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Flow Strength of Shocked Aluminum in the Solid-Liquid Mixed Phase Region[1]

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Shock waves have been used to determine material properties under high shock stresses and very-high loading rates. The determination of mechanical properties such as compressive strength under shock compression has proven to be difficult and estimates of strength have been limited to approximately 100 GPa or less in aluminum. The term "strength" has been used in different ways. For a Von-Mises solid, the yield strength is equal to twice the shear strength of the material and represents the maximum shear stress that can be supported before yield. Many of these concepts have been applied to materials that undergo high strain-rate dynamic deformation, as in uni-axial strain shock experiments. In shock experiments, it has been observed that the shear stress in the shocked state is not equal to the shear strength, as evidenced by elastic recompressions in reshock experiments. This has led to an assumption that there is a yield surface with maximum (loading)and minimum (unloading), shear strength yet the actual shear stress lies somewhere between these values. This work provides the first simultaneous measurements of unloading velocity and flow strength for transition of solid aluminum to the liquid phase. The investigation describes the flow strength observed in 1100 (pure), 6061-T6, and 2024 aluminum in the solid-liquid mixed phase region. Reloading and unloading techniques were utilized to provide independent data on the two unknowns (τ_c and τ_o), so that the actual critical shear strength and the shear stress at the shock state could be estimated. Three different observations indicate a change in material response for stresses of 100 to 160 GPa; 1) release wave speed (reloading where applicable) measurements, 2) yield strength measurements, and 3) estimates of Poisson's ratio, all of which provide information on the melt process including internal consistency and/or non-equilibrium and rate-dependent melt behavior. The study investigates the strength properties in the solid region and as the material transverses the solid-mixed- liquid regime. Differences observed appear to be the product of alloying and/or microstructural composition of the aluminum.

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