Def Sci J, Vol 36, No 4, October 1986, pp 389-394

Effect of L/D Ratio on Bomb Ricochet

R A Goel, Sudhish Chandra, Harbir Singh, A K Abrol & Bachan Singh
Terminal Ballistics Research Laboratory, Chandigarh-160 020

Received 6 August 1984; revised 18 June 1986

Abstract. Intensive experimental work carried out, to study the effect of the length of a projectile on its ricochet behaviour has been reported. The work is pertinent for designing the bomb to be delivered by low altitude/high speed mode for destruction of runways. Scaled models have been used to conduct these studies and a relationship showing the variation of critical angle of no-ricochet with L/D ratio is evolved.

1. Introduction

Ricochet is defined as the deflection of a projectile from its course while maintaining its integrity after its impact on the target. This phenomenon assumes great importance in the field of terminal ballistics as the ricochetted projectile proves of no utility to its launcher. On the other hand, this may create havoc on secondary impact at an undesired place. The importance of this phenomenon is manifolded more in the case of low altitude/high speed delivery mode against large horizontal concrete targets like runways or specific structures, since the attacking aircrafts always carry a big risk in enemy's domain and ricochet of the bomb makes the recci futile.

It is a nose shape. The velocity of the projectile and its relative material properties with target are the factors reported to influence its ricochet behaviour. Length of the bomb is an important factor and puzzles the designer to a great extent for its optimisation. No information regarding the effect of L/D ratio of the projectile on its ricochet behaviour exists in the literature. Experimental studies to investigate the same were undertaken using scaled models, as it is neither feasible nor economical to conduct full scale trials.

2. Experimental Procedure

Model projectiles of 31 mm dia and 2 5 CRH were launched horizontally from **smooth** bored launching system, Projectiles of L/D ratio 3, -1.5, *6.4,* 7.8 and 8.9 were used as shown in Fig. I. To project the projectiles of different L/D ratio with fixed value of

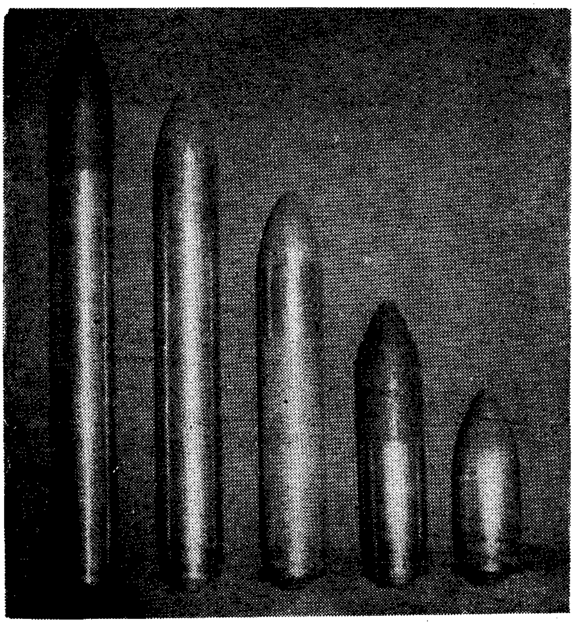

Figure 1. Model projectiles of 31mm. dia, CRH. 2.5 and L/D ratio 8.9, 7.8, 6.4. 4.5 and 3 respectively.

velocity, the quantity of charge was appropriately varied. But no alteration in charge weight was made to fire similar models unless a variation in velocity was desired.

Concrete blocks of size 75 × 75 × 25 cm were used as targets. These blocks were fabricated using cement, sand and coarse aggregate in the ratio of I : 1 : 2. Coarse aggregate of size 1.25 cms was used. All blocks were cured in water for 28 days. Use of mechanical mixer was made to properly mix and uniformly distribute the ingredients before pouring the mixture in the mould. The mixture in the mould was then vibrated with a needle vibrator to avoid porosity in the block.

For experiments, the concrete block was placed at a desired angle of impact with horizontal, facing the muzzle of the gun. The relative positioning of the target and gun muzzle was adjusted, to have the impact of the model projectile in the centre of the target. The position of the gun muzzle was fixed at a distance of 2.5 **m** from the concrete target. The velocity of model projectile was measured just prior to its impact with screen-counter method. Details of flight of projectile in pre-impact and post-impact stages were recorded using Spark Photographic Technique. The projectile was recovered after each experimental trial and examined critically for any damage incurred.

3. Results and Discussion

Initially, experiments were carried out to see the effect of velocity of the projectile on its ricochet behaviour. The work was confined to projectile having L/D ratio 3. These trials were conducted with velocities 163.0 ± 6, 221.0 ± 5 and 278.0 ± 10 m/sec. Fig. 2 shows sequentially the ricochet of a model projectile of L/D ratio 3 after

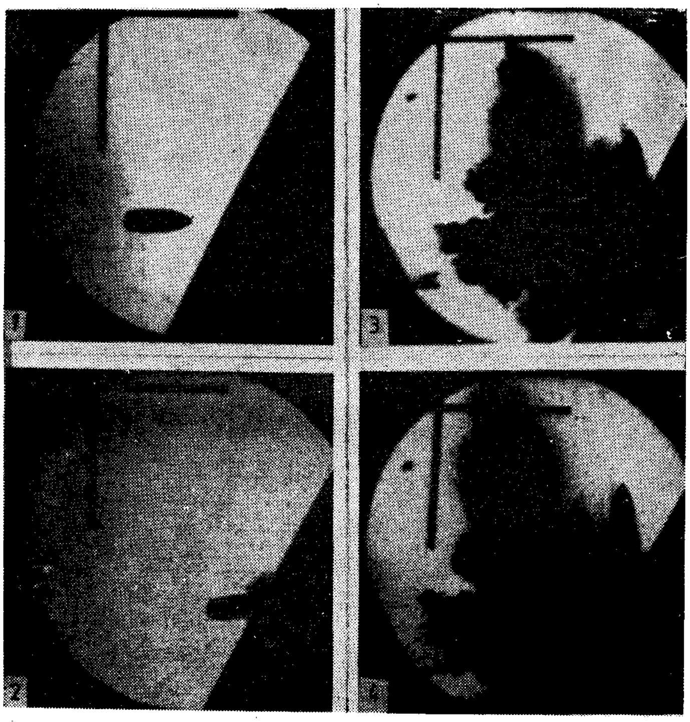

Figure 2. A specimen record showing sequentially interaction of a model projectile of L/D ratio 3 with concrete block, The concrete block of runway specifications having thickness 25 cms was placed at an angle of 63” with horizontal. In frame No. I the projectile is seen approaching towards the target, in frame No. 2, it is penetrating in the target while frame No. 3 & 4 show the projectile in the process of recochetting.

an impact on a concrete block placed at an angle of 63” with horizontal. The values of angle of no-ricochet recorded for these velocities have been graphically plotted and

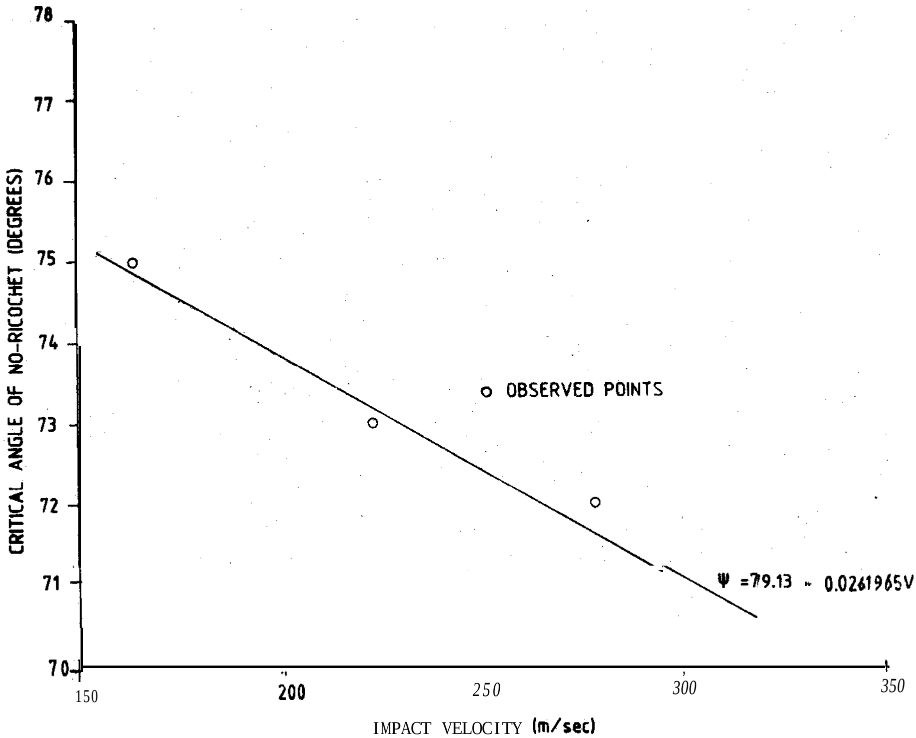

Figure 3. Dependence of angle of impact of no-ricochet on impact velocity.

shown in Fig. 3. It is evident from the graph that the value of angle of no-ricochet reduces linearly with the increase in velocity and the least square feet of straight line gives the equation :

$$\psi = 79.13 - 0.0261965V$$

where ψ is the minimum angle of impact for no-ricochet and V is the velocity of the model in m/sec.

It is evident from this equation that the maximum value of angle of impact for no-ricochet will be 79.13" or (say 80°) for a projectile of 2.5 CRH value.

Minimum values of angle of impact for no-ricochet have been measured by conducting extensive trials for projectiles of different L/D ratio projected with velocity 250 m/sec. The variation in velocity of $\pm$ 8 m/sec has been recorded. Taking this to be marginal, it has been overlooked. The flight of a model projectile of L/D ratio 6.4 in pre-impact, impact and ricochetting stages has been sequentially shown in Fig. 4. The variation in the values of angle of impact for no-ricochet with respect to L/D ratio has been shown in Fig. 5. The following relationship shows inter-dependence of the two factors :

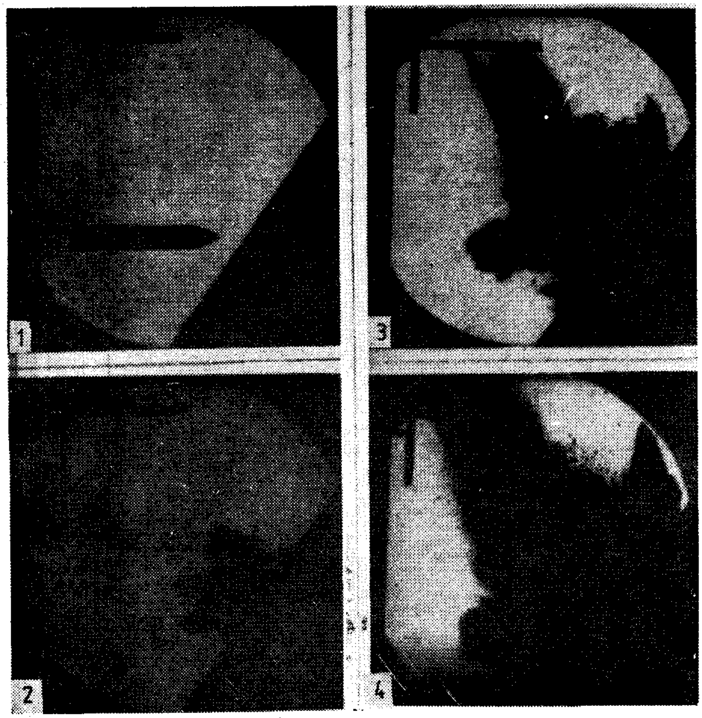

Figure 4. A specimen record showing interaction of a model projectile of L/D ratio 6.4 with concrete block of runway specifications in pre-impact, impact and post impact (ricochetting) stage. The block of thickness 25 cms was placed at an angle of 55” with horizontal. The projectile can be seen ricochetting in Frame No. 3 & 4.

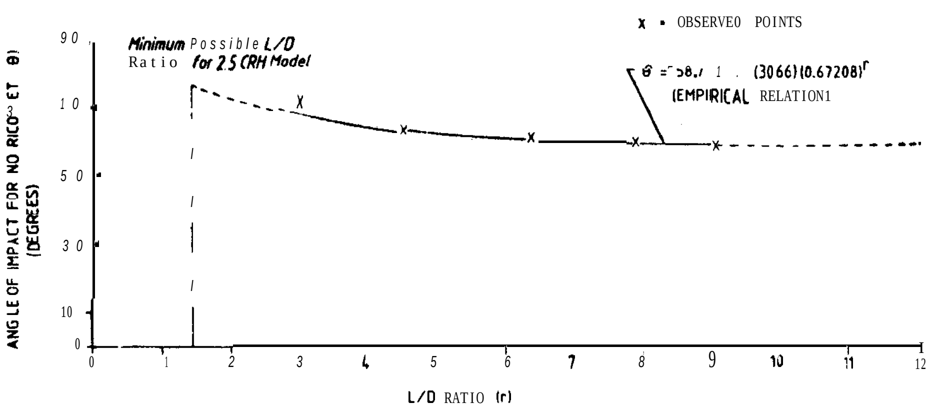

Figure 5. Dependence of angle of impact for no ricochet on L/D ratio. (Projectile model projectile of 31 mm dia & CRH 2.5, Impact velocity-:250 + 10 m/sec, Target : concrete block).

$$\theta = 58.7 + (30\ 66) \times (0.67208)^r$$

where θ = represents the minimum angle of impact for no-ricochet and r = the ratio of length and diameter of projectile.

The relationship is a modified form of exponential curve and shows the decreasing trend of value of θ with the increase of r in the initial stages. The lowest limit of θ is 58.7° which is approached tracing an asymptotic curve. This represents that if the trend of curve is extended indefinitely towards right, it would approach closer and closer to 58.7”. And for any value of r, however high it may be, the value of θ will not be less than 58.7”. ,

If the curve is extrapolated towards left, the maximum value of angle of no-ricochet will be 89.36” for zero value of r. This value is less than 90”. the maximum value of angle of impact. This proves the tracing of the curve lies within the boundary limits.

The minimum value of r (L/D ratio) of a projectile having 2.5 CRM can be 1.38 only as any further reduction in length, will slice the projectile from its shoulder. The value of θ for $r =$ 1.38 has been evaluated from the above relationship and found to be 76.4”. This represents maximum value of angle of impact for no-ricochet of any projectile of 2.5 CRH when fired with velocity of 250 m/sec.

It may be concluded from these observations that L/D ratio of projectile influences its ricochet behaviour. The effect is significant upto a certain finite value only. Beyond this the effect becomes insignificantly low and may be taken as nullified for practical purposes.

Acknowledgement

Authors are greatly indebted to Col H S Puri for his encouragement and able suggestions throughout the work. We also pay our solemn gratitude to Air Cmde SK Sen, Director, Terminal Ballistics Research Laboratory, Chandigarh for his numerous valuable suggestions and permission to publish this work.

References

1. Rinehart, J. S. & Pearson, J., ‘Behaviour of Metals Under Impulsive Loads’ (Dover Publications Inc., New York), 1954 pp 208-211.
2. Text Book of Air Armament Part I, Chapter 3 pp 8-26.
3. Text Book of Air Armament Part I, Chapter 5 pp 11-15.