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Muzzleloader Failure Analyses

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Abstract
Muzzleloading rifles (also known as "muzzleloaders") can be safe and enjoyable firearms for shooting and hunting if handled properly. There are a number of muzzleloader constructs such as inline, flint lock and percussion. These firearms operate on the ignition of black powder propellant or approved substitute charge, by a primer located at the back of the barrel. There are a number of mechanisms that can be utilized to ignite the powder (e.g. primers, percussion caps, etc.); once the powder is ignited, the pressure builds up rapidly and then decreases as the projectile moves down the barrel and the volume of the gas behind the projectile increases. If circumstances arise that impede the motion of the projectile, such as an obstruction, then a marked over-pressurization event may occur causing ductile fracture of the barrel. Often, the location of the fracture(s) provide clues as to what the obstruction was, for instance, if the muzzle end of the barrel ruptures, then the most likely cause was mud, ice or other debris accumulation in the end of barrel. If the obstruction occurs in the mid-barrel region, the most likely source of the obstruction was a second bullet or corrosion products from poor cleaning and maintenance. If the rupture occurs at the opposite end of the muzzle, near what is called the breech, then that was more likely due to the improper use of powder (either in amount or type). In this study, we investigate several cases where these factors acted as potential sources for over-pressurization that led to rupture failures of muzzleloader barrels.

1. Introduction

Muzzleloading, blackpowder rifles have been used for hundreds of years for purposes ranging from hunting, cultural festivals and for recreational shooting. Regardless of the use, muzzloaders must be maintained and properly operated to avoid potentional failures and safety hazards that can be life threatening. One of such potential failures involves the rupture of the barrel. While steel metallurgy has improved over time, the pressures generated by black powder and black powder substitutes such as Pyrodex mean that barrel ruptures can and still do occur.

The barrel of a firearm serves an essential role in its operation. In muzzleloaders, the barrel houses the primer, the propellant charge, and the projectile. It serves as a pressure vessel that can accommodate very high pressures. Once the rifle is fired, there is a highly powerful dynamic process that takes place in the barrel involving thermal, mechanical and chemical processes that affect the barrel. These processes influence the buildup and balance of pressure in the barrel. The pressures generated from the combustions of the propellant must be reduced by the volume created behind from the movement of the projectile down the barrel column. If the barrel pressure increases too rapidly (e.g., if an obstruction in the barrel slows the projectile down sufficiently), the capacity for the barrel to contain the pressure can be exceeded before the projectile can move and sufficiently reduce the barrel pressure. If the strength of the barrel is exceeded, it will bulge, swell, rupture and or split longitudinally (i.e., a fishmouth rupture) potentially on multiple planes. Several scenarios of pressure imbalances leading to the failure of muzzleloader barrels, such as barrel obstruction, the use of smokeless powder and excess propellent charge, are investigated.

2. Results

Three separate cases of muzzleloader failures will be examined. In all three cases, significant bulging and longitudinal splitting (petalling) of the barrel was observed, though the location of the bulge/petalling differed in some cases. A representeative structured light scan of a ruptured barrel is shown in Figure 1.

In all of these cases, the failures were from a single overpressure event owing to an obstruction. There was no evidence to indicate that the design or barrel materials were defective.

Finite element analyses were performed to evaluate the evolution of stresses throughout firing, accounting for potential misuse scenarios, such as barrel obstruction. The FEA demonstrated that failure to properly handle or maintain a muzzleloader can lead to stresses that quickly exceed the capacity of the barrel.

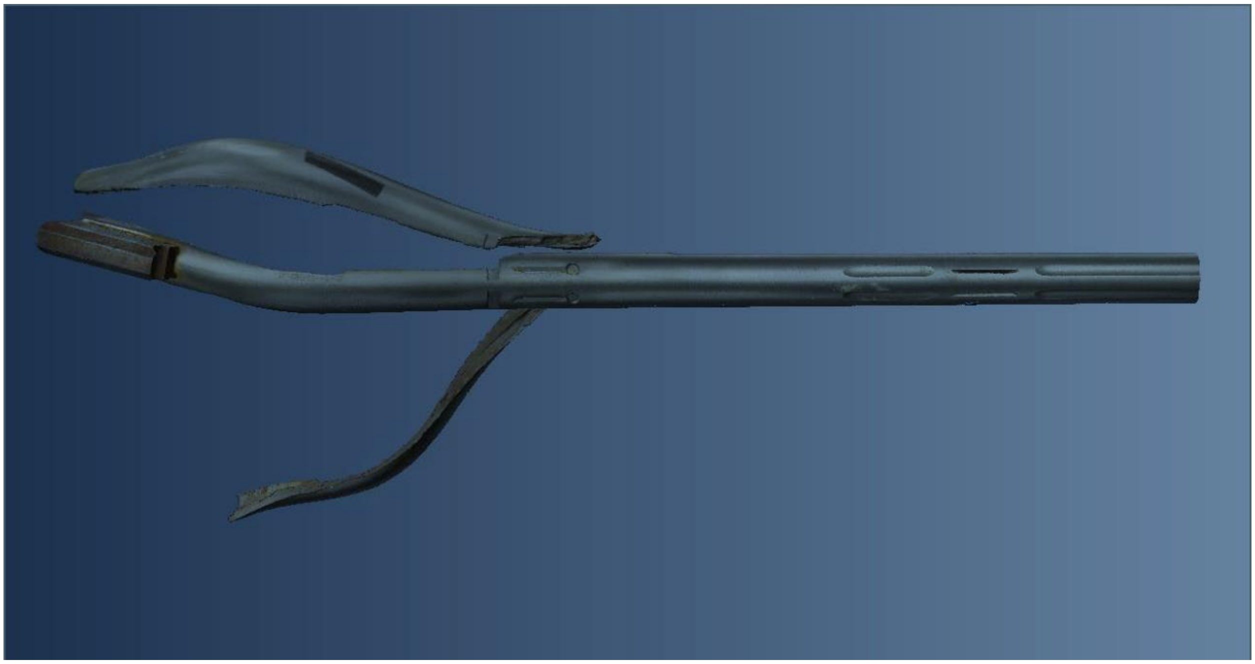

Fig.1 – Representative view of the breech section of the subject rifle, as captured in the three-dimensional structured light scan. Twisting, bulging and general deformation of the barrel is apparent. In this image, the muzzle region of the rifle is not pictured

3. Conclusions

When used responsibly, muzzleloader rifles can be safe and enjoyable firearms. Even with proper design and materials, muzzleloader rifles can pose a safety risk if they are used incorrectly or improperly maintained. Proper loading and firing procedures along with regular maintenance are critical for avoiding overpressure events that pose safety risks to the user.