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Experimental study of the expansion dynamic of 9 mm Parabellum hollow point projectiles in ballistic gelatin

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ABSTRACT

We study in this paper the expanding behaviour of hollow point 9 mm Parabellum projectiles (Hornady XTP® and Speer Gold Dot®). We defined a deformation rate that takes into account both the diameter increase and the length reduction. We plotted the behaviour of this parameter versus impact velocity (we refer to this curve as the expanding law). This expanding law has been plotted for different gelatin weight ratios and different gelatin block lengths. We completed our experiments with a set of high speed movies in order to correlate the deceleration to the state of expansion and size of the temporary cavity. Our results pointed out that full expansion is reached shortly after the projectile fully penetrates the gelatin. This result shows that the key point to accurately simulate human body interaction with a hollow point projectile is to accurately simulate the interface (skin, skull, clothes thoracic walls). Simulating accurately organs is only an issue if a quantitative comparison between penetration depths is required, but not if we only focus on the state of expansion of the projectile. By varying the gelatin parameters, we discovered that the expanding law exhibits a velocity threshold below which no expansion occurs, followed by a rather linear curve. The parameters of that expanding law (velocity threshold and line slope) vary with the gelatin parameters, but our quantitative results demonstrate that these parameters are not extremely critical. Finally, our experiments demonstrate that the knowledge of the expansion law can be a useful tool to investigate a gunshot in a human body with a semi-jacketed projectile, giving an estimation of the impact velocity and thus the shooting distance.

1. Introduction

The ballistic department of the Forensic Science Laboratory at Lille is daily commissioned to bring any useful information about gunshots. The main frustration we usually encounter holds in the fact that it is often an issue to estimate the shooting distance. Experiments and/or simulations can be useful tools to make an estimation of the shooting distance. Such tools can be used in the case of a non-human target [1] but human targets are often more important issues (murder, hunting accident, urban gunshot,...).

War surgery has been a good catalyst to trigger research in the field of ballistic wound [2,3] and it came now to a rather mature point [4,5]. However, the problem of simulating the human body is still undergoing some interesting researches in the fields of protection against ballistic hazard and war surgery. It is now widely admitted that ballistic gelatin is a good substitute for muscle tissues [6,7]. Resins are often used to simulate bones [8] and synthetic leather-like material simulates the skin [9]. Silicone or low weight ratio gelatins are likely to simulate organs like lungs, liver, brain, but the uncertainty inherent to any simulation has not been fully investigated yet.

Using gelatin test has already been reported to confirm a scenario involving gunshots in a human body [10]. A case where gelatin test was used to identify which scenario (among a finite number) was more likely to be the truth has also been reported [11]. On the other hand, using a quantitative prediction or results from a series of test (abacus) in order to give a quantitative information about a gunshot (like the shooting distance) is a scientific lock that has not been opened yet.

In the particular case of an expanding bullet (soft and hollow point) we believe that it is conceivable to go beyond as, according to our experience, impact energy is not always sufficient to fully expand the projectile [11,12]. This case (expanding bullets) is not an exotic case as FMJ are forbidden for hunting in France, revolver are usually loaded with soft point or hollow point projectiles. Furthermore, FMJ is not a standard anymore with semi-automatic pistols as most of the manufacturing companies propose soft point or hollow point projectiles in their catalogue, and the French

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government recently selected the Speer Gold Dot® hollow point ammunition for law enforcement purposes.

The biological tissue substitute we study here is ballistic gelatin. We investigated in a quantitative way the critical aspect of parameters like gelatin weight ratio, thickness or impact velocity by checking the reproducibility of the results. The measurable we choose for the study is the expansion state of the bullet. A deformation rate has been specifically defined for that purpose. It takes into account both the diameter increase and the length reduction, occurring when the bullet expands. This parameter is more accurate than the penetration depth or the permanent cavity size, even though the later may also be significant in the forensic field, especially if the bullet is not recovered.

2. Materials and methods

We used a Glock 26 semi-automatic pistol for the experiments. Different velocities were obtained by varying the amount of propellant (Vectan Ba 9) in home-made 9 mm Parabellum cartridges. We selected the Hornady XTP bullet for the study. This bullet is available separately for reloading, and widely enough available to let the reader perform complementary tests, using our results. We repeated the experiments with another type of projectile (Speer Gold Dot®) in order to demonstrate that the expansion law strongly depends on the projectile type. The shooting distance is set to 5 m. The impact velocity is measured 4 m away from the barrel muzzle with a commercial chronograph (ProChrono, Competition Electronics Inc., USA).

Targets were blocks prepared from 250 bloom 10% mass gelatin. The ballistic grade was first checked with steel spherical pellets (Copperhead). The influence of the gelatin mechanical properties (hence the preparation process) has been studied by moving the gelatin intentionally away from the ballistic grade, varying gradually the weight ratio from 20% to 0% (water).

The size of the gelatin block also follows a standard (500 mm × 150 mm × 150 mm) as the weight is a global parameter that influences its overall mechanical behaviour at impact. In the particular case of high velocity projectile (which is not the purpose of our study), projectile fracture may occur when it flips, after typically 10–15 cm of propagation. A 5 cm long gelatin block would be a poor simulator of the ballistic terminal effect. In order to study the influence of the block length, that parameter was also gradually moved away from the standard value (from 50 cm to 5 cm).

As the measurable we choose is the state of expansion of the bullet. We defined a parameter that takes into account both the relative increase of the diameter ($\delta D/D_0$) and the relative reduction of the length ($\delta l/l_0$). We will subsequently refer to this parameter as the deformation rate d (cf formula 1 and Fig. 1). The formula 1 is based on the basic RMS (Root mean square).

$$d = \left(\frac{1}{2}\left(\frac{\delta D}{D_0}\right)^2 + \frac{1}{2}\left(\frac{\delta l}{l_0}\right)^2\right)^{1/2} \quad (1)$$

with $\delta l = l - l_0$ and $\delta D = D - D_0$.

l_0 and D_0 are respectively the length are the diameter of the bullet before impact. The nature of d (single value) makes it more suitable for comparison. This parameter can theoretically be higher than 1.

For each experiment, a picture of the whole block is taken and the penetration depth is measured. The block is then broken, the bullet is collected and the deformation rate is calculated from caliper measures (diameter and length of the projectile).

We also experienced the use of a medical CT scanner as an alternative to such a destructive method. It is clearly demonstrated in the following segment that such a method would dramatically improve data processing, especially in the case of ballistic wound on human bodies, but further experimentation of this method is beyond the scope of this paper.

The experiments are also completed with a series of high speed camera movies (photron fastcam APX camera, up to 85 000 FPS). A deceleration curve is then extracted from the movie data.

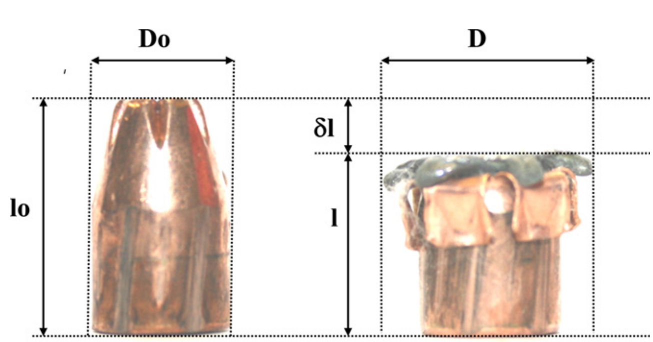

Fig. 1. Calculation of the deformation rate d.

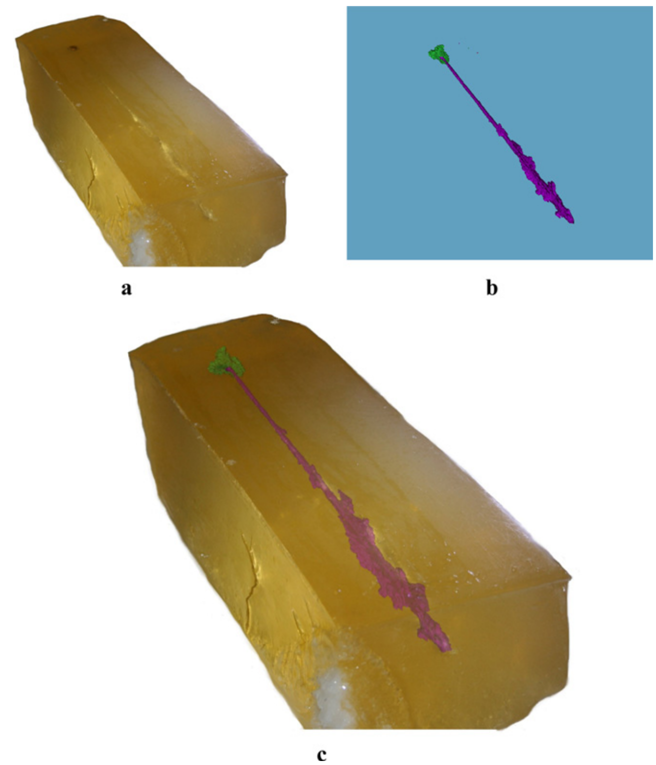

Fig. 2. Example of ballistic wound recorded in a gelatine block (9 mm Parabellum, Hornady XTP bullet, 320 m/s). Part (c) is a combination of a photograph (a) and an inverted contrast density scanning (b).

3. Results

The first step was to check the ballistic grade of the gelatin blocks. The blocks were prepared from 250 bloom gelatin (10% mass ratio) without acid catalysis. We filled the mould with warm water (50 °C) and simultaneously incorporated and stirred up the gelatin for 5 min. After the gelatin is fully incorporated, we kept stirring up for 2 min. The blocks were then left in a refrigerated box (4 °C) for at least 36 h. The temperature and humidity condition to keep the gelatin blocks are well known to be important, so we

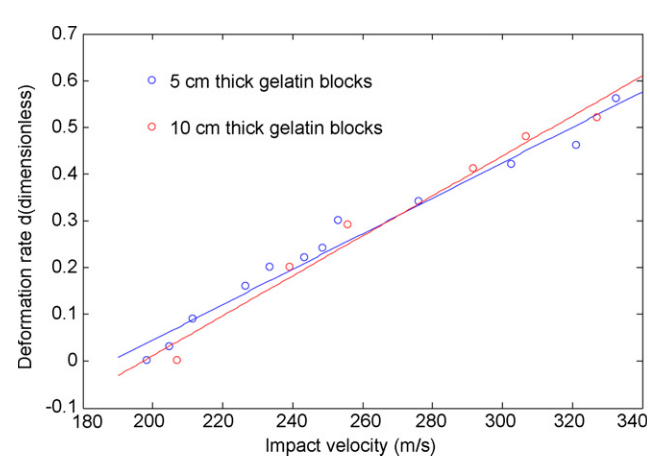

Fig. 3. Expansion law for 3 different gelatine block length. The dots are experimental data, the full line is a least square approximation.