

ANALYSIS OF THE FORCES ACTING ON A SHOULDERSUPPORTED WEAPON DURING FIRING

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Abstract. An analysis of the forces acting on the SA80 assault rifle during firing was undertaken to investigate barrel rotation whilst the bullet was travelling in the barrel. Bullet displacement and velocity from initial movement to the point when the bullet left the barrel were first calculated. Two separate numerical methods were used to calculate barrel angular displacement and angular velocity against time caused by the propellant pressure acting on the breech face and the angular acceleration of the bullet. The two different methods gave good agreement, giving a barrel angular displacement of 0.066rad and an angular velocity of 3.75×10^{-4} rad/s respectively.

INTRODUCTION

When a shoulder-supported weapon is fired, there are a number of forces acting on it, which tend to cause the weapon to move during the firing process and whilst the projectile is travelling down the barrel. Thus, when the projectile exits the barrel, it will be pointing in a different direction to when the weapon was initially aimed. If this movement is consistent, the weapon can be zeroed to compensate for these movements. With high levels of training it is possible for any inconsistencies to be reduced to an acceptable level. Unfortunately, in an operational environment, when high levels of stress are experienced by the firer, consistency deteriorates. Thus it is desirable to reduce weapon movement during firing to a minimum so that firer inconsistencies have minimum effect.

When being fired from the prone position, there is a tendency for the weapon to rotate about the point of support, which is the shoulder of the firer. The purpose of this paper is to analyse the movement of the weapon during firing if it is allowed to rotate about the butt. The weapon used in this analysis was the 5.56mm calibre SA80 Individual Weapon fitted with the SUSAT optical sight as used by the British Army.

PROPELLANT PRESSURE

The main force acting on the weapon results from the pressure in the chamber and barrel as the propellant burns and accelerates the projectile down the barrel. This pressure was measured using a piezoelectric transducer positioned immediately in front of the cartridge chamber and 51.5mm from the breech face. A digital recording oscilloscope was used to record the pressure. Ten pressure readings were taken and the numerical average taken for the subsequent analysis of weapon movement. The pressure was measured at intervals of $2\mu s$ over a period of 10ms giving a total of 500 pressure readings. Figure 1 shows the average measured pressure/time curve for the standard Radway Green L2A2 5.56mm calibre round measured over ten separate firings.

In addition to a knowledge of the pressure at the chamber, it is necessary to know the pressure at the base of the projectile as it passes down the barrel to enable the projectile velocity, and hence projectile position, to be calculated for different positions in the barrel. The following expression [1] was used for calculating the pressure on the base of projectile at different distances(s) from the breech:

$$p_x(t) = p_s(t) + \frac{C}{2A} \frac{s^2 - x^2}{s^2} \frac{dv_p}{dt} \tag{1}$$

where:

$p_x(t)$ = pressure at distance x from the breech;

$p_s(t)$ = pressure on base of projectile at a distance s from the breech;

C = propellant mass (1.69g for L2A2 5.56mm ball round);

A = bore cross sectional area ($25.5mm^2$ for 5.56mm barrel);

s = distance from base of the projectile the breech;

v_p = velocity of projectile; and

t = time.

Thus, pressure on base of projectile when $x = 0$ is:

$$p_0(t) = p_s(t) + \frac{C}{2A} \frac{dv_p}{dt} \tag{2}$$

If the pressure at $p_x(t)$ is known then the pressure $p_s(t)$ can be found. From this, the projectile velocity v_p and the distance travelled, s, in the barrel can be found.

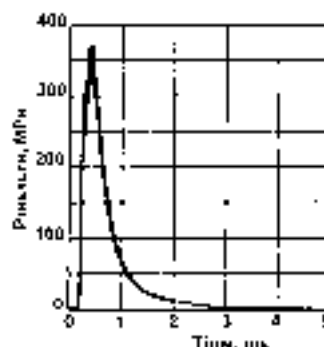


Figure 1. Pressure/time curve for the Radway Green L2A2 5.56mm round measured over ten firings.

The solution for the different differential equations cannot be achieved analytically, so the Runge-Kutta method improved with Fehlberg coefficients was used. This algorithm was already implemented in MATLAB [2] and the ode45 algorithm was used. However, it was necessary to obtain a numerical expression for pressure $p_x(t)$. Again