Investigation of the Thermomechanical Coupling Strength in High-Rate Plastic Deformation Processes

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14. ABSTRACT
    An advanced understanding of thermoplastic heating process in dynamic deformation events is one of the key steps which not only enhances design and analysis capabilities but also may lead to development of new material systems with unprecedented impact and blast protection performance. The main objective of this project is to develop reliable and repeatable experimental data to serve this purpose and develop predictive models for the fraction of plastic work converted into heat (i.e., thermo-mechanical coupling strength) in dynamically deforming metals. This

15. SUBJECT TERMS
    Thermoplastic heating, thermomechanical coupling, high strain rate deformation, high-speed infrared temperature measurement

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   19b. TELEPHONE NUMBER 312-567-3181
Investigation of the Thermomechanical Coupling Strength in High-Rate Plastic Deformation Processes

ABSTRACT

An advanced understanding of thermoplastic heating processes in dynamic deformation events is one of the key steps which not only enhances design and analysis capabilities but also may lead to development of new material systems with unprecedented impact and blast protection performance. The main objective of this project is to develop reliable and repeatable experimental data to serve this purpose and develop predictive models for the fraction of plastic work converted into heat (i.e., thermo-mechanical coupling strength) in dynamically deforming materials. This objective has been achieved by integrating high-strain-rate split Hopkinson pressure bar (SHPB) experiments with high-speed IR thermometry measurements, and by establishing repeatable calibration procedures. The results of experiments conducted on a series of alloys, including CP-Ti, OFHC copper (FCC), 1018 cold rolled steel and Al 2139-T8 alloy, have shown that thermo-mechanical coupling strength may evolve as a complex function of strain, strain rate, and deformation history. We have established that dislocation density based strain hardening models lend themselves to satisfactory prediction of thermo-mechanical coupling strength factor for most material systems with the exception of 2139-T8 aluminum alloy. The alloy 2139-T8, which is a newly developed aluminum alloy with promising properties to use in armor applications, has repeatedly showed that fraction of plastic work converted to heat is smaller than other alloy systems, and unlike other alloys this fraction does not reach to 0.9-1 interval but rather stays below 0.6 even at large plastic strains.

List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)


Number of Papers published in peer-reviewed journals: 1.00

(b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

Number of Papers published in non peer-reviewed journals: 0.00

(c) Presentations

“Experimental analysis and constitutive modeling of the thermo-mechanical response of Al 2139 alloy at high strain rates”, Invited talk, Aluminum for Defense Applications Workshop, Organized jointly by the U.S. Army Research Office (ARO) and Army Research Labs (ARL), Baltimore, MD, May 3-4, (2010).


Number of Presentations: 2.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts): 0

Peer-Reviewed Conference Proceeding publications (other than abstracts):


Number of Peer-Reviewed Conference Proceeding publications (other than abstracts): 1

(d) Manuscripts

Y. Xiao and M. Vural, “Investigation of thermomechanical coupling strength in metals via high-strain-rate adiabatic experiments”, to be submitted to Acta Materialia. (~September 2010)
Number of Manuscripts: 1.00

## Patents Submitted

## Patents Awarded

### Graduate Students

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<tr>
<td>Erhan Eren</td>
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<tr>
<td>Jahir Caro</td>
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<tr>
<td>Yi Xiao</td>
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**FTE Equivalent:** 3.00  
**Total Number:** 3

### Names of Post Doctorates

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**FTE Equivalent:**  
**Total Number:**

### Names of Faculty Supported

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<tr>
<th>NAME</th>
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<th>National Academy Member</th>
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<tbody>
<tr>
<td>Murat Vural</td>
<td>0.08</td>
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**FTE Equivalent:** 0.08  
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### Names of Under Graduate students supported

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**FTE Equivalent:**  
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### Student Metrics

This section only applies to graduating undergraduates supported by this agreement in this reporting period.

- The number of undergraduates funded by this agreement who graduated during this period: \( \ldots \) \( 0.00 \)
- The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields: \( \ldots \) \( 0.00 \)
- The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields: \( \ldots \) \( 0.00 \)
- Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale): \( \ldots \) \( 0.00 \)
- Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering: \( \ldots \) \( 0.00 \)
- The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense: \( \ldots \) \( 0.00 \)
- The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields: \( \ldots \) \( 0.00 \)

### Names of Personnel receiving masters degrees

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### Names of personnel receiving PHDs

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### Names of other research staff

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### Sub Contractors (DD882)

### Inventions (DD882)