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JET PERTURBATION BY HE TARGET

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We have previously reported the degree of attenuation and perturbation by a Cu jet passing through Comp B explosive [1]. Similar tests have now been performed with high explosive (HE) targets having CJ pressures higher than and lower than the CJ pressure of Comp B. The explosives were LX-14 and TNT, respectively. We found that the measured exit velocity of the jet where it transitions from perturbed to solid did not vary significantly as a function of HE type for each HE thickness. The radial momentum imparted to the perturbed jet segment did vary as a function of HE type, however, and we report the radial spreading of the jet and the penetration of a downstream target as a function of HE type and thickness.

ENHANCED JET EROSION IN HIGH EXPLOSIVE

We have previously shown that a transition between two flow patterns takes place in thick HE targets [1]. In this case, the jet will initially propagate into the HE at the same rate as into an inert material of the same density. The part of the jet that has stagnated and is flowing nearly co-axially with the incoming jet (but at a much lower speed) is being forced toward the surface of the incoming jet by the pressure of the reaction products but has not as yet made contact. After it makes contact, both axial and perpendicular momentum transfer takes place between the two jet components. After this transition, a new steady state will develop for the propagating jet, with the unperturbed front of the jet propagating at a slower rate than previously. The perturbed front of the jet is still propagating at or near the original rate, having had relatively little axial momentum exchange. However, it has acquired radial momentum and is spreading out as it is propagating. The perturbed has a reduced capability to penetrate targets downstream of the HE target.

Since the pressure in the HE determines the time at which the backflowing jet makes contact with the incoming jet, and thus determines the extent of the perturbed front of the jet, we have chosen HE targets having different CJ pressures in order to see whether the CJ is a significant factor in predicting the penetration of jets through HE.

EXPERIMENTS RELATING HE THICKNESS TO JET ATTTENUATION

The experiments were conducted for HE having thickness of 6, 8, and 10 cm. Each slab of explosive was cylindrical with a diameter of 20 cm. Each slab was also backed with 1.27 cm of steel plate. The explosive was Comp B. The shaped charge was a TOW2A placed at a distance of three charge diameters (CD) from the front surface of the explosive. This distance is 43.8 cm for the TOW2A. Three switches which triggered at jet arrival were placed between the HE and the shaped charge; their signal and their known location was used to determine the velocity of the jet prior to striking the explosive. A secondary target to measure residual jet penetration was placed at a distance of 105 cm. This target consisted of a number of stacked steel cylinders centered on the expected jet path, each 15.2 cm in diameter and 7.6 cm long. A switch was placed in front of each cylinder to measure the time of arrival of the jet. Radiographs of the jet in the region between the HE target and the cylinders were taken at specified times. Usually three radiographs were taken for each shot. The radiographs were used to determine the position and velocity of the tip of the perturbed jet and of the front of the unperturbed part of the jet. The latter velocity is defined as the exit velocity. For uniformly stretching jets, the exit velocity is easily related to the attenuation of the jet.

Radiographs of selected shots are shown in Figure 1 to illustrate the perturbed and unperturbed parts of the jet. A jet which has passed through an inert metallic target will look similar to that in Figure 1a. The jet has been attenuated by the normal process, but is not otherwise perturbed. If the target is a slab of thick HE, there are two parts to the jet, as shown in Figure 1b. The first part is highly perturbed and the second part is still solid. The speed of the tip of the perturbed jet is approximately that which would be expected for an inert target having the same thickness and density as the explosive. However, since the perturbed part of the jet has acquired a perpendicular velocity component in its passage through the HE, its ability to penetrate downstream targets has been compromised.

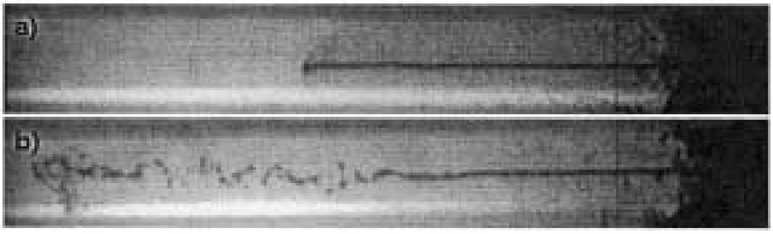

Figure 1. Radiographs of (a) an attenuated but unperturbed jet and (b) an attenuated and perturbed jet.

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RESULTS OF THE EXPERIMENTS

We can now add the data for LX-14 and TNT targets to the data obtained with Comp B targets. For a stretching jet, which is a reasonable approximation to a TOW2A jet, the loss of exit velocity is a measure of the loss of jet. Hence we plot the exit velocity of the perturbed and solid jet tips as a function of HE thickness in Figure 2. The data shows that the attenuation and perturbation for LX-14 and TNT is not significantly different, a somewhat surprising result in light of the previously established dependence of the perturbation process on the pressure of the HE detonation products. Only one point (TNT at 6 cm HE thickness) shows a significant variation from the Comp B data.

We examined the radial spread of the perturbed segment of the jet; the included angle of the conical envelope that would contain virtually all of the perturbed jet was measured. A plot of the angle versus the HE thickness for the different HE targets (Figure 3) showed that there was a difference in the radial perturbation to the jet. We see that the perturbation to the jet increases with target thickness after the transition region.

The TNT, which has a lower CJ pressure than Comp B or LX-14, has less radial perturbation to the jet than the others. On the other hand, there is no significant difference between Comp B and LX-14 even though LX-14 has the higher CJ pressure.

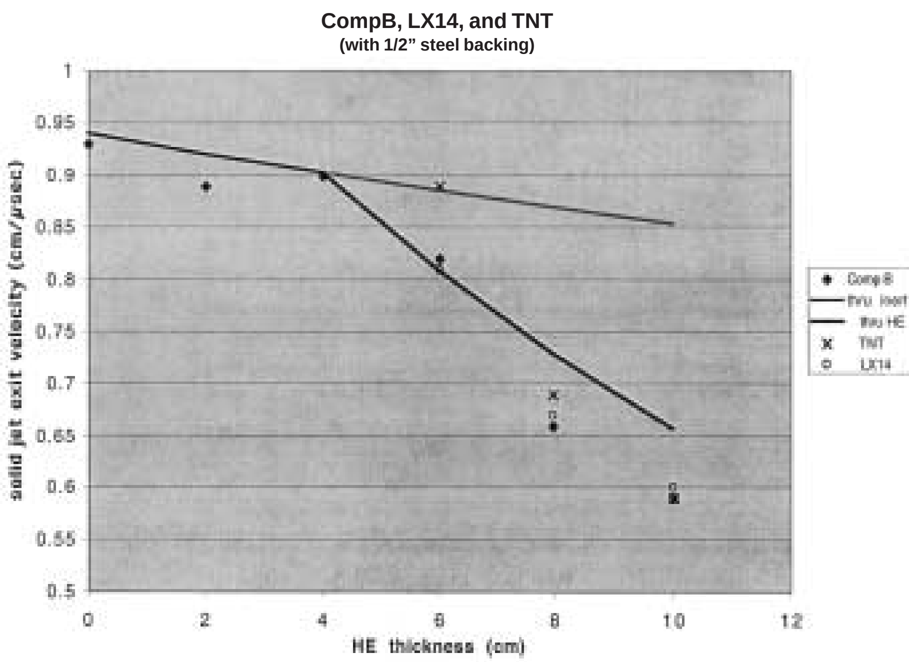

Figure 2. Exit velocity of a copper jet passing through Comp B, TNT, and LX-14 as a function of the thickness of the HE. The upper line represents the calculated exit velocity of the very tip of the perturbed or attenuated jet [1]. The downward sloped line represents the calculated exit velocity of the jet from HE without the steel backing. We don't as yet have a good model for the effect of the steel backing.

Finally, we have measured the maximum penetration of a target by the jet after its passage though the blocks of HE. Here we are looking for two effects: First the effect of the incident speed of the jet which in this experiment is the exit velocity from the HE. Second, the effect, if any, of the spread of the perturbed part of the jet on the penetration of a downstream target. These data are shown in Figure 4. For each of the HE's, the target penetration decreases with increasing HE thickness. That is due to the attenuation of the jet as well as the perturbation. Further examination of the data reveals that the jet that passed though LX-14 penetrates deeper into the target than a jet passing through either Comp B or LX-14. That is a most curious result since it does not correlate with the data for the angular spread of the jet shown in Figure 3. You'd expect that the TNT jet would penetrate more since it had less angular divergence, but that apparently is not the case. The data is not mislabeled and the target materials were the same for all shots, so there are no ready explanations for the data we obtained.

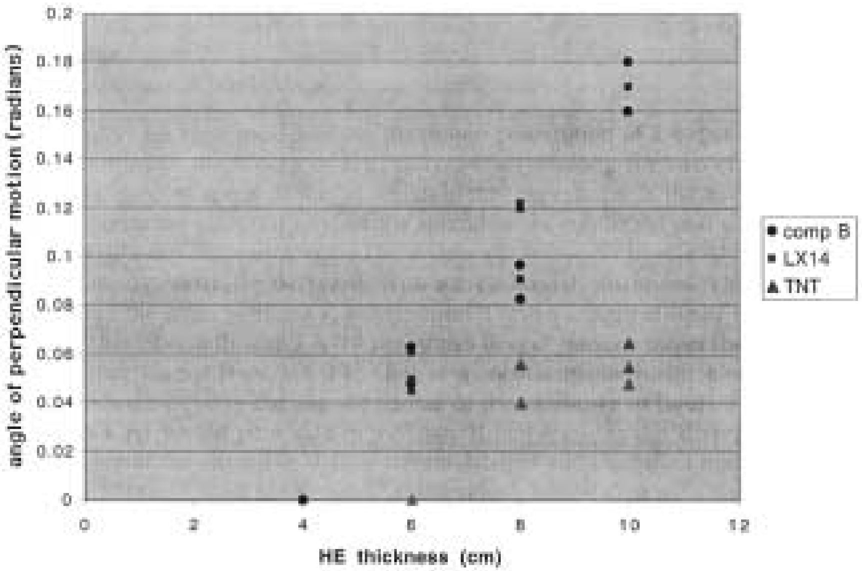

Figure 3. The angle of the perpendicular motion of the radial flow as a function of target thickness for Comp B, LX-14, and TNT. The angle increases with target thickness beyond the transition region, and is less for TNT than the others.

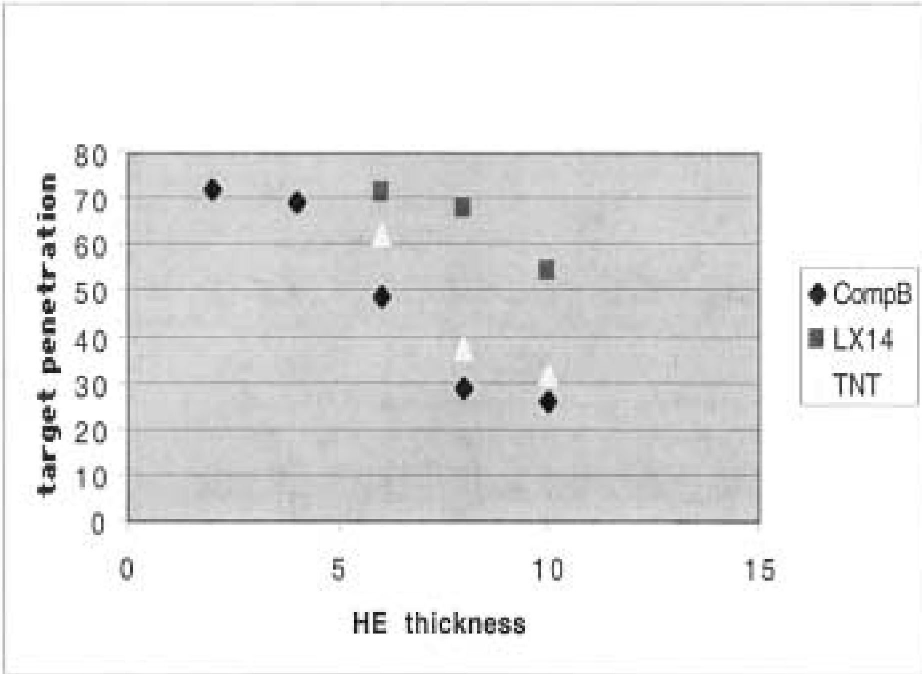

Figure 4. Penetration of a steel target located downstream of the HE.

CONCLUSION

We have examined the effect on a jet by its passage through TNT and LX-14, and compared the data to previously obtained data using Comp B. There is no significant effect on the extent of the perturbed segment of the jet. We did find that the radial momentum imparted to the jet differed for TNT, and we found that the jet passing through LX-14 penetrated deeper into the steel target than the others. The reason for this behavior is unexplained at present and must be left as future work.

REFERENCES

1. Poulsen, P. 1999. "Jet Penetration of High Explosive," 18th International Symposium on Ballistics, 15–19 November, 1999.

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