«EMR and inversion-based control of a piezoelectric actuator »

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1. **Introduction**
   - Introduction to piezoelectricity
   - Piezoelectric actuator

2. **EMR of a piezo-actuator**
   - Electromechanical modeling
   - Modeling in rotating frame

3. **Inversion-based control of a piezo-actuator**
   - Vibration amplitude control
   - Tracking of resonance frequency

4. **Conclusion**
«1. Introduction»
Certain materials produce electric charges on their surfaces as a consequence of applying mechanical stress.

Pierre Curie (1859-1906), Nobel Prize in Physics, 1903

Refers to a deformation of these materials that results from the application of an electric field.

Gabriel Lippmann (1845-1921), Nobel Prize in Physics, 1908

Piezoelectricity is extensively utilized in the fabrication of various devices such as: transducers, actuators, surface acoustic wave devices, frequency control and so on.
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- Piezoelectric actuator -

A: Langevin transducer
B: Metal mass
C: Pre-stressed Bolt
D: Piezoelectric elements
«EMR of a piezo-actuator»
« EMR and inversion-based control of a piezoelectric actuator »

- EMR of a piezo-actuator -

\[ \dot{\dot{w}} + d_s \dot{w} + c \dot{w} = \gamma v - f \]
$$m\ddot{w} + d_s \dot{w} + c w = \gamma v - f$$

$$w = (W_d + j W_q) e^{i \omega t}$$

$$v = (V_d + j V_q) e^{i \omega t}$$

$$f = (F_d + j F_q) e^{i \omega t}$$

$$(c - m \omega^2) W_d - \omega (2 m \dot{W}_q + d_s W_q) = \gamma V_d - F_d$$

$$(c - m \omega^2) W_q + \omega (2 m \dot{W}_d + d_s W_d) = \gamma V_q - F_q$$

Power supply

Piezoelectric actuator

Electrical source

Inverter

Rotation matrix

Electromechanical Transformation

Elastic Coupling

Accumulation element

Mechanical source
«Inversion-based control of a piezo-actuator»
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- EMR of a piezo-actuator -

Tuning path

Control path
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\[
\frac{W_q}{W_d} = \frac{(c - m\omega^2)}{\omega(2ms + ds)}
\]

\[
(c - m\omega^2)W_d - \omega(2m\dot{W}_q + dsW_q) = \gamma V_d
\]

\[
(c - m\omega^2)W_q + \omega(2m\dot{W}_d + dsW_d) = \gamma V_q
\]

\[
\frac{W_d}{V_q} = \frac{G}{1 + \tau_s}
\]

Electrical source \[\rightarrow\] Inverter \[\rightarrow\] Rotation matrix \[\rightarrow\] Electromechanical Transformation \[\rightarrow\] Elastic Coupling \[\rightarrow\] Accumulation element \[\rightarrow\] Mechanical source
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- **Graph 1:**
  - Frequency vs. Time [Hz]
  - Frequency range: 2.7905 to 2.793 x 10^7
  - Time range: 0 to 0.12 s

- **Graph 2:**
  - Vibration amplitude vs. Time [µm]
  - Vibration amplitude range: -0.5 to 2.5 µm
  - Time range: 0 to 0.12 s

- **Graph 3:**
  - Voltage vs. Time [V]
  - Voltage range: 30 to 60 V
  - Time range: 0 to 0.12 s

Graphs show simulated and measured data for vibration amplitude, frequency, and voltage over time.
Conclusion
Conclusion

- A piezoelectric model is described in a rotating frame
- Energetic Macroscopic Representation (EMR) and inversion-based control
- Results are confirmed with experimental validation and numerical simulation
- Control of the travelling wave in a finite beam, in both direction and vibration amplitude
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