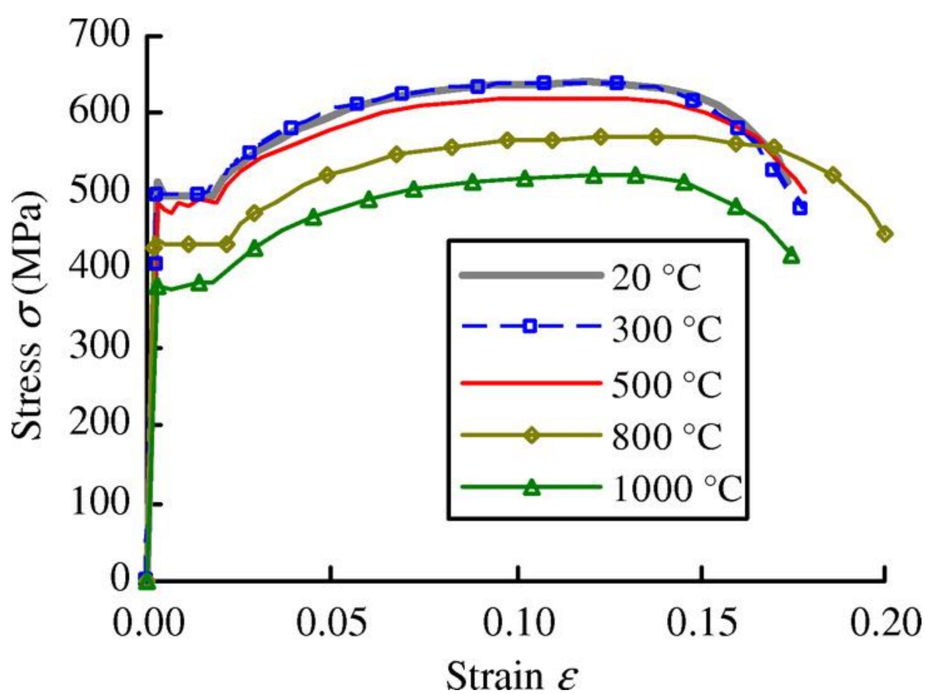
Problem 1 [40 points]:

A cylindrical pressure vessel is to be designed as the housing for a chemical process. The vessel is to be enclosed by welding hemispherical ends onto the cylindrical portion of the vessel. The design pressure of the vessel is to be 200 psi, and the design temperature is to be 500 ºC; however, the vessel may occasionally operate at lower temperatures. The chemical process in the interior of the vessel will involve corrosive chemical species, including concentrations of H_2S of which partial pressures should not exceed 0.05 psi per NACE MR-0175. The exterior of the vessel will be exposed to a high humidity air environment (relative humidity 90-100%). The vessel is to be designed to meet requirements per ASME BPVC (Pressure Vessel code), and the selected material of construction is to be a low carbon steel (<0.30 wt% C).

a) Assume that samples of the steel to be used for construction have been tensile tested, and the following results have been obtained in the figure below. Per code requirements, the hoop stress in the cylindrical section of the vessel (given by the equation below) must not exceed 40% of the 0.2% offset yield strength at the design temperature, and the elongation must not exceed 1 inch. If the outer diameter of the vessel is to be 3 m, and the overall length is 13 m, what is the minimum wall thickness required in order for the vessel to be code compliant?

$$\sigma = \frac{pr}{t}$$

p=design pressure, r=outer radius of vessel, t=wall thickness of vessel



b) It is desired to strengthen the steel used for this vessel to reduce the wall thickness. Discuss why rapid quenching of the steel to form martensite, or cold working the steel, may be ineffective mechanisms for strengthening considering the operating temperature, and recommend an alternate effective strengthening method.

Problem 2 [20 points]:

Consider a high density, semi-crystalline thermoplastic polymer containing both amorphous and crystalline phases. Discuss the relationship between strain rate sensitivity, viscoelasticity and percent crystallinity in this type of polymer, and indicate how deformation occurring in the microstructure influences this relationship. Hint: you may want to consider using semi-crystalline polymer tensile specimens subject to an increasing force applied at different strain rates in your explanation. How does a high percent crystallinity vs. low percent crystallinity tensile specimen compare in terms of what the microstructure looks like, and how each tensile specimen responds to increasing strain rates?

Problem 3 [25 points]:

Austenitized low carbon steel that is rapidly quenching to room temperature generally forms 100% martensite. In processes involving slower cooling in which unstressed, equiaxed pearlitic and ferritic grains form, the grain crystal structure takes on a BCC crystal structure morphology, while the martensitic grains often form a BCT arrangement.

a) Represent the family of planes and directions associated with dislocation motion for both the pearlitic BCC and martensitic BCT crystal structures using miller indices.
b) Explain why martensite is generally higher in strength, lower in ductility, and exhibits greater anisotropy than unstressed pearlitic and ferritic microstructures.

Problem 4 [15 points]:
Consider 6 kg of a Cu-Ag alloy that contains approximately 0.125 kg of β phase and 5.875 kg of α phase at 600 ºC.

a) Determine the wt % of the components in each phase, and the overall composition of the alloy.
b) If the alloy was originally liquid and cooled to 600 ºC, and the alloy is polycrystalline, draw a diagram illustrating what you would expect the microstructure to look like including both the α and β phases. Be sure to **clearly label** the phases in your microstructure drawing.

Bonus Question (20 Points)

Consider the operating environment from Problem 1, which includes a high humidity external environment, and an internal environment containing H_2S. Describe any metallurgical damage mechanisms that may be of concern regarding these operating environments, and indicate a possible mitigation for this damage susceptibility.