MAE 171A Final Review — review slides

• Error Analysis

Transducers: energy drawn from measured system $\leq \frac{1}{100}$ measuring energy

Keywords: accuracy, precision, resolution, threshold, repeatability, reproducibility

Farhenheit: 0 ≈ coldest temp in Western europe — 32 freezing

100 ≈ hottest ≈ — 212 boiling

Transducer → Filters, amplifiers } signal conditioning

power source → Transducer, power source → Filters, amplifiers

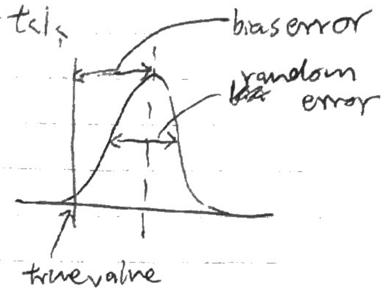
Zero order hold 

Multiplexer: N input channels → one ADC

switching rate, cross talk

4 types of errors

- intrinsic
- application
- interface
- sampling and approximation



Integration

- Riemann sums
- Trapezoidal rule (linear, 1st order approx)
- Simpson's rule (parabolic, 2nd order approx)

Variance $\sigma^2 = \frac{\sum(e_i-\mu)^2}{N}$

Gaussian $p(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/2\sigma^2}$ — 1σ, 2σ, 3σ: 0.68, 0.95, 0.997

z-value $= \frac{e_i-\mu}{\sigma}$

t-distribution: $t = \frac{\bar{e}_i-\mu}{s/\sqrt{n}}$ — s: sample SD, $s = \left[\frac{\sum(e_i-\bar{e})^2}{n-1}\right]^{1/2}$

Larger n → close to normal dist

$n > 30$

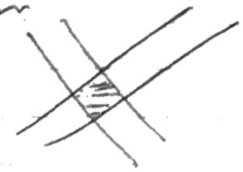
Taylor Series

$F = f(m_1, m_2, \ldots, m_n)$

$$\delta F = \pm\left[\left(\frac{\partial F}{\partial m_1}\right)^2 \delta m_1^2 + \left(\frac{\partial f}{\partial m_2}\right)^2 \delta m_2^2 + \ldots + \left(\frac{\delta f}{\delta m_n}\right)^2 \delta m_n^2\right]^{1/2}$$

Water Tunnel

Laser (monochromatic beams cross) → fringe pattern



- Gaussian intensity distributions of beams
- ↳ " of fringe

Faster particles → higher f of intensity

$$p = \rho g h, \quad U_\infty = \left(\frac{2\rho_1 \Delta h g}{\rho_\infty}\right)^{1/2}$$

$$D_{rag} = \int p \times \cos\theta \times da$$

$$C_p = \frac{p - p_{ref}}{\frac{1}{2}\rho U^2} \longrightarrow C_{D_p} = \frac{\int C_p \cos\theta \, da}{A} \longrightarrow C_{D_p} = \int_0^{2\pi} C_p \cos\theta \, d\theta$$

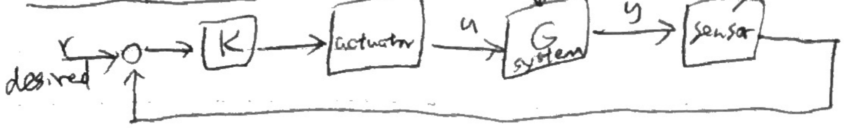
relative pressure throughout a flow field

Quantifies drag on object in environment

Why is $C_{D_p} \approx 0$ around cylinder?

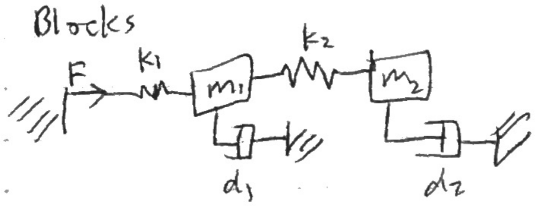
DAC → amplifier → actuator

Position control



encoder → ADC → DSP → PC

Blocks



$$m_1\ddot{x}_1 = -k_1x_1 - d_1\dot{x}_1 - k_2(x_1-x_2)+F$$
$$m_2\ddot{x}_2 = k_2(x_1-x_2) - d_2\dot{x}_2$$

Laplace

voltage to motor

TF $Y(s) = T(s)\,U(s)$

encoder position

$$\omega_n = \sqrt{k/m}$$
$$\omega_d = \omega_n\sqrt{1-\beta^2}, \quad \beta = \frac{d}{2\sqrt{km}}$$
$$\hat{\omega}_d = 2\pi\frac{n}{t_n - t_0}$$

$$C(s) = k_p + \frac{k_i}{s} + k_d s \rightarrow K(s) = \frac{k_d s^2 + k_p s + k_i}{s}$$

root-locus (OLHP), Nyquist (not encircling -1)

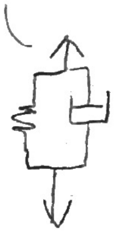
Stress relaxation: Maxwell model — $\dot{\varepsilon} = \frac{\dot{\sigma}}{E} + \frac{\sigma}{\eta}$

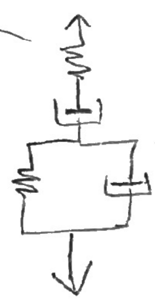
dashpot

plates fixed, stress decreases

Creep: Voight or Four element model

constant load

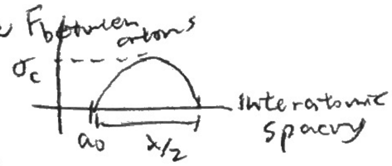




Fracture mechanics

Two ways to estimate strength

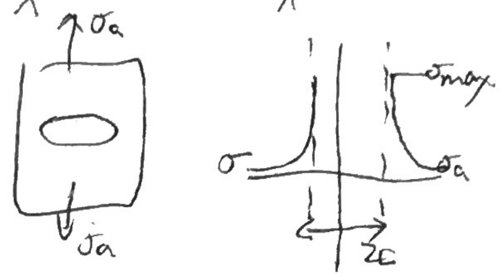
- theoretical cohesive strength: Force necessary to break atomic bonds
- work of fracture to create new surfaces: area under stress-strain curve



$\sigma = E\varepsilon$

$\lambda \sim 2a_0$

$\frac{E}{a_0} = \frac{2\pi\sigma_c}{\lambda} \rightarrow \sigma_c = \frac{E}{\pi}$



$$\text{Work} = \int_0^{\lambda/2} \sigma_c \sin\left(\frac{2\pi x}{\lambda}\right) dx$$

$$\sigma_c = \sqrt{\frac{E\gamma_c}{a_0}} \quad \gamma_s = \text{surface energy}$$

$\frac{\sigma_{max}}{\sigma_a} = 1 + \frac{2c}{b}$ stress concentration factor

c/b = larger for skinner cracks. $\frac{c}{b} = 1$ for circle

$\frac{\sigma_{max}}{\sigma_a} = K_t$ stress concentration factor for sharp notches

Griffith: ~~Fibers~~ Fibers are weakened by microscopic flaws on surface or interior of fiber

- Crack propagation → release of elastic strain energy → Decrease in energy
- crack extension → new surfaces created → increase of energy
- Plane strain condition

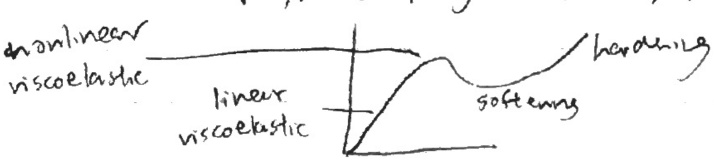
$K_{Ic} = Y\sigma_c\sqrt{c}$ fracture toughness [MPa $\sqrt{m}$]

Y = geometrical constant

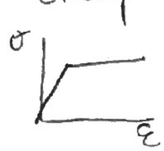
In tension . K_I : scale factor used to define magnitude of crack-tip stress field

$K_I = K_{Ic}$ at onset of crack growth

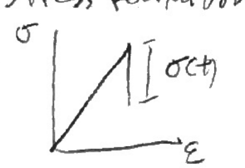
Polymers: long chains of C, H, O molecules (ex. thermoplastics)



Creep



Stress relaxation



Glass transition temp

$T < T_g$ brittle, glassy

$T > T_g$ elastic & plastic deformations