DYNAMIC PLASTIC RESPONSE OF ALUMINUM AT TEMPERATURES APPROACHING MELT

STEPHEN E. GRUNSCHEL* AND RODNEY J. CLIFTON †

* Division of Engineering
Brown University
Providence, RI 02912, USA

† Division of Engineering
Brown University
Providence, RI 02912, USA
Rodney_Clifton@brown.edu

This study investigates the plastic response of aluminum at very high strain rates, 10^5 s^{-1} – 10^6 s^{-1}, and at temperatures that approach its melting temperature. To achieve this combination of high strain rates and high temperatures, pressure-shear plate impact experiments are being conducted with modifications introduced by Kris Frutschy [1] to enable the experiments to be conducted at high temperatures. Frutschy and Clifton [2] showed that, for OFHC copper, the flow stress decreases with increasing temperature and increases with increasing strain rate over the full range of temperatures and strain rates examined. However, the flow stress at the highest temperatures and highest strain rates was substantially greater than predicted by models based on rate-controlling processes involving the thermally activated motion of dislocations past obstacles. This discrepancy suggests that phonon drag is becoming increasingly important in the motion of dislocations at the elevated temperatures. Because phonon drag increases with increasing temperature it has been suggested that as the temperature approaches the melting point, phonon drag would become the dominant mechanism and the flow stress would even begin to increase with increasing temperature at fixed strain rate.

For current experiments, a thin ($10 - 25\ \mu m$) aluminum sample, sandwiched between two tungsten carbide (6% cobalt) plates, is heated to a temperature below its melting temperature – 933.13 K at atmospheric pressure. A dual flyer, made of tungsten carbide (12% cobalt) backed by magnesium alloy ZK60A, impacts the target sandwich at an angle skew to the direction of travel generating pressure and shear waves in both the target and flyer plates. The pressure wave arrives at the sample before the shear wave, loading the aluminum to a pressure of 7 GPa and increasing the melting temperature to 1130 K. While the sample is being deformed in shear, a pressure release wave, caused by the impedance mismatch in the dual flyer, arrives at the sample and lowers the pressure to 1.1 GPa and the melting temperature to 1021 K. Since increases in sample temperature due to plastic working are approximately 100 K, the lowered melting temperature should make it possible to examine the dynamic response of aluminum on the threshold of melt.

Two tests have already been conducted on aluminum at starting temperatures of 300 K and 773 K and at strain rates of 1.15×10^6 s^{-1} and 1.78×10^6 s^{-1} respectively. The shear flow stress for the 300 K test peaked at 225 MPa and decreased gradually over the duration of the test. A gradual increase in shear flow stress, up to a plateau of only 115 MPa, is seen in the 773 K test. Experiments will be conducted at starting temperatures up to 925 K.

References

[1] K.J. Frutschy, "High-temperature pressure-shear plate impact experiments on OFHC copper and pure tungsten carbide," Ph.D. Thesis, Brown University, May, 1997.
[2] K.J. Frutschy and R.J. Clifton, "High-temperature pressure-shear plate impact experiments on OFHC copper," *J. Mechs. Phys. Solids* **46**, 1723-1743, 1998.

Keywords: aluminum, plasticity, temperature