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Scanning Electron Microscope Observation and Analysis of Police 9mm Revolver Pistol Shooting on Automobile Steel Plate

Juan Sun

Kunming University of Science & Technology, Yunnan, China

sunjuan@kmust.edu.cn

Keywords: Scanning Electron Microscope (SEM), Police 9mm Revolver, Car Steel Plate, Gunshot Residue (GSR), Shooting Distance

Abstract: In recent years, with the continuous emergence of urban security problems, people have begun to focus on the development and research of police weapons. However, there is currently no reliable method for detailed analysis of the performance of police 9mm revolver pistols. In order to conduct an in-depth analysis of the performance of the police revolver, this study selected a police 9 mm revolver and ordinary bullets to test the car steel plate from a firing distance of 15cm, 30cm, 45cm, 60cm, 1m, 1.5m and 3m, respectively. In this paper, gunshot residue (GSR) was collected from four places, and the morphology of gunshot residue particles was observed using a scanning electron microscope (SEM). Different shooting distances have a negative correlation with the distribution density of gunshot residues. The gunshot residue particles can be measured at close range, and a small amount of warhead particles can still be found at a long distance. There are more gunpowder particles when shooting at close range, and more warhead particles when shooting at long range. Even the samples at the paint peeling off the bullet holes of the automobile steel plate can detect the particles of the gunshot residue. Therefore, under the cross-comparison between the sample extracted on the suspected bullet hole and the sample in the shell, the particle analysis can not only confirm whether it is a bullet hole, but also infer the shooting distance.

1. Introduction

The 2005-style police 9mm revolver (hereinafter referred to as the police revolver) is the first self-developed police pistol in China. It was listed as a Chinese standard weapon by the Ministry of Public Security in July 2008. It has the advantages of flexible maneuverability, simple operation, low killing, safety and reliability, strong stopping effect, rapid crossover of dumb ammunition, and adaptability to different ammunition. Police revolver is widely used in the police force due to its special structural characteristics and firing cycle action, but because the current shooting analysis of this type of gun is not comprehensive enough, its research on automotive steel plates is not comprehensive.

Many research teams at home and abroad have conducted in-depth research on police revolvers and bullets of different materials. In [1], the author studied the effect of grip strength exercises on male shooters' target shooting accuracy scores, and used regression analysis to study the effect of power exercise on target shooting accuracy scores. Finally, it is concluded that grip strength and its movement have important value for shooting, and grip strength movement is one of the factors that actively improve the accuracy score of target shooting. In [2], the author explores different physical characteristics to successfully shoot, and predicts the most important attributes that help achieve high shooting performance. The authors used multivariate techniques of principal component analysis (PCA), hierarchical cluster analysis (HACA) and discriminant analysis (DA) for physical feature testing. The results of the current study may help to identify potential shooters based on their physical characteristics [3]. . In [4], the author studied the effect of temperature changes on the accuracy of firearm firing, established a numerical simulation model of the barrel, and conducted a numerical analysis of the heat transfer of the inner bore according to nonlinear thermodynamics. The experimental results provide an important theoretical basis for correcting deviations in the shooting process. In [5], the author established a 1D transient heat transfer mathematical model of the barrel for the life of the barrel caused by the transient thermal shock during the shooting process under complex shooting specifications. The experimental results verify the effectiveness of the built model and the algorithm used in the complex shooting specification [6].

Scanning electron microscope (SEM) is widely used for precise micro / nano image exploration. In the past few years, several strategies have been proposed to fine-tune those microscopes. This work proposes a new fine-tuning strategy for the scanning electron microscope sample stage using a four-bar piezoelectric actuation mechanism to find all possible inverse kinematic solutions of the proposed mechanism [7]. In [8], the authors compared the effect of four different desensitizing dentifrice on tubule occlusion under a scanning electron microscope (SEM) to treat hypersensitivity (DH). The author observes at a magnification of $\times 2000$ under SEM, and statistically analyzes the obtained results. In [9], the author used a scanning electron microscope (SEM) to analyze the plasticized polyvinyl chloride (P-PVC) waterproof membrane, and also performed elemental analysis on each sample by energy dispersive X-ray spectroscopy (EDS). In [10-11], the author performed a three-dimensional (3D) reconstruction of the sample surface from scanning electron microscope (SEM) images taken at two angles. The authors tested two stereo photogrammetric software packages and compared their reconstructed 3D models with the known geometry of virtual samples used to create simulated SEM images. Environmental scanning electron microscope (ESEM) technology helps to directly image the sample without any pretreatment [12]. The images obtained from ESEM describe the complete morphological characteristics of the fungal mycelium and its reproductive structure. This method can be used for rapid identification of fungi for classification purposes.

In this study, 9mm revolver and ordinary bullet were used to test the shooting distance of 15cm, 30cm, 45cm, 60cm, 1M, 1.5m and 3M respectively, and the gunshot residue (GSR) was collected from four places. The particle shape of gunshot residue was observed by SEM. In this study, the blank background samples of the automobile steel plates tested did not contain the characteristic elements of the gunshot residues and did not affect the analysis of the gunshot residues. Different shooting distances have a negative correlation with the distribution density of the gunshot residues. The gunshot residue particles can be measured at close range, and a small amount of warhead particles can still be found at a long distance. There are more gunpowder particles when shooting at close range, and more warhead particles when shooting at long range. Therefore, under the cross-comparison between the sample extracted on the suspected bullet hole and the sample in the shell, the particle analysis can not only confirm whether it is a bullet hole, but also infer the shooting distance.

2. Method

2.1. Introduction to Bullets and Automobile Steel Plates

(1) Introduction of bullets and gunshot residues

The bullet of the 9mm police revolver pistol is a bullet core with a lead pad and a full armor flat head composite warhead. The 9mm police revolver pistol is a blunt bullet. The internal charge is newly developed azide nitrate, which is characterized by high energy, low explosion temperature, low ablation, high burning rate, good mechanical properties, strong process adaptability, good physical stability and chemical stability. The gunshot residue is formed by the rapid condensation of a large number of high-temperature and high-pressure gunpowder gas masses generated from the barrel after the bullet is fired. Therefore, the surface and inside of the gunshot residue have the morphological characteristics of condensate, mostly in the form of molten micron-sized spherical, tumor-shaped or honeycomb-shaped particles.

(2) Introduction of automotive steel plate materials

Most of the car body shells are made of metal materials, steel plates, carbon fiber, aluminum, reinforced plastics, etc., and the materials of the car shells and different parts of different uses are also different. In automobile production, the most commonly used is ordinary low-carbon steel plate. The high-strength steel plate for vehicles can maintain the mechanical performance requirements of the car body even when the thickness is reduced, thereby reducing the weight of the car. At present, high-strength steels include paint-hardened steel plates, dual-phase DP steels, phase-induced plasticity steels, micro-alloyed M steels, and high-strength gapless solid-melt IF steels. On the inner and outer panels of the door, engine compartment cover, luggage compartment cover, etc. The body cover parts are mostly made of galvanized steel sheets with 0.6 to 0.8 mm. The car body paint mainly contains metal elements such as titanium Ti, magnesium Mg, calcium Ca, zinc Zn, barium Ba, lead Pb, cadmium Cd, chromium Cr and mercury Hg.

2.2. Police Shooting Marks with 9mm Revolver

(1) Traces of shooting warheads

Pull-out marks: Pull-out marks are line-shaped scratch marks formed by the friction of the warhead under the pressure of the gunpowder gas to overcome the pull-out resistance of the bullet shell to the warhead. It is located at the part where the cylindrical portion of the warhead is directly in contact with the mouth of the bullet casing, and is parallel to the bullet axis.

Ripple marks: Ripple marks appear on the cylindrical part of the warhead, affecting the lower end of the warhead's arc and the front end of the tail, and are parallel to the bullet axis in a beam shape. It is mainly used to identify shooting guns, and its morphological changes can be used to analyze the degree of barrel wear.

Thread marks: Thread marks are formed by squeezing, shearing, and friction when the warhead squeezes into the rifle and rotates forward in the bore. The rift mark starts at the end of the arc of the warhead, penetrates the cylindrical part, and ends at the front end of the tail of the warhead.

(2) Traces of shooting shells

Striking traces: The traces of the striker hitting the bottom fire shell with a certain kinetic energy, causing local deformation of the bottom fire.

Traces on the inner wall of the bore: During the firing process, as the gunpowder burns, the pressure of the gunpowder gas in the bore acts on all directions of the inner wall of the shell. The outer surface of the cartridge case comes into contact with the inner wall of the cartridge chamber, so that all the morphological features of the inner wall of the cartridge chamber will be imprinted on the outer surface of the cartridge casing, forming marks on the inner wall of the cartridge chamber.

Traces of bottom socket: Different types of firearms have different plane structure characteristics of bottom sockets of gun barrels. The type of processing marks on the bottom socket can be distinguished as the type of gun as the characteristics of the gun type, and the individual characteristics such as the number, width, spacing and relative position of the processing marks on the bottom socket can be regarded as the firearm.

2.3. Working Principle of Scanning Electron Microscope and Energy Spectrometer

(1) Scanning electron microscope (SEM)

Scanning electron microscope (SEM), compared with the traditional optical microscope, it has significant advantages such as high resolution, high magnification, large depth of field, and large field of view. Scanning electron microscope mainly includes 4 systems: electron optical system, vacuum system, detection system and computer control system. The electrons emitted by the electron gun are condensed and accelerated by the multi-stage electromagnetic condenser to converge into a nano-scale ultra-fine light spot. The scanning coil and the deflection coil set inside the lens then control the electron beam to shift on the x and y axes, so as to realize the point-by-point scanning of the electron beam on the sample surface.

(2) Energy dispersive spectrometer (EDS)

Qualitative analysis of material composition is an important means of material characterization. The energy spectrometer (EDS) is the detection method used to analyze the types and contents of the microelements of the material. It is equipped with scanning electron microscope and transmission electron microscope for auxiliary use. When a beam of high-energy electrons bombards the surface of a substance, electrons outside the nucleus of the substance will be excited to escape, and various signals will be generated in the excited area. The own probe of the scanning electron microscope mainly collects secondary electrons and backscattered electrons for imaging. The energy spectrometer is to collect characteristic X-rays, which can do element point, line and surface analysis on the surface of the material, as well as qualitative and quantitative analysis of the composition of the micro-area on the surface of the material.

3. Experiment

3.1. Data Source of Test Equipment and Police 9mm Revolver Pistol

Guns for test firing: 2005-type 9mm police revolver pistols and several rounds of common ammunition.

The material of the object to be shot: several side door panels (60 cm × 50 cm × 1 mm) of the car.

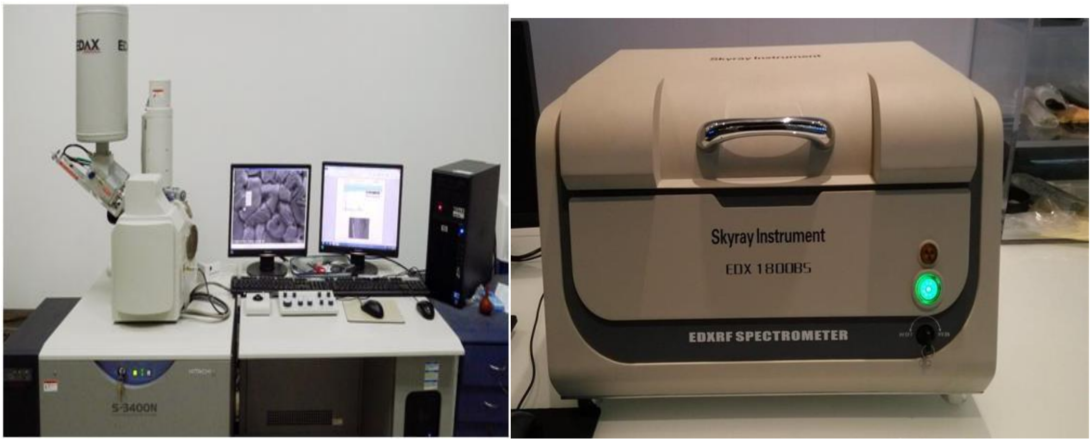
Equipment: Hitachi SN3400 scanning electron microscope (Figure 1a), vacuum coating instrument, EDEX energy spectrum analyzer (Figure 1b).

Other tools: plastic rods, range finder, tape measure, double-sided conductive adhesive, disposable cotton gloves.

The gun is equipped with two types of bullets, which are the 2005-type 9mm police revolver ordinary bullet and rubber bullet, codenamed GA / DZ2005-9 and GA / DXX2005A-9. Ordinary ammunition is a low penetration anti-personnel ammunition, consisting of a copper-headed flat head warhead, a flange-type brass bullet shell, a propellant, and a primer. The bullet is composed of a bullet shell, a plastic core, a lead core, and a sealing sheet. The initial velocity is 220 meters ±10 meters per second. It can vertically penetrate 25 mm thick pine boards at a distance of 50 meters. Accuracy (25m ordinary bullet gun value): R50≤2cm, R100≤5cm. Its main technical parameters are shown in Table 1.

Table 1. Main technical parameters of bullets

9mm Police Revolver		9mm Police Revolver Ordinary Bullet	
Caliber	9 mm	Bullet weight	8.5g
Full gun length	190 mm	Full length	24.5mm
Barrel length	76.2mm	Cartridge length	17 mm
Full gun quality	0.7 kg	Warhead length	13 mm
Magazine capacity	6 rounds	Warhead weight	4.5g
Muzzle velocity	220m ±10m/s	Diameter of bottom edge of cartridge case	10.5mm
Riveting direction, number	Right 6	Core weight	0.27g



(a) Scanning electron microscope (b) Energy spectrometer

Figure 1. Test equipment

3.2. Sample Extraction Method

(1) Test shooting

The police revolver is loaded with bullets, and it is directly fired on the automobile steel plate at a range of 5 cm, 15 cm, 30 cm, 45 cm, 60 cm, 1 m, 1.5 m, and 3 m in the indoor shooting range. 5 shots for each distance.

(2) Sampling

Before detecting residues on the surface of the car's steel plate, use a clean plastic rod to scrape the inside of the projectile shell, so that the residues in the shell fall off on the double-sided conductive carbon adhesive on the aluminum sample stage. Confirm the elemental composition of the gunshot residue in the shell, as a basis for comparison and interpretation of the analysis results. On the surface close to the edge of the bullet hole, 0.5 cm from the edge of the bullet hole, and the inside of the petals, use the aluminum sample stage with double-sided conductive carbon adhesive to repeatedly press and adhere to the attachment until the adhesive surface loses its viscosity. Among them, when there is paint peeling off on the 0.5 cm circumference around the bullet hole, another sample is taken. In order to confirm the elemental composition of the blank background particles and to facilitate the elimination or confirmation of background interference, blank control samples were taken on other parts of the steel plate that were not used as shooting targets.

3.3. Gunshot Residue (GSR) and Distribution Density Analysis

(1) Pre-finding of gunshot residue particles

In the vacuum coating instrument, the surface of each sample is coated with carbon film with a thickness of about 300A. GSR contains many heavy metal elements, and the backscattered electron image is brighter, which is easier to distinguish from the iron element image contained in the steel plate. Find the heavy element particles in the sample in a fast scan, and locate the heavy element particles related to the gunshot residue. The inspection area of the sample stage is divided into 200 micro-zones, the magnification is 250, and the pixels are 1024. Under this condition, the minimum detection particle size of the energy spectrum is 1.0 ± 0.5μm.

(2) Confirmation of gunshot residue particles

Use secondary electron images combined with X-ray energy spectrum analysis to analyze the found particles according to the microscopic morphological characteristics and elemental composition characteristics, confirm the gunshot residue particles and take images. Magnify the particles identified by the instrument to 2500 to 10000 times per field of view. While observing the morphology of the particles, observe whether the heavy element spectrum is in accordance with the composition of the gunshot residue particles of the police revolver. The particle statistics method is to use backscattered electron images to find eligible gunshot residue particles, collect spectrum, frame-by-frame scanning, multi-field measurement, automatic accumulation, and calculate the percentage of each of the three different particles.

(3) Calculate the average distribution density of gunshot residues

Calculation formula of distribution density:

$$Density(D) = \frac{GSR\ particles}{Distribution\ area\ (pcs/cm2)} \tag{1}$$

Among them, the distribution area = 3.14 × 0.6mm2 (radius of conductive adhesive wafer). When calculating the average distribution density of GSR particles in a part, the total number of particles in all samples in the part is added and divided by the total area of the samples, which is the approximate average particle density value.

3.4. Performance Test of Police 9mm Revolver

(1) Speed measurement by speedometer

The experiment uses FLG-V laser gun speedometer to measure the instantaneous velocity of the projectile. The experiment measured the speed of 9mm police revolver pistol shot at different ranges. Each range was measured 3 times and the average value was taken. Use a tray balance to measure the mass of 5 rubber bullets, calculate the average mass of the bullets, and calculate the kinetic energy value of the rubber projectile at different ranges according to the speed at different ranges, and find the specific kinetic energy of the section of the rubber projectile at different ranges. Assuming that the rubber projectile finally stops after interacting with the object, the maximum theoretical lethality evaluation data of the 9mm police revolver rubber projectile at different ranges can be obtained. See Table 2 for specific data. The relevant calculation formula is as follows:

$$E_0 = \frac{1}{2}mv_0^2,\ \ e_0 = E_d / \left(\frac{1}{4}\pi d^2\right) \tag{2}$$

In the formula, E0 is the instantaneous kinetic energy value of the projectile after the corresponding range distance in flight; m is the mass of the projectile; v0 is the average velocity of the projectile passing through the speedometer; e0 is the specific kinetic energy of the projectile of the projectile; d is the maximum diameter of the projectile.

Table 2. Velocity, kinetic energy and cross-sectional specific kinetic energy of bullets of 9mm revolver at different ranges

Range (m)	1	5	10	15	20	30	40
v0 speed average (m / s)	235.7	227.46	215.54	209.82	183.9	176.79	166.96
Kinetic energy (J)	31.39	29.23	26.25	24.87	19.11	17.66	15.75
Cross-section specific kinetic energy (J / cm2)	49.34	45.95	41.25	39.1	30.04	27.76	24.76

(2) Measurement of impact load cell

Adopt LSZ-F04 resistance strain type load cell (range 200kg) to record the impact force value of high-speed impact rubber bullet with electrical signal, and realize the computer to collect the force value at the moment of collision. In this experiment, the force value of 9mm police revolver pistol shot at different ranges was recorded. The range of each group was measured 5 times, and the average value was taken. See Table 3 for specific data.

Table 3. Impact force values of 9mm revolver pistol bullets at different ranges (g is 9.80N / kg)

Range (m)	1	2	5	10
Reading (kg)	128.71	116.96	104.42	89.91
Impact value (N)	1261.81	1146.62	1023.68	881.43

4. Results and Discussions

4.1. Distribution of Gunshot Residues Extracted from Different Parts of Automobile Steel Plates

The average distribution density of the gunshot residues extracted from different shooting distances, different parts of the experiment and the percentage content of different types of particles are shown in Figures 2 to 5. The distribution density of the gunshot residue particles in the samples extracted from the four parts decreased with the increase of the range. Since the paint particle size does not contain lead Pb, antimony Sb and other characteristic elements, it can be distinguished from the gunshot residue, without affecting the analysis of the residue.

(1) Close to the circumference of the edge of the bullet hole

This part is close to the bullet hole wiping zone. The residue particles collected within a range of 15 cm to 60 cm are mainly unburnt gunpowder particles containing potassium and calcium. When the shooting distance exceeds 60 cm, the number of residue particles decreases significantly. When the firing distance is more than 1 meter, no gunpowder particles are detected in the residue particles, but mainly the warhead particles carried by the warhead directly to the surface of the projectile. Although the number of spherical bottom fire particles gradually decreases, there are still a certain number of irregular particles containing bottom fire characteristic elements. Fig. 2 is the distribution diagram of GSR particles close to the circumference of the edge of the bullet hole.

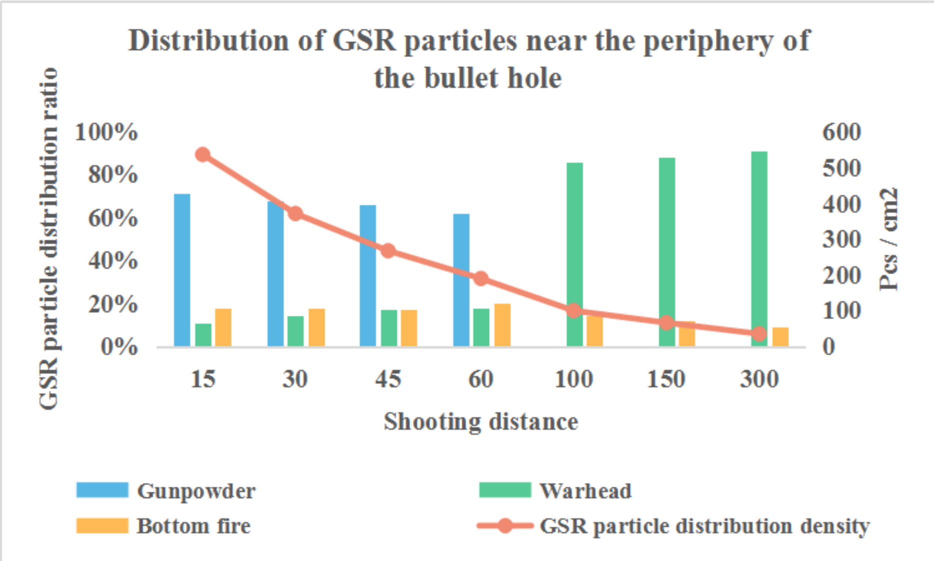


Figure 2. Distribution of GSR particles near the periphery of the bullet hole

(2) 0.5 cm from the edge of the bullet hole where the paint has not peeled off

When the shooting distance is less than 45 cm, the gunpowder particles are still dominant, but the density is reduced compared to the vicinity of the rubbing zone. At a range of 60 cm, a large amount of flaky particles can be observed. It is inferred that these particles are from warhead particles, not gunpowder particles. At a range of 1 meter, the residual particles are mainly primer particles, and warhead particles can also be detected. Different elements can also be detected on some primer particles and warhead particles. Compared with the paint elements of automobile steel plates, the analysis may be derived from the inorganic components in automobile paint. For samples with a firing distance of 1.5 meters, primer particles and warhead particles can still be found. For samples with a firing distance of 3 meters, only a few bullet particles can be found, and no primer particles can be found. Figure 3 shows the distribution of GSR particles at a position where paint does not come off 0.5 cm from the edge of the bullet hole.

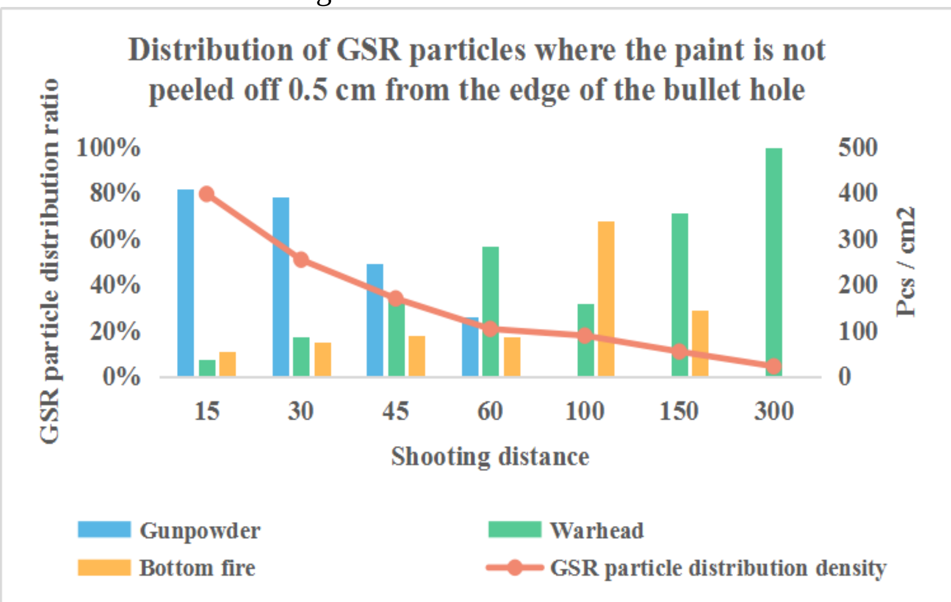


Figure 3. The distribution of GSR particles at a position where the paint is not peeled off 0.5 cm from the edge of the bullet hole

(3) 0.5 cm from the edge of the bullet hole

When the range is within 30 cm, a large number of large flake warhead particles, spherical bottom fire particles and gunpowder particles can also be found. Gunpowder particles cannot be detected at a range of 1 meter. Primer particles and warhead particles can be found, but the number of warhead particles is the majority. Samples up to a range of 3 meters can only detect warhead particles. Compared with the residues extracted at the same firing distance of 0.5 cm from the edge of the bullet hole where the paint did not fall off, the number of GSR particles observed was relatively small. It can be seen that when shooting the sprayed automobile steel plate, if there is paint peeling off around the bullet hole, the gunshot residue can still be extracted at the falling place. Figure 4 shows the distribution of GSR particles in the paint peeling off 0.5 cm from the edge of the bullet hole.

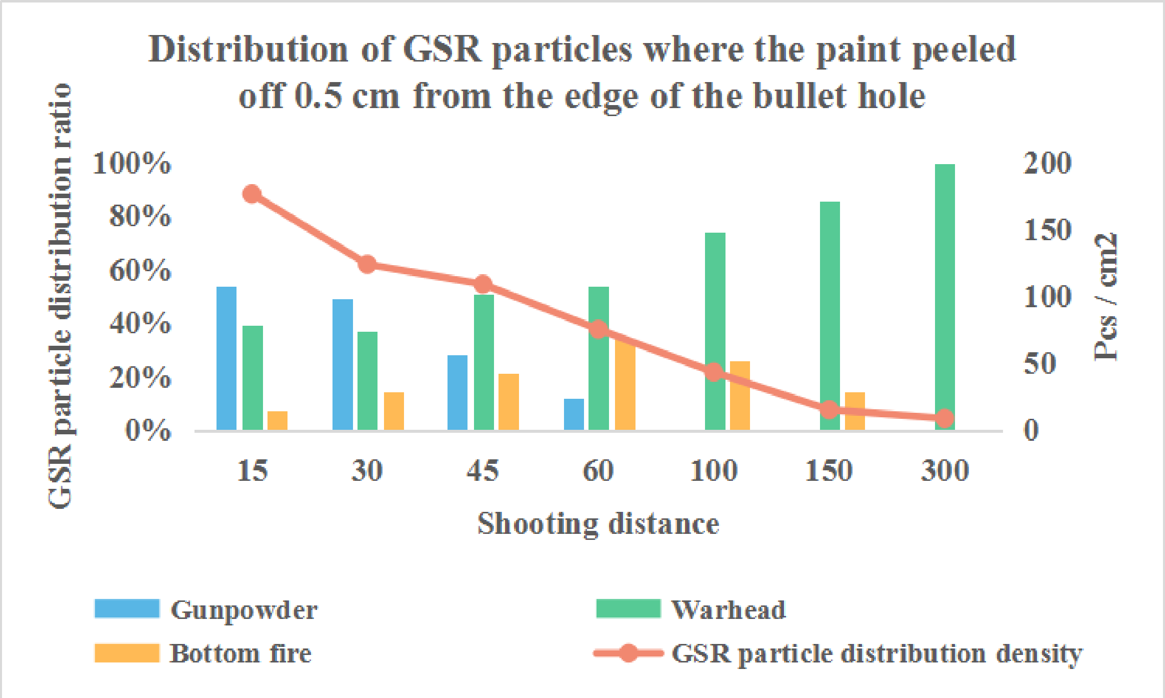


Figure 4. Distribution of GSR particles at the paint peeling off 0.5 cm from the edge of the bullet hole

(4) Inside the petals of the bullet holes

When the range is within 30 cm, spherical bottom fire particles, gunpowder particles, warhead particles can be found, and the number of warhead particles is mostly. When the range is 60 cm, spherical primer particles can no longer be found in the sample, but there are still irregular primer particles. The samples at a range of 1 meter are still dominated by warhead particles, and the bottom fire particles are only a few, and gunpowder particles cannot be found. A small amount of warheads and bottom fire particles can still be found in samples up to a range of 1.5 meters, but the particles are stacked into pieces or scattered irregularly. In the sample with a range of 3 meters, there were only warhead particles, and no other GSR particles were found. Figure 5 is the distribution diagram of GSR particles inside the petals of the bullet hole exit.

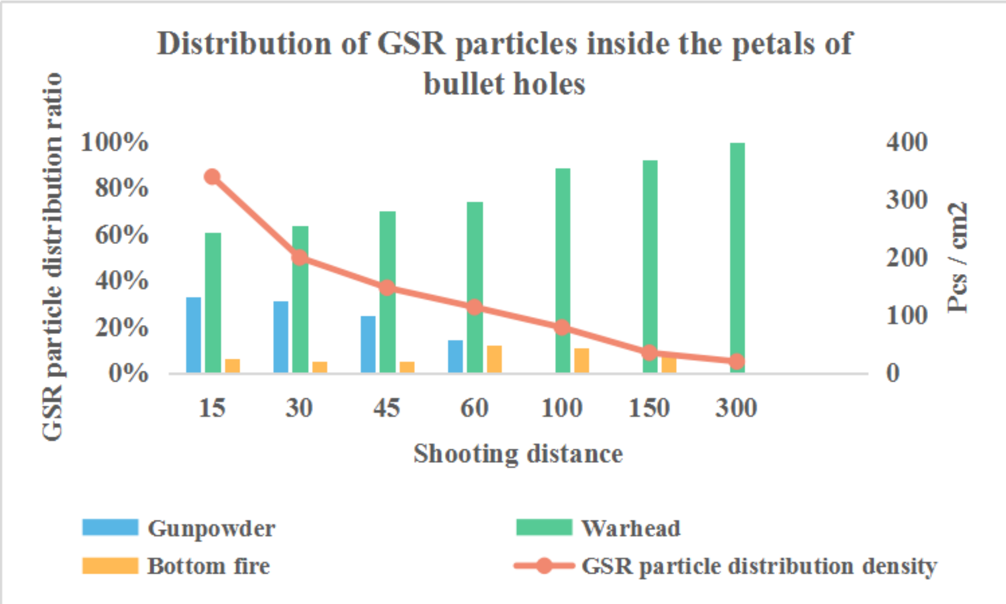


Figure 5. The distribution of GSR particles inside the petals of the bullet hole exit

4.2. Distribution of Gunshot Residues Extracted from Bullet Holes

At the same range, there are more GSR particles in the bullet hole wiper than on the epidermis around the bullet hole, and a small amount of gunshot residue attached to the bullet moving at high speed. When the warhead hits the car's steel plate, there will be a small amount of gunshot residue left with the friction of rotation and left inside the bullet hole. On samples with a shooting distance of 5 cm, a large amount of spherical primer particles containing lead, antimony, and barium can be found; on samples with a shooting distance of 50 cm, more irregular shapes and a small amount of spherical primer particles can be found. From the analysis in Table 4, when the distribution density of the gunshot residue is about 500 pieces / m2, it can be judged that it was shot at a close distance of about 50cm; when the distribution density of gunshot residues is between 300 and 500 / m2, it can be inferred that the shooting distance is in the range of 0.05m to 0.5m; when the distribution density of gunshot residues is between 60 and 180 / m2, it can be inferred that the shooting distance is in the range of 1m to 3m; when the distribution density value of the gunshot residue is about 45-60 pieces / m2, it can be inferred that the shooting distance is in the range of 3m to 5m; when the distribution density of gunshot residues is less than 45 pieces / m2, it can be judged that the shooting distance is above 5m; when the shooting distance is 15m, a certain amount of gunshot residue can still be detected at the bullet hole wiper.

Table 4. Approximate values of GSR particle distribution density of bullet hole wiper

Shooting Distance (m)	GSR Particle Density (pcs / m2)
15	529
30	301.3
45	186.9
60	64.2
100	45.3
150	23

From the experimental results in Table 5, it can be seen that compared with the bullet hole wiper sample, it is relatively difficult to infer the shooting distance by the range of the distribution density value of the gunshot residue compared with the sample of the bullet hole wiper. The elemental composition of the gunshot residue of the wound sample was similar to that of the wiper sample. For the wound samples with shooting distances of 5cm and 50cm, more irregular and small spherical bottom fire particles can be found. Only a small amount of warhead particles can be found in the 1m and 3m wound samples. For samples with a firing distance of 5m and 15m, only a very small number of warhead particles can be found. The average distribution density value calculated from the total number of samples is very low, only 0.2 and 0.1.

Table 5. Approximate values of distribution density of GSR particles in the wound

Shooting Distance (m)	GSR Particle Density (pcs / m2)
15	138.9
30	36.1
45	10.8
60	7
100	0.2
150	0.1

4.3. Trend Analysis of GSR Particles at Different Positions

The unburned or unburned powder particles with large particles and high energy in muzzle air mass, as well as the solid and metal fragments with small particle size, fly forward from the muzzle of the gun in a large cone shape, which will sink on the surface of the target and around the bullet hole when shooting at a short distance. The dispersion range increases with the increase of shooting distance, and the embedded area increases but the density decreases (see Figure 6). This result is confirmed by this experiment. It can be seen from Figure 6 that the number of residues at the circumference of the bullet hole and in the trajectories decreases more than 1 m above the shooting distance, and the GSR particle distribution density values collected from the samples collected by the bullet hole wiping ring at the shooting distance of 1 m to 3 m respectively decrease more smoothly. When the density of GSR particles is large, it should be judged that the range is less than 1m. Since the change of GSR particle density value within 0m ~ 1m changes greatly with the range, it is easier to accurately infer the range, but it is relatively difficult when it is more than 1m. It is easier to infer a more precise range from 0m to 3m based on the distribution density value of residues extracted from the bullet hole wiper.

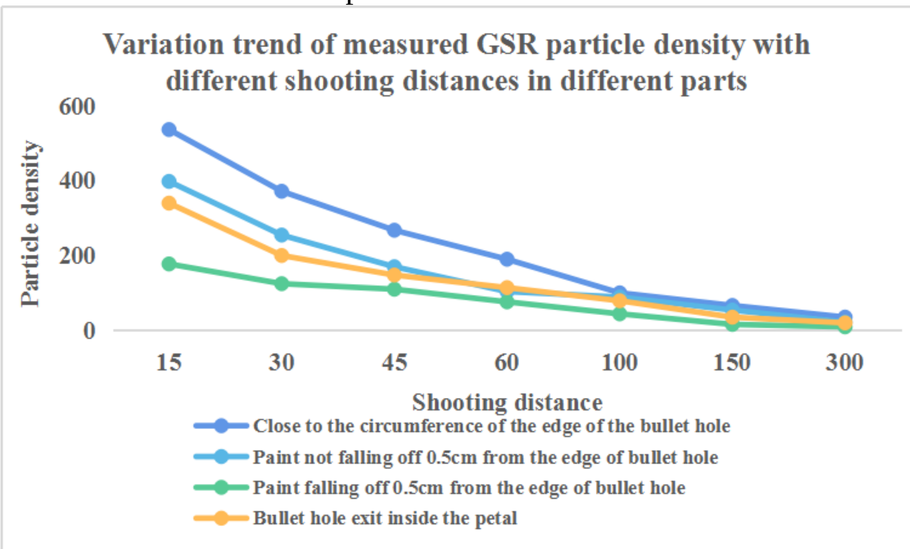


Figure 6. The trend of measured GSR particle density with different shooting distances in different parts

It was also observed in the experiment that the marks of the bullet hole rubbing band are relatively obvious in the range of 15 cm to 30 cm. The warhead armor rotates at a high speed to rub against the periphery of the entrance so that more warhead particles will still be detected as the shooting distance increases. At different shooting distances, this part can always detect more types of residue particles. More residue particles can also be collected at the 45 cm circumference of the bullet whole edge where the paint has not fallen off. When the paint comes off, a considerable amount of residue particles can still be found. The gunshot residues inside the petals of the shooting port mainly come from the friction transfer of the bullet. It can be found from Fig. 6 that the distribution density of the gunshot residue at this location decreases with the increase of the shooting distance, which is relatively stable compared to the other three, that is, it is least affected by the shooting distance. In addition, the material on the surface of the petal part of the ejection port is generally not easily damaged or rubbed off. Therefore, if the gunshot residue particle analysis method is used to confirm whether the suspected hole is a bullet hole, the inside of the petal of the ejection port may be a more reliable sampling location. If the shooting distance is inferred, the portion near the edge of the bullet hole may be the best sampling location.

5. Conclusion

In this study, 9mm revolver and ordinary bullet were used to test the shooting distance of 15cm, 30cm, 45cm, 60cm, 1M, 1.5m and 3M respectively, and the gunshot residue (GSR) was collected from four places. The particle shape of gunshot residue was observed by SEM. In this study, the blank background sample of the test firing vehicle steel plate does not contain the characteristic elements of the firing residues and does not affect the analysis of the firing residues. There is a negative correlation between different shooting distance and the distribution density of gunshot residues. The particles of gunshot residues can be measured in the short distance, and a small number of warhead particles can be found in the long distance.

Gunshot residue particles can be detected in the sample taken from the shooting distance of 5 cm to 3 m, the bullet hole wiper, the 0.5 cm circumference around the bullet hole, and the inside of the petals of the ejection port. There are more gunpowder particles when shooting at close range, and more warhead particles when shooting at long range. Spherical particles can be observed in most samples, and samples of gunshot residues piled up in the form of flakes can be found in the samples inside the petals. Even the samples at the paint peeling off the bullet holes of the automobile steel plate can detect the particles of the gunshot residue. Therefore, under the cross-comparison between the sample extracted on the suspected bullet hole and the sample in the shell, the particle analysis can not only confirm whether it is a bullet hole, but also infer the shooting distance.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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