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Determination of the Direction of Ball-Point Pen Motion from the Orientations of Burr Striations in Curved Pen Strokes

REFERENCE: Snape, K. W., **"Determination of the Direction of Ball-Point Pen Motion from the Orientations of Burr Striations in Curved Pen Strokes,"** *Journal of Forensic Sciences*, JFSCA, Vol. 25, No. 2, April 1980, pp. 386-389.

ABSTRACT: A relationship between the orientations of burr striations in curved ball-point pen strokes and the directions of motion of the pens which produced the strokes is described. The relationship enables directions of ball-point pen motion to be determined from an examination of such striations.

KEY WORDS: questioned documents, pens, directionality

Document examiners are familiar with the presence of ink-free striations in ball-point pen strokes [*1,2*]. They are caused by the removal of ink from the rotating ball by faults in, or damage to, the pen's ball housing, or by a failure of the ink fully to cover the rotating ball [*2*]. Striations produced by the former mechanism—"burr striations"—are usually extremely fine and may, with practice, be distinguished from those produced by the latter mechanism, which are often as broad as the pen stroke itself.

It is the purpose of this paper to draw attention to a unique relationship between the orientations of burr striations in curved ball-point pen strokes and the directions of motion of the pens which produced the strokes. Since burr striations are often visible to the unaided eye, or under low magnification, this relationship enables one to determine quickly and unequivocally, from the presence and correct identification of such striations, which of the two possible directions of pen motion have been used in writing such characters as *0* and *8*, or in making the cross bars (which are frequently slightly curved) of such characters as *5*, *t*, and block capital *A*, *E*, *F*, *H*, *I*, and *T*. An important part of the procedure for comparing handwritings consists of determining such directions, since differences between them would normally be indicative of different writers. Two of the more familiar features that allow the document examiner to make these determinations are accumulations of ink on the "upstream" sides of surface fibers of the paper [*3*] and faint secondary pen strokes connecting the main pen strokes of characters. However, features such as these are not always present or clearly observable, so any additional features that can be used are to be welcomed. This paper describes one such usable feature.

The relationship between the orientation of a burr striation in a curved ball-point pen stroke and the direction of motion of the pen is observable experimentally and can be

Received for publication 25 July 1979; accepted for publication 12 Sept. 1979.

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stated quite simply: the striation runs towards the outside edge of the curve in the same general direction as that in which the pen has moved. This is illustrated diagrammatically in Fig. 1.

Figure 2 shows some examples of letters whose pen strokes contain striations. They are all taken from the handwriting of one person. The striations in the *o* and in the loop of the *d* run towards the outside edges of the pen strokes in a generally counterclockwise

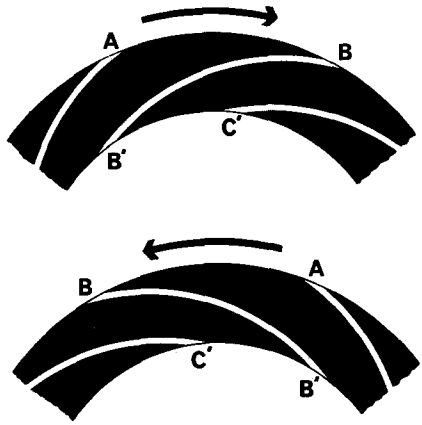

FIG. 1—*Diagrammatic representation of two curved ball-point pen strokes containing burr striations. The arrows indicate the directions of pen motion in the two strokes. The striations run towards the outside edges of the curves in the same general directions as those in which the pens have moved. Vertices* A *and* B, *at the points of intersection of the striations and the outside edges of the curves, point in the directions of pen motion. Vertices* B′ *and* C′, *on the inside edges of the curves, point against the directions of pen motion.*

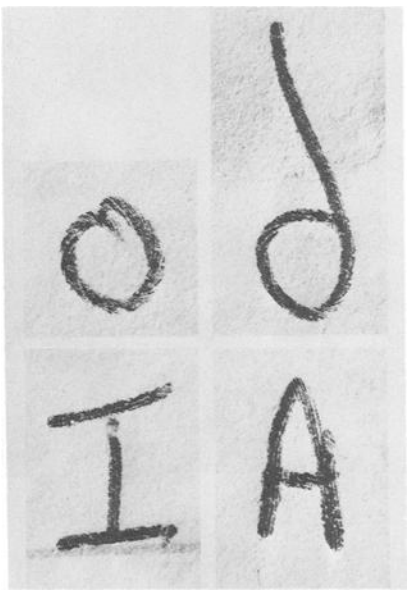

FIG. 2—*Photographic enlargements of the letters* o, d, I, *and* A *from one person's handwriting.*

direction. They show conclusively that the pen moved in this direction when it produced these letters and, deliberate disguise apart, distinguish this person's handwriting from that of someone who writes either or both of these letters in a clockwise direction. In the block capital *I* the upper horizontal stroke has a slight but definite curvature. The striations in this stroke run towards its lower edge (which is the outside edge of its curvature) in a generally leftward direction. They indicate that this was the direction in which the stroke was written and thereby distinguish this person's writing from that of someone who makes this stroke in the more common left-to-right direction. The lower horizontal stroke is too straight for the striation it contains to run towards either of its edges, and the direction in which this stroke was made cannot be determined from this striation. At the apex of the *A*, where the curvature of the pen stroke is greatest, the striations run towards the outside edge of the curve in a generally counterclockwise direction. They show that the left-hand limb of the letter was, unusually, made after the right-hand limb and serve further to distinguish this person's handwriting from that of most other people.

The unique relationship between the direction of pen motion and the orientations of burr striations arises from the way the axis of rotation of the ball changes orientation within a ball housing whose own orientation remains relatively unchanged as the pen describes the curve. It is illustrated diagrammatically in Fig. 3, which shows three successive positions of the ball of a pen that is describing a counterclockwise curve. Points *A* and *B* are points of damage to the ball housing that are removing ink from the rotating ball. In the first position, the ball is rotating about *XX'*, and damage at *A*, on the leading edge of the housing, is producing a striation in the pen stroke that is parallel to the stroke itself. Damage at *B*, on the axis of rotation of the ball, is not affecting the pen stroke since it is removing ink from a part of the ball that is clear of the edge of the stroke.

In the second position, with the orientation of the ball housing being unchanged but with the ball now rotating about *YY'*, the damage at *A* has moved clear of the outside edge of the curve and the parts of the ball from which it is removing ink are not producing any striations. At some point between the first and second positions, the striation produced by the damage at *A* has "run off" the outside edge of the curve. In running towards the outside edge, the striation has done so in the same general direction as that in which the pen has moved. In this second position, furthermore, the damage at *B* is no longer on

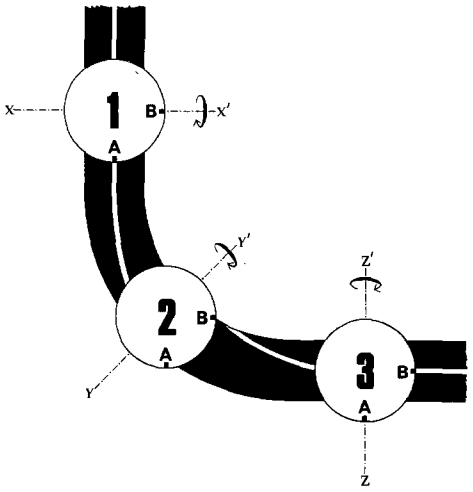

FIG. 3—*Diagrammatic representation of the production of burr striations in a curved ball-point pen stroke. See text for full explanation.*

the axis of the ball's rotation but is removing ink from parts of the ball that, although still clear of the stroke, are now much closer to its inside edge.

In the third position, with the orientation of the ball housing still being the same as in the first position but with the ball now rotating about ZZ', the damage at A is even further away from the edge of the pen stroke. However, that at B is now on the leading edge of the ball housing and is producing a striation parallel to the pen stroke's new direction. At some point between the second and third positions, the striation produced by the damage at B has "run onto" the pen stroke via its inside edge and has run towards, though not yet met, the outside edge of the curve in the same general direction as that in which the pen has moved.

If the curve in Fig. 3 had been traced in the opposite direction, that is, $3 \rightarrow 2 \rightarrow 1$, any striations it might have contained would have been produced by faults or damage on the sides of the ball housing opposite to A and B. The striations would have run onto and run off the pen stroke in a manner converse to that shown, maintaining the unique relationship to the direction of pen motion already described.

Near points of inflection, such as occur in wavy pen strokes, striations can sometimes be seen to run off the same side of the pen stroke that they have run onto. This is an apparent contravention of the above "law." However, the sense of curvature of the pen stroke undergoes a sharp change at the point of inflection, and the side of the pen stroke that was the inside of the curve before the inflection becomes the outside of the curve after it. In running off the same side of the stroke that they have run onto, the striations are merely responding to this change and are, in fact, continuing to observe the law correctly. In using the orientations of burr striations for determining directions of pen motion, great care should be taken to ensure that one has correctly recognized which side of the pen stroke is, locally, the true outside edge of the curve. Likewise, care should be taken to avoid using striations that are very close to the ends of pen strokes since such striations are produced by balls that may not be rotating fully and freely and may, therefore, be producing striations whose orientations are spuriously "incorrect." Provided such precautions are taken, the orientations of burr striations provide the document examiner with a simple and reliable means of determining the directions of ball-point pen motion.

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