# SPATIAL DISTRIBUTION OF FRAGMENTS OF EXPLOSIVELY LOADED SHELLS DURING FLIGHT.

**By Sampooran Singh**

**Defence Science Laboratory, New Delhi.**

ABSTRACT

This paper correlates theoretically the effects of flight of an explosively loaded shell and the spatial distribution of fragments. The effect of spin of a shell is almost negligible on the spatial distribution of fragments, while the forward velocity of the shell at detonation affects both the velocity and the direction of emission of the fragments.

## Introduction

When a detonating explosive in a static shell is fired, the metallic casing of the shell in the rear of the detonation wave front is subjected to extremely high pressures due to the detonating gases. The casing undergoes considerable plastic expansion, which results in reduction of wall thickness until the critical stress for failure at the rates of strain involved is exceeded. The casing is accelerated rapidly outwards till at the time of fracture the velocity with which it is moving will be nearly equal to the initial velocity with which the fragments are emitted, and the gas pressure will have dropped to a small fraction of its original value. Recently Singh[1] described the spatial distribution of fragments on static detonation of an explosively loaded shell and showed that the direction of emission of most of the fragments make an angle $\delta$ $(=7 \cdot 5°)$ to the normal to the inner surface of the shell and away from the exploder. The effects of flight of a shell are to superimpose a tangential velocity due to the spin of the shell and a linear velocity along the axis of the shell due to the forward velocity of the shell. The object of the present note is to correlate theoretically the effects of flight of a shell and the spatial distribution of fragments.

*Effect of spin of a shell*—Most of the fragments are obtained from the parallel portion of the metallic casing of the shell and for the present discussions we consider the shell as a cylinder having the metallic casing of the same mass per unit length and neglect the constraint exerted by the ends of the shell. Let Z represent the inner radius of an element in the shell before detonation. On detonation of the explosive, the metallic casing undergoes considerable plastic expansion and let R and $V_o$ be the radius and the velocity of the casing, respectively, at the end of the plastic expansion (or at the time of fracture). Let $\omega$ and $\Omega$ represent the angular velocities of an element in the orginal wall of the shell and of the corresponding element at the end of plastic expansion. Equating the angular momentum of an element in the shell before detonation and of the corresponding element at the end of plastic expansion, we have

$$\omega Z^2 = \Omega R^2 \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad (1)$$

The tangential velocity, $v$, of an element at the end of plastic expansion is given by the expression

$$v = \Omega R = \omega Z^2/R \quad \ldots \quad (2)$$

Let us now consider the forces on an element at the end of plastic expansion in a plane at right angles to the axis of the shell. Each element has a velocity $V_0$ along the radius and a tangential velocity $v$. Let $V_1$ represent the resultant velocity and is given by the expression:

$$V_1 = (V_0^2 + v^2)^{\frac{1}{2}} \quad \ldots \quad (3)$$

Substituting the value of $v$ from equation (2) in equation (3) and as a first approximation, we have

$$V_1 = V_0\left[1 + \frac{\omega^2 \; Z^4}{2 \, V_0^2 \, R^2}\right] \quad \ldots \quad (4)$$

Let $\phi$ represent the angle between the directions of projection of $V_1$ and $V_0$ and is given by the expression

$$\phi = \tan^{-1}\left(\frac{\omega Z^2}{V_0 \, R}\right) \quad \ldots \quad (5)$$

The conservation of mass of the original element and that at the end of plastic expansion suggests that $R = 1 \cdot 8 \; Z$ at the end of the plastic expansion[1]. In view of the largeness of $V_0$ as compared to $\omega$ and substituting $R = 1 \cdot 8 \; Z$ in equations (4) and (5), we get $V_1 \sim V_0$ and $\phi \sim 0°$. This suggests that the effect of spin is almost negligible on the spatial (angular) distribution of fragments.

*Effect of forward velocity of a shell*—On static detonation of a shell, the direction of emission of most of the fragments make an angle $\delta$ to the normal to the inner surface of the shell, we denote $\delta$ to be positive if the shell has a base fuze and negative if the shell has a nose fuze. Let U represent the forward velocity along the axis of the shell. Each element of the casing has two velocities —$V_0$ and U—in a plane parallel to the axis of the shell and let $V_2$ represent the resultant velocity. Let $V_2$ subtend an angle $\theta$ with the direction of $V_0$ in a plane parallel to the axis of the shell. Obviously $(\theta + \delta)$ represents the angle which the direction of emission of most of the fragments subtend with the normal to the inner surface of the shell if it detonates in flight. The magnitude of $V_2$ and $\theta$ are given by the law of parallelgram of forces and are as follows:

$$V_2 = (V_0^2 + U^2 + 2 \, V_0 \, U \sin \delta)^{\frac{1}{2}} \quad \ldots \quad (6)$$

$$\theta + \delta = \frac{\pi}{2} - \tan^{-1}\left[\frac{V_0 \cos \delta}{U + V_0 \sin \delta}\right] \quad \ldots \quad (7)$$

This suggests that the forward velocity of the shell at the time of detonation affects both the velocity and the direction of emission of the fragments. The experimental verification of this will be published elsewhere.

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## REFERENCE

1. Singh S., Proc. Phys. Soc. 69B, 1089, 1956.