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Title: CONSTITUTIVE BEHAVIOR, TEXTURE AND DAMAGE EVOLUTION IN BCC METALS USING TAYLOR IMPACT TEST

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Los Alamos
NATIONAL LABORATORY

Capturing the anisotropy evolution of Tantalum using real time imaging.

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To capture the evolution of anisotropy in textured metals under high rate conditions, we developed a method that enables us to digitally resolve this event. Using a Taylor Anvil Test Facility, we dynamically deformed unalloyed Ta, whilst capturing real time digital images of the radial flow at the impact surface. We measured the elliptical footprint and plotted its eccentricity (ratio of major to minor diameters) versus real time. The current engineering strength constitutive models allow for an initial texture, but they cannot accurately predict the texture evolution during deformation. This test will allow us to track anisotropy to better validate our constitutive models.

Constitutive Behavior, Texture and Damage Evolution in BCC Metals using Taylor Impact Test

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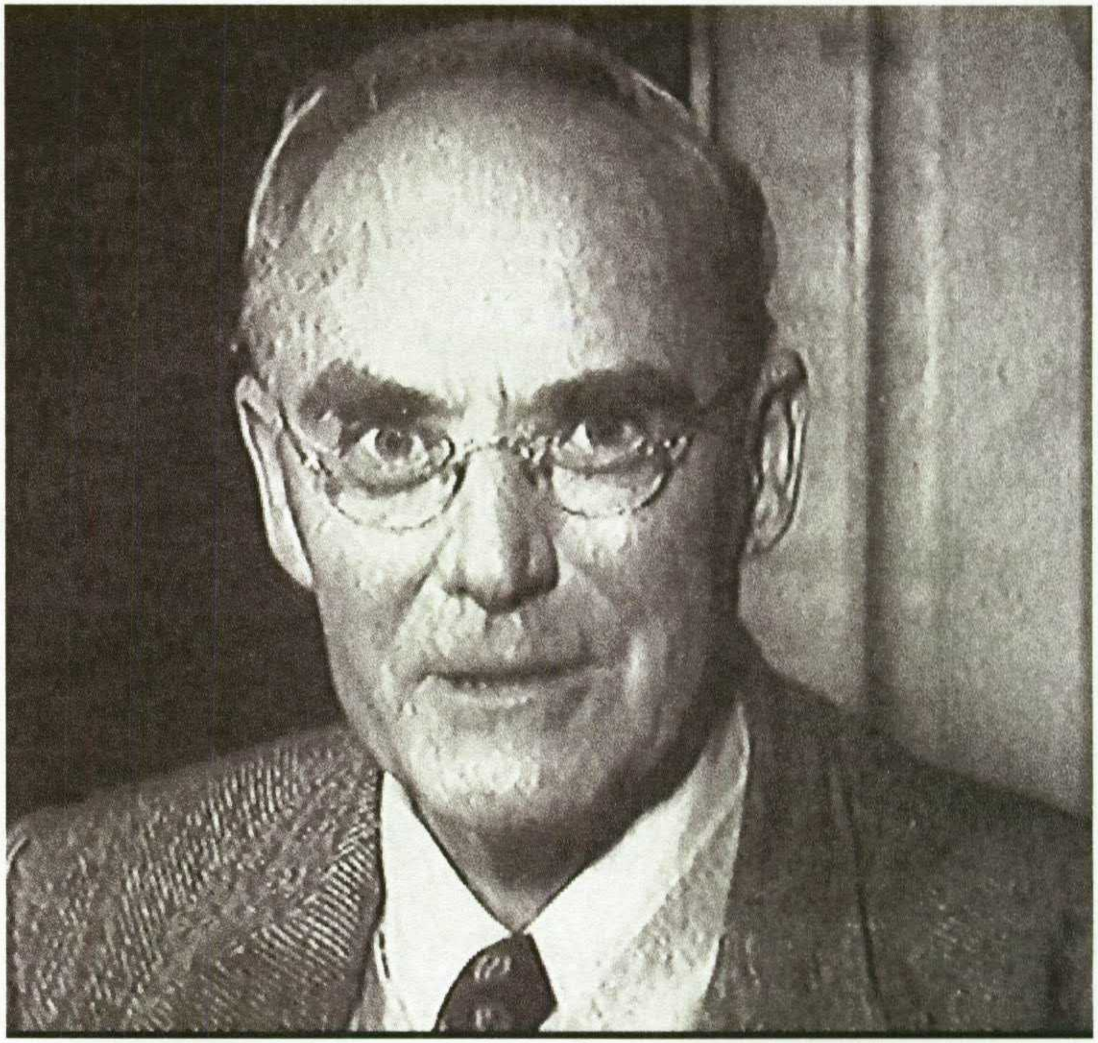
Taylor Cylinder Test

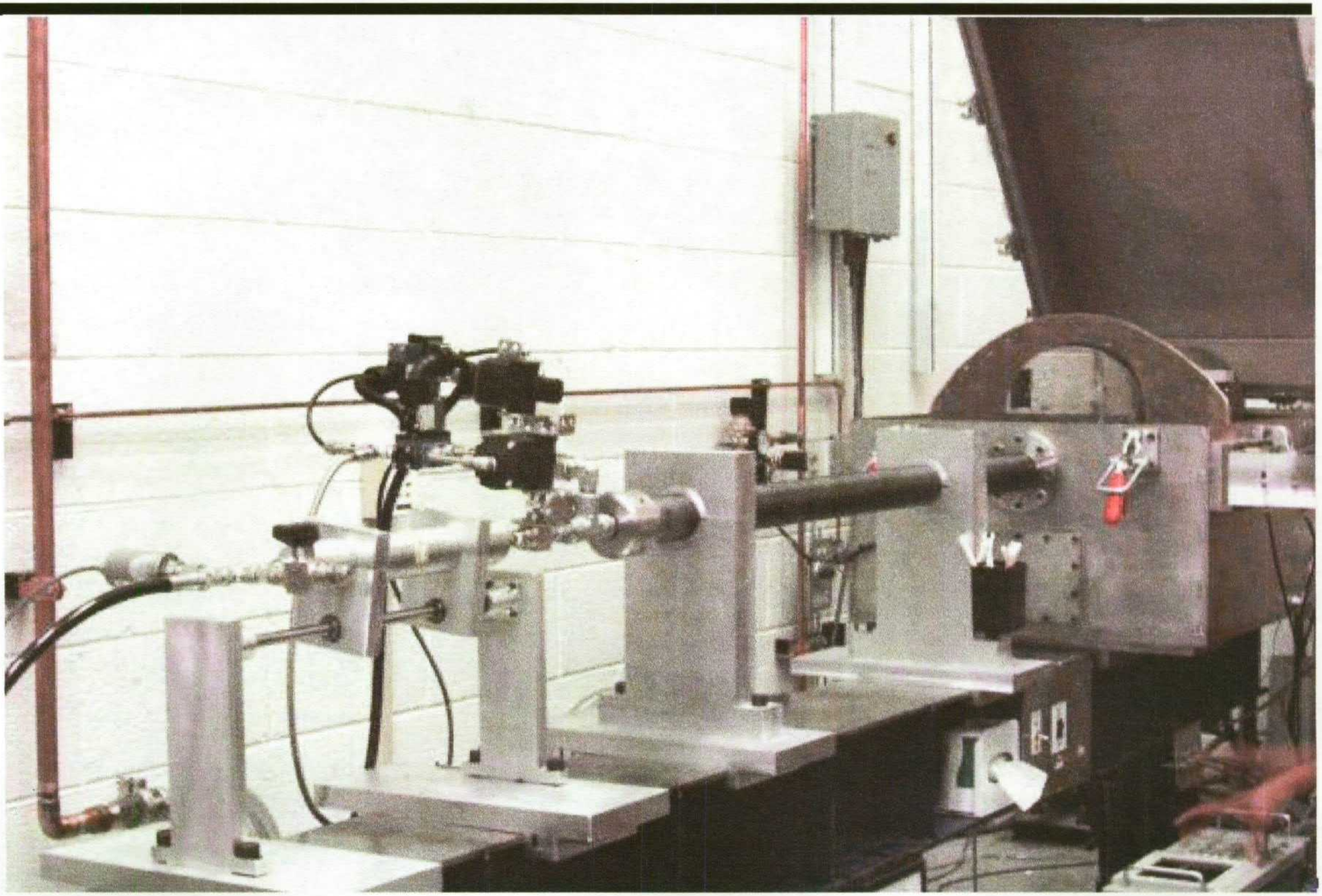
- The Taylor cylinder impact test, named after G.I. Taylor who developed the test to screen materials for use in ballistic applications during WW II , entails firing a solid cylinder rod of a material of interest, typically 7.5 to 12.5 mm in diameter by 25 to 40-mm in length, at high velocity against a massive and plastically rigid target.



LANL - Taylor Cylinder Testing

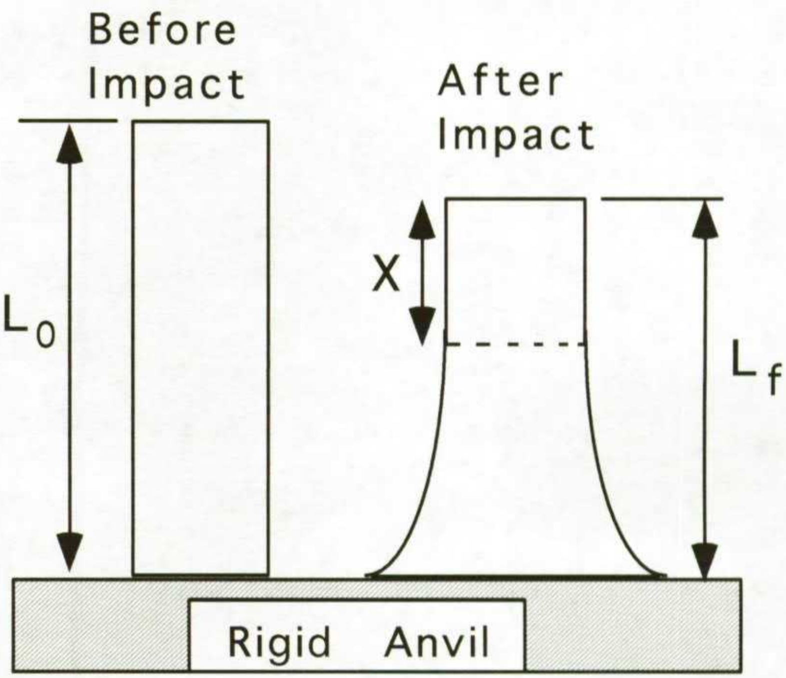
- Los Alamos National Laboratory (LANL) Taylor cylinders - launched using a 30-caliber 0.300 inch [7.62 mm] smooth-bore launch tube - designed to utilized high-pressure helium-gas propulsion of the cylinders rather than propellant drive.
- The HE-gas breech and valve design has been shown capable of reproducibly launching a 25 gram steel cylinder to 400 m/sec using 4500 psi He.
- The Taylor facility fires the cylinders into an evacuated thick-walled 304 stainless steel impact tank against a pneumatically-positioned AF1410 high-strength steel anvil (ground to a mirror surface finish). All testing is conducted under vacuum conditions (typically 10 torr).
- Velocity of the Taylor cylinders - measured using three laser beam timing circuits positioned between the muzzle of the barrel and the impact anvil so that the beams intersect the path of the Taylor cylinder in flight.

Taylor Cylinder Tests - Validation Tool for Constitutive Modeling



Taylor Cylinder Testing

- The Taylor cylinder test induces large gradients of stress, strain rate, and strain along the length of the cylinder. The final length, cylinder axial profile, and bottom footprint of the Taylor sample allow us to validate the material constitutive model implemented in the application code.
- Post-mortum microstructural analysis is also performed.

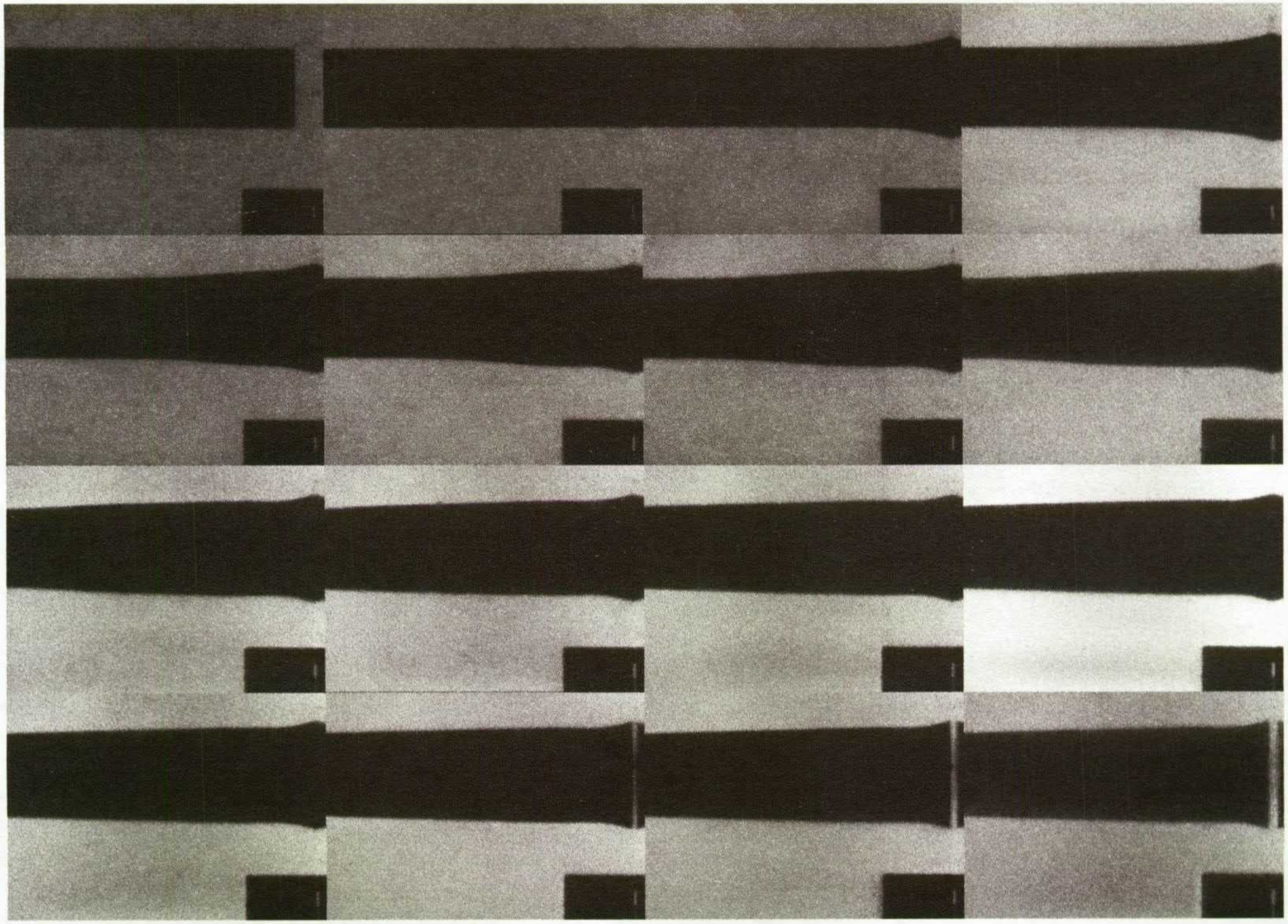


•Currently we are using an Imacon 200 High Speed Digital Camera to help capture the plastic strain as a function of time (time-evolution of plastic deformation).

Taylor Cylinder Testing

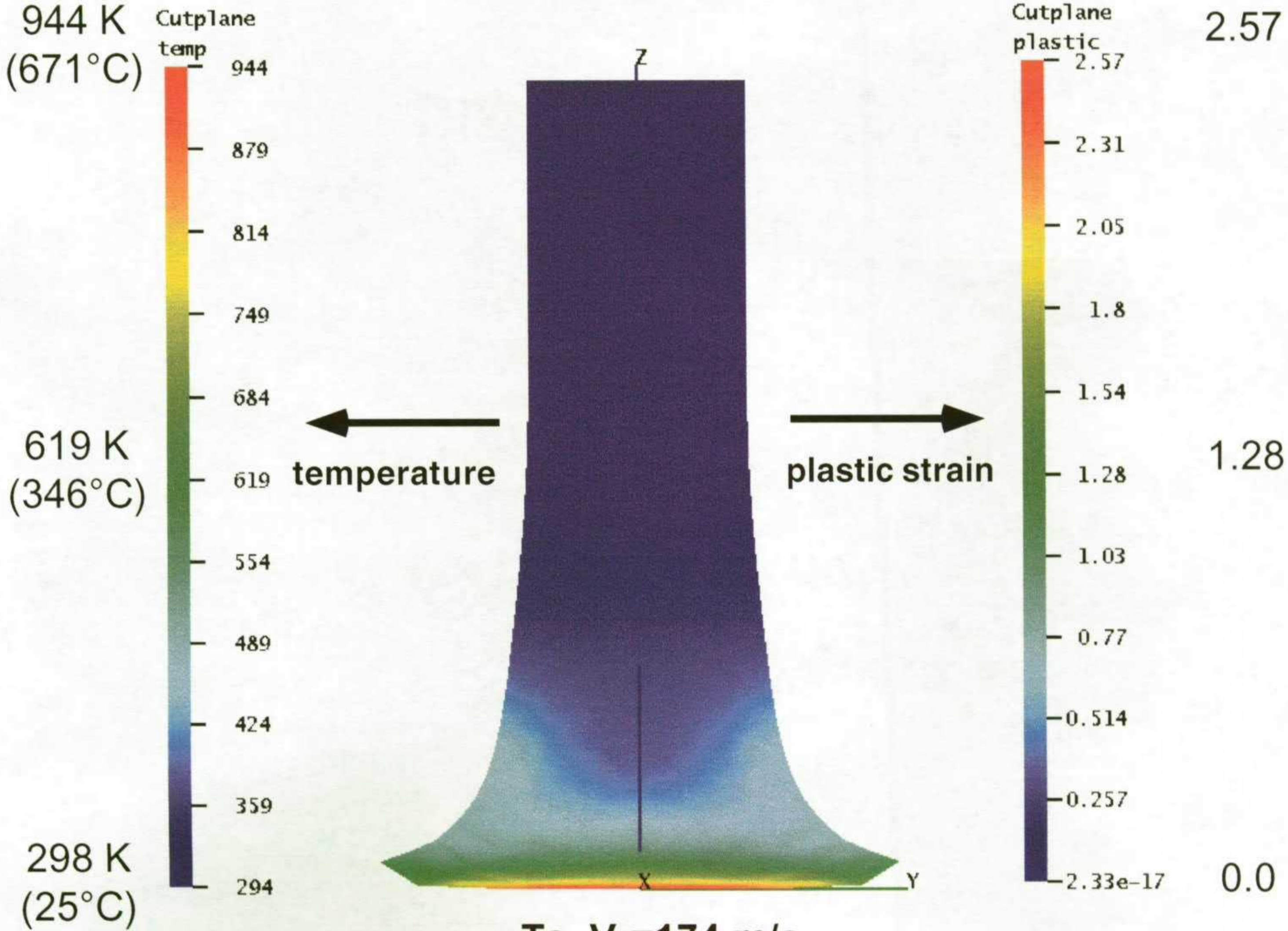
- Utilizing High Speed Imaging, we now have a more integrated test, capturing the plastic strain as it sweeps up the cylinder.
- For materials that display isotropic deformation and damage, a side profile of the cylinder is sufficient.
- This plasticity vs time evolution will allow us to better validate our constitutive models

Side Profile of Plastic Deformation of Steel



Isotropic Footprint

Taylor Cylinder

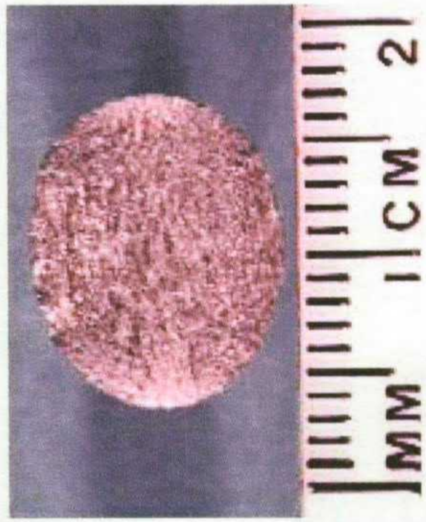


Ta, V_0=174 m/s

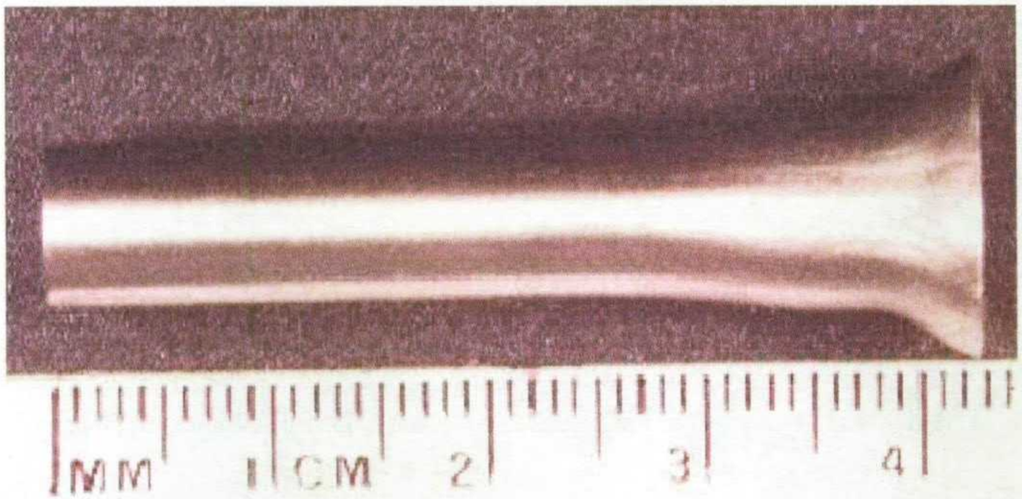
Taylor Cylinder Testing

- For materials that display anisotropic deformation, we developed a testing method that will allow us to capture the footprint of a cylinder as it deforms against the anvil.
- This will allow us to better understand how material processing affects the texture evolution of a material.

Taylor Cylinder Shape is Influenced by Processing

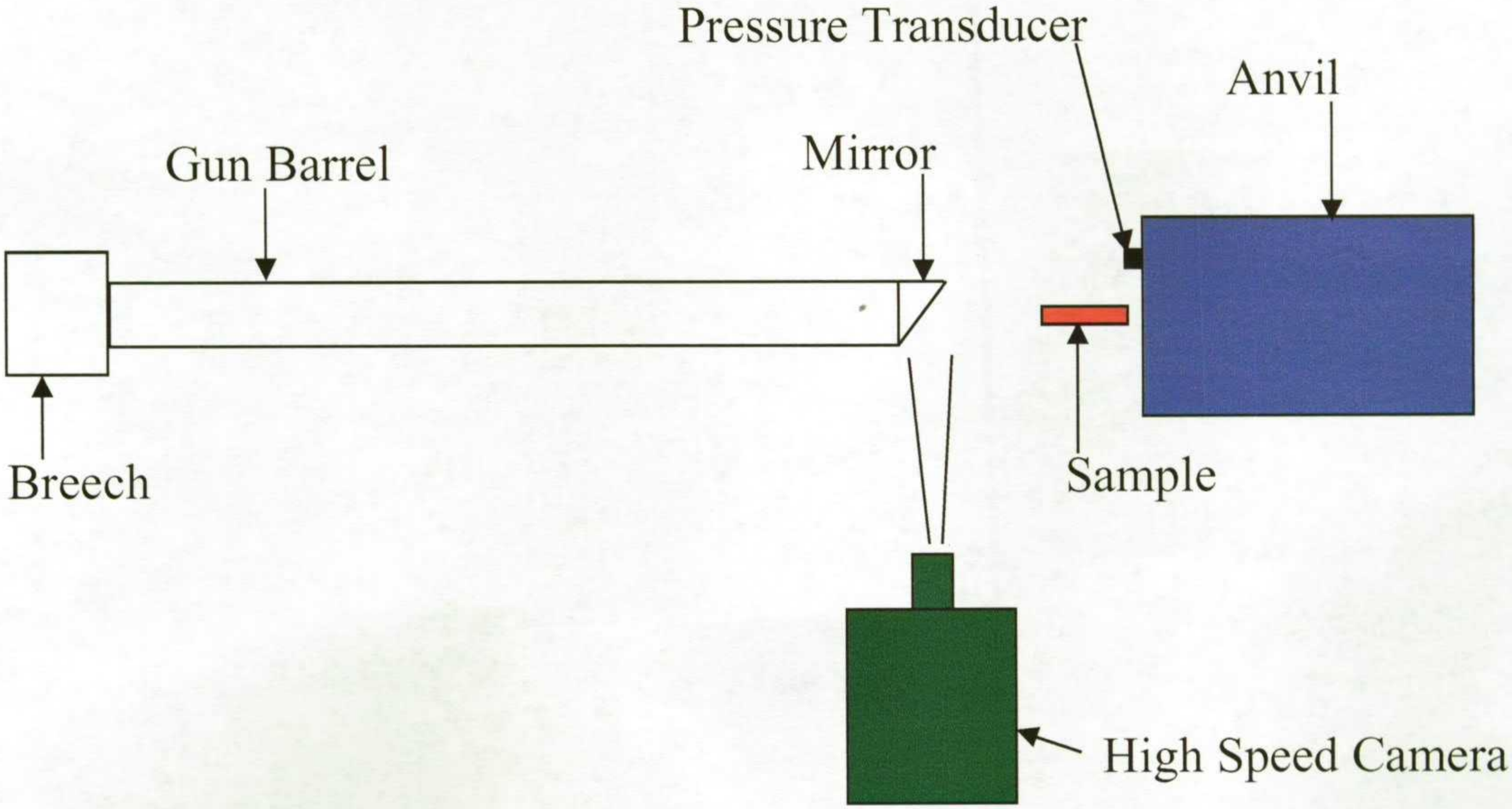


Wrought
Plate
<111>
Texture

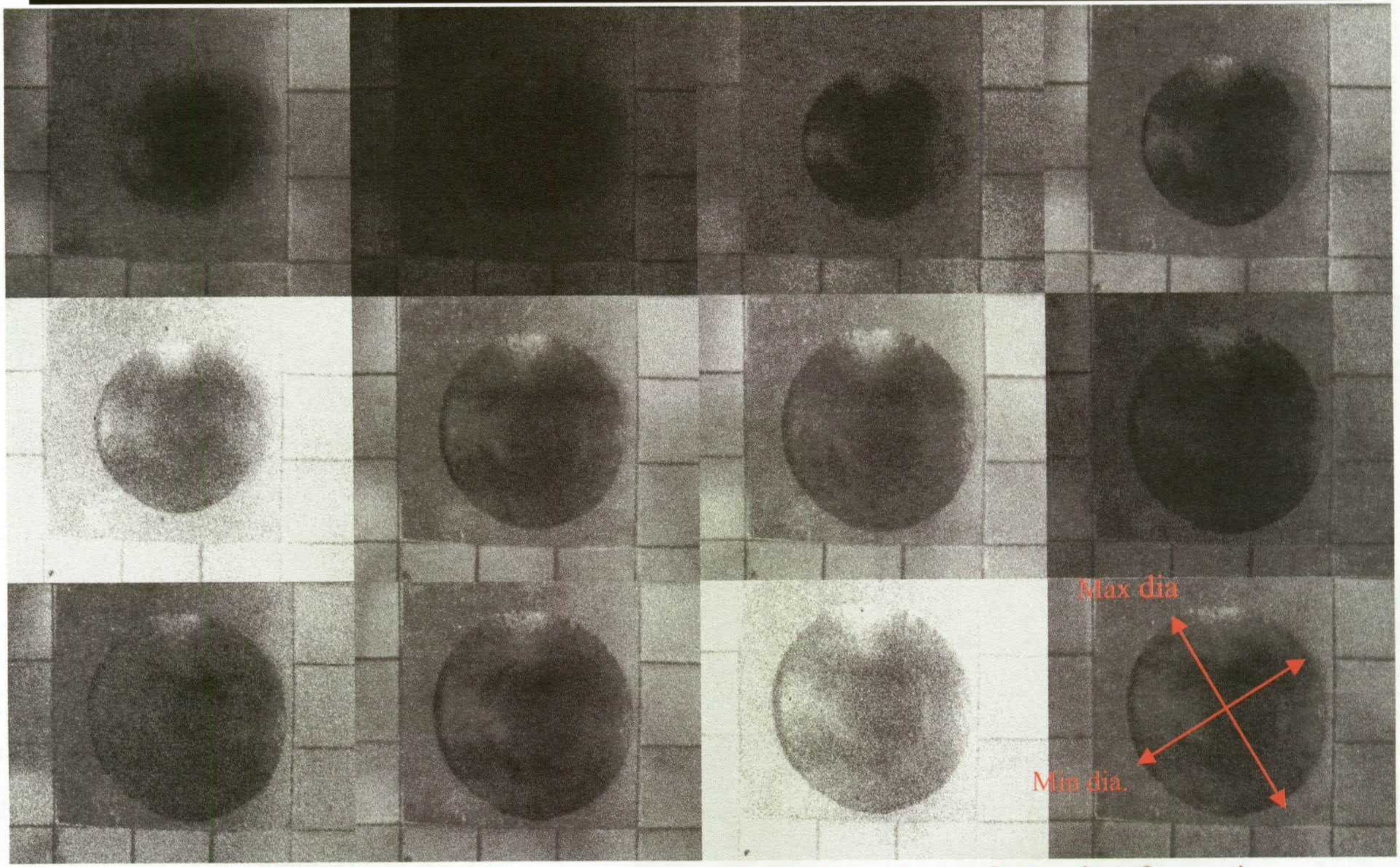


Extruded
Bar

Experimental Technique

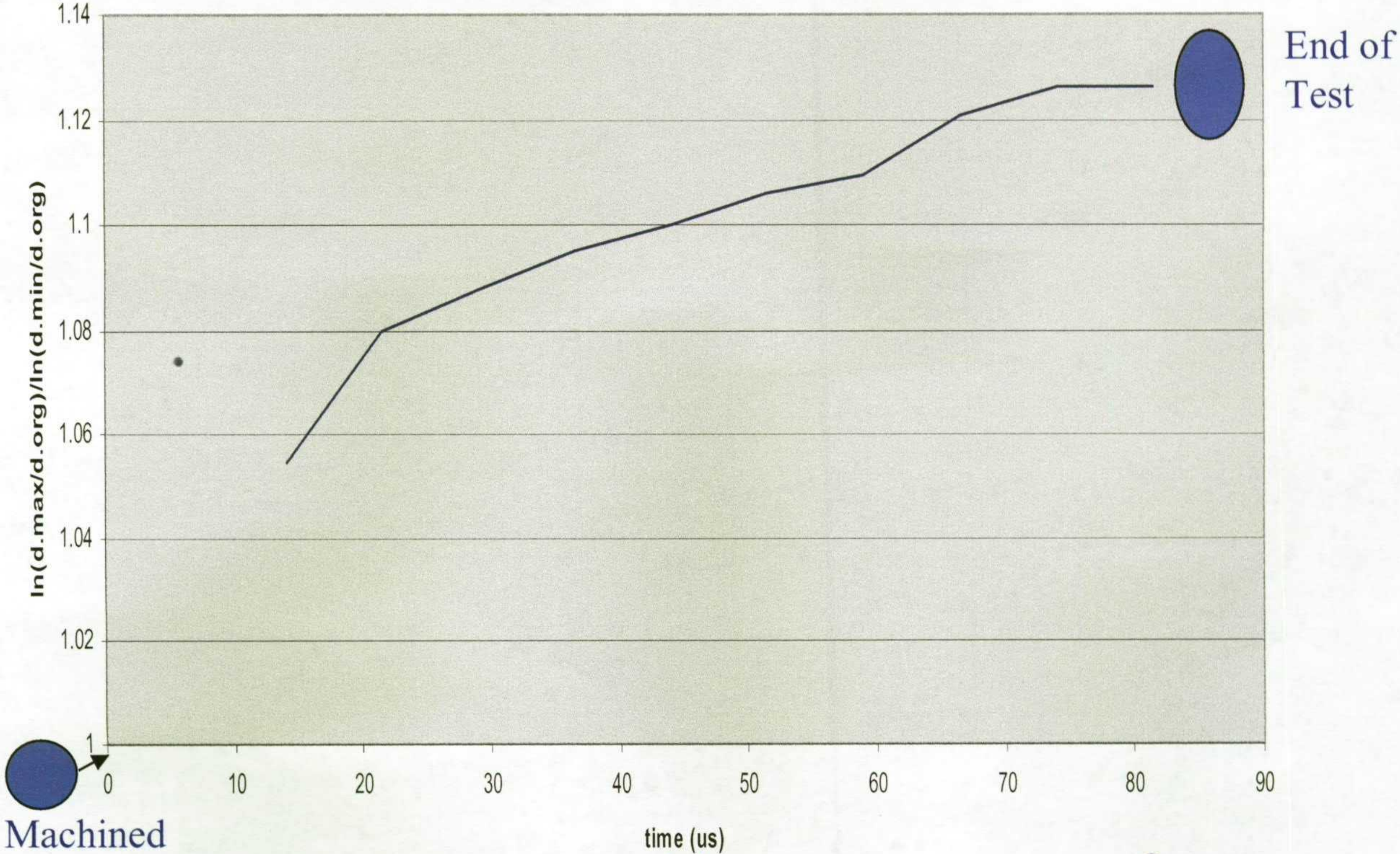


High Speed Image of High Purity Rolled Wrought Plate Ta Footprint 7us Interframe Time

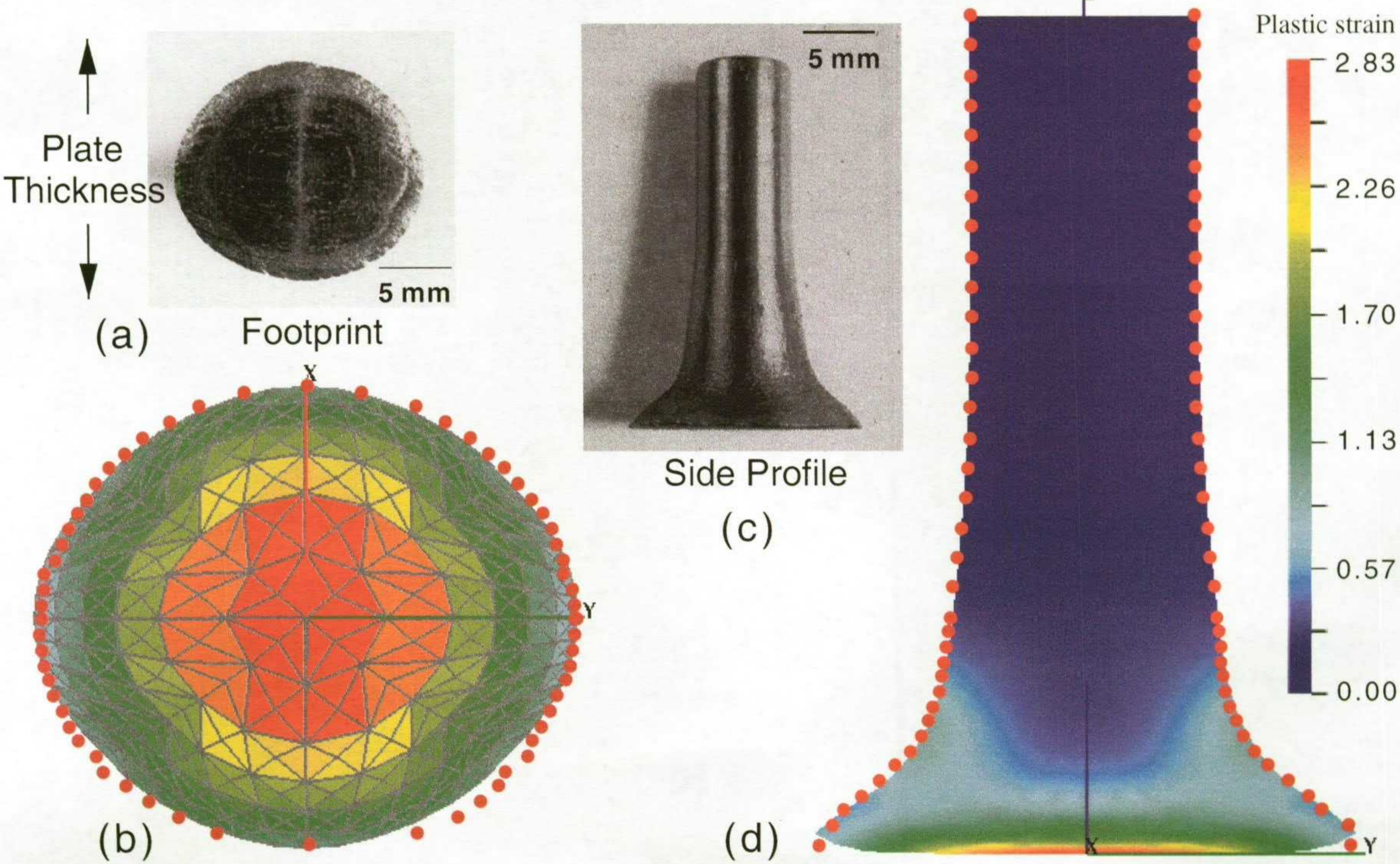


This technique allows time-resolved imaging of Taylor footprint.

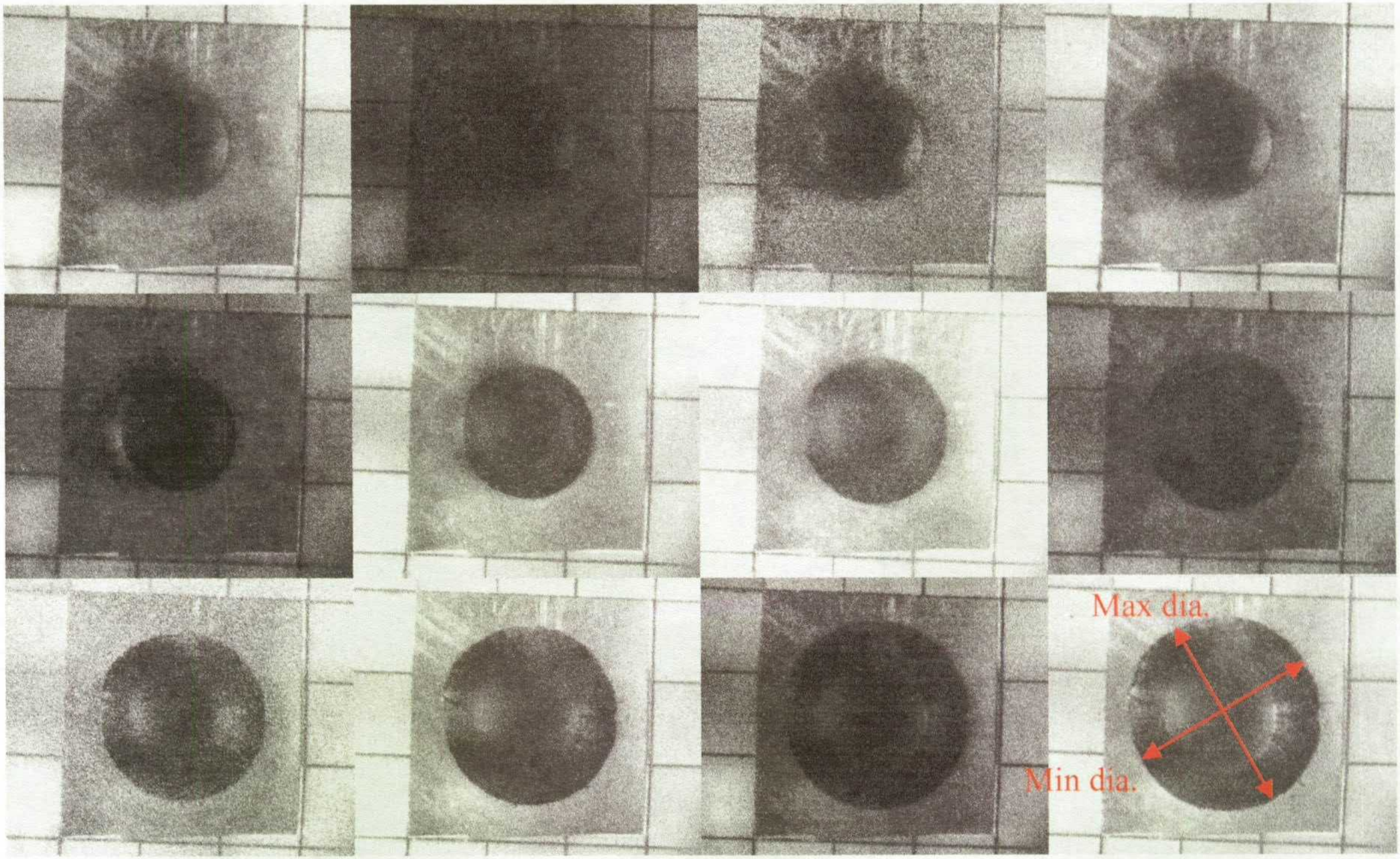
Wrought Plate Ta Footprint
Aspect Ratio vs. Time



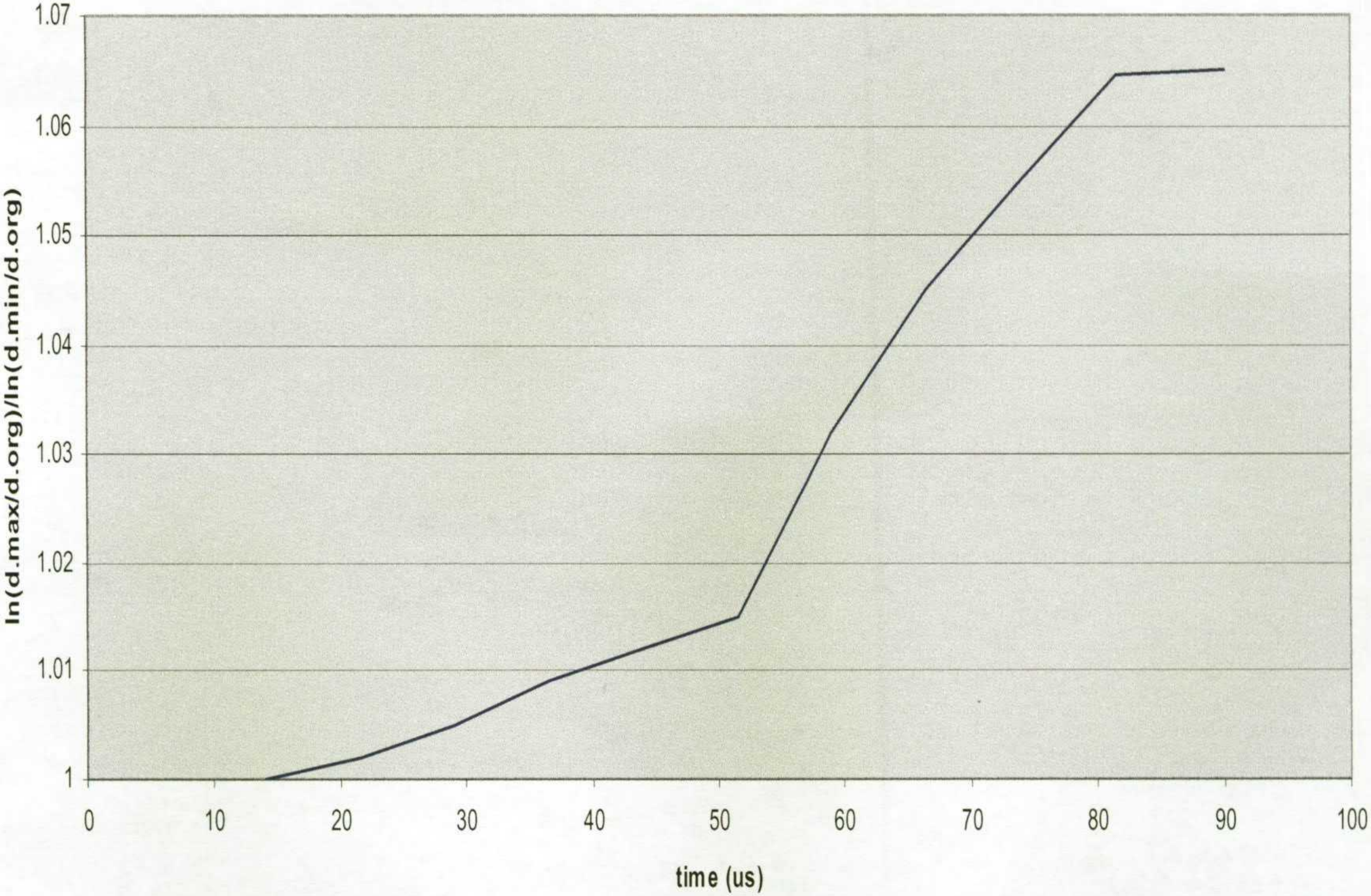
Taylor Cylinder: Ta plate - MTS Model



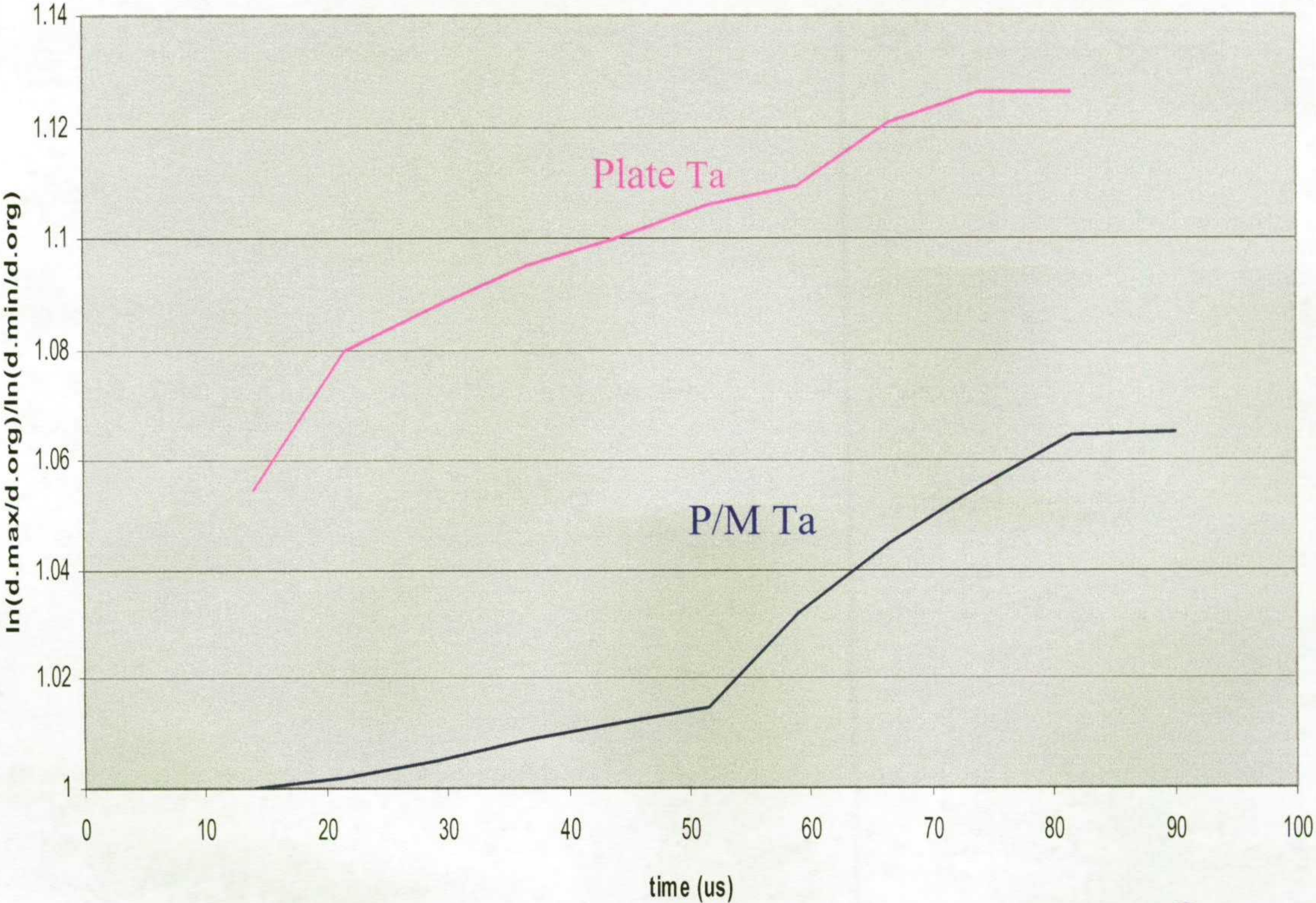
High Speed Image of Powder Metallurgy (isotropic) Ta Footprint 7us Interframe Time



P/M Ta Footprint
Aspect Ratio vs. Time

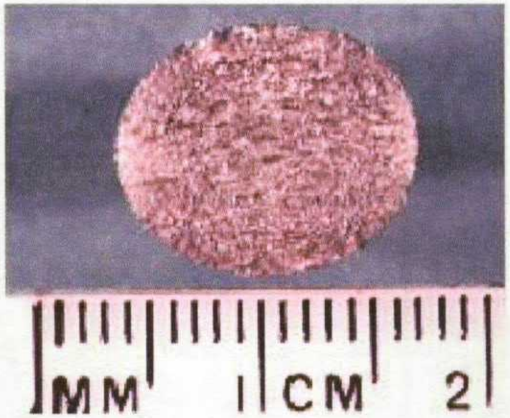


High Purity Wrought Plate Ta vs P/M Ta



Taylor Cylinder Results- Footprints

Ta-plate



Ta-bar

Half-hardened Cu

Al-1100

Summary

- Post-test specimens quantified in situ with high speed imaging can be compared with 3-D finite element simulations to validate the constitutive / damage evolution / fracture response.
- Probing the effects that material processing has on the texture of a material.
- Damage evolution in metals can be probed using the gradient in stress, strain rate, and strain in Taylor cylinder tests conducted under carefully selected impact conditions.