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The Assessment of Experimental Methods of Serial Number Restoration

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The Assessment of Experimental Methods of Serial Number Restoration

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ABSTRACT

Keywords: Serial Number Restoration, Nondestructive, Firearms Analysis

Serial number restoration is a common and successful process of revealing obliterated serial numbers on firearms. In a crime laboratory setting, obliterated serial numbers are commonly processed in order to tie a person to a crime scene or provide an investigative lead for officers. Currently serial numbers are restored using a chemical etchant method that can eat away at the metal on the firearm even after the examination is complete. It can also take several hours to complete and only provide an examiner with a partial number. There are other nondestructive options however little to no literature is available.

The purpose of this study is to discover new methods for nondestructive serial number restoration and to compare them to the traditional chemical method used. Metal bars of premeasured obliteration depths and different compositions were examined using three proposed experimental methods: near infrared imaging, cold frost, and scanning acoustic microscopy. Results did not indicate significant difference in the median number of visible digits recovered for each of the three proposed methods compared to the traditional chemical method. There were significant results in the median number of composition utilized and depth of obliteration. This indicates that different firearm compositions and depth of obliteration has an effect on serial number restoration.

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Introduction

Purpose and Significance of Study

Serial number restoration is a common laboratory procedure that firearm examiners practice, and the interest to discover new nondestructive methods is growing at a steady rate. This study will be beneficial for firearm examiners seeking new methods of serial number restoration that have the potential to be nondestructive. There are current methods in place for examiners to use, however, most of them use chemicals to retrieve the obliterated number. These chemicals etch away at the metal of the firearm and can take several hours to produce a partial number. This study is important because examiners need to know if these proposed methods work and if so to conduct more research to get the viable methods accepted in the scientific community.

When the National Research Council published their article in 2009 pointing out all the weaknesses in forensic science including the firearm and toolmark discipline, they missed a key issue (National Research Council, 2009). What the National Research Council did not mention is the fact that firearm examiners destroy evidence when they recover serial numbers. All methods in place but magnetic particle restoration remove some metal on the firearm. The metal removed is a small amount but it is permanent. If a defense attorney ever became knowledgeable to the fact that evidence is destroyed, every examiner that testified would have to reconsider their testimony. Before it gets to that point, the firearm community needs to push for and implement nondestructive methods. If these proposed methods work, they could be the first step in the movement to nondestructive methods only.

Research Hypotheses

This study sought to examine three proposed nondestructive serial number restoration techniques: near infrared imaging (NIR), "cold frost", and scanning acoustic microscopy (SAM). Each technique has been proposed in previous literature but there is no current literature to support results for the techniques. If one or all of the proposed methods produced visible serial numbers it would provide firearm examiners with a nondestructive technique that takes little time to complete, the following hypotheses were developed:

H_0: Using a NIR instrument will not make an obliterated serial number on a firearm become visible.

H_1: With the use of a NIR instrument, an obliterated serial number on a firearm will become visible.

H_0: After applying the "cold frost" technique, an obliterated serial number on a firearm will not become visible.

H_1: With the use of the "cold frost" technique, an obliterated serial number on a firearm will become visible.

H_0: Using a SAM will not make an obliterated serial number on a firearm become visible.

H_1: With the use of a SAM, an obliterated serial number on a firearm will become visible.

Limitations of the Study

This study will not attempt to recreate every serial number restoration that can possibly occur. The basis of this study is to explore new methods of serial number restoration and help push for more research. It is under that assumption that if any of the proposed techniques produce numbers, future research will be consider in order to validate the current study's methodology and approach.

Chapter 2

Review of the Literature

A serial number is a unique identifying number given to every legally produced firearm made in the United States after the Gun Control Act of 1968 (ATF, 2005). Some firearms are given more than one serial number, one on the barrel, one on the receiver, one on the frame, etc. However, the true serial number on a firearm as reported by many firearm examiners is primarily located on the frame (Christophe, 2011). There are several different methodologies for applying a serial number (Kuppuswamy, 2011). Some of the more common methods are dot matrix serial numbers, which are applied in a series of punched dots and laser etched serial numbers, which are etched into the metal using a laser. However, one of the most prominent methods for applying a serial number is by using a die stamp. This method has become one of the most popular (Katterwe, 1996). Once the serial number has been imparted on the firearm the metals structural integrity has been altered forever, and the serial number goes below the visible surface of the metal; essentially creating a deformity in the structure that is commonly referred to as plastic deformation. When obliterating a serial number it is important to note that one is not actually removing the serial number, but simply hiding it from the unaided eye, however a full removal can and may occur.

There are several methods for restoring obliterated serial numbers. Serial numbers may be retrieved with a simple visual examination using a low powered microscope if the damage is not extensive (Maiden, 2009). Another nondestructive method for the restoration of serial numbers is magnetic particle restoration, or *Magnaflux*®. Typically, methods that are more destructive are utilized. Chemical etchants and polishing are among the destructive techniques employed. Polishing consists of smoothing the area where the serial number once was and assuring that an even surface is available for visual examination prior to chemical etchant application. In such an instance, the visibility of an obliterated serial number is made possible using specular reflection (The Physics Classroom, 1996). The use of chemical etchants has been the most effective and least time consuming method to date (Knowles, 1985). The chemical utilized in chemical restoration depends on the metallurgical properties of the firearm. For example, a firearm that is a cheaper zinc alloy may require milder acids and a shorter processing time than a firearm made from cold rolled steel (Kennington, 1997). This brings to call an urgent need for more nondestructive methods that are just as reliable.

The first section of the literature review will describe the near infrared imaging method and its various methods. The next section describes the "cold frost" or dry ice method, its history in firearms analysis and its various methods. The final section reviews literature that involves the scanning acoustic method and its previous applications with metals similar to firearms.

Near Infrared Imaging

Near infrared (NIR) energy is defined by the International Union of Pure and Applied Chemistry (IUPAC) as the range of the electromagnetic spectrum, extending from 780-2500 nm (Davis, 1998, p. 17). In principle, NIR starts where the human eye generates no visual response. Near infrared radiation is not related to the temperature of the object being photographed with infrared film but to the molecular composition and vibration combinations in an item. Near infrared has an advantage over mid infrared because it can usually penetrate much farther into a sample. Near infrared can be useful for probing bulk material with little or no sample preparation because it can penetrate into the surface without any destruction. Fredrick William Herschel is credited with discovering near infrared energy in 1800 during a refraction experiment (Herschel, 1800). Herschel projected a rainbow onto a bench with the use of a prism to measure the relative heating effect of the different parts. He then moved from the blue light to the red noticing an increase in temperature. The temperature still increased when he came to the end of the diffracted spectrum. Herschel continued to measure the heat well into the black area where he discovered the highest temperature (Davis, 1998, p. 17). After Herschel, other scientists examined the electromagnetic spectrum, but no advances were made until the 1950s. In its first application, NIR was used simply as an accessory to other optical devices such as Ultraviolet-Visible Spectroscopy (UV/Vis) and Mid-Infrared Spectrometers (MIR). Karl Norris from the U.S. Department of Agriculture can be credited with the first industrial application of NIR energy in 1962. Norris introduced NIR analysis for the practical use in agricultural and food to grade eggs (Williams, 1982). It was not until the 1980s that a single self-sustaining near infrared spectroscopy system was available. Near infrared imaging was originally used in chemical analysis until light-fiber optics were developed in the mid-1980s. It was not until then that near infrared imaging became useful in scientific research. Near infrared imaging is now used in several fields of science including physiology, physics, medicine, and now forensic science.

Near infrared spectra are composed of absorptions due to overtones of fundamental bond stretching or bending vibrations occurring in the infrared regions and combinations of the same fundamental absorption and electronic vibrations (Davis, 1998, p.18). Every object that has hydrogen atoms will have a measurable NIR spectrum. When the hydrogen bonds change in length, it causes a shift in the absorption peaks, which is what NIR spectroscopy measures. Absorptions in the NIR region are much weaker than those in the IR region allowing the NIR spectra to obtain information from samples without dilution (Davis, 1998, p.18).

Ever since the first commercial IR instrument, the Beckman IR-1, launched in 1942, many IR instruments have been manufactured and sold. These instruments are similar to the instruments used in UV-visible and MIR ranges. NIR instruments can be classified into two categories: laboratory analyzers for research purposes and process analyzers for use in production lines (Lin, 2002). Fourier transform infrared (FTIR) instruments use an interferometer, a technique used to analyze protein conformation in any physical state and in highly complex matrices. FTIR allows one to study proteins in their natural environment, at acceptably low concentrations (Van De Weert, 2005, p. 131). Incandescent or quartz halogen light bulbs are often used as broadband sources of near infrared radiation for analytical applications as well as light-emitting diodes or LEDs (Sivakumar, Van Veggel, & Raudsepp, 2005). Many commercial instruments for UV/Vis spectroscopy are capable of recording spectra in the NIR range.

The instrument most important for this aspect of forensic science is the LEEDS N-IRC near infrared and white light imaging kit. The kit has a camera capable of taking real viable light pictures as well as near infrared images. The LEEDS N-IRC instrument package includes LEEDS vision and annotation software. The filter on the camera allows near infrared images to be taken in the 830 nm range. Leeds Forensic Systems has recently used the microscope to examine gunshot residue left behind on human hair. The software can show both a NIR image and a white-light image to facilitate side-by-side comparisons. At low and medium magnifications, it is difficult to differentiate the gun shot residue from the hair follicles. However when looking at the residue under a high magnification, under near infrared light, it is as if the hair disappears leaving the gun shot residue in plain sight. If this microscope could produce the same quality images for serial number restoration, it would be a breakthrough in recovering obliterated serial numbers. It would be a rapid, simple, and nondestructive examination that just about anyone could conduct.

Figure 1: A gunshot residue image taken at low magnification using white light on the left and NIR on the right. From LEEDS, 2014.

As in other fields of science, there are advantages and disadvantages to NIR spectrometry. NIR will give data regarding the composition of the sample if it is unknown. To save time NIR does not require any type of sample preparation and only requires a small quantity to sample. It is an inexpensive, rapid, nondestructive and multi-parametric method. NIR instruments tend to be reasonably priced because their optical parts are not harmed by environmental humidity (Patil, 2007). There is also no hazardous waste produced because NIR analysis does not require reagents or solvents. However, NIR analysis depends on less-precise reference methods and requires calibration before repetitive usages (Patil, 2007).

Near infrared technology is most commonly used in the medical field to monitor brain activity and qualitative production in agriculture. Other common applications of NIR spectroscopy include the astronomical spectroscopy, pharmaceuticals, agriculture, and combustion products. The field of medicine is focusing on non-invasive procedures to gain insight into the human body and near infrared technology can do so. NIR will absorb and transfer through the body tissues that contain information about hemoglobin concentration. NIR is very useful when it comes to monitoring brain activity because it can non-invasively monitor cerebral cortical oxygenation responses to various stimuli (Mehagnoul-Schipper, 2002). Unlike other equipment, near infrared spectroscopy (NIRS) instruments have the capability to go wireless making them accessible as well (Shadgan, 2009). NIRS is also used to quantify blood flow, blood volume, oxygen consumption, reoxygenation rates and muscle recovery time (Van Beekvelt, 2001). If NIR can be used to penetrate an important surface like skin without any damage there is reason to believe it could do so on crucial pieces of evidence like firearms.

NIRS is also used in astronomy to study the atmospheres of cool stars where molecules can form (Rudy et al., 2002). A phenomenon referred to as "interstellar reddening" occurs when matter like dust and gas is absorbed and scattered by electromagnetic radiation. This atmospheric reddening occurs in near infrared wavelengths making it plausible to capture in a near infrared image. In a "before" picture, this would be an image of stars with a dust covering some of them up and then the "after" near infrared image would be a clear image of all the stars. This also helps to determine the age of stars and their masses. A NIR camera smaller than a volleyball has recently been made available that has the capability of capturing deep-space readings. This small camera can capture images 10-50 light years away (Greenwood, 2007). The same camera is also being used to capture readings from atmospheres light-years away to determine if they have anything in common with Earth (Greenwood, 2007). It is plausible to believe that NIR could be used to examine serial numbers in metal frames if it is currently being used to see through rocks and solid debris in space.

As stated, near infrared imagining is used to see through materials where the human eye cannot distinguish. These materials range from human tissue to dust in the atmosphere. Gunpowder residue composition being similar to atmospheric rock leads forensic scientists to believe this NIR can be applied to serial number restoration by seeing through the obstruction on a firearm. NIR's noninvasive characteristic also deems is a very suitable technique to capture the "apparent, gone-forever serial numbers" without inflicting damage of its own.

Cold Frost

Dry ice has many uses in its raw form. These range from commercial to decorative uses but most importantly, it has the potential to serve as a scientific method in the discovery of obliterated information. French inventor Adiren-Jean-Pierre Thilorier is credited with the discovery of dry ice in 1835 (Thilorier, 1835, p. 194). He noted that when opening a large cylinder containing liquid carbon dioxide, most of it evaporated quickly. Only solid dry ice was left behind in the container. It was not until 1924 that Thomas B. Slate applied for a US patent in order to sell dry ice commercially (Killeffer, 1930, p. 1087). A year later in 1925 DryIce Corporation of America trademarked this solid form of CO_2 as "Dry Ice", thus leading to its common name (Killeffer, 1930, p. 1087). Dry ice is also referred at as "cardice" or "card ice", mainly in the region of Great Britain.

Dry ice is a solid form of carbon dioxide, made of a single carbon atom with two oxygen atoms attached. It has a sour zesty odor, slightly acidic, it's colorless, and nonflammable. Dry ice is a white substance similar to ice at atmospheric pressure at -109.3°F. Dry ice is special because it goes straight from being a solid to a gas with no liquid stage in between through a process termed sublimation. It can also go through an opposite process called deposition where CO_2 changes from gas to a solid or dry ice. The low temperature and director sublimation to a gas makes dry ice an effective coolant because it is colder than ice water and leaves no residue as it changes state (Yaws, 2001, p. 124)

Dry ice manufacturing starts with liquid carbon dioxide, which is, submitted to pressure in bulk storage vessels. Under intense pressures, this liquid CO_2 immediately transforms into CO_2 gas. The change from liquid to gases causes the temperature to drop quickly. Approximately 46% of the gas will turn into carbon dioxide snow leaving the rest to be released into the atmosphere or recovered to be recycled. The carbon dioxide snow is then compressed into block, pellet, or rice size pieces to meet the customer's requirements. In order to make the dry ice last longer, easier to handle, and have better performance when blast cleaning corroded objects it needs to be made more dense (Energy Institute, 2010, p. 10).

Dry ice has several applications including commercial, industrial, scientific, and hopefully soon forensic science. The most common use of dry ice is to preserve food via non-cyclic refrigeration (Yaws, 2001, p.125). Because dry ice does not need to be electronically powered, it makes it a convenient way to keep ice cream, biological samples, and medical supplies cold in places not equipped with electricity. Dry ice has another advantage over a refrigerator because it can prevent insect activity in closed food container products due to the extremely cold temperatures. Dry ice displaces oxygen without altering the quality or tastes of foods. Another popular use for dry ice is to create fog for dramatic effects. When dry ice is submerged in water, sublimation is accelerated and low sinking dense clouds that resemble fog are created. Most artificial fog machines produce fog that rises like smoke, whereas dry ice fog will hover above the ground. It also serves as a medical benefit by being used to freeze and remove warts (Lyell, 1966, p. 1576). Even though liquid nitrogen is preferred for wart removal because of its colder temperature, dry ice has the advantage of being stored easer because of its quick generation (Goroll & Mulley, 2009, p. 1317).

One of the largest mechanical uses of dry ice is blast cleaning. Blast cleaning is where dry ice pellets are shot out of a nozzle with compressed air, combining the power of speeding pellets with the action of sublimation. Blast cleaning is used to remove residues from industrial equipment like ink, glue, paint, mold, and rubber (Spur et, al, 1999, p. 402).

Dry ice is also used in scientific laboratories. A dry ice slurry is used in an organic solvent for cold chemical reactions and for condensing solvents in rotary evaporators (Housecroft, 2001, p. 410). It can also be used to intentionally change the amount or type of precipitation that falls from clouds. In the 1950s and 1960s, General Electric Labs in New York deposited dry ice via plane on cloud surfaces. This is return, increased precipitation, suppressed hail, and scattered fog to increase visibility (Griffith, 2006, p. 83). Experiments are still being conducted to determine what makes dry ice successful in affecting precipitation states (Griffith, 2006, p. 83). This process has proven to benefit agriculture, airports, and snow ski resorts. Dry ice has the advantage of being relatively cheap and non-toxic however, it needs to be delivered directly into the super cooled region of the clouds being manipulated (Griffith, 2006, p. 83).

The field of forensic science is also taking advantage of dry ice's amazing abilities. In 2009, the European Network of Forensic Science Institutes (ENFIS), Scientific Working Group on DNA Analysis Methods (SWGDAM) and Biology Specialist Advisory Group (BSAG) published a statement requesting that manufacturers of disposable plastic ware and other reagents utilized in the forensic field take precautions to prevent contamination in their manufacturing processes (Gill et. Al, 2009, p. 269). Investigators are discovering cross contamination incidents in cases worldwide, which led the organizations listed above to take action and compile a list of guidelines they would like manufacturers to adhere to. Promega Corporation, a manufacturer of enzymes for biotechnology, is just one company that made appropriate changes. They took it upon themselves to conduct extensive research on dry ice to enable the use in packaging. Promega uses dry ice in their genetic identity kits to ensure that their products do not go through a freeze-thaw cycle (Pearson, 2010). Dry ice has the capability to keep biological and other materials at a stagnate temperature for long periods at a time. The Federal Bureau of Investigation (FBI) also uses dry ice to prepare hair evidence for DNA analysis. If the hair is coated in a semi-permanent coating it can be removed by soaking the hair in a solvent or by rapid chilling using dry ice (SWGMAT, 2005).

For the purpose of restoring serial numbers from firearms and other objects, little research has been conducted. "Cold frost" is another name for this particular dry ice technique. Generally, the obliterated serial number is covered in dry ice, coating the top surface brining it to a frozen state. The underlying stamped impression is thought it be revealed per not dropping to as low of a temperature. The technique is listed in handbooks for restoration of obliterated serial numbers and firearm articles however there is no significant background research, methods, or a definitive conclusion. In Methods for the Restoration of Obliterated Serial Numbers by Richard S. Treptow (1977), he uses Claude Cook's, from the Colorado Bureau of Investigation, idea of how to use the cold-frost method. Cook suggests the firearm should be polished first and then wiped over with dry ice to produce a viable frost pattern (Cook & Rhoden, 1978). However, Cook only proposed that serial numbers may become visible but never produced any evidence to support his theory. Treptow then follows Cook's exact steps, on two different metals, and came to the conclusion that no restoration was accomplished (Treptow, 1977, p. 95).

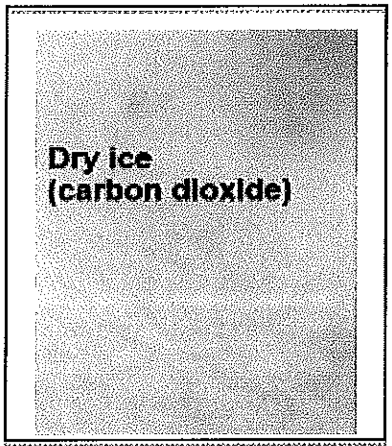

Figure 2: This illustrates what the firearm would look like after dry ice has been applied. From Silva, 2014.

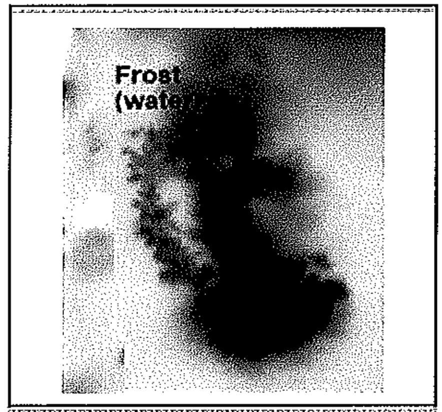

Figure 3: This illustrates what the obliterated serial numbers would look like after the dry ice has been applied. From Silva, 2014.

Gregory S. Klees, a noted Firearms examiner, has spent several years researching and perfecting serial number restoration techniques. A recent article of his examines two other nondestructive methods: scanning electron microscopy and x-ray mapping. Klees also lists other nondestructive methods in his article most of which have not been thoroughly tested before. The cold frost method is listed with an experimental status and no usage (Klees, 2009, p. 184).

Dry ice has several uses in a variety of industries including packaging in forensic science. Cold frost is not mentioned frequently when it comes to firearm restoration methods partly because of Cook's article. However there is not sufficient evidence to completely rule out the cold frost method. Therefore, extensive research needs to be conducted on the cold frost method to either completely rule out the method or bring to light its ability to restore obliterated serial numbers in a nondestructive manner.

Scanning Acoustic Microscopy

Sergei Sokolov is credited with the idea of developing an acoustic microscope imaging device in the early twentieth century (Sokolov, 1941, p.160). Sokolov and his colleagues first conducted experiments to secure acoustic images by using high-frequency acoustic waves. However, it is Lemons and Quate who developed the first SAM at Stanford University in 1973 (Lemons & Quate, 1973, p. 18). During the same time, another group of researchers at Zenith Radio Research Labs led by L.W. Kessler developed their own version of SAM, which underwent several improvements in order to enhance image resolution (Kessler & Korpel, 1972, p.111). The improved SAM, whose techniques are used today, applied pulsed acoustic waves instead of continuous waves (Briggs, 1992, p. 868). By the late twentieth century, electronic circuit and gradual mechanical improvements had been made to automate the image collection. The development of the atomic force acoustic microscope has made it possible for the conventional acoustic microscope to take measurements in nanometers (Rabe & Arnold, 1994, p. 589-598).

Scanning acoustic microscopy is an extraordinary tool that enables researchers to examine internal structures in objects without staining or destruction their surface. It allows scientists to explore deeper into a specimen and reach goals by possessing the capability to observe and analyze micro-environments. Scanning acoustic microscopy is commonly used in biological and medical research, on opaque materials, and hopefully soon firearms for restoration. Two different techniques are available: the Scanning Acoustic Microscope (SAM) and the Scanning Laser Acoustic Microscope (SLAM). SAM structures use sound energy to produce images with the use of transducers. Images are produced by measuring the acoustic reflectance or transmission of an object in a focused spot (Arnold & Reiter, 1985 p. 85). Whereas SLAM uses plain sound waves to penetrate further into the sample but at lower resolutions.

The SAM is different from other microscopes because it operates on a set of principles unlike the standard microscope: the use of acoustic waves, far-field wave imaging, and scanning. The SAM is unique in the way that it can see all points of the object at the same time unlike a conventional microscope. The SAM uses a transducer that shoots a beam through a liquid; typically water, to the object being scanned. The object causes the beam to scatter, which is then detected piezoelectrically. Piezoelectrics are crystalline materials with a unique capability; when the crystals are put under stress or have some type of external voltage applied, the material will deform and an electrical charge is generated. Therefore, in a SAM, when the voltage is applied to the transducer it deforms the crystal that then produces an ultrasonic wave. This ultrasound wave interacts with the object being examined and is then recaptured by the same transducer (or, depending on the operating mode, by a secondary transducer) and converted into an electrical charge. This charge is then processed to generate an image. The process is repeated by scanning each point individually to eliminate opportunities for interference and then combined to create an overall image. This same procedure occurs as the object is completely scanned over, the voltage is recorded in each position of the focused beam and an image is formed.

Another principle that the SAM utilizes that no other microscope does, is the use of a focused beam. As the focused beam is formed by converging propagating waves, it effects the size of the focal spot (focal area) making it limited by diffraction (Zinin & Wieland, 2004, p. 655). In addition, the SAM has a detector isolated from the sample ensuring that no near-filed effects of the waves can be deployed.

The third principle that the SAM operates on is imaging with ultrasound. SAM uses frequencies between 100 MHz and 2 GHz; these high frequencies make it possible to void distributions with a resolution of up to 1 μm at a depth of 10 um and obtain accurate measurements (Zinin &Wieland, 2004, p. 656). However, the liquid used makes it impossible to use the high frequencies, which makes the maximum distance between the sample and the microscope about 60 um at 2 GHz. In most acoustical images, there are speckles and the images produced are grainy because there is interference in the waves that are too small to be resolved by the microscope. However, in the SAM the transducer always detects and emits sound consistently leading to clearer images (Zinin &Wieland, 2004, p. 656).

There are two different common techniques used to achieve the convergence of the ultrasound wave in the SAM. The simplest way is to use a piezoelectric transducer or for a higher-resolution an acoustic lens made from a buffer rod can be used (Zinin &Wieland, 2004, p. 655). In order to nondestructively examine objects the microscope needs a cylindrical lens. The cylindrical lens yields better results than that off spherical lenses because it produces a more focused beam of light (Kushibiki & Chubachi, 1985, p. 189-212).

Like each instrument used in science the SAM has both benefits and limitations. As previously stated it has the ability to view features inside an object without any change or deformation. This is made possible by the use of ultrasound waves, which typical microscopes do not use. Ultrasound waves produce more accurate data because they can limit diffraction by the use of a focal point. When examining inside the SAM can see some features a standard x-ray cannot detect like die attach voiding (the adhesive used between an IC chip and circuit) and popcorn cracking. SAM also takes better measurements than other microscopes at the micro-level. Another quality feature is the ability to distinguish carbon-fiber from other materials that a manufacturer might use to fortify an object. Nevertheless, the SAM is not perfect. It does not have the ability to block out naturally occurring sound waves. As of right now there is not a way to manipulate sound waves to speed up the processing time and limit the sensitivity of an area containing mechanical toughness, at a relatively low cost. These limitations prevent the SAM from becoming a widespread and accepted form in scientific study. If the SAM recovered obliterated serial numbers, it could potentially become a valued instrument.

There are still several applications for the SAM because of its nondestructive qualities and accurate measurements. SAM is used for vendor qualification, product reliability testing, research, counterfeit detection, process validation, and quality control. Failure analysis is one of the most widespread and important uses of SAM; it enables companies to examine the quality of a product before they ship it out. If the product is damaged pre-shipping, the company can prevent it from leaving the warehouse. This saves a tremendous amount of money, which would be spent on return shipping as well as to help satisfy consumers. The microelectronics industry greatly values the SAM and uses it to determine if a product is defective or not in order to sell to a consumer. Some electronic companies use the technology in analytical labs to determine the quality of flip-chips, a new component in computer circuit boards (Ouellette, 2004, p. 15). IBM, Motorola, and Hewlett-Packard are just a few of the companies who use SAM as part of their failure-analysis procedure (Ouellette, 2004, p.16).

SAM is also being utilized in the biological field. Unlike a standard microscope, when using the SAM to examine soft tissues the researcher does not have to stain the tissue or prepare the sample in any way (Saijo, 2013, p. 291). The SAM cannot only be used to examine cells but also bone, cartilage, tendon, and cardiovascular tissues for biomechanical properties (Saijo, 2013, p. 291). Whenever a SAM uses 100 MHz or higher frequency, it can capture specific details inside cells as finite as the nucleus (Saijo, 2013, p. 291). There is still further study on how far SAM can be used to examine and study the human body.

Currently there is no research or validation for SAM in the field of forensic science. However there is promising research when it comes to recovering serial numbers from firearms and other metal objects. In 2004, Paul L. Benson and Robert S. Gilmore conducted a study using a SAM to recover hallmarks and engravings from metal objects. Different types of metal spoons, forks, and coins were examined in hopes of determining the illegible and worn-off marks by using scanning acoustic techniques. Benson and Gilmore produced successful images from the silver items composed of other alloys, whereas gold did not produce images because of its malleability. Imaging from worn-off or illegible hallmarks and engravings was successful one hundred percent of the time when residual flow was still present in the metal (Benson & Gilmore, 2004, p.2).

Figure 4: An image of the original hallmark. From Benson & Gilmore, 2004.

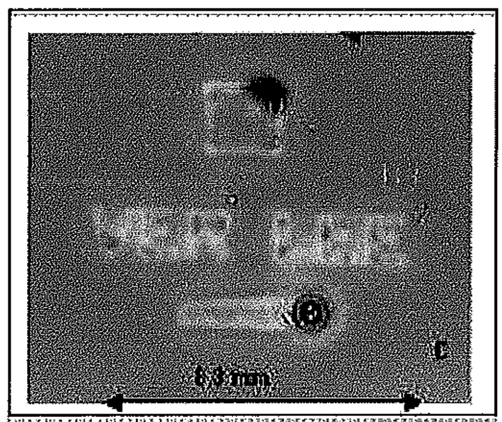

Figure 5: A 20 MHz F/1 surface wave image of the original hallmark. From Benson & Gilmore, 2004.

Eva Drescher-Krasicka and J.R. Willis conducted research in 1996 using acoustic microscopy to examine the presence of mechanical stress. Drescher-Krasicka and Willis used the acoustic principle that the speed of sound in a solid is altered in the presence of mechanical stress (Drescher-Krasicka & Willis, 1996, p. 52). This effect can be utilized to form the basis of acoustic microscopy whereby images of stress patterns in a material are obtained by monitoring the times of flight of sound pulses (Briggs, 1992). When using different acoustic wavelengths, an image of stress inside on object can be captured ranging in size from microelectric devices to welds in pressure vessels (Drescher-Krasicka & Willis, 1996, p. 52). This could potentially be beneficial when recovering a serial number stamped into a firearm. There are different methods for placing serial numbers on firearms as previously mention with stamping being most common. Firearms are made from metals, and like most solids, are composed of a crystal structure and a chemical bond between the atoms called metal-metal bonds (Houck & Siegel, 2006, p. 571). When using the stamp method on a firearm two things happen. First, the metal is compressed making it denser than the surrounding metal. Then the metal-metal bonds are disrupted making the metal weaker. When there is an attempt to file off the serial number, the perpetrator will remove the raised weaker metal however, what they do not realize is that the stamping goes deeper into the metal. Therefore, the SAM could possibly be used to examine the stamped serial number deep in the metal even after the number has been polished off past visibility. An obvious limitation is that this method can only apply to firearms where the serial number was stamped on. Background research has opened new possibilities for the use of SAM in forensic science. Because of its capability to examine objects internally without destruction, it could be a new nondestructive serial restoration method.

Chapter 3

Article Submission #1

Prepared for the AFTE Journal

The Assessment of Near Infrared Imaging Use in Serial Number Restoration

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Keywords: Serial Number Restoration, Near Infrared Imaging, Nondestructive, Aluminum, 4140, Stainless Steel

Abstract

The purpose of this study was to analyze whether the experimental use of near infrared imaging has the ability to nondestructively recover obliterated serial numbers in comparison to the current used method of chemical restoration. This study is beneficial for labs and firearm examiners conducting serial number restoration by the chemical application of acids, which in turn damages the surrounding metal. Using a sign test, the researcher was able to examine the effects of near infrared imaging on obliterated numbered bars by counting the restored numbers and then comparing those numbers to the chemical method. The results of this experiment indicate that near infrared imaging is nondestructive but cannot recover any obliterated numbers whereas chemical restoration can. However, only one type of near infrared imaging was applied, NIR filters placed on a camera. There are still other types of equipment that have the ability to perform near infrared imaging at greater wavelengths, which should be explored.

Introduction

The practice of serial number restoration has been around for many years, and has several methods that have achieved scientific acceptance in the relevant community. There are various chemical etchants that have been found to be reliable in the retrieval of serial numbers while there is a lack of scientific research identifying various nondestructive methods [1]. Chemical etchants are a convenient way of restoration and show reliability. However, the etching rate and corrosion can alter the metal both during and after the restoration process has ended. Klees notes in his article two nondestructive methods that are established and common (relief polishing and magnetic particle), in comparison to the list of destructive methods that well outnumber the nondestructive methods [2]. He also briefly mentions the use of infrared imaging as experimental, and that currently no use of the method has been applied [2]. Since this method is purely experimental, an assessment of the concept was created at the W. Roger Webb Forensic Science Institute to investigate this nondestructive restorative method further and report relevant literature results based on its application.

Literature Review

Near infrared (NIR) imaging can be difficult to understand. Typical digital cameras contain internal filters to block out all IR light, as well as UV light. Most Single-Lens Refelex (SLR) digital cameras can be altered to accommodate NIR photography [3]. A qualified professional may remove the internal IR, NIR, and UV filters to enable the SLR camera to shoot NIR photography. There are also different types of lenses that may be purchased to further enhance NIR imaging. In addition to internal alterations, an NIR pass filter may be installed in the camera to allow for speedier NIR photo shoots [3]. Please note that the alterations and lenses to allow for NIR photography are very costly, and once the ALR camera has been modified to allow for this type of imaging, it is essentially useless for conventional photography. IR, NIR, and UV photography is currently used in various ways by law enforcement. The Crime Scene Unit of the Oklahoma City Police Department has utilized IR, NIR, and UV photography as in aid in criminal investigations where injuries were invisible to the human eye. The use of alternative light penetrates deeper through the tissue unlike how visible light can. In such instances where bruising and bite marks were an investigative inquiry the use of IR, NIR, and UV photography has been advantageous in revealing such marks that appear healed in visible light. In other instances, the use of IR, NIR, and UV photography has been very beneficial in illuminating blood and gunshot residue deposits on dark colored garments.

Materials

Numbered Bars

Nine obliterated metal bars were utilized in this study. Precision Forensic Testing assembles serial restoration sample kits composed of various types of obliterated numbered bars to assist in serial restoration research. In this study, three bars consisting of stainless steel, three bars consisting of carbon steel, and three bars consisting of aluminum alloy were used.

Aqua Regia Reagent

Aqua regia is a solution of nitrohydrochloric acid that was used during this study to etch away at the obliterated area for chemical restoration purposes. It is comprised of a three to one mixture of hydrochloric acid and nitric acid respectively.

Sand Paper

60-grit sandpaper was used in this study to polish the surface of the obliterated bars during the chemical restoration process.

Equipment

Cotton swabs, weigh boats, and distilled water were utilized to apply the chemical etchants and clean the glassware when finished. The camera employed in this study was a Nikon D2 SLR camera that Fuji modified to a Fuji IS Pro with Nikon AF-S Micro Nikor 60mm 1.28 G Lens. The filters employed were Peca filters - 900, 902, 904, 906, 908, 910, 912, 914, 916. The filters allow different wavelengths to be captured.

Methods

Procedure for Collecting Data

Due to the experimental nature of this research, the researcher established a method that would compare the results from the NIR photographs to the current standard procedure used in many labs for serial number restoration: chemical restoration. Before and after each method was applied, a photo was taken for documentation. If numbers would become visible after the NIR filters were applied to the camera, then they were noted and then that bar would be coded with a 1. If no numbers appeared, then that bar would be coded with a 0.

Each of the nine bars were individually placed on the laboratory table to be photographed using the camera with the different NIR filters attached. The camera was set in manual mode and placed upon a tripod to aid in changing of the filters. The household lamp was also turned on to generate heat throughout the metal bars in order for the NIR filters to capture. The camera was also hooked up to a television in the laboratory to provide a larger image for the researches to view. The different filters utilized in this research ranged from 690-1100 nm. Each filter was then screwed on the camera lens starting with the shortest wavelength and then the researcher adjusted the focus to capture a clear image. The image was then displayed on the television for the researchers to note any changes on the bars that resulted in visible numbers. This process was repeated with each of the seven filters on each of the nine obliterated bars.

After each of the nine bars had been through the NIR portion, chemical etching utilizing aqua regia was then applied. Each bar was processed one at a time. Each bar was polished using the 60-grit sandpaper to make the obliterated surface have a smooth, mirror like finish. Then using a cotton swab, the aqua regia reagent is applied to the surface utilizing a back and forth motion for thirty seconds. The sixty-grit sandpaper is then applied to make the surface smooth again for approximately thirty seconds. When the aqua regia was applied again, it was poured directly on the surface to form a pool for thirty seconds. Then the sixty-grit sandpaper was applied again to make a smooth surface. Swabbing, sanding, pooling, and sanding for thirty seconds each was repeated for two hours while taking note if a number became visible.

Procedure for Assessing Data

After each bar had completed the NIR and chemical etching method, it was examined for any kind of surface change it was coded with a 0 or 1. The code 0 meant that there was no change in the surface and no number appeared to indicate a full or partial serial number. The code for 1 meant that there was some change in the surface indicated a full or partial serial number. If only some numbers became visible, they were documented with spaces between the still obliterated numbers. For example, if three numbers appeared not in sequence, they were document in the lab notebook as 3 _ 5 4 _ _. The zeros and ones were then statistically compared using a sign test to evaluate any significance between the experimental method of NIR to the commonly used method of chemical etchants.

Results

One hypothesis was assessed for this experiment, which included different components like composition and depth of the bars. To determine statistical significance sign tests (for the median difference) were performed for each variable of interest and seen in Table 1. Due to the non-normality of the data, the results of the Sign Tests are preferred. *P*-values less than 0.05 are considered to be significant. All tests were performed in SAS v. 9.3.

Table 1.

Tests for differences in the methods.

	Sign Test	
	M	*p*-value
NIR vs. Chemical Etch	1.5	0.250

1. H_0: Using a NIR instrument will not make an obliterated serial number on a firearm become visible.

The results indicated that there was no significant differences in the number of digits recovered by the NIR method and the chemical etch method.

The mean number of digits recovered is only available for the chemical method because NIR did not recover any digits. The summary statistics are seen in Table 2.

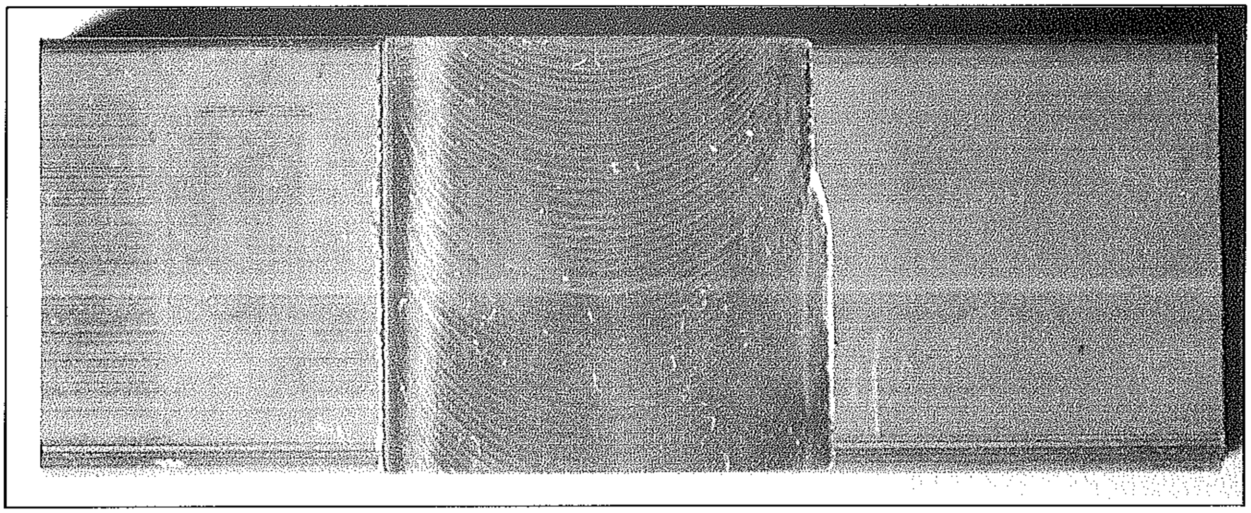
Table 2.

Summary statistics for the number of digits recovered by method.

Method	*n*	Mean	Median	Std. dev.	Range
NIR	9	0	0	0	0-0
Chemical Etch	27	1.2	0	1.8	0-6

Figure 1.

Stainless steel .003 in. obliterated bar under 1100 nm NIR filter



No digits appeared even in the longest wavelength utilized (1100 nm) as seen in Figure 1. The curved lines that appear are caused from the machine utilized to obliterate the bar at a premeasured depth.

Conclusion

The results indicate that there is no significant difference in the digits recovered from the NIR experimental method and the currently used chemical etchant method. Therefore, the current chemical method should continue to be used in firearm laboratories until a better nondestructive method is introduced into the field.

Limitations

The NIR wavelengths range from 750-2500 nm and the Peca filters utilized in this study only reached 1100 nm. Wavelengths that exceed 1100 nm should be applied to the obliterated bars to see if any digits appear.

The NIR methodology was completely nondestructive including relief polishing. Polishing would have made the surface smooth and shiny instead of having the rough curved lines present. It is unclear if those lines hindered the recovery of the digits but it could be explored.

In order to make a statistically sound comparison, there could only be one methodology utilized for the chemical etchant no matter the composition of the bar. In casework a firearms examiner will use chemicals that are specific to the composition on the bar and may even compound chemical reagents. The use of one chemical and a set time affected the successful outcome of recovered serial numbers.

Future Research

Future research needs to be conducted to fully assess how far NIR waves can penetrate different metal compositions. The NIR spectrum extends to 2500 nm. At the end of this project, the farthest wavelength reached was 1100 nm. Other experiments could be conducted by looking into the longer wavelengths. Also, the temperature of the object being examined plays a role in the image reflected back, raising or lowering the temperature of the bars to see if the obliterated area reflects back differently could be conducted in other experiments.

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Chapter 4

Article Submission #2

Prepared for the AFTE Journal

The Assessment of "Cold Frost" Use in Serial Number Restoration

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Keywords: Serial Number Restoration, Cold Frost, Dry Ice, Nondestructive, Firearms Analysis

Abstract

The purpose of this study was to analyze whether the experimental use of "Cold Frost" or dry ice has the ability to nondestructively recover obliterated serial numbers in comparison to the current used method of chemical restoration. This study is beneficial for labs and firearm examiners conducting serial number restoration by the chemical application of acids, which in turn damages the surrounding metal. Using a sign test, the researcher was able to examine the effects of cold frost or dry ice on obliterated numbered bars by counting the restored numbers and then comparing those numbers to the chemical method. The results of this experiment indicate that cold frost is nondestructive but cannot recover any obliterated numbers whereas chemical restoration can. This was a research experiment to attempt to advance the field by assessing a proposed nondestructive technique. Future research is vital to discover and implement a reliable nondestructive serial number restoration technique.

Introduction

The practice of serial number restoration has been around for many years, and has several methods that have achieved scientific acceptance in the relevant community. There are various chemical etchants that have been found to be reliable in the retrieval of serial numbers while there is a lack of scientific research identifying various non-destructive methods [1]. Chemical etchants are a convenient way of restoration and show reliability. However, the etching rate and corrosion can alter the metal both during and after the restoration process has ended. Greg Klees notes in his article two nondestructive methods that are established and common (relief polishing and magnetic particle), in comparison to the list of destructive methods that well outnumber the nondestructive methods [2]. He also briefly mentions the use of cold frost as experimental, and that currently little use of the method has been applied [2]. Since this method is purely experimental, an assessment of the concept was created at the W. Roger Webb Forensic Science Institute to investigate this nondestructive restorative method further and report relevant literature results based on its application.

Literature Review

The current literature on the cold frost method and its use on firearms is limited. Claude Cook, a firearm examiner from the Colorado Bureau of Investigation, proposed the idea of applying dry ice to the surface of an obliterated serial number in the early 1970s [3]. Then Richard Treptow, a metallurgist at Chicago State University, documented Cook's theory in his serial restoration handbook but also added that the results may be speculated by the author [3]. In Mr. Cook's methodology, an examiner would first polish the obliterated area and then wipe over it with dry ice. After the surface frosts over the number would then be visible in the frost pattern. Mr. Treptow tried using Mr. Cook's methodology on a piece of alloy steel and was unsuccessful in obtaining any numbers. There was no other information provided such as amount of time dry ice was applied, how the number was obliterated, and the environment this study was conducted in. The current study applied the dry ice for a set amount of time, on different types of metal, and on different obliteration depths.

However, other manuals and textbooks will reference the cold frost technique as a possible restorative method but do not provide any documentation or evidence of a successful or non-successful application [4, 5]. Therefore, there is not enough evidence to completely disregard this experimental approach.

Materials

Numbered Bars

Nine obliterated metal bars were utilized in this study. Precision Forensic Testing assembles serial restoration sample kits composed of various types of obliterated numbered bars to assist in serial restoration research. In this study, three bars consisting of stainless steel, three bars consisting of carbon steel, and three bars consisting of aluminum alloy were used.

Dry Ice

One pound of dry ice was utilized in this study to lower the temperature of the numbered bars and make a frost like appearance.

Aqua Regia Reagent

Aqua regia is a solution of nitrohydrochloric acid that was used during this study to etch away at the obliterated area for chemical restoration purposes. It is comprised of a three to one mixture of hydrochloric acid and nitric acid respectively.

Sand Paper

60-grit sandpaper was used in this study to polish the surface of the obliterated bars during the chemical restoration process.

Equipment

Cotton swabs, weigh boats, and distilled water were utilized to apply the chemical etchants and clean the glassware when finished. An Igloo cooler was used to keep the dry ice in for the duration of the experiment.

Methods

Procedure for Collecting Data

Because this study is completely experimental, it was decided that it would be best to compare the results from the cold frost method to the current standard for serial number restoration: chemical etching. Before each method was applied, a picture was taken and then once the process was complete another picture was taken. If any numbers became visible, they were noted and then that bar would be coded with a 1. If no numbers appeared, then that bar would be coded with a 0.

The nine bars were first individually photographed and then placed on top of the dry ice brick inside an Igloo cooler for fifteen minutes one at a time. After the allotted time expired, the obliterated bar was removed from the cooler and photographed. At this time, the obliterated area was examined to see if any of the obliterated numbers became visible and the results were recorded in the lab manual.

After each of the nine bars had been through the cold frost methodology, chemical etching utilizing aqua regia was then applied. Each bar was processed one at a time. Each bar was polished using the 60-grit sandpaper to make the obliterated surface have a smooth, mirror like finish. Then using a cotton swab, the aqua regia reagent is applied to the surface utilizing a back and forth motion for thirty seconds. The sixty-grit sandpaper is then applied to make the surface smooth again for approximately thirty seconds. When the aqua regia was applied again, it was poured directly on the surface to form a pool for thirty seconds. Then the sixty-grit sandpaper was applied again to make a smooth surface. Swabbing, sanding, pooling, and sanding for thirty seconds each was repeated for two hours while taking note if a number became visible.

Procedure for Assessing Data

After each bar had completed the cold frost and chemical etching method, it was examined for any kind of surface change it was coded with a 0 or 1. The code 0 meant that there was no change in the surface and no number appeared to indicate a full or partial serial number. The code for 1 meant that there was some change in the surface indicated a full or partial serial number. If only some numbers became visible, they were documented with spaces between the still obliterated numbers. For example, if three numbers appeared not in sequence, they were document in the lab notebook as 3 _ 5 4 _ _. The zeros and ones were then statistically compared using a sign test to evaluate any significance between the experimental method of cold frost to the commonly used method of chemical etchants.

Results

One hypothesis was assessed for this experiment, which included different components like composition and depth of the bars. To determine statistical significance sign tests (for the median difference) were performed for each variable of interest and seen in Table 1. Due to the non-normality of the data, the results of the Sign Tests are preferred. *P*-values less than 0.05 are considered to be significant. All tests were performed in SAS v. 9.3.

Table 1.

Tests for differences in the methods.

	Sign Test	
	M	*p*-value
Cold Frost vs. Chemical Etch	2.5	0.063

1. H_0: Using the cold frost method will not make an obliterated serial number on a firearm become visible.

The results indicated that there was no significant differences in the number of digits recovered by the cold frost method and the chemical etch method.

The mean number of digits recovered is only available for the chemical method because cold frost did not recover any digits. The summary statistics are seen in Table 2.

Table 2.

Summary statistics for the number of digits recovered by method.

Method	*n*	Mean	Median	Std. dev.	Range
Cold Frost	9	0	0	0	0-0
Chemical Etch	27	1.2	0	1.8	0-6

Figure 1.

Aluminum .003 in. obliterated bar frosted over from cold frost method

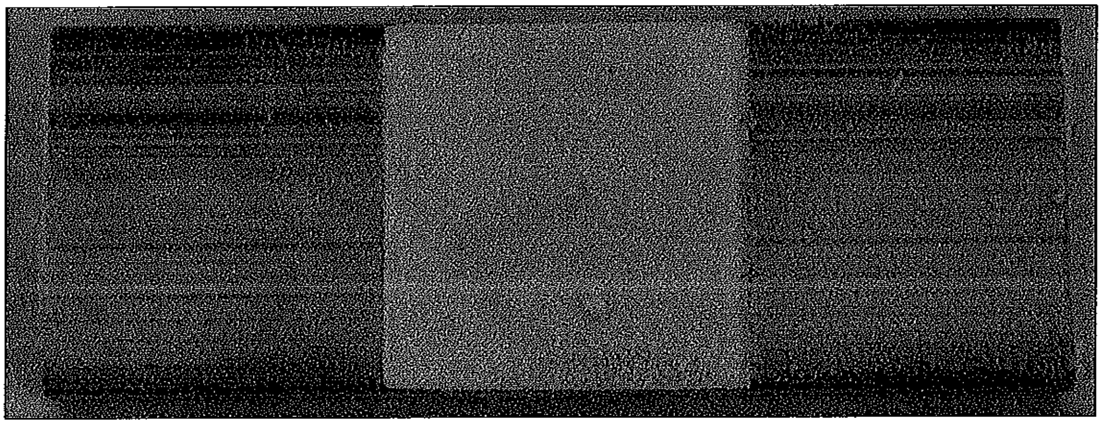

Figure 1. represents what each of the bars looked like after they were placed on the dry ice for fifteen minutes. They all had a white frosted appearance but no digits appeared darker in the frost.

<u>Conclusion</u>

The results indicate that there is no significant difference in the digits recovered from the cold frost experimental method and the currently used chemical etchant method. Therefore, the current chemical method should continue to be used in firearm laboratories until a better nondestructive method is introduced into the field.

Limitations

When the dry ice was applied the metal it became to sublimit immediately. It was recommended by a chemistry faculty member to perform the study in an airtight chamber to help keep the temperature constant for the dry ice. There is no such thing on UCO's campus, therefore the study was conducted in an ice chest to try and help with the temperature control.

In order to make a statistically sound comparison, there could only be one methodology utilized for the chemical etchant no matter the composition of the bar. In casework a firearms examiner will use chemicals that are specific to the composition on the bar and may even compound chemical reagents. The use of one chemical and a set time affected the successful outcome of recovered serial numbers.

Future Research

Future research needs to be conducted on the list of experimental serial number restoration techniques that Klees provided until one is proven to work consistently. Currently there are only a couple of nondestructive methods being used in a firearm laboratory; one of which only works on ferrous metals. Chemical restoration has the ability to obstruct the obliterated number further and it can be a timely process.

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Chapter 3

Article Submission #1

Prepared for the AFTE Journal

The Assessment of Scanning Acoustic Microscopy Use in Serial Number Restoration

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Keywords: Serial Number Restoration, Scanning Acoustic, Nondestructive, Aluminum, 4140, Stainless Steel

Abstract

The purpose of this study was to analyze whether the experimental use of scanning acoustic microscopy (SAM) has the ability to nondestructively recover obliterated serial numbers in comparison to the current used method of chemical restoration. This study is beneficial for labs and firearm examiners conducting serial number restoration by the chemical application of acids, which in turn damages the surrounding metal. Using a sign test, the researcher was able to examine the effects of scanning acoustic microscopy on obliterated numbered bars by counting the restored numbers and then comparing those numbers to the chemical method. The results of this experiment indicate that scanning acoustic microscopy is nondestructive but cannot recover any obliterated numbers whereas chemical restoration can. However, there were some areas that reflected back images that indicted a number was there, just unidentifiable. Future research should be conducted to explore different aspects of SAM to determine definitively if it is a plausible method for nondestructive serial number restoration.

Introduction

The practice of serial number restoration has been around for many years, and has several methods that have achieved scientific acceptance in the relevant community. There are various chemical etchants that have been found to be reliable in the retrieval of serial numbers while there is a lack of scientific research identifying various non-destructive methods [1]. Chemical etchants are a convenient way of restoration and show reliability. However, the etching rate and corrosion can be detrimental to the metal both during and after the restoration process has ended. Greg Klees notes in his article two nondestructive methods that are established and common (relief polishing and magnetic particle), in comparison to the list of destructive methods that well outnumber the nondestructive methods [2]. He also briefly mentions the use of scanning acoustic microscopy (SAM) as experimental, and that currently no use of the method has been applied [2]. Since this method is purely experimental, an assessment of the concept was created at the W. Roger Webb Forensic Science Institute to investigate this nondestructive restorative method further and report relevant literature results based on its application.

Literature Review

The current literature on SAM and its use of firearms is nonexistent. Therefore, other applications of this method on materials similar to firearms were examined. Jamaliah Idris, a mechanical engineer at the Universiti Teknologi Malaysia, conducted a study using a SAM to detect flaws in metallic materials. The principle of operation of a SAM is to produce acoustic images of exterior and interior of a solid by passing high frequency acoustic pulses through the material and then displaying the received signal in the image from as shades of grey [3]. Idris selected her samples by using a Vickers harness test, quenched samples, and porosity samples. Some of her samples included stainless steel and aluminum, which are consistent with the make up of firearms. Idris was able to obtain images from the samples she examined that contained cracks in voids in the metal. She also noted that in order to obtain the best images it depends on the operating frequency of the instrument used and the smoothness of the surface on the object being examined [3]. This is significant to the application of a SAM on obliterated serial numbers because most of the time the surface will be the opposite of smooth.

Materials

Numbered Bars

Nine obliterated metal bars were utilized in this study. Precision Forensic Testing assembles serial restoration sample kits composed of various types of obliterated numbered bars to assist in serial restoration research. In this study, three bars consisting of stainless steel, three bars consisting of carbon steel, and three bars consisting of aluminum alloy were used.

Aqua Regia Reagent

Aqua regia is a solution of nitrohydrochloric acid that was used during this study to etch away at the obliterated area for chemical restoration purposes. It is comprised of a three to one mixture of hydrochloric acid and nitric acid respectively.

Sand Paper

60-grit sandpaper was used in this study to polish the surface of the obliterated bars during the chemical restoration process.

Equipment

Cotton swabs, weigh boats, and distilled water were utilized to apply the chemical etchants and clean the glassware when finished. Priority Labs utilized a Matec Micro-Electronics Scanning Acoustic Microscopy to scan the obliterated bars. The transducer is capable of producing a variety of frequencies from 15-110 Mhz.

Methods

Procedure for Collecting Data

Due to the experimental nature of this research, the researcher established a method that would compare the results from the SAM images to the current standard procedure used in many labs for serial number restoration: chemical restoration. Before and after each method was applied, a photo was taken for documentation. If numbers would become visible after the SAM scanned the bar and produced an image, then they were noted and then that bar would be coded with a 1. If no numbers appeared, then that bar would be coded with a 0.

Each of the nine bars were individually placed under the SAM to be examined. Three different transducers were utilized: 110Mhz, 50Mhz, and 15Mhz. It would take approximately two minutes for the transducer to scan over the obliterated area. Once the transducer scans the obliterated area, an acoustic image of the bar is formed on the display monitor. Each image was captured and saved for documentation purposes.

After each of the nine bars had been through the SAM portion, chemical etching utilizing aqua regia was then applied. Each bar was processed one at a time. Each bar was polished using the 60-grit sandpaper to make the obliterated surface have a smooth, mirror like finish. Then using a cotton swab, the aqua regia reagent is applied to the surface utilizing a back and forth motion for thirty seconds. The sixty-grit sandpaper is then applied to make the surface smooth again for approximately thirty seconds. When the aqua regia was applied again, it was poured directly on the surface to form a pool for thirty seconds. Then the sixty-grit sandpaper was applied again to make a smooth surface. Swabbing, sanding, pooling, and sanding for thirty seconds each was repeated for two hours while taking note if a number became visible.

Procedure for Assessing Data

After each bar had completed the SAM and chemical etching method, it was examined for any kind of surface change it was coded with a 0 or 1. The code 0 meant that there was no change in the surface and no number appeared to indicate a full or partial serial number. The code for 1 meant that there was some change in the surface indicated a full or partial serial number. If only some numbers became visible, they were documented with spaces between the still obliterated numbers. For example, if three numbers appeared not in sequence, they were document in the lab notebook as 3 _ 5 4 _ _. The zeros and ones were then statistically compared using a sign test to evaluate any significance between the experimental method of SAM to the commonly used method of chemical etchants.

Results

One hypothesis was assessed for this experiment, which included different components like composition and depth of the bars. To determine statistical significance sign tests (for the median difference) were performed for each variable of interest and seen in Table 1. Due to the non-normality of the data, the results of the Sign Tests are preferred. *P*-values less than 0.05 are considered to be significant. All tests were performed in SAS v. 9.3.

Table 1.

Tests for differences in the methods.

	Sign Test	
	M	*p*-value
SAM vs. Chemical Etch	2.0	0.125

1. H_0: Using a SAM instrument will not make an obliterated serial number on a firearm become visible.

The results indicated that there was no significant differences in the number of digits recovered by the SAM method and the chemical etch method.

The mean number of digits recovered is only available for the chemical method because SAM did not recover any digits. The summary statistics are seen in Table 2.

Table 2.

Summary statistics for the number of digits recovered by method.

Method	*n*	Mean	Median	Std. dev.	Range
SAM	9	0	0	0	0-0
Chemical Etch	27	1.2	0	1.8	0-6

Figure 1.

Stainless steel .003 in. reflected SAM image at 15 MHz

The SAM showed some progress as demonstrated in Figure 1. Towards the middle on the left side there is some curvature visible. It does correspond to where the first digit would be located on the bar.

Conclusion

The results indicate that there is no significant difference in the digits recovered from the SAM experimental method and the currently used chemical etchant method. Therefore, the current chemical method should continue to be used in firearm laboratories until a better nondestructive method is introduced into the field.

Limitations

Priority Labs, the laboratory who assisted with the study, primarily examines computer chips for failure analysis. They utilized a SAM instrument that had three transducer abilities (110, 50 and 15 MHz). Figure 1. produced the most promised and was captured when the 15 MHz transducer was used. Priority Labs also shared that SAM instruments are being used to examine airplane wings for damage and use a 1-5 MHz transducer. Future research needs to examine obliterated bars with transducers than can perform at smaller ranges.

SAM instruments are extremely sensitive and perform best on smooth flat surfaces. This study was completed nondestructive, which includes relief polishing. The images reflected back contained curved lines that were produced during the obliteration stage to obtain premeasured depths. Obliterated bars that have a smooth surface should be examined to see if better images can be produced.

In order to make a statistically sound comparison, there could only be one methodology utilized for the chemical etchant no matter the composition of the bar. In casework a firearms examiner would use chemicals that are specific to the composition of the bar and may even compound chemical reagents. The use of one chemical and a set time affected the successful outcome of recovered serial numbers.

Future Research

Future research needs to be conducted before this experimental approach is fully eliminated. In each of the images produced, there were no distinct digits visible but there were curved lines to indicate a digit was once there. Different transducers and/or magnifications could be explored. There was some relief polishing conducted on a few of the bars before examining them with the SAM. However, the purpose of this study was to be truly nondestructive which included polishing. During relief polishing, there are still fine amounts of material that are being taken away. A future study should be conducted to see if better images could be obtained if polishing was included in the methodology.

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Chapter 5

Discussion

Introduction

Nondestructive serial number restoration techniques are available but they are not truly nondestructive and they only work on ferrous metals. Most restoration techniques destructive and nondestructive contain relief polishing. When the examiner utilizes the back and forth motion with a textured surface they are removing small amounts of metal from the firearm. This study wanted to see if there could be a method for recovering serial numbers that is nondestructive entirely. This was done by selecting three completely experimental methods suggested by a veteran firearm examiner who specializes in serial number restoration. It was hypothesized that some of the obliterated numbers would become visible after the application of each of the proposed experimental methods.

The current literature on each of the proposed methods is limited. Each method is currently being utilized in some of field of science but has never been applied for restoration of serial numbers. Dry ice is used to transport biological materials where NIR is used for space exploration. The researcher had to explore the methodologies for the common uses of the proposed methods and apply them to metal for serial number restoration.

In the following discussion, the implications of this study will be discussed. The statistical results will be evident through the following tables and statistical tests. Each hypothesis will describe the results between the experimental methods and how they compared to the current method of chemical etching. Limitations will also be discussed as well as future recommendations for this research.

Hypotheses

Sign tests were performed for each variable of interest. Due to the non-normality of the data, as seen in Table 4., the results of the Sign Tests are preferred. *P*-values less than 0.05 are considered to be significant. All tests were performed in SAS v. 9.3 (Morris, 2015).

Hypotheses 1: H_0: Using a NIR instrument will not make an obliterated serial number on a firearm become visible.

The results indicated that there was no significant difference in the mean number of digits between the experimental method of NIR and the current method chemical etching seen in Table 1 (Morris, 2015).

Hypotheses 2: H_0: After applying the "cold frost" technique, an obliterated serial number on a firearm will not become visible.

The results indicated that there was no significant difference in the mean number of digits between the experimental method of cold frost and the current method chemical etching seen in Table 1 (Morris, 2015).

Hypotheses 3: H_0: Using a SAM will not make an obliterated serial number on a firearm become visible.

The results indicated that there was no significant difference in the mean number of digits between the experimental method SAM and the current method chemical etching seen in Table 1 (Morris, 2015).

Table 1.

Tests for differences in the methods.

	Sign Test	
	M	*p*-value
Cold Frost vs. Chemical Etch	2.5	0.063
SAM vs. Chemical Etch	2.0	0.125
NIR vs. Chemical Etch	1.5	0.250

Two additional research questions became apparent within the study. While study the effects of serial number restoration, the statistical results indicated that there was a significant difference in the number of digits recovered by the nondestructive and chemical method on the aluminum bars (p=.016) found in Table 2. (Morris, 2015). This indicates that firearms with an obliterated serial number that are composed of aluminum will have a higher chance of recovery.

Another interesting point was the depth of obliteration. Looking at the sign test results, there is a significant difference in the number of digits recovered by the nondestructive and chemical etch methods on the bars obliterated to a depth of 0.003 in. (p=0.031) which is noted in Table 3. (Morris, 2015).

Table 2.

Tests for difference in the methods by composition.

	Sign Test	
Composition	*M*	*p*-value
Aluminum	3.5	0.016
Stainless Steel	2.5	0.063

Table 3.

Tests for difference in the methods by depth.

	Sign Test	
Depth	*M*	*p*-value
0.003 in.	3.0	0.031
0.015 in.	2.0	0.125
0.024 in.	1.0	0.500

Table 4.

Summary statistics for the number of digits recovered by method.

Method	*n*	Mean	Median	Std. dev.	Range
Cold Frost	9	0	0	0	0-0
SAM	9	0	0	0	0-0
NIR	9	0	0	0	0-0
Chemical Etch	27	1.2	0	1.8	0-6

Importance of the Study

The purpose of this study was to explore new possible nondestructive methods for serial number restoration and that is exactly what the researcher did. Of all the methods examined, the SAM method showed the most promise and therefore more research needs to be conducted to examine all its potential. The researcher applied three new techniques to obliterated bars and was unsuccessful in recovering any numbers. However, that is still advancement for the firearm and toolmark discipline. Another researcher can now eliminate NIR and cold frost from the experimental list of methods and try another proposed technique. The goal was to advance the discipline by experimenting with new methods and finding one that is more beneficial in comparison to chemical etching. Even though none of the experimental methods were statistically significant in comparison to the current chemical method, the study did discover that firearms composed of aluminum will have a better serial restoration outcome and after .003 in. of metal has been removed, the chance of serial number restoration lowers significantly.

Limitations of the Study

While none of the proposed methods provided any statistically significant results, this study provided more literature for nondestructive methods and promise for future use with a SAM instrument. With this new methodology comes the need for future studies.

The researcher had to reach out to several laboratories and universities that utilized the proposed method for other areas of study. There were no set methodologies in place for the nondestructive methods therefore some trial and error was utilized. NIR and SAM instruments are not currently used on objects made of metal. The OCPD and Priority Labs had to adjust their current methodologies to fit the size and composition of the metal bars. The nature of this study was purely experimental which leaves a lot of room for adjustment. The ranges of wavelengths utilized needs to include the later end of the NIR spectrum and the SAM transducers megahertz frequency should be adjusted as well. When an obliterated serial number is examined in a firearm laboratory, there is no way to measure the depth of the obliteration to have a known range of common depths. This study now provides some insight and methodology for other researchers to reference to when trying different wavelength or other proposed experimental methods.

Recommendations for Future Research

Future research should explore additional methodologies and frequencies for a SAM instrument. In one of the images captured, the researcher could see curved lines, which almost made out a clear digit. More research should also be conducted on Klees proposed nondestructive restoration techniques. Each of his proposed techniques would be completely experimental as well but advancement with one method could help another researcher adjust his methodology as well.

Conclusion

Overall, this experiment sought to establish a methodology for three proposed experimental serial number restoration techniques and then compare them to the current chemical method. This study sought to see the difference in the time spent on each of the methods and the differences in composition and obliterated depth. Specifically, the study sought to establish a truly nondestructive method for serial number restoration. This was achieved by examining metal bars with premeasured obliterated depths and three different common firearm metal compositions utilizing three experimental serial number restoration techniques. Counting the number of digits was a quantitative way of analyzing if the experimental techniques produced better results than the current chemical method.

The first hypothesis looked at if NIR was a viable option for nondestructive serial number restoration. There was not a statistically significant result found between the mean number of digits visible between the NIR and chemical methodology. This indicated that NIR was completely nondestructive but did not recover any portion of the serial number.

The second hypothesis looked to see if cold frost could be a practical option for nondestructive serial number restoration. There was not a statistically significant result found between the mean number of digits visible between the cold frost and chemical methodology. This indicated that cold frost was completely nondestructive but did not recover any portion of the serial number.

The third and final hypothesis looked to see if SAM could be possibly become a technique for nondestructive serial number restoration. There was not a statistically significant result found between the mean number of digits visible between the SAM and chemical methodology. This indicated that SAM was completely nondestructive but did not recover any portion of the serial number.

This study was a practical evidence processing experiment meant for possible laboratory implementation. Because it involves firearm analysis, laboratories and universities that utilize this field could benefit from this study. By providing a starting set of wavelength and frequency ranges for NIR and SAM methodologies, other researchers and firearm examiners could perform experiments before completely ruling these proposed techniques out. This study has laid the foundation for others to explore more nondestructive techniques and hopefully implementation into a crime laboratory setting.

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