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SPALL WAVE-PROFILE AND SHOCK-RECOVERY EXPERIMENTS ON DEPLETED URANIUM *

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Depleted Uranium of two different purity levels has been studied to determine spall strength under shock wave loading. A high purity material with approximately 30 ppm of carbon impurities was shock compressed to two different stress levels, 37 and 53 kbar. The second material studied was uranium with about 300 ppm of carbon impurities. This material was shock loaded to three different final stress level, 37, 53, and 81 kbar. Two experimental techniques were used in this work. First, time-resolved free surface particle velocity measurements were done using a VISAR velocity interferometer. The second experimental technique used was soft recovery of samples after shock loading. These two experimental techniques will be briefly described here and VISAR results will be shown. Results of the spall recovery experiments and subsequent metallurgical analyses are described in another paper in these proceedings.

INTRODUCTION

Previous shock compression studies of depleted Uranium and alloys have shown a dependence of spall strength on alloy solute concentration as well as strain rate rate (or peak particle velocity).(1) In the case of U-Ti, U-Mo, U-Rh, and U-Nb alloys, a spall strength higher than that of pure U is observed at all realized strain rates. For pure depleted Uranium an increase in spall stress with increasing peak free surface velocity has been observed.(2)

The work described below was undertaken to attempt to obtain a better micro-mechanical understanding of the spall process in both very pure and "dirty" Uranium. Our approach was to do a series of experiments reaching to different final stress states (or free surface velocities). For each material, and at each stress state the free-surface velocity was measured, and a sample recovered in an experiment done as close as possible to the same conditions. In this way we hoped to freeze the spall processes at various stages in its development. Soft recovered samples underwent further metallurgical analyses.

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Spall Recovery Target Assembly

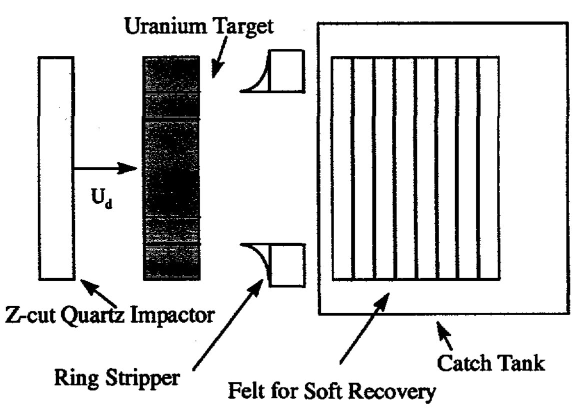

FIGURE 1. Recovery assembly.

EXPERIMENTAL DETAILS

Samples were taken from plates of the two different purity levels of depleted Uranium. The high purity material had carbon impurity levels of approximately 30 ppm. Grain size for this material

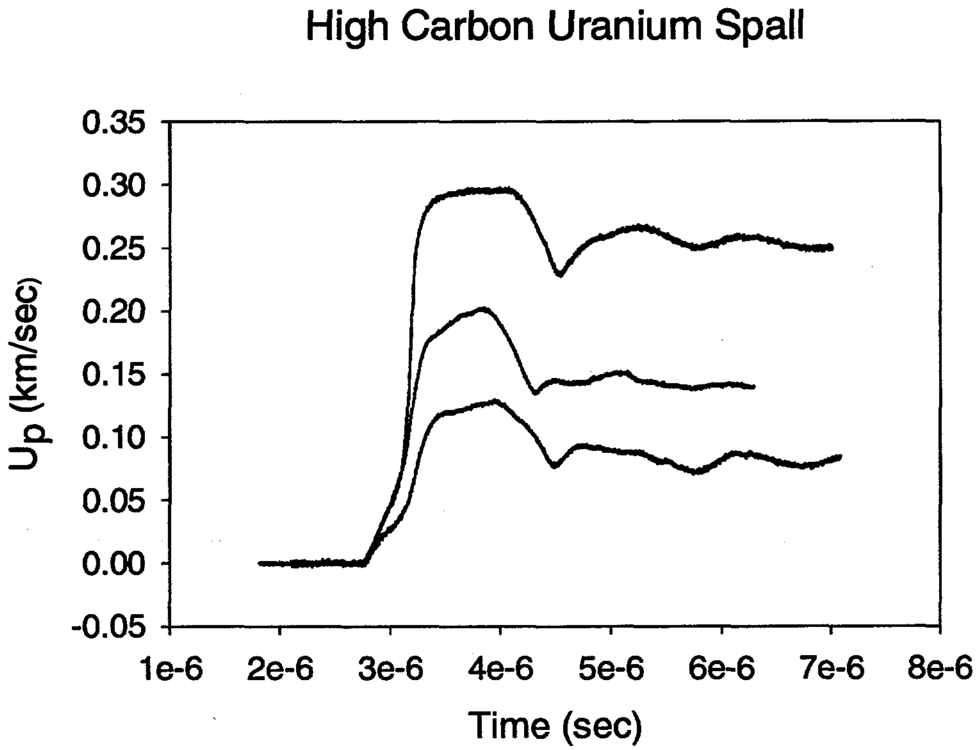

FIGURE 3. Free-Surface Velocities—low-purity uranium.

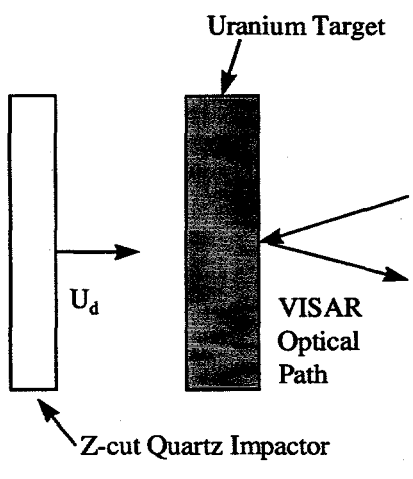

FIGURE 2. VISAR Experimental Geometry.

was measured to be 10 microns. The second, lower purity material, had about 300 ppm carbon impurity. Grain size was approximately 200 microns. Samples were machined into right circular cylinders for the VISAR (Velocity Interferometer System for Any Reflector(3)) experiments with faces flat and parallel to 0.002 mm. One surface of each sample was polished to a reflecting condition between diffuse and specular. For soft recovery experimental assemblies were made as shown in Fig. 1. The concentric rings act as momentum traps as described by Gray.(4) Experiments were performed on a 50 mm single-stage gas gun. Projectile velocity and tilt were measured using stepped array of six shorting pins, and impacts were measured to be planer to within 1–2 mrad. Z-cut quartz impactors were used for all experiments because their response remains purely elastic over the pressure range of these experiments.

The experimental geometry for the VISAR shots is shown in Fig. 2. A commercially available optical fiber probe was used to illuminate the polished part of the target, and to collect reflected light and return it to the Los Alamos designed

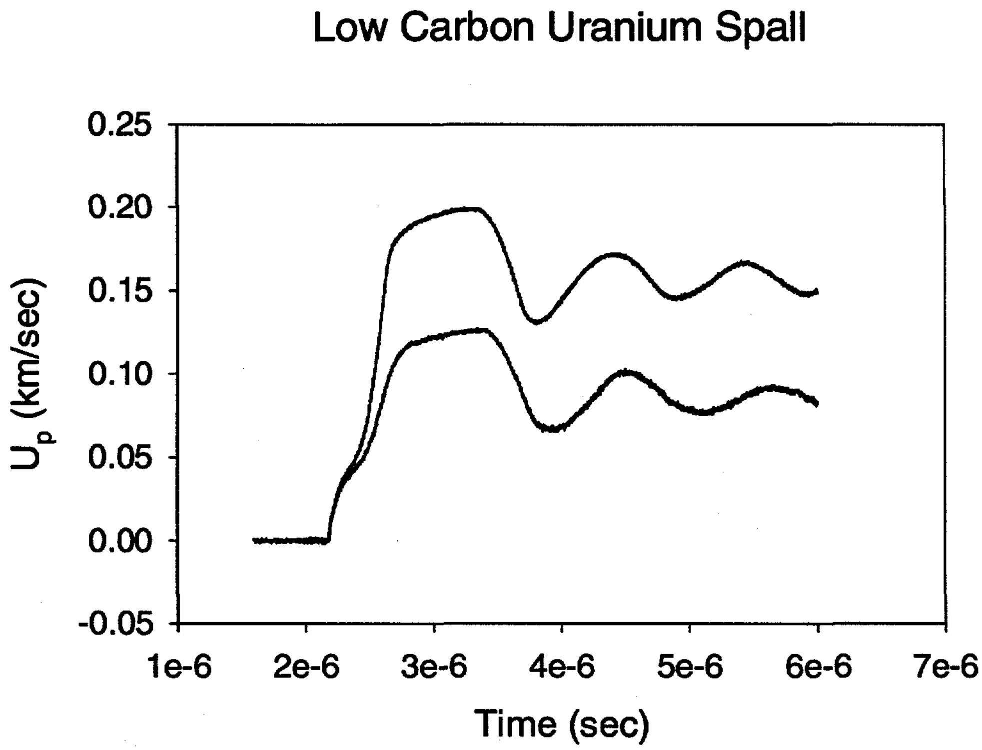

FIGURE 4. Free-Surface Velocities—high-purity uranium.

and built interferometer. For these experiments a high level of sensitivity was required, and so an 8 in. Bk-7 glass etalon was used as a delay leg. The VISAR wave-forms were recorded with a single Tektronix digitizer. This allowed all VISAR data to be collected on a common time base. Data was analyzed with a Los Alamos VISAR data reduction program.

Spall recovery experiments were done in a geometry similar to that shown for the VISAR experiments. These experiments were done separately from the VISAR shots in order to avoid a reshock of the sample due to impact on the probe and holder. Samples were recovered in a felt filled cylinder. In order to minimize oxidation, samples were placed in very pure alcohol immediately after recovery.

RESULTS

Data obtained on the "dirty" material at the three different final free surface velocities are shown in Fig. 3. Well defined elastic precursors are observed in all experiments as well as a fast rising (30 ns) plastic wave. After the fast rising part of the plastic wave there is a slower rising region leading up to the final particle velocity. For the experiment done at the highest particle velocity we see reverberations of the release wave trapped in the spalled part of the target. We took this to be evidence of complete separation, and this was verified by the spall recovery results. Data obtained for the pure material at two different final particle velocities are shown in Fig. 4. These data indicate that complete spall separation will occur between 35 kbar and 53 kbar. Spall strengths have been calculated using the technique of Romanchenko.(5) A summary of VISAR experiments and calculated spall strength results are given in Table 1.

CONCLUSION

Spall measurements on the two materials studied reveal very similar strength in tension as determined by the particle velocity change using the

TABLE 1. VISAR Experimental Results.

Material	Flyer u_d (m/s)	Impact Stress (kbar)	Spall Stress (kbar)	Strain Rate (10^5/s)	Target (mm)	Flyer (mm)
high C	285±1	37	15	1.4	5.09	4.07
	399±0.5	53	18	1.8	5.08	4.08
	596±2.0	81	19	1.6	5.09	5.09
low C	268±0.2	35	16	1.4	3.84	4.08
	403±0.2	53	19	2.0	3.84	4.08

Romanchenko correction. The measured free surface particle velocity for the two different purity materials show different behavior in the spall pullback region. For the low purity material, the highest initial stress experiment showed a sharp change in slope in particle velocity. This can be interpreted as indicative of a rapid opening of the spall surface. For the corresponding experiment in the high purity material, the particle velocity change in slope at pullback is more gradual. This can be interpreted as meaning that the spall took longer to occur. Such behavior is consistent with the recovery experiments. As discussed in the paper by Zurek *et al.* (these proceedings), the two materials show different microstructure in the spalled region. The wave profiles from the lower impact stress experiments are not as easy to interpret—the particle velocity pullback seems to be incomplete. Recovery experiments bear this out: for the lower impact stress experiments, damage zones were created but the recovered samples remained in one piece. Calculations of the spall stress for these experiments are therefore less accurate.

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