SMART NEST

Smart Hybrid Semi-Active Dampers

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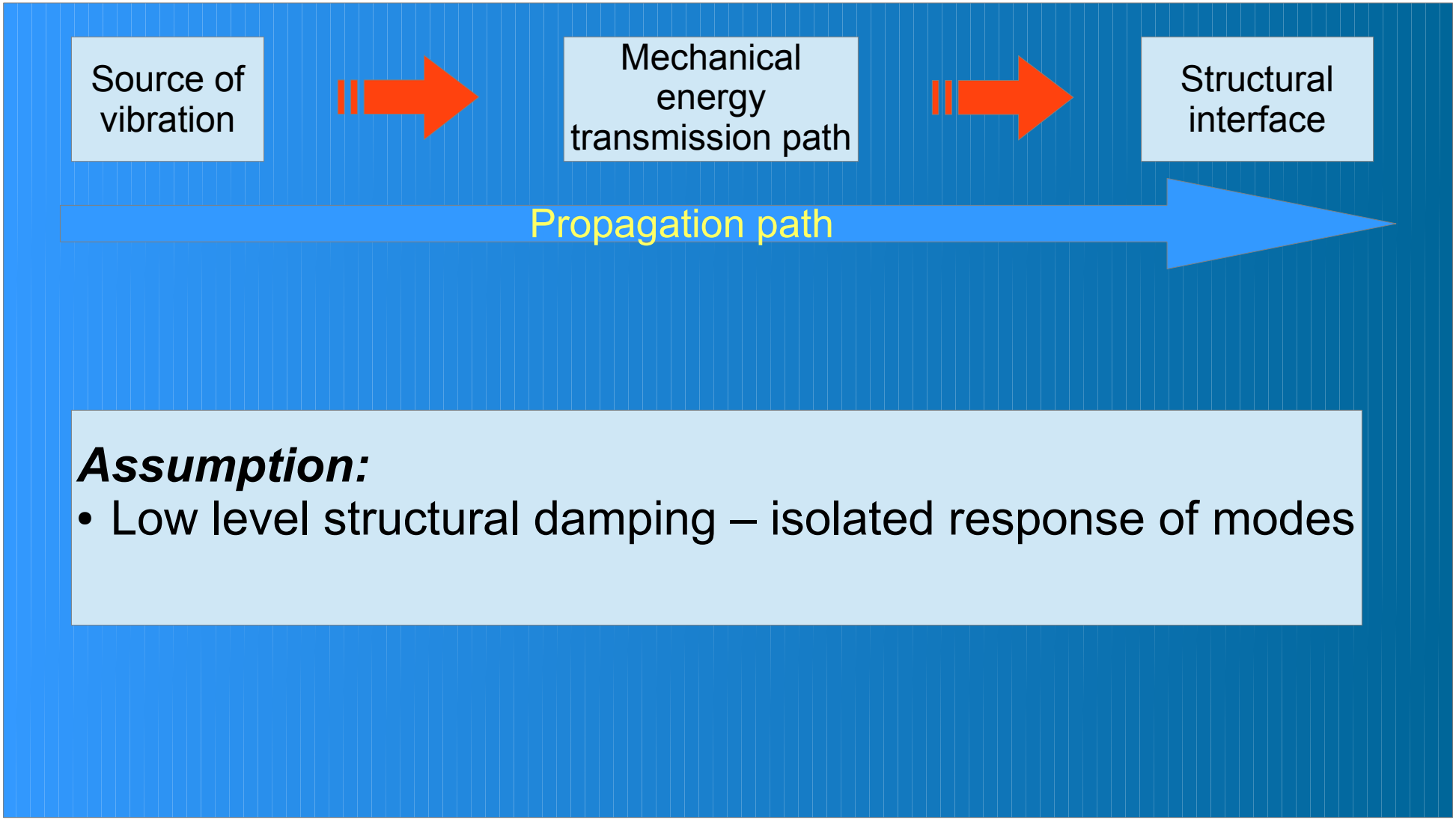
Outline

- **Vibration control problems classification**
- **Current challenges in the vibration control systems**
- **Specific features of piezoelectric materials and applications to vibration control**
- **Hybrid approach and planned activities**

Vibration control problems classification



Assumption:

- Low level structural damping – isolated response of modes

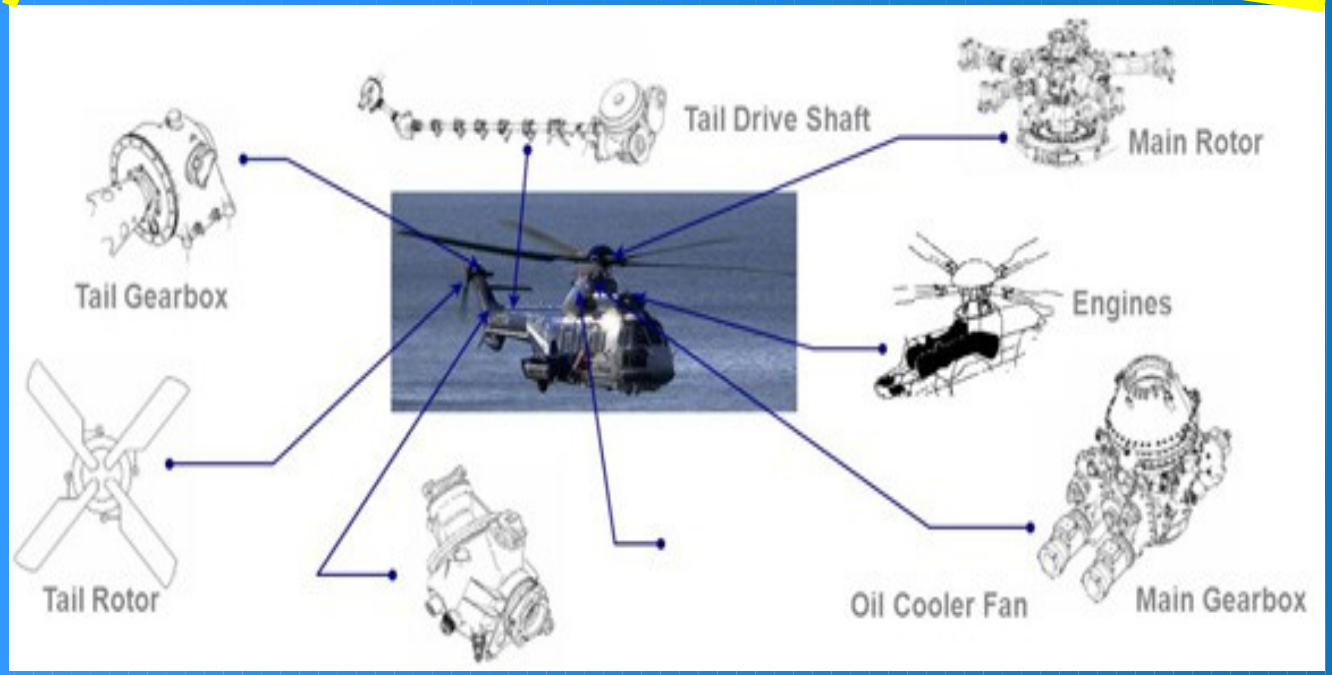
Vibration control problems classification

Source of vibration

Mechanical energy transmission path

Structural interface

Propagation path



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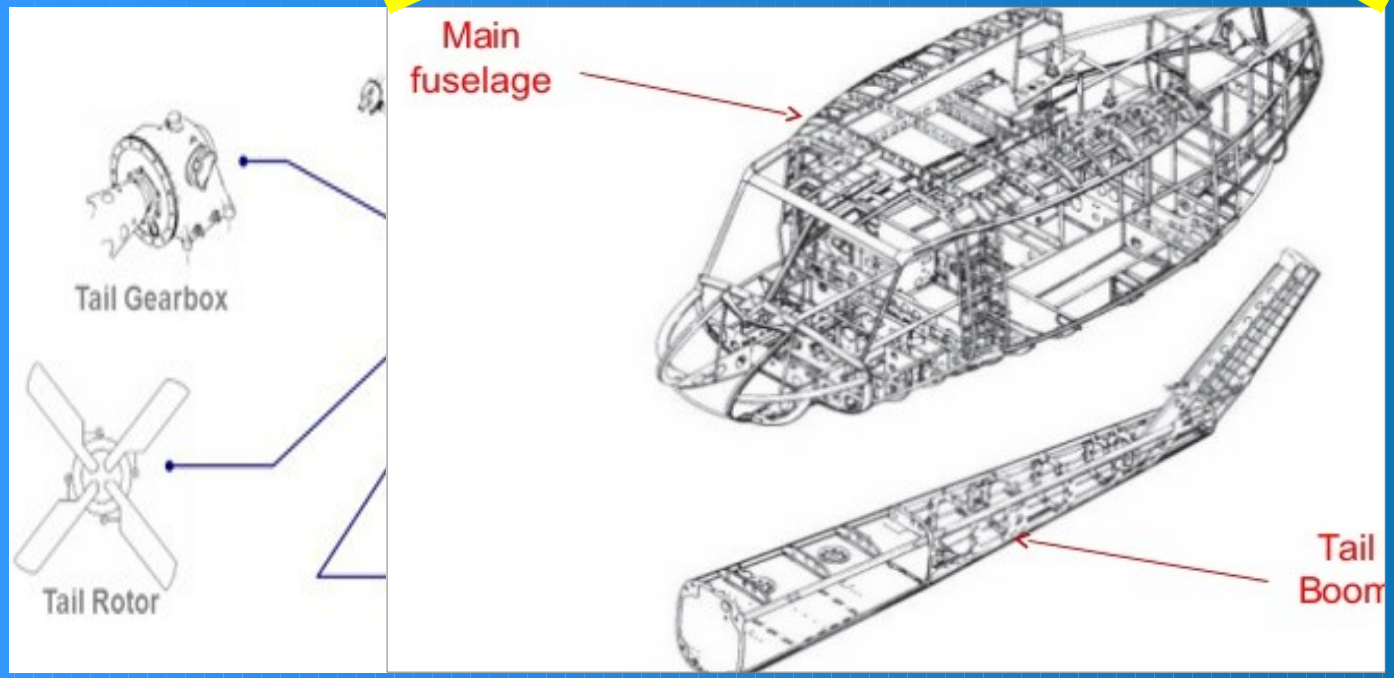

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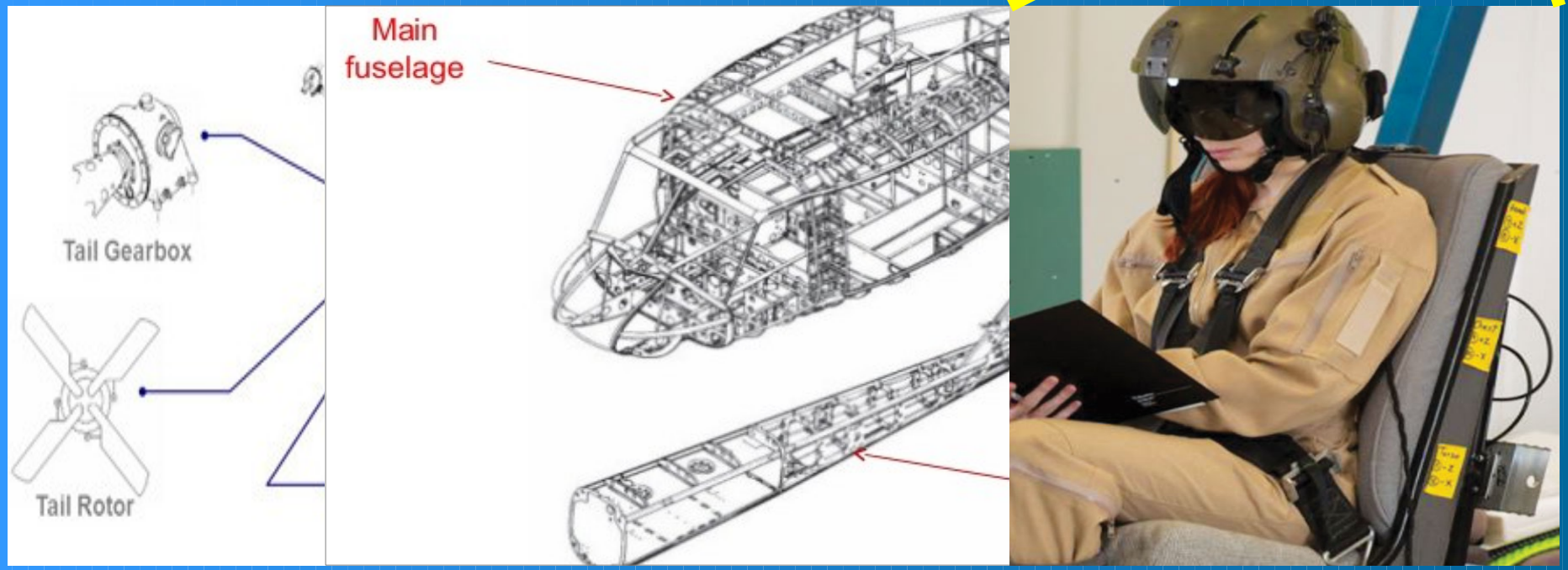
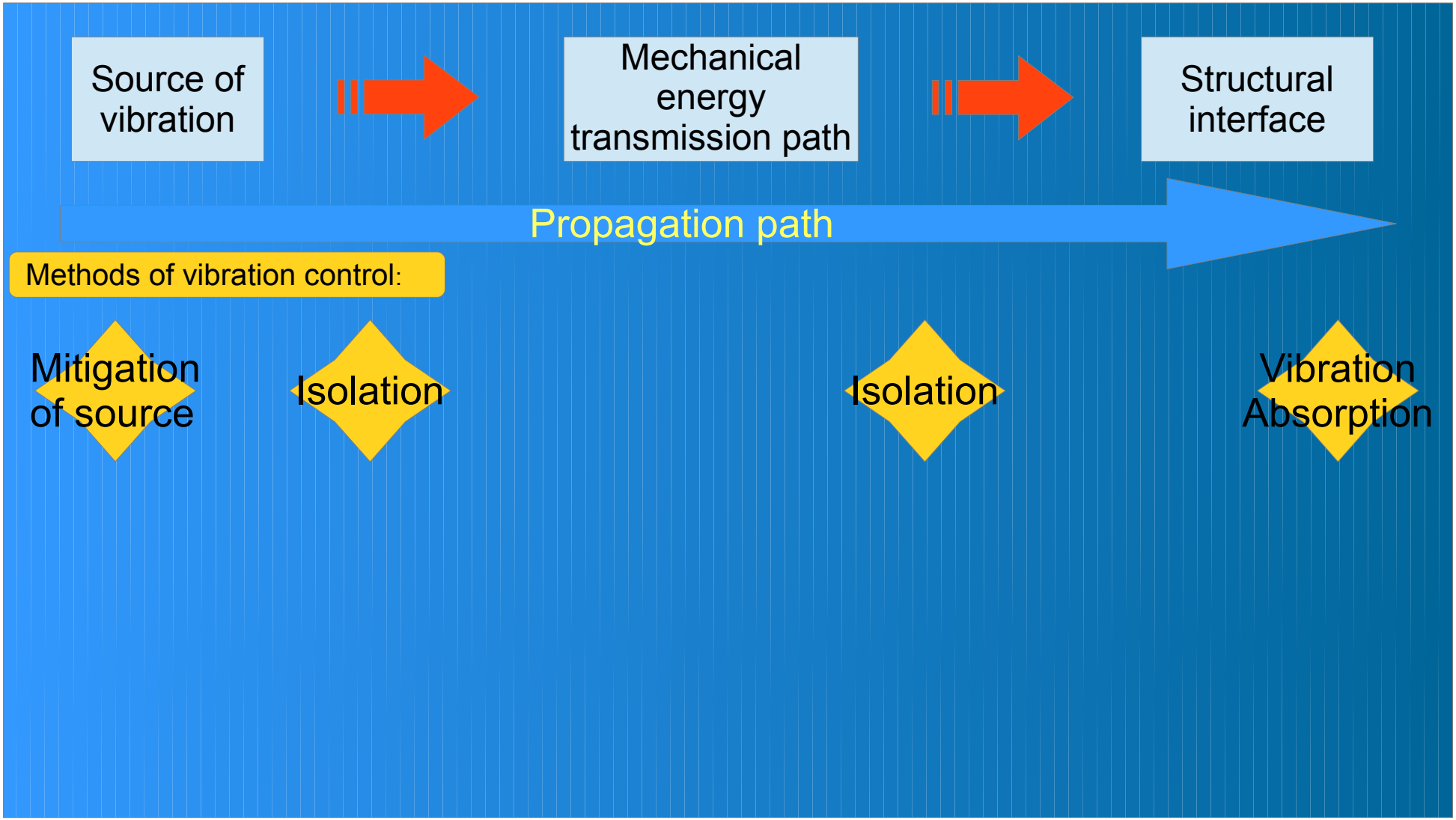


Vibration control problems classification



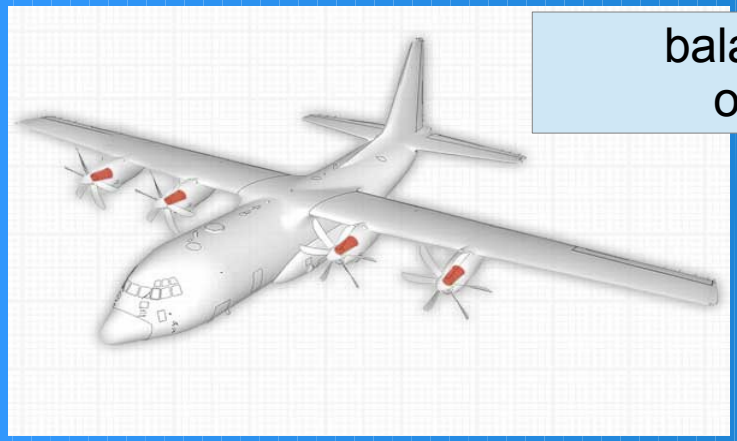
Vibration control problems classification

Source of vibration → Mechanical energy transmission path → Structural interface

Propagation path

Methods of vibration control:

- Mitigation of source
- Isolation
- Isolation
- Vibration Absorption



balancing systems for rotors of the propeller engines

Vibration control problems classification

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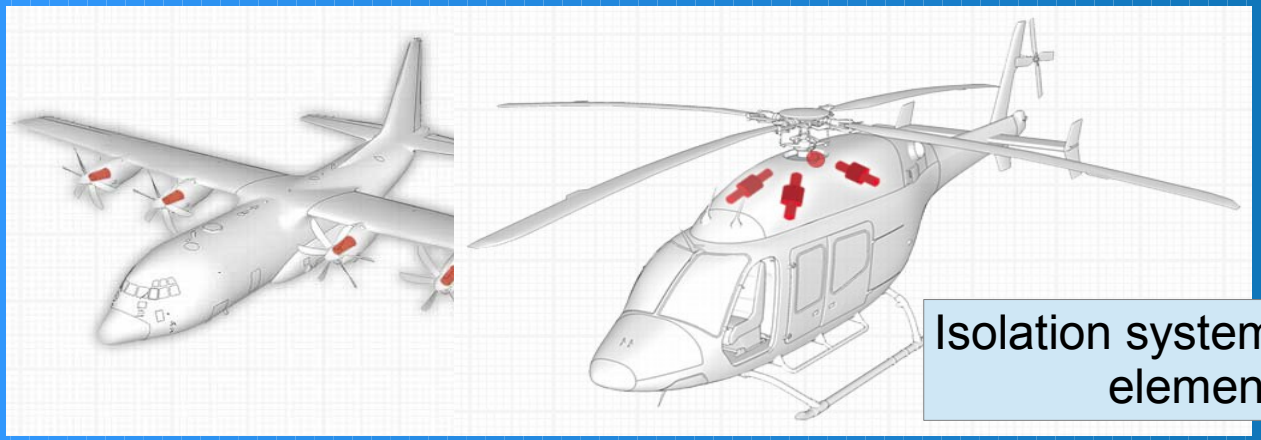

Isolation systems on the main structural elements of a rotorcraft

Vibration control problems classification

Source of vibration → Mechanical energy transmission path → Structural interface

Propagation path

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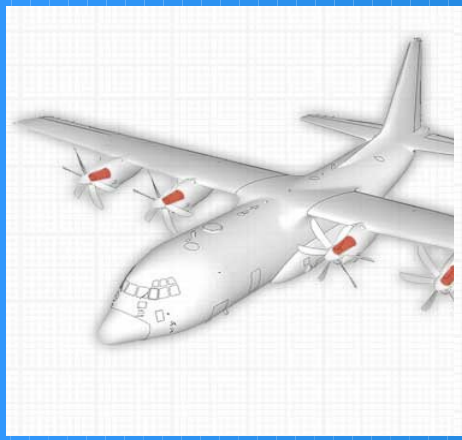
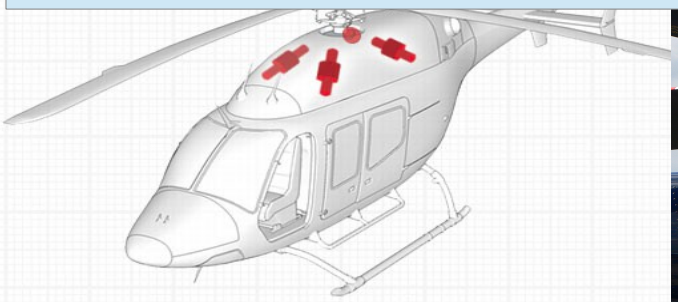
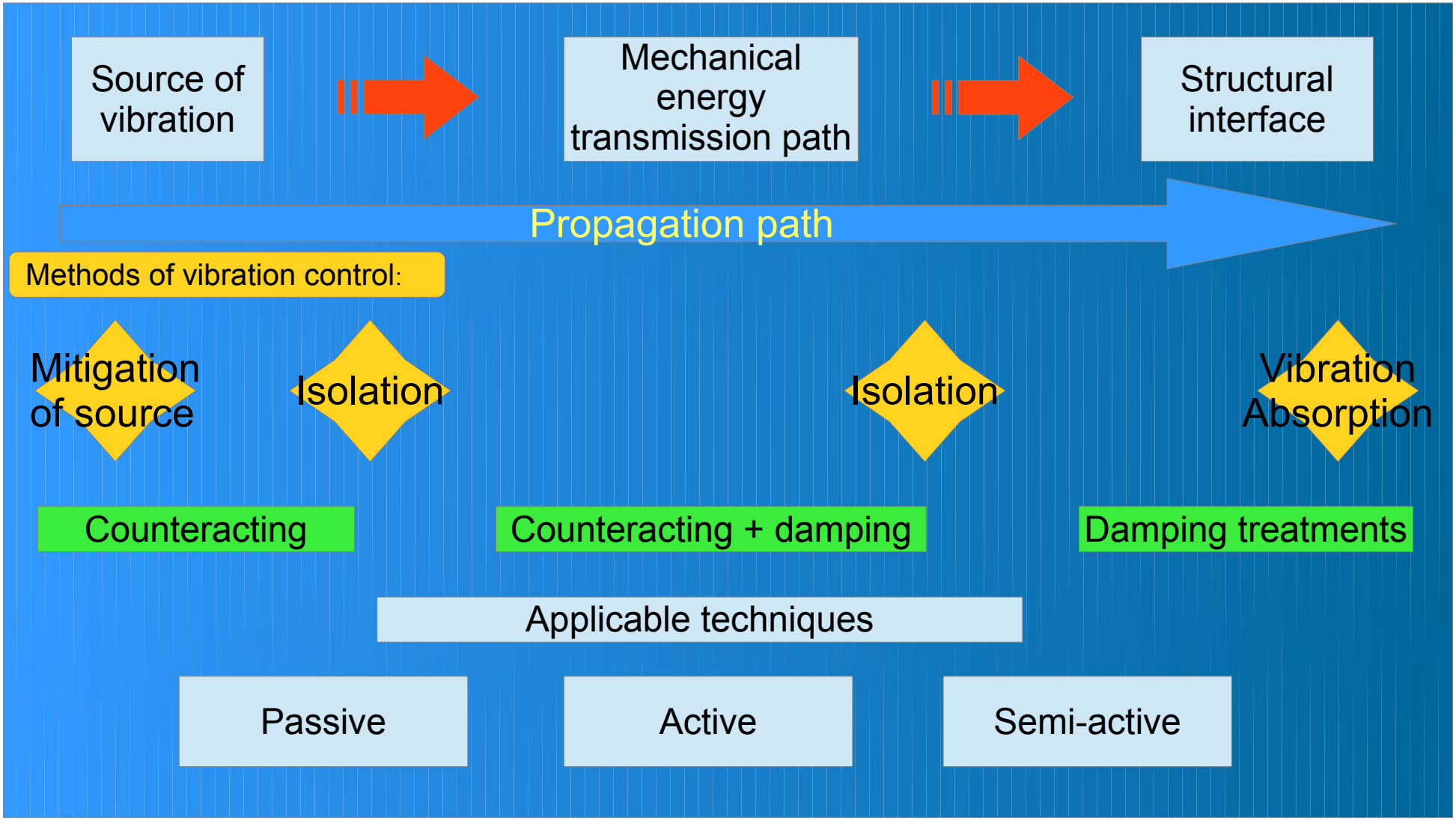


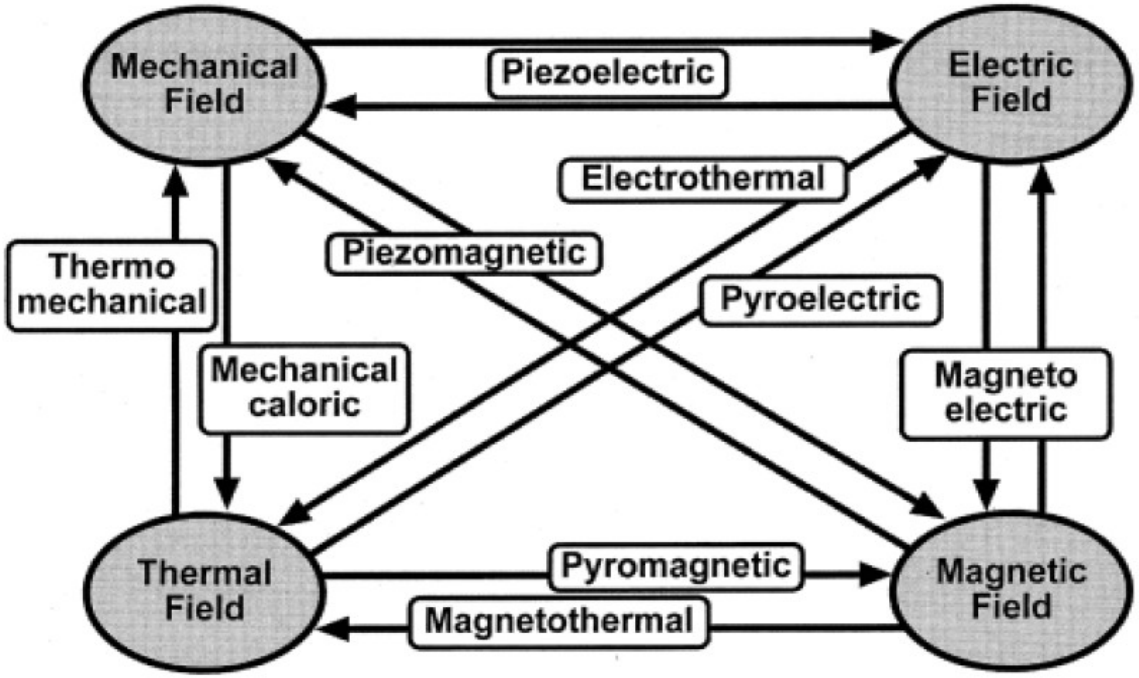
Bifilar vibration absorbers on the main rotor



Vibration control problems classification



Functional materials

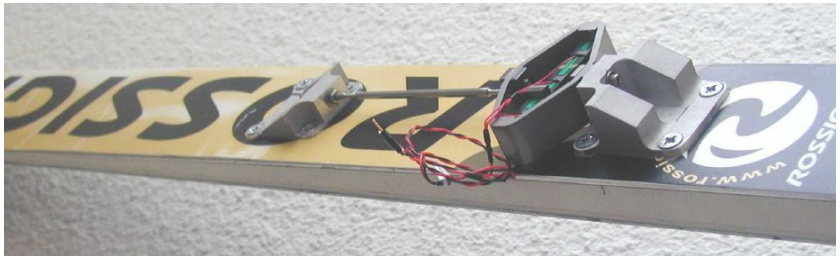


- SMA shape memory alloys NiTiNol
- Magnetostrictive Terfenol
- Piezoelectric ceramics PZT
- MRF magnetorheological fluids

- **Features awaited for vibration control:**
- Reversity of the phenomenon
- Wide frequency response
- Efficiency of conversion

Vibration control systems based on functional materials – examples:

- **Source mitigation** – active system

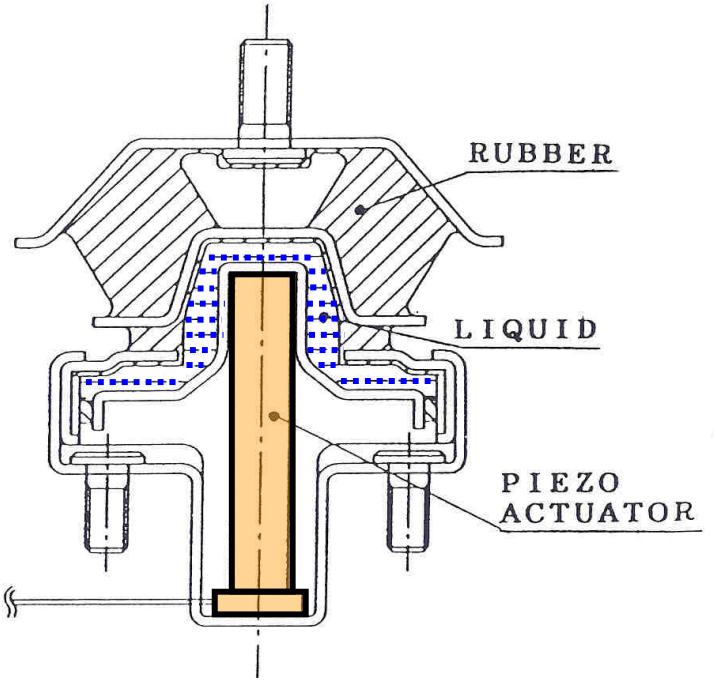


- Bending reduction system based on piezoelectric actuator by Cedrat Tech.

- **Vibration isolation** - Semi-active hydro-mounts

- Semi-active hydromount

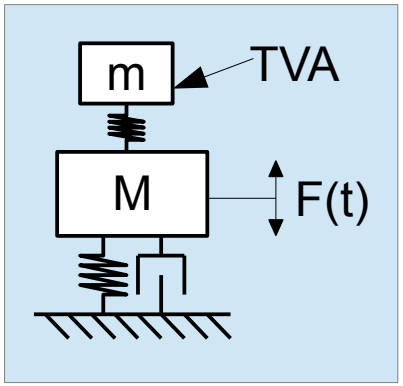
- **Vibration isolation** - active system



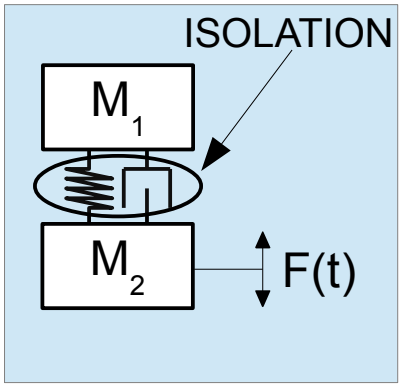
- Active hydro mount

Adaptive demands for classical vibration control systems

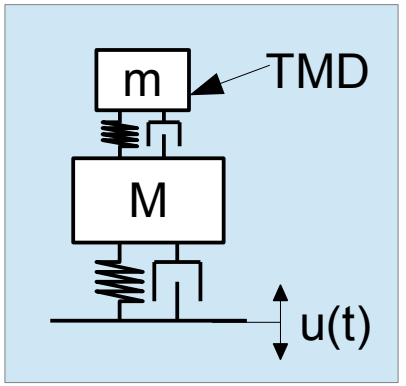
- **Source mitigation**



- **Isolation**

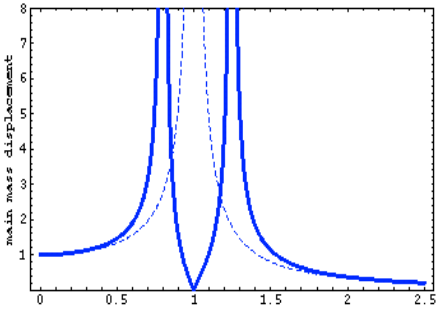


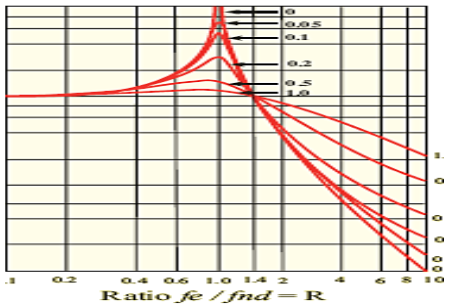
- **Absorption**

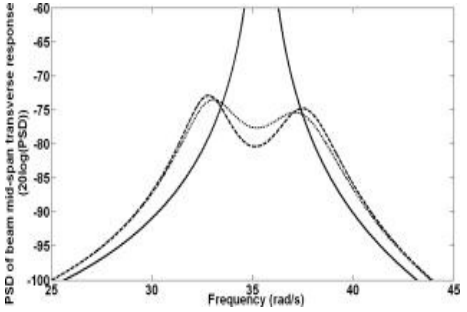


- **Demands:** adaptivity within a certain bandwidth (e.g. resistance to temperature variations)

- **Frequency response functions:**







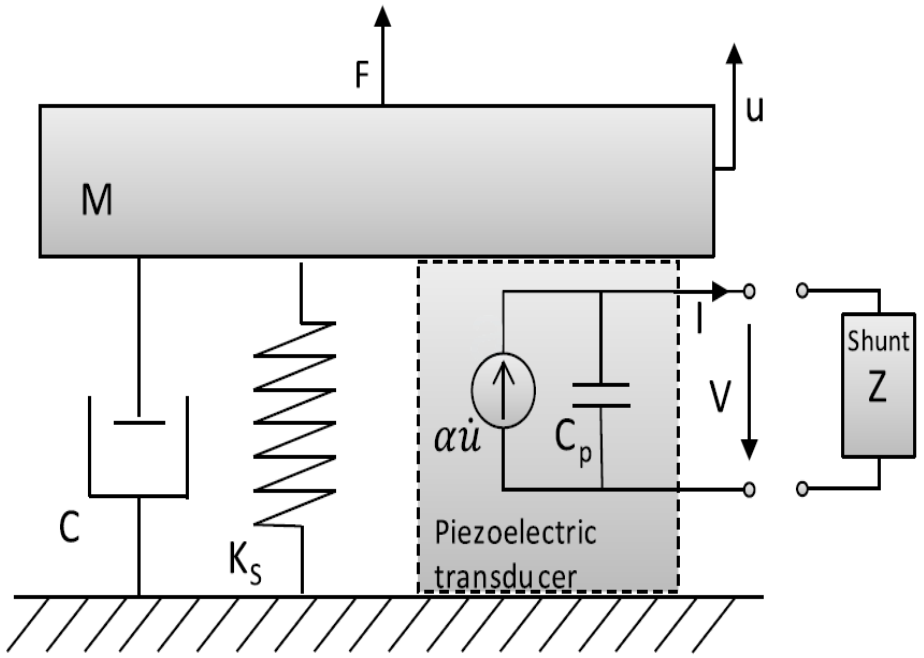
Possible means of tuning by modification of:

Stiffness *Damping+Stiffness* *Damping+Stiffness*

Shunting techniques -modifiable mechanical properties of piezoelectric ceramics

Stiffness:

Capacitive shunt: a capacitive element in the shunt network will change the apparent stiffness of the piezoelectric element without affecting the damping properties of the structure.



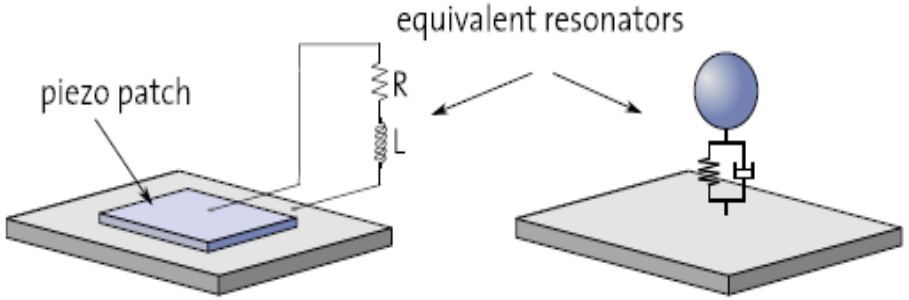
Structural damping:

Resistive shunt: shunting a resistive element to the piezoelectric element means that some of the electrical energy is lost in the circuit through Joule heating. This virtually works as augmenting the structural damping

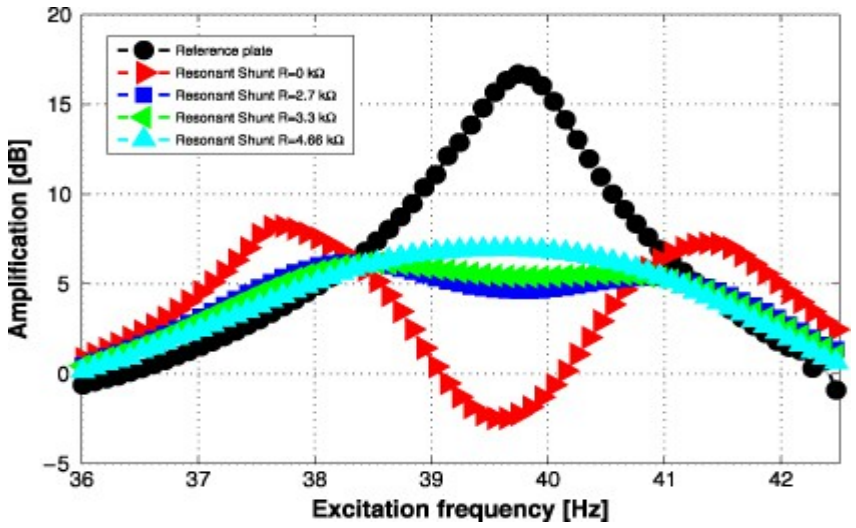
Shunting techniques - resonant circuit of piezoelectric ceramics

Resonant system:

Inductive shunt: since the piezoelectric element behaves electrically as a capacitor, shunting an inductive element will result in a resonant LC circuit.



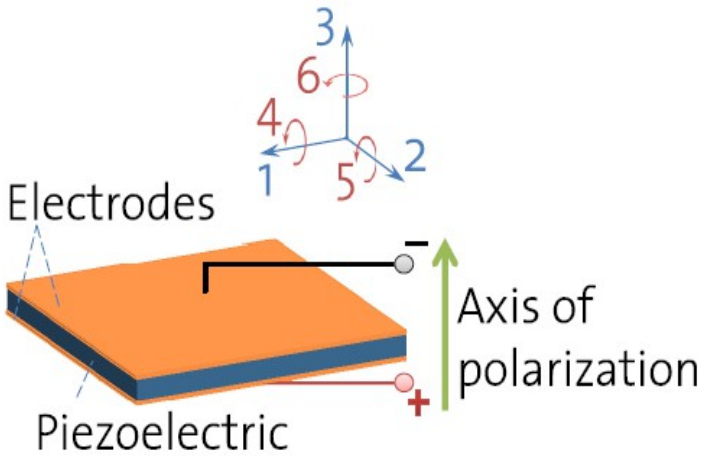
$$\omega_e = \frac{1}{\sqrt{LC}}$$

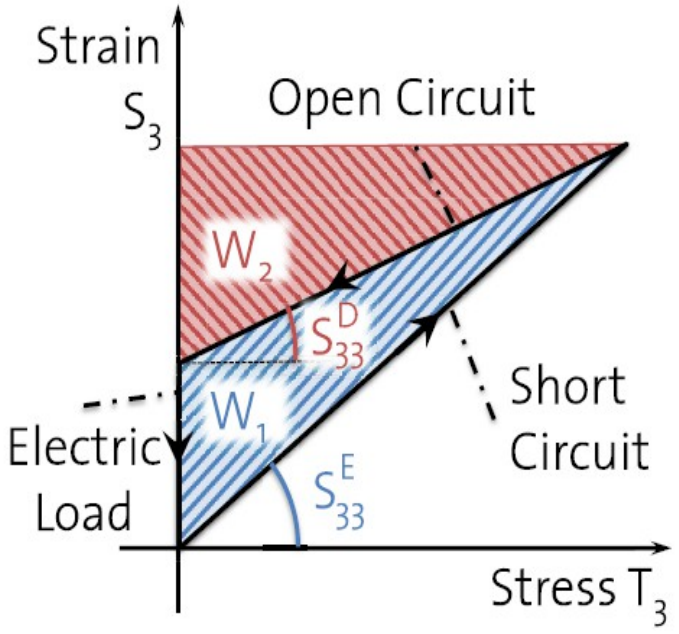


Disadvantage: In the low frequency range the tuned electrical circuit needs a coil of inductance above 10 H, which requires a significant amount of volume.

Switch shunting techniques

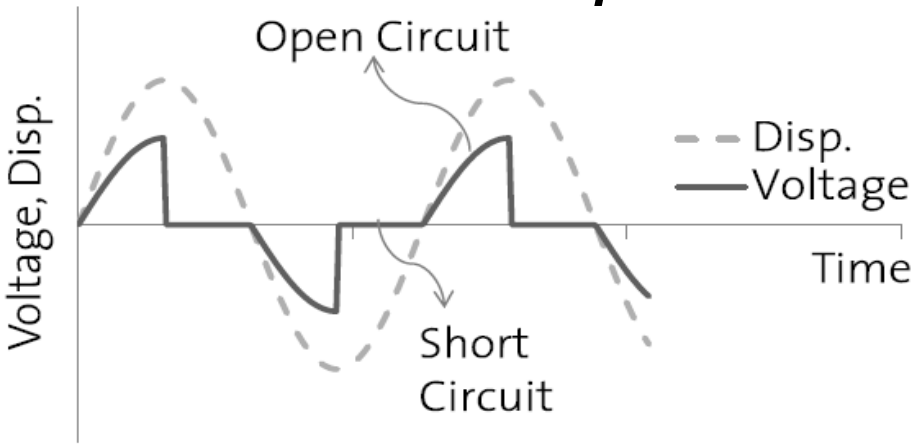
Switched shunt: a switched network can change its characteristics rapidly based on the state of the mechanical system. This enables a control of the energy transfer.

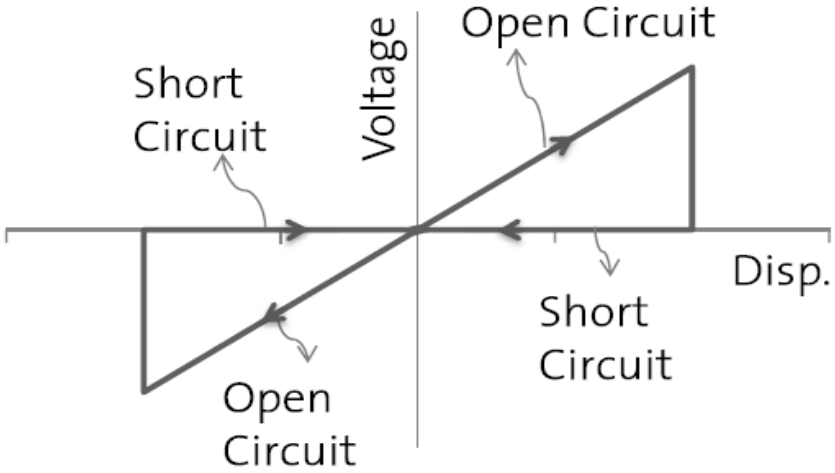




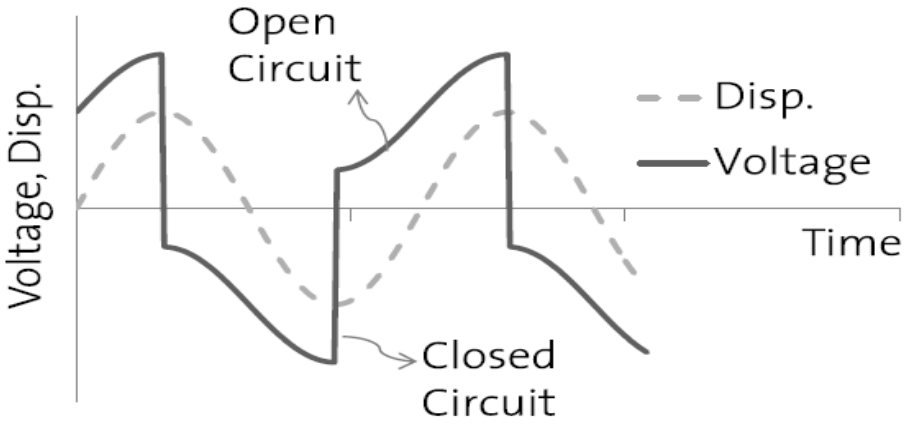
Electro-mechanical conversion of switch shunted piezoelectric ceramics

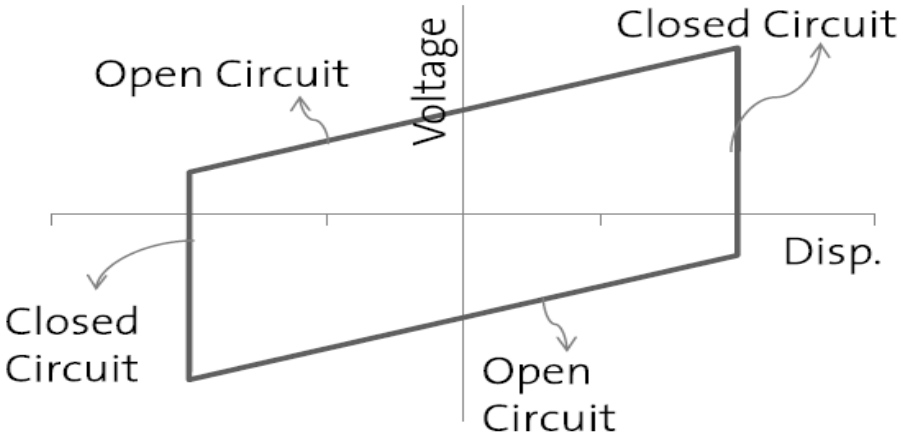
State switched shunt responce:



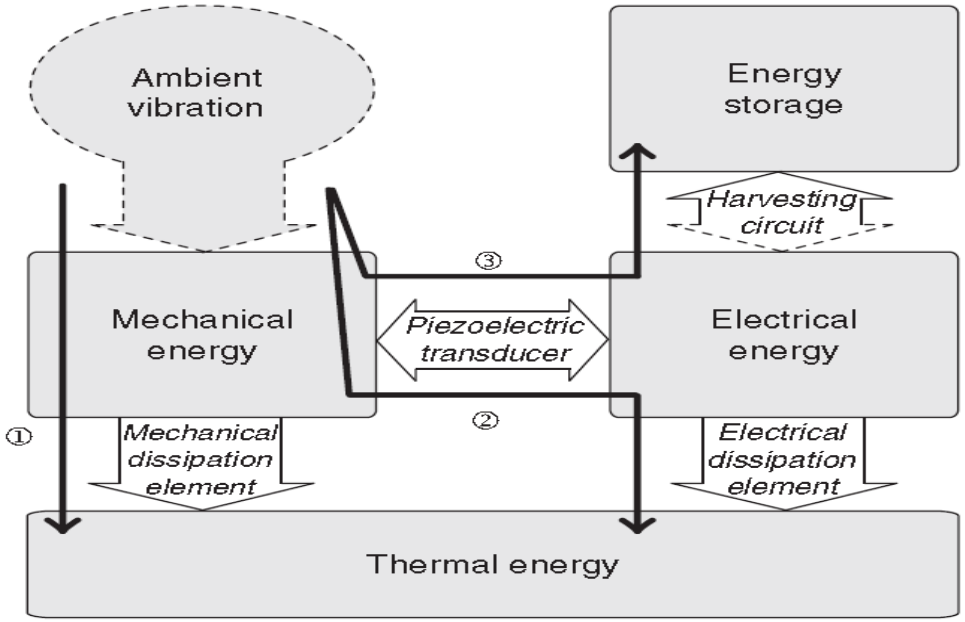


Synchronised switched shunt responce:

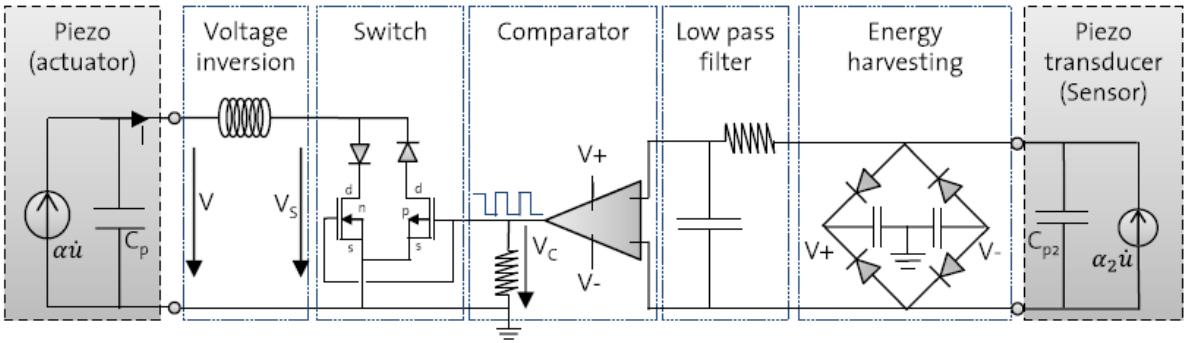




Hybrid System for Vibration Control



Self power system concept by Liang and Liao (2009)



Self power SSD system proposed by T. Delpero (2014)

Objectives:

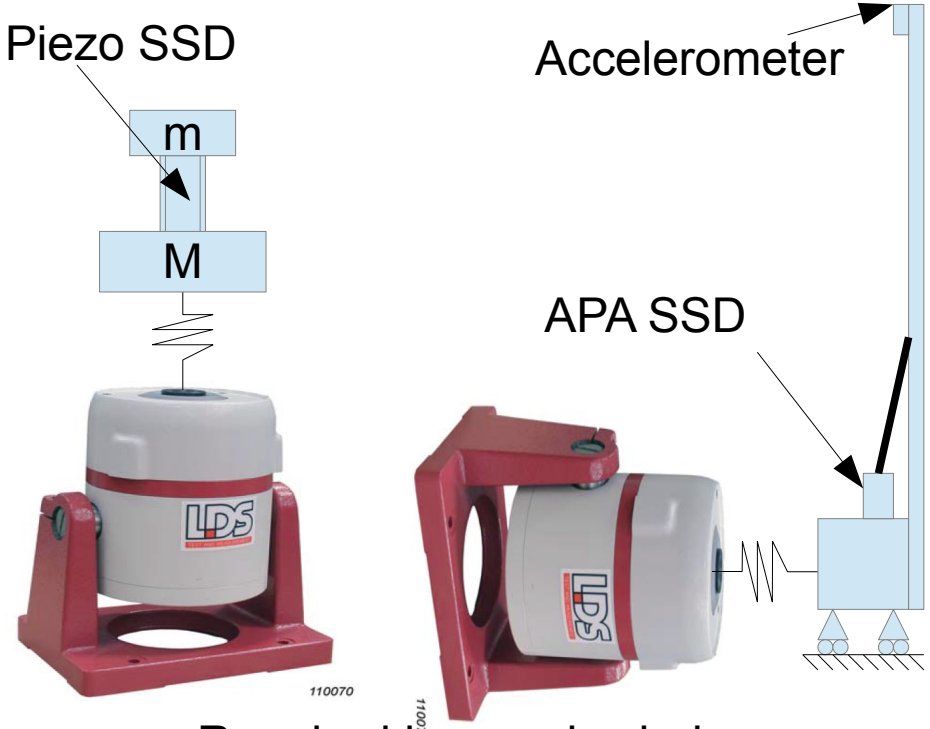
- The objective for the hybrid systems development is to provide good performance in vibration level mitigation like with active systems, but with lower energy supply requirements.
- The performance does not have to be as high as in the case of active systems but the energy consumption should be much lower.

Further research steps

Tests on a lab demonstrator -
Switch shunt damping

Single mode case
SSD - TMD

Multi mode case
SSD - BEAM



Required harmonic shaker

Conclusions

- The objective of this investigation was to recognize the vibration control technique based on semi-active methods.
- A broad literature sources encourage to utilize the SSD technique as efficient in the vibration control task.
- A feasibility study of semi-active vibration control systems **based on SSD and a synthetized electrical impedance was chosen for further development**.