Environmental Effects on Cartridge Case Primer Shear Marks

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Stephanie M. Pollut, M.S.[1,2]*

Peter Diaczuk, Ph.D.[2,3]

Carol J. Gambino, M.S.[4]

Nicholas D. K. Petraco, Ph.D.[2]

[1]New York City Police Department Crime Laboratory, 150-14 Jamaica Ave, Jamaica, NY 11432

[2]John Jay College of Criminal Justice, 524 W. 59th Street, New York, NY 10019

[3]Pedico Research Institute, Waymart, PA 18472

[4]Bourough of Manhattan Community College, 199 Chambers Street, New York, NY 10007

Full Paper

Abstract

In order to address the scarcity of publications dealing with the comparison of cartridge cases subjected to environmental exposure, this pilot study investigated how the surface features of fired cartridge cases were affected when exposed to a moist environment over well defined periods of time. The primer shear marks of 25 (9mm) Remington 115 grain brass metal cartridge cases fired from a Glock 19 were examined. Five of these cases were not exposed (time = 0) to the environment so they could serve as control templates. All were viewed under a comparison microscope prior to exposure to confirm that the firearm was making reproducible marks on the primers. The cases were buried in a sun exposed forested plot in northeastern New Jersey (USA) during the summer months and analyzed at intervals of three, six, nine, and twelve weeks. The retrieved cases were examined once again with a comparison microscope. All buried cases were still capable of being matched with the unburied control cases despite some visible wear. Further examination with confocal microscopy was performed, in which 30 different surface parameters were measured. One-way Analysis of Variance (ANOVA) was applied to the mean surface parameters to determine if environmental exposure over time contributed significantly to observed variability (a rejection of the null hypothesis). All but one of the 30 parameter mean values met the 5% confidence level. The outlier value "Ssk" (p-value= 0.004), a height parameter which measures skewness of the height distribution, was further analyzed with the post hoc test Tukey HSD. It identified the comparison between the unburied case with the three week interval buried case as the source of the low probability (under 0.05).

Keywords: forensic science, toolmarks, firearms, cartridge cases, microscopy, statistics, pattern matching, surface metrology, surface topography, environmental effects.

Introduction

Forensic science uses physical evidence to determine the series of events that led up to a crime. There are seven different schemes for classifying physical evidence [1]. One such scheme is impression evidence. Impressions are created when an object leaves an imprint on another softer material. A few common examples of impressions are fingerprints, shoeprints, bite marks, tire tracks, and tool marks [2]. Firearms can be placed within the tool mark classification due to the mechanism that occurs when the gun is fired. "Firearms identification is the art and science of matching cartridge cases and bullets fired from the same firearm, based on the characteristic striation marks and impressed marks left by the gun," [3].

During the firing process, the bullet separates from the cartridge, leaving the case behind. This process produces toolmarks on the cartridge case specific to the gun that fired it. These toolmarks can hence be used to individualize the cartridge case to a specific firearm. To "individualize", means a sample can be traced to a single origin, in exclusion of every other [4]. An identification, according to the Association of Firearm and Toolmark Examiners's enables opinions of common origin to be made when the unique surface contours of two tool marks are in "sufficient agreement" [5,6,7]. Common tool markings left on cartridge cases include firing pin impressions, ejector marks, breech face marks and primer shear marks, (cf. figure 1). This study focused exclusively on primer shears.

A primer shear is a surface feature produced when the relatively soft, malleable metal used to manufacture the primer cup is displaced outward (rearward) into the firing pin aperture due to the pressure generated by the burning propellant. The primer is then scraped by the margins of the aperture when the breech is unlocked, forcing the rear of the barrel downward (figure 2). This is even more apparent in firearms that have large firing pin apertures, such as the Glock which has a characteristic rectangular shaped aperture to accommodate its elliptical firing pin.

It is not uncommon for investigators to recover firearm evidence weeks or months after a crime. Exposure to the environment could lead to surface corrosion and wear, potentially blighting the characteristic striations. In 1977, during a court case, it was asked whether or not the striation marks on a cartridge case would still be recognizable after suffering corrosion due to environmental factors [8]. In this study, we begin to answer this question by burying twenty fired cartridge cases for a period of up to twelve weeks to determine if the effects of environment and time alter shear mark striations sufficiently enough so that they can no longer be identified to their firearm of origin.

Primer shear marks were analyzed using comparison microscopy. The comparison microscope is the standard instrument used in forensic laboratories throughout the world to identify firearms by visual examination [9]. It allows two samples to be viewed side-by-side simultaneously, making it easier for the examiner to determine whether striation patterns are in agreement. There are, however, some contentions with the use of comparison microscopy alone. The comparison microscope was both time consuming and prone to error [10]. In general, it has been suggested that firearm and tool mark examination had no scientific basis or calculable error rates to satisfy the standards set by the Daubert ruling [11]. The controversy over firearms identification is mostly due to the subjective nature of the visual comparisons, as what constitutes a match is based on the examiner's own opinion and experience, variables which cannot be reproduced experimentally. In order address these concerns, confocal microscopy was also employed.

Confocal microscopy is a quick and nondestructive imaging technique that is capable of producing three-dimensional surface topographies [12]. A good in-depth review article of confocal microscopy is written by Artigas [13]. The resulting 3-D images not only allow visual comparisons, but also surface measurements which can then be used to do statistical analysis [12, 14, 15, 16]. In all, 30 surface parameters were measured for each of the 25 buried and unburied primer shear marks. The parameters were averaged and then subjected to one-way Analysis of Variance (ANOVA), to find out if there was any quantitative evidence that environment affected the individualization of cases within a particular time interval.

Experimental

Materials

Twenty-five cartridges were fired through a Glock 19 pistol for this experiment. The specific cartridge information is as follows: Caliber: 9mm Luger; Bullet Weight: 115 Grain; Bullet Style: Full Metal Jacket; Case Type: Brass. Five of these cases were left unburied to represent the time zero baseline. The rest were buried in the soil of a forested area exposed to sun in northeast New Jersey. The weather conditions over the course of this experiment were recorded every day (available upon request). At every three week interval, five cases were retrieved. Wet casings were left out to dry before packaging. A soft bristled paint brush was used to clear away any soil that clung to the surface.

The primer shears of the five fired, but unburied cases (labeled Unb) were checked under a comparison microscope for the repeatability of the striation marks. Once determined that the five unburied cases had indeed matching striation patterns, two were randomly selected (Unb1 and Unb4) as templates in which to compare all the buried cases against. The buried cases were labeled with the time interval they were collected followed by a number one through five randomly. For example, the cases collected after three weeks of burial were labeled 3wk1, 3wk2, 3wk3, 3wk4, and 3wk5.

A Lieca FS M (Leica Microsystems Inc. 1700 Leider Lane Buffalo Grove, IL 60089 United States) comparison microscope was used to make all the visual matches of buried and unburied cartridge cases under a 4x (0.14NA) objective. The comparison microscope was connected to a computer for visualization using LAS v3.8 (Leica Application Suite) software. Within this program images could be captured using the attached Leica DFC295 camera.

A Zeiss Axio CSM 700 white light confocal microscope (Carl Zeiss Microscopy, LLC One Zeiss Drive Thornwood, NY 10594 United States) was used to take 3-dimensional images of the primer shear marks under a 50x (0.95NA) objective and 0.15um resolution. Because shear marks tend to have a tilt with respect to the surface plane, cartridge cases were mounted on a goniometer during scans in order to make the shear marks as normal to the objective beam path as possible, resulting in decreased scan times. An example of the entire scanned image of a shear mark is shown in figure 3.

Surface Processing and Measurement

Noise removal was performed on the scanned images in the Ziess software using Z-interpolation. All scanned and noise removed images were imported into Mountains Map software for further surface processing and measurement. Images were cropped at the edges to remove non-striae areas and then subjected to form removal using a third order polynomial to take the curvature and twist out of the surface that would otherwise obscure the line pattern. An example of the resulting cropped and form removed image is shown in figure 4. Once the surface was processed the surface parameters were calculated. There were a total of 30 different parameters measured, under the categories of height, functional, functional volume, spatial, hybrid, and feature parameters [17].

Statistical Analysis

One-way analysis of variance (ANOVA) was performed on the surface parameters [18]. This kind of analysis can reveal evidence of statistically significant differences in the means of the measured parameters due to the environment with time thereof. We considered the "levels" of the explanatory (experimental) factor to be unburied, buried week 3, 6, 9 and 12 (five-levels), while the response variables were the surface parameters computed on each 3D primer shear surface. Under the null hypothesis, the variance of a parameter, grouped by this factor, is assumed to be the same. Rejecting this null is tantamount to stating that there is quantifiable evidence that the surface features of the cartridge cases change significantly due to effects of environment with some amount of exposure over time.

ANOVA was carried out using the open-source statistical software suite R [19]. The means of each of the explanatory levels for all the surface parameters were computed. Example box plots for the Ssk (surface skew) and Sz (average z-height) parameters are shown in figures 5 and 6. The box for each parameter was computed off of five primer shears.

The resulting p-values from ANOVA (Table 1) were examined to see if any statistically significant differences were indicated in the parameter mean values at the 5% level of significance (or less, *i.e.* p-value < 0.05). If a p-value indicated evidence of a difference, the (conservative) Tukey-HSD post hoc test was performed to examine which levels of the factors show evidence of difference.

Results and Discussion

The comparison microscopy results show very clearly that the cartridge cases from the selected weeks can be identified and individualized. When compared to the unburied cartridges, each buried case's striations still matched up. The cases from the 12 week period gave the most difficult comparison due to increased wear, however, there was not enough degradation to eliminate all of the match points. The major striation components were still visible and lined up when viewed next to each other.

The direction that the cartridge case (from any week set) fell into the ground also had an impact on how much degradation was found. If the case fell in with the headstamp down, the soil adhered to the primer shear more, and hence more wear was found than if the case fell with the headstamp facing up. Also, if the case fell on its side the part facing down eroded more.

Figures 7-11 are typical comparison micrographs of the different collection time periods. Note that the images show agreement in the striations for all time periods against the unburied control cases. Over the 12 week time period, the striation lines of the primer shears did not perceptibly vary. We do note that, generally, among the tinier striation lines, particularly those found on the bottom of the primer shear, they became more difficult to see, or disappeared as the time interval increased.

When the primer shears were obtained in 3D, the parameter information was computed on each of the five cartridge cases at each time point. The parameters of the five cases for a given week were then cross-compared against each other. When the parameters of the cases from each time period were averaged, then compared to the other weeks and the unburied averages, the numbers correlated closely. There were a few numbers that appeared to be outliers, but the statistical analysis showed that they were not, and therefore, used in the calculations.

Table 1 lists the p-values found under the experimental design. The p-values for differences in the surface parameter means by and large did not show any evidence of statistically significant differences. That is to say, there was generally no quantitative evidence found that the surfaces of the cartridge cases examined changed upon burial and exposure to the environment over the period of the study. These findings are consistent with the visual examinations on the comparison microscope. The one notable exception is for the Ssk (height distribution skewness) parameter (box-plots shown in figure 6). The p-value for this parameter was 0.004. The pairwise comparisons within the Ssk parameter group were further examined using the Tukey-HSD (see Table 2). The tests revealed one pair, unb-w3, was responsible for the rejection of the ANOVA null. That is, the Ssk parameter mean for week 3 of burial showed evidence of differences from the unburied cartridge cases. This can be due to ANOVA falsely rejecting the null hypothesis. ANOVA was run at the 95% confidence interval, which includes a 5% possibility of it falsely rejecting the null hypothesis. There was no evidence of any dirt contamination on the cartridge case to cause this anomaly as the visual examination with the comparison microscope concluded with a positive match. Also, if the case was not cleaned properly, the other parameters would have shown deviations from their sample averages. We speculate that the finding is a random anomaly rather than a typical effect that would be seen in larger study of the same design. With these results it can be said with confidence that even after 12 weeks of environmental exposure in the stated conditions, a match can still be made.

Conclusions

In this study we sought to determine if exposure to a moist (North Eastern U.S.) environment significantly altered the surface characteristics for the primer shears of 9mm Glock fired cartridge cases when buried in soil from 3 to 12 weeks. Traditional comparison microscopy was complemented with statistical assessment (ANOVA). The primer surfaces were quantified by a standard array of surface parameters used by the surface metrology community. Both methods showed that there was virtually no issue betweem comparisons of primer shear surface features for Glock fired cartridge cases with at least 12 weeks of the described environmental exposure. Any degradation that occurred in this time interval did not interfere with the ability to identify buried cartridges qualitatively or statistically with their unburied counterparts.

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Table 1 Probabilities from ANOVA calculations from R

Parameter Name	P-Value	Parameter Name	P-Value
Sq	0.25	Vm	0.31
Ssk	0.004	Vx	0.34
Sku	0.30	Vmp	0.31
Sp	0.20	Vmc	0.36
Sv	0.17	Vvc	0.38
Sz	0.14	Vvv	0.12
Sa	0.30	Spd	0.71
Smr	0.93	Spc	0.25
Smc	0.34	S10z	0.43
Sxp	0.17	S5p	0.17
Sal	0.21	S5v	0.26
Str	0.42	Sda	0.32
Std	0.92	Sha	0.23
Sdq	0.59	Sdv	0.48
Sdr	0.63	Shv	0.52

Table 2 Tukey values for the Ssk Parameter[1]

Week Pair	diff	lwr	upr	p adj
w12-unb	0.69	-0.07	1.45	0.09
w3-unb	1.15	0.39	1.91	0.001
w6-unb	0.79	0.03	1.55	0.04
w9-unb	0.65	-0.11	1.42	0.11
w3-w12	0.46	-0.30	1.22	0.40
w6-w12	0.10	-0.66	0.86	0.99
w9-w12	-0.03	0.80	0.77	0.99
w6-w3	-0.36	-1.12	0.40	0.63
w9-w3	-0.49	-1.26	0.27	0.33
w9-w6	-0.14	-0.90	0.62	0.98

[1]In Table 2: diff is the difference of the averages; lwr is the lower limit of the confidence interval; upr is the upper limit of the confidence interval; p adj is the adjusted probability

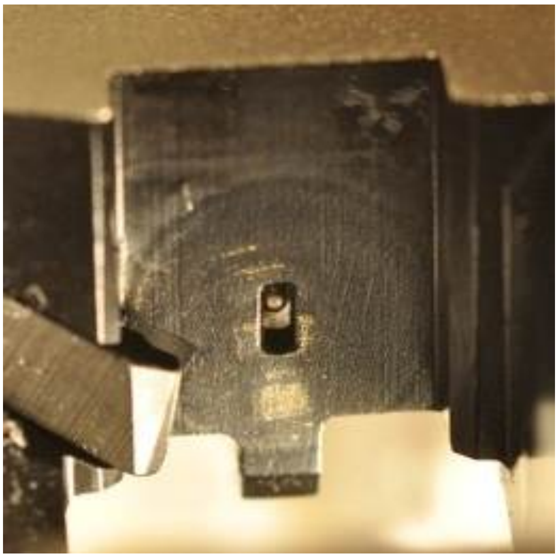


Figure 1: Image of breech face and firing pin of the Glock 19

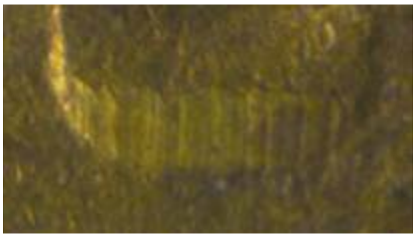


Figure 2: Image of an enlarged primer shear mark on a buried cartridge case.

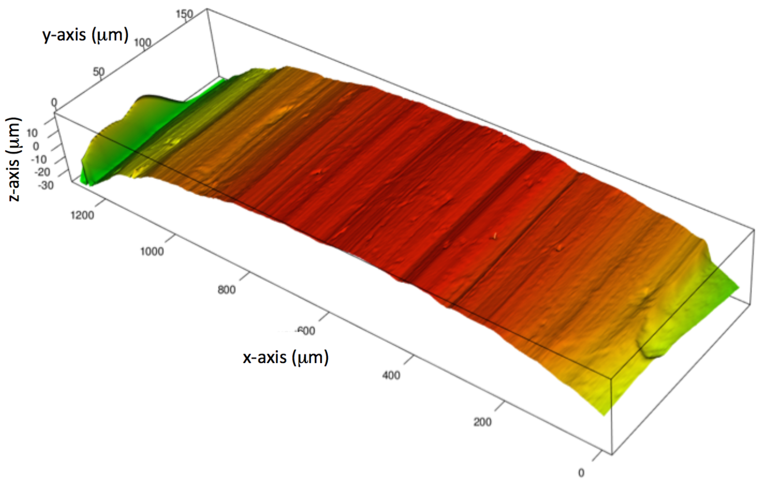


Figure 3: Linked image from confocal microscope of 3wk1 primer shear

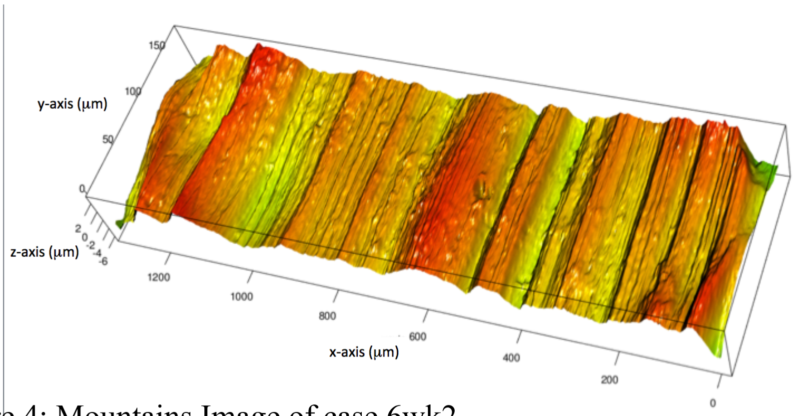


Figure 4: Mountains Image of case 6wk2

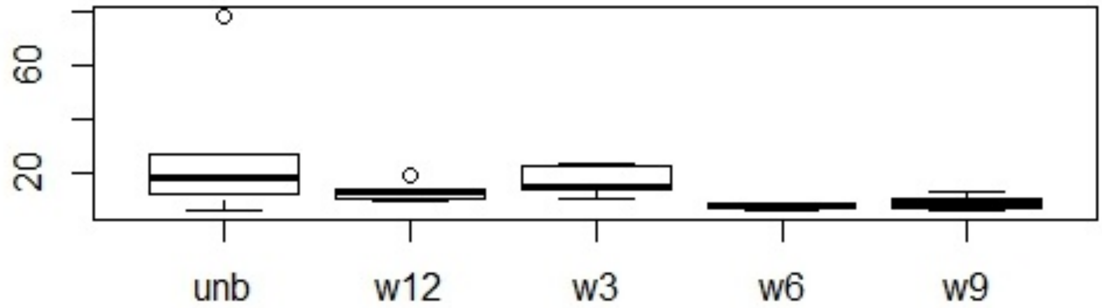


Figure 5: Sz Box plot from R; note that week 12 is in the second position

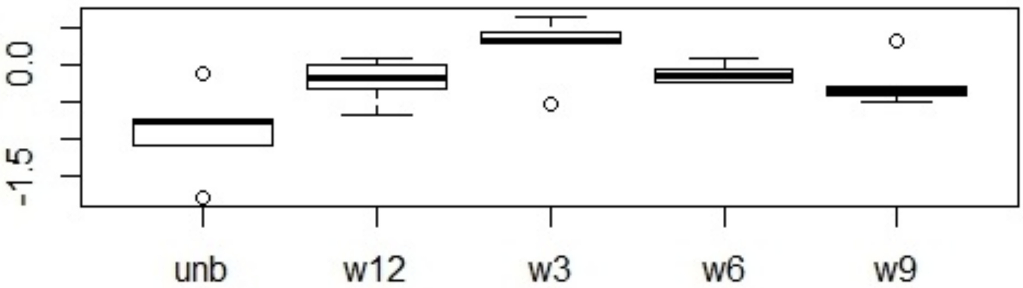
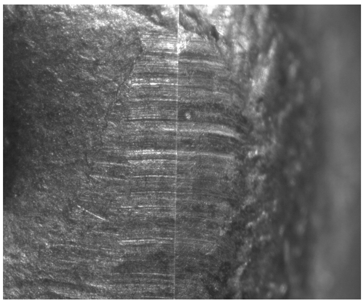
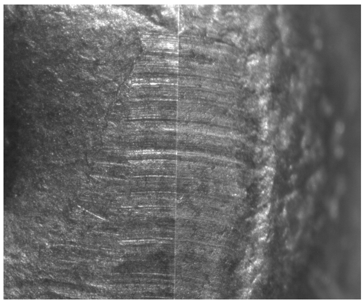


Figure 6: Ssk Box plot from R; note that week 12 is in the second position

a) 

b) 

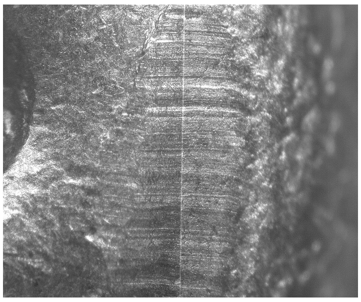
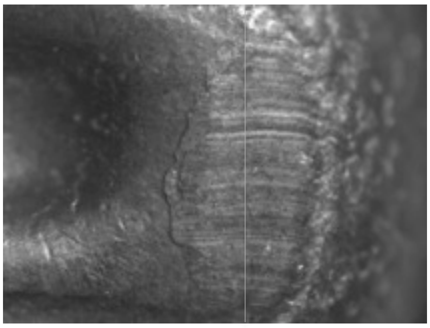
c) 

Figure 7: a) Image of Unb 1 compared to Unb 3; b) Image of Unb1 compared to Unb 4; c) Image of Unb 3 compared to Unb 4

a) 

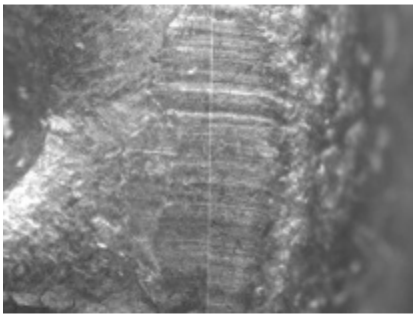
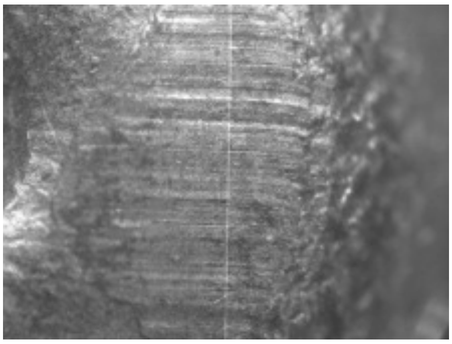
b) 

Figure 8: a) Image of 3wk4 compared to Unb 4; b) Image of 3wk5 compared to Unb 4

a) 

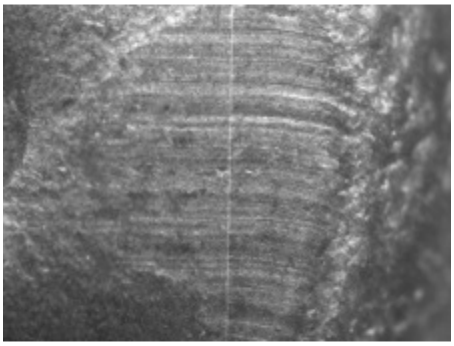
b) 

Figure 9: a) Image on 6wk2 compared to Unb 1; b) Image of 6wk4 compared to Unb 4

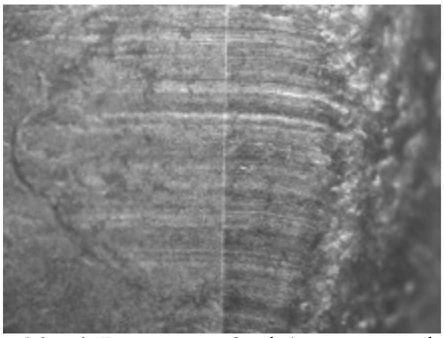
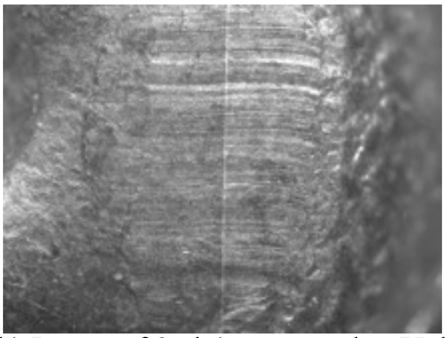
a)  b) 

Figure 10: a) Image on 9wk1 compared to Unb4; b) Image of 9wk4 compared to Unb 1

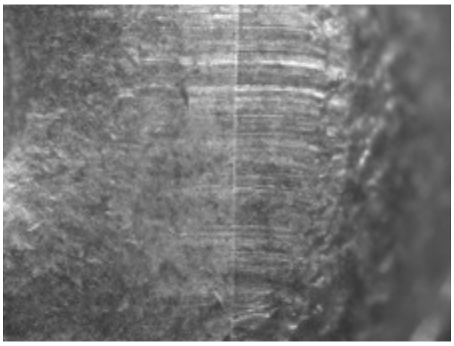
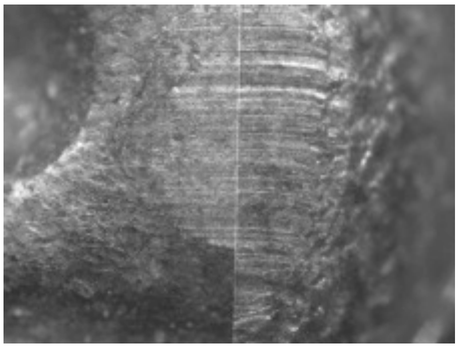
a)  b) 

Figure 11: a) Image on 12wk2 compared to Unb1; b) Image of 12wk5 compared to Unb1