

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

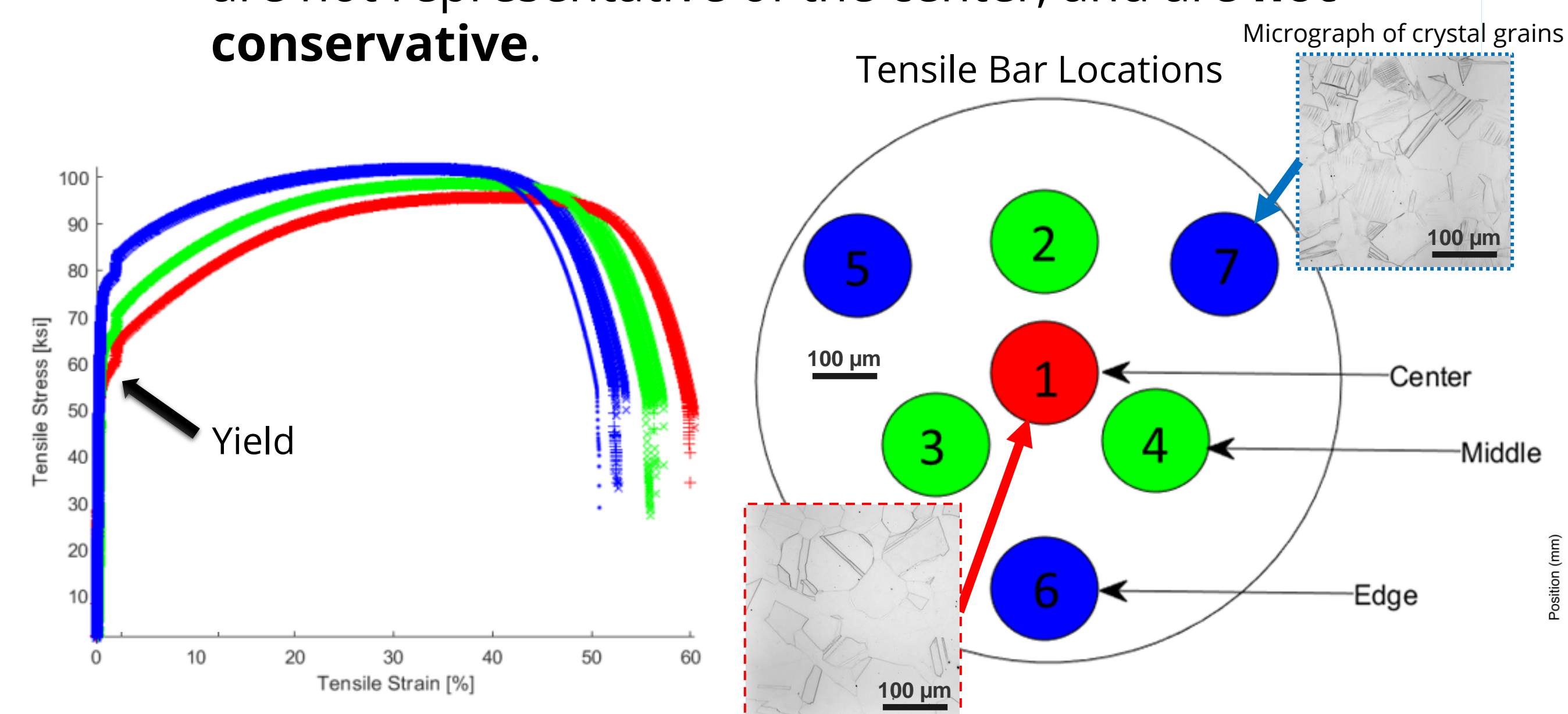
This “annealed” material demonstrated spatial variability in yield strength and other properties. These bars were manufactured using electro-slag remelting, a refinement technique fit for critical applications that improves **property uniformity**. The bars were straightened after remelting. What is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

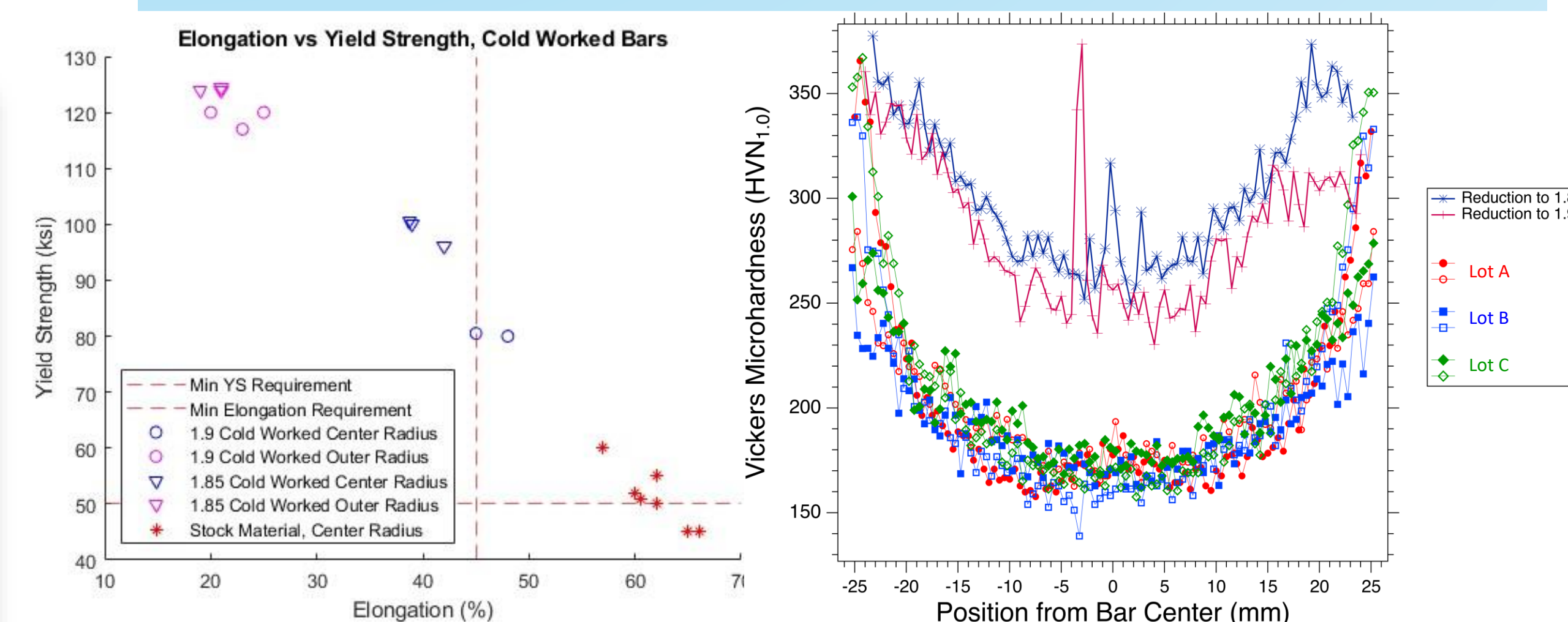
Distinct Radial Yield Distribution

- 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**.



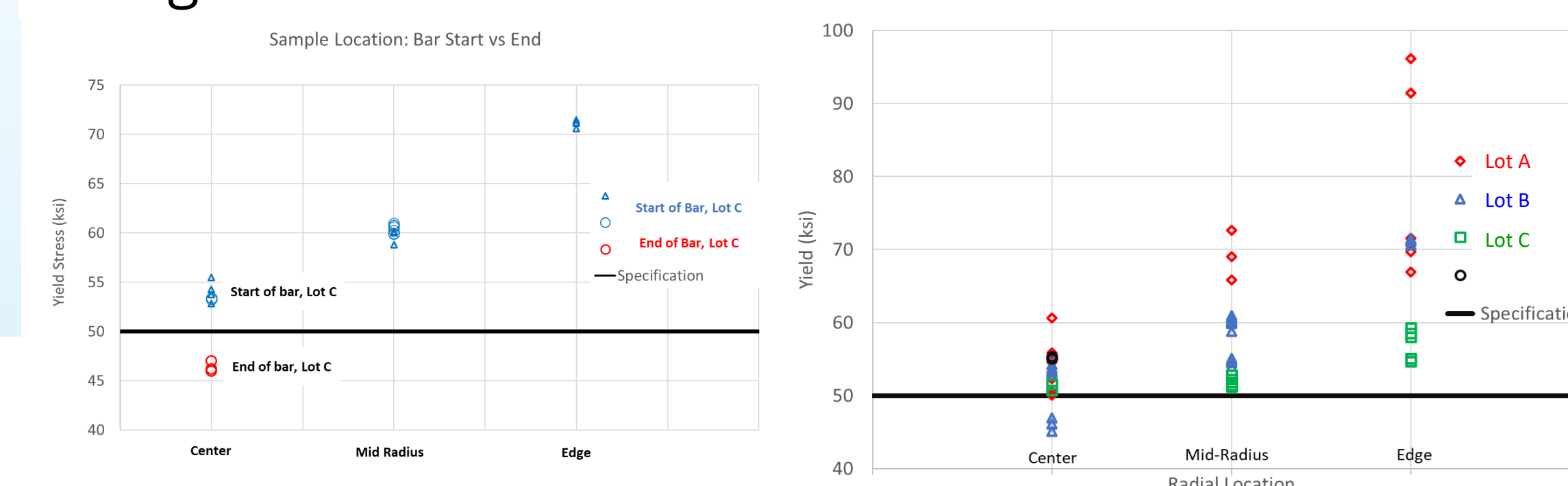
- Outer samples are stronger than inner samples

Effects of Cold Work



Variability: Longitudinal and Radial

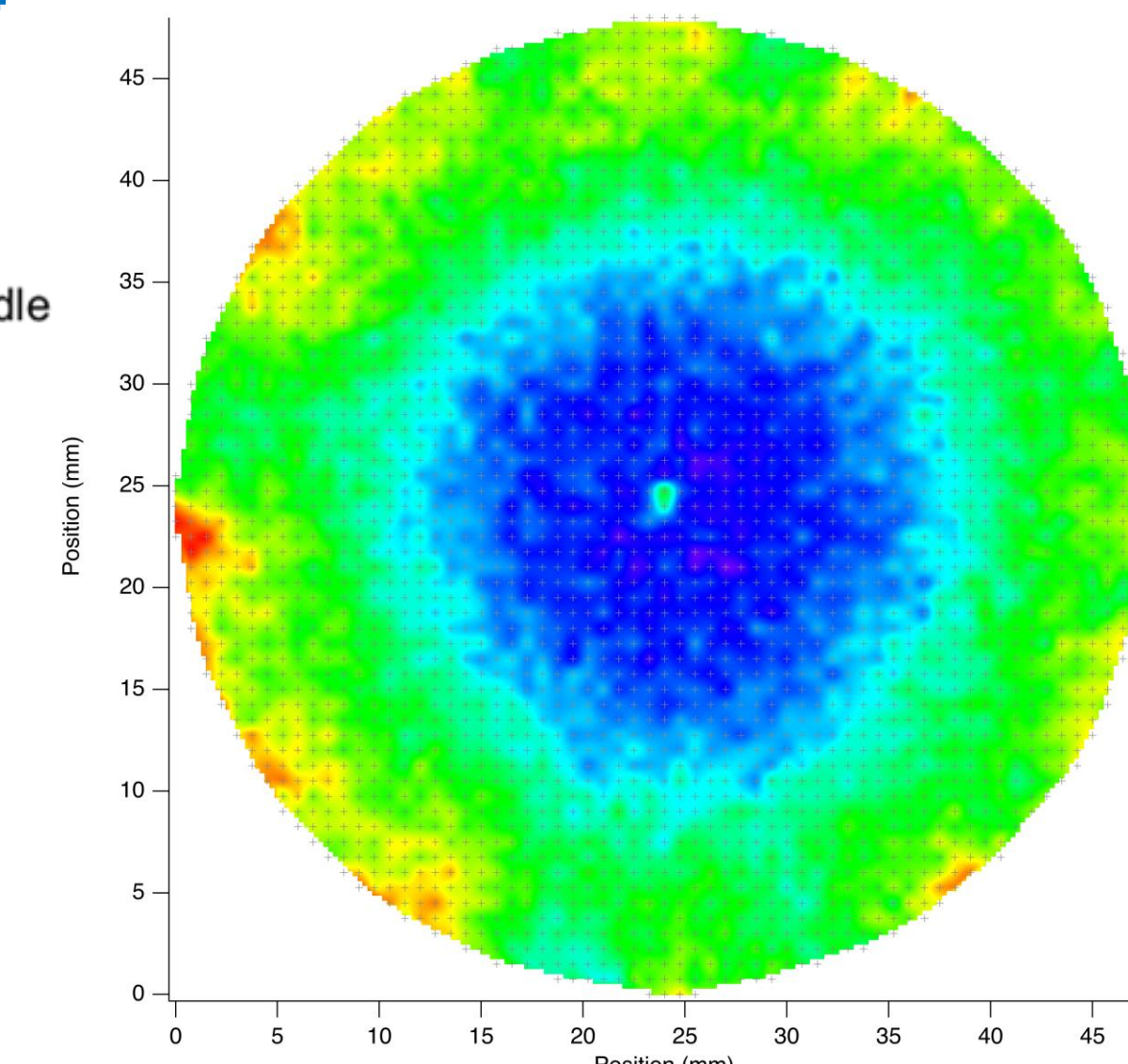
- Center yield strength shows groups according to bar longitude



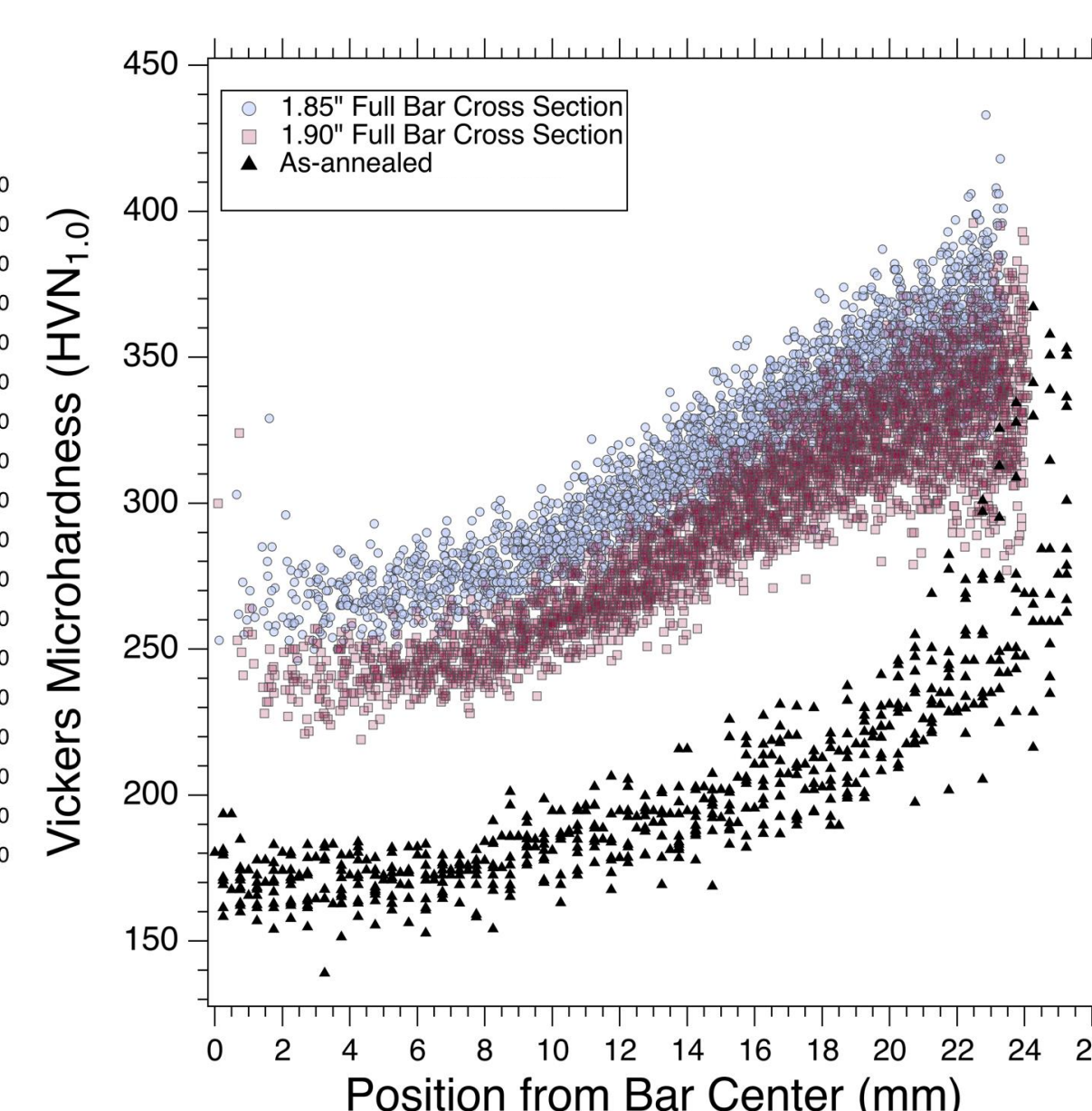
High Yield in center, variability in edge

- 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



Annealed vs Cold Worked

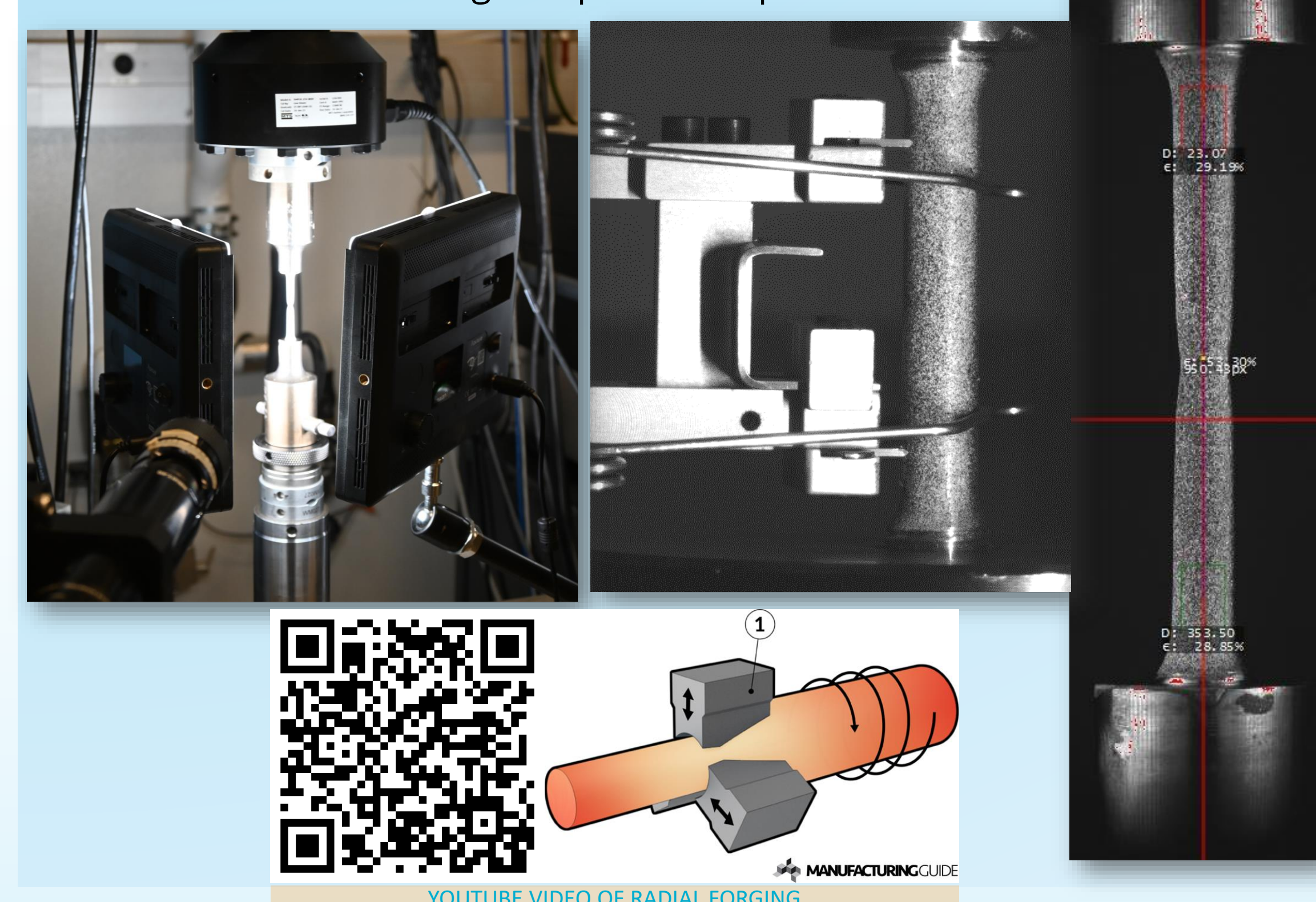


- Hardness qualitatively predicts tensile properties

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.

Tensile Testing Setup and Samples



YOUTUBE VIDEO OF RADIAL FORGING

MANUFACTURING GUIDE