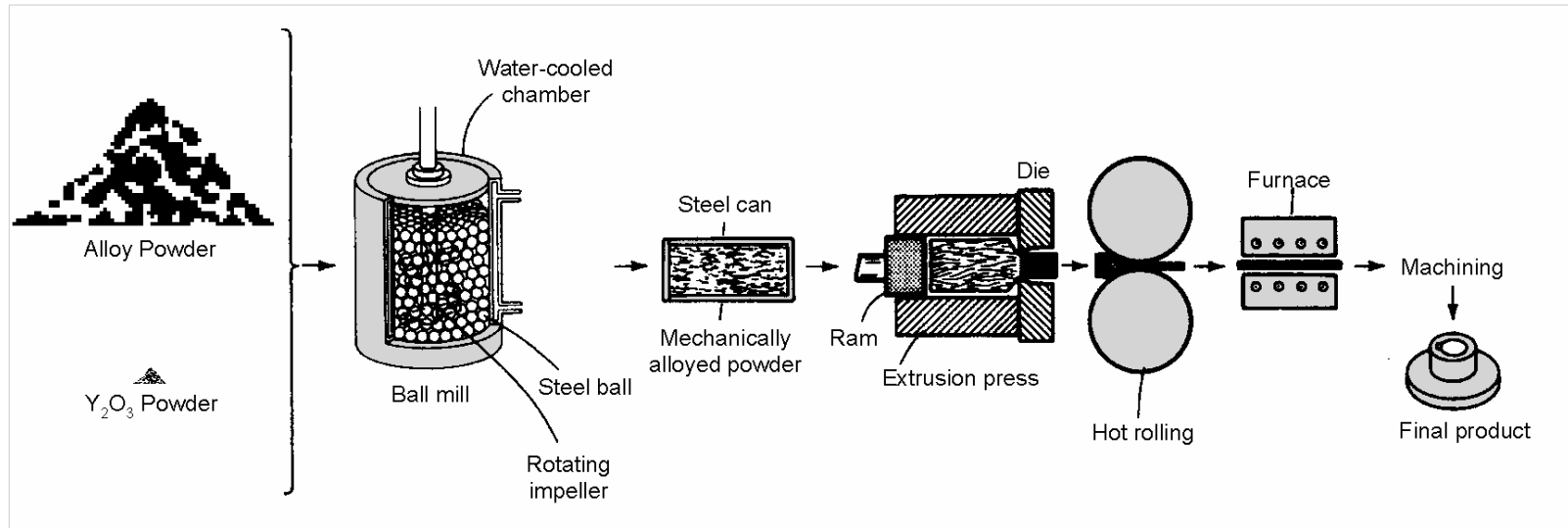


Development of New Nano-Particle-Strengthened Steel

- **Materials scientists on US Fusion Program have devoted extensive efforts to develop advanced high-strength steels, similar work carried out elsewhere and on other programs**
- **Substantial interest in reproducing and improving Kobe Steels “12YWT,” a 12 Cr steel with ~0.25 wt-% Y_2O_3**
- **Such steels prepared by powder metallurgy and mechanical processing techniques to produce steels with fine (nm-scale) dispersion of oxide clusters**

Preparation of ODS Steels by Mechanical Alloying and Processing

- Overview

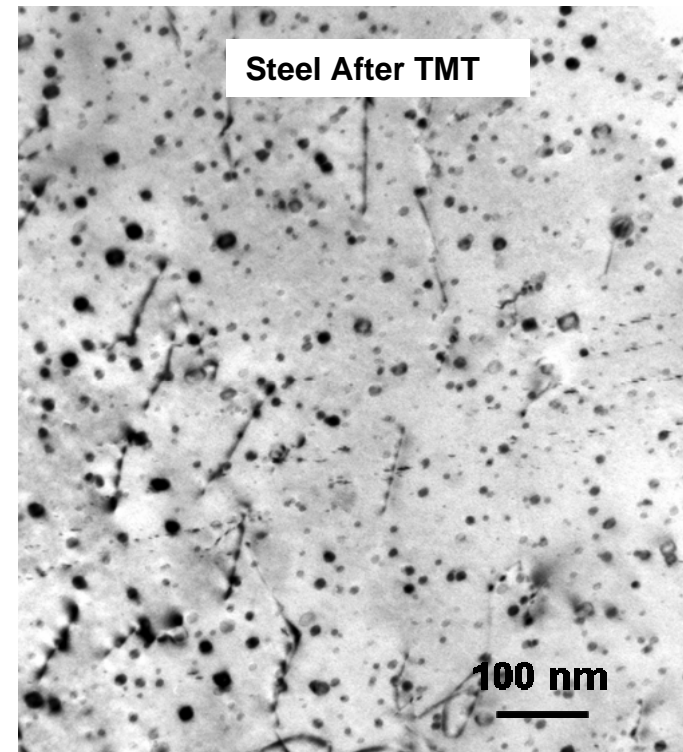
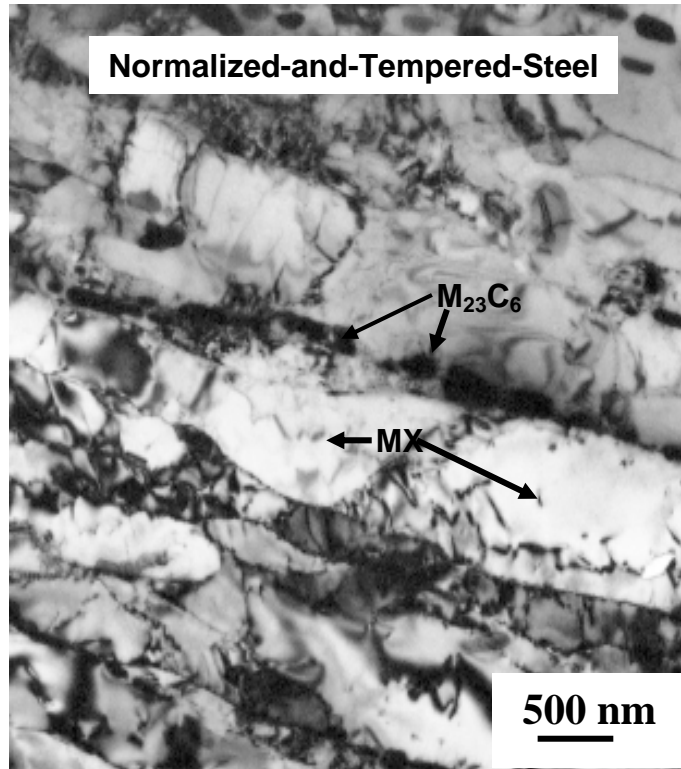


- Versatile processing method for producing structural alloy with high temperature strength since it allows for any desired combination of matrix composition and dispersoid
- However, the method is inherently time-consuming and frequently produces materials with non-uniform microstructures and highly anisotropic properties

Alternate Processing Path to High-Strength Steels

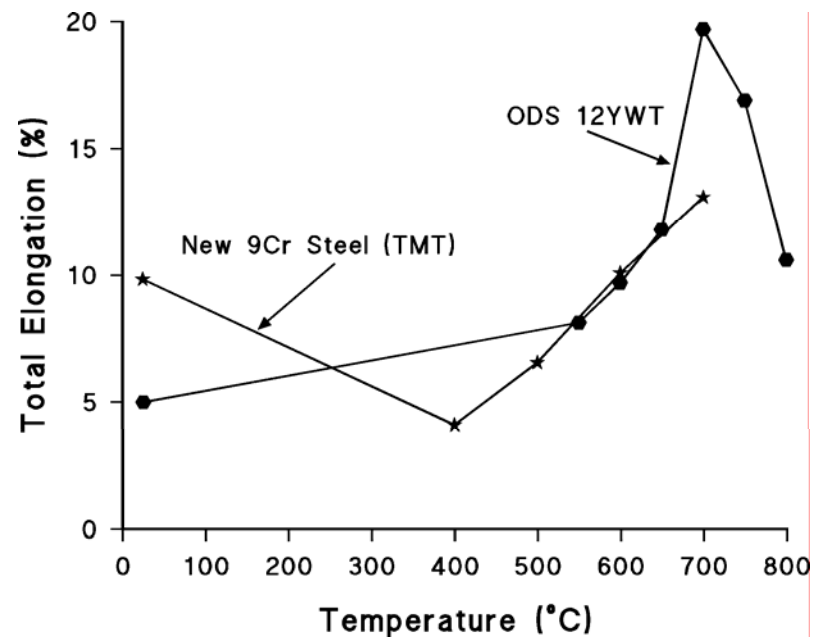
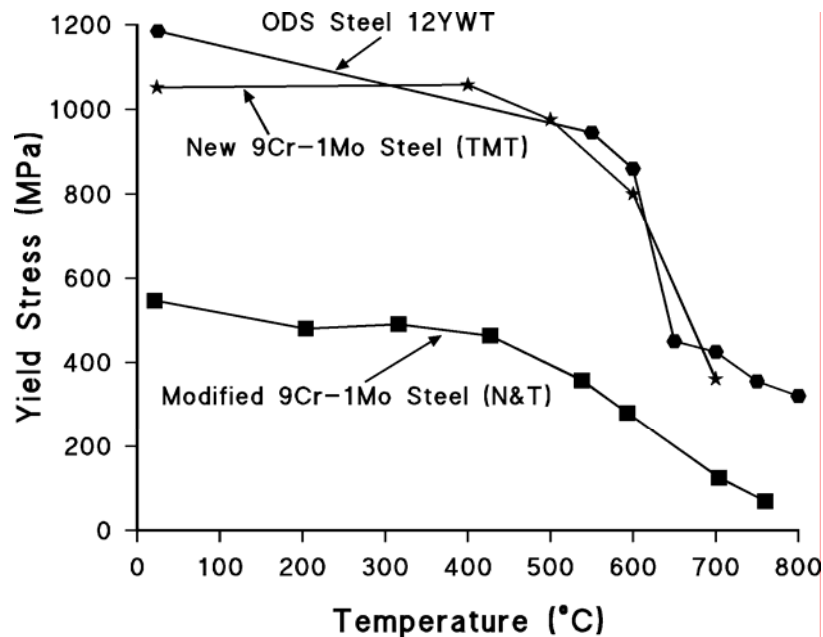
- **Method uses conventional metallurgical processing to produce ODS steels**
- **Thermo-mechanical treatment (TMT) used to produce strength**
- **A high number density of small MX particles precipitate on dislocations produced by TMT**
- **Adequate creep strength at 650-700°C (or higher)**
- **Method can be used on new steel compositions or on commercial nitrogen-containing steels**
- **Following example based on novel TMT of commercial modified 9Cr-1Mo (similar results with 12 Cr steel, HCM12A)**

Microstructural Improvement with Thermo-Mechanical Treatment



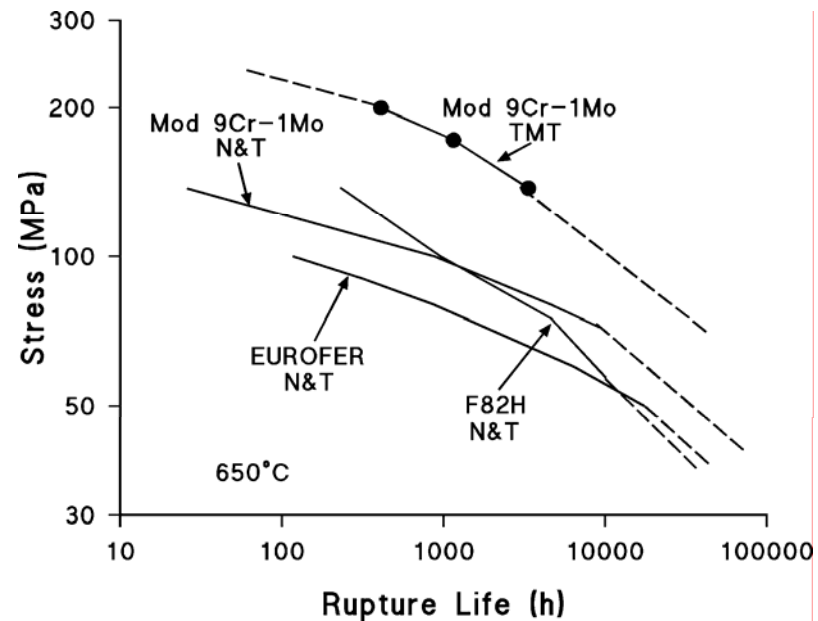
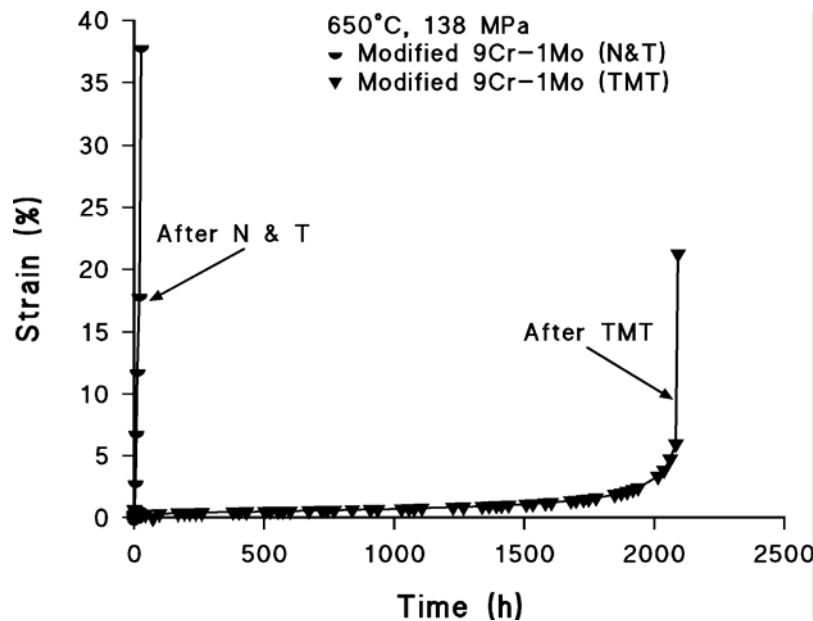
- Strength derived from large number of small particles
- Number increased up to 10,000 times and size decreased by 8 times over Normalized-and-Tempered steel depending on TMT and steel composition

Tensile Properties Improvement with Thermo-Mechanical Treatment



- **Strength and ductility comparable to best high-strength experimental ODS steel (12YWT)**

Creep Properties Improvement with Thermo-Mechanical Treatment



- Rupture life increased ~80 due to by TMT
- Excellent ductility for such high strength

- TMT produced steel with 100,000 h rupture stress 2* reduced-activation (RA) steels
- New RA steels possible