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Electro-Thermo-Mechanical Characterization of Microscale Ti-6Al-4V Wires using an Innovative Experimental Method

Background

Effective metal forming in the manufacture of commercial products requires that material properties after forming must be maintained or improved, and the metal forming steps must be cost-effective. Achieving both of these conditions is challenging because there is a trade-off between material performance and processing cost. Many current methods have explored both traditional forming methods (e.g., rolling, extrusion, forging, drawing) and novel forming methods (e.g., cryoforming, severe plastic deformation, electrically-assisted deformation).

Electrically assisted deformation (EAD) focuses on increasing the formability of a conductive workpiece by applying an electrical current during mechanical deformation. EAD offers attractive advantages for processing metals with limited ductility (e.g., pure titanium and its alloys), including improved manufacturability through reduction of yield strength, flow stress, and springback while achieving a larger strain to failure. However, accurate mechanical characterization becomes increasingly challenging with the reduction of sample size, such as with fine wires or thin sheets, because sample preparation/handling becomes non-trivial.

Invention Description

Researchers at Arizona State University have developed a novel electro-thermo-mechanical tensile testing apparatus for micron-scale Ti-6Al-4V fine wires. The testing apparatus consists of a 3D-printed sample holder, along with an electronic balance, piezo-actuator, optical microscope, IR thermometer, and DC power supplier. Initial results showed that large surface-to-volume ratio minimizes the Joule heating effect, which is crucial to investigating plastic deformation behavior under different electrical currents. The wires can be quantitively characterized with both experimental temperature and finite element analysis and utilized for accurate evaluation of the temperature profile in the samples.

Potential Applications

- Turnkey micro-scale mechanical testing
- Modular components for specialized fine-scale commercial mechanical testing

Benefits & Advantages

- Eliminates potential damage to the specimen during preparation of sample
- Able to measure around 350nm displacement as a minimum
- Measures accurate force while wire is being deformed
- Able to characterize mechanical properties of wire under electrical current

- Sample holder can be modified using 3D printer based on sample size/shape
- Lower cost compared to current tensile testers

Related Publication: Effects of electrical current on the plastic deformation behavior of pure copper, iron, and titanium