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A Review of Forensic Ballistics: Methods and Techniques for Cartridge Case Analysis

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Abstract:

Forensic ballistics is a crucial discipline within forensic science, focusing on the identification and analysis of firearms, ammunition, and related evidence to assist in criminal investigations. This review paper provides a comprehensive overview of the methods and techniques employed in cartridge case examination, emphasizing their significance in weapon identification. Fired cartridge cases contain various marks on their surfaces, including striation marks, ejector marks, extractor marks, breech face marks, head marks, firing pin marks, firing pin drag marks, chamber striation marks, and magazine marks. These marks are unique to each firearm, making them critical for linking a cartridge case to a specific weapon. The challenges posed by cartridge cases fired from country-made weapons often exhibit irregular and unique markings due to unconventional manufacturing processes. These firearms, typically produced with less precision than standard firearms, create cartridge cases with distinctive characteristics that differ significantly from those of standard firearms. This complexity not only adds to the identification process but also provides unique forensic opportunities. The paper explores traditional techniques such as visual inspection and comparison microscopy, foundational methods in forensic ballistics that rely on expert analysis of microscopic and macroscopic markings. Modern advancements, including digital imaging and automated matching algorithms, have significantly enhanced the precision and efficiency of these examinations. Technologies such as the Ballistic Identification System (Ball Scan) are streamlining the comparison and identification of cartridge cases. Through a detailed examination of existing methodologies and recent advancements, this review aims to enhance the reliability and effectiveness of cartridge case analysis in criminal investigations.

Keywords: *Forensic Ballistics, Firearms, Ammunition, Cartridge Case, Country-Made Weapons, Ballistic Identification System.*

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Introduction

Forensic ballistics is an essential and highly specialized branch of forensic science that focuses on the study and analysis of firearms, ammunition, bullet, cartridge, missile and their impact and related evidence to aid in criminal investigations. This field plays a crucial role in the criminal justice system, providing key insights that help solve crimes and secure convictions **(Heard, 1997)** Cartridge case examination involves the detailed analysis of various marks imprinted on the surfaces of cartridge cases during the firing process. The marks on cartridge cases are unique to each firearm **(Zhang et al., 2017)** Like fingerprints, these markings serve as distinctive identifiers, making it possible to trace a cartridge case back to the firearm that discharged it. The use of cartridge case examination in forensic investigations offers numerous benefits. It enhances the ability of law enforcement agencies to solve crimes more efficiently and accurately. Moreover, technological advancements have further augmented the field, with digital imaging and automated matching algorithms significantly improving the speed and precision of examinations. Systems like IBIS and Ballistic Identification System exemplify these technological advancements, enabling faster and more accurate comparisons of cartridge cases.

This review paper aims to provide a comprehensive overview of the methods and techniques employed in cartridge case examination, emphasizing their significance and impact in forensic investigations. By exploring both traditional and modern methodologies, the paper seeks to highlight the advancements and challenges in the field, ultimately contributing to the ongoing efforts to improve the reliability and effectiveness of forensic ballistics in criminal investigations.

Firearms

Firearms are complex mechanical devices designed to discharge projectiles at high velocities. They come in various types, including handguns, rifles, and shotguns, each with unique characteristics and mechanisms. Firearms based on their make can be broadly classified into standard and country-made firearms **(Burrard, 1962).**

Standard Firearms

Standard firearms are typically produced by established manufacturers and adhere to rigorous standards of quality and precision. The consistent manufacturing processes of standard firearms result in more uniform and predictable markings on cartridge cases, which can be more straightforward to analyze and match in forensic examinations **(Mattijssen, 2019)**

Country-Made Firearms

Country-made firearms are typically produced by local artisans or small-scale manufacturers with less precision and consistency. These firearms often do not adhere to any regulatory standards and are produced using rudimentary techniques and materials. The irregular and unique manufacturing processes of country-made firearms create distinctive characteristics on cartridge cases, which can complicate the identification process but also offer unique forensic opportunities. These distinctive marks require forensic experts to employ advanced analysis techniques to accurately identify the firearm used **(Jain et al., 2004; Bradford and Burrard, 1952).**

Cartridge Cases

Cartridge cases, also known as shell casings, are the metallic containers that hold the primer, propellant (gunpowder), and projectile (bullet) in firearms. Cartridge cases generally come in three shapes **(Logan, 1959):**

1. **Straight cased: -** case diameter is approximately the same all along the length.

2. **Bottle-necked case: -** the body is wide and the mouth of the case is reduced in diameter.

3. **Tapered cases: -** The cartridge has a wide base and along with its length the diameter gradually decreases.

Based on the configuration of the base, the cartridge cases are further sub-divided into five more types:

1. **Rimmed:** the flange present at the base is larger in diameter as compared to the body of the cartridge case.

2. **Semi-rimmed:** The flange is slightly bigger in diameter as compared to the body of the cartridge case and the groove around the case body is in front of the flange.

3. **Rimless:** the diameter of the flange and the body of the cartridge case are the same and the groove around the body is in front of the flange.

4. **Rebated:** these cartridge cases have an extractor flange which is smaller in diameter as compared to the body.

5. **Belted:** these type of cartridge cases has a pronounced raised belt encircling the base of the cartridge.

Figure No.1: Cartridges of different calibers

Examination Process

The examination of cartridge cases has evolved significantly over time, driven by advancements in technology, forensic science methodologies, and the increasing sophistication of firearms. This evolution has played a crucial role in forensic investigations, enabling forensic experts to more accurately link cartridge cases to specific firearms and aid in criminal investigations **(Monturo, 2019; Gunther and Gunther, 2015)** The examination process involves several steps, including:

- **Photographic Documentation:** Photography played a fundamental role even in early times, allowing forensic experts to document and compare cartridge case markings over time. However, the quality and resolution of photographs were limited by the technology available.

- **Visual Inspection:** Initial examination of the cartridge cases primarily relied on visual inspection and comparison under microscopes. Observing the head of the cartridge case for manufacturer stamps, caliber markings, etc. The cartridge case's dimensions, including length, diameter, and wall thickness, are measured using precision instruments like calipers and micrometers.

Identification marks present on cartridge cases are **(Walker, 2012):** -

- **Striation Marks:** Grooves and scratches caused by the rifling in the firearm barrel as the bullet is propelled forward.

- **Ejector Marks**: Imprints left by the firearm's ejector mechanism when the cartridge case is expelled from the chamber.

- Extractor Marks: Marks made by the firearm's extractor mechanism as it pulls the cartridge case from the chamber.

- Breech Face Marks: Impressions from the breech face of the firearm that come into contact with the base of the cartridge case during firing.

- Head Marks: Manufacturer and caliber information stamped on the head of the cartridge case.

- Firing Pin Marks: Indentations made by the firing pin striking the primer to ignite the gunpowder.

- Firing Pin Drag Marks: Scratches from the firing pin dragging across the primer as the cartridge case is ejected.

- Chamber Striation Marks: Marks left on the cartridge case by the chamber walls during the firing process.

- Magazine Marks: Marks from the magazine during the loading and feeding of ammunition.

These marks are unique to each firearm. Forensic experts would manually compare marks present and other physical characteristics to identify similarities between cartridge cases recovered from crime scenes and those associated with suspect firearms **(Sinha, 2014; De Ceuster and Dujardin, 2014).**

- Microscopic Analysis: Using comparison microscopy, forensic experts conduct a detailed microscopic analysis of the markings and striations on cartridge cases. This method involves comparing these intricate features with those obtained from suspect firearms or known firearms. By scrutinizing these markings under high magnification, analysts identify similarities and differences that help establish potential links between a crime scene and a specific firearm, thereby providing critical evidence in criminal investigations.

- Digital Imaging: The integration of digital imaging technology enhanced the documentation and analysis of cartridge case markings. High-resolution digital cameras and imaging systems enabled forensic experts to capture detailed images of microscopic features, facilitating more accurate comparisons and archival of evidence.

- 3D Surface Profiling: Advanced techniques such as 3D surface profiling and laser scanning have allowed forensic experts to capture detailed three-dimensional topographical data of cartridge case surfaces. This approach provides additional information beyond traditional two-dimensional analysis, aiding in more precise firearm identification.

- Automated Matching Algorithms: Utilizing advanced software and algorithms to automatically compare and match cartridge case markings with database entries, enhancing the speed and accuracy of the examination. Integration of ballistic databases on a national and international scale has facilitated collaboration among forensic laboratories and law enforcement agencies. This has improved the capability to link cartridge cases from different crime scenes and track firearms used in multiple incidents.

Integrated ballistic identification system (IBIS)

Firearms identification is an empirical science that relies on objective observation and subjective interpretation of mark values present on the cartridge cases. Under the U.S. Department of Justice, the U.S. Federal Bureau of Investigation (FBI) and Bureau of Alcohol, Tobacco, Firearm and Explosive (ATF) created a database of imaging systems to store and analyze cartridge shells and fired bullet images. IBIS is a screening tool that is used for the acquisition, of cartridges, projectiles, and shotshell images to be uploaded and stored in a database. These uploaded digital images can also be compared to the digital images of fired cartridges or shotshell cases which are stored in the Canadian Integrated Ballistic Identification Network (CIBIN) further these digital images of fired cartridge cases can be compared with the database of United States of America called National Integrated Ballistic Information Network (NIBIN) which gives the information that the firearm may have originated or passed through United States of America. When the IBIS database is searched the linkage may occur at that time or later when the system is updated with other uploads. When linkages are found with other cases then a linkage report or firearm investigation aid notification letter is issued to find out the agencies involved in it**.**

Ballistic Identification System (Bal-scan):

The Bal-Scan system is a laboratory imaging device that is used for the scanning, live examination, markings and comparisons of fired ammunition. It can give both 2D and 3D structures which is very helpful for comparison. Two servers in this system are connected with workstations within a private network which are ‘Active’ and another is ‘Passive’. These workstations are related to each other. In an Active workstation, the examination is done by scanning cartridge cases and bullets and digitalizing them and it can create new cases, edit cases, search in database and comparison can be done. A universal cartridge case holder (used for all sizes of the caliber of cartridge cases 0.22inch- 12 bore) is used to keep cartridge case in a particular position for scanning and different sizes of bullet holders are used according to the bullet caliber for scanning. Whereas in a passive workstation only editing in cases, searching in the database and comparison is done and scanning of cartridge cases and bullets cannot be done. This database can filter and show the list of maximum matches of all the cartridge cases and bullets based on their caliber, particular impression or marks present on the cartridge case like-extractor, ejector, striation, firing pin marks etc. with the help of advanced algorithm **(www.forensic.cz).**

The Bal-Scan system is more of a database which is often called an Oracle database and it is an integral part of the system in which all the data is saved. It is a special software in which we create two logical units;

1. Criminal case database: in this type of database we scan cartridge cases and bullets recovered from the crime scene which hold evidential properties.

2. Firearm database: In this type of database, we scan test cartridge cases and test bullets of a weapon that is recovered from the crime scene for comparison purposes.

All the cartridge cases and bullets scanned are saved in the database separately with their case number, month and year and later on, can be compared and searched according to the caliber of cartridge cases.

Figure No. 2: Cartridge case examination in Ball Scan.

Discussion

- High resolution(3µm/px).
- Very efficient, easy to control and use
- Give 3D and 2D images and skew can be adjusted.
- More than two cartridges can be compared together
- Comparison can be done with the help of highlighting the topography and colour can be changed according to need.
- Possibility to scan highly deformed fragments
- Searching from the database shows filtered and relevant records by giving the probability of a match.
- Helps in linking to other cases.

Conclusion

In conclusion, examining cartridge cases fired from country-made weapons presents significant challenges due to their unconventional manufacturing and variability. These firearms lack standardization, leading to inconsistencies in dimensions and markings, complicating forensic analysis. Automated matching algorithms like IBIS, NIBIN, and Bal-Scan have enhanced efficiency by allowing rapid comparisons against extensive databases. However, ongoing advancements in forensic methodologies are essential to overcome these complexities and improve accuracy in identifying firearms used in criminal activities. The evolution of cartridge case examination from early manual methods to advanced digital technologies has significantly enhanced forensic capabilities in firearm identification and criminal investigations. These advancements underscore the critical role of forensic ballistics in modern law enforcement and justice systems, continually improving accuracy, efficiency, and reliability in solving crimes. Continued advancements in artificial intelligence and machine learning are expected to further enhance the capabilities of automated ballistic identification systems. These technologies may enable more sophisticated pattern recognition and analysis, improving accuracy and efficiency in firearm identification. This ongoing evolution not only improves the effectiveness of forensic ballistics but also enhances the overall capabilities of forensic science in serving the criminal justice system.

Features of Bal-Scan:

- Database is secured with a username and user password.
- Good quality monochromator camera for imaging and scanning and LED circular segmented ring right.
- Telecentric lens developed especially for Bal-Scan.

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