B98 An Objective Comparison of Striated Tool Marks Produced From Ten Consecutively Manufactured Cold Chisels Measured by Contact and Optical Surface Profilometry and Comparison Microscopy

Robert M. Thompson, BS, NIST, Special Programs Office-Forensic Sciences, 100 Bureau Drive, MS 8102, Gaithersburg, MD 20899; Junfeng J. Song, MS, NIST, 100 Bureau Drive, MS 8212, Gaithersburg, MD 20899; and Wei Chu, NIST, 100 Bureau Drive, MS 8212, Gaithersburg, MD 20899*

The goals of this presentation are: (1) to inform attendees of the developments in quantitative measurement comparison of striated toolmarks; (2) to introduce recent developments in tool mark profile measurement using 2D and 3D surface profile instruments; and, (3) to demonstrate the robustness of proposed mathematical-based comparison scoring methods on a challenging tool mark test set.

This presentation will impact the forensic science community by informing and maintaining currency in the development, testing, and validation of the emerging technology of tool mark comparisons using 3D profilometry and objective mathematical comparison methods.

In the forensic science specialty of tool mark identification (which includes firearm identification), "tool marks" are the result of a harder surface acting upon a softer surface, usually but not exclusively metal alloys. The method for tool mark comparison relies on an objective side-by-side evaluation of the agreement by comparison microscopy; however, the opinion of "sufficient agreement" for conclusion to identify a tool source is subjective in nature, relying on the education, training, and experience of the examiner.

The first extensive study focusing on quantifying matching patterns of tool mark stria was performed by Biasotti in 1959.[1] His work demonstrated that consecutive matching stria groups were diagnostic for a quantitative measurement of similarity when two striated tool marks are microscopically compared, now termed Quantitative Consecutive Matching Stria (QCMS). Known Matching (KM) and Known Non-Matching (KNM) rifling land impressions on fired bullets were compared and the consecutive matching stria were counted. In non-matching comparisons, small QCMS numbers were observed, demonstrating the quantity of agreement observed by chance, understanding that agreement sufficient for identification must exceed that quantity. The minimum number of QCMS that was necessary for an accurate conclusion of the firearm source was empirically determined. The QCMS method is currently used by many examiners to quantify the agreement in striated tool mark comparisons.[2-7]

Optical 3D systems are emerging as objective methods in forensic tool mark measurement and comparison. These adapted instruments are useful due to the increasing computational power of modern computers and control systems tasked with handling high-definition 3D data.[8-17]

This is the first scientific investigation to employ consecutively manufactured tools (chisels) to produce striated tool marks whose contour profiles were measured by: (1) contact stylus profilometry; (2) non-contact 3D optical profilometry employing focus variation instrumentation; and, (3) the QCMS method. Striated tool marks were created pairwise in a controlled manner from ten consecutively manufactured cold chisel blades. Comparison tests between tool marks created in this manner have the best potential for producing microscopic agreement between two or more different tool sources, resulting in false positive identification. The striated tool mark profiles were measured using contact stylus 2D profilometry and non-contact optical 3D profilometry. Profile similarity and differences of KM and KNM tool marks were compared using two mathematical methods: Cross-Correlation Function Maximum (CCF_{MAX}) and the recently developed Congruent Matching Profile Segments (CMPS).

Both 2D- and 3D-acquired profile comparisons exhibit a wide separation between KM and KNM CCF score distributions when the full-length profile comparisons were made. Similarly, large separations of KM and KNM score distributions were also the result of segmented profile comparisons performed by CMPS. Replicas of the KM and KNM chisel tool marks were also compared using comparison microscopy, and the similarity and differences were measured by the QCMS method. Results of these comparisons also demonstrate a wide separation of distributions between the QCMS "runs" in KM and KNM tool mark comparisons, and no KNM comparisons exceeded three consecutive matching stria. The score distributions were also examined in a subjective statistical manner for their theoretical estimations of matching probability and demonstrate an exceedingly rare probability of sufficient agreement that would result in false positive identifications.

Conclusions: The results support the use of quantitative methods of profile comparisons for the discrimination of matching and non-matching striated tool marks. Both contact and non-contact methods of profilometry are useful in later mathematical comparison and score methods; however, in actual casework, the non-contact methods would be more acceptable because the contact stylus method may introduce stylus marks onto the evidence tool marks and, therefore, change the original evidence features. Additionally, the full profile comparison method in the CCF_{MAX} method is not as applicable to casework because the vast majority of striated tool marks on evidence items or collected at crime scenes exhibit partial tool marks from the full tool-working surface. The CMPS method exhibits the best promise for an objective comparison method and is better designed to compare much smaller profile segments of the striated tool mark profile to typically larger reference profiles. The evaluation of the tool mark peak frequency could also be employed to select optimum profile segment widths for the tool marks to be compared.

Reference(s):

1. Biasotti A. A Statistical Study of the Individual Characteristics of Fired Bullets. *J. Forensic Sciences.* (1959) 4:34–50.
2. Biasotti, A. and Murdock, J. Firearms and Toolmark Identification: Scientific Status. *Modern Scientific Evidence: The Law and Science of Expert Testimony.* Faigman, Kaye, Saks, and Sanderson, West Publishing Co., 1997, Vol. 2.
3. Miller, J. and McLean, M. Criteria for the Identification of Toolmarks. *AFTE Journal*. Vol. 30, No. 1, (Winter 1998).
4. Miller, J., "Criteria for the Identification of Toolmarks Part II Single Land Impression Comparisons", *AFTE Journal*, Vol. 32, No. 2, (Spring 2000)
5. Miller, J. Criteria for the Identification of Toolmarks Part III Supporting the Conclusion. *AFTE Journal.* Vol. 36, No. 1, (Winter 2004).

6. Miller, J. An Estimation of the Application of the Conservative Criteria for Identification of Striated Toolmarks Using Bullets Fired from Ten Consecutively Rifled Barrels. *AFTE Journal*. Vol. 33, No. 2, (Spring 2001).

7. Moran, B. The Application of Numerical Criteria for the Identification in Casework Involving Magazine Marks and Land Impressions. *AFTE Journal*. Vol. 33, No. 1, (Winter 2001).

8. Bachrach, B., Jain, A., Sung, J, and Koons, R. A Statistical Validation of the Individuality and Repeatability of Striated Tool Marks: Screwdrivers and Tongue and Groove Pliers. *Journal of Forensic Sciences.* Vol. 55, No. 2, March 2010.

9. Chu, W., Song, J., Vorburger, T., Thompson, R., and Silver, R. Selecting Valid Correlation Areas for Automated Bullet Identification System Based on Striation Detection. *J. of Research of NIST*. 116, May – June, 2011, pp.647-653.

10. Song, J., Chu, W., Vorburger, T.V., Thompson, R., Yen, J., Renegar, T.B., Zheng, A, and Silver, R. Development of ballistics identification – From image comparison to topography measurement in surface metrology. *Meas. Sci. Technol.* 23, 4, 054010 (6pp), 2012, online publication at: http://stacks.iop.org/0957-0233/23/054010.

11. Zheng, X., Soons, J., Vorburger, T.V., Song, J., Renegar, T., and Thompson, R. Applications of Surface Metrology in Firearm Identification. *Surf. Topogr.: Metrol. Prop.* 2 (2014) 014012.

12. Chu, W., Song, J., and Vorburger; T. Pilot Study of Automated Bullet Signature Identification Based on Topography Measurements and Correlations. *J. Forensic Sciences*. 55 (2), 341-347 (2010); DOI: 10.1111/j.1556-4029.2009.01276.x.

13. Petraco, N., Kuo, L., Chan, H., Phelps, E., Gambino, C., McLaughlin, P., Kammerman, F., Diaczuk, P., Shenkin, P., Petraco, N., and Hamby, J. Estimates of Striation Pattern Identification Error Rates by Algorithmic Methods. *AFTE Journal.* Vol.45, No. 3, Summer 2013.

14. Baiker, M., Keereweer, I., Pieterman, R., Vermeij, E., van der Weerd, J., and Zoon, P. Quantitative Comparison of Striated Toolmarks. *Forensic Science International.* 242, (2014).

15. Chu, W., Thompson, R., Song, J., and Vorburger, T.V. Automatic Identification of Bullet Signatures Based on Consecutive Matching Striae (CMS) Criteria. *Forensic Science International.* 231, 1–3, 2013, pp137–141 (ERB Control # G2012-0773, PubID 911028).

16. Zheng, X., Soons, J., Thompson, R., Villanova, J., and Kakal, T. 2D and 3D Topography Comparisons of Toolmarks Produced from Consecutively Manufactured Chisels and Punches. *AFTE Journal.* Vol. 46, Spring 2014.

17. Vorburger, T.V., Song, J., and Petraco, N. Topography Measurements and Applications in Ballistics and Toolmark Identifications. *Surf. Topogr: Metrol Prop.* 4 (2016) 013002.

Tool Mark, Objective Comparison, Profilometry

*Presenting Author