Armor Simulation Experiments At Dragonfire Facility

Farrokh Najmabadi, John Pulsifer, and Kevin Sequoia

HAPL Meeting

June 2-3, 2004
UCLA

Electronic copy: http://aries.ucsd.edu/najmabadi/TALKS
UCSD IFE Web Site: http://aries.ucsd.edu/IFE
Thermo-Mechanical Response of Chamber Wall Can Be Explored in Simulation Facilities

**Requirements:**
- Capability to simulate a variety of wall temperature profiles

**A suite of diagnostics:**
- Real-time temperature (*High-speed Optical Thermometer*)
- Per-shot ejecta mass and constituents (*QMS & RGA*)
- Rep-rated experiments to simulate fatigue and material response
  - Relevant equilibrium temperature (*High-temperature sample holder*)

**Vacuum Chamber provides a controlled environment**

**Laser pulse simulates temperature evolution**

**Capability to isolate ejecta and simulate a variety of chamber environments & constituents**
We had achieved excellent reliability Last October: Less than ± 1% change in calibration constant over a 12 day period of tests.

~ 2% change in calibration constant after reassembly of thermometer in our new lab.

Two issues:

1. Different calibration constants at low and high frequencies!
2. Large ~500 MHz noise in the new lab leading to < ±10% noise in temperature measurements.
Thermometer Is Calibrated Based on The Melting Point of Tungsten

- In a set of successive shots, laser energy is increased and temperature measurements have been made. After certain threshold for laser energy, sample temperature does not increase. ⇒ Sample is melted.
- Calibration constant is determined based on meting point of W (3700 K).
- Calibration constant during last month run matches those found last September.
Laser fluence is estimated based on laser profile and assuming a reflectivity of ~ 0.4 for W (from tables).

Temperature measurement from thermometer (range indicates current noise in the system). No temperature reading at 150 mJ/cm² shot.
Both Surface Temperature and \( \frac{dT}{dz} \) are Important
**Armor Irradiation Test Matrix**

- **Test environment:**
  - Powder metallurgy tungsten samples from Lance Snead.
  - Samples cleaned in sonic bath before test.
  - Laser output energy was fixed. Laser energy on the target was varied using a wave-plate/cube arrangement to ensure constant laser profile on the target.
  - Specular reflected laser light was measured (10-15% of incident laser energy).
  - Post irradiation test: Optical microscopy, WYCO, SEM

- **Test matrix:**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Laser energy</th>
<th>No. of Shots</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1:</td>
<td>up to 900 mJ</td>
<td>Varied</td>
<td>Air</td>
</tr>
<tr>
<td>Sample 2:</td>
<td>150 mJ</td>
<td>100, 1,100, 10,000</td>
<td>Vacuum</td>
</tr>
<tr>
<td>Sample 3:</td>
<td>300 mJ</td>
<td>100, 1,100, 10,000</td>
<td>Vacuum</td>
</tr>
<tr>
<td>Sample 4:</td>
<td>450 mJ</td>
<td>100, 1,100, 10,000</td>
<td>Vacuum</td>
</tr>
</tbody>
</table>
Powder Metallurgy Tungsten Samples After Laser Irradiation

- Samples are polished to a “mirror-like” finish.
- The “damaged” area has a “dull” finish.
- A brown background is placed in the photograph to enhance contrast.

1,100 shots
10,000 shots
300 mJ (DT= 2000K, dT/dz=3.5k/nm)
50X Optical Microscopy

As seen

False color

1,100 Shots

10,000 Shots
300 mJ (DT= 2000K, dT/dz=3.5k/nm)
500X Optical Microscopy

1,100 Shots

10,000 Shots

No Laser

“Transition”

Beam Center
450 mJ (DT= 3000K, dT/dz=5.5k/nm)
500X Optical Microscopy 1,100 Shots

No Laser

“Transition”

Beam Center
450 mJ (DT= 3000K, dT/dz=5.5k/nm)
500X Optical Microscopy

Beam Center

No Laser

1,100 shots

10,000 shots
450 mJ (DT= 3000K, dT/dz=5.5k/nm)

500X Optical Microscopy Transition Region

No Laser

1,100 shots

10,000 shots
450 mJ (DT= 3000K, dT/dz=5.5k/nm)
SEM 100 Shots

No Laser

Beam Center
SEM Examination of Melted Sample

450 mJ
100 shots

Melted sample
Up to 900 mJ
Plans for the Next Period

Plans:
- Repeat experiments with heated samples.
- Mass loss measurements with RGS and QMS.
- Higher shot counts.
- Experiments in intermediate energies: Is there a threshold?
- Shots with KrF laser (UV) to compare with YAG laser (IR).

Questions to Material Working Group:
- How can we connect microscopic changes in sample to macroscopic changes in properties and lifetime?
- What should we measure?