

VARIABILITY AND TRADEOFFS OF MECHANICAL PROPERTIES IN POST PROCESSING 21-9-6 STAINLESS STEEL BARS

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Motivation

Insufficient yield strength was found in a batch of 21-9-6 (Nitronic 40), while other batches passed requirements.

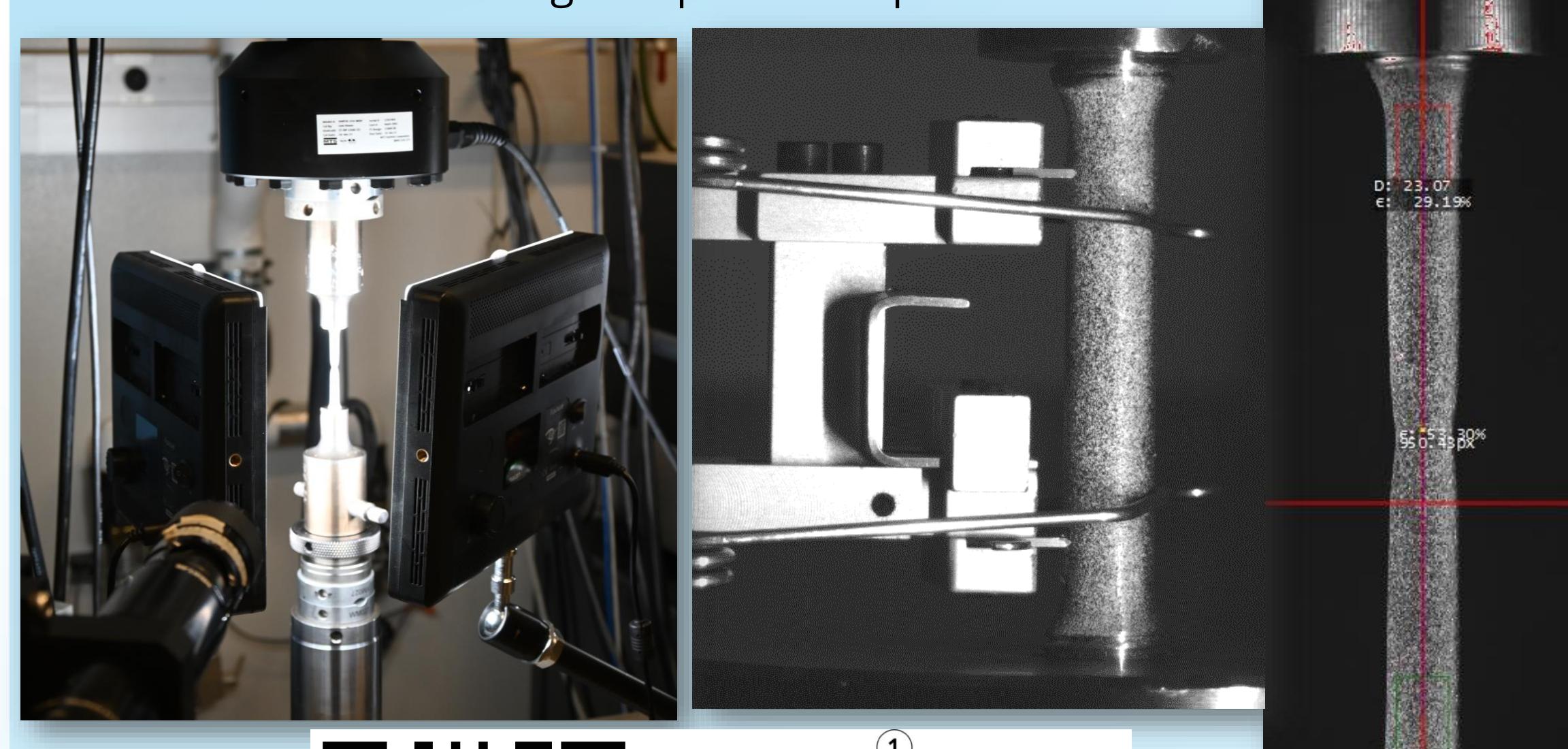
Background

This "annealed" material demonstrated spatial variability in yield strength and other properties. These bars were manufactured using electro-slag remelting, a refinement technique fit for critical applications that improves **property uniformity**. The bars were straightened after remelting. What is the impact of that post processing method?

Methods

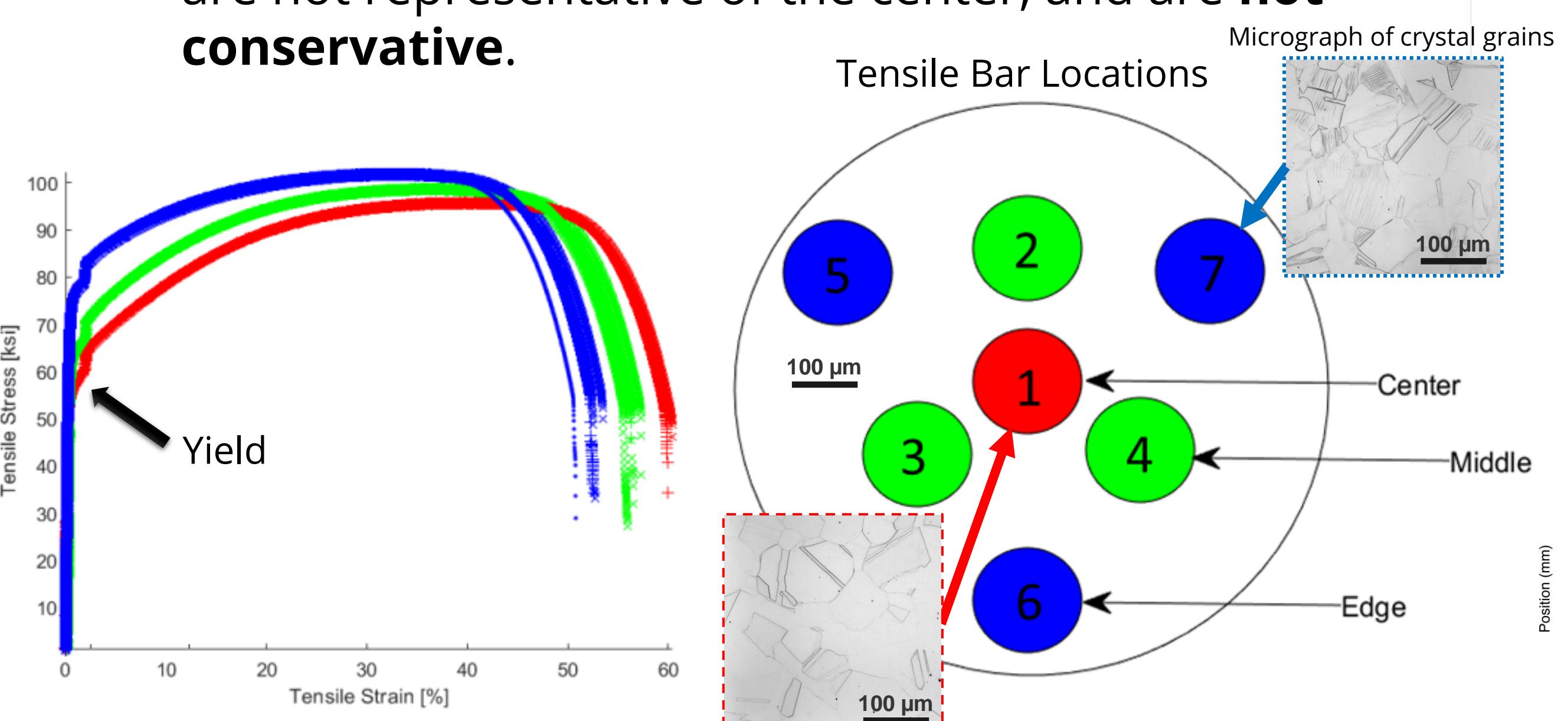
- Tensile bars were machined from different locations in the 2" diameter bar.
- Vickers microhardness profiles were measured across bar slices.
- Some bars were cold worked using **radial forging** to 10% and 14% reduction in area for comparison.

Tensile Testing Setup and Samples



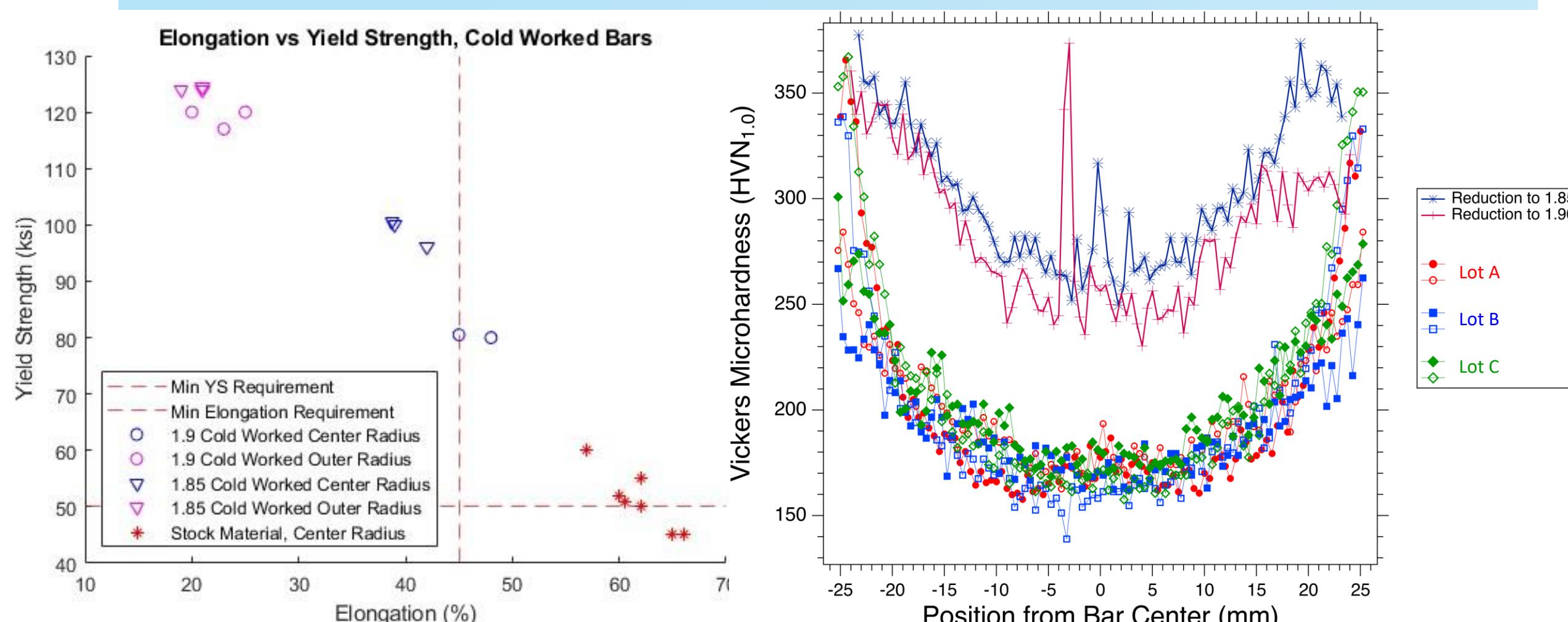
Distinct Radial Yield Distribution

- Yield strength increases with distance from the center of the bar.
- Material properties from mid-radius (ASTM standard) are not representative of the center, and are **not conservative**.



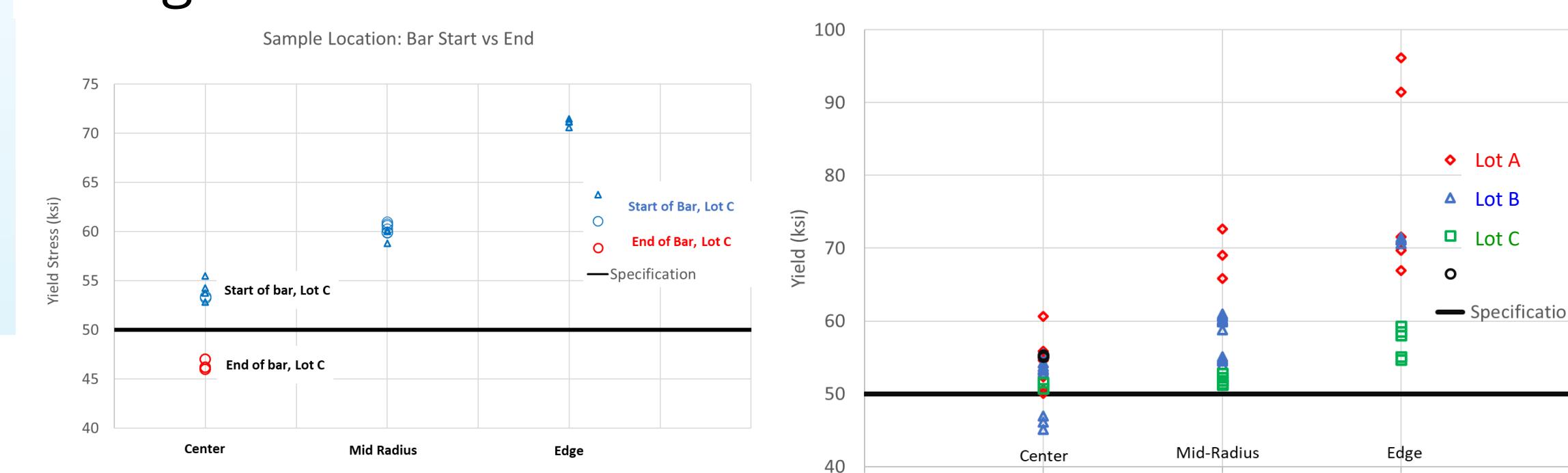
- Outer samples are stronger than inner samples

Effects of Cold Work



Variability: Longitudinal and Radial

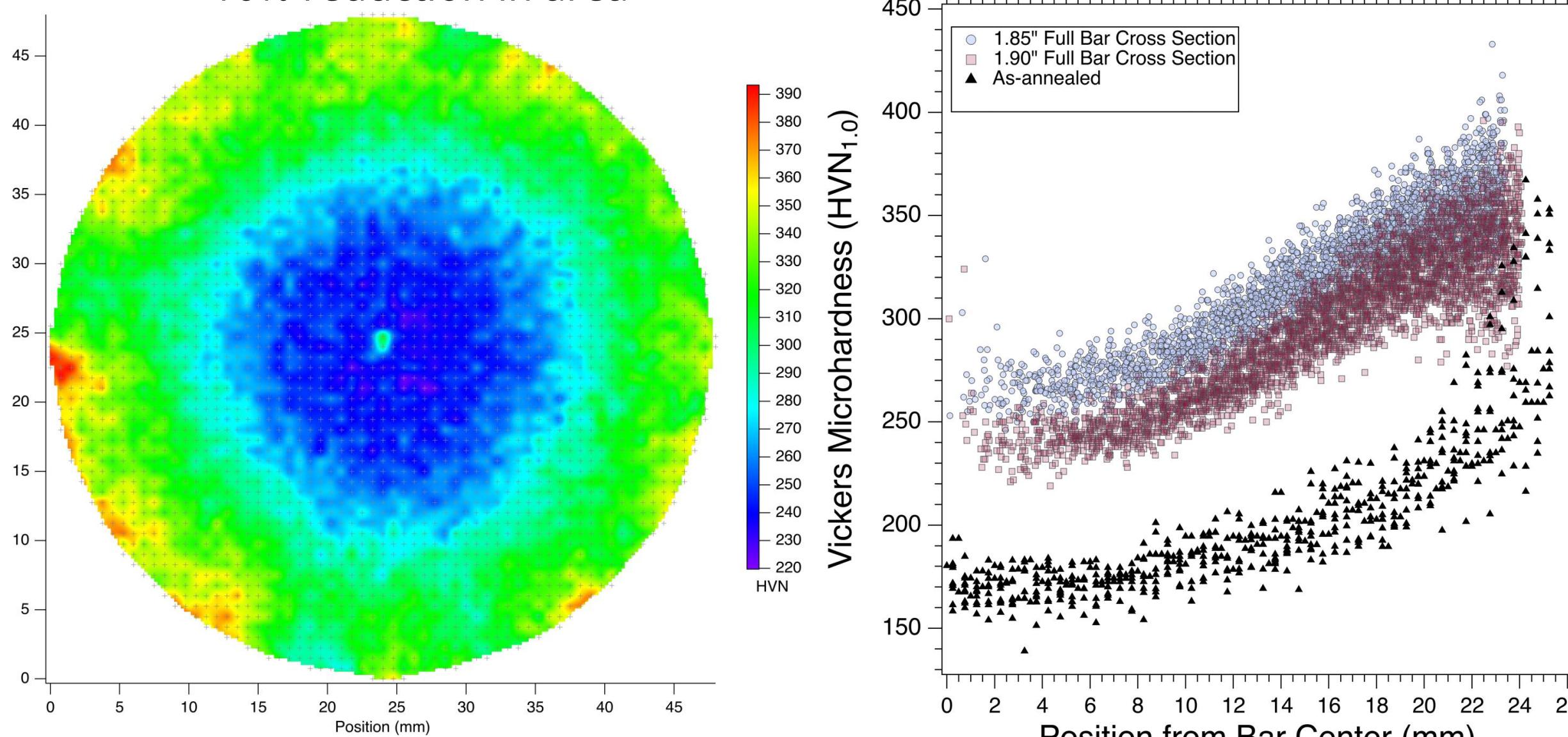
- Center yield strength shows groups according to bar longitude



High Yield in center, variability in edge

- Cold worked bars have higher microhardness with the magnitude of change more pronounced in the center.
- Cold work in the outer diameter occurs due to mechanical straightening after annealing which introduces radial and longitudinal variability in the bar.

Vicker's Microhardness Indenting Map: 10% reduction in area



- Hardness qualitatively predicts tensile properties

Conclusions

- Radial forging and straightening methods may have a pronounced effect on components that do not utilize the bulk length of the bar.
- Cold working predictably improves the yield strength in the bar at the cost of ductility, but variation in hardness increases along the OD.
- The desired amount of cold work needed for material property requirements can be determined accordingly because the native property distribution is characterized.