An Examination of Five Consecutively Rifled Hi-Point 9mm Pistol Barrels with Three Lands and Grooves Left Twist Rifling to Assess Identifiability and the Presence of Subclass Characteristics

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ABSTRACT

Consecutively manufactured tools are the most likely to share characteristics and features associated with the forensic comparison process, and therefore present a worst case scenario for the firearm and tool mark examiner. Similar to previous studies on consecutively manufactured tools, this research examines the individuality of marks present on a bullet fired from one of five consecutively rifled barrels and the ability to use those marks to identify a fired bullet to the specific barrel from which it was fired. In addition, the potential for subclass characteristic carryover created during various processes associated with the manufacture of Hi-Point 9mm pistol barrels with three lands and grooves left twist rifling was assessed by observing key steps in the manufacturing process, and examining and comparing the barrels and bullets fired from them.

Introduction

The individuality of firearm components originates with the manufacturing processes involved in producing the finished parts. Processes such as filing, sanding and grinding lend themselves to more individuality due to the randomness with which the tool surface makes contact with the component part and the relative quickness with which the tool surface changes through wear. Processes such as casting, forging and molding tend to produce relatively uniform component parts because each component part comes into contact with the tool surfaces in the same manner and the tools wear much less quickly. Therefore, these processes do not typically impart significant individuality, but individuality may be produced if the component part undergoes subsequent finishing processes such as filing, sanding or grinding.

With these manufacturing processes in mind, it is generally accepted that consecutively manufactured items, regardless of manufacturing process, pose the highest probability of similarity when microscopically examined. That is, two consecutively manufactured items will share physical characteristics imparted by the manufacturing process and tool(s) used and be more alike than similar items manufactured using different methods or tools. Therefore, consecutively manufactured component parts constitute a worst case scenario in the field of forensic firearm and tool mark identification – surfaces of two component parts sharing very similar physical characteristics and features, which then transfer those characteristics to another surface (e.g. bullet, cartridge case).

With that in mind, demonstrating that sufficient individual characteristics exist between two or more consecutively manufactured component parts, and that properly trained firearm and tool mark examiners can utilize those marks to accurately identify the specific source from a set of consecutively manufactured parts is one of the best methods for validating the science of firearm and tool mark identification.

Background

Several studies examining consecutively manufactured firearm barrels have been conducted [1 – 10]. These studies involved various numbers of consecutively manufactured firearm barrels, rifling methods and tools, firearm types, and manufacturers. In each of these previous studies the researcher(s) determined bullets fired from consecutively manufactured barrels contained the quantity and quality of individual characteristics necessary to reliably discriminate and accurately identify each bullet to the specific barrel from which it was fired. This was confirmed through comparison by properly trained firearm and tool mark examiners or automated comparison technology using mathematical algorithms to assess the strength of the comparisons.

Similar to previous research, the present research is generally concerned with the examination and comparison

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Note: All design specifications, manufacturing processes, and technical data contained in this paper are based on information provided by the manufacturers. Design specifications, manufacturing processes, material suppliers, etc. are subject to change at any time. Although the information contained in this paper is a summary of current design specifications and manufacturing processes at the facilities identified, it does not include specifications and processes utilized in the past or those that may be used in the future, unless otherwise stated.

of bullets fired from consecutively manufactured barrels. More specifically, Hi-Point 9mm pistol barrels that have been consecutively rifled using the same rifling method and tool. This research differs from previous research regarding consecutively manufactured or rifled barrels in the following three ways:

(1) Hi-Point Firearms uses pre-formed steel alloy tube for the production of their firearm barrels. The manufacture of these barrels does not involve drilling, reaming, honing, burnishing, or lapping.

(2) A finishing process for Hi-Point firearm barrels involves a coating of epoxy paint to protect the barrel from damage and corrosion. This coating is applied by dipping the barrels, which coats the exterior as well as the bore surface of the barrel.

(3) The rifling characteristic of Hi-Point 9mm pistol barrels is currently three lands and grooves with left twist. These general rifling characteristics are unique to Hi-Point 9mm pistol barrels and were chosen by the manufacturer in an effort to assist forensic firearm examiners with casework.

The primary objectives for this research were to answer the questions; do consecutively rifled Hi-Point 9mm pistol barrels exhibit subclass characteristics as a result of the manufacturing or rifling processes, and do bullets fired through consecutively rifled Hi-Point 9mm pistol barrels exhibit a sufficient quantity and quality of individual characteristics to be identified to the specific barrel in which they were fired? To achieve these objectives key steps in the manufacture of Hi-Point pistol barrels were observed and five consecutively rifled 9mm pistol barrels were obtained from the manufacturer (Hi-Point Firearms in Mansfield, Ohio). Bullets were test fired and recovered from each barrel, a cast of the muzzle portion of the bore of each barrel was made, and the bore casts and test fired bullets were examined and compared.

Materials & Methods

Five 9mm pistol barrels were consecutively rifled using the same process and tool and marked by stamping the number "0," "1," "2," "3," or "4" on the outer surface of the barrel near the muzzle. The barrel numbers represent the order in which the barrels were rifled. Prior to rifling, the barrel blanks were not tracked and had not necessarily been consecutively manufactured or machined [11]. However, based on observed manufacturing processes, it is reasonable to conclude that the barrel blanks used to create the five consecutively rifled barrels for this research were cut from the same length of steel alloy tube. After rifling, the barrels continued through additional finishing processes with their identities preserved by the stamped number.

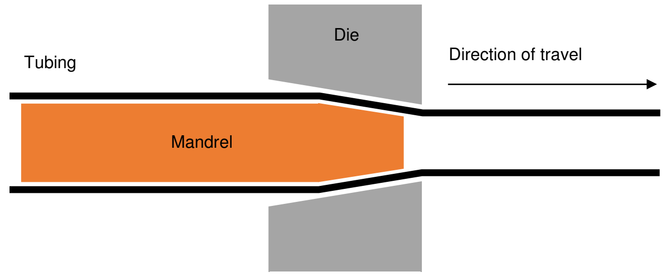

Figure 1: Drawn over mandrel (DOM) method of reducing the diameter of steel tubing

Hi-Point Firearms uses vendors to provide various materials and perform various manufacturing processes for some of their firearm component parts [11]. As it pertains to this research, the materials and relevant manufacturing processes used to produce Hi-Point pistol barrels will be briefly discussed. The Plymouth Tube Company (PTC) facility located in Streator, IL produces the steel alloy tubing to the outer and inner diameters specified by Hi-Point Firearms. PTC starts with steel alloy tube of a larger diameter purchased from another source. The steel alloy specified by Hi-Point Firearms for the production of firearm barrel blanks is ASTM A-519, Grade 4130 chrome-molybdenum, or chrome-moly, with a maximum hardness of RC25. The dimensional specification for the outer diameter of the tubing is 0.563-0.568 inch (14.30-14.43mm), with an inner diameter measurement of 0.341-0.346 inch (8.66-8.79mm), and a wall thickness of 0.1085 inch (2.756mm) [12]. Chrome-moly steel alloy provides a better strength to weight ratio than conventional steel, and is commonly used for high temperature and pressure applications. These properties make chrome-moly steel alloy a suitable material for firearm barrels.

PTC prepares the chrome-moly tubing for the drawing process by annealing, cutting to length, and pickling. The pickling process used by PTC is similar to the pickling process used in the manufacture of ammunition cartridge cases. The final step in the preparation is the application of a dry lubricant, sodium stearate, which facilitates the drawing process. PTC uses a process known as drawn over mandrel (DOM), which is a cold drawing process that simultaneously reduces the inner and outer diameters of the tubing. The tubing is slid over a mandrel and lowered into position in front of the die. A previously formed nose (significantly reduced diameter of approximately 6 inches in length) at one end of the tube is fed through the die and gripped by a shuttle. The shuttle pulls the tubing over the mandrel and through the die in a single step (**Figure 1**). The tubing can be drawn twice using this process without reannealing. Once the specified inner and outer diameters are achieved, the tubing is treated with heat (annealed) to relieve the stress imparted by the drawing process, after which it is straightened, checked for quality, and marked with the manufacturer's name and product information [13].

Vulcan Products, LLC in Galion, OH is a metal machining shop that purchases chrome-moly steel tubing from PTC. Vulcan uses computer numerical control (CNC) machines to transform the steel alloy tubing into barrel blanks for Hi-Point Firearms. The stock 18 to 24-foot (5.5-7.3m) lengths of tubing are first cut into 42-inch (1.1m) sections. These sections are then loaded onto the CNC magazine to feed into the machine. A section of tubing is drawn into the CNC machine where approximately 0.010-0.015 inch (0.254-0.381mm) is trimmed to square the leading edge. A rough chamber is reamed in what will become the breech end of the barrel blank. Next, a band approximately 0.06 inch (1.52mm) deep and approximately 0.20 inch (5.08mm) wide is cut approximately one half inch (12.7mm) from the end of the work piece. This band will be used to properly seat and secure the barrel blank in a hydraulic press during the rifling process done at Hi-Point Firearms. The outer diameter is then reduced to approximately 0.520 inch (13.208mm) for approximately 0.25 inch (6.35mm) of the breech end of the barrel blank. This area is then knurled to produce a surface suitable for a subsequent process. The last steps for the CNC machine are to cut the radius of the crown followed by a perpendicular cut to separate the blank from the remaining stock. The lifespan of this cutter is approximately 600-700 pieces before it is replaced. This cutter is discarded (recycled) and is not resharpened [12].

The final machining step is to clean up the burrs remaining at the junction between the crown and bore formed as a result of the perpendicular cut made in the CNC machine. A worker takes each barrel blank and manually deburrs the muzzle end of the barrel blank using a 4-fluted counter sink bit mounted on a drill press (**Figure 2**). This step in the process is important because it is done manually and chips accumulated on the bit are not removed prior to deburring the next work piece. These factors create unique surface features at the junction between the crown and bore, the last surface to come into contact with a fired bullet.

Vulcan Products sends batches of machined barrel blanks to Hi-Point Firearms in Mansfield, OH. Prior to rifling, the barrel blanks are soaked in a solvent to remove unwanted oils. A moderate amount of lubricant (85W-140 gear oil) is introduced into the interior of the barrel blank, which is then seated and secured, breech end up, under a small hydraulic ram (**Figure 3**). A solid carbide rifling button, manufactured by Drill Masters Eldorado Tool, is placed into the rough chamber and the hydraulic press is activated, pushing the button through the bore. After being pushed through the length of the barrel, the button drops out of the barrel onto a chute for use in the

Figure 2: Manual deburring method used by Vulcan Products, LLC Galion, Ohio

Figure 3: Button rifling apparatus used by Hi-Point Firearms Mansfield, Ohio

next barrel blank. The newly rifled barrels are packaged for shipping to Yoder Industries for the next process.

Yoder Industries, Inc. located in Dayton, OH receives the newly rifled barrels from Hi-Point Firearms. Yoder, an aluminum and zinc casting company, casts a block of zinc around the breech end of each barrel. Although this process has no effect on the bore surface, it is mentioned for the purpose of maintaining the continuity of the manufacturing process. The newly cast barrels are returned to Hi-Point Firearms for trimming and sanding [11].

The final step before assembly is to apply a protective coating to the barrels at Industrial Paint and Strip West, LLC in Waynesfield, OH. Barrels are first cleaned then coated with zinc phosphate before an epoxy electrocoat is applied. Because the barrels are electrically charged during the electrocoating process, the coating of the interior surface is not as uniform as the exterior surface. This was observed on each of the five consecutively rifled barrels used in this research because the barrels obtained from Hi-Point Firearms were new and unfired. The barrels then move through an oven to cure [14]. Once the coating process is complete, the barrels are sent back to Hi-Point Firearms for chamber reaming, assembly, test firing, packaging, and shipping to distributors.

Hi-Point Firearms changed their 9mm pistol barrel rifling characteristic from 9 lands and grooves with left twist to its current characteristic of 3 lands and grooves with left twist in September 2011. The serial number of the first Hi-Point Model C9 9mm pistol manufactured with a 3 left barrel was P1622200 [11]. Hi-Point Firearms offers a comprehensive lifetime guarantee for its firearms and have had Model C9 pistols returned for repair. Those pistols returned for issues related to accuracy will have the 3 left barrel replaced with a 9 left barrel. The processes for the manufacture of the 9 left barrels are identical to the 3 left barrels with the exception of the rifling button used [11].

In order to preserve a representation of the condition of the bore and to examine and compare the surface features present, casts were made of barrels 1 and 3 using Mikrosil™ casting material. Upon examination of these casts it was found that the epoxy coating on the barrel obscured many of the individual characteristics resulting from manufacturing processes. At the completion of test firing (fifty-five bullets fired in each barrel), casts were made of the muzzle end of the bore of barrels 0, 1, 2, 3, and 4. These casts were microscopically compared and found to contain random linear surface imperfections present on the lands and grooves that were parallel with the longitudinal axis of the bore (**Figure 4**).

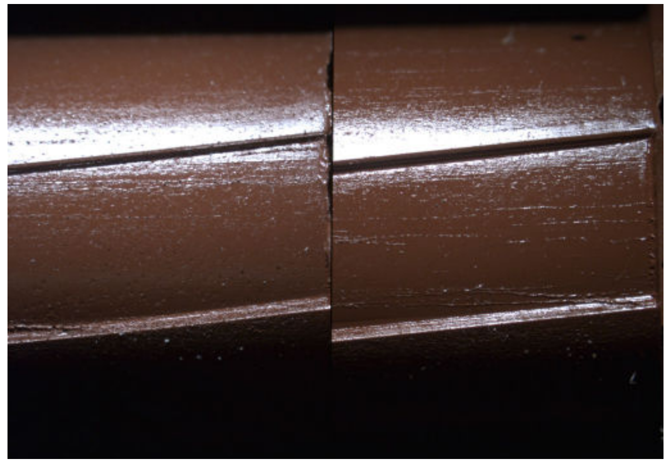

Figure 4: Comparison of bore casts of consecutively rifled Hi-Point 9mm pistol barrels (completion of test firing). Barrel 0 (left), Barrel 1 (right), 10X.

The first step in obtaining fired bullets for comparison was to fire several bullets through each barrel to sufficiently remove the epoxy coating from the interior surface of each barrel. A quantity of fifty rounds was chosen for the break in period. During the break in period, four bullets fired from each barrel were recovered, marked and retained for comparison. The sequence interval for these bullets was 1, 10, 25, and 50 for each of the five barrels. With the exception of the recovered bullets, Federal 9mm Luger caliber, 147 grain Hydra-Shok® jacketed hollow point cartridges were fired during the break in period and were not recovered.

Selected bullets were recovered using a horizontal water tank and marked by scribing each with the appropriate barrel number and sequence number. For example, the first bullet fired through barrel 0 was marked “0/1,” the tenth bullet was marked “0/10,” the twenty-fifth bullet was marked “0/25,” and so on for each of the bullets fired in each of the five consecutively rifled barrels. The bullets were marked immediately after recovery to avoid mislabeling or mixing them up during examination and comparison. For each of the five barrels, fired bullets 1, 10, 25, 50, 51, 52, 53, 54, and 55 were recovered and marked as previously described. Each barrel was cleaned using a lubricated patch followed by dry patches after firing bullet 50. A total of forty-five fired bullets, nine from each barrel, were recovered and retained for use in this research. A single box of American Eagle® Federal Cartridge Company (lot Q22G005) 9mm Luger caliber, 115 grain full metal jacket cartridges was the source of all forty-five recovered fired bullets. The same Hi-Point Model C9 frame and slide were used to test fire each of the five barrels.

Figure 5: Interior surface of steel alloy tubing manufactured by Plymouth Tube Company Streator, Illinois, 20X

Results and Discussion

The cold drawn over mandrel process used by the Plymouth Tube Company in the production of chrome-moly steel alloy tubing creates a seamless and macroscopically smooth finished product. The interior surface of the tubing however exhibits microscopic imperfections running parallel with the length of the unrifled tubing (**Figure 5**). During the drawing process the die, mandrel and tubing are not rotated or twisted. The die and mandrel are stationary while the tubing is drawn straight through the die and over the mandrel. The exact cause of these linear imperfections is not known but may originate from contact with the working surface of the mandrel, stresses caused by the compression of the tubing material, or a combination of these and other factors. The linear imperfections were observed to be discontinuous and randomly distributed on the surface. These imperfections persist, at least to some extent, through the remaining manufacturing processes to the finished pistol barrel because the only subsequent processes to affect the interior surface of the tubing are the rifling and coating processes.

Because these imperfections are parallel with the length of the tubing, the twist pattern of the rifling crosses them at a shallow angle. A bullet engaging the rifling will travel down the barrel crossing the topography of the imperfections at the same angle as the twist pattern of the lands and grooves. Some of these prominent imperfections are visible on the lands of the rifling, while their profiles have been reduced significantly and are not as readily observed in the grooves as a result of the cold swage button rifling process. These imperfections cannot be considered subclass characteristics due to their intermittent nature. Any imperfections that may extend a sufficient length to carry over between barrels cut from the same length of tube may create a subclass characteristic in the barrels. However, the fact that the bullet does not follow the marks in a parallel direction negates their potential influence as subclass characteristics.

The CNC machining utilized at Vulcan Products creates very uniform barrel blanks. However, the manual deburring process introduces individual characteristics at the junction of the bore and crown. This area has a high potential for leaving marks at the heel of a bullet as it is the last portion of the barrel to make contact with the bullet as it leaves the bore. Despite the product consistency and uniformity achieved by CNC machining, the manual deburring process creates individuality and uniqueness that may assist in the identification of bullets fired from consecutively machined barrels.

Hi-Point Firearms has always used the button swage method of rifling for the production of their firearm barrels. Rifling buttons are used by Hi-Point Firearms until they break, usually as a result of being dropped on the concrete floor of the facility. A rifling button may rifle thousands of firearm barrels before it is replaced. This rifling process and the fact that a single tool is used to rifle numerous barrels have the potential for creating subclass characteristic carryover. However, careful examination and comparison of the bore casts and bullets fired from the consecutively rifled barrels used in this research showed no significant subclass carryover in the barrels or the bullets fired from them.

The bore casts and fired bullets were examined and compared using a Leica FS C comparison microscope. Images were captured using a Leica DFC420 camera mounted to the comparison microscope. Little time was devoted to comprehensive intra and inter comparisons of fired bullets 1, 10, 25, and 50 (break in period). Comparison of these bullets was limited to determining if a fired bullet could be indexed with the next recovered fired bullet in the sequence (i.e. 0/1 with 0/10, 0/10 with 0/25, etc.). Surprisingly, all but one pair of fired bullets could be indexed. The fired bullets that could not be indexed were 0/1 with 0/10. Fired bullets 50 (end of the predetermined break in period) and 55 (final bullet fired through each barrel) from each barrel were also compared in the same manner. All pairs were able to be indexed with the exception of 3/50 and 3/55. These two pairs of fired bullets could not be confidently indexed due to insufficient reproduction of individual characteristic marks.

Based on the correspondence observed when indexing fired bullets 1, 10, 25, 50, and 55, intracomparisons of fired bullets

53, 54 and 55 from each barrel were then performed (**Table 1**). That is, fired bullets 53 and 54, 53 and 55, and 54 and 55 from barrel 0 were compared. Fired bullets 53, 54 and 55 from each of the five consecutively rifled barrels were compared in the same manner. Of the fifteen comparisons conducted, approximately one half resulted in an identification. Inconclusive findings resulted from insufficient reproduction of individual characteristic marks.

Identifications were made for all three comparisons of bullets 53, 54 and 55 fired from barrel 2. No identifications could be made for the three comparisons of the bullets fired from barrel 3. Barrels 0 and 1 each had one identification and two inconclusive results. Identifications were made for the comparison of bullets 53 and 54, and 53 and 55 fired from barrel 4, but while some agreement of individual characteristics was observed when comparing bullets 54 and 55, the agreement was insufficient for identification.

To determine if any subclass characteristics were present and could be observed, intercomparisons were then performed for bullets 53 and 54 fired from each barrel. Bullet 53 fired from barrel 0 was first intercompared with bullet 53 fired from barrels 1, 2, 3, and 4. These comparisons continued until bullet 53 fired from each barrel was compared with bullet 53 from each of the other barrels. The same comparisons were then performed for bullet 54. Finally, bullets 53 and 54 fired from each of the five consecutively rifled barrels were inter-compared. A total of forty inter-comparisons were performed. While some coincidental agreement of individual characteristics was observed during some of these comparisons, it was limited in nature. When the bullets were rotated, any coincidental agreement of individual characteristics quickly gave way to disagreement in subsequent land impressions. **Figure 6** through **Figure 11** show examples of some of the agreement and disagreement observed while performing these comparisons.

The land widths were measured and found to be approximately 0.130-0.134 inch (3.302-3.404mm) and the groove widths approximately 0.217-0.221 inch (5.512-5.613mm) for the 3 left rifled barrels. These measurements were obtained from Mikrosil™ barrel casts due to the poor and inconsistent reproduction of the trailing edges of the land impressions on the fired bullets.

Barrel No./Bullet Sequence		Conclusion
0/53	0/54	ID **
0/53	0/55	INC (2)
0/54	0/55	INC (2)
1/53	1/54	ID **
1/53	1/55	INC (2)
1/54	1/55	INC (2)
2/53	2/54	ID *
2/53	2/55	ID **
2/54	2/55	ID *
3/53	3/54	INC (2)
3/53	3/55	INC (2)
3/54	3/55	INC (2)
4/53	4/54	ID **
4/53	4/55	ID *
4/54	4/55	INC (1)

ID = Identificaiton

** Sufficient agreement in two land impressions

* Sufficient agreement in one land impression

INC = Inconclusive

(1) Some agreement, insufficient for identification

(2) Neither agreement nor disagreement due to absence, insufficiency or lack of reproducibility

Table 1: Comparison of the 53rd, 54th, and 55th bullets fired from each barrel

Conclusions

This research confirms the observations and conclusions of research previously conducted regarding consecutively manufactured or rifled barrels. First, the consecutively rifled barrels used in this research possess individual characteristics that may be transferred to bullets, and these marks on the fired bullets can be used to accurately identify the specific barrel through which the bullet passed. Second, while some coincidental agreement of individual characteristic marks was observed on bullets fired from different barrels, the disagreement of individual characteristics observed on other corresponding areas of the bearing surfaces of the bullets far outweighed the minimal coincidental agreement. An issue with the barrels and/or ammunition used in this research was a lack of consistent marking. However, when a sufficient quantity and quality of individual characteristic marks were present in the same relative position on the bearing surfaces of two fired bullets, a correct identification could be made.

Subclass characteristics were not observed on the interior surface of the five consecutively rifled barrels used in this research. Subclass characteristics should not be expected in Hi-Point 9mm pistol barrels primarily due to two steps in the manufacturing process, specifically cold drawing and manual deburring, that tend to create individual characteristics on barrel surfaces that may be subsequently transferred to the bearing surface of bullets fired in them. No significant subclass characteristics resulting from the button rifling process used by Hi-Point Firearms were observed.

Acknowledgements

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Mr. Ralph Chamberlin, President of Vulcan Products, LLC, and Mr. Cam Valle, General Manager and Mr. Dave Miller, Production Engineer at Plymouth Tube Company provided access to production facilities, information and materials that were instrumental in interpreting the results of this research.

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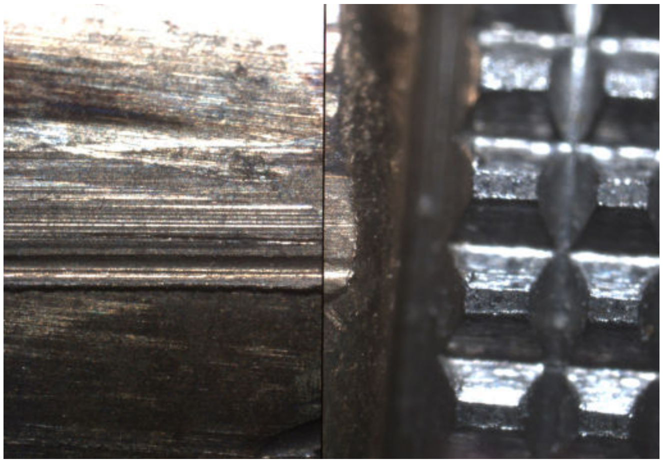

Figure 6: Barrel 0 Bullet 53 (left), Barrel 1 Bullet 53 (right). Driving edge of land impression 1, 40X

Figure 7: Barrel 0 Bullet 53 (left), Barrel 1 Bullet 53 (right). Driving edge of land impression 2, 40X

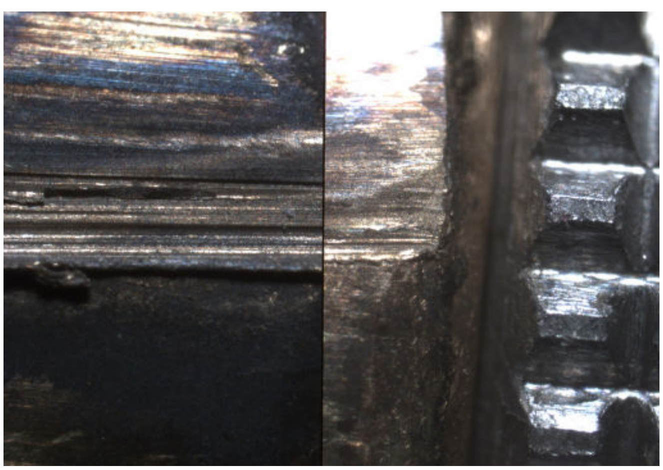

Figure 8: Barrel 0 Bullet 53 (left), Barrel 1 Bullet 53 (right). Driving edge of land impression 3, 40X

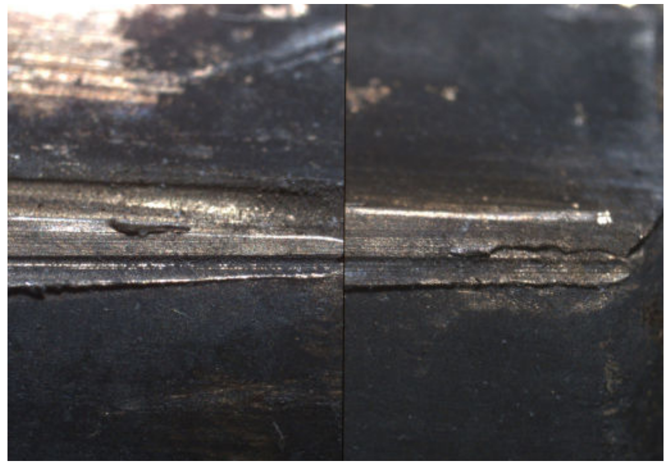

Figure 9: Barrel 0 Bullet 54 (left), Barrel 4 Bullet 54 (right). Driving edge of land impression 1, 40X

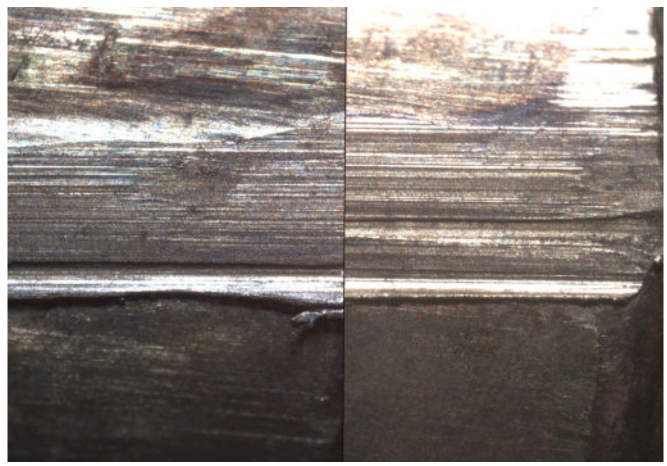

Figure 10: Barrel 0 Bullet 54 (left), Barrel 4 Bullet 54 (right). Driving edge of land impression 2, 40X

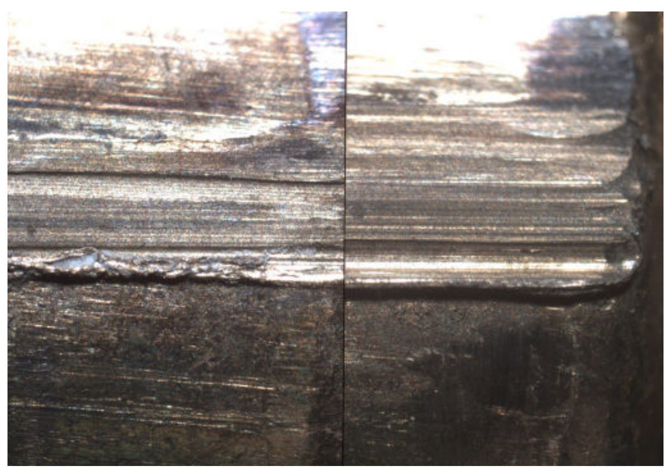

Figure 11: Barrel 0 Bullet 54 (left), Barrel 4 Bullet 54 (right). Driving edge of land impression 3, 40X