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Behaviour of a Kinetic Energy Projectile on Angular Impact

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ABSTRACT

Experiments of high velocity impact have been carried out with 30 mm armoured piercing projectiles on 55 mm thick hard steel plate. Angle of impact has been varied from 10° to 90°. Damage inflicted on target with varying angle of impact has been reported and discussed in this paper. Comparative behaviour with 20 mm APP shot has also been discussed.

1. INTRODUCTION

Interaction of high velocity projectile with hard targets is a complex phenomenon and depends on many factors such as plate thickness and its hardness, striking velocity of the projectile, angle of impact, nose shape, calibre, mass and material of the projectile. No experimental data of the interaction of 30 mm APP shots with steel was available in the country. To generate the same, experiments have been conducted and observation pertaining to the behaviour of the shot and damage inflicted on the target are discussed.

2. EXPERIMENTAL DETAILS

Projectiles of 30 mm calibre were fired from 30 mm Aden gun. Quantity of charge weight of 47.00 gms was kept fixed and the velocity of the bullet was recorded 685 ± 2.3 m/sec. The details of projectile is shown in Fig. 1. Core of the projectile is made of tungsten carbide, which is enveloped with an alloy of aluminium. Hardened steel plate of hardness No. 360 B H N and thickness 55 mm was used as target. The projectile was fired horizontally. The target plate was kept vertically or obliquely to have a normal or oblique impact of the projectile. Angle of obliquity was varied from 10° to 90° . The angle was always measured and fixed with horizontal. Multiple Spark

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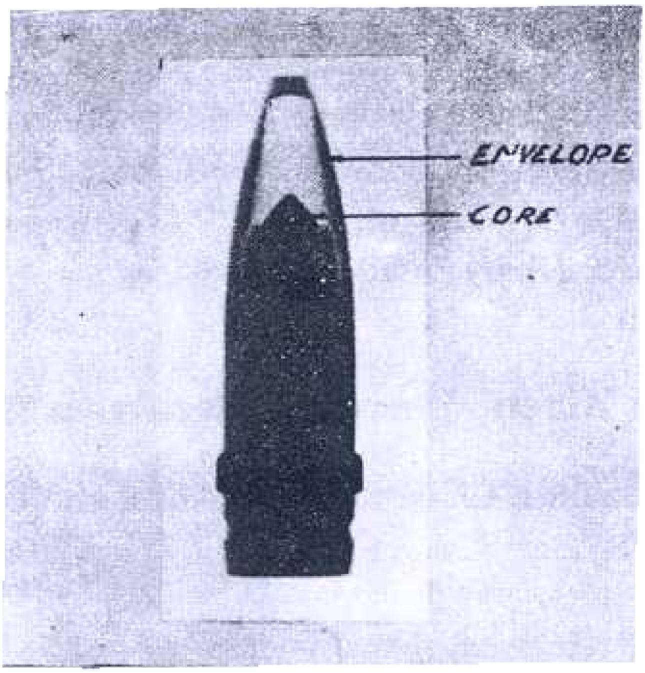

Figure 1. Details of 30 mm AP projectile.

Photography[1] was used to record the transient behaviour of high velocity impact. The velocity of the projectile was measured in each experiment using screen counter method.

3. OBSERVATIONS AND DISCUSSIONS

Envelope of the projectile was shattered immediately after impact. The core after impact was found ricochetting, rebouncing or sticking in the target. It was either intact, broken into two pieces or shattered depending upon the angle of impact. Up to 50° angle of impact, the projectile was found ricochetting and at 60° it started getting rebounced. 55° angle of impact was the critical stage in which the projectile attained the tendency of getting into the target and its nose portion was found absorbed in the target. The rear was shattered. At 70° and above the projectile got stuck into the target plate. The photograph of damage inflicted on the target plate after ricochet, rebounce and embedment of the projectile is shown in Fig. 2.

As the angle of impact was changed the damage inflicted by the projectile on the target varied in length, width and depth. All these parameters were noted in each experiment, and have been given in Table 1. To see the variation of these parameters with respect to angle of impact, graphs were plotted taking angle of impact along x-axis and length, width and depth on y-axis. These graphs have been shown in Fig. 3 and 4 respectively.

4. LENGTH AND WIDTH OF THE DAMAGE

It is evident from Fig. 3 that the length of the damage inculcated on the target increases linearly up to a maximum value of 67.5 mm, at angle of impact of 50°, beyond which, it exponentially reduces to a minimum of 19 mm (approximately equal

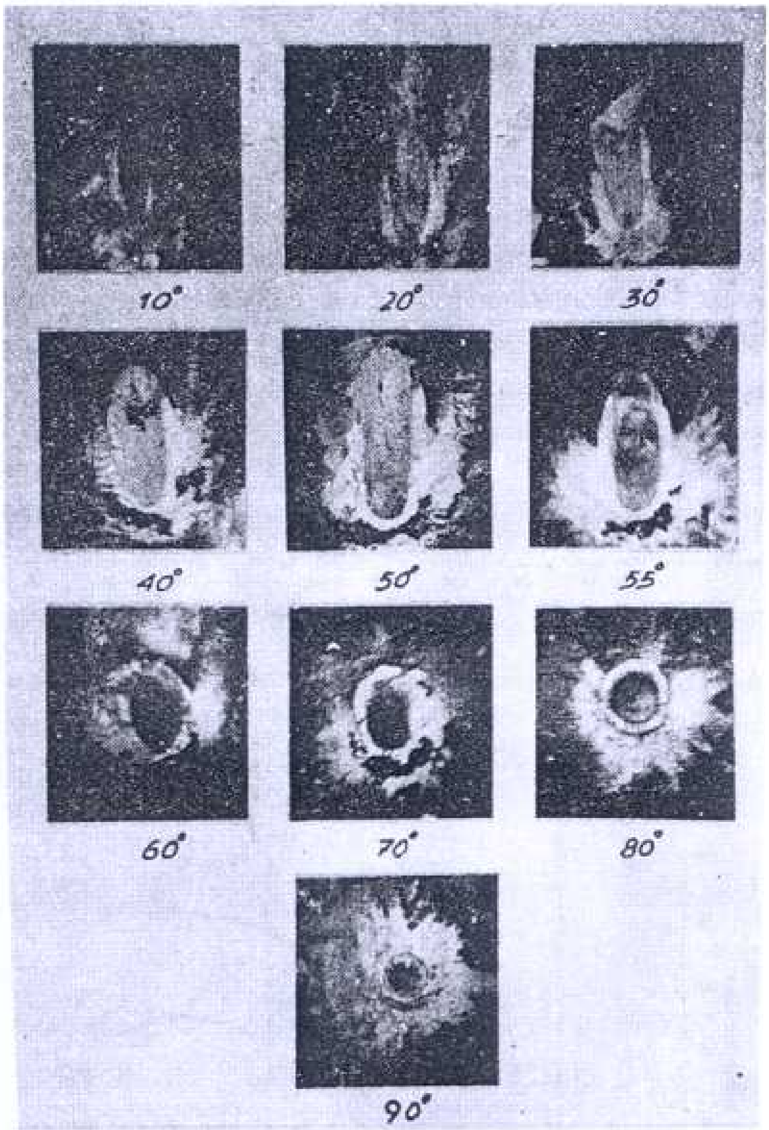

Figure 2. Damage inculcated on 55 mm hard steel plate at different angles of impact by 30 mm AP shots.

Table 1. Details of damage inculcated on 55 mm hardened steel plate by 30 mm APP shot

Sl. No.	Angle of impact in degrees	Damage on target		
		Length (mm)	Width (mm)	Penetration (mm)
1.	10°	52.0	10.0	0.8
2.	20°	58.5	14.4	3.8
3.	30°	55.0	17.5	8.2
4.	40°	62.8	18.8	11.0
5.	50°	67.5	19.5	23.0
6.	60°	31.5	20.5	45.8
7.	70°	26.0	18.0	50.0
8.	80°	25.0	18.25	51.0
9.	90°	19.0	18.0	50.7

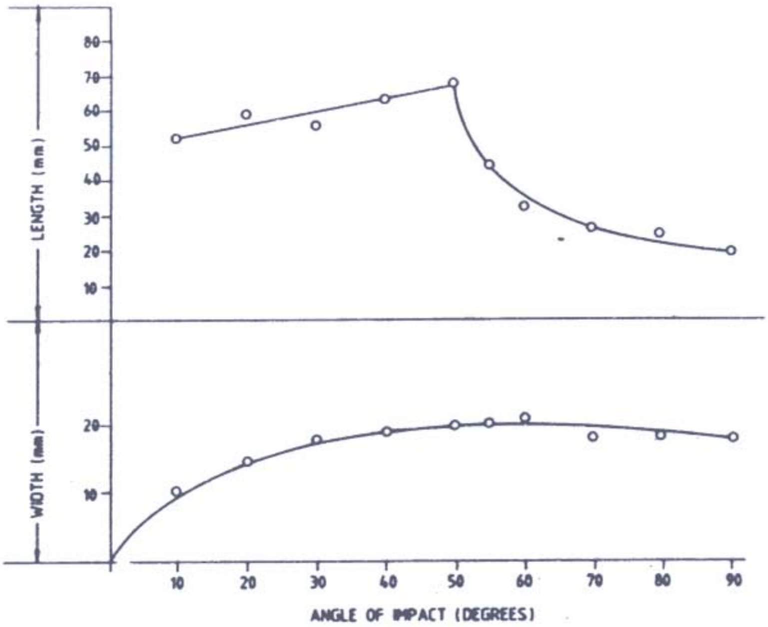

Figure 3. Variation of two dimensional damage with angle of impact.

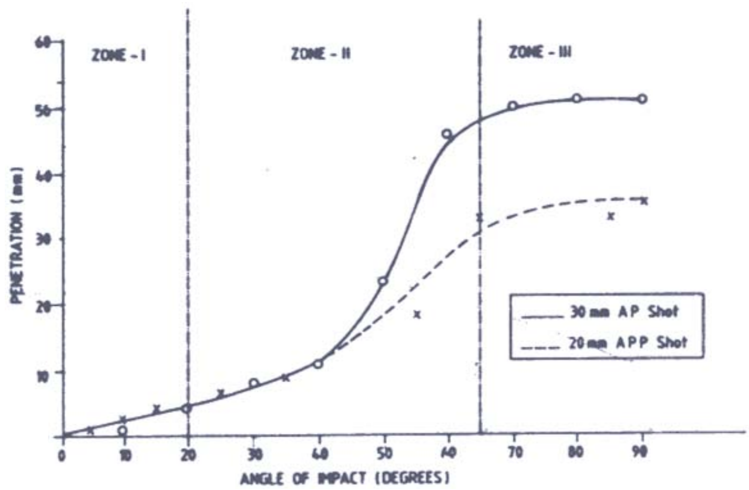

Figure 4. Variation of penetration with angle of impact

to diameter of core) at 90°, since the core got embedded into the target. 50° is the limiting value of angle of impact up to which the projectile has been found ricochetting and above this angle the projectile was either rebounced or embedded in the target plate.

Width of the damage has also shown an increasing trend, which reaches its maximum in the range of angle of impact of 50° to 60°. This shows that maximum plastic flow of material on front surface has occured in this range. Any further increase in angle of impact increases the tendency of the projectile to penetrate deeper into target and hence reduction in the width of the damage. The width has been reduced to 18 mm (approximately equal to the diameter of the core) for angle of impact 90°. As mentioned earlier the core was embedded into the target at 90° angle of impact.

5. PENETRATION

Variation of depth of penetration with angle of impact has been shown in Fig. 4. The behaviour is similar to that recorded for 20 mm APP projectile and reported in our paper Influence of Angle of Attack on Target[7] presented in Workshop on Terminal Ballistic held in December, 1981 at Institute of Armament Technology (IAT), Pune. For comparison, curve showing the variation in penetration of 20 mm APP projectile with respect to angle of impact for impact velocity 677 m/sec and target 55 mm hardened steel has also been shown in the same figure. Table 2 shows their numerical values. The target plates in the two experiments were from the same lot. The details of 30 and 20 mm shot is shown in Fig. 5. The velocity of 30 mm projectile (685 m/sec) and 20 mm projectile (677 m/sec) have only marginal difference and may be taken same for comparing performance of two shots. 20 mm APP projectile was

Table 2. Penetration on 55 mm hardened steel plate by 20 mm APP shot

Sl. No.	Angle of impact in degrees	Penetration
	5°	0.8
2.	10°	2.5
3.	15°	3.8
4.	25°	6.2
5.	35°	8.6
6.	55°	18.2
7.	65°	33.0
8.	85°	33.5
9.	90°	35.5

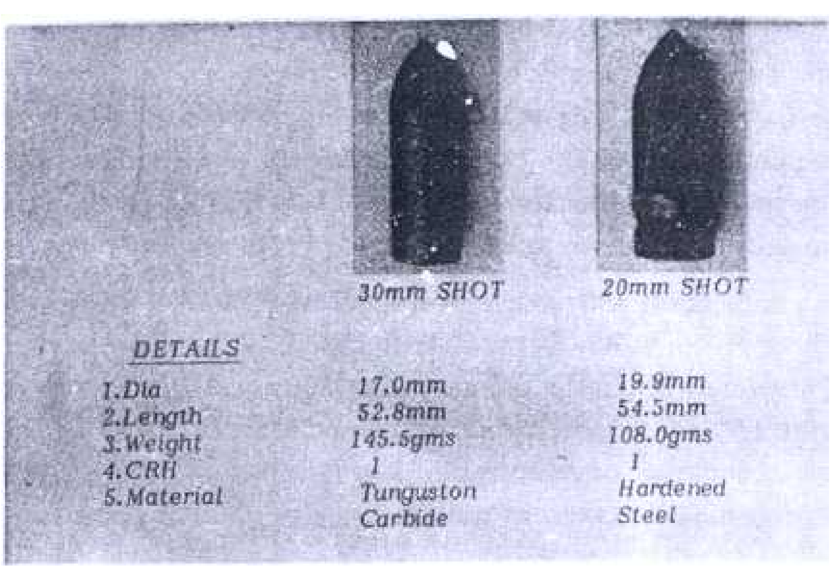

Figure 5. Details of 30 mm and 20 mm shots.

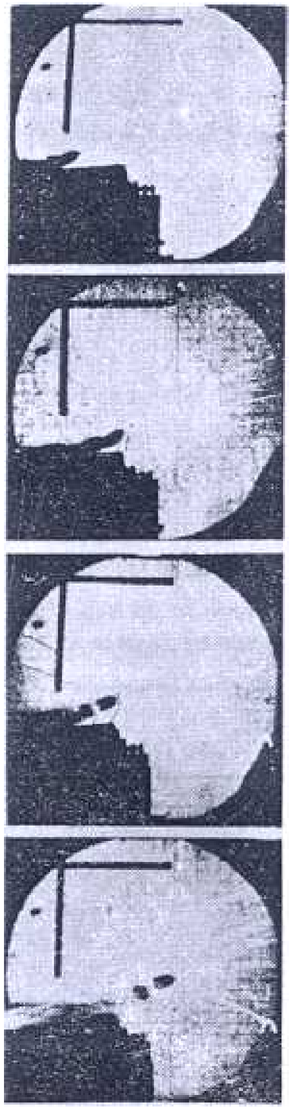

Figure 6. Sequential record showing a 20 mm APP, projectile ricochetting and subsequently breaking into two pieces after an oblique impact on 55 mm thick hardened steel plate.

also found ricochetting, rebouncing and sticking into the target after an impact on it in a similar manner as 30 mm APP projectile. Fig. 6 shows sequentially a 20 mm APP projectile ricochetting and subsequently breaking into two pieces after an impact on 55 mm thick hardened steel plate. The two curves of Fig. 4 have got similar contours at all levels and the penetration of the two projectiles up to 40° angle of impact is same. It can therefore be inferred that the obliquity of target effected the penetration behaviour of the two projectiles in an alike manner.

The increase in penetration with angle of impact of 30 mm APP projectile can be distributed into three zones as had been done in case of 20 mm projectiles[7]. Zone I, up to 20° angle of impact in which the increase in penetration is not steep and Zone II, above 20° and up to 65° where penetration increased steeply. Zone III, above 65° in which the gradient of increase of penetration is minimum and the effect of angle of impact on penetration may be taken as nullified.

Attempts were also made to investigate the existence of any trigonometric relationship between penetration at normal impact and oblique impact. No single relation could be formed covering the entire region of 10° to 90°.

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