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Comparison of individual characteristics on surface of a bullet fired from polygonal-rifled barrel using super-high vertical resolution non-contact 3D surface profiler

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ABSTRACT

This research aims to study individual characteristics on surface of a bullet fired from polygonal-rifled barrel and to apply super-high vertical resolution non-contact 3D surface profiler to compare individual characteristics on bullet surface. Four 9-mm full metal jacket bullets were fired from three individual semi-automatic firearms with polygonal rifling. The results show the efficiency of the super-high vertical resolution non-contact 3D surface profiler in identifying the individual characteristics on the surface of a bullet fired from polygonal-rifled barrel. Mean and statistical relationship of depth (Z-axis) of land-engraved areas from the same and different firearms show that the Z-axis of individual characteristics on the surface of a bullet fired from the same polygonal-rifled firearm has no difference in statistical significance at 0.05. Thus, the super-high vertical resolution non-contact 3D surface profiler can be applied to identify and compare individual characteristics on the surface of a bullet fired from a polygonal-rifling barrel.

Keywords: bullet surface; 3D surface profiler; polygonal rifling

1. INTRODUCTION

Bullets and cartridge cases can be linked back to the specific firearms and thus can serve as pieces of evidence in crime scenes. However, cartridge cases are sometimes not found at the crime scene since they are not ejected from a revolver. Moreover, if a gunman fires from a car, the cartridge cases will fall inside the car cabin. Considering the above, bullets are the more important evidence (Akejakrawan, 2017). Therefore, comparative forensic examinations of the bullets from suspected firearms are used to prove the facts in crime commission (Chris, 2008). The comparative study of the bullets is conducted using a comparison microscope (George et al., 2013), whereby skilled and experienced specialists examine and identify the compatibility of the individual characteristics on the bullets and cartridge cases. The markings are compared in two dimensions, the X-axis and Y-axis, to identify the markings of the twists in the barrel, which are similarly characterized among firearms (George et al., 2013), albeit from the same manufacturers (Peter, 2008).

Compared with bullets fired from other types of firearms, those fired from polygonal-rifled firearms with barrel feature rounded and curved patterns (rifling), have different markings on their surface. The less degree of contact between the bullets and twists in

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the barrel causes individual characteristics on bullet surface to be small and shallow (Akejakrawan et al., 2017a). It is known among firearm investigators that the individual characteristics on bullets surfaces are not compatible with the corresponding firearms. This is probably due to polygonal rifling manufacturing process (Criminal Defense Newsletter, 2008). A Comparison microscope, a tool currently used in Thailand to examine and compare ammunitions, cannot clearly detect individual characteristics on surface of bullet fired from a polygonal rifled barrel. Therefore, the investigators cannot clearly see individual characteristics on the bullet surface, which affects their confidence in examining and comparing the markings on the bullet surface (Akejakrawan et al., 2017b).

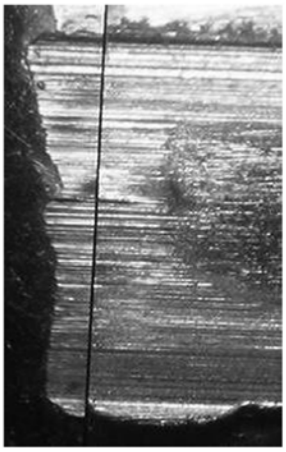

Figure 1 Comparison of the individual characteristic on a bullet surface (Vanderkolk, 2009)

The super-high vertical resolution non-contact 3D surface profiler is a tool used for several industrial applications, for example, to measure the surface of micro drill bits. It is also used to record data on CDs and DVDs. This tool, having interesting features of light wave and high magnification, can measure the surface texture in 3D format: width, length and depth (X-, Y- and Z-axes). Its computer software features color adjustment to represent the depth of the object surface, and this helps distinguish the differences in height (Nikon Corporation, 2014).

To find a tool to compare the individual characteristics on the surface of a bullet fired from a polygonal-rifled barrel, the super-high vertical resolution non-contact 3D surface profiler, a high-magnification microscope, was studied. It can measure the surface of an object in 3D format, and its computer software with color adjustment to represent the depth of the object surface also helps distinguish the differences in height.

2. MATERIALS AND METHODS

2.1 Firing Test

Four shots each were fired from three semi-automatic polygonal-rifled 9-mm Glocks, with Winchester bullets, 115-grain full metal jacket, into a bullet recovery tank, totaling 12 shots. The bullets, with one as the control bullet and the other three as replications, were fired at the bullet recovery room, Central Police Forensic Science Division, Royal Thai Police, Thailand.

2.2 Identification and Photographing of Individual Characteristics on Bullet Surface

The condition of the bullet was checked, and then, curved area of the bullet, which is not used for examining individual characteristics on the bullet surface, was attached to the spindle with hot glue so that the bullet is at 180° (horizontal line) to the spindle. The starting point was set at 0° of the bullet with the metric circle. The rotating platform with attached bullet was placed on a stand of the super-high vertical resolution non-contact 3D surface profiler. Then, a rotating platform was attached to the stand with the big fold back. The spindle was adjusted to 0° perpendicular to the ground. A 5x magnification lens was used, and the focus of the image was adjusted. Then, the platform was slid inward to make the base of the bullet visible on the screen. The bullet spindle was gradually rotated to the right to locate the area where the bullet was scraped with the twists in the barrel (which will be the default spot tracing for the individual characteristics). A 20x magnification lens was used, and the focus of the image was adjusted. The image was slid downward by about 1 mm. Then, the spindle was slightly rotated to the right. The individual characteristics will be seen on the right side of the image. (The main scrapes are seen extending to the left of the image.) Then, the bullet surface was photographed with a super-high vertical resolution non-contact 3D surface profiler. The file details and the photographed positions of the bullet surface were recorded. The bullet surface was photographed until about half of the cylindrical bullet, where the variance occurred. Then, the 5x magnification lens was used to photograph all the scrapes in accordance with the number of twists in the barrel. In this research, the 9 mm semi-automatic Glock with polygonal rifling had a total of six twists. After photographing, the big fold back, which holds the spindle onto the platform, was taken out in order to remove the bullet spindle from the stand of the super-high vertical resolution non-contact 3D surface profiler. The bullet was carefully removed from the spindle and inserted in a plastic holster that records the details of the bullet and firearm used.

2.3 Data Gathering and Individual Characteristics Comparison

The images of each marking on the bullet surface were arranged in order. Each bullet had six markings. Firearm specialists from Central Police Forensic Division, Royal Thai Police (Thailand), examined and identified the individual characteristics on the surface of a bullet fired from the polygonal-rifled barrel. Four bullets were fired from one firearm. Then, the control bullets were compared to identify the individual characteristics on their surfaces before comparing the individual characteristics on the surfaces of replication bullets. If the individual characteristics from the polygonal rifling were found to match, the depth of the bullet surface (Z-axis) was measured using the computer. The depth was divided into two parts: the straight embankment line, mountain-like, referred to as land, with the value set as (+), and the straight lower line, river-like, referred to as groove, with the value set as (-). After measuring the depth of the matched individual characteristics on the bullet surface, the height of the bullet surface was statistically analyzed to comparatively study the individual characteristics.

3. RESULTS

Black lines were drawn to distinguish the individual characteristics on the bullet surface. Here A, B, C, represent the three firearms, while number 1 represents the control bullet and numbers 2, 3, 4 represent the replication bullets. For example, A1 is the first bullet fired from the first firearm. The computer software allows for color adjustment, as seen in the image (Figure 2), to represent the depth of the object surface. Red and blue denote high and low surface, respectively, to distinguish the difference in height. Some images have similar codes; however, the individual characteristics on the bullet surface are different in the land-engraved areas (LEAs). Owing to the firearms used in this research, a bullet renders six LEAs.

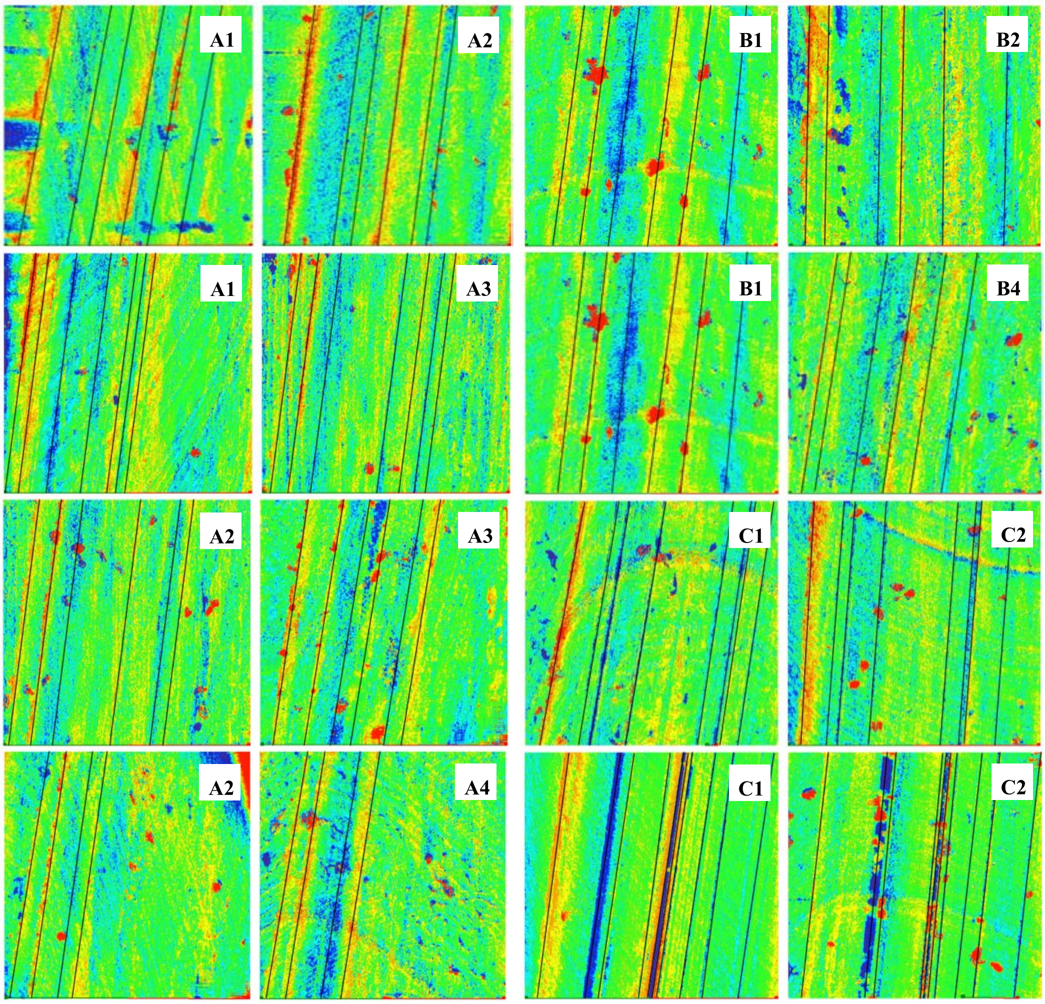

Figure 2 Examples of the matching of the individual characteristics on the bullet surface

Table 1 Matching of the individual characteristics on A1 and A2 bullets surface

Bullet	land	land	land	land	land	groove
A1	1.4 µm	0.4 µm	0.5 µm	1.2 µm	1.0 µm	-0.6 µm
A2	1.5 µm	0.4 µm	0.5 µm	1.2 µm	0.8 µm	-0.6 µm

Table 2 Matching of the individual characteristics on A1 and A3 bullets surfaces

Bullet	land	land	groove	groove	land	groove	land
A1	1.2 µm	1.0 µm	-0.8 µm	-0.5 µm	0.5 µm	-0.6 µm	1.0 µm
A3	1.1 µm	1.2 µm	-0.9 µm	-0.5 µm	0.4 µm	-0.5 µm	0.8 µm

Table 3 Matching of the individual characteristics on B1 and B2 bullets surfaces

Bullet	land	land	groove	land	land	groove
B1	1.2 µm	1.0 µm	-0.8 µm	0.7 µm	0.9 µm	-1.2 µm
B2	1.2 µm	1.0 µm	-0.8 µm	0.7 µm	0.9 µm	-1.2 µm

Table 4 Matching of the individual characteristics on B1 and B4 bullets surfaces

Bullet	land	land	groove	land	land	groove
B1	1.2 μm	1.0 μm	-0.8 μm	0.7 μm	0.9 μm	-1.2 μm
B4	1.1 μm	8.0μm	-0.7 μm	0.6 μm	0.8 μm	-1.1 μm

Table 5 Matching of the individual characteristics on C1 and C2 bullets surfaces

Bullet	land	groove	groove	groove	groove	groove	land	groove
C1	1.2 μm	-1.0 μm	-1.0 μm	-0.8 μm	-0.5 μm	-0.8 μm	1.0 μm	-0.5 μm
C2	1.5 μm	-1.0 μm	-1.2 μm	-0.9 μm	-0.6 μm	-0.8 μm	1.0 μm	-0.7 μm

Table 6 The matching of the individual characteristics on C1-2 and C2-2 bullets surfaces

Bullet	land	groove	land	groove	groove	land	groove	groove	groove	groove
C1	1.0 μm	-2.0 μm	0.5 μm	-1.0 μm	-3.0 μm	1.0 μm	-0.4 μm	-1.0 μm	-1.0 μm	-0.8 μm
C2	0.9 μm	-2.0 μm	0.4 μm	-1.0 μm	-3.0 μm	1.0 μm	-0.5 μm	-0.9 μm	-1.0 μm	-0.7 μm

The A1 and A2 bullets had six matched LEAs markings: five markings of land and one marking of groove (Table 1). Seven matched LEAs markings: four markings of land and three of groove were found between A1 and A3 bullets (Table 2). Six matched LEAs markings: four markings of land and two of groove were observed between B1 and B2 bullets (Table 3) and B1 and B4 bullets (Table 4). In Table 5, it is found that C1 and C2 bullets had eight matched LEAs markings: two markings of land and six of groove. Another comparison on C1 and C2 bullets (i.e., C1-2 and C2-2) had ten matched markings of the LEAs: three markings of land and seven of groove (Table 6). From these results, it can be concluded that the individual characteristics of the land and groove found on all pairs of bullets surfaces had no significant difference ($p>0.05$).

The super-high vertical resolution non-contact 3D surface profiler provides only the object stand with no spindle to attach and rotate the bullet. Hence, inventing a bullet rotating platform to use with the super-high vertical resolution non-contact 3D surface profiler was necessary. The invented rotating platform consists of four main parts: a holder attached to the object stand, a spindle attached to the bullet, a rotary shaft holder and metric circle parts. However, during an experiment, the rotary shaft is movable, which causes a discrepancy in capturing the bullet surface. Therefore, the bullet rotating platform had to be developed by adding another rotary shaft to prevent the rotation of the spindle. Thus, bullet surface capturing by manual operation on the bullet rotating platform will be more stable.

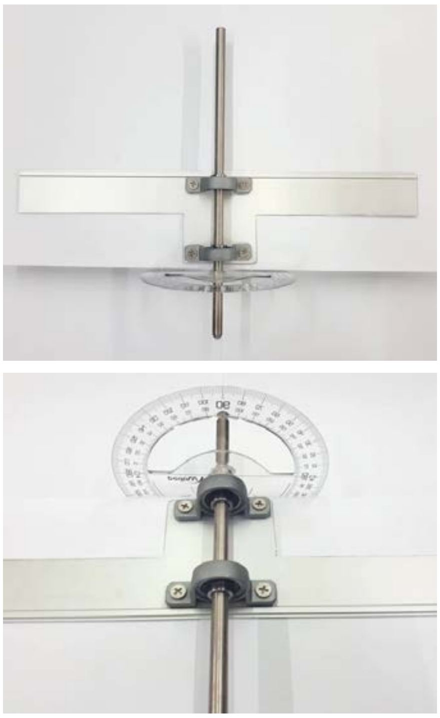

Figure 3 Bullet rotating platform designed for using with 3D surface profiler

4. DISCUSSION

The super-high vertical resolution non-contact 3D surface profiler features state-of-the-art technology, which includes high-resolution image capturing, surface measurement technique with an objective lens to emit and combine light from the reflected object surface within the same lens, and a computer color adjusting software that helps distinguishing the difference in height so that the depth of the surface (Z-axis) can be measured. The super-high vertical resolution non-contact 3D surface profiler can also help increase the specialist's confidence in comparing the individual characteristics on the surface of a bullet fired from a polygonal-rifled barrel, which consequently enhances the investigation. The present comparative study of the bullets fired from the same firearm yielded no significant difference at 0.05, and the bullets fired from different firearms yield a significant difference at 0.05.

In the present study, it was not possible to measure the length of the individual characteristics on the bullet surface (Y-axis) because they were 20 times longer than the area of the lens to photograph. The profiler could only capture a surface area of 0.5 × 0.5 mm (width × length). To measure the length of the individual characteristics on the bullet surface, the total length must appear in one image. Moreover, it was not possible to measure the width of the individual characteristics on the bullet surface (X-axis) because there was variance in the individual characteristics on the surface. This is because the twists in the barrel were rounded and curved, which reduced the depth on the individual characteristics on the bullet surface. This resulted in scrapes and slip, which were variables in the experiment. Therefore, the width of the individual characteristics on the bullet surface could not be statistically analyzed. In a comparative study on the individual characteristics on the bullet surface, numerous markings on the bullet surface have to be photographed, and there is no software to help the specialists to compare the individual characteristics on the bullet surface. Moreover, several images have to be examined, and comparing the individual characteristics on the surface of a bullet fired from a polygonal-rifled barrel is time-consuming.

The super-high vertical resolution non-contact 3D surface profiler should be further developed in terms of hardware and software. Such development will result in a faster and more continuous bullet surface capturing, which will contribute to an easier and more convenient 3D study of the bullet surface and support further developments.

5. CONCLUSION

The super-high vertical resolution non-contact 3D surface Profiler can effectively detect the individual characteristics caused by the twist markings on the surface of a bullet fired from a polygonal-rifled barrel. Thus, the individual characteristics on the bullet surface can be clearly seen. The super-high vertical resolution non-contact 3D surface profiler can therefore be effectively applied to compare the individual characteristics on the surface of a bullet fired from a polygonal-rifled barrel.

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