Definition of Plasticity

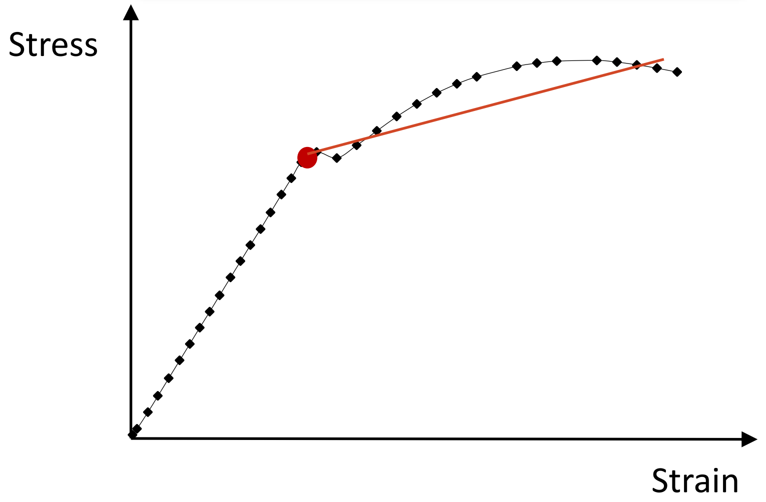
Metal Plasticity – Lesson 4

Define Plasticity

In defining a material for a solid mechanics design or analysis problem, material data is usually given by the testing lab or found in the literature. We can use uniaxial tensile test data to define plasticity for a ductile material.

1. Define the yield point, where the material enters plasticity.
2. Decide if perfect plasticity or hardening should be used. Perfect plasticity leads to conservative results.
3. If hardening is considered, define the hardening model.

Testing data of uniaxial tensile test

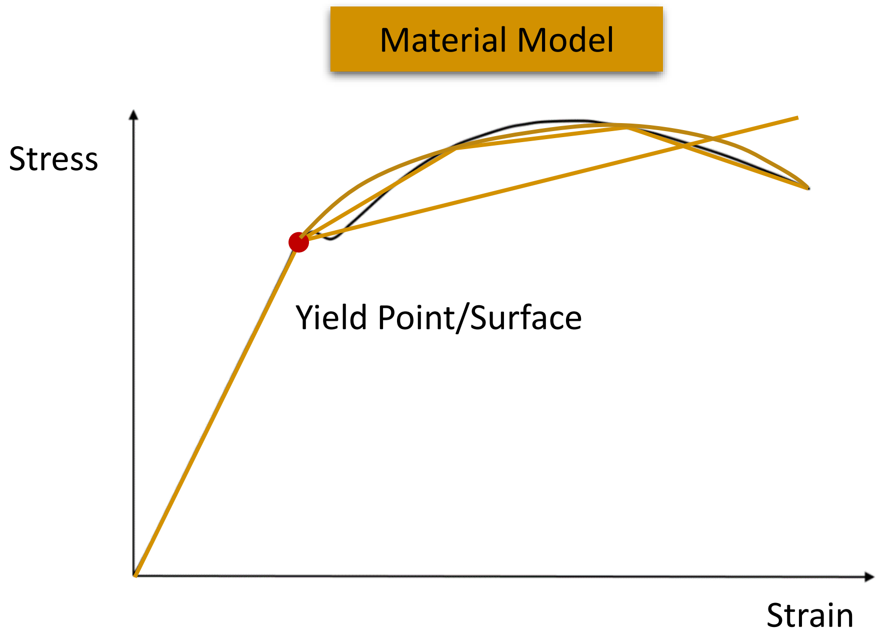


Define Plasticity: Define Hardening

The data curve for a material is usually complex and irregular. We need to simplify and smooth the data to define a hardening model. The hardening can be defined as:

- One linear line/bilinear plasticity
- Piece-wise linear/multi-linear lines
- Nonlinear curve/high-order function

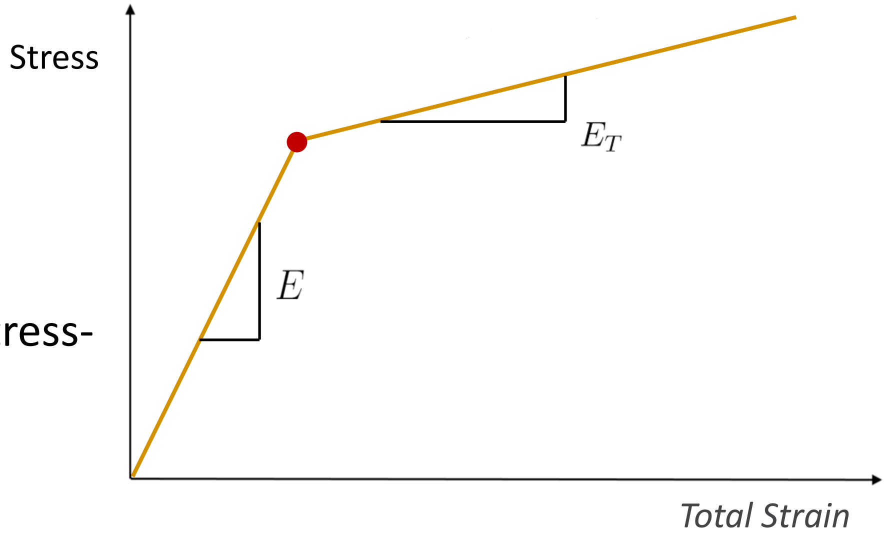
Let's see how bilinear hardening can be defined.

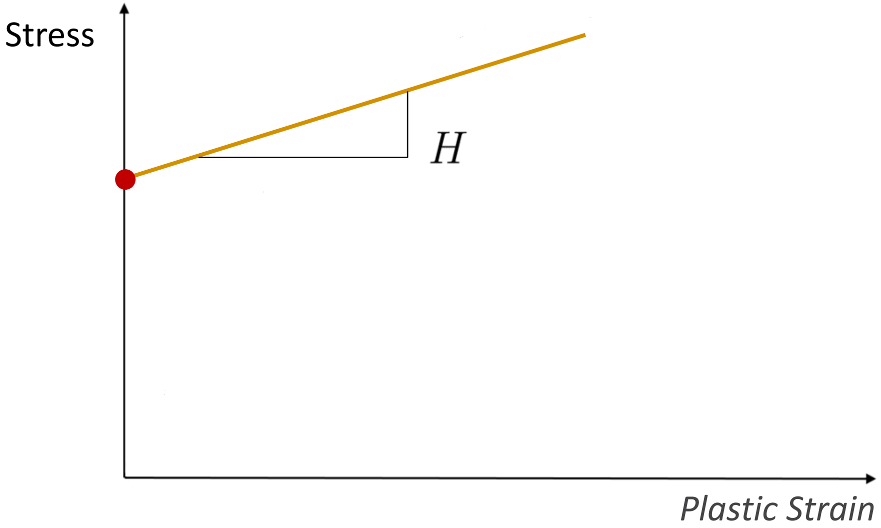


Define Plasticity: Bilinear Hardening

For bilinear hardening, one needs to find two parameters:

- Young's modulus *E* : the tangent of the initial linear part of material stress-strain plot.
- Hardening modulus *H* : the tangent of stress vs *plasticity strain* curve.





Note that the tangent of the linear hardening on stress vs total strain curve is E_T. It should be differentiated from H.

Define Plasticity: Bilinear Hardening (cont.)

Plastic strain is the residual strain if unloading the plastic material to zero stress.

- Plasticity strain is total strain minus elastic strain

$$\varepsilon_p = \varepsilon_{tot} - \varepsilon_e$$

- Elastic strain can be found from stress and Young's modulus

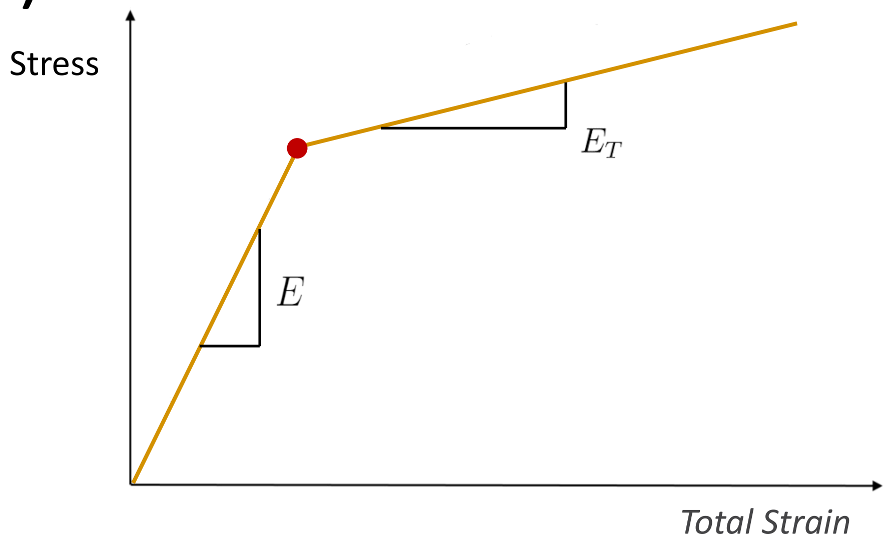
$$\varepsilon_e = \frac{\sigma}{E}$$

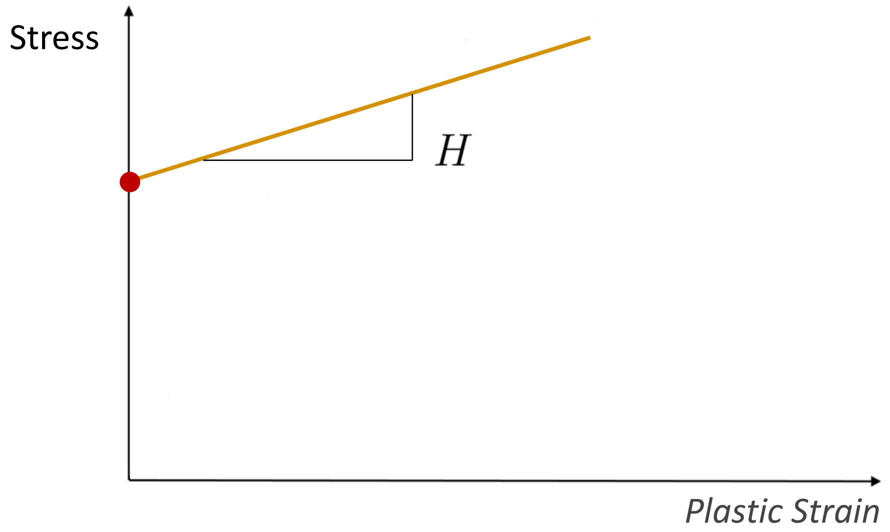
- Plasticity strain can be found as:

$$\varepsilon_p = \varepsilon_{tot} - \frac{\sigma}{E}$$

- Hardening modulus:

$$H = \frac{\sigma - \sigma_y}{\varepsilon_p}$$ Or $$H = \frac{E_T}{1 - \frac{E_T}{E}}$$





Metal Plasticity: Bilinear Hardening

Define bilinear plasticity for the material data given below.

1. Decide yield point, calculate Young's modulus as it is not given.

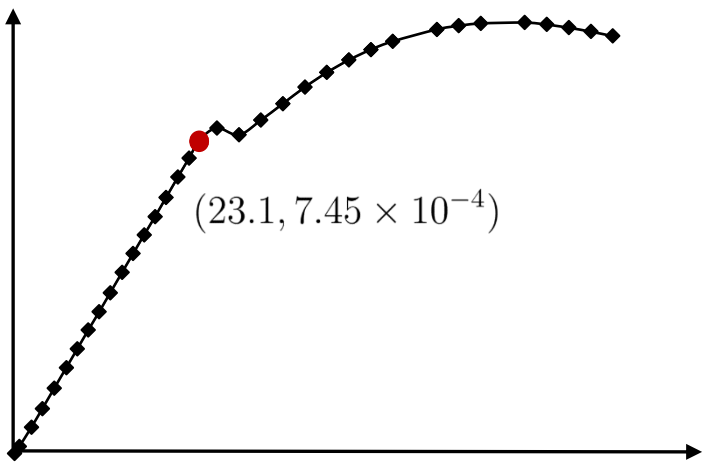
$$E = \frac{\sigma_y}{\varepsilon} = \frac{23.1}{7.45 \times 10^{-4}} = 3 \times 10^4 Mpa$$

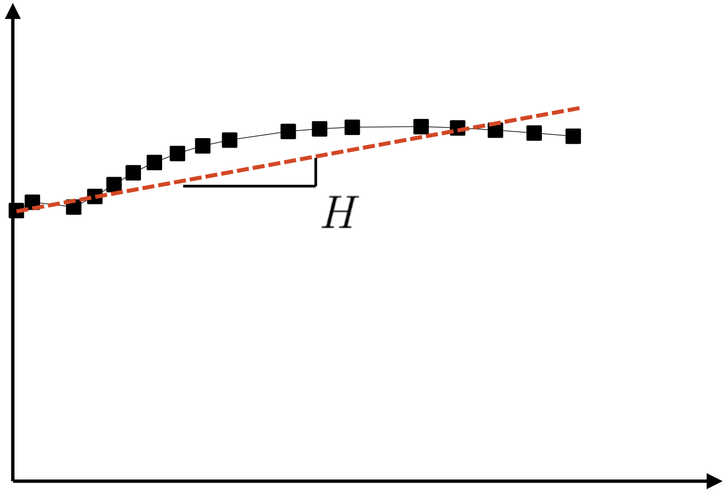
2. Find plastic strain. Plot the stress vs plastic strain curve.

$$\varepsilon_p = \varepsilon_{tot} - \frac{\sigma}{E}$$

3. Find trendline of stress vs plastic strain curve, record tangent modulus H.

$$H = 3 \times 10^3 Mpa$$





Three inputs are needed for definition of bilinear plasticity: Young's modulus, yield point and hardening modulus.

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