Adaptive Structure

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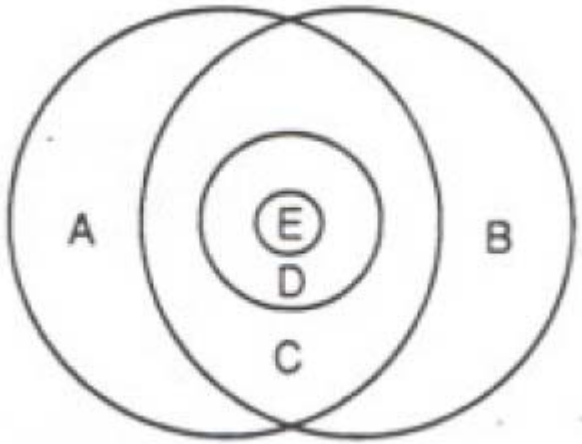
Adaptive Structure

❖ 1. General framework



A ... Adaptive Structures
B ... Sensory Structures
C ... Controlled Structures
D ... Active Structures
E ... Intelligent Structures

Fig.1 Proposed Framework.

Adaptive Structure

❖ 2. Basic Categories

"sensory" structures … which possess sensors that enable the determination or monitoring of system states or characteristics

"adaptive" structures … which possess actuators that enable alteration of system states or characteristics in a controlled manner

"controlled" structure … both sensors and actuators in a feedback architecture for the purpose of actively controlling system states or characteristics

Conventional structure + separate and distinct control system

"active" structures … contains sensors and/or actuators that are highly integrated into the structure and have structural functionality in addition to control functionality

"intelligent" structures … highly integrated control logic and electronics that provide cognitive element of a distributed or hierarchic control architecture

Adaptive Structure

Ⅱ. Adaptive structures … “can purposefully vary its geometric configuration as well as its physical properties”

① Geometry adaptive

- Deployable space antenna, Hoop Column Antenna
- Space Crane
- Variable Geometry Truss (VGT)
- Adaptive wing geometry … swing wing, fowler flaps, lifting surface with maneuver flap scheduling

② Feed forward control of mechanical properties

- change of the damping characteristics of viscoelastic materials
- electro-rheological material
- shunted piezoelectric damping or passive electronic damping
- shape memory materials (Nitinol) … plastic strain ≃ 2%
  recovering stress = 100.000 psi

Adaptive Structure

Ⅲ. Controlled structures … both sensors and actuators, connected through a feedback architecture

- Rigid body control … state to be controlled → attitude, position

  bandwidth of the controller << fundamental flexible frequency → rigid body

  bandwidth of the controller >> fundamental flexible frequency → flexibility

  must be considered → attitude controllers for spacecraft with flexible appendages

- More advanced type → relative motion i.e, shape and dynamic response

  → { vibration control … damping, propagation, rejection characteristics
    { shape control

- Vibration control

  i) Active damping … proof mass actuator

  ii) SMA wire … actively damp a vibrating beam

  iii) Active isolation and wave propagation control

  iv) Active stabilization …. Suppression of aircraft flutter, gust alleviation

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- Shape control … control of optical surfaces

Ⅳ. Active structures … integrate the control sensors and actuators with the structure to such a degree that the distinction between control functionality and structural functionality is blurred.

actuators widely applied to the surface or are embedded

- strain actuation approach

① Distributed strain actuation … actuation materials are bonded to the surface or embedded within a composite structure

$$\varepsilon = \frac{\sigma}{E} + \Lambda$$

↖ Actuation strain (analogous to thermal strain)

strain induced in the structure

$$\varepsilon = \frac{\alpha}{\alpha + \psi}\Lambda$$

ψ : measure of the relative mechanical impedance

α : depends only on geometry

- piezoelectrics … natural crystals, polymers, or ceramic materials, hysteresis

Adaptive Structure

- electrostrictive … monopolar nonlinear relation between electric field and strain. No hysteresis
- magnetostrictive … couple applied magnetic field and strain relatively small strain, large bandwidth
- shape memory metal … heating or cooling will cause a martensitic/ austenitic phase change, cyclically recoverable strain relatively large strain ~ 8%

surface bonded … segmented piezoceramics → position feedback , active damping wave propagation property, quasi-static shape control

Embedded inside a composite laminate … enhanced load transfer free of fragile components and connections more options for finding the optional geometry. complications include electrical insulation and manufacturing of ceramics and electrical leads

② Discrete Active Structures

- Active truss