Chapter 6

Mechanical Properties of Metals

金屬的機械性質

Stress and Strain in Metals

Elastic and Plastic Deformation 彈性與塑性變形

1. elastic deformation 彈性變形

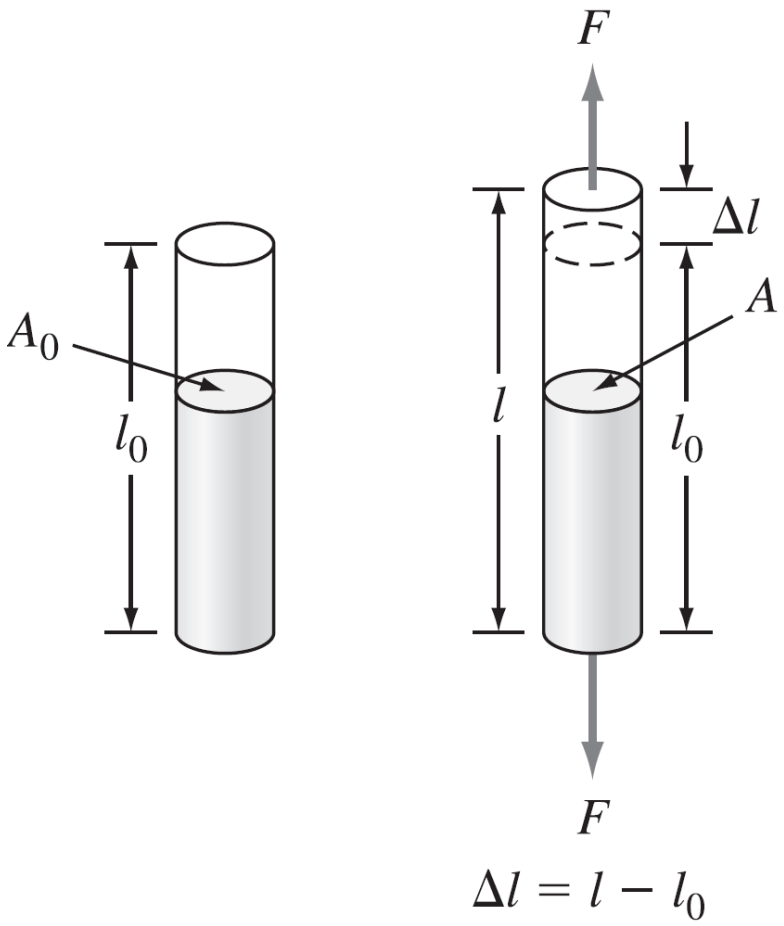
金屬受一軸向外力拉伸時，會發生變形。若外力移去，材料恢復其原有尺寸。

2. plastic deformation塑性變形

材料受變形後， 無法回復原有尺寸。

Engineering stress (應力) and engineering strain (應變)

工程應力 σ = $\frac{\text{F (average uniaxial tensile force)平均軸向拉伸外力}}{\text{A}_0\text{ (original cross-sectional area)原截面積}}$



工程應力的單位； **PSI or N/M^2 (Pascals)**

1 PSI = 6.89 x 10^3 Pa

工程應變 = ε = $\frac{\text{試片長度變化量}}{\text{試片原長度}} = \frac{\ell - \ell_0}{\ell_0} = \frac{\Delta\ell}{\ell}$

工程應變的單位； 英吋除以英吋**(in/in)**
或公尺除以公尺 **(m/m)**。

1. U.S. customary (英制): lb_f

2. SI: International unit (國際單位) Pa, N/m^2

   1000 psi = 1 ksi = 6.89 Mpa

   1 psi = 1 lb_f / in^2

Ex> A 1.25 cm-diameter bar is subjected to a load of 25 kg. Calculate the engineering stress on the bar in MPa. (一根直徑為 1.25 厘米的棒材承受 25 公斤的載荷。計算鋼筋上的工程應力，單位為 MPa。)

Soln>

$F = m\,a / g_c$, $g_c = 1$

$= 2500 \times 9.8$

$= 24500$ N

$\sigma = F / A_o = (24500\text{ N}) / [(\pi/4)\,(0.0125\text{ m})^2]$

$= 200$ MPa

Engineering stress (工程應變)

- Engineering stress, ϵ

$\epsilon = (l - l_o) / (l_o) = \Delta l$ (change in lengh of sample) / l_o (original length of sample)

1. U.S. unstomary: in/in
2. SI unit: m/m

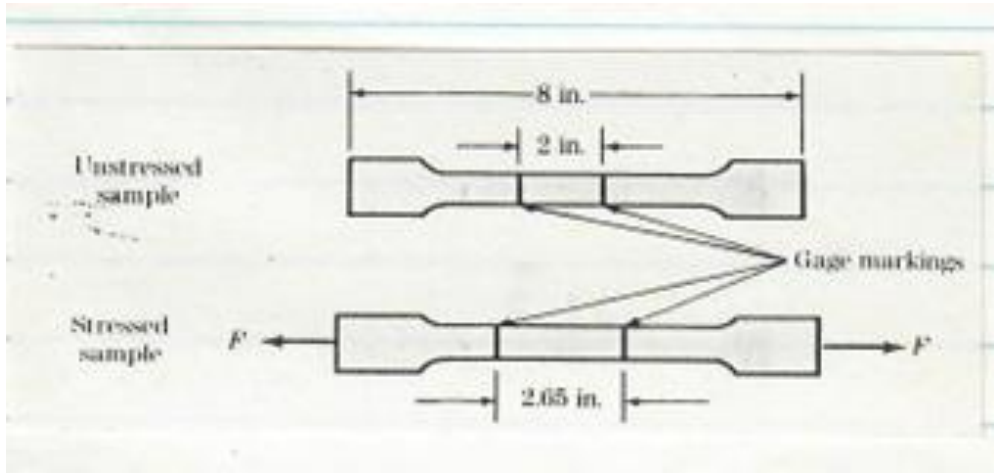
% engineering stress $\epsilon = (l - l_o) / (l_o) =$ **%** elongation 伸長量

EX> Aluminum 0.500 in wide, 0.04 in thick, and 8 in long which has gage markings 2 in apart in the middle of the sample is strained so that the gage markings are 2.65 in apart. Calculate the engineering strain and the percent engineering strain elongation which the sample undergoes.

寬 0.500 英寸、厚 0.04 英寸、長 8 英寸的鋁（在樣品中間有 2 英寸的量規標記）被拉緊，使得量規標記相距 2.65 英寸。計算樣品經受的工程應變和工程應變伸長百分比。

Soln> $\epsilon = (l - l_o) / (l_o) = (2.65\text{-}2) / 2 = 0.325$

$= 32.5\ \%$

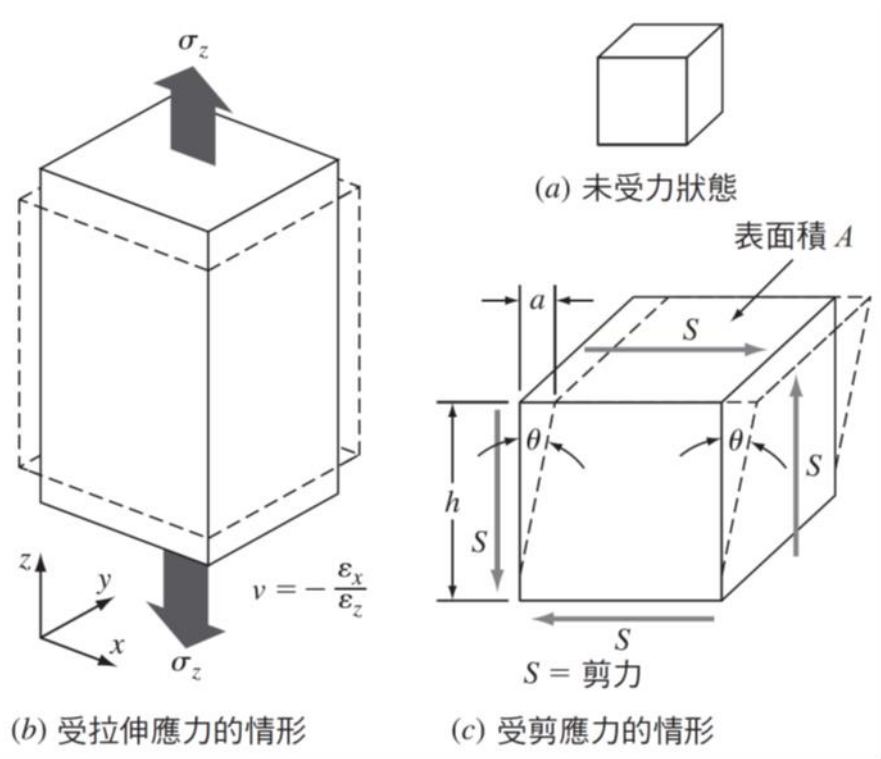


Poisson's Ratio 卜易松比例, ν

$\nu = -[\epsilon \text{ (lateral) 側面}] / [\epsilon \text{ (longitudinal) 軸向}]$

$= -\epsilon_x / \epsilon_z$

$= -\epsilon_y / \epsilon_z$



Shear stress (剪應力) and shear strain (剪應變)

- 1. τ (shear stress) = S (shear force) / A (area over which shear force acts)

  Unit: ib_f/in^2 (psi), N/m^2 (Pa)

- 2. shear strain, γ 檢應變

  剪位移除以剪力作用的距離

  $\gamma = a / h = \tan(\theta)$

- 3. 單純彈性剪力而言

  $\tau = G \cdot \gamma$

The Tensile and the engineering stress-strain diagram 工程應力應變曲線

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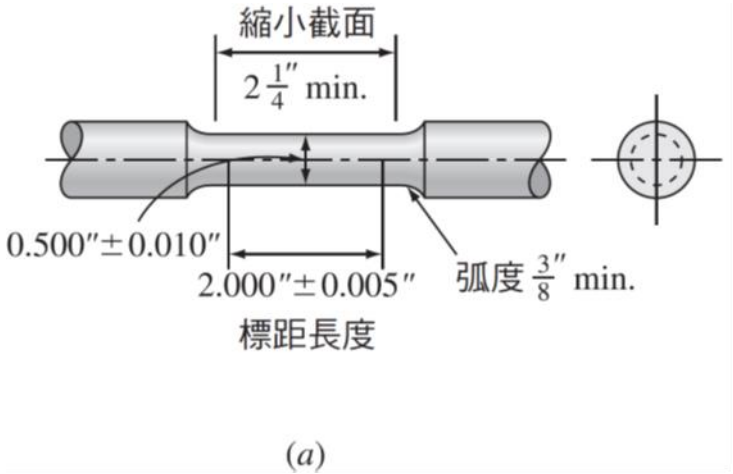
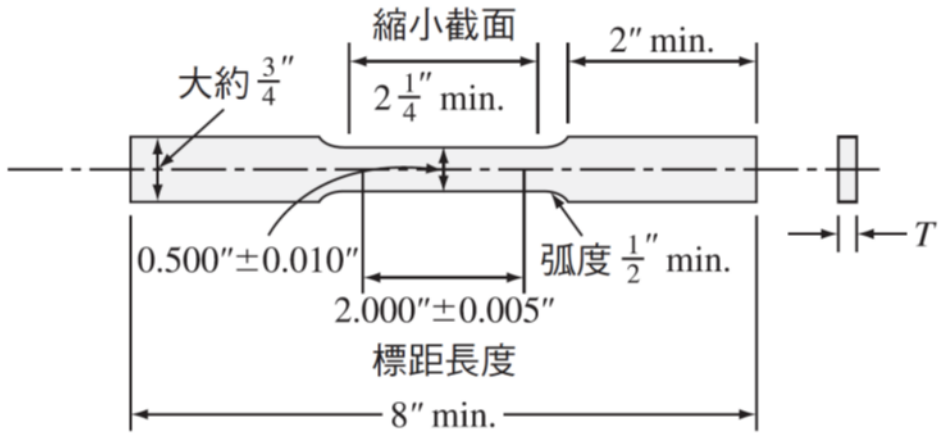
拉伸試驗



(*a*)

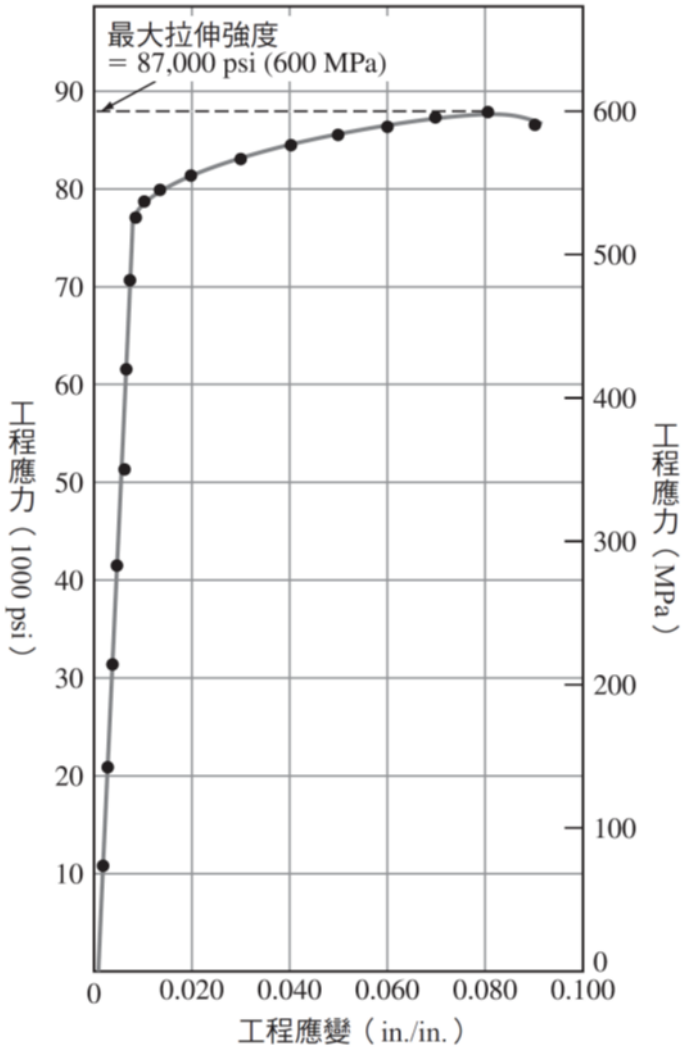


(*b*)

Modulus elasticity 彈性模數

- 如圖之直線合乎Hook's Law 虎克定律
- σ (stress) 應力= E ϵ (stress) 應變

- E = σ (stress) / ϵ (stress)
- E: modulus of elasticity or
  Young's modulus (楊氏係數)

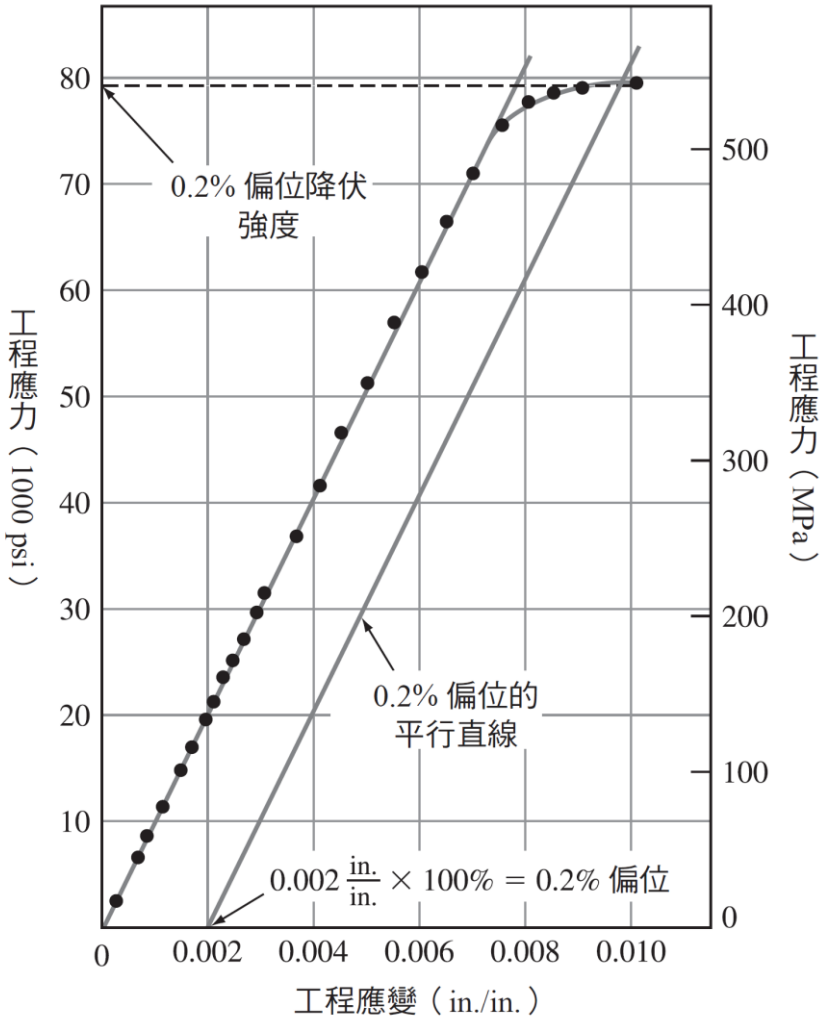


Yield strength, 降伏強度

- 降伏強度：當金屬處於此一應力時，代表金屬或是合金已經產生明顯的塑型變形

- 0.2%***偏位降伏強度*** 等於發生0.2%塑性應變時的應力.

- 作圖線, 0.2%應變處畫一直線平行應力－應變曲線之彈性(線性)區



Ultimate tensile strength 最大抗拉強度
engineering stress-strain 曲線上的最大強度

Percent elongation 伸長率

% elongation = $[(l\text{-}l_o) / (l_o)] \times 100\ \%$

$$= \frac{\ell - \ell_0}{\ell_0} = \frac{\Delta\ell}{\ell}$$

Percent reduction in area 斷面收縮率

% reduction in area = $[A_o - A_f \text{ (final)} / A_o] \times 100\%$

Ex> A 0.5” diameter round sample of a 1030 carbon steel is pulled to failure in a tensile testing machine. The diameter of the sample was 0.343 in at the fracture surface. Calculate the % reduction in area of the sample.

一直徑為 0.5 英寸的 1030 碳鋼圓形樣品在拉伸試驗機中被拉斷。樣品在斷口處的直徑為 0.343 英寸。計算樣品面積減少的百分比。

Soln> % reduction in area

$= [(A_o - A_f)] / (A_o)] \times 100\%$

$= [\ 1 - (A_f/A_o)] \times 100\ \%$

$= [1 - (\pi/4)(0.343)^2] / [\ (\pi/4)(0.5)^2]$

$= 53\ \%$