Determination of ultrahigh strain rate impact hardness of metals by energy dissipation method

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Mechanical response of materials is now being commonly studied using microscopic instrumented indentation methods. These methods have been designed and developed for studying material characteristics like plastic flow behavior at different strain rates. Strain rate dependence of deformation dynamics is well-recognized. At ultra-high strain rates (HSR), elastic, plastic, and shock waves propagating through the material can interact with the microstructures leading to HSR deformation and failure, that can be potentially different from those at low strain rates (LSR). Therefore, study of material properties at a wide range of strain rates will shed a better light on rate-dependent mechanisms contributing to plastic deformation processes and strength of metals. Although LSR and quasi-static hardness has been studied extensively using instrumented microscopic indentation methods, very few studies can be found about ultra-HSR hardness (via supersonic impact) due to limited instrument capability.
Material hardness can be measured by indentation or impact by a microsphere. Typically, hardness is defined by an applied force and plastically deformed surface area. However, in this work, quasi static hardness was determined via the energy dissipation from the load-depth profile of a ~ 20 μm diameter spherical indenter. The ultra-HSR impact hardness of a specimen was determined through supersonic collisions of ~ 20 μm diameter alumina microspheres on a target substrate (pure alumina and pure copper). The impact behavior of the single microsphere was quantified using the advanced laser induced projectile impact test (α-LIPIT). As the amount of energy dissipation during the collision depends on the volume of the plastic deformation, the impact hardness was calculated using the post-impact residual volume measured by an optical profilometer. This study showed a significant strain rate hardening effect on both aluminum and copper as the ultra-HSR impact hardness was found to be greater than LSR hardness. Precise simulations of the microscopic collision events and quasi-static nanoindentation results establish a quantitative relationship between the strain-rate and material impact response. This demonstrated approach will provide a new method of non-destructive ultra-HSR characterization.

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