a pair of zigzag parallel marks on the tool. These marks were compared with a set of standards made with the same nails on another strip of galvanized iron. Although the

marks were mere scratches, the fine line structure and contour were easily demonstrable as having an identical origin.

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