Design of Piezoelectric Active Structure

LECTURE 1. Introduction to Active Materials and Structures

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Adaptive Structures

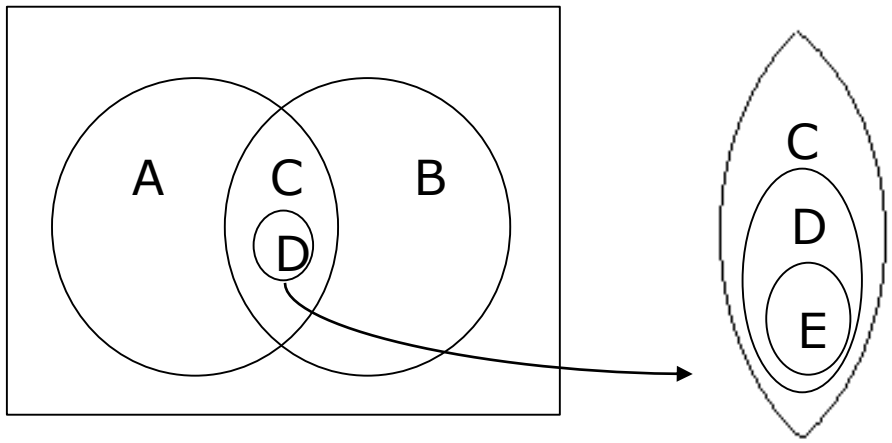
- **Adaptive structure…characteristics can be beneficially changed in response to environment**
  - Actuation
  - Sensing
  - Control
- **Characteristics**
  - shape, geometry
  - stiffness, damping
  - vibration characteristics
  - random signature
  - acoustic reflectivity
- **Stimuli**
  - external force
  - pressure field
  - applies voltage
  - applies magnetic field

Adaptive Structures

❖ Controllable Response

- actuator, sensor control to increase performance to enhance functionality
- complexity not pay for itself

❖ Hierarchy of Adaptive Structure



A : Actuated or Adaptive Structures

B : Sensory Structure (Monitoring of system stats)

C : Controlled

D : Active Materials and Structures

E : Intelligent Structure

Adaptive Structures

❖ Active Structures…analysis tools for integration

➢ Motivation

- Increased Functionality
- Complexity is generic trend

➢ Applications

- Vibration Suppression : multi-payload platform
- Precision Optical [Pointing] System (Interferometry)
- Precision Machining
- Static Shape Control
- Helicopter Vibration
  - Optical Surface Correction
  - Active Optics
  - Deformable Lifting Surfaces
- Active Noise Control
  - Interior…Fuselage, Cockpit
    Elevator
    Rooms
  - Exterior…Torpedoes, Submarines
    Helicopters
- Solid State Motors
- Structural Damage Detection
- Dynamic Flow Structure Interaction
- Gust Buffet Load Alleviation
- Flutter Suppression

Adaptive Structures

❖ Adaptation Mechanisms

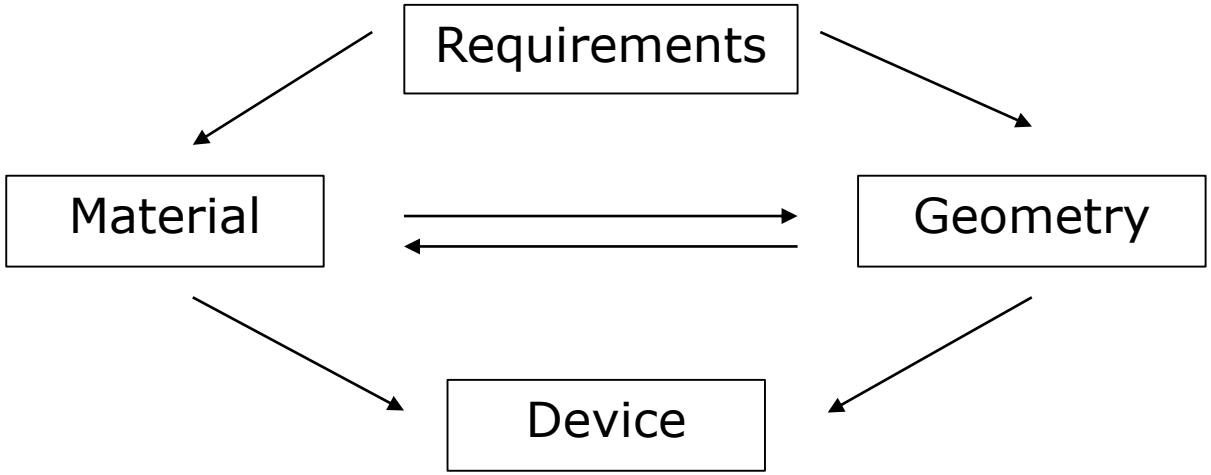
- Material
- Controllable Size
  - Electrically … Piezoelectric Ceramics, Polymers
  - Thermally … SMA
  - Magnetically … Magnetostrictors
  - Optically
  - Chemically
- Controllable stiffness
- Controllable viscosity
  - Electrorheological
  - Magnetorheological

❖ Transducer … works both ways

=> Solid State Actuation Sensing

Adaptive Structures

❖ **Design of Active Structures/Devices**



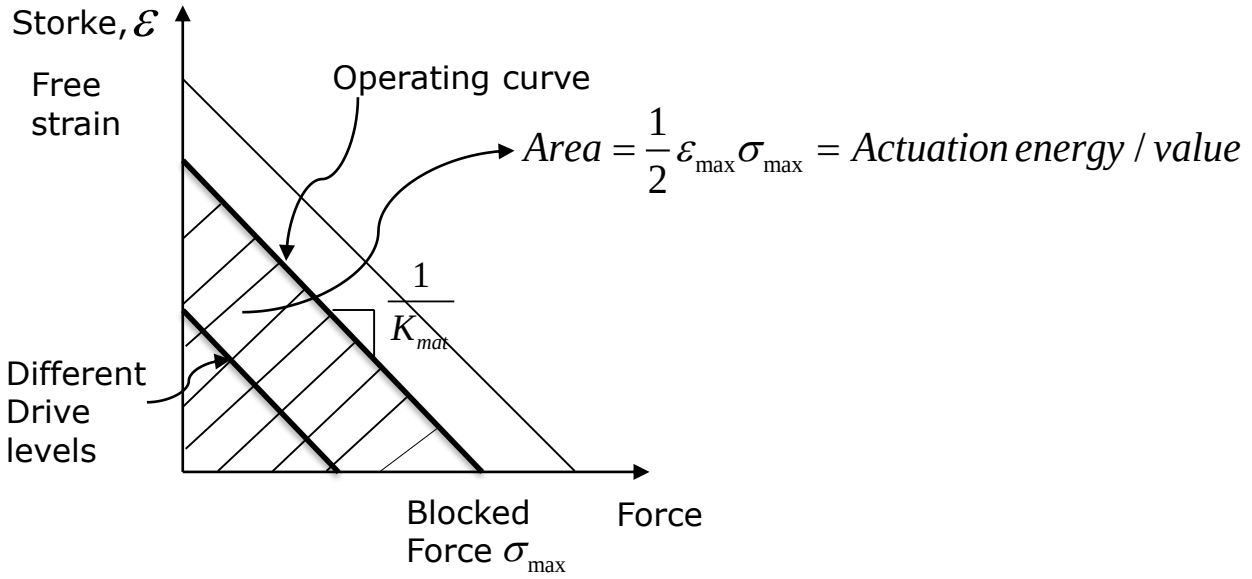
➢ 2 Problems

1) Elastic Actuation
2) Solid State Physics
   - Couple of Fields

Adaptive Structures

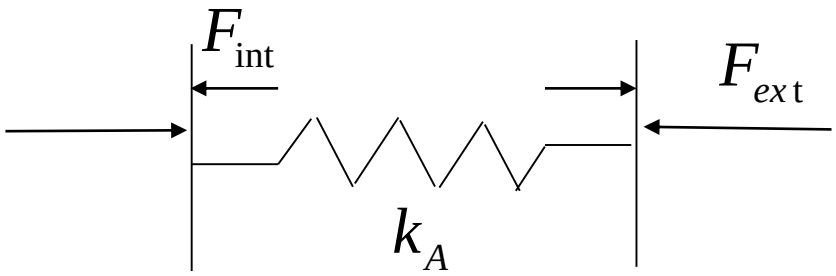
❖ Activation Figures of Merit

- stroke, ε^{free} , ε^{free} /Field
- mcx
- sensitivity
- force, stress
- max, clamped
- Sensitivities



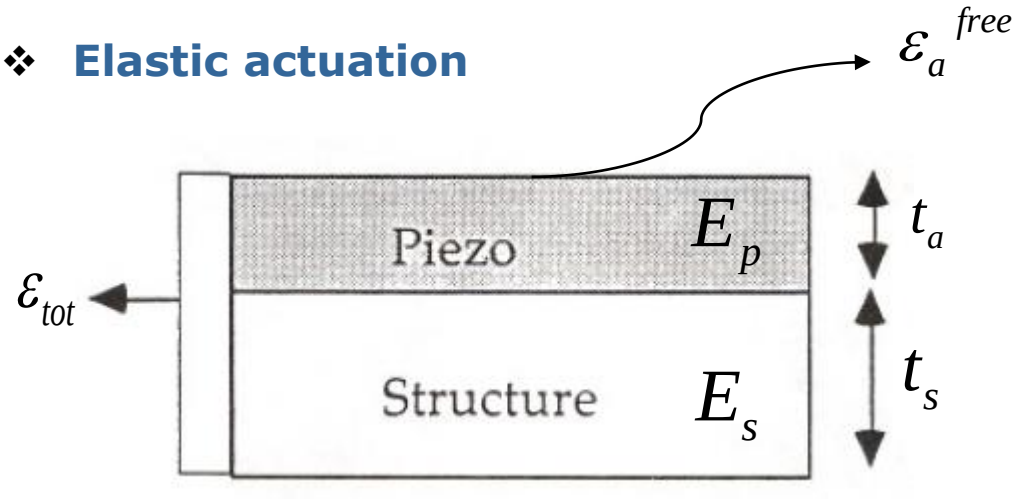
Adaptive Structures

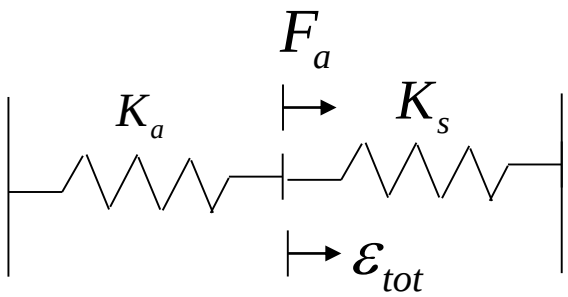
- **1-D (Simple) model**



$$\frac{F_a}{k_a} = x_a$$

- **Elastic actuation**

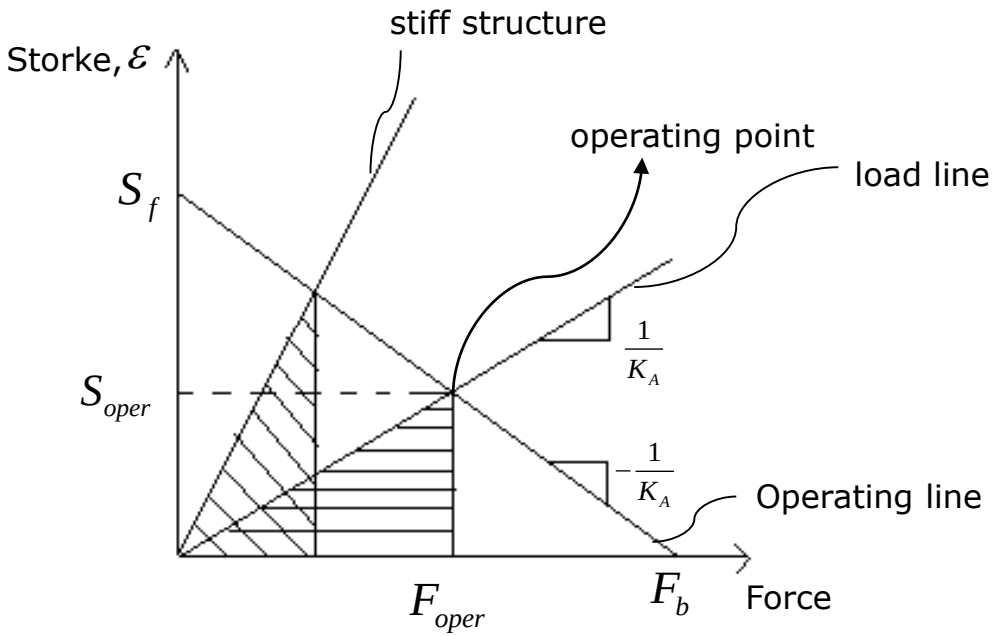




$$\varepsilon_{tot} = \varepsilon_a^{free}\left(\frac{1}{1+\psi}\right), \quad \psi = \frac{E_s t_s}{E_p t_a} = \frac{K_s}{K_a}$$

Adaptive Structures

- Graphical Representation



Maximum work delivered to load is $\frac{1}{4}\cdot\frac{1}{2}S_f F_b = \frac{1}{4}\cdot\frac{1}{2}\varepsilon_a^{\,free}\sigma_a^{\,blocked}$

Actuation Energy Density = $\dfrac{\frac{1}{2}\varepsilon^f \sigma^b}{\rho}$