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# Characterization of Wear Patterns in Gun Barrel's Throat Region using Forensic Microscope: Insights into Long-term Effects of High-Pressure Gas Exposure

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***ABSTRACT***

This research aims to explore the damage sustained by the gun barrel's throat region over a long period of use, shedding light on the wear characteristics, and providing valuable insights into the long-term effects of high-pressure gas exposure during firing. To achieve this objective, the appearance of the gun barrel's throat region was characterized using forensic microscopy techniques. Visual and microscopic examinations were conducted on five (5) gun barrels with ten years or less of service usage and five (5) gun barrels with over ten years of service usage from the Philippine National Police to assess the degree of wear in the barrel's throat region. The findings revealed varying degrees of wear in the barrel throat regions. Firearms with 10 years or less of service usage exhibited moderate corrosion, narrow cracks, and minimal soot particle presence while firearms with over 10 years of service usage showed severe corrosion, deep cracks, scattered potholes, superficial scraped surfaces, and heavy soot particle presence. This research contributes to the understanding of barrel performance, maintenance, and potential hazards associated with aging firearms, thus providing novel insights into the long-term effects of high-pressure gas exposure during firing. By examining the changes in material properties and surface roughness of the gun barrel's throat region, this study seeks to improve the understanding of how repeated firing impacts gun barrel performance and longevity. This, in turn, may aid in developing future maintenance practices to enhance firearm durability and safety.

**Keywords:** *Gun Barrels, Wear Characteristics, Gun Barrel Throat Region, High-Pressure Gas Exposure, Wear Patterns*

## 1. INTRODUCTION

Gun barrel failure can be attributed to various factors such as fatigue fracture and erosion damage. With current researches focusing on erosion damage, as the fatigue properties of various gun barrels have been found to exceed service requirements. Damage to gun steels caused by erosion is evident through the development of erosion cracks and pits, which can worsen the effects of hot gas attacks or the melting of the steel substrate. When erosion cracks or erosion pits in gun steels propagate, the chromium layer on chrome-coated gun barrels tends to peel off. This unfortunate occurrence results in a significant decline in the ballistic performance of the gun barrels [1] [2].

A gun barrel is an essential component of ranged weapons that are similar to guns, such as air guns, artillery, and small firearms. It is the straight-shooting tube, typically composed of rigid high-strength metal, through

which a projectile is propelled out of the front end at a high velocity using a confined rapid expansion of high-pressure gases. To guarantee that the bullet is blasted out at its maximum muzzle velocity, a gun barrel must be able to contain the expanding gas produced by the propellants. The barrel itself may suffer catastrophic failure and explode if the material used for the barrel is unable to withstand the pressure inside the bore. This would not only destroy the gun but also pose a serious hazard to everyone nearby.

When a rifled gun fires, the projectile is blasted from the muzzle of the gun at a high velocity toward a target after being propelled along the barrel of the gun by the propellant combustion gas. Typically, these interior ballistics firing process lasts no longer than 20 milliseconds [3]. During this process, the gun barrel is subjected to high thermal and mechanical stress caused by the combustion of propellants inside the cartridge which then creates an extremely high-temperature expanding gas that exits and hits the barrel's throat region first then to the muzzle of the gun towards the target [4].


Figure 1. *Illustration of a launching procedure of a projectile causing wear at the Gun Barrel's Throat Region: (a) before the exit of high-pressure gas (b) first impact of high-pressure gas to the barrel's throat region (c) maximum impact of high-pressure gas to the barrel's throat region.*

It is crucial that the barrel of the weapon does not explode during use, as this could harm the user. Additionally, a common issue with gun barrels has been interior barrel erosion or corrosion. This issue has gotten much worse with some types of guns and related devices as firing rates have increased [5].

Several researches have been conducted about the barrel wear and its strength degradation. Ma [6] studied the law of barrel wear on large-caliber barrels where he established that there is a power function relation between the number of rounds fired and the barrel wear amount at the commencement of rifling. Wang [2] explored and characterized the gun barrel damage of a machine gun and concluded that the failure of the gun barrel is correlated with the peeling and softening of the Cr layer on the bore surface. This peeling and softening eventually translates into wearing of the gun barrel and consequently resulted to an increased deformation of the bore surface and increment of bore diameter which leads low firing accuracy performance.

The deterioration of gun barrels causes decreased gun performance and availability and raises the cost of barrel replacement throughout the course of a gun system's lifetime [7]. Near the start of rifling, a rifled barrel's bore diameter often rises due to wear. As the pistol fires continuously, the wear advances nearer the muzzle. The point of greatest wear is on the throat region of the gun barrel where extreme high temperature gas expansion starts. Worn barrels should be avoided because they permit gas to escape beyond the shot, lowering muzzle velocity, range, and accuracy. The shot loses directional stability as the muzzle wears.

**Gun Barrel Erosion**

Wu et al. [0] described three significant occurrences regarding damage and fracture of gun barrel under wear-fatigue interaction that takes place in the enclosed space created by the bullet, gun barrel, and breechblock. The first phenomenon is erosion, which is brought on by the high-temperature propellant combustion gas. The second occurrence that happens between the projectile's revolving band and the cannon barrel surface is friction. The third phenomenon is fatigue, which is brought on by mechanical stress

from barrel-projectile interaction, thermal stress from a significant temperature gradient, and dynamic loading with high gas pressure. Gun barrel deterioration in law enforcement results in decreased gun performance and availability as well as higher barrel replacement costs over the course of a gun system's lifetime. For firearms that operate in high performance ballistic regimes, it is especially difficult. Due to inconsistent gun performance and availability, it may limit operational effectiveness. Under normal shooting conditions, a gun barrel's erosion typically shows up as damage to the internal bore surface and a gradually growing bore diameter [0].

The frequent barrel changes and associated downtime caused by excessive barrel erosion might result in unsatisfactory or unsuccessful launches. By saturating the hydrogen working gas with eroded barrel material, excessive barrel erosion can also lower the maximum velocity that can be achieved [9]. In some instances, a gun barrel's rated fatigue life, measured in firing cycles, might be attained before the barrel erodes past condemning limitations [7]. However, in most cases, the rate of erosion outpaces the rate of fatigue crack development, and erosion is what causes barrel retirement.

During the use of a firearm, its barrel is subjected to high thermal and mechanical stresses. It is, in particular, important for the barrel not to explode during the firing of the weapon, which might injure its user [4]. The temperature rises during firing causes the strength of the barrel steel to fall. If the temperature reaches 700℃, then its yield stress drops to less than half of its room temperature value. Fortunately, because the barrel wall is thick, the outside remains only warm, unless undergoing an intense rate of fire which then leads to strength loss and loss of accuracy especially during an exponential increase with temperature [10].

Along with the chemical action of gunpowder gases on the inner metal surface of the barrel during firing, repetitive cooling and heating cycles and changes in metal characteristics, all contribute to barrel erosion. As a result, material begins to erode off the inner surface due to the bullets' and gases' scouring activity. The inner chamber's size fluctuates due to material erosion from the barrel's inner bore, which lowers chamber pressure and, in turn, the projectile's initial velocity. In the end, it causes the ballistic performance to decline or disappear [11].

A firearm's barrels' survivability has a significant impact on how long it will continue to function. As the number of rounds fired grows, the bore of a firearm becomes more vulnerable to erosion, which leads to constant increases in barrel diameter and an unintended deterioration in ballistic performance [12].

Ma [5] stressed out that there is a large gap between theoretical and experimental values regarding barrel wear. He added that theories of barrel wear are complex and inaccurate. Thus, experimental data should be used to discover new laws on barrel life. Researches mentioned above concerning barrel wear were done using experimental methodology on large artillery barrels. The current research focuses on small arm's gun barrel throat region to determine and characterize the wear patterns at a specified number of years used. Specifically, it examines the appearance of Barrel throat region markings of Philippine National Police's (PNP) service pistols with less than 10 years of use and those with service time of 10 years and above. Finally, it aimed at determining the differences in appearance of Barrel throat region markings of PNP service pistols between brand new and with 10 or more years of use.

## 2. METHODOLOGY

The study used qualitative observation for data collection. The researcher used the forensic microscope to visualize the details inside the barrel's throat region. The examination was conducted at the College of Criminal Justice Education's Crime Laboratory located inside West Visayas State University – Lambunao Campus. The subject of the examination was the gun barrel of service pistols obtained from the Philippine National Police's municipal station of Lambunao and was then subjected to microscopic examinations to investigate the wear characteristics of the gun barrels' throat region. Detailed visual and microscopic examinations were carried out on the gun barrel using Forensic Comparison Microscope set at 4X magnification. Inverted lighting position was utilized to visualize and capture the minute details present at the barrel's throat region. These details were recorded using a Nikon D3400 camera with a f-stop set at 0, Exposure time at 1/4000 of a second, ISO speed at ISO 1600 and with Exposure bias set at 0. Coincidental

viewing was also employed on a computer using ToupTek ToupView software for simultaneous verification of significant details during examination.

## 3. RESULTS AND DISCUSSION

During visual investigation, it was observed that the barrel's throat region of firearms with 10 years and below service usage was moderately corroded as the barrel surface are seldomly exposed to the high-pressure gases from firing. Narrow cracks (Fig. 3) on the throat region were also identified and presence of minimal soot particles was seen. The same examination was done to barrel's throat region of firearms with above 10 years of service usage. It is noticed that the barrel surface was severely corroded as it was tremendously exposed to high-pressure gases during years of continues firing. Microscopic examination also reveals the presence of deep and sizable cracks at the throat region (Fig. 4). Scattered potholes (Fig. 5) were also identified, superficial scraped surface due to metal-to-metal rubbing that causes corrosion and sliding wear (Fig. 6), and presence of heavy soot (Fig. 7) particles were also observed. Wang et al. [6] has observed the same phenomenon on the barrel of a machine gun with increasing gun life. This was also aligned to the law of barrel wear by Ma [5] that the number of rounds fired corresponds to the wear amount of a gun. Furthermore, Ma added that the number of rounds fired from a gun can be used to predict the wear of a barrel.

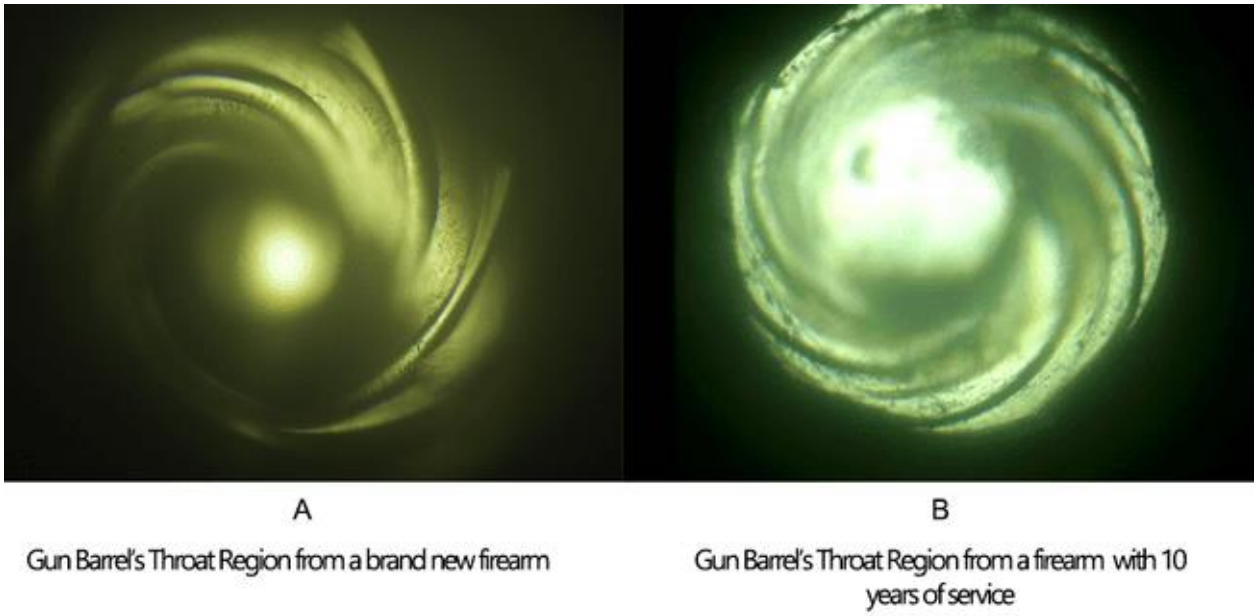


**Figure 2.** Side by side comparison of gun barrels' throat region with contrasting service usage.

As shown in the figure, there is a clear deviation between the gun barrel's throat region of a brand-new firearm and the one with ten (10) continuous years of service. It also suggests that there is a noticeable difference between the condition of a new gun barrel and the one that has been used continuously for ten years. These deviations can cause changes in the accuracy and performance of the firearm.

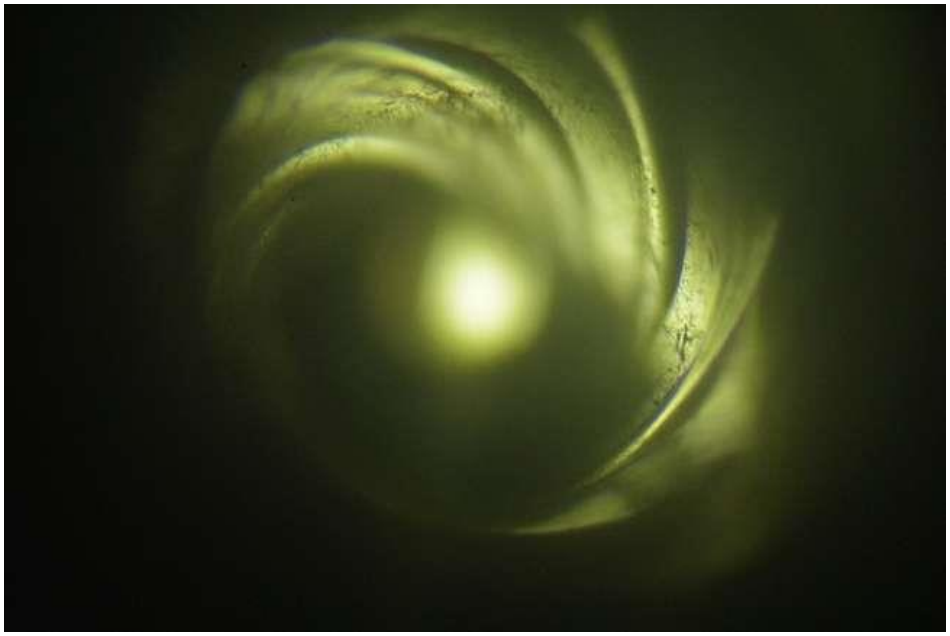

**Figure 3.** *Narrow crack formation starting to propagate at the gun Barrel's Throat region.*

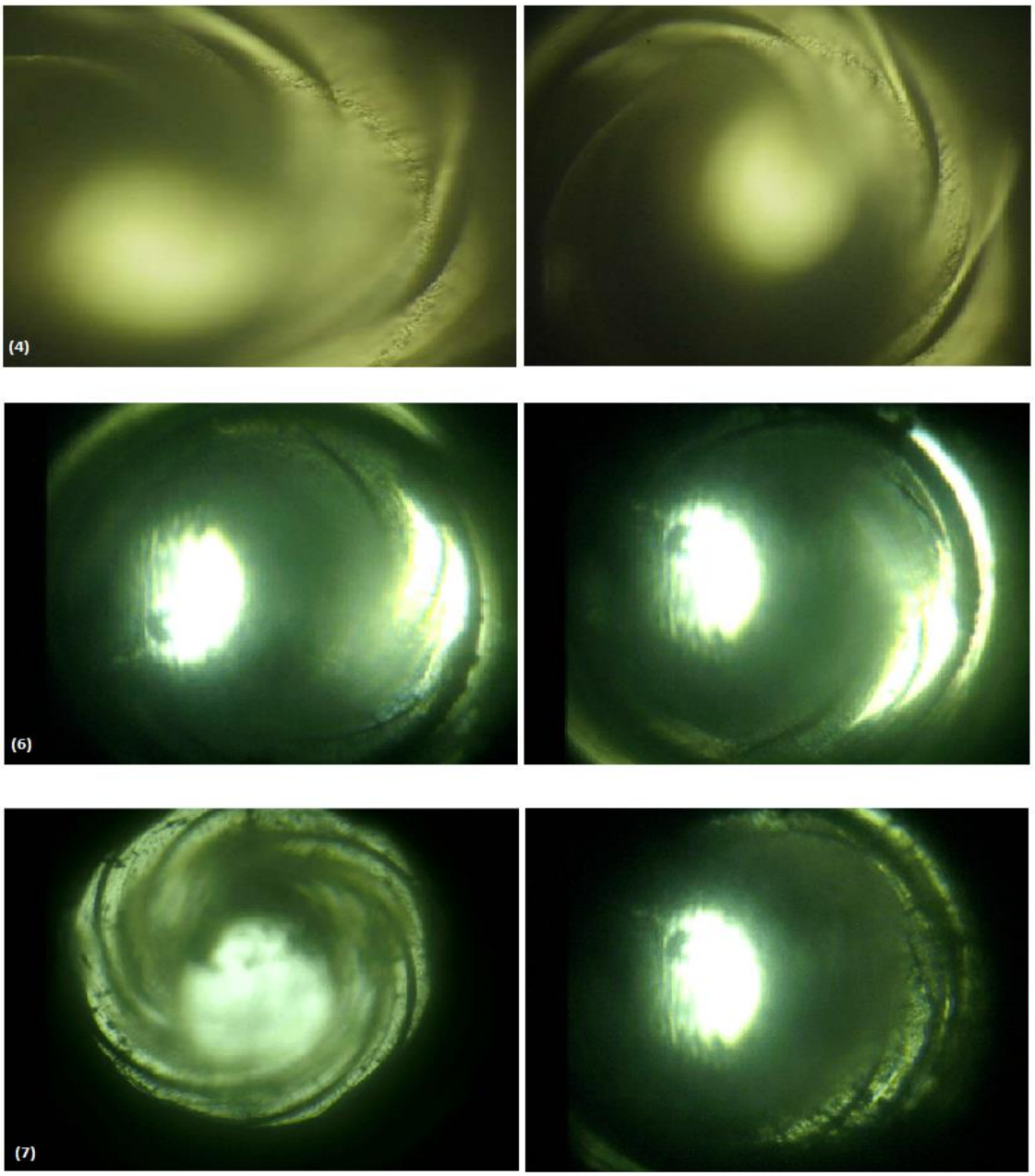


**Figure 4.** *Crack formation caused by the extremely high pressure from gas expansion during firing.*
**Figure 6.** *Superficial scraped surface due to metal-to-metal rubbing which causes corrosion and sliding wear.*
**Figure 7.** *Presence of heavy soot particles around the gun barrel caused by continuous use of the firearm.*

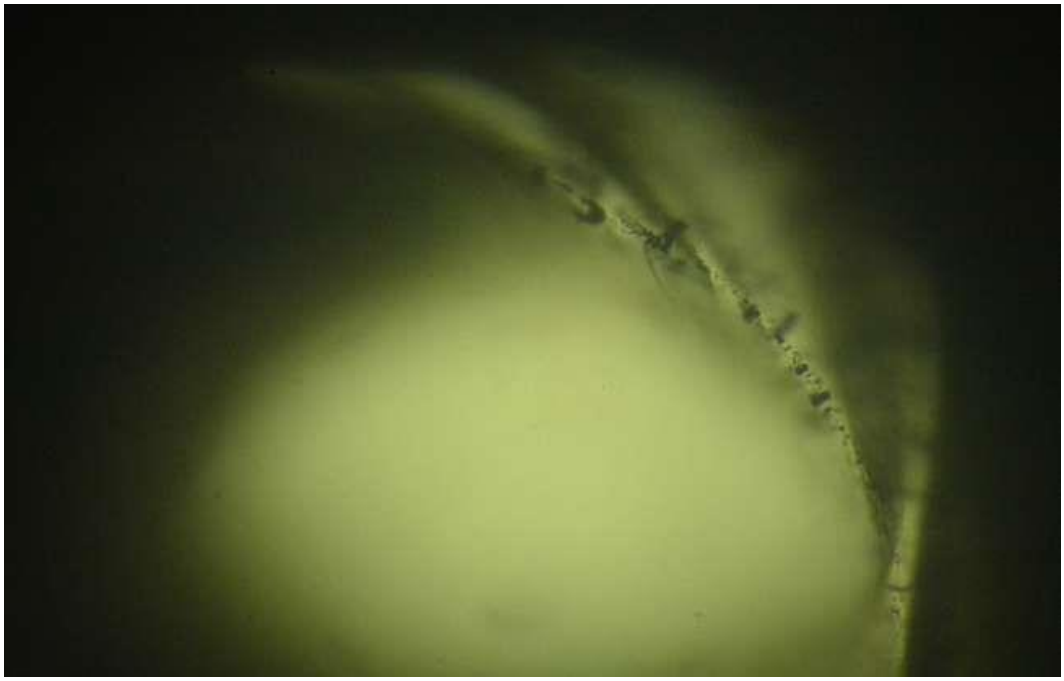

**Figure 5.** *Sizeable pothole-like tear on the surface of gun barrels' throat region.*

The extreme heat cause by the combustion inside the cartridge case along with the substantial pressure from the gas particles as it exits the case, caused the accelerated wear and tear (Fig. 5) on the surface of the firearms' barrel throat region. Weld defects such as pin holes and macro pores during the rifling process on the barrel were severely dissipated due to metal-to-metal chafing of bullet against the barrel (Fig. 6). This may impact the accuracy and precision of bullet trajectory.

The results of the current investigation also indicate that the life of gun barrels is a critical problem in artillery engineering, as firing accuracy depends on it. To extend the service life of gun barrels, as suggested by Hou et. al. [13] that various technologies should be used such as composite barrel technology, propellant charge technology, repair technology, and the surface coating technology. It also affirmed Wang's [6] findings that the barrel's bore surface exhibits varying damage characteristics along the axial direction.

Numerous studies about gun barrels have already been published but none of them focused more on the gun barrels' throat region as investigated in this paper. The throat region received most of the damage as it is exposed in extremely high temperature, causing higher damage rates compared to other gun barrel regions [14]. This high temperatures and pressure from shooting soften the gun barrel, increasing plastic deformation and bore diameter, reducing shooting accuracy.

## 4. CONCLUSION

Based on careful investigation, the wear characteristics of gun barrel's throat region was established. Wear characteristics such as cracks, scratches, potholes, heavy soot particles, and superficial scraped on the surface of firearms' barrel throat region indicates that the firearm is nearing the end of its service life. With this finding, a prediction for a firearms serviceability and condition can be established. Also, the characterization of gun barrel's throat region will serve as guidelines in the maintenance and care of all firearms. Finally, it is important to note that the findings of this investigation were solely based on the physical characteristics a gun barrel's throat region indicates and might differ from the findings of other research approach.

**Recommendation**

Given the intricate nature of barrel wear characteristics, it is recommended that gun barrels should be checked regularly regarding their serviceability in terms of accuracy, precision, and overall performance. Police Offices should maintain records of the lifecycle of service firearms and formulate a matrix as to the limitations of its usability when a certain number of rounds fired is reached. Finally, a regular and systematic examination should be conducted on gun barrels with high firing frequency to determine its condition and utility based on the wear characteristics it indicates.

**Declaration of Competing Interest**

The authors affirm that they have no known financial or interpersonal conflicts that would have appeared to have an impact on the research presented in this study.

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