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A correlative demonstration of various tool-marks of 9 mm auto-loading pistols on the spent cartridge cases based upon the formulation mechanism

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ABSTRACT

The formulation of the mechanism of traditional tool marks of ten modern 9 mm auto-loading pistols is discussed. The specific tool marks that are engraved after the firing operation of special type of firearms are tested respectively and deliberately. The following characteristic tool marks are illustrated to verify their specific gun as well as the firing mechanism：breech face impression, firing pin drag mark, firing pin hole impression and firing pin hole shear mark. Through this experiment the morphology and orientation of different type of tool marks and the variation of how the pistol was manipulated in firing had been examined. They are illustrated with photographs and diagrams. Furthermore, the tool marks are compared with their consistent reproducibility so as to confirm the stability of respective forming mechanism. By doing this study, we have found that with the spent 9mm cartridge cases we could predict the possible shooting firearms and gun manipulating conditions to a very good extent due to not uniform strength and speed of mechanical actions (feed, extract, eject). Significantly, various gun manipulating conditions will cause apparently distinctive tool marks. E.g., Beretta series will normally cause the distinctive J-shaped extractor marks under different gun manipulating conditions; the breech block mark-A could beused to distinguish the uppermost round from the spent cartridge cases without being fed by magazine there is no breech block mark-A. Various class characteristics of tool marks can be applied to narrow down the possible firearms involved in order to predict the suspect gun. Outstanding example such as Glock series weapon could be reached due to the cogent proof of rectangular firing pin impression, the pointed ejector marks near to primer at 8-9 o'clock, and the vertical breech face impression, etc.

Keywords: Firearm Identification,Tool-Marks,Class Characteristics,Individual Characteristics,Gun Manipulating Conditions,Firing Pin Drag Mark, Firing Pin Hole Impression, Firing pin Hole shear Mark, Breech Block Mark

Introduction

Whenever the fired bullets and spent cartridge cases were found in the crime scene of a gunshot case they were collected for examination if they are relevant with this or other cases. Apparently it could be compared with a specific weapon available based upon individual characteristics, yet quite often it is time-consuming. However, if the manipulating conditions of the shooting pistol can be predicted according to the tool marks left on the cartridge case surface then both the type of weapon and the shooting conditions will soon be narrowed down. This first aid screening might be instrumental in establishing the correct investigative scenario. In the past several decades the majority of illegitimate weapons recovered in committing crime or those guns confiscated from smuggling or unlawful ownership of htem in Taiwan are prineipally small arms, which are lightweight, easy-to-hide-and-carry and above all, they are highly lethal. If these suspected powerful firearms can be predicted shortly, the investigative task can be rather

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economically effective. Howerer, if the regular tool marks tested from the suspected guns could not match the subclass-characteristics of the fired cartridge cases secured in the crime scene, it still indicates even more valuable information for the law enforcement officer to go further.

The first approach of this article is to categorize the characteristics of the possible pistols from the attributable tool marks of the corresponding cartridge cases. Both class and subclass characteristics which could be present on the fired cartridge cases from various pistols are tested and documented. Different 9 mm auto-loading pistols which were manufactured from several countries were adopted for this experimentation to test fire with Fiocchi 9×19mm FMJ ammunition imported from Italy. By setting different conditions in the firing process the characteristic tool marks which are inherently produced from a specific pistol, we attempt to formulate the tool marks with the forming mechanism of its relevant pistols. The reproducibility consistency of the characteristic tool mark is also discussed from the outcome of experiment with different mechanical function in steps of feeding, extracting, and ejecting action.

By far there is one study report to sort out the distinctive tool marks from different shooting conditions which was accomplished in 1999 by the author, though it only utilized S & W 5904 auto- loading pistol for experiment. This paper is presuming to carry on the research in an attempt to categorize various potential tool-marks of more auto-loading pistols from the impression forming mechanism on spent cartridge cases so as to formulate a likely rule to follow. The scanty source of weapons by far might appear a hindrance in this research for attaining a perfect conclusion to reach, yet a systematic empirical data will be attributable to provide the possible reference to trace the questioned guns and the practicable shooting conditions.

Experimental

Auto-loading pistols and ammunitions utilized

1. Experimental firearms

The following thirty-one 9 mm auto-loading pistols from seven countries of different makes are tested as target weapon：

(1) Four Italy Beretta, model 92FS, serial number BER365121Z、BER378940Z、BER392313Z、BER413211Z.
(2) Three Italy Beretta, model 92F Compact, serial number E14773Z、87005、D6589Z
(3) Three Austria Glock, model 17, serial number BMR634、BHP442、YM757
(4) Three Austria Glock, model 19, serial number AZC553、KP185、AUE438
(5) Three Czech Republic CZ, model 75B, serial number 2558N、4368R、4788R
(6) Three South Korea Daewoo, model DP51, serial number BA006428、BA703784、BA701469、BA708817
(7) Three Switzerland Sig-Sauer, model P228, serial number B195476、B241084、B196922
(8) Three Germany Heckler & Koch, model USP Compact, serial number 27-045194、27-045195、27-045193
(9) Two USA Smith & Wesson, model SW9C, serial number PAL3438、PAL6406
(10) Three USA Smith & Wesson, model 5904, serial number TVU0816、TVU0837、TVT8587

2. Experimental ammunitions: The Italy Fiocchi 9×19mm Full Metal Case (FMC,115 grain) ammunitions.

3. Comparison Microscope, Leica DM-C Model of West Germany.

4. Stereomicroscope, Olympus SZ-11 of Japan.

5. Digital Camera, Nikon cool-pix 995 of Japan.

Experiment：

Discharging conditions

Five steps of different manipulating conditions were set forth to load and unload cartridges to examine various tool marks：

Step 1 Single round ammo was loaded into the magazine of every pistol without inserting it into the grip and retreated it right after.

Step 2 Single round ammo was loaded into the magazine, the latter was inserted into the grip and slide was forced into position without discharging.

Step 2A：slowly pulling the slide backward----releasing the slide slowly ----slowly pulling back to eject cartridge without discharging.

Single round was loaded into the magazine, which was inserted into the grip, slowly pulling the slide

rearwards, it was then released slowly forward to fit the ammunition into the chamber, without firing then the slide was slowly pulled backward to eject the unfired ammunition.

Step 2B：slowly pulling slide backward----releasing the slide without control---- slowly pulling back to eject cartridge without discharging.

Single round was loaded into the magazine, it was inserted into the grip, the slide was slowly pulled rearwards to the end, then the slide was completely let go abruptly to thrust the ammo into chamber by force, then the slide was slowly pulled backward till the unfired ammunition was ejected.

Step 2C：slowly pulling slide backward----releasing the slide without control---- ejecting the unfired cartridge by swift pulling slide backward.

Single round was loaded into the magazine, it was inserted into the grip, the slide was completely let go abruptly to thrust the ammo into chamber by force, then rapidly pulled the slide backward to eject the unfired ammunition.

Step 3 Single round was loaded into the magazine and was manipulated as step 2, then trigger the pistol to discharge

Step 3A：slowly pulling the slide backward----gently releasing the slide to forward----then discharge the ammo.

Single round was loaded into the magazine, inserted into the grip, the slide was pulled rearward slowly, it was then released gently forward to fit the ammunition into the chamber, and discharge the ammo.

Step 3B：slowly pulling the slide backward----releasing the slide without control ----and discharge the ammo

Single round was loaded into the magazine, the magazine was inserted into the grip, the slide was pulled slowly to the rear, and the slide was completely let go abruptly to thrust the ammo into chamber by force, then discharge the ammo.

Step 4 Three rounds were loaded in the magazine and were manipulated as step 2 without discharging.

Step 4A：rapid pulling the slide----releasing slide with mechanical force to fit the first round into chamber---- slowly pulling back to eject the cartridges one by one without discharging.

Three rounds were loaded into a magazine, inserted it into the grip, swiftly pulled the slide backward, and the slide was completely let go abruptly to thrust the ammo into chamber by force, then slowly pulled the slide backward to eject the first unfired ammunition；following the same procedures to eject the second and the third one without discharging.

Step 4B：rapid pulling the slide----releasing slide with mechanical force to fit the first round into chamber----rapid ejecting without discharging

Three rounds were loaded into a magazine, inserted it into the grip, swiftly pulled the slide backward, and the slide was completely let go abruptly to thrust the uppermost ammo into chamber by force, then rapidly pulled the slide backward to eject the first unfired ammunition and swiftly let the slide go forward to fit the second round into position, following the same procedures to eject the second round and same dealing of the third one without discharging.

Step 5 Three rounds were loaded in a magazine and were manipulated as step 2, then they were discharged one by one.

Step 5A：the uppermost round was fit by pulling slide slowly to the end then gently releasing it into position and then discharge the ammo one by one

Three rounds were loaded into magazine, inserted it into the grip, the slide was pulled slowly to the end thereafter it was released gently to fit the uppermost round into position, then it was discharged. The second and third rounds were followed as the same procedures to finish discharging.

Step 5B：the uppermost round was fit by pulling slide slowly to the end and swiftly let the slide thrust forward to fit it, then it was discharged；the second and the third round were then discharged.

Three rounds were loaded into a magazine, inserted it into the grip, the slide was pulled slowly to the end and let it go completely to force the uppermost round into position, then it was discharged. The second and third rounds were followed as the same procedures to finish discharging.

Results and Discussions

Together there could have ten kinds of tool-marks on the spent cartridge cases after discharging of ten auto-loading pistols. A descriptive diagram is shown in Fig.1.

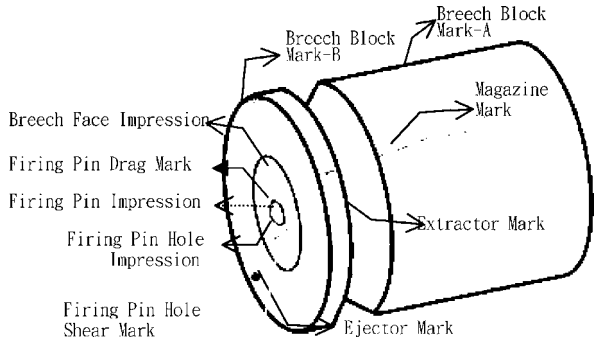

Fig.1 Various tool-marks left on spent cartridge cases (from 9mm auto-loading pistols)

1. Magazine Mark：

The cartridge case ejected from H＆K USP Compact, no matter discharged or not, the magazine scratch mark is vertical to the axial direction of the cartridge case.(Fig 2) Marks from this weapon is manifestly different with those from the other types of guns.（The rest appears parallel axially.）

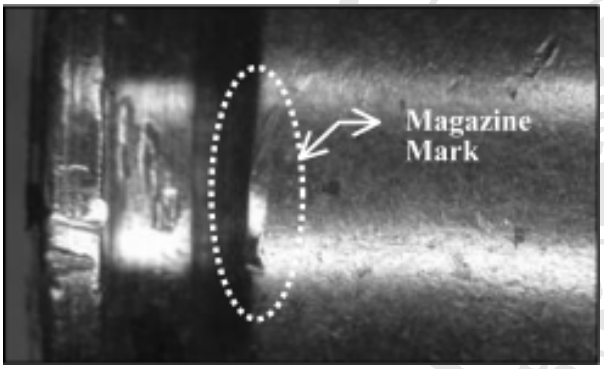

Fig.2 The magazine scratch mark of H＆K USP Compact, being vertical to axis of cartridge case.

2. Breech Block Mark－A：4

All of the scratching mark due to loading near the lip surface of the case is in straight line, though it can not be uniquely characteristic, however, being positioned at 12 o'clock, it can be referred to as the orienting point of other marks. It is caused by the lateral movement of the bottom edge of the bolt to rub the cartridge case rim when a new round is pushed into the chamber. (Fig.3.4) Breech block mark-A should not be confused with the magazine mark. It could be absent when a firearm was loaded by direct feeding without magazine. Breech block mark-A is a feeding mark, hence it may be used to indicate a certain type of firearm even the ammunition is just loaded and immediately retreated without discharging.

When a magazine was loaded with three cartridges or more simultaneously, the breech block mark-A of the uppermost round will be evident. While the second and third ones are not so discernible as comparing to the top one, moreover, these marks are shorter. This could assist to determine which one is the very first shot.

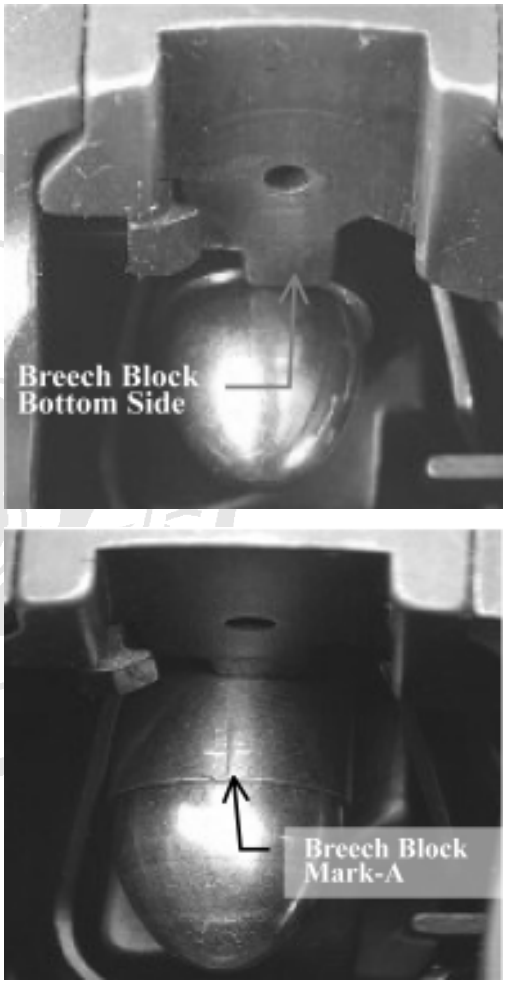

Fig. 3 Breech block mark-A ---when the bolt moves backward once a shot has been discharged, the breech block bottom side slides over the upper surface of the top cartridge in the magazine. (Parallel skid mark)

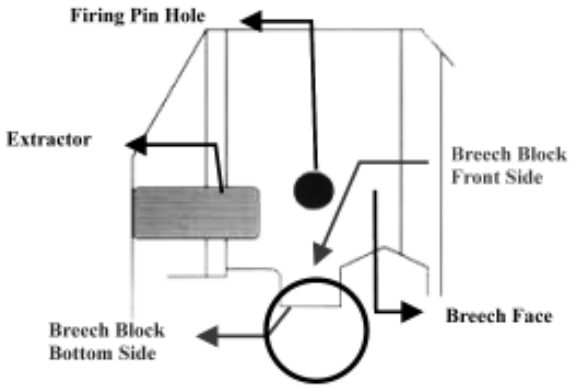

Fig. 4 The breech block bottom side move over the upper surface of the top round cartridge.

3. Breech Block Mark－B：

When the slide is retreating to the end it will be forced to push the slide to move forward by the pressure to drive the top round ammunition in the magazine to fit into the chamber of the barrel. Class characteristics can be formed under different gun manipulating condition. Whether the imprint mark by the thrusting impact of the bolt is evident or not can be used to determine the gun operating condition. Once the cartridge is impelled mechanically by the bolt shoving the stamping mark is evident, otherwise, the mark is indistinctive. The latter can be used to determine how the gun was most likely to be employed. (Fig 5.6)

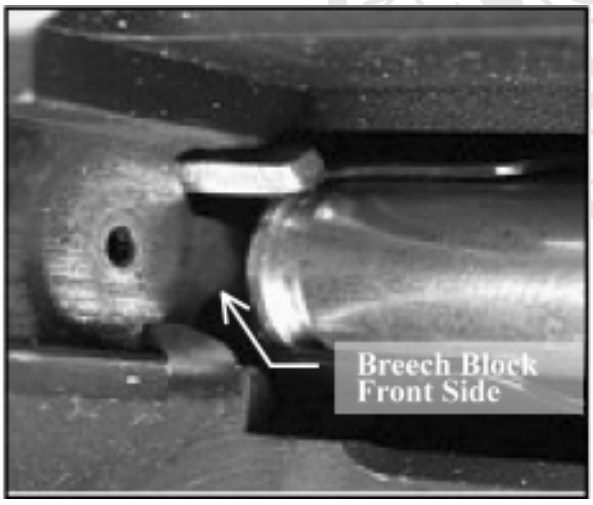

Fig. 5 Diagrammatical sketch of breech block mark-B formation

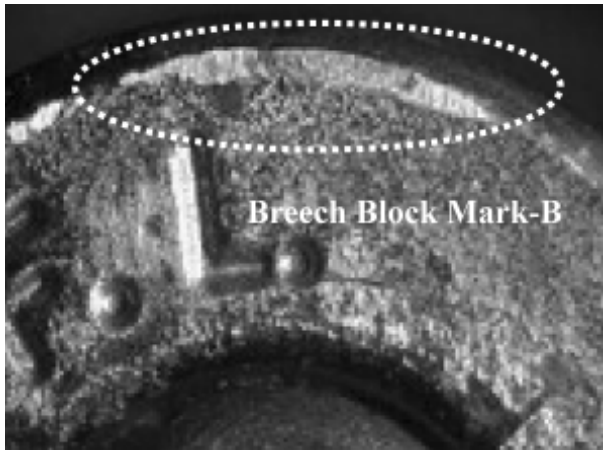

Fig. 6 Impact pattern of breech block mark － B on upper edge of cartridge case.

4. Extractor Mark：7

They can be distinguished into three types by their shapes. There are irregular shape, J-shape and elliptical shape. (Fig 7.8)They are either marked in the groove or struck upon the inner face of rim. Therefore, extractor mark can also be utilized to determine the operating condition of gun discharging. Some guns can only cause weaker extractor mark on condition of slow pulling slide without discharging. (Fig. 9) Once firing, the extractor mark make little difference.

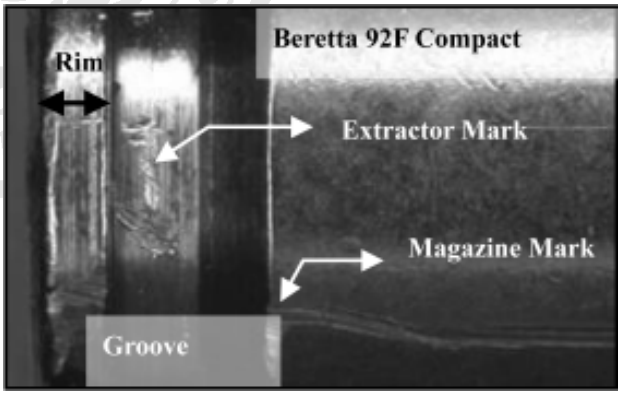

Fig. 7 J-shaped extractor mark in the groove of the unfired cartridge case. (Beretta model 92FS)

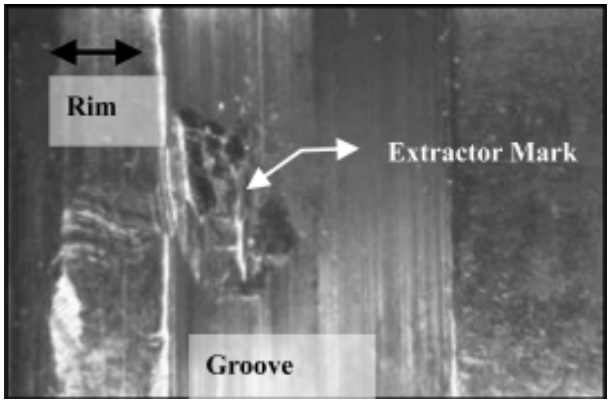

Fig. 8 Irregular extractor mark in the groove of the unfired cartridge case. (Sig-Sauer P226)

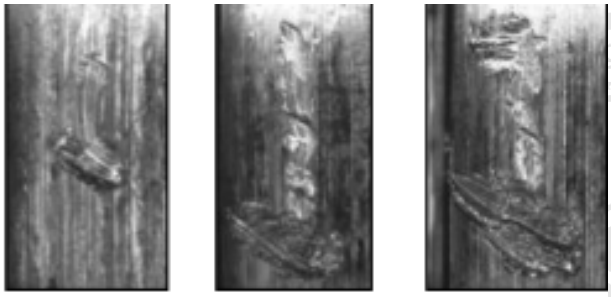

Fig. 9 J-shape extractor marks are different in length on unfired conditions. (For Beretta 92 FS or the series)

5. Ejector Mark：

There could be classified into six different types by their patterns as fan-shape, pointed, straight, circular, triangular, and linear. Their locations can be separated into three groups ：close to the rim of case, in between the rim and the primer, and close to the primer. (Fig 10.11. 12)They are specific characteristics to discriminate from one another. However, only swift ejecting the cartridge case under unfired condition could result ejector mark, not found by gentle ejection.

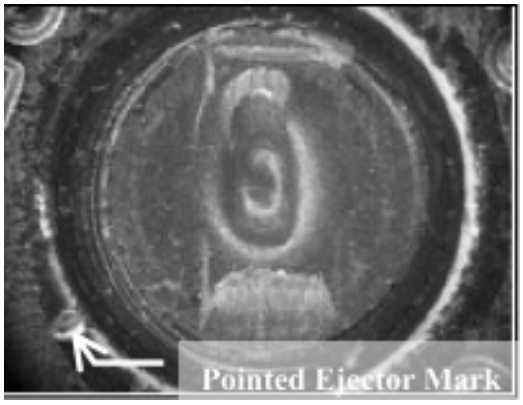

Fig.10 The pointed ejector mark near the primer of cartridge at 8-9 o'clock position. (Glock 17)

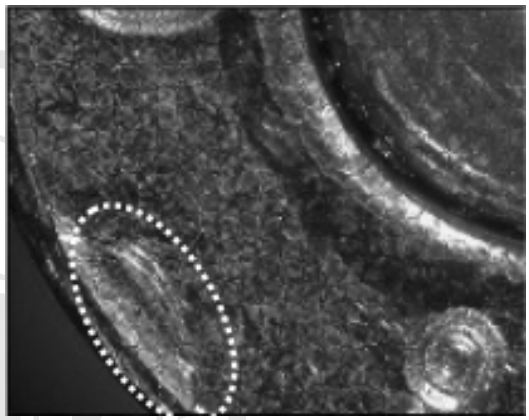

Fig.11 The fan-shaped ejector mark at 8 o'clock near the cartridge rim. (Beretta 92FS)

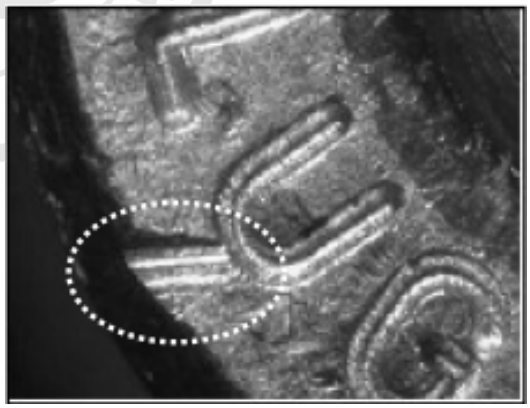

Fig.12 The triangular shaped ejector mark are near the rim of cartridge at 8 o'clock position. (Sig-Sauer P228)

6. Firing Pin Impression：10

Firing pin impression is the indentation contour which was made during the firing pin impinges the primer of cartridge case. They can be classified into two types by their shape：circular and rectangular. (Fig 13.14) They could be sub- class characteristics. On different firing conditions, firing pin impressions makes little difference.

Fig.13 Rectangular firing pin impression impinged on primer of spent cartridge cases. (For Glock 17 & 19)

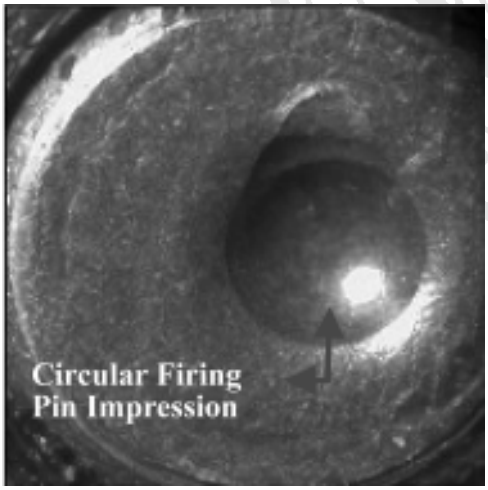

Fig.14 Circular firing pin impression impinged on primer of spent cartridge cases. (Beretta pistols)

7. Firing Pin Drag Mark：10

At the instant of discharging of an auto-loading pistol, the slide is driven to retreat along the barrel from a tightly locking together position. After a short distance, the barrel is halted, and the locking device is withdrawn from the slide. In certain types of weapons the firing pin was not pushed to its thorough stretching position and the barrel will simultaneously be lowered to bring the firing pin to make drag-mark on the spent cartridge cases. (Fig.15) Firing pin drag mark normally appears at 12 o'clock position of firing pin impression. The probability of various guns can be highly different.

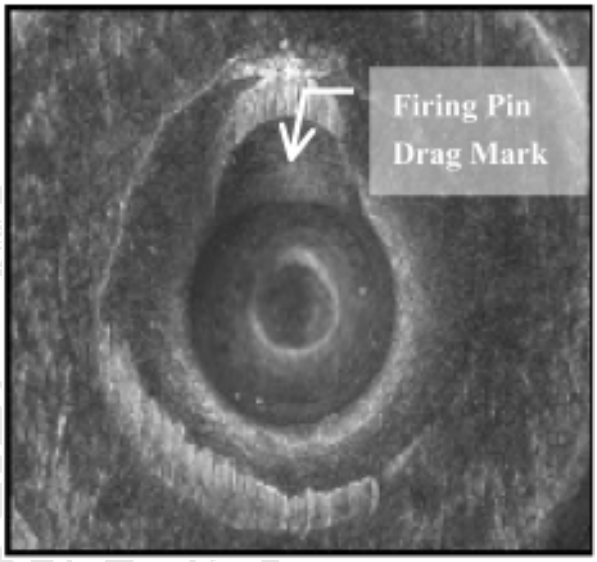

Fig.15 Firing pin drag mark on the upper north side (12 o'clock position) of firing pin impression.

8. Firing Pin Hole Impression：6

As a gun is discharged, the metal surface of primer cup was thrust rearward against the firing pin hole to form its characteristic impression amidst the firing pin impression of the primer. The firing pin hole impression is similar to a crater in configuration. If the hole gap surrounding the firing pin on the breech block face is spacious (Fig. 18), it would cause the primer surface to squeeze into the firing pin hole(Fig. 16) to form firing pin hole impression as the cartridge is discharged.

There has been two types of firing pin hole impression based on the weapons experimented in this research, i.e., the circular and rectangular configuration. The impressions are similar in shape under different discharging conditions for a specific gun, however, it can intrinsically be utilized as sub-class characteristics. (Fig. 17)

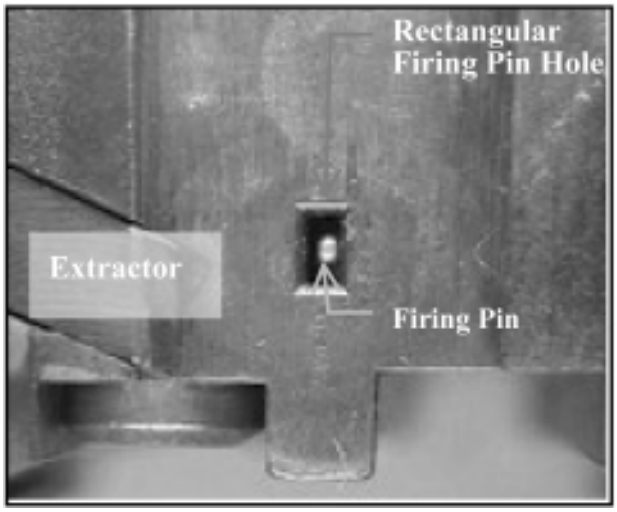

Fig.16 The rectangular firing pin hole of Glock pistol.

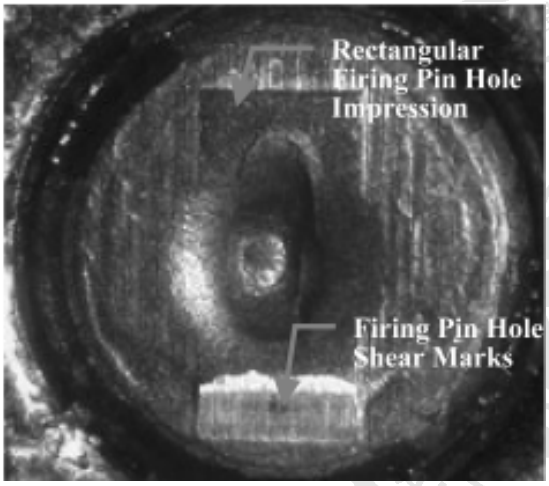

Fig.17 Rectangular firing pin hole impression on the spent cartridge cases produced by Glock pistols.

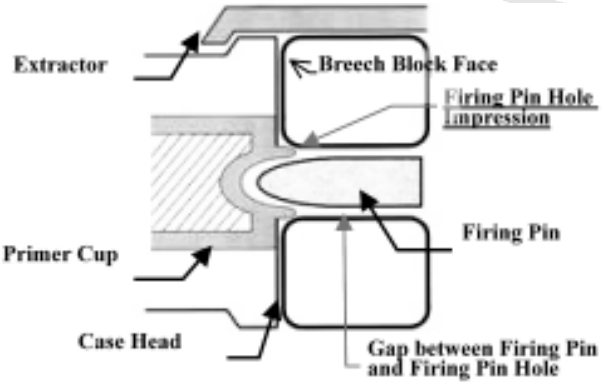

Fig.18 Mechanism of forming firing pin hole impression.

9. Firing Pin Hole Shear Mark：7.8.9

In the test firing experiment as certain 9 mm auto-loading pistols were discharged, the surface of the cartridge case will be inherently left with the breech face impression and the firing pin impression by the backward recoil. Besides, a firing pin drag mark was found at the upper edge of the firing pin impression. The slightly lowering movement of the gun barrel as the firing pin was not fully extended, might render the firing pin to tip the primer surface of the fired cartridge and cause it to be left with a firing pin drag mark on its upper edge. Moreover, the lowering movement of the barrel in some instance would render the edge of the firing pin hole to scrape the firing pin hole impression so as to form the firing pin hole shear mark. The characteristics of the firing pin hole shear mark as observed in this study could be manifestly individualized at the lower portion of the firing pin hole impression. (Fig. 19)

There could possibly be observed three kinds of tool mark, the firing pin hole impression, the firing pin hole shear mark and the firing pin drag mark. The first mark to be formed is the firing pin hole impression, while the last one is the firing pin hole shear mark.

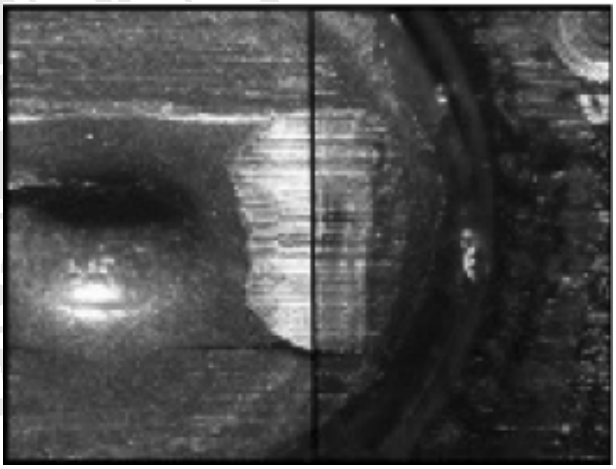

Fig.19 A match comparison of firing pin hole shear mark of two fired cartridge cases with identical Glock 17 pistol.

10. Breech Face Impression：10.11

The breech face rests against the head of the cartridge case and holds the cartridge case in the chamber of the firearm. When the head of a cartridge case slams against the breech face, the negative impression of any imperfections in the breech face is stamped onto either the primer or the cartridge case itself. The morphological contour on the breech face originated from manufacturing and the final finish which was coated

onto it by the manufacturer will leave their configurative impression on the surface of the case head.

Breech face impression can be distinguished into five types by their shapes, i.e., circular, vertically straight line (Fig.20), transversely straight line, crossing, and irregular protuberant contour. They can be manifestly individual sub-class characteristics but they are unable to be used for determining the conditions of how gun was manipulated. However, once the ammunition was discharged, the tool-mark makes little difference.

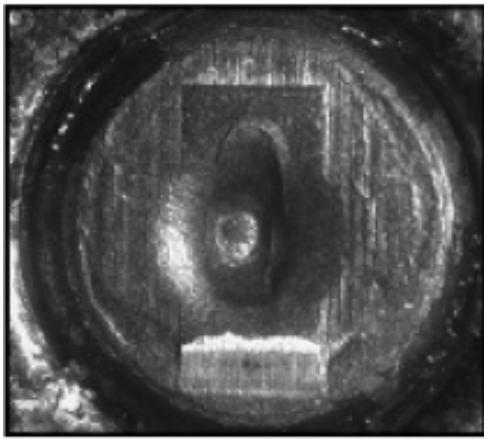

Fig.20 Vertically straight line breech face impression produced by the Glock Model 17

Table 1 Tool-marks formulated on the cartridge cases of various 9 mm auto-loading pistols

Types / Marks	Beretta 92FS、Beretta 92F Compact	Glock 17、Glock 19	CZ 75B	Daewoo DP51	Sig-Sauer P228	H&K USP Compact	S&W SW9C	S&W 5904
Magazine Mark	With H&K USP Compact, no matter discharged or not, the scrape mark is vertical to the axis of cartridge case. The rest of guns appears parallel.							
Breech Block Mark-A	All of them are straight, but can't be taken as class characteristics. When a gun was loaded with three or more rounds, the breech block mark-A will be obvious in the uppermost. The uppermost can be told very clearly, but the second and the third can't.							
Breech Block Mark-B	Not clear	Evident	Evident	Not clear	Evident	Not clear	Evident	Not clear
Extractor Mark	J-shaped marks on extracting groove	Irregular marks on forward face of cartridge rim	Irregular marks on extracting groove	Elliptical marks on extracting groove	Irregular marks on extracting groove	Irregular marks on extracting groove	Irregular marks on extracting groove	Irregular marks on extracting groove
Ejector Mark	Fan-shaped ejector marks near the rim at 8 o'clock position	Pointed ejector marks adjacent the primer at 8-9 o'clock position	Straight ejector marks near to the rim at 8-9 o'clock position	Circular ejector marks between the rim and the primer at 9 o'clock position	Triangular ejector marks near to the rim at 8 o'clock position	Circular ejector marks between the rim and the primer at 7-8 o'clock position	Line-like shaped ejector marks between the rim and the primer at 7-8 o'clock position	Triangular ejector marks near the rim at 8 o'clock position
Firing Pin Impression	Circular	Rectangular	Circular	Circular	Circular	Circular	Rectangular	Circular
Firing Pin Drag Mark	0% occurrence	100% occurrence	13% occurrence	13% occurrence	90% occurrence	100% occurrence	100% occurrence	90% occurrence
Firing Pin Hole Impression	Circular	Rectangular	Circular	Absent	Absent	Absent	Rectangular	Absent
Firing Pin Hole Shear Mark	Absent	Shear marks above and below firing pin hole impression (100%)	Shear marks surrounding firing pin hole impression (97%)	Absent	Absent	Absent	Shear marks above and below firing pin hole impression (100%)	Absent
Breech Face Impression	Not clear	Vertically straight line	Crossing	Vertically straight line	Circular	Vertically straight line	Irregular protuberant contour	Transversely straight line

Conclusions

The firing pin impression, breech face impression, extractor mark, and ejector mark on the discharged cartridge cases have been conventionally utilized in traditional firearm identification as class and subclass characteristics. In the case where 9mm auto-loading pistol is inevitably connected, if the firing pin drag mark, firing pin hole impression, firing pin hole shear mark, and magazine mark could be manifestly observed in addition to the above-mentioned, both the type of gun and most likely how the gun was manipulated can be determined based on the tool-marks left on the discharged cartridge cases.

The tool marks exemplified and verified in this research from thirty-one auto-loading pistols of ten countries different manufactories adopted for testing have been proved to be advantageous in criminal investigation if the positive determination of possible manipulating condition of gun can be understood. Just like if no breech block mark-A could be found on the discharged cartridge case for example, a conclusion could be reached that some round of ammunition would most likely be loaded directly into the chamber without being fed via the magazine, the same principle could be equally applied to determine whether a Beretta pistol was connected in a gunshot case and meanwhile it was fired in a mode that the slide must have been manipulated in slow pulling, gently releasing, and slow ejecting because of the presence of shorter extractor mark["J" shape configuration].

According to this study the different pistols will apparently leave distinctive tool marks on their spent cartridge cases respectively. On the other hand, if several discharging were carried out with the identical weapon but were manipulated in a variety of different way in loading and/or retreating process of ammunition, the tool marks left on the case would appear characteristically distinctive. A tool marks reference table from thirty-one 9mm auto-loading pistols from seven noted manufactories worldwide is illustrated in the contents. The contemporary experimental results demonstrates quite significant correlation for an approximate prediction between the tool marks and the potential weapon utilized together with the likelihood of determining manipulation of the pistol, however, it still remains premature before more types of gun can be utilized and more conditions can be grasped under control to result in a better conclusive identification.

The feasibility of a logical reasoning of various types of tool marks on the fired cartridge case can be reached on condition that the tool mark formulating mechanism could be thoroughly comprehended and the consistent reproducibility of the mark could be positively demonstrated. Since each type of tool mark is almost unique in specific weapon under specific discharging condition, hence an attempt to establish both class and subclass characteristics of various tool marks for a variety of guns in similar group is worthwhile and useful. Nevertheless, the correlating process can't be too arbitrary. It is essential to accomplish a more thorough empirical study to apply more weapons with more manipulating conditions in order to attain more perfect conclusion.

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