A THEORY ON THE REDUCTION OF PENETRATION POWER OF METAL JETS IN CERTAIN COMPOSITES

Cheng Chemin(郑哲敏) Tan Qingming(谈庆明) Gao Juxian(高举贤)
Ye Dongying(叶东英) Wu Yuyan(吴玉炎)
Institute of Mechanics, Academia Sinica Beijing, China

INTRODUCTION

It is known that the penetration power of a metal jet produced by a shaped charge suffers a great reduction in targets made of certain composites. This paper offers a theory to explain this fact.

REDUCTION OF PENETRATION POWER

It is found that the P-T(Penetration-Time) relation follows closely the curve based on the hydrodynamic theory until when breakage of the jet due to necking occurs. Afterwards,the broken jet loses significantly its penetration power, resulting in an apparently high critical jet velocity(CJV) anywhere from 2.6 to 3.8 km/s, depending on the target material. We recall that the CJV of a typical steel target is about 1.5 km/s.

EXPERIMENTAL FINDINGS

Systematic experiments are conducted in our laboratory to explore this phenomena. The principal means of observation are flash X-ray radiograms and postmortem examination. The following facts are established.

1. Unlike in metal targets, the cavity collapses and wraps around the jet(Fig.1). The collapsing speed of the cavity wall as observed by flash X-ray radiography ranges from 0.65 to 1.4 km/s.

本文发表在 Proceedings of the International Symposium on Intense Dumamic Loading and Its Effects In:Zheng Zhemin(C.M.Cheng),Ding Jing,eds.Beijing:Science Press,China,1986.347~351

It is to be noted that many composites undergo pyrolysis at relatively low temperature. A special effort was made at the Institute of Mechanics to measure the temperature in the target close to the cavity. Typical temperature measurements yield values from 550-760 degree Centigrade,about 4mm to the cavity wall. Laboratory static pyrolysis test of our target material shows that within this temperature range a large amount of gaseous product is formed. Next,it can be shown by data available in the literature that the rate of pyrolytic reaction is such that a significant amount of the target material can be pyrolysed within one microsecond.

The energy required for pyrolysis clearly comes from plastic work. It is reasonable to assume that the greater the plastic work, the greater the conversion into gaseous product by pyrolysis. Let η denote the mass portion of material which becomes an ideal gas with polytropic exponent γ under the stagnation pressure $p = \frac{1}{2}\rho_t u_t^2$, then we can estimate the collapsing speed of the cavity by the following formula

$$V = \sqrt{2\eta\frac{P_o}{(\gamma - 1)\rho_o}}$$

where ρ_o is the density of the two phase medium. This formula yields value of V in general agreement with our experimental observation. Hence we conclude that it is the potential energy of the gas generated as a result of pyrolysis during plastic deformation which is responsible for the high speed collapse of the cavity.

VERIFICATION OF THE THEORY

The above theory is put to test by running several sets of experiments. In the first set of experiments gypsum of approximately the same density is used as target.Since gypsum does not pyrolyse,the broken jet remains undisturbed(Fig.3). In the second set of experiments,the target material is reduced in strength by a factor of 10 while other mechanical and thermal properties remain the same. In this case, since plastic work is far less,no pyrolysis takes place and

2. Caving in of the target material apparently does not affect the behavior of the jet as long as it remains integral. However,when the jet breakes into droplets,the motion of each droplet (fragment) is altered in a very significant way. The droplet is then pushed out of the line of sight of the jet and suffers a distortion in shape(Fig.2), both of which lead to reduction in penetration power in terms of penetration depth. While the velocity of the droplet along the original jet axis is only slightly altered,the sidewise or lateral velocity may be as high as 200-300 m/s.

3. Radiograms also show that certain droplets may disappear from the original series of droplets as a result of lateral motion. This observation is matched by the discovery of fragments of the jet embeded in the target in postmortem examination.

4. Postmortem examination also reveals the existence of tar and carbon black on the wall as well as in the cracks.

These observations show beyond doubt that the reduction of penetration power is the result of the jet droplets being knocked out of line of sight by the collapsing target material.

PYROLYSIS OF TARGET MATERIAL

It is necessary to provide a theory to substantiate the above conclusion.

First of all, it should be noted that the contraction or collapsing of the cavity can not be explained on the basis of the usual elasto-plastic dynamics alone, because according to elastodynamics, the collapsing speed, V, can be roughly calculated from the following relation.

$$\rho_t CV = \frac{1}{2}\rho_t u_t^2$$

where ρ_t,c,u_t are the density, sound velocity of the target material and the penetration velocity respectively. This formula yields a value V significantly smaller than the observed value. Hence, we have to look for other energy sources to count for the rebounding of the cavity wall.

the broken jet suffers no significant disturbance(Fig.4 and 5). These tests provide convincing evidence of the validity of our theory.

CLOSING REMARKS

The interaction between metal jet and a target composed of certain materials is described in detail. An outstanding feature is that the target material rebounds and wraps around the jet. In the case of a broken jet, this can lead to distortion and lateral motion of the fragments, leading to a serious reduction of the penetration power of the jet.

A theory based on plastic deformation and pyrolysis of the target material is presented. It appears that this theory is capable of explaining many of the important observations of jet penetration in such materials.

Fig.1 The cavity collapses and wraps around the jet

Fig.2 Droplets pushed out of the line of sight of the jet

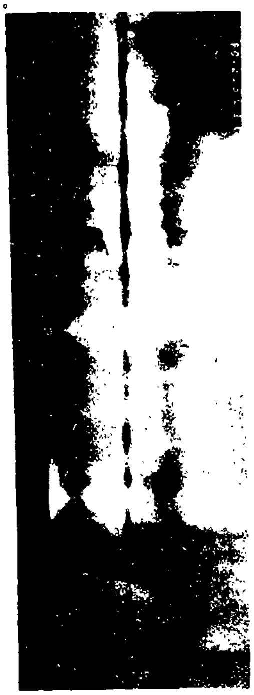

Fig.3 Substituting polymer by gypsum in composite

Fig.4 Reducing strength of the composite

Fig.5 Reducing the strength of composite