A NOTE ON THE DETERMINATION OF RICOCHET TRACE OF SMALLA RMS AMMUNITION

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(*Received* 1 *December* 1973; *revised* 11 *August* 1975)

A method of obtaining the relationship between various parameters governing the ricochet phenomenon of a projectile has been described. The experimental procedures for determining such parameters and their use have also been discussed.

The problem of ricochet of any projectile when it fails to hit the target or after its impact on the target, is of great importance for the services as well as for the police personnel. The ricochet process is of constant concern for the Airforce authorities also during air to ground attack, due to the chances of hit to own aircraft from own fire. Whenever any bullet hits the ground short of target, it may deflect considerably from its original path due to high energy it possesses. The ricochetted projectile may travel in a direction quite different from its original one and up to a distance which depends on a number of factors related to the ammunition, nature of ground, angle of impact and initial velocity of bullet etc. Though some classified literature is available for calculating the ricochet distance and ricochet height in the case of APDS projectiles, nothing of this sort is available to predict the same for small arms ball ammunition, where the projectile undergoes deformation on impact.

The object of this paper is to high light the basic parameters governing the ricochet process of small arms ball ammunition, their relationship with the initial condition of fire. The basic parameters which play vital role during ricochet have been given in Fig. 1 which is self explanatory. The set up used for determining these parameters is shown in Fig. 2.

$$\text{Post ricochet angle } (e) = \tan^{-1} \frac{Y_2 - Y_1}{\{ (X_2 - X_1)^2 + (Z_2 - Z_1)^2 \}^{1/2}} \tag{1}$$

$$\text{Azimuthal deflection angle } (\alpha) = \tan^{-1} \frac{X_2 - X_1}{Z_2 - Z_1} \tag{2}$$

$$\text{Angle of incidence } (i) = \tan^{-1} \frac{\text{height of the rifle Muzzle}}{\text{Distance between point of impact and Muzzle}} \tag{3}$$

$$\text{Angle of total deflection } (\beta) = \cos^{-1} (-\sin e \sin i + \cos e \cos i \cos \alpha) \tag{4}$$

X-axis is horizontal, perpendicular to the line of fire, Y-axis is vertical and Z-axis is horizontal, parallel to the line of fire. (X_1, Y_1, Z_1) and (X_2, Y_2, Z_2) are coordinates of the points of impact of the bullet on ground and on recording panel.

The ricochet process mainly depends on the pre-ricochet conditions viz. angle of impact, pre-ricochet velocity and nature of ground while the post ricochet conditions mainly depend on the post-ricochet

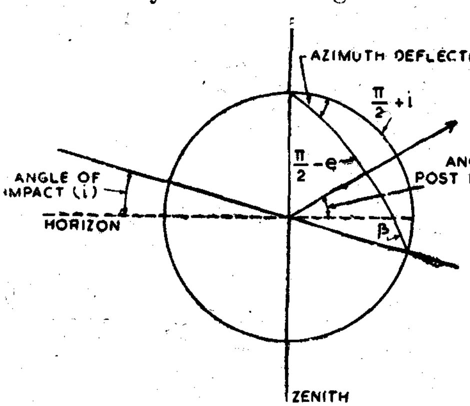

Fig. 1—Geometrical derivation of the values of, total deflection (β) post ricochet angle (e) and azimuthal deflection (α).

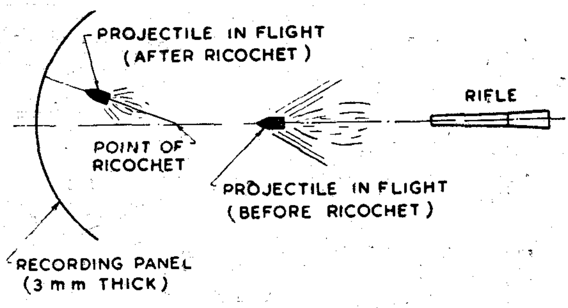

Fig. 2—Experimental set-up for determining different ricochet parameters.

angle of departure e, loss of velocity on impact, the extent of deformation of the bullet and the angle of deflection from the line of fire.

In order to determine the extent of loss in velocity on impact, it is observed that a relationship of the form

$$(v/u) = 1 - K\beta^2 \tag{5}$$

where u, v are pre and post ricochet velocities respectively, gives a good fit. β represents the angle of total deflection, which, from definition, includes in it all ricochet parameters. From practical trials it has been seen that the value of the constant K is related to the nature of ammunition and ground.

The case of 'No Ricochet' is explained in two ways, (*i*) either through complete dispersal of energy or (*ii*) through non-emergence from the ground. The former case would occur, as indicated from (5), when $\beta = 1/\sqrt{K}$. The case of non-emergence will depend only on the angle of impact. It has been observed that ricochet occurs upto a certain critical angle of impact after which the shot penetratesi nto the ground.

This prompts one to relate the angle of the incidence i with angle of total deflection β as β itself signifies post ricochet events.

The observed values of β corresponding to different values of i were fitted to obtain a parabola of the form

$$\beta = a_1 i + b_1 i^2 \tag{6}$$

by the method of least square. As pointed out earlier, the ricochet phenomenon in the case of small arm ammunition differs from that of APDS shots etc, in the sense that in the former case the projectile deforms. Compared to the range usually achieved by small arm ammunitions this factor cannot be ignored. Due to this, the change in ballistic coefficient of the projectile cannot be neglected . In the case of ammunitions of higher calibre (longer range) the ballistic coefficient can be assumed to be constant. The ballistic co-efficient of the deformed shot alongwith other parameters can be determined either from the field trials or in a closed range by measuring the post ricochet velocities at two different points and using the space functions. The correlation between post ricochet conditions and variation of ballistic coefficient was analysed and it was seen that there exists a close relationship of the form

$$C_0 = a_2 + b_2 \beta + C_2 \beta^2 \tag{7}$$

The value of the constants were obtained by employing the method of least square.

Thus when all the parameters relating to the pre and post ricochet conditions are determined with the help of above relationships, it is possible to draw a ricochet trace as explained below.

DRAWING OF RICOCHET TRACE

From any impact conditions i.e. for certain i and u we know β from (6). For any arbitrary values of α and β ($\beta > \alpha$) from (4), the value of v is obtained from (5) and value of post ricochet angle of departure (e) is determined from

$$\sin e = \frac{-\sin i \cos \beta \pm \sqrt{\cos^2 i \cos^2 \alpha \,(\sin^2 \beta - \cos^2 i \sin^2 \alpha)}}{(1 - \cos^2 i \sin^2 \alpha)} \tag{8}$$

since, $e < \pi/2$, only + sign of square root need be taken, the Ballistics Coefficient is determined from (7). Knowing all these, the ricochet range is determined.

The terminal conditions at the end of first ricochet will serve as the initial conditions for the second ricochet. This process will continue till the ricochet ceases either due to loss of energy or due to the penetration of the bullet. The extreme ranges achieved by the bullet for different values of α may then joined to get the ricochet trace.

DISCUSSION

As pointed out earlier it is seen from (6) that extreme value of β occurs when

$$i = -a_1/2\,b_1 \tag{9}$$

since $\beta = 0$ for $i = 0$, it is obvious that extreme value is maximum. Further from (6) it is obvious that ricochet will cease due to non-emergence from ground for a value of

$$i = (a_1 - 1)/b_1 \tag{10}$$

The value of i given by (9) is greater than the value of i given by equation (10) if $a_1 > 2$ which is true for all practical cases. From equation (6) there will be no ricochet through complete dispersal of energy if

$$\beta = 1 / \sqrt{K}$$

The method outlined here may well be applied to determine the ricochet safety trace for ammunition of higher calibre also.