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The ballistic performance of the bombard Mons Meg

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Abstract

The bombard Mons Meg, located in Edinburgh Castle, with a diameter of 19 inches (48 cm), was one of the largest calibre cannons ever built. Constructed in 1449 and presented to King James II of Scotland in 1454, Mons Meg was used in both military and ceremonial roles in Scotland until its barrel burst in 1680. This paper examines the history, internal, external and terminal ballistics of the cannon and its shot. The likely muzzle velocity was estimated by varying the propellant type and the cannon profile was investigated to identify weak spots in the design that may have led to its failure. Using the muzzle velocity calculated from the internal ballistics, simulations were performed with granite and sandstone shot for varying launch angle and ground temperature. The likely trajectory and range of the cannonballs are described. The internal and external ballistics informed the initial conditions of the terminal ballistic impact scenarios. The performance of the cannonball against both period and modern targets, in the form of a pseudo-castle wall and a monolithic concrete target, respectively, were simulated and are presented and discussed.

Keywords: Analytical; Hydrocode; Muzzle velocity; Cannon barrel design; Trajectory; Castle brick target

1. Introduction

As one of the larger and well documented surviving medieval cannons, Mons Meg stands in pride of place at Edinburgh Castle and in its history (Fig. 1). Constructed around 1449 in Mons, part of what is now modern day Belgium, at the request of Duke Philip the Good of Burgundy [2], the bombard was intended as a wedding present to King James II of Scotland, who, in 1457 married Duke Philips' great niece, Mary of Gueldres.

Customs records date Mons Meg's first arrival on Scottish shores around 1457 [3], seemingly first taking place in battle at the siege of Roxburgh Castle in 1460, although this is not yet backed up in any way other than stories from the time [3]. The earliest written record of her active role in service is during the 10 day bombardment of Norham Castle in 1513 [4] during which she is reported to have destroyed both the castle's inner and outer wall. Her last use as a defensive weapon was during the Lang Siege 1571–73, after which she was only used for ceremonial duties.

One of the most famous stories about the bombard was the two month siege of Threave Castle by James II. The story goes that the first cannonball fired at the keep passed straight through the wall and severed the hand of Margaret Douglas as she was drinking inside.

Once retired from active military service she found a new role as a display piece at Edinburgh Castle. However, on 30 October 1680, to celebrate the visit of James Duke of York and Albany to Edinburgh, the barrel burst, effectively ending her operational life.

This paper investigates and discusses the internal, external and terminal ballistics of the cannon. The internal ballistics

Fig. 1. Mons Meg at Edinburgh Castle. Licensed under creative commons attribution-share alike 2.0 generic license [1].

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calculates the likely muzzle velocity of the cannon and analyses the possible reasons for the barrel bursting. The external ballistics uses the results from the internal ballistics to analyse and predict the cannonball trajectory and likely final velocity and impact angles. This is used to investigate its terminal performance against modern targets and period, castle-type targets.

2. The cannon

Mons Meg is constructed of wrought iron, sometimes called charcoal iron, a highly variable iron, both in chemical composition and slag content. However it is a very ductile metal and the levels of slag have made the iron extremely resistant to corrosion [5]. It measures over 4 m in length, with a bore of 50 cm and weighing over 6000 kg [3], easily making it one of the largest (by calibre) stone firing cannons in history.

It is divided into 2 distinct parts, the powder chamber, and the barrel. The powder chamber measures 1.16 m in length, and varies from 0.59 to 0.53 m in diameter (Fig. 2). It is likely that the powder chamber is constructed from one billet of iron which has been hammer-beaten on a mandrel to achieve the correct inner dimensions. The barrel measures 2.88 m in length externally, and varies from 0.63–0.75 m in diameter. It is constructed from 25 staves running the length of the barrel which are covered and held in place by 33 hoops. These would have been heated in a furnace and placed over the staves, as these cooled they would tighten to hold the barrel together and fasten the staves to the powder chamber.

Mons Meg fired cannonballs roughly 490 mm in diameter. During Mons Meg's operation lifetime in the 15th and 16th centuries, iron shot was not available and the cannonballs were made from local stone. There are records [7] which indicate both sandstone and granite shot was used to give mass ranges of 130–140 kg and 160–170 kg for the different stone, respectively.

Black powder was used as the propellant charge for the bombard but there is no specific data about the amount used for Mons Meg. A minimum and maximum likely propellant mass [7] of 29.5 kg and 34 kg, respectively, was assumed.

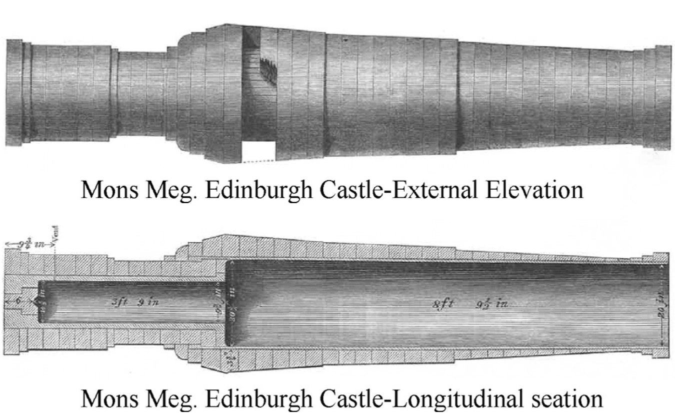

Fig. 2. External and cross-sectional view of Mons Meg [6].

Table 1
Pressured produced by period black powder compositions [7].

Period	Composition name	Range of pressure/MPa	Average muzzle velocity/(m·s^{-1})
14th century	John Arderne Feuerwerkbuch	44–51	328.6
16th century	Whitehorne	22–25	231.1
16th century	Bruxelles	66–76	385.4
17th century	British government Formula	92–105	425.3

3. Internal ballistics

3.1. Muzzle velocity

To calculate the muzzle velocity of Mons Meg, the analytical code Proteus was used. Proteus is a 1 dimensional, lumped parameter code used to solve for combustion of gases and internal pressures; it is similar to IBHVG2 [8], and internal studies have shown the predictions of both codes to be comparable.

There were three likely black powder compositions in use during Mons Meg's operation lifetime and one from when the barrel burst, each with a different range of pressure produced. Proteus matched these shot pressures to calculate the muzzle velocities. The results shown in Table 1 average the propellant mass and pressure range, whilst assuming a 160 kg granite cannon ball, to produce a single muzzle velocity for each composition.

As there is no definite source for which type of powder was used in Mons Meg, an average of the 14th and 16th century powders (its operational timespan) was used as the expected muzzle velocity of the cannon, 315.0 m/s. This value was taken forward to be used in the external ballistics section.

The above value of 315.0 m/s was reached after several refinements to the model. An initial value of 319.1 m/s was previously calculated and used in both the external and terminal ballistics work as the research was running in close to parallel due to time and resource limits.

3.2. Internal pressure and the bursting of the barrel

As mentioned above in 1680, the barrel of Mons Meg burst during ceremonial duties. This section investigates whether the amount or type of powder could explain the manner and location of failure.

Following research from various sources, agreed values for the key dimensions of the cannon were used in the QinetiQ Barrel Design Software (QQ-BDAS). Although the method of manufacture of Mons Meg is different from that assumed in QQ-BDAS, it was decided that this software would give sufficiently representative pressure limits.

QQ-BDAS is a QinetiQ proprietary code and thus has not been referenced in open literature, although it was developed using the gun design calculation methods outlined in "Textbook of Ordnance and Gunnery" [9] authored by William H Tschappat, and "Vickers and Sons Maximum Ltd – Their works and manufacturers" [10] by Alex Richardson.

The cannon profile input in QQ-BDAS is show in Fig. 3.