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NIST REFERENCE MATERIAL (RM) 8240/8250 PROJECT – STANDARD BULLETS AND CASINGS

J. Song, T. Vorburger, R. Clary, L. Ma and E. Whitenton*
National Institute of Standards and Technology (NIST), Gaithersburg, MD 20899, U.S.A.
* Guest Researcher at NIST

M. Ols
Bureau of Alcohol, Tobacco and Firearms (ATF), Rockville, MD 20850, U.S.A.

Abstract - Standard bullets and casings are currently under development to support the National Integrated Ballistics Information Network (NIBIN) in the U.S. Based on a numerically controlled diamond turning technique, 20 RM 8240 standard bullets were fabricated in 2002. Test results show high repeatability and reproducibility for the bullet signatures on these RM bullets. Prototype standard casings were also manufactured using an electro-forming technique, and are currently under test. These RM bullets and casings are intended for measurement traceability and quality control for ballistics laboratories nationwide.

Keywords - bullet signature, standard bullet, standard casing.

1. INTRODUCTION

As with fingerprints, bullets, when fired, and casings, when ejected from guns, pick up characteristic signatures which are unique to the weapon. The marks on the bullet come from its passage though the gun barrel. The marks on the casing are made by the firing pin, breech face and ejector. By analyzing these signatures, firearm examiners can connect a particular firearm to criminal acts. NIST Reference Materials (RM) 8240 and 8250, standard bullets and casings, are currently under development to support the coming National Integrated Ballistics Information Network (NIBIN) in the US.

2. RM 8240 STANDARD BULLETS

For the development of RM 8240 standard bullets, six master bullets shot under a standardized firing procedure at the National Laboratory Center of the Bureau of Alcohol, Tobacco and Firearms (ATF) and the Federal Bureau of Investigation (FBI) were measured at NIST using a stylus measurement system. A resulting set of six digitized 2D profile signatures was used as a 2D virtual bullet signature standard for the production of RM bullets with a numerically controlled (NC) diamond turning machine at NIST [1-4]. 20 RM 8240 standard bullets were manufactured with simultaneous setup on the diamond turning machine (Fig. 1). Test results show high repeatability and reproducibility of the bullets signatures on the prototype standard bullets [1-4]. 20 RM standard bullets were manufactured in January 2002, and are currently under test. Another 20 bullets will be delivered soon.

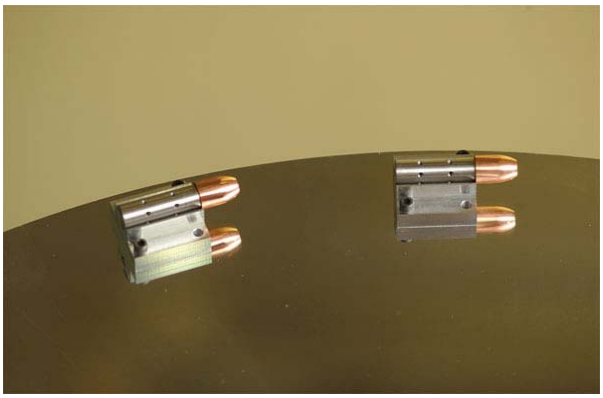

Fig. 1 Two of the 20 RM 8240 standard bullets manufactured with the simultaneous setup on a numerically controlled diamond turning machine at NIST.

3. NIST BULLET SIGNATURE MEASUREMENT SYSTEM

A new parameter using autocorrelation functions (ACF) was developed at NIST [5, 6], and is used for analysis of stylus measurements of the signature differences between these RM bullets and the 2D virtual bullet signature standard. Based on the statistical properties of the autocorrelation functions:

- When two bullet signatures are compared with each other, one of them is taken as a reference and the other is the compared signature. If these two signatures are exactly the same, their ACF achieves the maximum value (1.00) when the shift distance is zero;
- If two compared bullet signatures have the same pattern but small differences in the profile details, for

example, when two bullets are fired from the same gun, their signatures should have strong correlation. When the shift distance is zero, their cross correlation function (CCF) has a maximum value, but not as large as the maximum value of the autocorrelation function of the reference signature (1.00), because there are small differences between these two signatures;

- If one signature comes from a bullet fired from different gun than the other signature comes from, only random variations should be appeared on the cross-covariance function (CCV) curve without a clear correlation peak.

Based on the auto- and cross-correlation functions, a difference function for bullet signature comparisons was developed at NIST for quantifying bullet signature differences [5, 6]. Fig. 2 shows a case in which two correlated, but shifted, bullets signature A and B are compared with each other using the NIST bullet signature measurement system. A correlation peak can be seen on the CCF curve, CCF = 0.985. The signature difference (B – A), derived from the difference between signature A and B at the maximum correlation position of these two signatures, is also shown in Fig. 2. A comparison parameter called relative profile (bullet signature) difference, D_s [5, 6], is calculated and shown in Fig. 2, D_s = 3.06%. If the two compared signatures are exactly the same, the signature difference (B – A) is zero, and D_s = 0. The NIST proposed parameter and algorithm has several features [5, 6]:

- It can be used for quantifying signature differences for both 2D bullet signatures and 3D casing signatures;
- Because signature information of all 2D or 3D data points is used for comparison, the NIST comparison parameter could have high sensitivity, and can yield high repeatability and reproducibility;
- For the collection of all two-profile comparisons, the minimum profile difference of zero could only occurs when the two profiles are exactly the same. On the other hand, when any two compared 2D or 3D profiles have a profile difference of zero, these two profiles must be exactly the same (point by point).

4. ESTABLISHING BALLISTICS MEASUREMENT TRACEABILITY USING NIST STANDARD BULLETS

The RM 8240/8250 standard bullets and casings are aimed to provide reference standards for ballistics laboratories of the ATF and FBI for instrument calibration, measurement quality control and establishment of measurement traceability.

Fig. 2 Two compared signatures A and B with the same signature pattern but shifted in the lateral direction. There is a correlation peak on the CCF curve. Signature B – A shows the difference between Signature A and B.

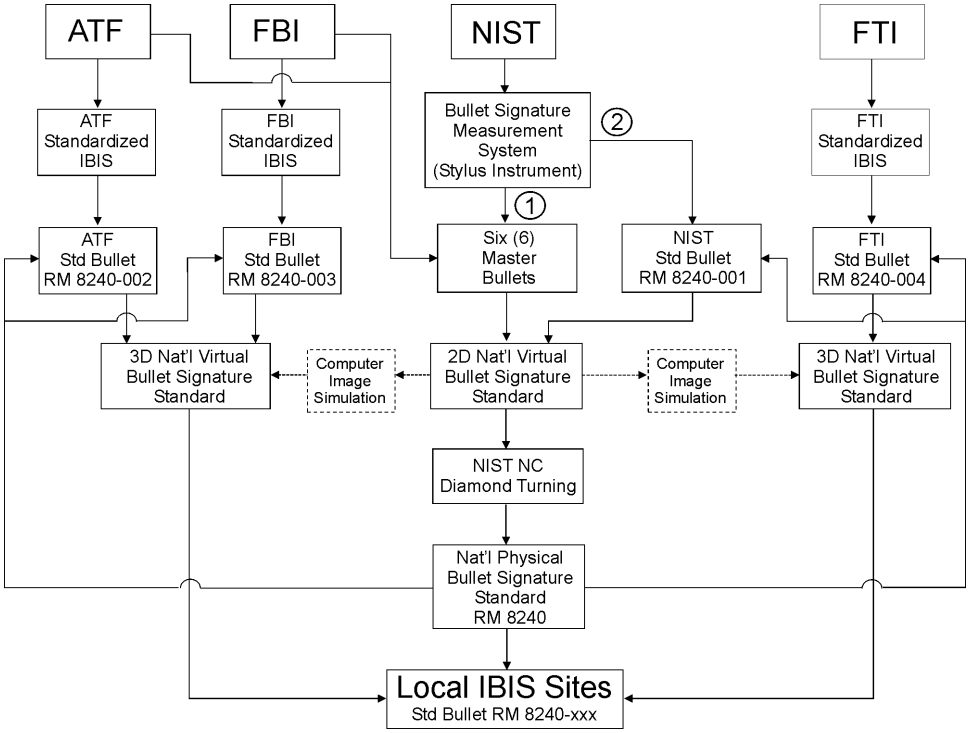

Fig. 3 A proposed national bullet signature measurement traceability system.

In order to establish measurement traceability for ballistics measurements at local laboratories to NIST, ATF and FBI central laboratory, a proposal for use of NIST RM 8240 standard bullets is shown in Fig. 3.

First, ATF and FBI provided NIST with six master bullets. These bullets were profiled at the NIST Surface Calibration Laboratory using a stylus instrument, as shown in Fig. 3, branch 1. The set of six digitized 2D bullet signatures was used as a 2D virtual bullet signature standard to control a numerically controlled diamond turning machine at NIST to produce the NIST RM 8240 standard bullets as physical standards. One of them, numbered RM 8240-001, would be kept at NIST as a check standard. This check standard would be routinely measured at the NIST's Surface Calibration Laboratory, and compared with the established 2D virtual signature standard for measurement quality control, as shown in Fig. 3, branch 2. The other RM bullets would be distributed to ATF and FBI central laboratories, to FTI (Forensic Technology Inc., Montreal, Canada, manufacturer for the Integrated Ballistics Identification System,* or IBIS) and to local IBIS sites. The IBIS is a computerized bullet and casing signature comparison system. It consists of a data acquisition station (DAS) and a signature analysis station (SAS). The IBIS score is a proprietary estimator of the degree of matching between pairs of optical images. For bullet signature comparisons, the IBIS score may be calculated between a single pair of land images or between two sets of images containing, say, six lands each. At the ATF and FBI central laboratories and the FTI measurement laboratory, these RM bullets, numbered RM 8240-002, 003 and 004, respectively, would be measured under a set of pre-determined standardized IBIS testing conditions. The resulting digitized 3D optical intensity images would be used as the 3D virtual bullet signature standard and be transferred to local IBIS sites. The 3D virtual standard might also be generated by computer-imaging techniques using the NIST 2D virtual bullet signature standard as input, and would be verified by measured IBIS images on the RM bullets. Meanwhile, the RM bullets would be available for purchase for the local IBIS sites. By measuring these RM bullets at local IBIS sites, and comparing the measured images with those of the 3D virtual standard measured at ATF, FBI or FTI under standardized conditions, differences in testing conditions between the local IBIS sites and ATF, FBI and FTI can be perceived. That can enable traceability for ballistics measurements nationwide to NIST, ATF and FBI, and ensure the measurement quality control of local IBIS sites. Detailed information may be found in Ref. [7, 8].

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* Certain commercial equipment, instruments, or materials are identified in this paper to specify adequately the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

5. RM 8250 STANDARD CASINGS

For the development of RM 8250 standard casings, the master casings were obtained from the ATF's National Laboratory Center by a standardized firing procedure. The

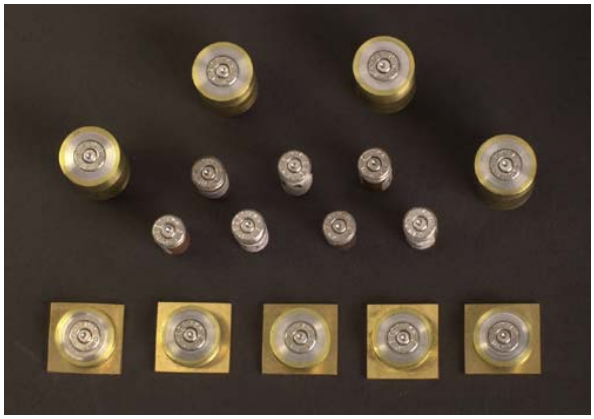

Fig. 4 Three different designs for RM 8250 standard casings, all manufactured by an electro-forming technique.

electro-forming technique, which we have previously tested for replication of surface roughness specimens at NIST [9], was used for replication of these RM casings. Three different designs were tested (Fig. 4). Initial test results showed high agreement and reproducibility between the casing signatures of different standard casings [10]. Further testing is still in progress.

6. SUMMRRY

The NIST RM 8240/8250 project, standard bullets and casings, is currently under development to support the National Integrated Ballistics Information Network (NIBIN) in the U.S.

So far 20 standard bullets have completed manufacturing and are currently under tests. Prototype standard casings with three different designs are also under test. A bullet signature measurement system has been established using a NIST proposed parameter and algorithm for bullet signature measurements. A measurement traceability scheme is also proposed for the establishment of bullet signature measurement traceability.

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Contact: John Song
100 Bureau Dr., Stop 8212
NIST
Gaithersburg, MD 20899-8212
U.S.A.
Phone: 301 975-3799,
Fax: 301 869-0822,
E-mail: song@nist.gov