APPLICATION NOTE

Firearms & Tool Marks

Bullet Comparison

Introduction

The goal is to determine if an 'unknown' bullet found at a potential crime scene has been fired with a specific firearm. Firearms leave characteristic marks on the bullets they fire, so firing a second 'known' bullet and comparing the marks can be used to link the firearm with a specific event.

Specifically, fired bullets have a number of land-engraved areas (land impressions) that depend on the barrel rifling (Figure 1). To guarantee a true match, all of these impressions have to match in both form and in sequence around both bullets.

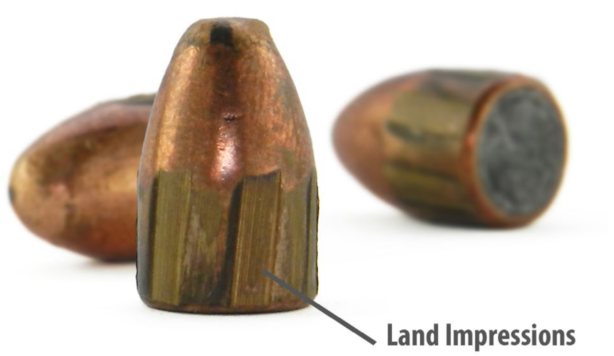

Figure 1. Impressions left on a Beretta bullet.

The task is thus to measures the land impressions and match them up from one bullet to the other (Table A). If a full match is not possible, the bullets were perhaps not fired from the same firearm.

Figure 2. Fired Beretta bullets have six land impressions that are analysed to find a match in both form and sequence .

	Know Bullet (B1)					
Unkown Bullet 1 (U1)	B1L1	B1L2	B1L3	B1L4	B1L5	B1L6
U1L1					match	
U1L2						match
U1L3	match					
U1L4		match				
U1L5			match			
U1L6				match		

Table A. Ideal land impression matches between two bullets, well known (B1) and unkown (U1).

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Establishing a match between two land impressions

The Alabama Department of Forensic Sciences (ADFS) has developed a method for comparing land impressions using the PLu neox and the SensoMAP software (Premium Edition) and the Sensofar Forensic Module[1]. The steps are:

1 Measure an extended topography, about 1mm wide and the full length of the land impression (Figure 3).

2 A region of interest (ROI) is selected and individual characteristics of the surface are obtained by filtering (Figure 4).

3 A profile is extracted and both bullets are compared directly (Figure 4).

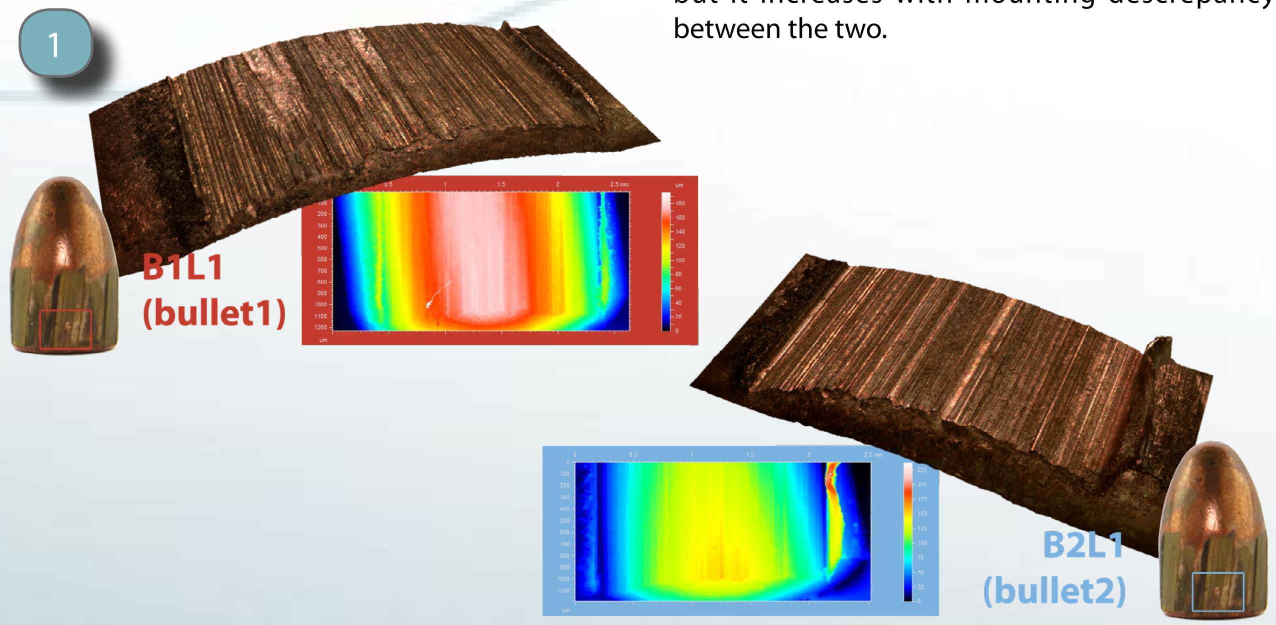

Figure 3. Land impression and scanned regions on two bullets fired with the same firearm.

Step 3 on figure 4 shows profiles extracted from measurements obtained on matching land impressions of two bullets known to be fired from the same firearm. NIST has developed two reliable parameters to describe the degree of similarity[2,3]:

a Compute the Cross-Correlation Function (CCF). The key parameter is CCF_{MAX}, which is one if the two profiles are identical. For the two profiles shown in Figure 4 the value of CCF_{MAX} is 0.957.

b Compute the Signature Difference (D_S):

$$D_S = R'^2_Q / R^2_Q$$

This parameter was proposed by NIST for quantifying signature differences. R'_Q is the roughness of the difference between mean profiles (bullet 1 and 2) and R_Q is the roughness from bullet 1. If the two profiles are exactly the same, D_S is obviously zero, but it increases with mounting descrepancy between the two.

Table B lists the values CCF_{MAX} and D_S for all (in this case) six land impressions on two known bullets. For the profiles in Figure 4 (B1L1 and B2L1) CCF_{MAX} is 0.957 and D_S is 11.4%. Note that CCF_{MAX} is high for other pairs of profiles shown in the table while D_S has larger vairability.

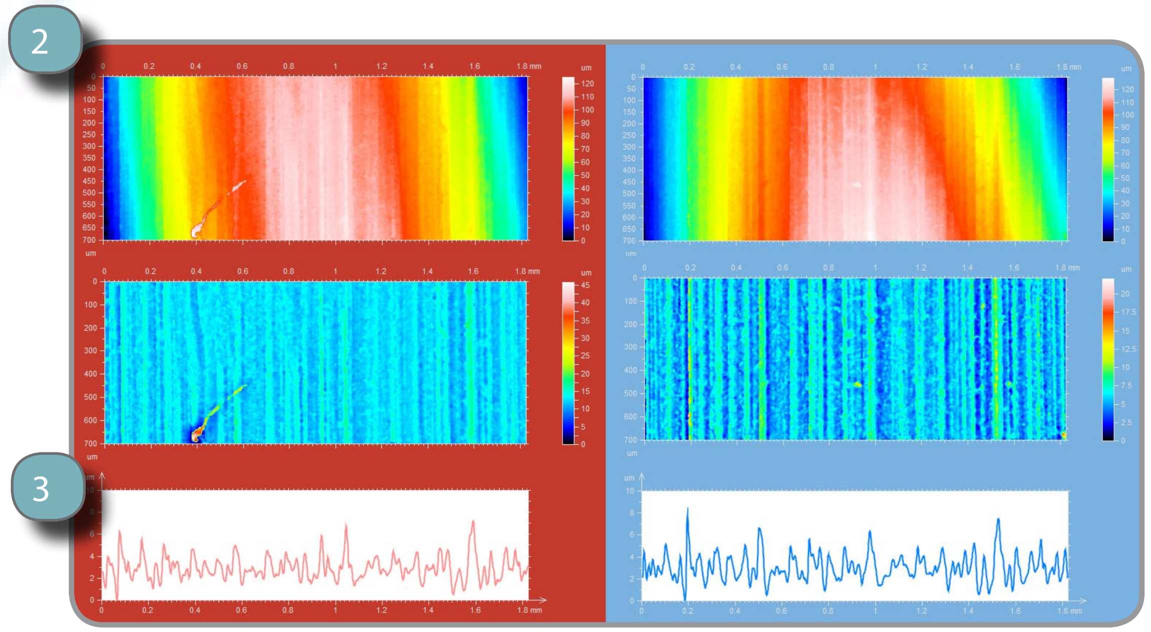

Figure 4. SensoMAP data processing on both scanned areas for bullet 1 and 2.

	B1L1	B1L2	B1L3	B1L4	B1L5	B1L6
	B2L1	B2L2	B2L3	B2L4	B2L5	B2L6
CFF_{MAX}	0.957	0.896	0.902	0.855	0.896	0.949
D_S(%) (k)	11.4	17.2	57.5	67.0	26.8	22.8

Table B. Similarity parameters for two known bullets.

Comparing unknown profiles

These values are now used to compare one single land impression of a known bullet to all land impressions of an unknown bullet. Figure 5 shows a contour rendering of six pairs of profiles, where the known profile is plotted to the left of every unknown profile. The known profile corresponding to the land impression B1L1 best matches the unknown profile corresponding to the land impression U1L1.

A comparison of the two parameters CCF and D_S for the matching and non-matching land impressions confirms this conclusion (Table C). The land impression were the differences are smaller is L1 and for the other land impressions the differences are very high.

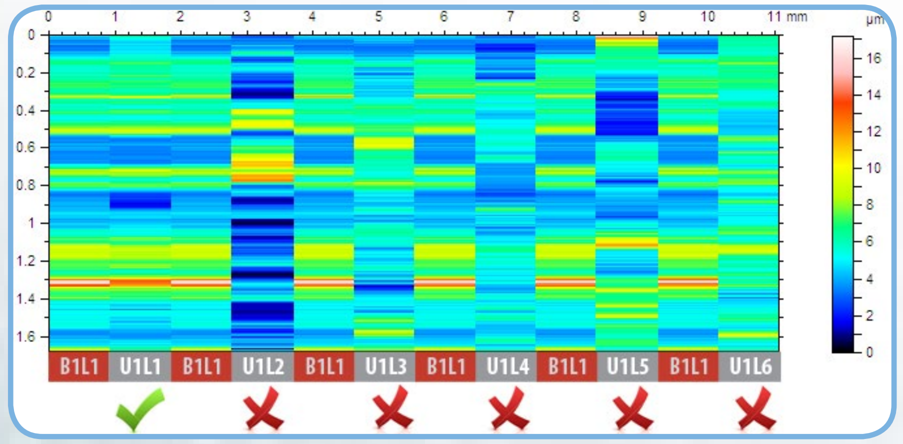

Figure 5. Comparison of a known profile (B1) to a set of unknown profiles (U1).

	B1L1					
	U1L1	U1L2	U1L3	U1L4	U1L5	U1L6
CFF	0.915	0.706	0.752	0.602	0.773	0.727
Difference from CFF_{MAX}	0.042	0.196	0.144	0.253	0.123	0.252
D_{SU} (%)	11.4	130	67.0	346	49.8	107
Difference from $D_s(k)$	0.0	72.5	49.8	279	23	84.2

Table C. CCF and Ds values for the matching and non-matching land impressions.

Conclusions

1 3D optical comparative measurements assist with confirming casework determinations made using traditional analysis such as comparison microscopy

2 PLu neox instrument, SensoMAP software and Sensofar Forensic Module are a complete solution. You can use confocal techniques to obtain the most accurate 3D measurements and state of the art software to automatically calculate key analysis parameters such as CCF and D_s

3 It is possible to add objectivity to Firearms and Tool Marks analyses by using 3D Confocal Microscopy Measurements.

[1] D. S. McClarin, D. Stella: 'The 10 Consecutive Ruger Barrel Study: A 3D look using the PLu neox from Sensofar', 2nd Annual AFTE Training Seminar, Chicago, May 2011
[2] L. Ma, J. Song, E. Whitenton, A. Zheng, T. Vorburger and J. Zhou: 'NIST bullet signature measurement system for SMR (Standard Reference Material) 2460 standard bullets', J. Forensic Sci., 49, No. 4, July 2004, pp. 649-659
[3] J. Song, T. Vorburger, L. Ma, J. Libert and S. Ballou: 'A metric for the comparison of surface topographies of standard reference material (SMR) bullets and casings', 2005

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