The Potential for and Persistence of Subclass Characteristics on the Breech Faces of SW40VE Smith & Wesson Sigma Pistols

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ABSTRACT

An article published in the 2007 AFTE Journal Summer edition discusses a situation in which a high degree of subclass characteristics were found in two firearms during routine casework. Gene Rivera of the Charlotte-Mecklenburg Police Department Crime Laboratory describes how these two firearms came to be discovered through the use of NIBIN, and reemphasizes the importance of the firearms examiner's job to be able to recognize and distinguish subclass characteristics when present. It was this striking case that prompted further research into the propensity and persistence of subclass characteristics in the Sigma Series line, and the potential for individuality to be established on these firearms.

Review and Background

Recognizing subclass characteristics can be one of the biggest challenges and most important tasks of the firearms examiner. Failure to do so when they are present could lead to their being confused with individual characteristics. However, subclass need not be a thorn in the side of the discipline of firearms identification. Over the years many papers have been written and research conducted identifying the causes of subclass characteristics and the types of machining processes that have the potential to produce them. Warnings have been given time and time again regarding the need to identify subclass characteristics when present, and distinguish them from individual characteristics before drawing a conclusion during an examination. Fortunately, subclass characteristics are uncommon and occur infrequently on machined surfaces. When they do occur, they can be recognized by a well trained and conscientious firearms examiner.

As defined by AFTE subclass characteristics are:

Discernible surface features of an object which are more restrictive than Class Characteristics in that they are:

- Produced incidental to manufacture.
- Are significant in that they relate to a smaller group source (a subset of the class to which they belong).
- Can arise from a source which changes over time.
- Examples would include: bunter marks, extrusion marks on pipe, etc.

(Caution should be exercised in distinguishing subclass characteristics from Individual Characteristics.) [5]

Subclass characteristics are not individual because they are not unique to only one tooled surface. Hence, these characteristics are those that exist on more than one surface produced from the same machining process in close succession. The tool that machined them did not change sufficiently during the process as to create readily discernable markings from one surface to the next. If subclass characteristics indeed do appear during an examination, it is the firearms examiner's job to recognize them as such and disregard them when making an identification.

Because subclass characteristics only exist on surfaces that are machined from the same tool in approximately the same state of wear, surfaces that are consecutively machined or formed are the only ones that would have the potential to possess them. For this reason, many studies have been conducted validating the science of firearms and toolmark identification using consecutively manufactured items. Previous studies have identified some of the types of machining tools with the propensity to cause subclass as to include the end mill, lathe turner, and broach. Subclass characteristics usually exhibit as gross, continuous, uniform, evenly spaced, parallel and/or concentric markings.

In a study of consecutively manufactured Ruger bolt faces, Lopez and Grew found "an alarmingly high level of correspondence between the milled striae" of three consecutively manufactured bolt faces when comparing their casts [2]. The examiners concluded from their study that "the sharpened surfaces of the milling cutter do not appear to [have

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worn] quickly enough to create striated marks that are readily distinguishable from one another on consecutive work pieces. Therefore, the striations produced by the cutting blades should not be used to make an identification, rather accidental marks, such as tearing, chatter and scratches provide the unique signature for this type of machined item" [2].

Similar to the "alarming" correspondence in the Ruger study, another case of subclass described as "alarming" drew the attention of the firearms identification community more recently [3]. In a 2007 AFTE Journal article, Gene Rivera of the Charlotte-Mecklenburg Police Department Crime Laboratory discusses a remarkable occurrence of subclass characteristics exhibited on the breech faces of two Smith and Wesson Sigma Series pistols that were close in serial number. The discovery of the subclass was made during routine casework through NIBIN examinations. When the two firearms in question were examined, casts of the breech face were taken that exhibited "virtually indistinguishable" parallel toolmarks [3]. Test fires from the two pistols were obtained using Remington, Federal and CCI brand cartridges. The original evidence submitted in the case contained PMC cartridge cases. On the cartridge cases gross, uniform, parallel striae were apparent on the primer. The toolmarks on the casts were much finer than those exhibited on the discharged cartridge cases.

Individuality could be established using the firing pin aperture shear marks, which were markedly different between the two pistols. However, not all brands of ammunition mark exactly the same due to a variety of reasons including metal hardness, pressure differences, etc. This phenomenon is exemplified in this study on the CCI brand test fires, which produced much less shear than the Remington and Federal cartridge cases. Rivera postulates that some brands may not exhibit shearing at all, complicating the potential for individuality to be established if subclass is present on the rest of the primer markings. Because the subclass characteristics in this study were so compelling, concern was raised that a firearms examiner might unwittingly use them for an identification if no shear marks are present.

Rivera points out in his article that although the two firearms were close in serial number (separated by only eleven numbers), there was no way to determine in what order the slides were produced [3]. Consultation with Smith and Wesson elicited critical information on the manufacturing process and offered the reason why serial number order did not mean order of slide production. After being broached, he notes that approximately 200 slides are tumbled and then randomly restacked in bins for assembly. Any consecutiveness before tumbling would be obliterated during this process and further complicated when the slides and frames are randomly picked from separate bins when being fitted together. For this reason, it could only be surmised that the slides were produced during a run between sharpenings of the broach, anywhere from "between a couple of hundred to one thousand slides" [3]. But do the broach's individual characteristics change so little over that entire span that all slides produced in that run would exhibit subclass characteristics, or does this broach, like most other machining tools, wear substantially enough to change the characteristics left behind on the slides produced as proximity decreases?

That is one question among others that Rivera's article evoked and prompted for further research. Could these two slides have been produced one after the other, and just so happened to have coincidentally been used in crimes that led to their being confiscated and examined? Or were they produced by the same tool but separated by a longer period of time between productions, with many other slides sharing similar subclass characteristics in between them? Is there any way even to find out this information? And are the subclass characteristics that the slides share an insurmountable problem for the firearms examiner, say for instance, if the quite blatant individual shear marks do not happen to be produced on all cartridges fired in them?

The findings of this particular case study and questions that followed led to the undertaking of research for further information. In addition to the questions above, another uncertainty was whether or not slides produced consecutively for this pistol line usually do exhibit subclass characteristics when new. It was expected that under the same manufacturing conditions they would, but only further research could support or refute that hypothesis. And if they do exhibit subclass, are the test fires still able to be identified to the slides from which they are fired based on their individual characteristics?

Research

In order to attempt to answer these questions and examine the propensity and persistence of subclass characteristics on the Sigma Series 40 S&W caliber pistols, it would be necessary to obtain new, consecutively manufactured slides from Smith and Wesson. The first area to be addressed would be how many slides would be studied in this undertaking. Many factors would influence this decision. First, what is an appropriate number of slides from a purely research-oriented perspective? Second, depending on cooperation from the manufacturer, what would the budgetary concerns allow for? Third, what is a practical number of slides to study within the given time period for conducting the research, as time restraints would play a key role in what could be accomplished? Finally, what foundation has past similar research laid for the number of specimens chosen for consecutive studies?

Over the course of the discipline's history, studies have been conducted using consecutively manufactured tools to test for individuality and at the same time, identify areas of potential subclass. In prior studies of consecutively manufactured tools, ten has commonly been the number chosen to examine. This number seems to allow for a wide enough span to examine toolmarks from the first produced in the run to the last, and make a statement on whether or not subclass characteristics continue to carry-over, or whether the tool producing them has changed enough to produce only individual marks. Additionally, it is not too large a set in which the researcher would need unlimited time and resources to complete the necessary work demanded from such a study. Finally, due to the cost of materials, more than ten consecutively produced slides could be impractical.

Therefore, ten consecutively manufactured slides and one frame were specially ordered from Smith and Wesson for the purpose of this research project. In order to understand the complete manufacturing process of the slides and for quality assurance of the product, arrangements were made with Mr. Joe Bergeron of Smith and Wesson for a visit to the factory in Springfield, Massachusetts to observe critical parts of production.

Because the cutting process by the broach was indicated to be the critical step in production that affected the markings on the breech face and henceforth the fired cartridge cases, consecutiveness in production hinged on that step. The goal was to obtain slides as they would be made in normal production, but for the task of tracking them after the broaching process. This way, all machining prior to broaching would be made to slides as they would normally travel through production, and once ready to be broached, the slides would be marked by the order in which the breech faces were cut, and tracked thereafter.

Plans were made in advance to facilitate special production of ten consecutively broached slides that would be tracked by Smith and Wesson personnel through completion. The broaching process and punching of a unique identifier would be observed by the researcher for quality assurance of the items' production. These ten slides (slide assemblies) plus one frame would then be purchased from Smith and Wesson for the purposes of this research.

On June 16, 2009, a tour of Smith and Wesson's .40 caliber model SW40VE pistol production was given by Mr. Adam Young, Pistol Process Line Manager for the company. Mr. Young explained the process from the time the raw material arrives by truck to the facility all the way to assembly and packaging. Detailed descriptions of key steps were given by the actual machinists at each station during the tour.

The .40 caliber Sigma slide production starts with twelve foot bar stock of 416 stainless steel delivered by truck to the Smith and Wesson factory. From this point forward, there are two different ways of making the same model slide. Smith and Wesson is phasing out the current or "old" way of producing the slides, and phasing in a "new" way that involves fewer machines and stations. At the time of this tour, both methods were currently being employed. Essentially, the "new" production method is the process that the Military & Police (M&P) models have undergone since their introduction to the pistol line. Because this process employs fewer machines and steps, it is easier and more cost effective. Smith and Wesson began producing some of their Sigma Series slides using the same equipment. However, for years the Sigma Series pistol slides were manufactured using the "old" method. It is this method that was examined for the purpose of this research, because the pistols referenced in Gene Rivera's 2007 article were more likely to have been produced in this way. More will be discussed on the "new" method later [4].

The twelve foot bar stock steel is first cut by a shearing action into billets of appropriate length. The billets then go through a forging process, at which time they are induction heated to 2000 degrees until red hot. A billet is placed on the forger and a huge hammer comes down and smashes it multiple times into the desired slide shape. The hammer descends with approximately 5000 pounds of force each time it is dropped on the billet. A ridge of metal called flash is formed at the edge of the forging where excess metal has been squeezed out. This flash is trimmed off and recycled. The rough slides are then annealed to relieve stress from forging. They are then de-scaled to remove their rough edges in a process similar to tumbling with abrasive grit. The forgings are now ready for machining.

The forgings make their way to the machining cells in a large tub filled with many pieces. The first station is called the straddle mill or twin mill, where the forging receives its first rough cut. The forged piece is placed on the mill and passed through two milling heads, rotating simultaneously on each side of the horizontally placed slide, rendering each side flat. Once they pass through the twin mill they are placed in a bin that is moved to the next station when it becomes full. The process of placing the slides into and removing them from the bin is random.

The next station is a CNC machine in which another rough milling process takes place. The slides are placed randomly onto one of four machines that are designated for this process. Once on the machine, first side A of the slide is milled, then it is turned and side B gets milled. In this process, the ejection port pocket and the inside of the slide are being opened up (rough milled) for subsequent finer milling. With the slide now taking more of its shape, the next station is the horizontal broach for cutting the breech face.

In normal production, the slides would be collected and placed in a tray that holds a total of sixteen items and moves from station to station. Once the tray arrives at the broach, slides are randomly taken one at a time from the tray and run through, then placed back in the tray (in no particular order). For the purposes of this research project, ten slides were placed in their own special tray as they were collected from the rough milling CNC machine. On the tray was placed a specially made sign reading "Do Not Mix" to distinguish them from the rest of the general population. The sign would remain with these particular slides throughout the rest of their production as a reminder to the machinists working with them that they are being specially made.

At this point for the purpose of this research, each slide was punch stamped with a unique identifier (number 1 through 10) to distinguish the broaching order, and each slide was marked with a red ink. The red ink was placed on one end of the slide as an indicator to the workers that they were in a special state of production. After broaching, consecutiveness of manufacture was maintained through all machining processes up through heat-treating. The batch was subsequently kept together during the remainder of production in order to easily retrieve them at the end.

The breech face of the slide is cut by one pass of a horizontal broach manufactured by Associated Broach Company of Michigan. The broach is approximately 4 ½ feet long, 10mm wide and is made of heat treated M2 tool steel. The progressively taller rectangular cutting teeth are ground, and number 143 in succession. Each tooth is slightly smaller than the one behind it and is responsible for removing very little material.

The slide is positioned onto a slot, front end (barrel opening) down with the interior of the slide facing the broach. The broach is positioned teeth up on a horizontal plane and cuts the slide through the ejection port as it passes through. The operator initiates the movement of the slide by pressing a button, which hydraulically drives the broach across the breech face one time. The slide is removed from the slot and the broach is retracted to its original position. The next slide is placed in the slot and the operation is repeated. The marks observed after this stage on the breech face from the cutting action are shiny parallel longitudinal lines.

For the purposes of this project the broaching process of the specially made slides was observed. Chip formation was observed on the broach toward the end, but not on the final cutting edges (teeth). These final teeth are those that would leave the resultant markings on the breech face of the slide. After each slide was fed consecutively through the broach by number, it was placed onto a gauge to check for straightness, and placed back on the tray in its spot.

During normal production, after broaching the slides travel in their tray to the gun drill machine. The gun drill machine has two separate drills that work simultaneously, so two slides are drawn from the tray and placed on under each drill at the same time. For the purposes of this project, Smith and Wesson maintained consecutiveness of the slides during the drilling process, so only one drill was utilized. Here the extractor hole, firing pin assembly hole, and firing pin aperture hole are drilled into the slide. The noteworthy area in this process is the firing pin aperture hole, which has the potential to affect the markings on cartridge cases when fired. The drill that produces this particular hole is .081" in diameter and drills in a downward direction from the outside of the slide through to the breech face. A small burr will be left immediately following this process from the metal that gets pushed through the hole onto the breech face. However, this burr is removed later during other processes. After drilling the slides are placed back on the tray from which they came and travel to the next station.

Following the gun drill, the slides go to another CNC machine where an angled hole is cut into the underside of the slide. This hole is described as a breather or clean-out hole in the underneath of the slide for debris drainage in order to avoid a malfunction. There is no contact with the breech face during this step. Next they move over to another CNC machine where a number of finer machining processes take place. In this station there are a total of nine CNC machines devoted to making Sigma slides at any given time. The slides are randomly placed into one of nine machines where a number of drills and end mills cut slots, rails and other areas of the slide not affecting the breech face. However, again for this project all slides were machined consecutively on the same machine. After exiting this station, normally produced slides are stacked back into the trays of sixteen randomly. Given that there are several machines, slides may end up in any number of trays in any order during normal production.

The slides then go to a CNC milling machine, on which two are placed at a time where the tops of the slides are milled.

After this step, serrations for racking the slide are cut on their sides. They are then inspected and de-burred before heat treating. Any burrs remaining, including those on the breech face resulting from the drilling of the firing pin aperture hole, will be removed by an operator through hand-sanding. The hand-sander contains ultra-fine abrasives that buff the burr from the breech face. The feeling of the working surface is similar to a very fine finishing nail file. It contacts mainly the area immediately around the firing pin aperture hole.

From here, the trays of slides go over to a rack on which they are stacked to await heat treating to achieve final hardness. Each hour, a train stops by this rack and picks up two boxes of slides to go to the heat treating department. Once in the heat treat area, the slides are placed into huge bins, mixing them randomly. Heat treating is a three step process that involves stress relief, hardening and finally tempering to achieve its Rockwell C hardness. In this process the slides spend about 8-10 hours in the ovens. After heat treating the slides go to the finishing processes.

Finishing is a several step process. First the slides are placed on a four-head Hammond machine on which the sides of the slides are sanded smooth. Next they get tumbled to remove any remaining sharp edges, primarily on the outside of their surfaces. Many slides at a time are placed into a large vibrating vat filled with a soapy acid and pyramid-shaped ceramic media. The tumbling media begin as approximately 1 ½" diameter base pyramid shaped stones that wear down indefinitely. When they get very small, they are removed from the tumbler to prevent them from getting stuck in the slides' interiors or between small parts. However, while the smaller worn stones are still in there the potential that they contact the breech face does exist.

The next station is the roll-stamp on which the slides receive the Smith and Wesson logo and caliber designation. They then go through a rough finishing process called sand-blasting, where sand is directed at them at four different angles to hit the top, front, left side and right side of the slides to render a smooth surface. The sand blast step is not only for cosmetic but also functional purposes, giving the slides better lubricity. Although the sand is not specifically directed at the breech face in this process, it was observed that the sand can indeed make contact with it.

Glass-beading is the next and final finishing process, where the slides get held vertically on a rotating stack and very fine glass powder is blasted at them for a final satin finish. The potter's quality Ballotini impact beads are actually extremely fine glass powder, similar to the consistency of ultra fine powdery sand, soft to the touch. Several nozzles are aimed at the slide by an operator in different orientations, and the glass powder is blasted directly at its many surfaces. Not only does the entire stack rotate, but so too does the prong fixture on which the slide is placed. While the nozzles are not intentionally directed towards the breech face, it is almost inevitable that the material makes contact with it because according to Adam Young, "the glass-beading gets everywhere" [4]. It was observed on this tour that the glass-beading did contact the breech faces of the slides being produced. The slides get blown with air to remove any remaining dust left from this process.

The slides are then restacked and go to the next area to get passivated. Passivation is a chemical process that removes excess iron from the steel to prevent rust. The slides are put through a series of chemical baths where the free iron left over from the machining process is removed by electrolysis. The slides then go through a wash before being heat dried prior to assembly.

At the time of this visit approximately 600 Sigma Series pistols were being assembled daily, but that volume varies month to month based on market demand. At assembly the slide receives the extractor, sights, and strikers, and then gets matched up to a barrel and frame kit. The frames are made at an outside vendor, but all parts are inspected at Smith and Wesson before being assembled. After being assembled, every firearm gets test fired with five to ten rounds of ammunition. One out of every 100-200 guns is randomly selected to be a Q-gun, or qualification gun. Anywhere from 100-300 rounds is fired in a Q-gun.

There are several differences in the "new" process of making the Sigma Series slides compared to the "old" method. The main difference between the old and the new process is that all machining is done on one CNC machine with the new process, whereas the slides pass through 8 separate machines during the old process to accomplish the same result. For the "new" method, the twelve foot bar stock is cut into billets with a saw, as opposed to shears used in the "old" method. These billets do not get forged, but instead go directly to a CNC cell where they will be machined. The billets go through a total of five stations on a pallet. At each stage, additional cuts are made until the slide is finished. The breech faces are cut using two separate broaches. First a flat broach goes through and flattens out the rough area, and then a second step-broach with seventeen cutting edges finishes the breech face. The firing pin channel and aperture hole are cut during this process on the same machine. A spot drill cuts the main hole which is then reamed, and a .081 diameter gun drill then cuts the firing pin aperture hole. This CNC machine was not running Sigma Series slides at the time of the tour so it was not possible to observe the resultant marks.

The slides then travel to a wet-blasting station. Wet-blasting is a step unique to the "new" process where a very fine carbide grit mixed with water is directed at the different sides of the slide for de-burring of the rough edges caused by tooling. The carbide grit is a powdery material like shiny grey sand. At this station, first they are de-burred with a hand-sander and then the firing pin aperture hole is punched out with a tool to ensure the channel is clear. The slides are then wet-blasted and finally all markings are machine engraved on both sides of the slide before going to heat treating. Finishing is the final process where the slides get tumbled, sand-blasted, glass-beaded and finally passivated.

Materials and Methods

Several weeks after the tour, ten slide assemblies were received from Smith and Wesson complete with individual barrel, firing pin and extractor. One slide assembly (slide number one) was received fitted to a frame as a complete firearm. [See Photo #1] This would be the frame onto which all other slide assemblies would be interchanged and test fired throughout the project.

One box of brown Mikrosil casting material was utilized for casting the breech faces of each slide. Use of the laboratory microscopes was based upon daily availability. Depending on availability of work stations during the project, one of the following two stereo microscopes was used to conduct initial visual examinations: Reichert-Jung Stereo Star Zoom and the Leica MZ6. Similarly, two comparison microscopes were used to conduct comparisons: a Leica DMC with Leica DC 300 camera, or a Leica UFM IV with Leica DFC 290 camera. Magnification ranged between 20x and 40x on the UFM, and between 15.6x and 40x on the DMC.

Upon receipt of the slides, they were inventoried and immediately checked for their unique identifier. Overall photographs of the firearm and slide number one (#1) were taken. Additionally, photos were taken of each punch-stamped number on the inside of each subsequent slide.

A visual and stereo-microscopic examination was performed on each slide in consecutive order. The breech faces of one through ten were examined for their markings in succession, and photos were taken of each. All orientations described henceforth relating to the visual appearance of the breech face are from the perspective looking directly at the breech face, sights up, extractor in the seven o'clock position. Longitudinal, parallel lines could be observed by the naked eye running along the breech face in the twelve to six o'clock direction on all sides of the firing pin aperture. These longitudinal lines become much more distinct and apparent when viewed microscopically. Additionally, microscopic examination elicited a granular or matte appearance overtop the underlying parallel lines. [See Photo #2] Markings were heaviest at twelve, far three and far nine o'clock of the firing pin aperture. The lightest, least distinct marks were observed directly six o'clock of the aperture, and immediately around the hole. As the diameter around the hole increased, so too do the heaviness of the markings. This was most likely a result from the hand-sanding of the burr left behind from the drilling of the firing pin aperture.

It is presumed that this granular appearance is a result of the finishing processes that come in direct contact with the breech face. After the slide is broached, the shiny sharp cut marks

Photo #1: Smith & Wesson SW40VE.

Photo#2: General example of slides breechfaces.

that remain are buffed out by the sand-blasting and glass-beading. Although the surface results in a matte finish, the longitudinal lines do remain visible. Some slides visually exhibited marks unique to only themselves. Chatter marks were observed on some slides, exhibiting as horizontal skip marks randomly dispersed.

Next, a Mikrosil cast was made of each slide and placed into a pre-labeled plastic bag. Once the casts were taken, they were inter-compared to each other on the comparison microscope. The lower of the two numbered casts was always placed on the left stage. Inter-comparisons of the casts were conducted from slide to slide, starting with slide #1 to #2, all the way through slide #1 to #10. A total of forty-five comparisons were conducted, each slide having been compared to each other. Photos were taken of each comparison. A chart was made to track results of comparisons between slides for easy reference when evaluating results. Notes were made in the chart to indicate whether or not subclass was observed, where it was observed on the casts, and to what degree it was present.

Four different types of ammunition were chosen to obtain exemplars based on Rivera's test fires in his study. The article listed Remington, CCI and Federal as the brands chosen for his test fires, and PMC was the brand of the evidence cartridge cases. For this reason, similar ammunition of the same brands was chosen for this study: Remington UMC, 40 S&W, 180 gr., FMJ – brass case, nickel primer; CCI Blazer, 40 S&W, 180 gr., FMJ – aluminum case, nickel primer; Federal American Eagle, 40 S&W, 180 gr., FMJ – brass case, brass primer; and PMC, 40 S&W, 165 gr., JHP – brass case, nickel primer.

The slides were successively test fired using the four brands of ammunition, with four test fires per brand. Prior to test firing, each cartridge was engraved over black ink (for highlighting) on the case body with the number of the slide from which it would be shot. Immediately after each cartridge was engraved, it was replaced bullet-side-up back into the tray in the box of ammunition from which it came to indicate it had already been marked. The cartridges were replaced back into the row of the tray corresponding to its number. For example, all cartridges for slide #1 were placed in the first row, cartridges for slide #2 were placed in the second row, all the way back to row ten. By the end, forty out of fifty cartridges were engraved and facing bullet-side up, ready to be test fired by appropriate slide. This system made it easy to retrieve cartridges in a meaningful order when test firing, and minimized the chances of mixing up numbers.

Plastic bags were labeled with the slide number at the top, followed by ammunition information (brand, bullet weight, bullet type) and initials. Four bags per slide were prepared prior to test firing. All materials were transported to the gun range at MPD. Once ready to test fire, slide #1 was placed onto the frame, each box of ammunition was opened to expose only the row of the test fires to be shot, and the four plastic bags corresponding to the appropriate slide were laid out in order. The magazine was loaded with four cartridges of the same brand of ammunition. Each cartridge was checked for appropriate engraving prior to placement in the magazine. The firearm was test fired four times, with each ejected cartridge case retrieved after each test fire and placed into the appropriately labeled plastic bag. This system was followed for each brand of ammunition with each slide until all test shots were fired (160 in total). During the test firing process, each slide was visually checked for its stamped number prior to being placed onto the frame for quality assurance purposes.

At a later time it was decided that an additional brand of ammunition would be fired to obtain a broader range of specimens. All ten slides were further test fired with four cartridges of Winchester, 40 S&W, 180 grain, FMJ cartridges (brass case/brass primer) following the same system used previously. In the end, a total of five brands of ammunition with four cartridges per brand were fired per slide, giving a total of 200 test fires from the ten slides.

Test fires from each slide were compared to each other (intra-slide) for reproducibility and individuality. Beginning with slide # 1, tests from each brand of ammunition were intra-compared. For example, Remington was compared to Remington, CCI to CCI, etc. All four cartridge cases per brand were compared with each other. Then different brands of ammunition were inter-compared to examine for differences in ammunition type and how that would affect potential for identifications.

Slide #1's test fires were then inter-compared to test fires from all other nine slides, per brand. Starting with CCI, the test fires from slide #1 were compared with those from slide #2, then slide #3, all the way through slide #10. Then Remington test fires from slide #1 were inter-compared with those from slide #2, etc. This was done for all five brands of ammunition for slide #1. Notes were taken listing each brand in relation to slide number with those that exhibited possible subclass characteristics and to what degree. Once all comparisons for slide #1 were completed, the observations were evaluated.

Test fires from all different slides were inter-compared for subclass characteristics. It was determined for practicality purposes that from this point on, only two brands of ammunition would be inter-compared from slide to slide. However, all five brands of ammunition would first be compared for test to test reproducibility within each slide. No further inter-comparisons of ammunition brands within a slide would be compared from this point on. The two brands chosen to be inter-compared from slide #2 through #10 were PMC and CCI. PMC was chosen because it exhibited the most generous amount of markings in all pertinent areas. CCI was chosen because the markings were much lighter and subclass was observed during some of the comparisons between slide #1 and the others. This way, comprehensive comparisons could be made from one extreme to the other with all slides.

Rivera's study emphasized the importance of the presence of firing pin aperture shear marks (primer shear), as they were indeed the basis of his identifications due to overwhelming subclass displayed in the breech face marks. The article raises concern of a potential for of a mis-identification should the shear marks not be present to use as an area of comparison. For this reason, and because it was found during the examination process that the primer shear marks were present on most of the test fires and proved to be the best area for identifications, it was decided that additional brands of ammunition would be tested for their susceptibility to producing these marks. Two cartridges of each of the following brands of ammunition were test fired in slides #1 and #10 to obtain a general sampling: Federal Hydra-Shok, 40 S&W, 180 gr., JHP; Speer Lawman, 40 S&W, 180 gr., FMJ; Independence, 40 S&W, 180 gr., FMJ; Wolf, 40 S&W, 180 gr., FMJ; Fiocchi, 40 S&W, 170 gr., FMJ; and Corbon, 40 S&W, 165 gr., JHP.

The purpose of conducting these additional test fires was to determine if ammunition brand affected the potential for producing firing pin aperture shear marks. Two cartridges of each brand were fired in each slide. The order of loading the magazine and firing order were documented for each cartridge. Each cartridge case was examined microscopically for the presence of firing pin aperture shear marks. The shear was noted either to the right or left (or both) of the firing pin impression, with the orientation of the firing pin drag at three o'clock.

Because of the role of NIBIN in Rivera's article, it was decided that cartridge cases from each slide would be entered into the system to test for potentiality of being a High Confidence Candidate (HCC). MPD describes a High Confidence Candidate as a NIBIN correlation result that contains such a degree of similarity observed during the evaluation process as to merit a live examination (potential hit). Two cartridges from each slide were entered into NIBIN under the reference case event "Other," and the reference exhibit event "Other," each within its own Case ID. All slides were represented with the PMC brand of ammunition, chosen because of their plentiful markings. The second test fire entered from each slide was chosen among the other brands represented in the study.

Per MPD laboratory policy, only the top ten correlation results are evaluated from the correlation list. For the purpose of this study, any of the slides that fell in the top ten "Breech face image results" were logged, and images were compared on the screen. Any images that would be considered HCCs were printed out and the cartridge cases were compared under the comparison microscope again. Any slides that fell in the top ten "Firing pin image results" were compared on the screen, and those that would be considered HCCs were printed out for second comparison. These were not logged though because they were not correlated in the system using their breech face marks, but rather their firing pin impression.

The final phase of the project was the administration of test kits to other qualified firearms examiners, for verification of results and sample blind testing.

Results

Mikrosil cast comparisons

The comparisons of the Mikrosil casts yielded very close agreement from slide to slide. A toolmark identification of the broach could be made for each breech face. Subclass carry-over did result from one breech face to the next from the broaching process. [See Photo #3] In other words, the gross marks observed on the casts were identified to the broach, and were subclass to each other (between slides). Out of a total of forty-five comparisons of the casts, 100% exhibited subclass agreement. The degree of agreement was somewhat related to the proximity of the slides being compared. The slides closer in broaching order exhibited a slightly higher degree of agreement than those farther apart. However, even slide #1 compared to slide #10 exhibited enough agreement to

Photo #3: Cast comparison of Slide 8 – Slide 9 (10x magnification).

determine they were made by the same broach.

All casts were examined under the comparison microscope in the same orientation, with the parallel lines going in a horizontal direction, the top of the slide being represented to the right. All observations and photos were accounted for with this orientation in mind. It was noted that because the markings on each cast were heavier and more defined to the right of the firing pin hole, more subclass agreement could be seen here than to the left. The subclass was also stronger below the hole than above it. These observations directly correlate with the visual observations made of the new breech faces earlier. As the slide numbers got farther away from each other, slight differences in characteristics on the left of the cast became more distinct. The characteristics on the right side of the casts remained very similar for each comparison. This phenomenon could be attributed to the orientation of the hand-sander during deburring. Most contact would have been on the slide just below the firing pin aperture hole, whose area is represented on the left side of the cast.

Overall, the area with the closest correspondence between all of the casts was to the right of and below the firing pin aperture. Continuous, uniform lines were present there that could be lined up with one another. The least amount of correspondence was between eight o'clock and twelve o'clock, primarily because this area on the breech face contained the fewest markings altogether. Directly around the firing pin aperture the markings were rather light, with the grossness of striations taking form as the distance from the hole increased. The further away from the hole, the more pronounced the markings were. This observation also correlates to the visual observations made directly of the breech faces and could be attributed to the hand-sanding. Some individual characteristics were noted on different casts when a discontinuous, apparently unrelated marking was observed on one cast but no other.

Striking differences were noted between the casts taken by Gene Rivera in his study and the casts taken in this one. Rivera's casts show extremely clear, gross, well-defined parallel lines across the breech face. [Refer to photos in reference #3] They are deeper and more abundant than those in this study. The casts in this study exhibited a granular surface appearance visually observed on the breech face that made the parallel marks less defined. [See Photo #4] Under higher magnifications, slight breaks in the overall lines (striations) are evident.

Adam Young was contacted to discuss these differences and help assess the potential causes of them. A number of reasons could account for the different appearance of the breech face markings in Rivera's study. While the finishing processes have not changed over the years, slight variances within the processes may have caused unintentional differences to result on the finish. Minute variations in pressures and angles, changes in media, different machines and different operators could all account in some way for the varied effects. It was explained that because the nozzles directing the glass-beading get aimed by an operator, the directionality may vary slightly among different operators or during different runs. Couple that with a slightly different machine with a slightly different pressure, and an entirely different broach that may have been in a duller state of wear at the time of cutting, a different appearance to the finishes on a microscopic level would not be an unusual phenomenon.

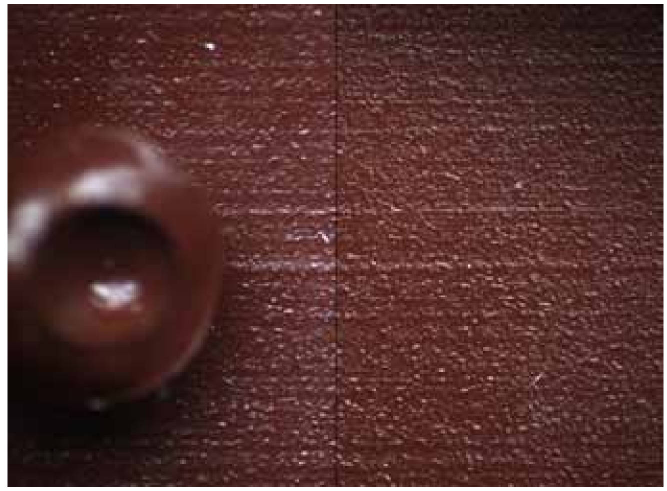

Photo #4: Casts comparison of Slide 1 – Slide 2 at high magnification (20X).

It was observed during the tour of Smith and Wesson that the glass-beading was in fact contacting the breech faces (unintentionally) of the slides produced at that time. This would likely account for the granular appearance remaining on the finished product. Additionally, the broach in this study may have been more recently sharpened so as to not yield as many striae as observed in the Rivera study. The broach that produced Rivera's slides may have been in a rougher state of wear, accounting for the deeper and more prolific straie in those casts. Because it can not be determined exactly what took place when the Rivera slides were produced, these explanations can only be speculated upon as possible contributors rather than a definite answer to the question.

Comparisons of test fires were conducted on breech face marks only, not firing pin impressions or chamber marks due to the nature of the study. Because the goal of this research was to look for potential subclass characteristics between slides' breech faces, and determine whether that subclass influenced the markings subsequently made on the cartridge cases, other areas usually considered in an examination were set aside. Some general observations were made regarding the overall microscopic analysis of the cartridge cases fired from all slides. The impressions imparted to the cartridge cases from the breech faces were observed on both the primer and the case head for most brands of the ammunition. Breech face impressions on the primer appeared most prominently on the Federal, Winchester and PMC brands. They were not as well defined or plentiful on the CCI and Remington cases in this area. Breech face marks in the headstamp area marked well on all but the CCI brand. Depending on individual cartridge case, headstamp markings were not always prominent and well-defined, but were often observed on the Remington, Federal, Winchester and PMC brands. The CCI usually contained marks only around the perimeter of the case head.

The breech face marks on the headstamp areas tended to be gross marks with lots of fine markings within those marks. These marks corresponded to the gross lines observed on the casts as the distance from the firing pin hole increased. Markings on the primers tended to be less gross in nature which could be accounted for by the lighter nature of the toolmarks observed on the casts directly around the hole.

Primer shear marks were produced on all of the brands of ammunition, however, not all of the time. CCI contained the most test fires that lacked primer shear. Winchester and PMC were also noted to lack primer shear on a few occasions in the study. Although Remington usually had the most abundant primer shear marks, this brand was observed at least once not to exhibit any. Based on the tests performed with the additional six brands of ammunition, there appears to be no obvious explanation as to when primer shear will exhibit. All of the eleven brands test fired at some point contained these marks. The few occasions that they did not demonstrates that it is possible for primer shear to either be present or not , with no known explanation at this point for when it was lacking.

One other type of marking of value appeared on most of the cartridge cases directly below the ejector mark. This mark was first noticed during comparisons of the tests from slide #1 around the ten or eleven o'clock position on the cartridge case heads, when the firing pin drag was at three o'clock. The marks were striated and similar in nature to the shear marks on the primer, and occurred in the exact location on the case head that would rest against the ejector cutout. [See Photo #5]

Tests were conducted to determine what was causing these marks. In an attempt to identify these types of marks and rule them out as a result of cycling, several cartridges were

Photo #5: Example of marks below ejector mark – ID from Slide 10.

cycled through the firearm by racking the slide continuously. Each cartridge was microscopically examined and found to contain ejector marks, but none contained these striated marks beneath them. This indicated that the marks were indeed caused as a result of firing, not cycling. However, it was still undetermined exactly what produced them during firing.

The possibility of them being the result of a scraping on the ejector cutout was tested by scraping pieces of lead across the edge of the ejector cutouts of three different slides. The slides' toolmarks on the lead were compared with the marks on the cartridge cases, but none were identified to each other. It is unknown at this time if this is because the exact areas on the slides were not contacted by the lead, or if the angle was off, or some other variable that caused the marks not to transfer in the same manner. Differences in material - lead vs. brass – were also considered as a variable causing non-reproducibility. But due to the location of the marks in relation to where the case head rested on the breech face during firing, strong inclinations toward a shearing action on the edge of the ejector cutout were still suspected.

Another experiment was conducted in an attempt to determine if the marks were caused by the edge of the ejector cutout. Correction fluid was placed on the edge of the ejector cutout (and only this area) of slide #6 (chosen randomly). A cartridge was test fired with slide #6, and a microscopic examination was conducted on the cartridge case and the slide to look for transfer of correction fluid. Indeed, correction fluid was observed exactly on the suspect markings on the cartridge case, and nowhere else. When the slide was examined at 25X magnification using the Leica DMC, it was observed that correction fluid was missing from a small area of the ejector cutout leaving the surface shiny only in this area. The results of this experiment confirmed the hypothesis that the marks were being caused by the edge of the ejector cutout. This experiment was repeated using another slide assembly (#7), with the same results achieved. Because the suspected area of contact was verified to be the edge of the ejector cutout, the striations produced on the cartridge case will be referred to from here on out as "ejector cutout shear marks."

Intra-brand comparisons from all slides

Identifications were made on test fires within each group. PMC and Federal brands exhibited the best (most abundant, well-defined) markings on the case head. Both had significantly well-defined breech face marks on the primer and headstamp, firing pin aperture shear marks, and ejector cutout shear marks. With all of these marks taken into account, identifications were relatively easily achieved with these brands.

The Remington had poorly defined breech face impressions on the primer but abundant primer shear marks. The primer shear marks were best for effecting an identification on these cases. The Winchester brand cartridge cases overall marked generally well, and identifications could be effected using primer shear and breech face impressions. The CCI contained the least amount of breech face markings on both the primer and case head. The headstamp area of the CCI cases were almost bare, but for the very outer edge that contained some gross and fine marks along the perimeter. When primer shear was present, the CCI cases contained sufficient individual characteristics for an identification. However, without primer shear, a result of inconclusive was usually rendered for this particular group of cartridge cases due to insufficient markings. All brands of cartridge cases exhibited ejector cutout shear marks that were found to be individual to each particular slide. Within those marks were sufficient individual characteristics to effect an identification in most cases.

Inter-brand Comparisons from Slide #1

When different brands of ammunition were compared to each other, identifications could be made on the primer shear marks (when present) 100% of the time. However, in the case that the primer shear marks were not present, identifications were not always possible using only breech face marks, especially with the CCI and Remington due to lack of sufficient individual characteristics. Many breech face markings did contain sufficient individual characteristics for an identification however, such as in the case of Federal to PMC and PMC to CCI.

What was discovered during the examination process initially with slide #1 and then later with the others as well, was that the ejector cutout shear marks were exhibiting characteristics of sufficient agreement to be identified to one another, similar to the primer shear. The test to test comparisons, both intra and inter-brand from slide #1 were all identified by these marks.

Inter-slide comparisons

Comparisons of test fires from slide #1 with those from the subsequent slides yielded some areas of subclass agreement; however, in this author's opinion, it was not enough to cause a mis-identification. In general, results of the other slide inter-comparisons were similar to those from slide #1. The subclass longitudinal lines on the slides produced gross characteristics that exhibited similarities between some of the test fires from different slides, but did not transfer to the cartridge cases to such a high degree as those observed in Rivera's study. The gross parallel lines on the test fires in the Rivera study were uniform and photographically appeared to be almost identical. That was not the case in this study.

When the areas of subclass were oriented in the best position of correspondence, the observation was compelling. However, slight movement from that position would usually throw off any similarity. For example, if the hairline was moved from the right of the case to the left, the markings on the other side would no longer be in close correspondence. The spatial relationship of the markings were often just slightly off from one to the next, and the alignment of the gross marks would need to be constantly adjusted. When a few marks could be lined up, any movement from that area would cause those above or below to fall out of agreement. Often if the gross markings lined up, the finer ones within those marks would not connect. On some occasions both the gross and fine markings in a particular area agreed well, but away from that particular area consistent correspondence was not observed. No competent examiner would effect an identification in that one area of agreement alone if following the standard set in the AFTE Theory of Identification of "sufficient agreement of individual characteristics" [5].

For a true identification to be made, agreement must be sufficient over the entire area being considered, not just where the markings line up in one small spot. That was not found in this study when test fires from two different slides were compared. Even in the cases where the subclass was strong and might be misleading in a photo, once the cases were viewed in a different area the agreement eventually dropped off. The cases had to be constantly manipulated for different markings to agree, which showed that the spatial relationship of the markings on the two different cases were off, supporting individuality of the markings.

Closeness in slide order did not necessarily yield the closest subclass agreements. While the CCI test fires from slide #1 and slide #2 showed a relatively substantial amount of subclass correspondence, so too did the CCI test fires from slide #1 to #3, and #1 to #5. [See Photos #6 and #7] In fact, subclass was still strong between the slide # 1 test fires and the slide # 8 test fires in the headstamp area. This corresponded to the grosser, more defined longitudinal marks on the slides as distance from the firing pin hole increased. Additionally, one of the comparisons with some of the strongest subclass agreement occurred between slide #4 and #9. [See Photo #8]

NIBIN

The entries into NIBIN were evaluated after correlations were made by the system. There was no consistency or pattern to the results of the NIBIN entries. Some of the slides showed up in the top ten lists while some did not. Proximity in broaching order had no relationship with order on the correlation list. Also, when one slide listed another as a candidate, it was not always the case in reverse. For instance, slide #10 listed slide #1 in the third position, but slide #1 did not list slide #10 at all. Slide #5 did not list any other slides at all, including itself. The listed candidates lay anywhere from positions one through ten, dispersed with no apparent meaning.
Every correlation was evaluated visually on the screen for

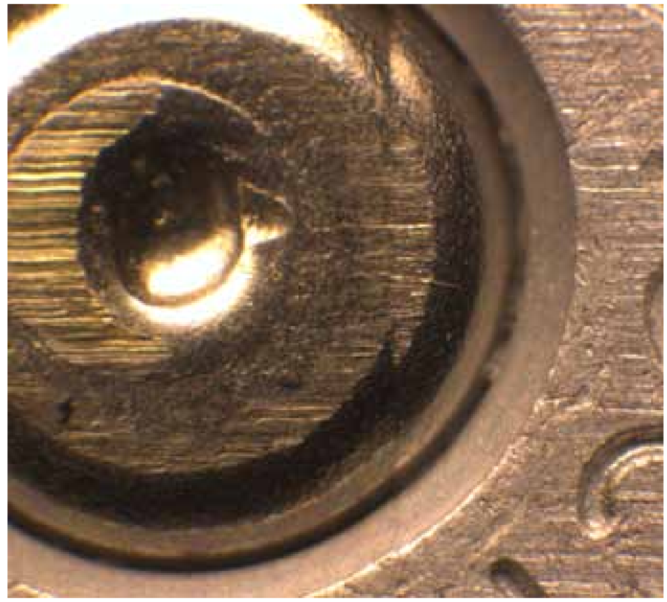

Photo #7: Example of gross markings (subclass correspondence) on CCI cases fired from Slide 1 and Slide 5.

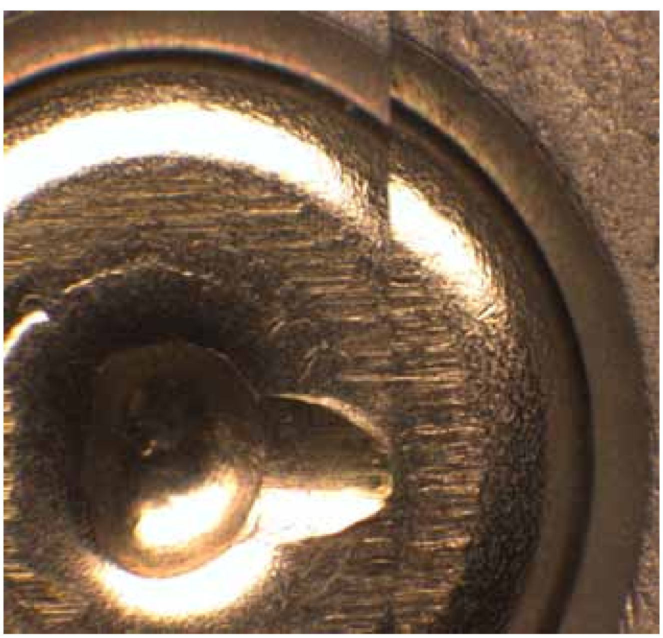

Photo #6: Example of gross markings (subclass correspondence) on CCI cases fired from Slide 1 and Slide 2.

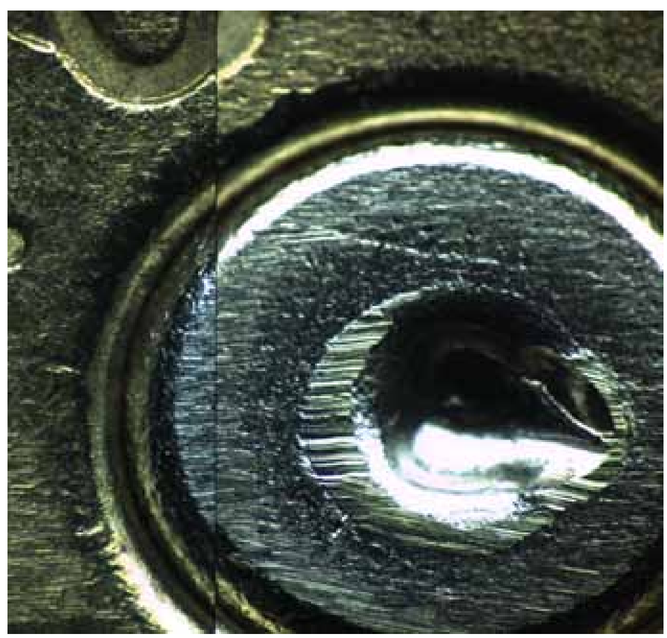

Photo #8: Example of gross markings (subclass correspondence) on PMC cases fired from Slide 4 and Slide 9.

correspondence in the same way that any casework would be evaluated. Any two cartridge cases that would be marked as an HCC due to a high degree of similarity on the screen were retrieved. The casings were reexamined in the same areas of high correspondence. In no instance were the similar markings apparent through NIBIN cause for a potential false identification. Once the cartridge cases were moved to a different orientation and their entirety was examined, they were distinguishable from the other, especially when primer shear was present. A worst case scenario would most likely be cause for an inconclusive, rather than a false identification.

Just the fact that many of the slides did show up on each other's lists did indicate that real life situations might be reflected in this way as well. Potential hits made through NIBIN from cartridge cases fired from consecutively manufactured slides could likely be a common occurrence if those firearms were dispersed throughout the same geographic region, just as was the case in Rivera's study. It is up to the examiner comparing the actual cartridge cases to do a thorough and careful examination of all areas, as with any other examination.

Primer shear tests

Out of the twenty-four cartridge cases fired, twenty (83%) exhibited primer shear marks on the left side of the firing pin impression. Twenty-two (92%) exhibited primer shear marks on the right side of the firing pin impression. Shear marks were produced on 100% of the cartridge cases, on either one side or the other. Only the Speer Lawman failed to exhibit any shear marks on the left of the firing pin impression. No significant relationship between presence of shear marks and firing order was observed. The results of the primer shear tests in conjunction with the original test fires taken in this study indicate that it may be possible to obtain evidence cartridge cases discharged from a Sigma Pistol that do not contain shear marks, although it is much more likely that they would be present.

Tests to other examiners

It was presumed that confirmation bias would play a role in this study for identifications made on same slide test fires and eliminations of those from different slides. In order to test the results of the primary researcher, three different types of tests were created and administered to other qualified firearms examiners.

In order to verify intra-slide test-test findings, test fires from each slide were given to an experienced firearms examiner to compare, with the knowledge of the slide number from which they were fired. In other words, this was not a blind test and was given strictly to determine whether like test fires contained sufficient agreement for an identification. Each bag was labeled with the slide number from which the cartridge cases were fired, and contained only one make of ammunition inside the particular bag. Different types of ammunition were represented among the ten slides. Instructions were given to indicate whether or not the like test fires could be identified to each other, and on what marks the identifications were based. One qualified firearms examiner participated in this test, and identified all test fires from the different slides. Nine out of ten identifications were based on primer shear marks, and the other was based on breech face marks because of lack of shear on one of the primers in the set.

In the second test seven kits were prepared containing cartridge cases for other experienced examiners to compare. Instructions advised only to use breech face markings for their comparisons, not the firing pin impression or chamber marks. Some cartridge cases were chosen that exhibited subclass influence, others were chosen that were fired from the same slide, and others were chosen randomly. Each slide was represented in the study in at least one of the kits. This test was an attempt to mimic a situation where an examiner would receive evidence cartridge cases from scene with no gun. Two qualified firearms examiners took this test.

The test contained four sets of two test fires from the same slide. Both examiners correctly identified three of these sets. The fourth set, although fired by the same slide, were marked quite differently and did not exhibit sufficient individual characteristics for an identification. One examiner correctly called this comparison inconclusive, while the other examiner called it an elimination. However, this was not caused as a result of subclass, for they were from the same slide. It was most likely caused as a result of the examiner not using other areas that he/she would normally use in a comparison. Had he/she been able to examine the firing pin impression or chamber marks, an accurate conclusion would most likely have resulted. At this point it was recognized that the test was flawed, and a more reliable test was constructed. It is worth noting however, that no false identifications were reported. The rest of the sets of comparisons were fired by two different firearms. These were all correctly eliminated or deemed inconclusive by both examiners.

The third test was conducted as closely to a blind validation study as possible. Bunch and Murphy lay out a list of important elements that must exist in a reliable validity test [1]. Anonymity of examiner, blindness of exams, mandatory returns of results, unambiguous responses and qualified participants are all factors that must be met in order to meet quality assurance standards. Based on these requisites, the testing of other qualified examiners in this study did meet the criteria of a true validation study.

Two test fires from each slide were placed in ten different envelopes. Twelve questioned cartridge cases were labeled with a letter, chosen randomly. Each cartridge case was placed inside its own labeled plastic bag. Instructions were given to examiners to compare the questioned cartridge cases and determine whether or not they could be identified to any of the test fire envelopes. An answer sheet was provided with a uniform format for all participants.

Two qualified firearms examiners took this test and were able to identify all of the unknowns to the correct slide, rendering 100% accurate results. The test included test fires from all ten slides, with twelve questioned exhibits. Only eight of the slides were represented in the questioned exhibits, and four contained more than one. This way, there was no way to use process of elimination to match the cartridge cases back to the appropriate slide. The incorrect assumption that all slides were being represented would have resulted in an incorrect result, which did not take place.

Conclusions

It is impossible to state exactly when the two slides in Rivera's study were broached in relation to each other, as the research in this study fails to answer the question of proximity. In this study, however, it was found from the Mikrosil casts of the breech faces of each slide that each one contained subclass characteristics from the broach that produced them successively. Therefore, the subclass carry-over did persist through at least ten slides. These subclass characteristics did not, however, transfer in the same character to the cartridge cases fired from them. Some similar gross markings were present on cartridge cases fired from the different slides. These marks were not sufficient, though, to make false identifications to the wrong slide. There were individual characteristics present on each slide which allowed for breech face impressions on fired cartridge cases sufficient for identifications to each individual slide. Whether or not the individual characteristics were sufficient often depended on the ammunition type.

The markings on the cartridge cases caused by the subclass on the slides did not manifest itself on test fires produced by the different slides. The marks produced on the test fires from each slide were individual to only that slide. It is speculated that the granular finish caused by a combination of the hand-sanding, sand-blasting and glass-beading individualized the otherwise subclass characteristics on the slides, because the abrasives changed the planar structure of the surface of the toolmarks on the breech faces. Even though the breech faces have the overall same striated appearance when viewed perpendicularly, topographically they are different in that the raises and depressions caused by the abrasive finishing causes them to mark differently during the dynamic process of firing. The slight breaks on the surface of the gross striae on the breech face perhaps caused them to produce individual characteristics which allowed differentiation of the cartridge cases produced by each slide. Had the slides gone directly from broaching to assembly skipping the finishing processes, the results might have been different. Perhaps the sharp, sleek striations left behind from broaching (as observed during the machining process) might have transferred into the cartridge cases in a way such that the subclass characteristics would have been better defined and less distinguishable between slides. But this idea can only be speculated upon.

Although some of the test fires display a similar general appearance due to the gross broach stria, the actual patterns displayed by the individual markings were too dissimilar to cause a false identification for a competent examiner. The spatial relationship of the other markings was off when one area was in agreement. In the comparisons with the most subclass influence, the general appearance and layout were similar, but the fine detail was never in sufficient agreement to make a false identification.

As was the case in Rivera's study, when primer shear was present on both cartridge cases in a comparison, an identification or elimination could be made rather easily. These individual markings were easily distinguishable among the different slides. It was found that primer shear marks occurred on most of the fired casings in this study, but it was not brand specific as to whether or not they did occur. Firing order of cartridges also was not found to have an influence on whether or not primer shear was produced on a cartridge case. Also found to be reproducing in a unique pattern were the ejector cut-out shear marks.

This study further stresses the importance of using as many areas of the cartridge case as possible when forming conclusions. Although firing pin impressions and chamber marks were not the focus of this study, the results emphasize the necessity to use these areas in conjunction with others whenever possible. Although the subclass exhibited on the test fires in this study was not as compelling as that in Rivera's, it could still render a comparison quite difficult. However, out of the 200 cartridge cases studied in this particular instance, no inter-comparison yielded enough agreement for the potential of a mis-identification.

The results of this study are specific to Smith and Wesson

Sigma Series pistols; however, within the firearms industry many manufacturers use the same or similar machining processes. Breechfaces of slides produced with a broach and then finished with sand-blasting and glass-beading may yield similar markings, regardless of make and model.

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