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INVESTIGATION OF SEVERAL POSSIBILITIES TO DISTURB THE JETTING PROCESS OF 40 MM / 60° CHARGES

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We present experimental results concerning several possibilities to disturb the jet formation process of shaped charges. Following methods were studied: steel cylinders positioned in the shaped charge cavity at various “negative stand-offs”; synthetic fibers placed in the cone; liner partially filled with low density materials, containing eventually randomly distributed metallic fragments. In each case, we used X-ray photography to evaluate the jet quality as well as its tip velocity. We also report the penetration capability of the perturbed jets.

INTRODUCTION

In an elder study of 40 mm / 60° precision experimental shaped charges [1], it was observed that the jetting process is strongly perturbed by a thin cylindrical metallic rod positioned in the liner cavity along its axis of symmetry. In that experiment, the cylinder went through the apex of the conical liner and was used as shock transfer element to initiate the detonation of the charge. This small rod induced large perturbations during the jetting process. As a consequence, the resulting shaped charge had poor penetration capability in a steel target.

These observations form the starting point of the present systematic study of the various possibilities to disturb jet formation with small objects placed in the cavity of the shaped charge (i.e., at “negative stand-off”).

These tests can be viewed from two standpoints. On the one hand, shaped charge conceptors find here the order of magnitude of jet perturbations which have to be expected when small objects enter the shaped charge cavity at the time of initiation; on the other hand, these investigations provide some hints about the various ways which are open in order to protect vehicles against attacks with shaped charges.

After a short description of the experimental geometry, we shall briefly present results for the several investigated situations, either with small rods at negative stand-offs, or with materials partially filling the liner cavity.

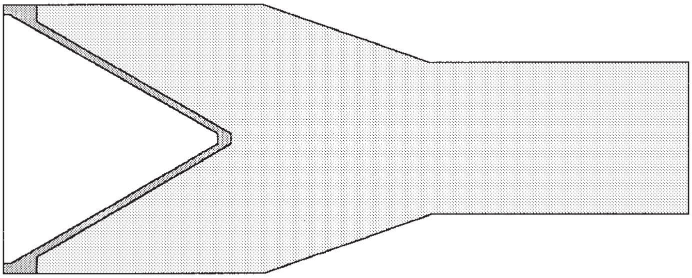

Figure 1: Sketch of the charge used in the present experiments. It consists of a 40 mm / 60° shaped charge. The explosive body is made of octastit 8G and the liner material is copper. The charge is centraly initiated at its rear end with a precision booster.

EXPERIMENTAL GEOMETRY

The experiments described below were performed with the charge pictured in figure 1. It consists of an octastit 8G body with maximum external diameter 40 mm. The front cavity is lined with a 1.0 mm thick copper cone; the latter has an opening angle equal to 60° and an overall length of 34 mm. The charge is “naked”, i.e., is not enclosed in a case. In all tests, the jet tip velocity was measured by use of triple X-ray flashes and the jet residual penetration depth in a steel target located at 400 mm stand-off was recorded. All results presented hereafter are condensed in Table 1.

EXPERIMENTAL RESULTS

When fired against a steel target (269–311 HB) located at 400 mm stand-off, the charge used in these experiments has a penetration capability of 200 mm. Its tip velocity is equal to 7.6 km/s (Fig. 3.1).

Cylinders of Steel or Synthetic Material Positioned in the Liner

As a first test, we placed a steel cylinder (Ø 3 mm and 60 mm long) on the cone axis, the cylinder touching the liner apex (Fig. 2.a). This leads to a maximal jet disturbance. The copper liner collapses on the steel cylinder and, as soon as formed, is eroded. As a consequence, one only observes copper dust emerging at high velocity from the charge, and the maximum penetration in the target only reaches 10 mm.

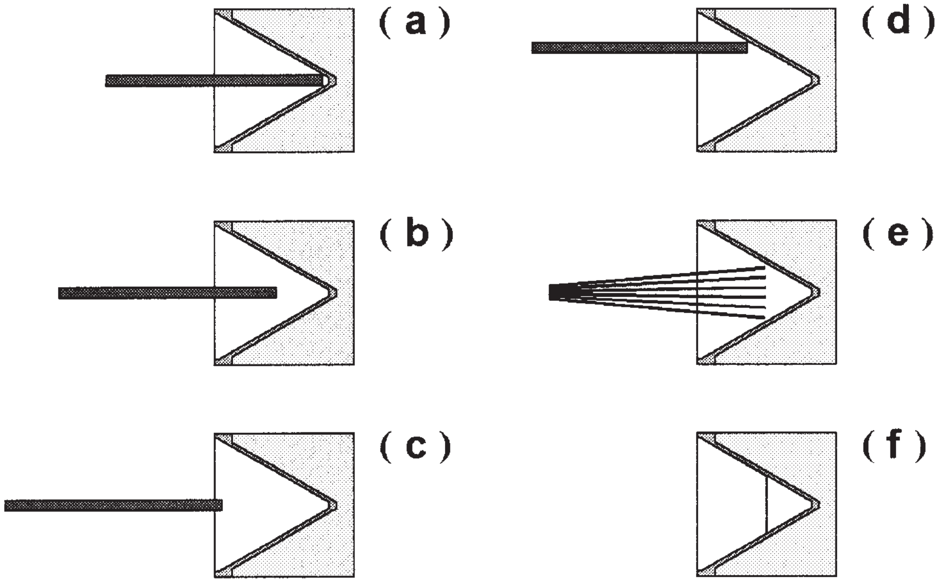

Figure 2: The various tests performed with the shaped charge are pictured here. In experiments (a), (b), (c) and (d), a steel cylinder (Ø 3 mm, length 60 mm) was placed in the liner cavity. In (a), (b) and (c), the cylinder was located on the symmetry axis, the distance to the cone apex being respectively 0 mm, 17 mm and 34 mm. In (d) the cylinder lies 9 mm at the side of the axis. In experiment (e), a bundle of 70 synthetic fibers, 60 mm long and 0.5 mm thick, is introduced in the cone. At last (f), low density material fills about two thirds of the cone.

As next experiments, the steel cylinder was on the liner axis but at a distance of 17 mm or 34 mm from the bottom of the cone (Fig. 2.b and 2.c). As expected, the jet disturbances remain important. In the first case, the jet is again completely eroded; in the target, dust particles produce several small craters with maximal depth 3 mm. In the second case, due to the velocity gradient within the jet, it stretches sufficiently before impacting the cylinder ; a residual jet reaches the steel target, producing a 25 mm deep hole.

Finally, a steel cylinder was positionned 9 mm at the side of the charge symmetry axis (Fig. 2.d). As can be inferred, the jet is strongly disturbed at a small distance behind its tip. As long as the jet remains unparticulated, this perturbation propagates forward and backwards, so that even the front of the jet is somewhat out of axis (Fig. 3.3). The 50 mm deep crater presents a keyhole shape.

To further investigate the jet disturbances induced by objects positioned within the shaped charge cone, a bundle of 70 small synthetic fibers of length 60 mm and diameter 0.5 mm was introduced 20 mm deep in the liner (Fig. 2.e). The result, shown on figure 3.2, is a perturbed jet in which particles are no longer aligned on the charge axis, and which presents a poor penetration capability (18 mm) in the steel target.

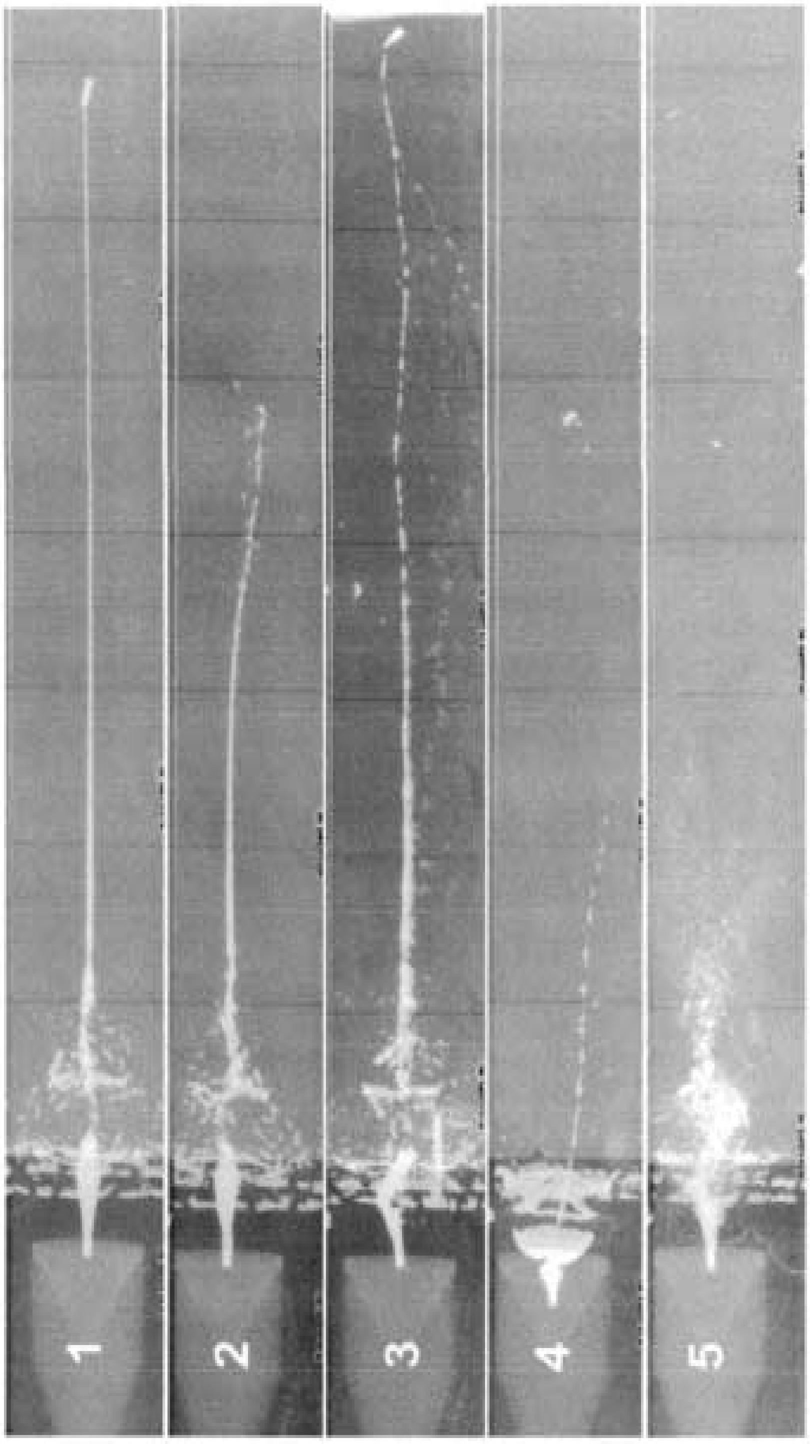

Figure 3: X-ray pictures of the 40 mm / 60° charge with various perturbation factors. (1) Unperturbed charge. (2) Bundle of 70 synthetic fibers placed in the cone (60 mm long fibers, Ø 0.5 mm). (3) Steel cylinder (60 mm long, Ø 3 mm) positioned slightly at the side of the charge symmetry axis; a part of the cylinder is still visible on the picture. (4) Gyskoplast with density 1.42 g/cm^3 fills about two thirds of the cone. (5) Cone partially filled with sagex containing 60 randomly embedded steel spheres of diameter 0.6 mm.

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Table 1

Object inducing disturbance	Effect on jet	Jet velocity [km/s]	Penetration [mm]
No disturbance (reference charge)		7.6	200
Cylinder on the axis, 0 mm to apex	No jet, only copper dust	2.6	10
Cylinder on the axis, 17 mm to apex	No jet, only copper dust	2.4	3
Cylinder on the axis, 34 mm to apex	Strongly eroded jet	2.4	25
Cylinder 9 mm beside the axis	Jet disturbed but coherent	7.5	50
Bundle of synthetic fibres	Jet eroded and perturbed	4.4	18
Cone filled with sagex (0.030 g/cm^3)	Jet slightly perturbed	7.4	162
Cone filled with styrofoam (0.038 g/cm^3)	Jet perturbed	7.4	60
Cone filled with gyskoplast (1.42 g/cm^3)	Jet strongly perturbed	7.4	4
Sagex with steel spheres in layers	No jet, only copper dust	2.6	5
Sagex with spheres randomly distributed	No jet, only copper dust	2.4	5
Sagex with needles randomly distributed	No jet, only copper dust	4.4	12

Synthetic Material Filling the Liner

This section is devoted to the description of the effects on the jet formation of material filling the liner cavity. In all cases reported hereafter, the cone was filled with 20 mm thick low density material (Fig. 2.f).

The first attempt was made with a very low density synthetic material (“sagex”) whose specific mass is equal to 0.030 g/cm^3. An X-ray picture of the resulting jet didn’t reveal any major disturbance, with the only exception of a lower tip velocity (v_{jet} = 7.4 km/s) than a normal jet and a slight misalignment of the jet. Due to this, the penetration performance was somewhat reduced in comparison with an unperturbed jet and reached 162 mm.

Filling the cone with another synthetic foam (“styrofoam”) characterized by a density of 0.038 g/cm^3 led to a similar picture. Due to the higher filling material density, the jet perturbation was however strong enough to prevent efficient penetration in the steel target; it presented a residual penetration of 60 mm.

Replacing styrofoam by another synthetic material named “gyskoplast” with a density of 1.42 g/cm^3 leads to a further decrease of the jet penetration performance which then only reaches 4 mm (Fig. 3.4).

In a last experimental series, we prepared sagex with embedded metallic spheres or needles. On one hand, we distributed in the filling material 60 small steel spheres (Ø 0.6 mm) either randomly or in three homogeneous layers; on the other hand, we distributed homogeneously 13 thin steel needles (Ø 1.0 mm) in the sagex (among them, 7 were 20 mm long and 6 had 10 mm length). As can be infered from the previous results, the liner never collapsed properly, producing in each case a cloud of uncoherent copper particles (Fig. 3.5) that had no penetration capability.

CONCLUSION

Several simple methods to perturbe the jetting process have been reported. It is striking to observe how sensitive shaped charges are against perturbation during the jet formation phase. Small objects placed in the liner cavity usually don't reduce drastically the jet tip velocity; however they have dramatic effects on the jet quality. Small cylinders may disturb the jetting process to the point that no clean collapse of the liner material takes place, resulting in a cloud of incoherent particles. Similarly, low density material placed into the cone cavity perturbs the jet formation; according to our data, a density increase (from 0.030 g/cm^3 to 1.42 g/cm^3) leads to a strong decrease of the jet performance. At last, the most efficient way to destroy the shaped charge effect consists in bringing some low density material with embedded metallic spheres in the cavity of the shaped charge; the jetting process is then completely perturbed: the charge only produces a cloud of liner material fragments having no penetration capability in a steel target.

REFERENCE

1. C. Voumard, «Résultats des essais de tir avec trois variantes d'une charge creuse de calibre 40 mm», Project report 690'257, Defence Procurement Agency, Thun, 1986.