DESIGN OF AN IMPACT TEST FOR ESTIMATING THE DEFORMATION ENERGIES OF PROJECTILES IN WOUND BALLISTICS STUDIES

M. JAUHARI & A. BANDYOPADHYAY

Central Forensic Science Laboratory, Calcutta-700014

(*Received* 27 *January* 1979)

The paper suggests an impact test which can be used to evaluate the deformation energies of small arm projectiles. Such an evaluation is of significance in wound ballistics studies while determining the amount of energy actually consumed in causing cavitation. Various sources of error inherent in the test have been discussed and it has been concluded that although approximate, the test can serve the useful purpose of providing a basis for interpreting the energy loss figures in gel on a rational and scientific basis.

One of the experimental material used by researchers in the field of wound ballistics in 20% gelatin gel maintained at a temperature of 50° F. This material is not only found to qualitatively duplicate the various phenomena occurring during the passage of a missile through the soft tissues of a human body, but its drag co-efficient also appears to be quite close to that for the live tissues. Measurement of loss of energy suffered by a projectile during its passage through a fixed length of gel (say fifteen centimeter) are, therefore, often made and used to interpret the relative effectiveness of two or more projectiles. [1,2] When a projectile deforms during its passage through the gel, the energy loss as computed by measuring the entrance and exit velocities becomes of dubious value because it includes within itself the energy consumed in deforming the projectile itself, the latter being unavailable for causing cavitation. In general, the energy loss E_L in gel computed by chronographing the entrance and the exit velocities of the projectile may be written as

$$E_L = E_L' + E_D$$

where E_L' represents the energy available for causing cavitation and E_D the energy consumed in deforming the projectile itself. Obviously, therefore, one is interested in determining E_L' for interpreting the effectiveness of a missile which requires a knowledge of E_D in addition to E_L.

In the present paper, an impact test has been described which enables one to calculate E_D and hence evaluate E_L' in an approximate manner. Determination of E_D and hence E_L' for 0.410 lead ball and 0.315 SN bullet, both of which deform during passage through gel, has been attempted as an illustration.

EXPERIMENTAL DESIGN

The time taken by a projectile discharged through a firearm in traversing a gel block of, say, 15 cm length is of the order of a fraction of a second. If F is the retarding force acting on the projectile during the time of passage τ, the change in linear momentum of the projectile or the impulse I can be written as

$$I = M\,(V_S - V_R) = \int_0^\tau F\,dt, \tag{1}$$

where M is the mass of the projectile and V_S and V_R are the striking and remaining velocities respectively. If $\bar{F}$ represents the average value of F over a time interval τ one can write

$$I = M\,(V_S - V_R) = \bar{F}\,\tau$$

or

$$\bar{F} = \frac{M\,(V_S - V_R)}{\tau} \tag{2}$$

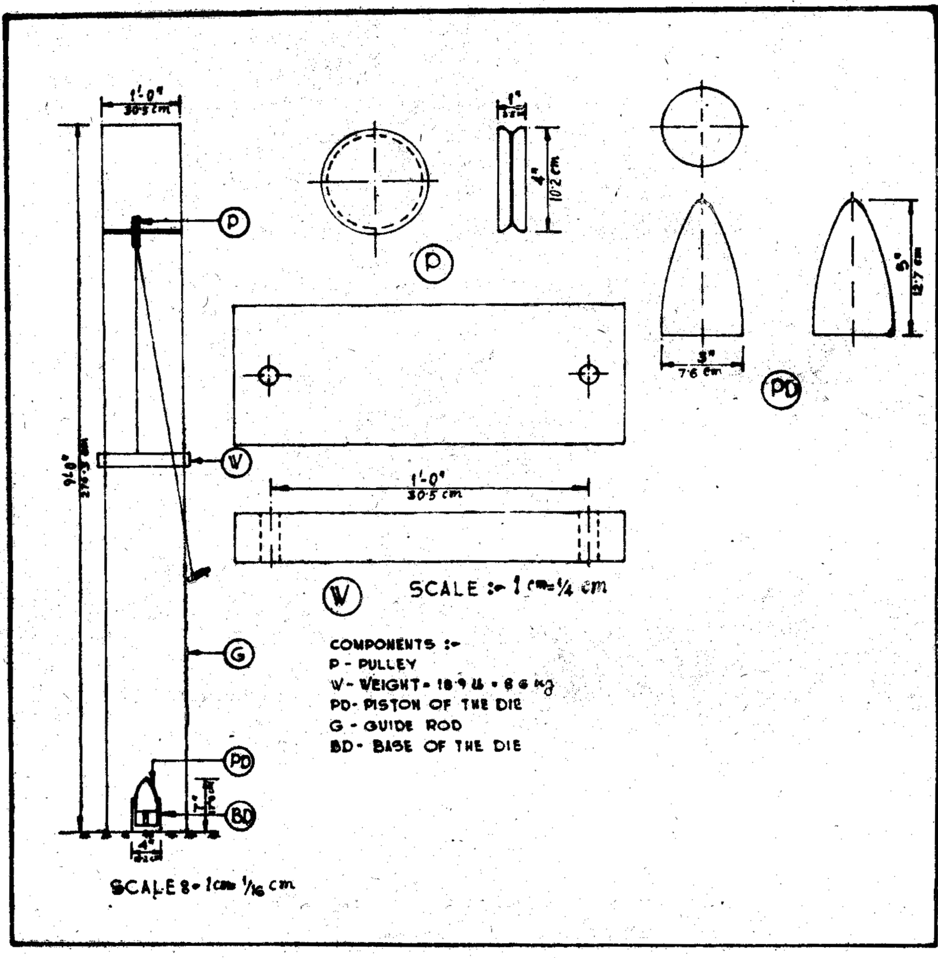

Fig. 1—Schematic diagram of impact test.

As τ tends to zero, $\bar{F}$ tends to infinity; the product $\bar{F}\tau$ representing the impulse, however maintains a finite value. It is, therefore, seen that for short intervals of time as are encountered while firing small arm projectiles through gel block, the retarding force is mostly impulsive in nature. In view of the impulsive nature of the forces involved, it appears that probably an impact test might offer a plausible solution of the problem of determining the deformation energies of the projectiles. Accordingly, an impact test suitable for small arm projectiles was designed.

BD is a specially prepared die made of hard steel having dimensions as indicated in the Fig. 1. The projectile whose deformation energy is to be determined is placed erect at the centre of the base of the die. A frictionless solid piston PD of the die rests just upon the projectile. The energy required for deforming the projectile is derived from the vertical fall of a weight W through a height H. The weight W is allowed to hit the die at the end of its vertical fall and come to rest thereby consuming all its kinetic energy in deforming the projectile. To ensure a vertical fall without any sideways motion, the weight W is made to travel along a set of vertical guide rods which are lubricated to minimize loss of energy due to friction.

In an actual experiment, the weight W is pulled to the desired height by a metallic string, and then allowed to fall and hit the piston PD. As a result of impact, the weight W comes to rest and its kinetic energy, acquired during the fall, is consumed in deforming the projectile. The kinetic energy of the weight W i.e., WH acquired during its fall through a height H can thus provide a measure of the deformation energy corresponding to the deformation produced in the projectile.

While determining the deformation energies of 0.410 ball and 0.315 SN bullet, the weight W weigh- 8.6 Kg. The load W was dropped from different heights H and the corresponding thickness of the deformed projectile was noted. A fresh projectile was used corresponding to each of the heights experimented The experimental data for the two projectiles is given in Table 1. Since the observed thickness of the 0.31

TABLE 1

IMPACT TEST DATA (APPLIED LOAD W=8.6 KG.)

Observation No.	Deformation of 0.315 SN Bullet			Deformation of 0.410 Ball		
	Height (H) from which the load was dropped (cm)	Deformed Thickness (cm)	Deformation Energy (WH) (Joule)	Height (H) from which the load was dropped (cm)	Deformed Thickness (cm)	Deformation Energy (WH) (Joule)
1	167.6	1.78	141.0	15.2	0.74	12.7
2	182.9	1.63	153.8	30.5	0.61	25.6
3	198.1	1.45	166.5	38.1	0.53	32.0
4	205.7	1.37	173.0	45.7	0.48	38.5
5	213.4	1.29	179.4	61.0	0.41	51.2

and 0.410 projectiles in gelatin gel experiments were 11.43 mm and 5.08 mm respectively, the corresponding deformation energies can be determined by plotting the thickness of the deformed projectile against the deformation energy, drawing a smooth curve through the plotted points and then reading off the deformation energy corresponding to the observed thickness of the deformed projectiles. These are found to be 195 and 35 Joules for 0.315 SN bullet and 0.410 ball respectively. Since the loss of energy in 15 cm length of gel block was found to be 1770 and 976 Joules for 0.315 SN and 0.410 ball respectively, the corrected figure for energy loss E_L in the two cases would be 1575 and 941 Joules respectively arrived at by deducting the respective deformation energies from the observed energy losses in the two cases.

DISCUSSION

The impact test described above cannot provide an accurate estimate of the deformation energies because of certain inherent sources of error as detailed below.

(*i*) The bullet passing through the gel might be tumbling and hence the force acting on it need not be axial as was more or less in the impact test. This error may also crop up in case of 0.410 ball which although spherical in shape may after entering the gel deform and then tumble in a random manner.

(*ii*) There is some loss of kinetic energy of the falling weight as heat on impact due to instantaneous heating of the projectile as well as the die. Some energy loss also occurs as sound as well as due to mechanical vibrations, etc.

(*iii*) It is impossible to exactly simulate the shape and size of the projectile as encountered in the gelatin gel experiments.

(*iv*) It is also not known whether the strain rate produced in the impact test is the same as is experienced by the projectile in gel.

It might be possible to neglect the losses due to heat, sound and mechanical vibrations, etc. in comparison to the total energy loss figure, but the error cropping up due to lack of exact simulation of deformation may be worth considering, although its magnitude is not known. Further it was not possible to measure the time of impact during which the projectile was being strained by the load W. There is, therefore, every possibility that this undetermined time was different from the average time of passage of 0.315

bullet and 0.410 ball through the 15 cm long gel block (306μ sec and 532μ sec respectively). This difference in the straining rate might affect[3] the experimentally derived values of deformation energy but, as far as the authors know, there is no standard working formula available in literature, which would directly correlate the deformation energy with the rate of straining.

With all these shortcomings in view, the impact test described above can at best provide an approximate practical method for estimating the deformation energies of small arm projectiles. It is also expected to provide a reasonable basis for rational and scientific interpretation of energy loss figures vis-a-vis the wounding effectiveness of a projectile till such time a more accurate method is discovered.

REFERENCES

1. DIMAIO, V.J., JONES, J.A. & PETTY, G.S., *Journal of Police Science & Administration.*, **1** (1973), 269-273.
2. JAUHARI, M. & BANDYOPADHYAY, A., *Journal of Forensic Sciences.* **21** (1976), 616-624.
3. DICTER, C.E., 'Mechanical Metallurgy' (McGraw-Hill Kogakusha Ltd., Tokyo), p. 254.