Metal Injection Molded Strikers and Extractors in a Smith & Wesson Model M&P Pistol

By: Michelle Hunsinger, Monroe County Crime Laboratory, Firearms & Toolmark Section, Rochester, NY

Keywords: Electropolishing, Extractor, Firing Pin Impression, MIM, Metal Injection Molding, Smith & Wesson model M&P, Striker

ABSTRACT

During the summer of 2009, Smith & Wesson (S&W) began selling their M&P model pistols with metal injection molded (MIM) strikers. Currently, all calibers except the .45 use such strikers, but all M&P pistols contain MIM manufactured extractors. Five MIM strikers and extractors were obtained from S&W. Firing pin impressions, firing pin drag marks and extractor marks were used to compare class and individual characteristics within these markings, to assess the potential of subclass characteristics, as well as the durability of the working surfaces.

MANUFACTURING METHODS

Metal Injection Molding

A tour to Remington Arms in Ilion, NY is used as the basis for the MIM manufacturing process because S&W does not produce MIM parts for their products in-house.[4] Remington MIM molds have an average life of 250,000 injections per cavity. Remington purchases their MIM molds, which are made of tool steel and the cavities are cut by electro-discharge machining (EDM) and polished as needed. Excess material is less than that of traditional machining operations and the scrap that is produced can be re-used.

Remington provided a tour of the MIM portion of their facility which will serve as the basis for the MIM manufacturing process. MIM begins by combining finely powdered metal or alloy particles with a binder. This binder typically consists of plastics and other proprietary materials. Any sprues or runners from previous moldings can be re-used in this step. The binder and metal are heat mixed and ground to form feedstock which may be stored or immediately used. For Remington, the feedstock is extruded, cooled and then cut into pellets. At this point the feedstock has the consistency of a crayon, and can be readily broken with one's fingertips.

The feedstock is heated until its consistency is similar to that of toothpaste. It is then forced into a closed mold. This step involves a hot or cold runner system. The hot runner systems keep the feedstock in a liquid state until it enters the mold. The cold runner systems, such as Remington's, maintain a supply of solid feedstock. A bucket of feedstock is set up near the mold and a set volume is transferred to a hopper at the top of the mold machine via a vacuum system. The hopper releases the feedstock pellets into a heated tube. The tube gets progressively hotter as it nears the injection end. On this tour it started at 320°F to melt the feedstock and at the injection end it was 350°F to ensure all the feedstock was thoroughly melted. After cooling, this part is removed from the mold and a mold seam or part line is a key sign of this step. Remington places these parts, referred to as green parts, on a porous ceramic plate and the parts are not touched until MIM is complete.

The next step is debinding. Thermal and/or chemical means are used to steadily remove only the binding material. This step removes a vast majority of the binder, but leaves behind small amounts as well as an interconnected porous network throughout the piece. Debinding causes about a 1% shrinkage of parts. Because binders are carefully controlled and made, their properties (such as melting point) are known and are well below any temperature that would affect the metal. Binder melting point is often below 500°F [4].

Next, is sintering of the piece. Debinded pieces are placed into an oven with a controlled and often inert atmosphere. The temperature is brought up to below the metal's melting point, commonly between 2100-2500°F [4]. This causes an additional loss of binder and more importantly a softening of the molecular structure of the metal. This allows the metal particles to fill in the pores left behind by the binder which causes the piece to shrink in size in a known pattern. This shrinkage is consistent and controllable. Pieces shrink by 10-25%. At Remington, porous ceramic setter trays carrying green parts to be sintered ride along a slow moving conveyor

Date Received: October 14, 2011
Peer Review Completed: November 28, 2012

belt. The time and pace helps to minimize potential distortion of parts at this high temperature. After, the piece is cooled and may be polished, but this is usually not necessary.

Electropolishing

During research for M&P production, Smith &Wesson discovered that their strikers needed a finishing process because too many were suffering from stress fractures due to the repeated impact of firing [8]. It was found that a smoother surface was required to prevent fractures that can lead to failures of strikers. Electropolishing is the process Smith & Wesson uses to polish their strikers. Unlike traditional polishing methods, this process does not use an abrasive to strip away material.

For electropolishing the work piece is attached to a rack; which acts as an anode. The strikers are attached at a flat recessed portion of the body. The rack of parts and cathode plates are lowered into an electrolyte bath. The cathodes and anode are attached to a power supply so that when a current is applied, it travels through the strikers and steadily removes the surface metal into the solution it is submerged in. This process strips away the surface metal ion by ion. This enables the surface tip of the strikers to be smoothed out. As Keisler and Fazio [5] point out in their article, pits will still be present in the final products, just smoother. This is because electropolishing works primarily on high points of a work piece. Keisler and Fazio studied heavily pitted and cracked barrels. They noted that electropolishing provides a significantly smoother product, but imperfections were still present.

Microscopically, pitting can be observed on the tip of the strikers, however the electropolishing process does significantly smooth the tips as Smith &Wesson desires.

Melonite Processing

After manufacturing, a Melonite finish may be added to case harden iron based metals. After a work piece is heated it is dipped into a series of molten salt baths and quenches before being cooled and rinsed. Carbon within the metal is also pulled towards the surface. [6,7] A significant benefit of Melonite is that the work piece is not physically changed from the process.

Model M&P Information

Smith & Wesson has been using MIM on their commercial products for a few years on most calibers of M&P pistols. They previously tried MIM firing pins on Sigma pistols, but the product was found to be inferior so it was short lived. [2,3] While not the only manufacturer to MIM extractors, Smith & Wesson does seem to be the first to successfully MIM strikers.

A Smith & Wesson representative [8] made it known that prototypes and early products were made on a single cavity aluminum mold, as were the strikers used in this project. It was unknown just how the molds were made, but it is suspected by this representative that the aluminum mold was machined and hand polished. Tool steel molds (for extractors and eventually strikers) have the cavity shape "essentially burned into" it; which could refer to EDM. Aluminum molds have an average life of approximately 100,000 pieces or about one year. The tool steel molds for extractors (four cavities each) average 800,000 – 1 million pieces before replacing or resizing/resurfacing.

After the M&P strikers are made they undergo electropolishing. [8] Where electrodes contact the striker black marks sharply contrast the shiny silver color of the final product. It is a flat spot on the body that has these marks (**Figure 1**). There are no additional finishes to the strikers. After M&P extractors are made they receive no polishing. They are given a Melonite finish, which leaves them a matte black. This coating helps protect the extractors from corrosion and wear. Only strikers receive the polishing because they encounter significantly higher stresses than extractors during their use. Both the strikers and extractors are stainless steel.

As previously mentioned, the two components used in this research were made in two different types of molds. Since extractor molds have multiple cavities, each is labeled so a small number within a circle appears on the side of the final product, indicating the cavity it originated from (**Figure 2**). Since the aluminum mold has only one cavity this is not apparent on early MIM strikers. Protocols for utilizing steel molds for strikers are underway. [8] and a one or two cavity mold will be used. As long as a stress point is not created, it is anticipated that multiple cavities would be identified for this mold as well.

Smith & Wesson began to incorporate MIM strikers into their M&P pistols in August 2009. It was a staggered entry, with

Figure 1: Overall of striker showing the black mark left from electropolishing

Figure 2: Extractors & cavity identifier

primarily law enforcement orders receiving this product. [8] As of October 2009 all M&P pistol orders (except the .45 caliber) have a MIM striker. The MIM extractor is nothing new to the model. The extractors are interchangeable across the board for M&P pistols. Strikers are also interchangeable in all models, except for the M&P45; these have a longer striker. Towards the end of 2010 Smith & Wesson was anticipating releasing the model M&P45 with a MIM striker as well [8].

There are no external differences between the two versions of M&Ps. Upon disassembly one notices the color differences between MIM and machined strikers. MIM strikers are shiny silver while the machined strikers are matte black. MIM strikers require one retaining collar, where the tooled version uses two. As long as one obtains the new collar a MIM striker can be placed into a pre-MIM firearm. Upon looking at the strikers themselves the mold seam is the most obvious feature of the MIM striker. When assembled this seam runs vertically in the firearm. A dimpled appearance to the piece is also characteristic of MIM from the debinding and sintering processes (**Figure 3).** Not all MIM processed pieces will exhibit this mold seam. For example, at Remington, some of their products will have the seam "hidden" on an edge or sharp corner.

RESEARCH

There have been several studies looking specifically at the durability of toolmarks left by firearms. These have been done by looking at individual characteristics over hundreds and even thousands of test fires [10-13]. Due to time constrictions 300 test fires were collected using each striker and extractor in this study.

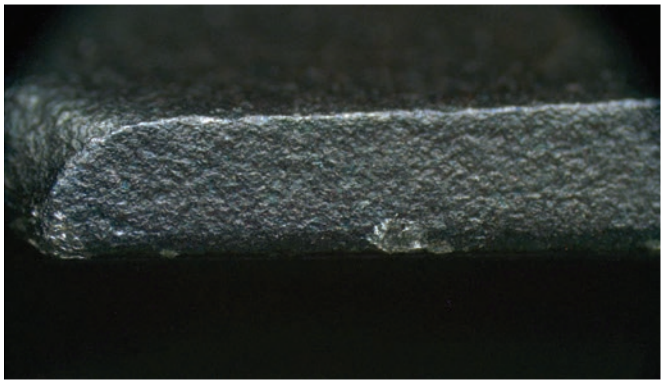

Figure 3: Dimpled appearance from MIM manufacturing process (extractor C 80x)

Supplies/Equipment

- One M&P 40 S&W caliber pistol (serial number DUF4597) was purchased for this project
- Five MIM strikers and five MIM extractors were obtained from Smith & Wesson
- 40 S&W caliber Speer ammunition was used for all test fires
    - o Ammunition was nickel primer cup and nickel coated brass cartridge case with 165 grain copper jacketed hollow-point bullet.
    - o Cartridges were engraved with a firing pin, extractor, and sequential test fire marks
- A Leica model FSM comparison microscope was used for comparisons

Procedure

Twenty cartridges were discharged utilizing the factory components of the firearm to observe its markings. After observing consistent firing pin drag marks no index marks were applied to test fires. Photographs were taken of each firing pin and extractor prior to use and after the final shot. A striker and extractor were paired together and assembled into the firearm. Three hundred tests were created using such pairings. Shots were fired into a water tank, rubber and steel backstop, as well as a Snail Trap. All cartridge cases were collected for later comparisons. After the 1,500th test fire the entire firearm was thoroughly cleaned. A 1,501st test fire was collected to observe any effects of fouling and/or buildup on the marks.

RESULTS

Firing Pin Impressions

Firing pin impressions are hemispherical with a seam mark running the diameter of the impression from 12:00 to 6:00 with the drag mark oriented at 12:00. It was quickly discovered that this feature is very helpful for orienting cartridge cases.

The first and 300th test fire from each striker was compared to see whether or not the marks changed enough to inhibit identifications. Each striker's firing pin impressions contained individual characteristics sufficient enough for identifications. The closer test fires were to one another, sequentially, the easier identifications were. Test fires that were shot far from one another (like TF1 – TF200) routinely posed more of a challenge for comparison. Individual characteristics were smooth and had gradual depth changes creating the primary difficulty for comparisons. Their predominantly small sizes also were a factor.

Eliminations were also distinguishable between strikers using firing pin impressions. Looking microscopically at the overall impression one can notice the overall smoothness or irregularity of the impression. Some firing pin impressions (like those from striker 5) were difficult to work with because there were noticeably fewer individual characteristics initially observed when compared with the other strikers.

The first test fires of all five strikers were compared to determine the potential for subclass characteristics. Sporadically there were marks that appeared similar, however correspondence could not be found. During the comparison of strikers 2 and 3 an impressed e-shaped mark was observed that was similar between the first fired cartridge cases. However, they had slightly differing orientations in relation to the mold seam mark. **Figure 4** demonstrates that the mark hovers relatively centered over the seam of striker 2. In the impression from striker 3 this mark is shifted significantly more to the right of the seam and the firing pin impressions are not fully aligned; the impression from striker 3 is shifted down. This mark was also observed comparing TF1 of strikers 1 and 5. However, it again differs slightly between strikers. This mark demonstrates the closest example of a subclass characteristic observed in the firing pin impressions

Areas like those demonstrated in **Figure 4** may have been the same location on the mold, but the procedures each striker goes through after molding may change those marks. Because only finished parts were supplied from Smith & Wesson it cannot be determined at this point.

It should be emphasized that these impressions are not easy marks to examine. Granular impressions are difficult marks in and of themselves. The individual characteristics are so small in the firing pin impressions comparisons were carried out primarily at 40x. A significant amount of lighting and stage manipulation is to be expected when looking at these

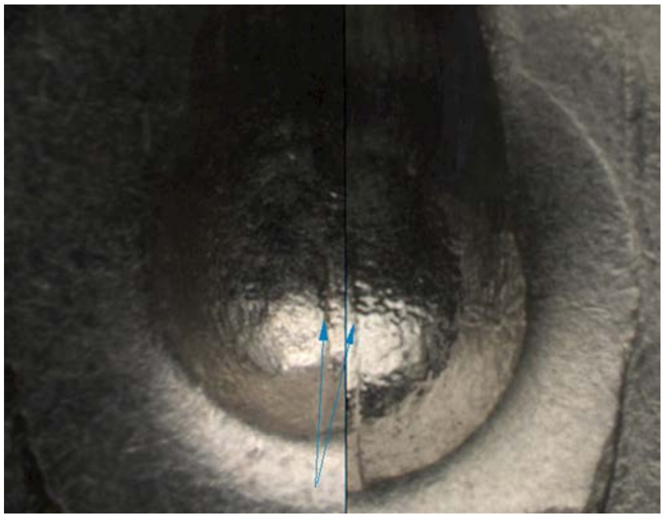

Figure 4: "e"-shaped marks, Striker 2 TF1 vs. Striker 3 TF1 40x

marks. Some of the impressions were quite shallow and may not be noticeable if lights are at different angles, the case is rotated too much or the tilt angles are different.

Firing Pin Drag Marks

Every cartridge case had a prominent firing pin drag mark. The M&P breechface contains an uncommon feature; a teardrop shaped ramp at the 6:00 position of the firing pin aperture. This feature is called the weep hole [9] (**Figure 6**).

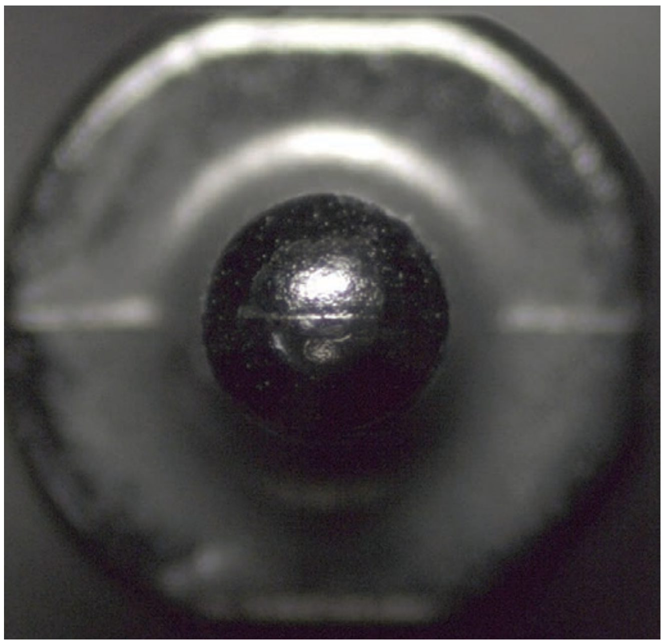

Figure 5: Mold seam on strikers 40x

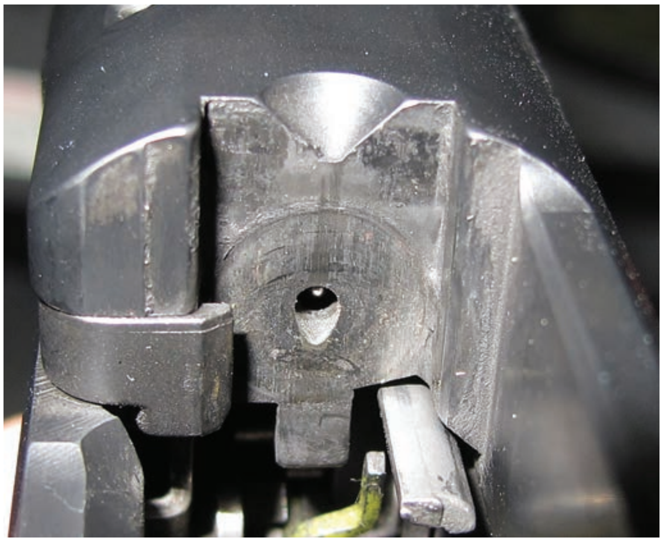

Figure 6: M&P breechface showing weep hole at base of firing pin aperture

This was added by Smith &Wesson to prevent the buildup of primer cup material as it would commonly tear on the aperture due to blowback during firing [9]. In the drag marks there is an elongated "u" from this feature. This feature leaves a mark in the firing pin aperture shear mark that is indicative of the M&P (**Figure 7**).

Figure 7: Fired cartridge case showing outline of weep hole & shear (40x)

Several drag marks also contained marks that are best described as elongated oval-shaped striations with defined borders running in the same direction as the striated marks (**Figure 8**). The first 100 test fires of striker 1 were examined to track these marks. While their lengths would vary from drag mark to drag mark, their locations and widths were consistent making them identifiable. There was a mark directly below the seam drag mark that was predominantly used which had cartridge cases where it ranged from very short to running a majority of the length of the drag mark. It was observed that when the oval-shaped striation did occur in later test fires it was present through a larger group of consecutive test fires. For example, it occurred first in TF3-5 and then later TF73-86 in striker 1 as well as in between these groups.

Much like the firing pin impressions the firing pin drag marks were difficult to work with initially as they are not quite like drag marks previously examined. The distinction between striations appeared more gradual than sharp shoulders. It is almost analogous to polygonal rifling compared with conventional rifling, though less extreme (**Figure 9**). In a vast majority of comparisons it seemed most beneficial to orient the cartridge case with the drag mark at 3:00 and then adjust lights and the angle and positioning of the cartridge case from there.

Distinctions could be made between strikers using the firing pin drag mark. The separation of test fires did not have as much effect on these comparisons. Some random agreement did occur between strikers, but enough was not noticed to hinder with differentiating strikers. As with the firing pin impressions there was a significant amount of manipulation needed to compare drag marks.

During comparisons of the impressed and striated marks from strikers it was observed that striker 5 was overall the smoothest of the five strikers. 1, 2 and 4 were all comparable regarding the surface of their tips while 3 and 5 were smoother. It is suspected that this smoothness played a role in the increased difficulty of examining cartridge cases fired by striker 5. The electropolishing process focuses primarily on high spots to smooth them down [5]. It is possible 3 and 5 were submerged for a longer period. They could have also had less pitting on their surfaces before electropolishing.

Extractor Marks

When observing extractor A test fires 1 and 300 multiple

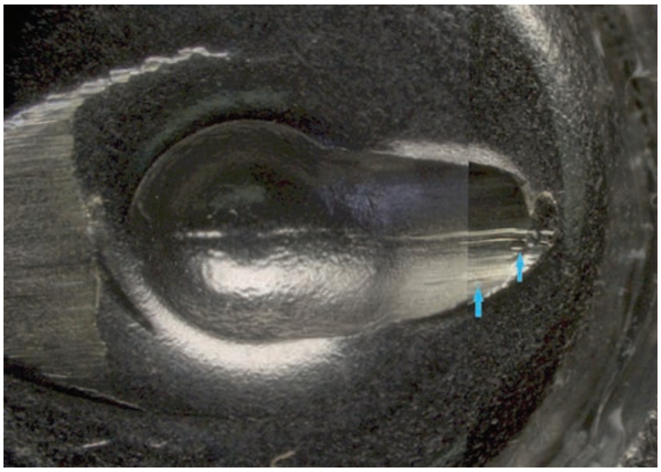

Figure 8: Oval-shapes rather than clean // lines common to drag marks (Striker 5 TF1 vs TF100 40x)

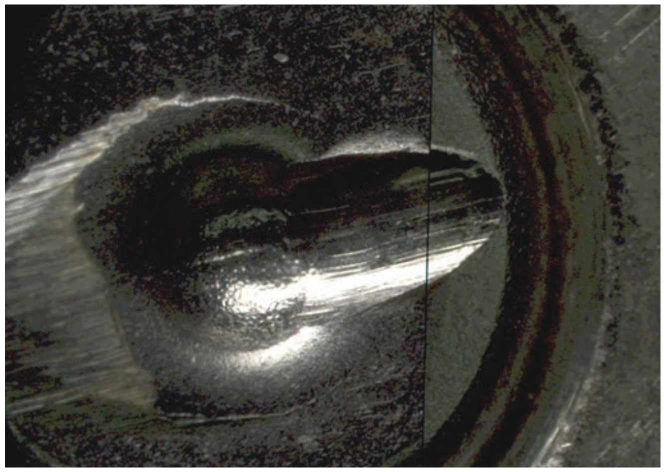

Figure 10: Additional drag photo (Striker 4 TF1 vs TF50 40x)

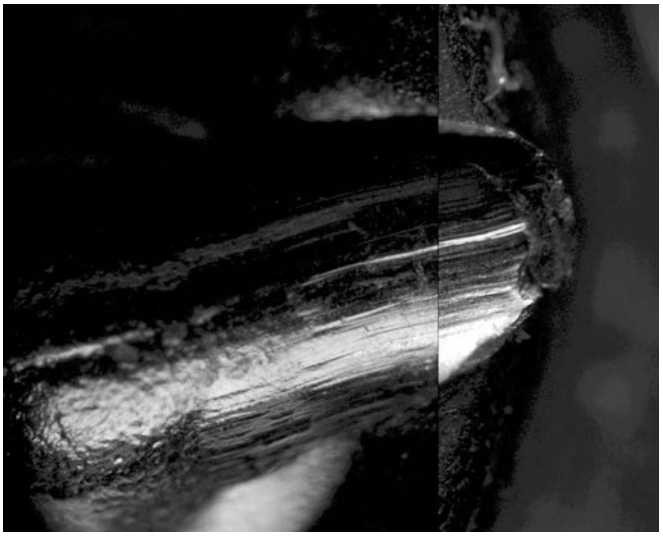

Figure 9: Smoothness of drag marks (Striker 1 TF1 vs. Striker 2 TF1 80x)

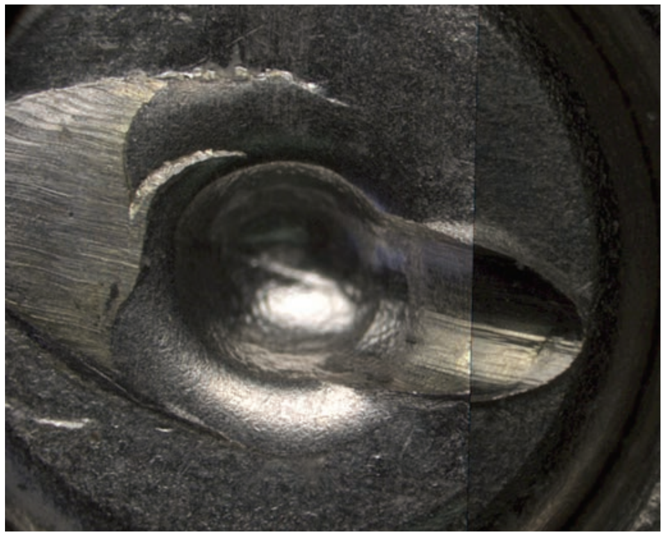

Figure 11: Additional drag photo (no direct reference in paper) (Striker 4 TF200 vs TF50 40x)

striated areas were observed. Within the extractor groove of the cartridge cases one set ran circumferentially under the rim while the other was more perpendicular to the rim. Both were difficult to compare due to sharp changes in their depths, but both could be identified. Dummy cartridges were repeatedly cycled through the firearm with careful attention paid to feeding, chambering, extraction and ejection. The slide was unable to be controlled to observe cartridge cases as they were fed and chambered, but slight rotation was seen during ejection. At this time it is suspected that the higher forces and speed during normal cycling create distorted extractor marks during ejection. Test fires contained extractor marks that had a torn, irregular appearance. Sporadic samples contained striated areas within the extractor mark which may or may not contain sufficient characteristics. These striated areas also had various degrees of movement. Some would run circumferentially while others were angled up to about 45^{o}. Extractor marks were also commonly found under the cartridge case rim. Though not thoroughly examined, it should be noted that this is another area that could be utilized for comparisons. These marks were also striated. This area was more difficult to compare due to the greater amount of manipulation required so the extractor groove was the focus of comparisons.

When microscopically comparing the first test fires of extractors A and E several striations corresponded. Correspondence was also seen between the first test fires from extractors B, C, and

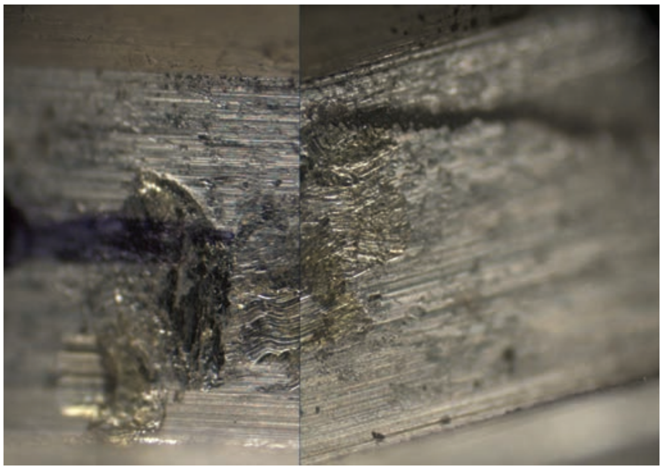

Figure 12: Extractor agreement (Extractor B TF1 vs. Extractor D TF298 80x)

Figure 13: Agreement Extractors C & D 35x

D. Within the extractor groove all three cartridge cases have a striated oval area and a larger area with the torn or rough non-directional appearance. The oval area has corresponding striations between all three cases (**Figure 12**). Some cartridge cases had striated marks within the torn area of the extractor mark, some did not. The first test fire of extractor D and the 298th test fire of extractor C were microscopically compared and again corresponding striations were observed. Test fires 299 and 300 were originally used, but they contained an insufficient amount of striations for comparisons.

Examination of the extractors C and D found areas in agreement (**Figure 13**). Even after both had been used over 300 times some agreement could be found. The corresponding areas are small and irregular; not what examiners are taught to be typical subclass. Examiners are taught that subclass characteristics are typically uniform, larger marks that run the length of a toolmark. Further studies are needed, and in progress, into the potential of subclass characteristics within MIM extractors.

Unlike the strikers, the extractors underwent no finishing procedures after molding. They received a Melonite coating, which appears to offer minimal, if any, changes to the surface of extractors. It is not known how Smith & Wesson applies this coating so there is a potential for the coating to be uneven and form random high points or fill in pre-existing pits on the surface. Either of these could produce individual characteristics unique to an extractor. If the application is more controlled then a more even layer is expected, lowering the potential for individual characteristics to show up at this step. If this is the case, it is suspected that the individuality of extractors comes from the debinding and/or sintering steps of the MIM process.

CONCLUSION

This project started with the fundamental issue of if and how MIM affects comparison work in fired ammunition components.

While learning the significance of MIM in firearms manufacture it was discovered that MIM is no new development to the field. Remington has had a MIM department for roughly twenty years. While MIM does seem to be more prevalent in parts that do not contact ammunition, Smith and Wesson has been paving a path to change this. Their latest M&P models contain MIM strikers and extractors. The extractor is no stranger to MIM; select Remington shotgun models also utilize these. Smith and Wesson does, however, seem to be the first to MIM strikers/firing pins. As more was learned a validation study was added to this project to see if examiners could discern MIM strikers based on firing pin impressions and firing pin drag marks.

Looking at the information gathered from comparing striker marks and extractor marks it suggests that MIM itself has a potential for agreement of characteristics within toolmarks made by separate tools from the same mold. The agreement of subclass characteristics from the first and last suitable test fires of different extractors supports this theory. The fact that there are several other areas examiners can and should utilize for these comparisons lessens the severity of this statement. The electropolish finish of strikers seems to diminish the possibility of subclass between different strikers from the same mold, as demonstrated by the comparison work performed on them.

It is highly unlikely that examiners will have to determine origin of cartridge cases and be able to use only one of these two firearm components, but being aware of the uniqueness of the Smith & Wesson M&P models is important, especially for examiners serving any of the ever-growing law enforcement agencies carrying this model. There was a brief period where the S&W Sigmas also used MIM strikers, so attention should be paid if any of these firearms are submitted for casework or when developing a list of possible firearms.

As recognized by the author the total elimination of the possibility of subclass characteristics cannot be concluded at this time. Examining the strikers during the MIM process and before and after electropolishing would allow one to track any progression of characteristics and their potential for subclass.

How the extractors mark during manual cycling was not examined and may vary how the extractor marks the cartridge case. Given more time a more thorough exam of the extractors and their marks should be performed to gain a better understanding of them and the potential of subclass marks. One theory proposed for the jagged portion of the extractor mark in the groove is that during firing the case may vibrate, causing the extractor to leave behind the very jagged, uneven surface. And during feeding or extraction/ejection the case rotates slightly, producing the circumferential marks seen under the rim of the case.

Similarly, the firing pin drag marks could also gain from further analysis and comparisons. The changes and durability of all three marks examined is of interest to see how comparisons may be affected. Three hundred test fires are but a fraction of some durability studies discovered during research. The issue of break-in period cannot be ignored and may present another factor affecting the cartridge cases.

The author would like to add great thanks to the following individuals who provided significant assistance in this project. Adam Young of Smith & Wesson; Maryann Wright of Remington; John Clark and Eric Freemesser of Monroe County Crime Laboratory; and the plentiful list of instructors with the NFEA training program.

REFERENCES

[1] AFTE Training and Standardization Committee. AFTE Glossary. 4th Ed. 2001.

Former MIM Firing Pins

[2] McCombs, Nancy. “Fired Cartridge Case Comparisons: 9mm and .40 Caliber Glock vs. Smith and Wesson Sigma Series Pistols.” AFTE Journal 36(2) 2004. p150-154.

[3] Downs, Kim. “The Enhanced Version of the Smith & Wesson Sigma Pistol.” AFTE Journal, Fall 1999 pp 498-499.

[4] Wright, Maryann. Personal Communication, July 20, 2010.

Electropolishing

[5] Keisler, Mark A.; Fazio, James. “Blackstar Bore Treatment and the Threat to Firearms Examiners.” AFTE Journal 29(2) 1997. pp 235-238.

Melonite Finish

[6] “H.E.F. USA” Melonite/QPQ/Arcor <www.hefusa.net/melonite-QPQ-arcor.htm> Accessed 2010 Aug 18.

[7] “Burlington Engineering, Inc.” Melonite Processing <www.burlingtoneng.com/melonite.htm> Accessed 2010 Aug 18.

Smith & Wesson

[8] Young, Adam. Personal Communication, Dec. 22, 2009.

[9] Smith and Wesson representative. Tour, April 18, 2010.

Durability of Toolmarks

[10] Shem, Robert; Striupaitis, Peter. “Comparison of 501 Consecutively Fired Bullets and Cartridge Cases from a .25 Caliber Raven Pistol.” AFTE Journal, 15(3). 1989. pp 109-112.

[11] Kirby, Shane. “Comparison of 900 Consecutively Fired Bullets and Cartridge Cases from a .455 Caliber Smith & Wesson Revolver.” AFTE Journal, 15(3). 1983. pp 113-126.

[12]. Yoshimitsu, Ogihara; et al. “Comparison of 5,000 Consecutively Fired Bullets and Cartridge Cases from a .45 Caliber M1911A1 Pistol.” AFTE Journal, 15(3). 1983. pp 127-140.

[13] Francesco, Vinci; et al. “Morphological Study of Class and Individual Characteristics Produced By Firing 2,500 Cartridges In a .45 Caliber Semi-automatic Pistol.” AFTE Journal. 37(4). 2005. pp 368-372.

Validation Study

[14] Buckleton, John; et al. “Experimental Design for Acquiring Relevant Data to Address the Issue of Comparing Consecutively Manufactured Tools and Firearms.” AFTE Journal 37(2) 2005. pp 142-147.

[15] Smith, Erich. “Cartridge Case and Bullet Comparison Validation Study with Firearms Submitted in Casework” AFTE Journal 36(4) 2004. pp 130-135.

[16] Nichols, Ron. "Validation Study for Impressed Marks." 41st Annual AFTE Conference. Henderson, NV, May 2010.
[17] Lyons, Dennis. "The Identification of Consecutively Manufactured Extractors." AFTE Journal 41(3) 2009. pp246-256.

MIM

[18] "SSI Technologies Sintered Specialties Division." Metal Injection Molding page <http://www.ssisintered.com/MIM_index.html> Accessed 2009 Dec 9.

References Reviewed but not Referred to in Text

"Able Electropolishing." Electropolishing Basics <www.ableelectropolishin.com/electropolishing.htm> Accessed 2010 June 28.

"Powder Injection Moulding International." Introduction to PIM <http://www.pim-international.com/aboutpim> Accessed 2009 Dec 9.

"FloMet, LLC." Technology:MIM < http://www.flomet.com/MIM.asp> Accessed 2009 Dec 9.