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LINER STABILITY EXPERIMENTS AT PEGASUS:
DIAGNOSTICS AND EXPERIMENTAL RESULTS

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LINER STABILITY EXPERIMENTS AT PEGASUS: DIAGNOSTICS AND EXPERIMENTAL RESULTS

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Abstract

A series of experiments to compare imploding liner performance with magneto-hydrodynamic (MHD) modeling has been performed at the Los Alamos National Laboratory Pegasus II pulse power machine. Liner instability growth originating from initial perturbations machined into the liner has been observed with high resolution. Three major diagnostics were used: radiography, Velocity Interferometer for a Surface of Any Reflector (VISAR), and fiber optic impact pins. For radiography, three flash x-ray units were mounted radially to observe liner shape at three different times during the implosion. Liner velocity was measured continuously with the VISAR for the entire distance traveled in two experiments. Optical impact pins provide a high-resolution measure of liner symmetry and shape near the end of travel. Liner performance has compared well with predictions.

Introduction

Nine liner stability (LS) experiments have been conducted at the Los Alamos National Laboratory Pegasus facility in New Mexico. The purpose of the experiments is to measure performance of imploding liners under different initial conditions and compare the results to predictions. A good understanding of instability growth will provide valuable input for liner specifications and fabrication on future high energy liner experiments at ATLAS.

Several different liner types have been used in the series. Some have been completely smooth with no initial perturbations. Others have had sinusoidal grooves of a single wavelength machined into the outside of the liner while still others have had grooves of different wavelengths and amplitudes on each half of a single liner. The effect of different surface qualities has been observed as well. Major liner performance diagnostics used in the series are radial x-rays, VISAR, and fiber optic impact pins. Each diagnostic provides a unique view of the liner and a cross check of performance with the other diagnostics. All three diagnostic systems were mounted on LS-8 and LS-9.

Radiography

Over the past several years, the P-22 radiography team has developed a family of portable flash x-ray sources for dynamic radiography (Plattsflashes).¹ These sources were designed to meet the experimental requirements of the High Energy Density Physics program. They are compact, shielded against extreme electromagnetic pulse (EMP) environments, battery powered, and fiber optically controlled. The x-ray tubes are inexpensive and can be disassembled to change the

anode material thereby modifying the spot size and x-ray spectral characteristics. These units have been tested and fielded extensively.

At Pegasus, three Plattsflash x-ray sources aligned radially with respect to the liner with lines-of-sight at 120° intervals are used to provide dynamic x-ray images of the implosion. They are fired sequentially to obtain radiographs of the liner at three different times during the implosion. The radial Plattsflash x-ray systems are specially equipped to operate in the extreme EMP environment of the 4 MJ Pegasus discharge without accidental misfires. Figure 1 is the third radiograph taken on LS-8. It shows that the original $10\text{ }\mu\text{m}$ amplitude perturbations of 1.2 mm and 6 mm wavelength (left and right halves) have grown to large amplitude. Fiber optic pins in their supporting tubes can be seen at the bottom of the image.

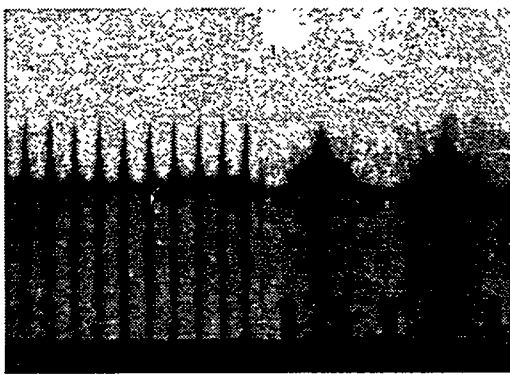


Figure 1. Flash x-ray radiograph of the LS-8 liner $10.10\text{ }\mu\text{s}$ after current start. Initially, the perturbations machined into the liner outer surface were 6.0 mm and 1.2 mm wavelength with a $10\text{ }\mu\text{m}$ peak-to-peak amplitude.

VISAR

VISAR (Velocity Interferometer for a Surface of Any Reflector) has a proven reputation for its ability to accurately measure the velocity and position of highly accelerated surfaces.²³ The inclusion of this diagnostic on PEGASUS imploding cylindrical liner experiments allows for experimental validation of MHD computer models which predict liner performance. Also, VISAR measurements on imploding liners may allow for the characterization of a number of hydrodynamic mechanisms: instability growth and shock breakthrough signatures, melt time determination, target shock pressure, and others. Therefore, VISAR becomes an invaluable diagnostic tool for liner stability experiments since it provides a continuous high precision measurement of the liner radius and free surface velocity from the initial start time to the final target implosion time. Briefly, VISAR operates by measuring the optical Doppler shift of single-frequency laser light reflected off the liner surface. The Doppler shift is propor-

tional to the surface velocity and produces fringes in a fringe counting interferometer. The fringes are recorded electronically in quadrature and are then analyzed to extract the velocity and position information.

VISAR measurements were performed on two liner stability experiments, LS-8 and LS-9. Both liners were driven by the PEGASUS capacitor bank under near identical conditions (78 kV charge voltage and 10.1 MA peak current). While the LS-9 liner was initially smooth, the LS-8 liner had prefabricated sinusoidal axial perturbations on the outer surface (10 μm peak-to-peak amplitude and 1.2 mm wavelength on the half containing the VISAR). The VISAR recorded the inner surface velocity and radius in each experiment. Figure 2 displays the VISAR results for the LS-8 and LS-9 experiments.

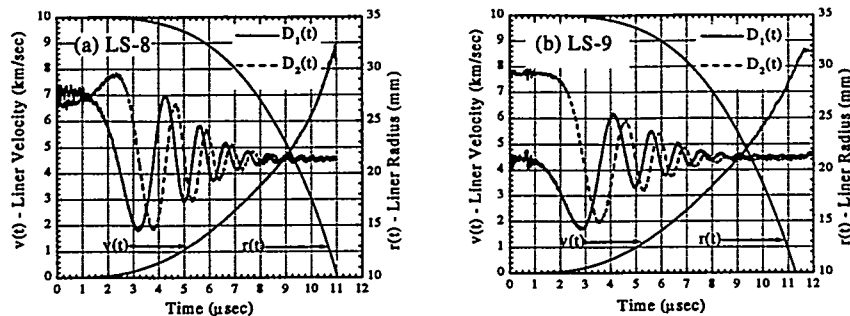


Figure 2. VISAR recorded quadrature fringe data $D_1(t)$ and $D_2(t)$, retrieved velocity profile $v(t)$, and liner radius $r(t)$, versus time for liner stability experiments: (a) LS-8 and (b) LS-9. Peak liner velocities of 8.8 km/sec and 8.26 km/sec are recorded for LS-8 and LS-9 respectively.

The VISAR data are in excellent agreement with the radiographic and optical impact pin data also used to track liner motion. Future integration of VISAR on imploding liner experiments will extend VISAR from free surface velocity measurements to also include particle velocity measurements using shock wave profiling techniques.

Fiber Optic Impact Pins

Fiber optic impact pins have been used in place of electrical contact pins in many types of experiments for detecting shock arrival times since the mid 1980's.⁴ A pin consists of an optical fiber placed in a stainless steel hypodermic tube and mounted so that it is struck on the end by the moving material. Shock heating of the fiber material causes a light to be emitted. The light travels along the fiber to a photodetector and the detector output is recorded by a digitizer or oscilloscope. A sharp increase in the light signal occurs when the pin is struck. Occasionally, when the pins are mounted so that they protrude from the target, a second shock can be seen when the moving material strikes the target material holding the pin.

Optical fibers offer the advantage of being small and quite flexible. Therefore, they are used in the target cylinder of the Liner Stability experiments to measure velocity and axial and azimuthal symmetry of the liner as it nears the end of travel. Optical pins are also used in the glide plane to measure implosion velocity. Figure 3 compares radiographic data from the inner surface of the liner with pin data from LS-8. The original 10 micron amplitude has grown to approximately 1.5 mm.

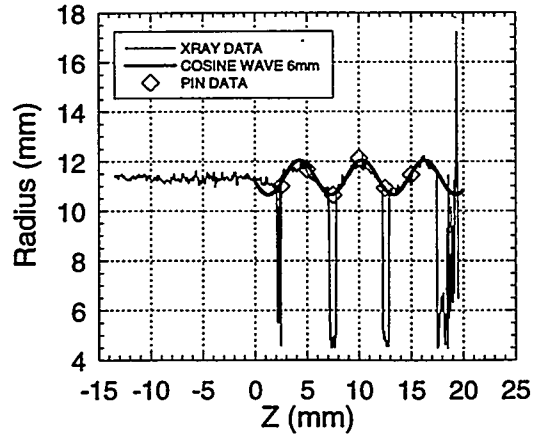


Figure 3. Comparison of optical pin data and x-ray data. The light solid line is a photo density scan along the inner surface of the liner from the radiograph in Figure 1. The large negative excursions occur when the scan picks up one of the optical pins. The heavy line is a 6 mm wavelength sinusoid fit to the pin data. The x-ray data and the pin data both have the same wavelength as the original perturbation machined into the liner.

Summary

A series of experiments at Pegasus to observe liner stability issues has been conducted. Instability growth as a result of perturbations and surface finish characteristics machined into the liners has been observed and compared to calculation. Three major diagnostics, radiography, VISAR, and fiber optic impact pins, have observed instability growth and agree with each other very well.

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