« Speed estimation for a forging vibrating tool »

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- Outline -

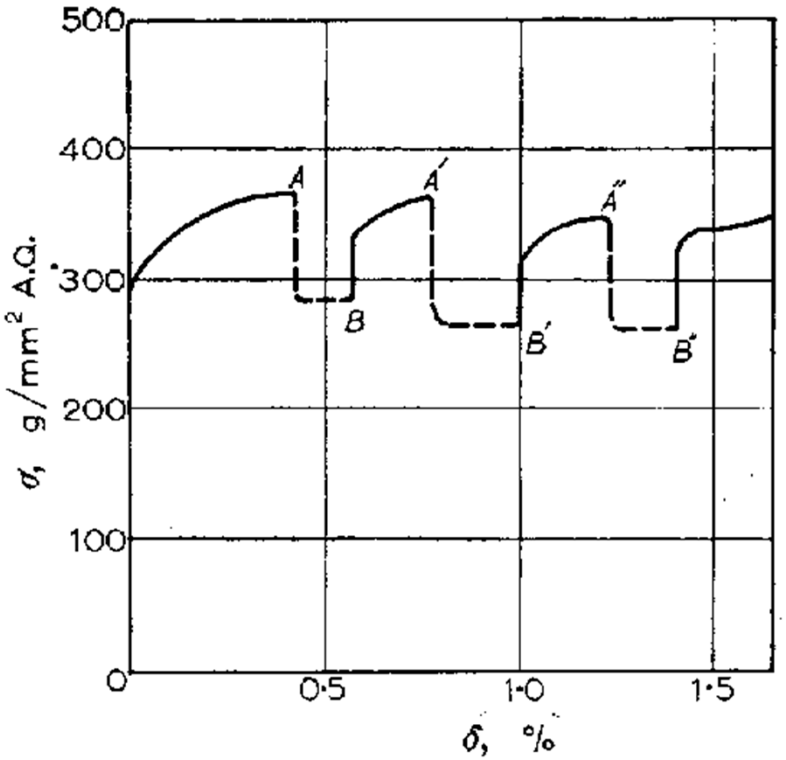
1. Context

2. Piezoelectricity

3. EMR and speed estimator

« Part 1 context »

Ultrasonic vibrations superimposed during tensile tests reduce the forging load



[Blaha 1959]

Many research have applied this to several forming processes :

- Results are promising
- Questions are still open
- Small displacements, high forces and fast dynamic are required therefore piezoelectric actuators are interesting

Experimental set-up : upsetting with superimposed vibration

Forging in literature : only simulation

Experiments : Effect of waveforms, at low frequencies on aluminium, copper or plasticine during upsetting

Experimental set-up

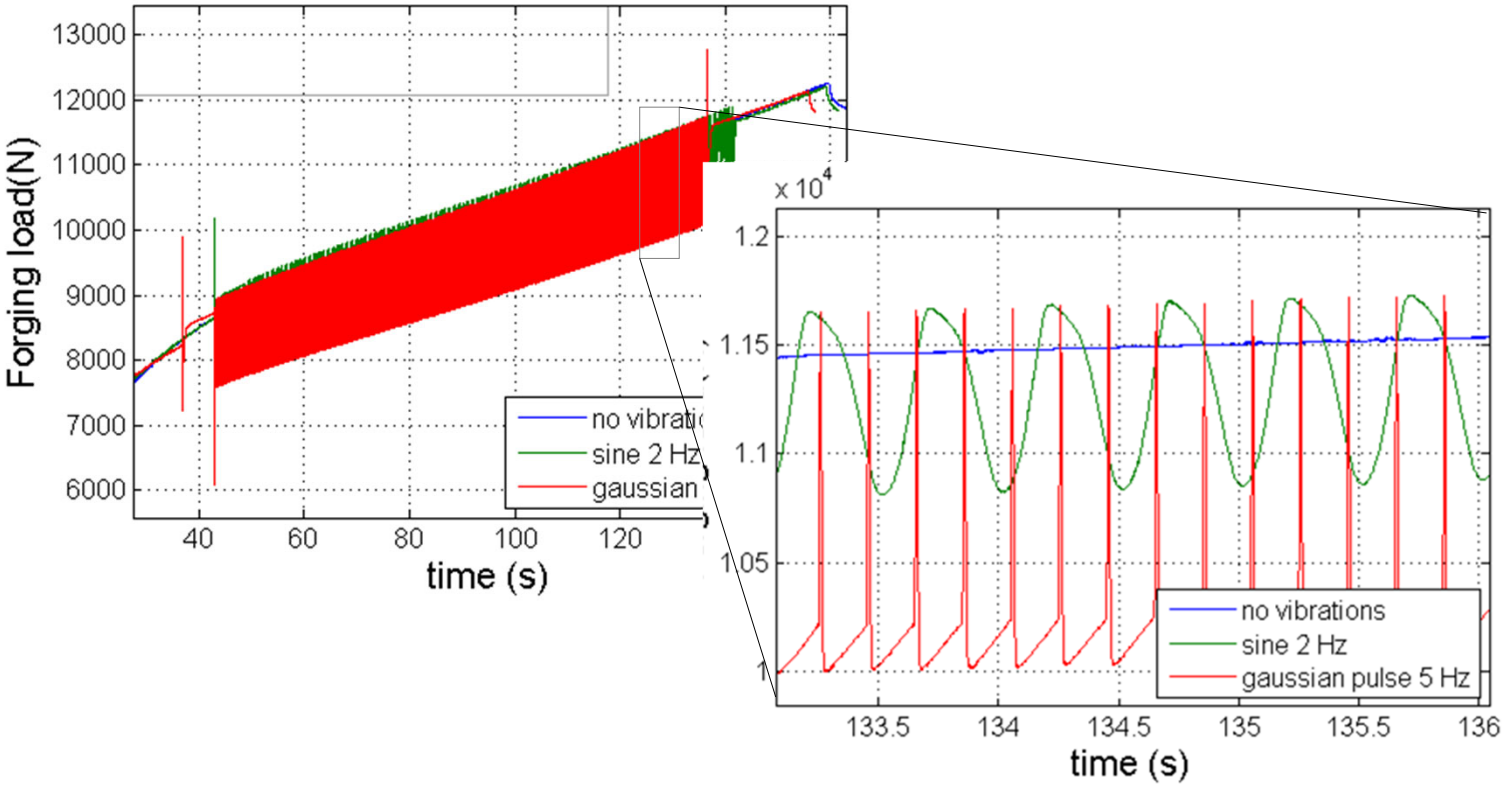
Hydraulic press

Vibrating tool

Displacement sensor

Results [Ly 09, Nguyen 12]:

- Similar effect are obtained at low frequencies
- Key parameter : waveforms



« Part 2 : Piezoelectricity »

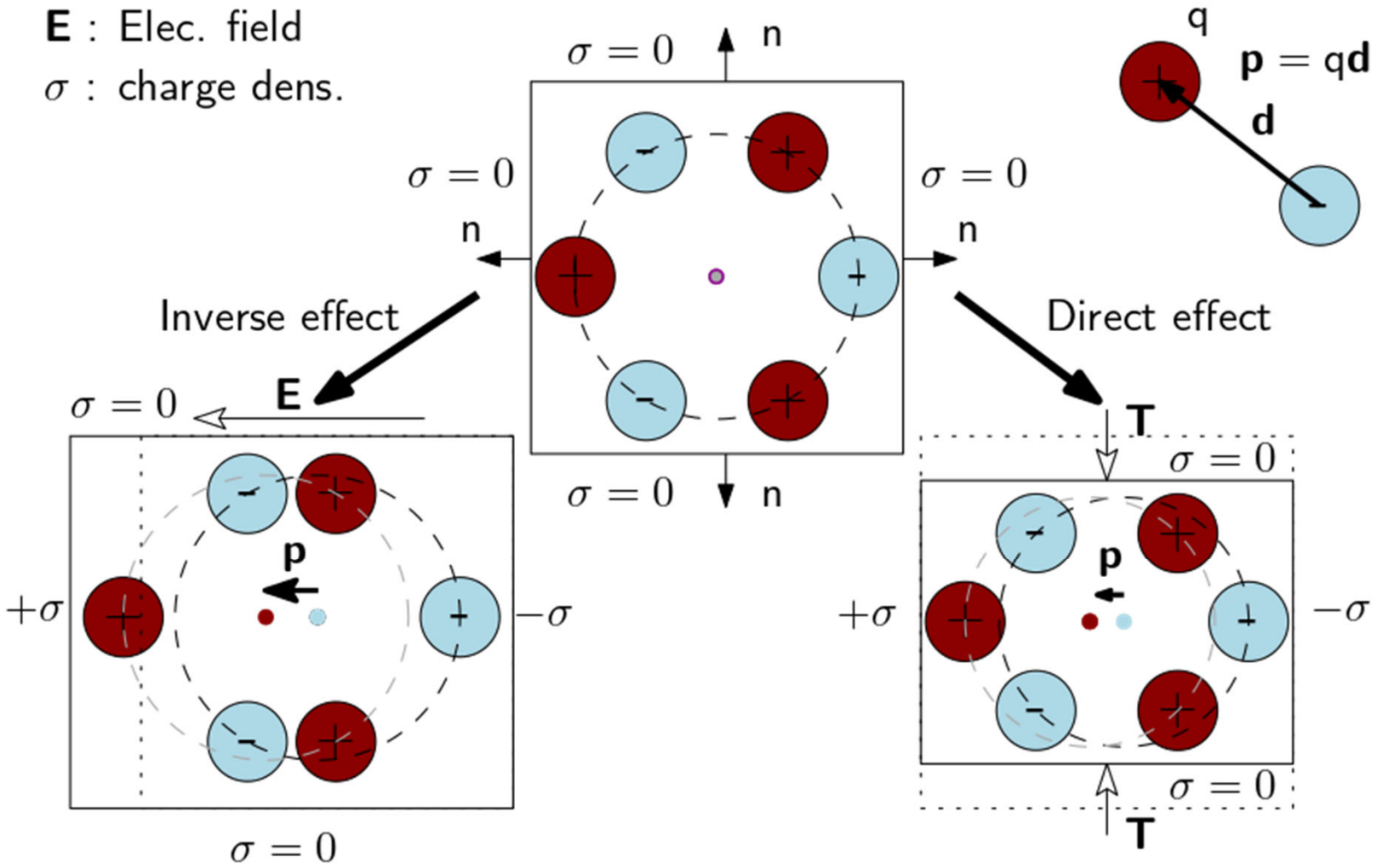
The piezoelectric effect : local effect

T : stress

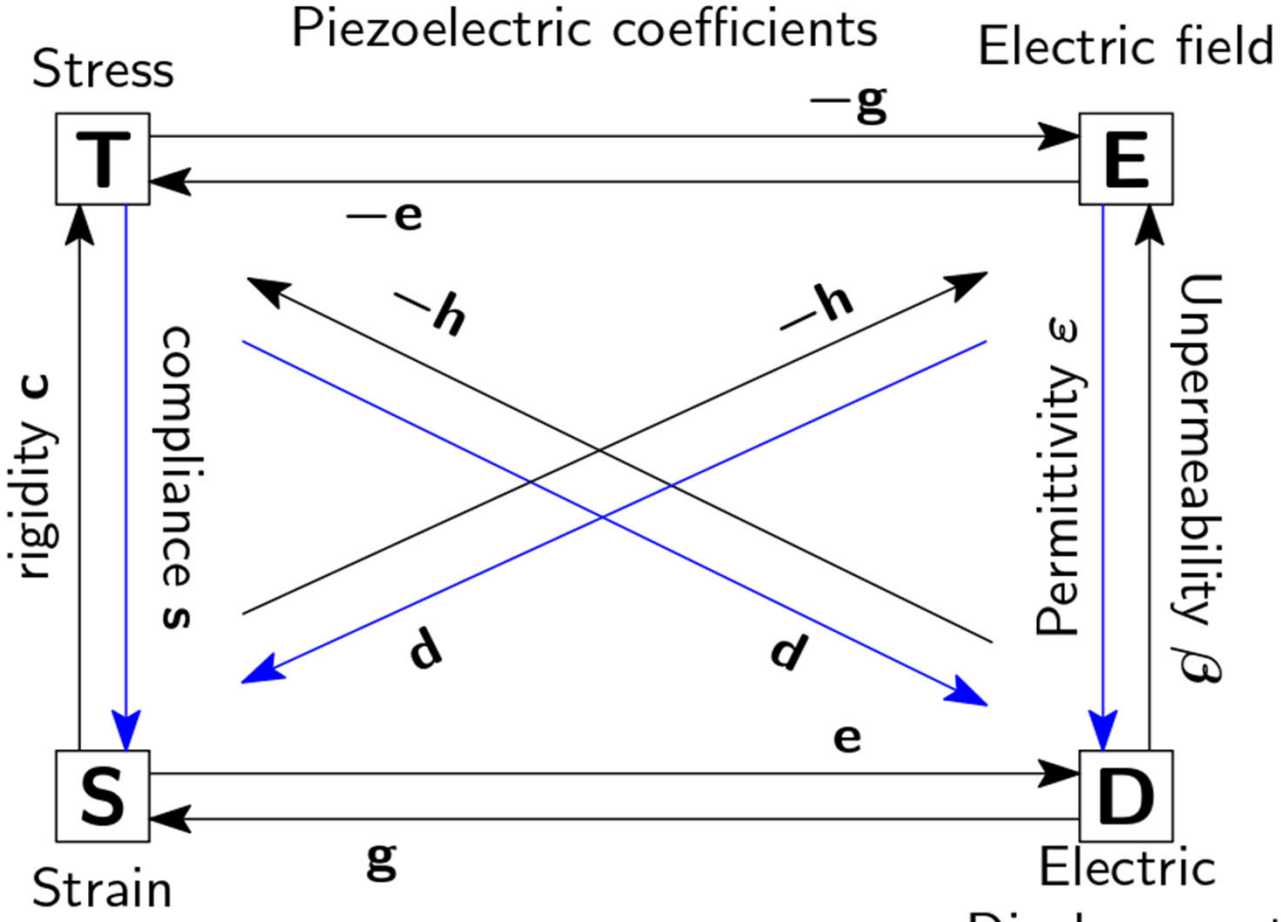
E : Elec. field

σ : charge dens.

q : charge **p** : polarization



The piezoelectric effect : constitutive laws



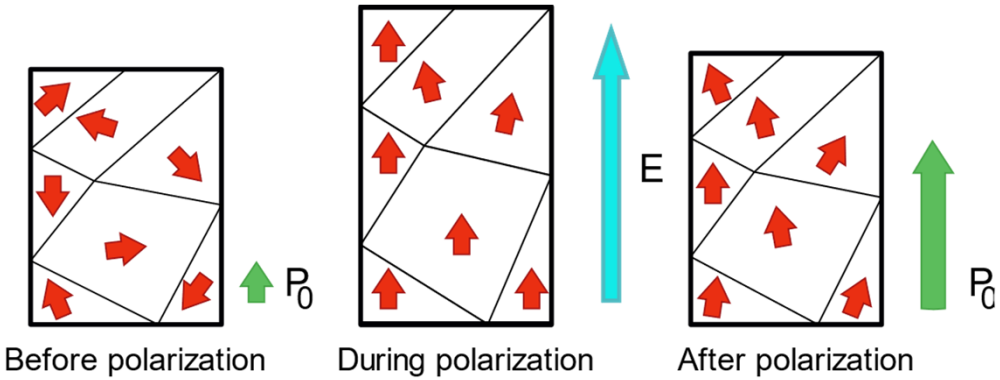
$$\mathbf{S} = \mathbf{s} \cdot \mathbf{T} + \mathbf{d} \cdot \mathbf{E}$$

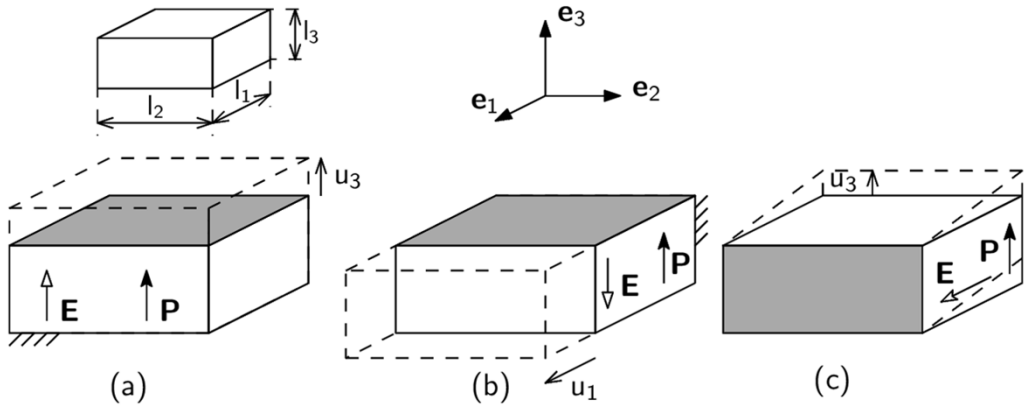
$$\mathbf{D} = \mathbf{d} \cdot \mathbf{T} + \boldsymbol{\varepsilon} \cdot \mathbf{E}$$

Industrial ceramics used in actuators : sintered ferroelectrics powders

pressed into shapes

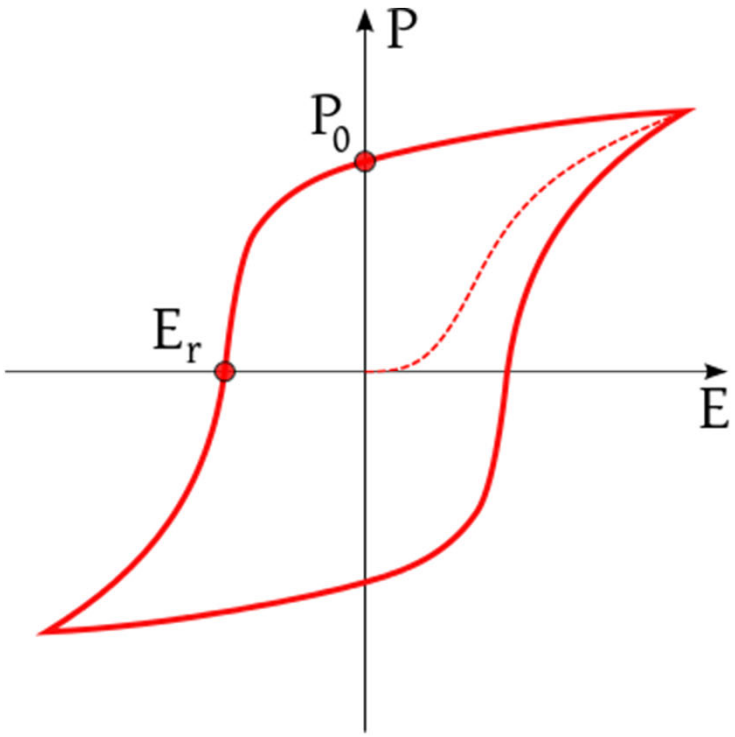
then polarized

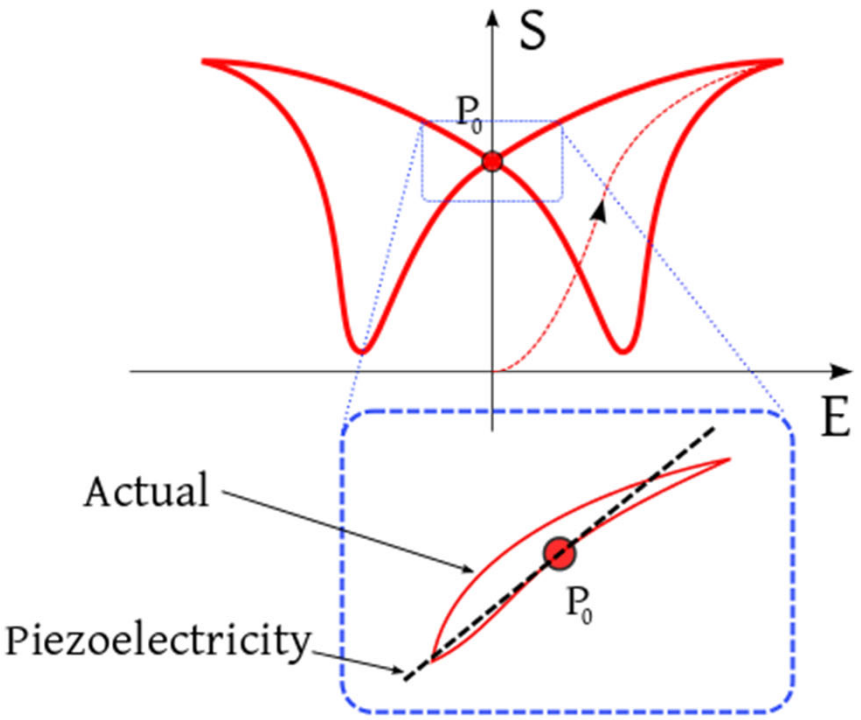




Coupling : direction of deformation w.r.t direction of applied field

Ferroelectric ceramics



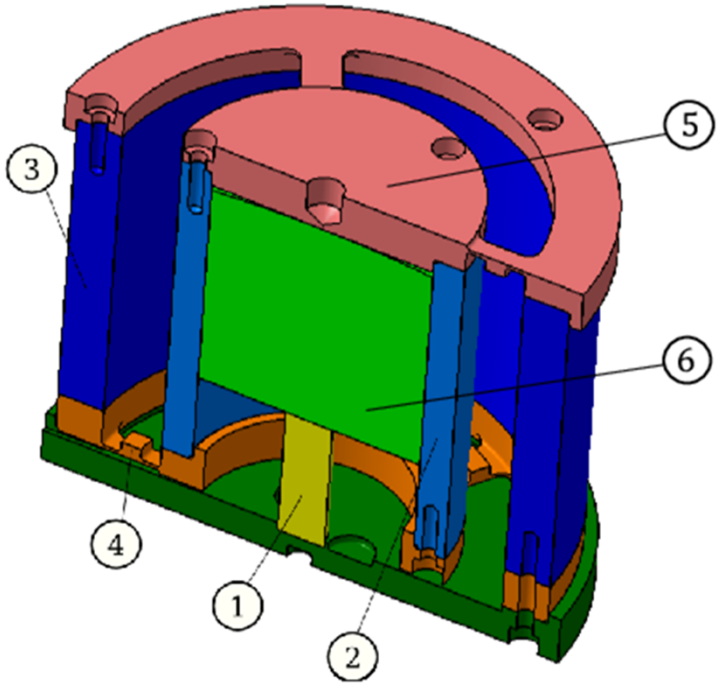


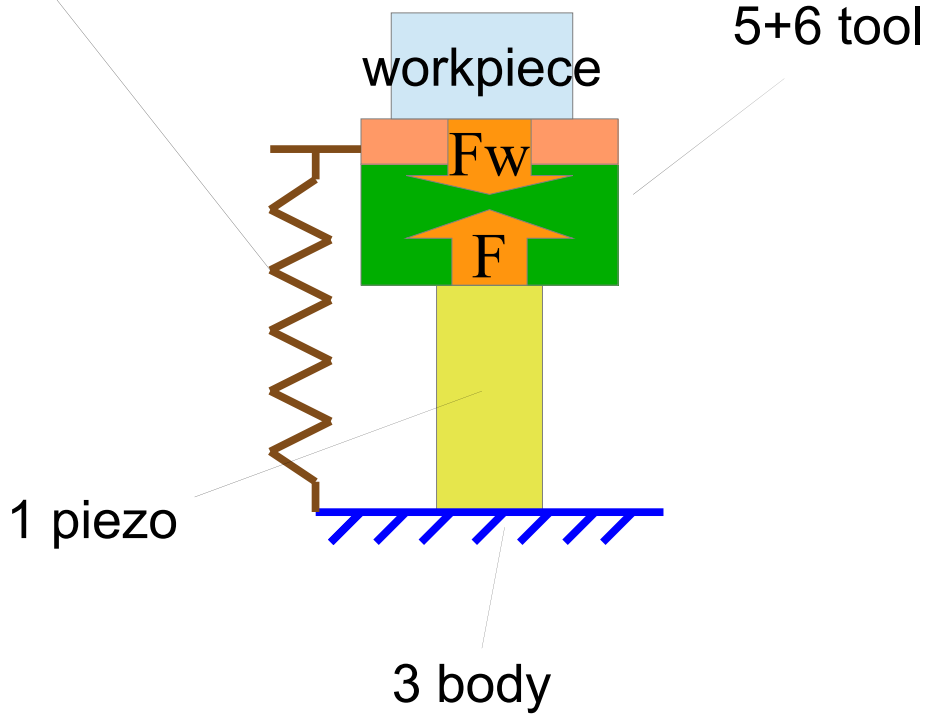
Hysteresis in ferroelectric ceramic : Piezoelectricity is an approximation
A closed loop is required to control the waveform

« PART 3
EMR of a piezoelectric actuator »

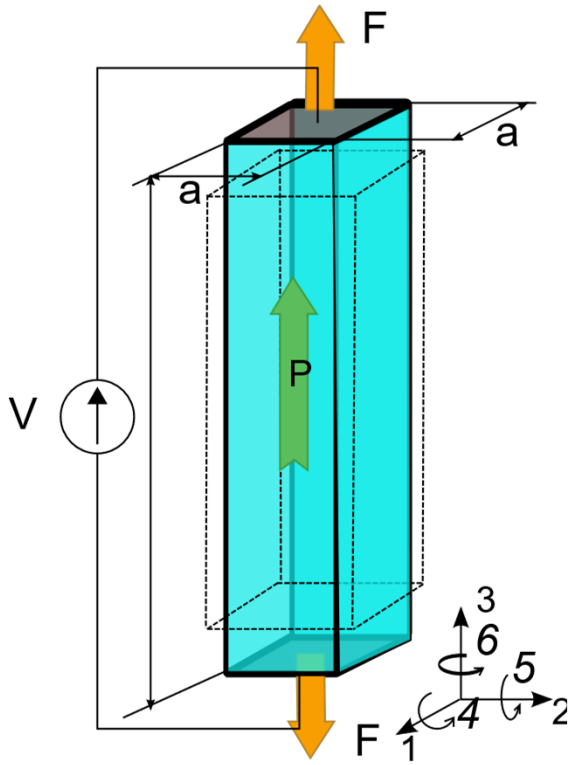
Vibrating tool

4 flexible link (negligible)





The waveforms must be controlled, but the sensors are too expensive : estimator



Slender piezoelectric rod :

- Quasi static motion
- 33 coupling
- Mechanical load applied on the horizontal surfaces of the rod
- Voltage is imposed on the electrodes
- Unidimensional problem

$$\begin{cases} u_3 = \dfrac{s_{33}^E l_0}{a^2} F - d_{33} V \\ Q = -d_{33} F + \dfrac{\varepsilon_{33}^T a^2}{l_0} V \end{cases}$$

Introducing causality

Storages :

$$\begin{cases} u_3 = \int \dot{u}_3 \, dt & \dot{u}_3 : \text{speed} \\ Q = \int i \, dt & i : \text{current} \end{cases}$$

$$\begin{cases} u_3 = \dfrac{s_{33}^E l_0}{a^2} F - d_{33} V \\ Q = -d_{33} F + \dfrac{\varepsilon_{33}^T a^2}{l_0} V \end{cases} \Rightarrow \begin{cases} \int \dot{u}_3 \, dt = \dfrac{s_{33}^E l_0}{a^2} F - d_{33} V \\ \int i \, dt = -d_{33} F + \dfrac{\varepsilon_{33}^T a^2}{l_0} V \end{cases}$$

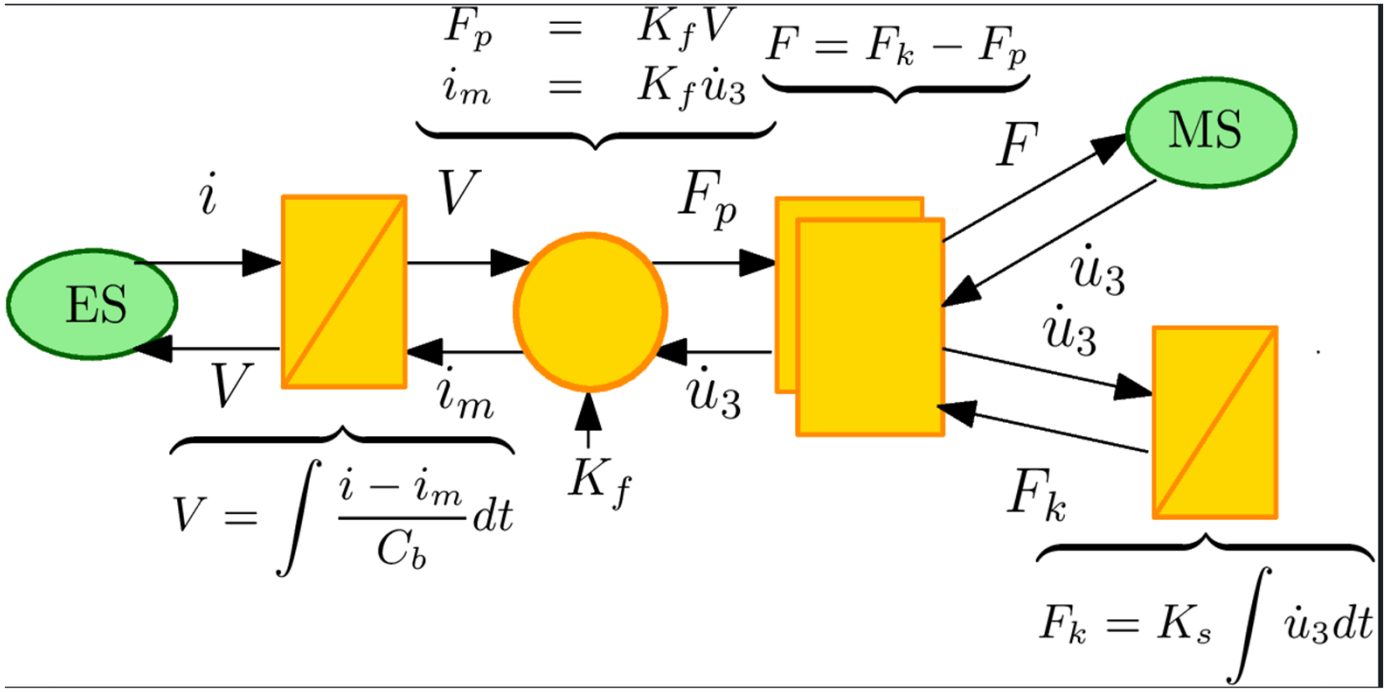
Definitions :

$$\begin{cases} K_s = \dfrac{a^2}{s_{33}^E l_0} & \text{the rigidity of the rod (N/m)} \\ K_f = -d_{33} K_s & \text{conversion (N/V or C/m)} \\ C_0 = \dfrac{\varepsilon_{33}^T a^2}{l_0} & \text{« free » capacitance (F)} \\ C_b = C_0 - d_{33}^2 K_s & \text{« blocked » capacitance (F)} \end{cases}$$

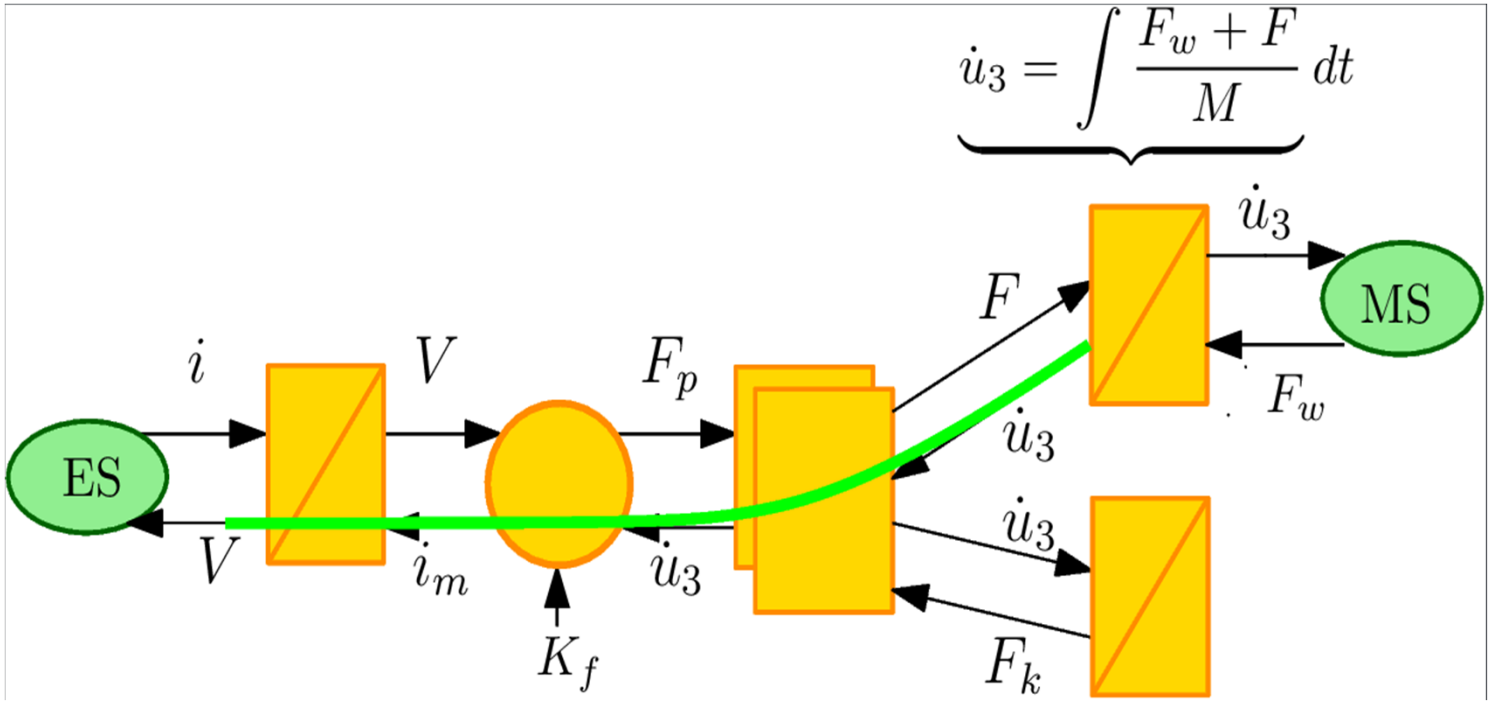
We rewrite : $\begin{cases} F = K_s \int \mathring{u}_3 \, dt - F_p \\ V = \dfrac{\int i - i_m dt}{C_b} \end{cases}$ with $\begin{cases} F_p = K_f V \\ i_m = K_f \mathring{u}_3 \end{cases}$

storages

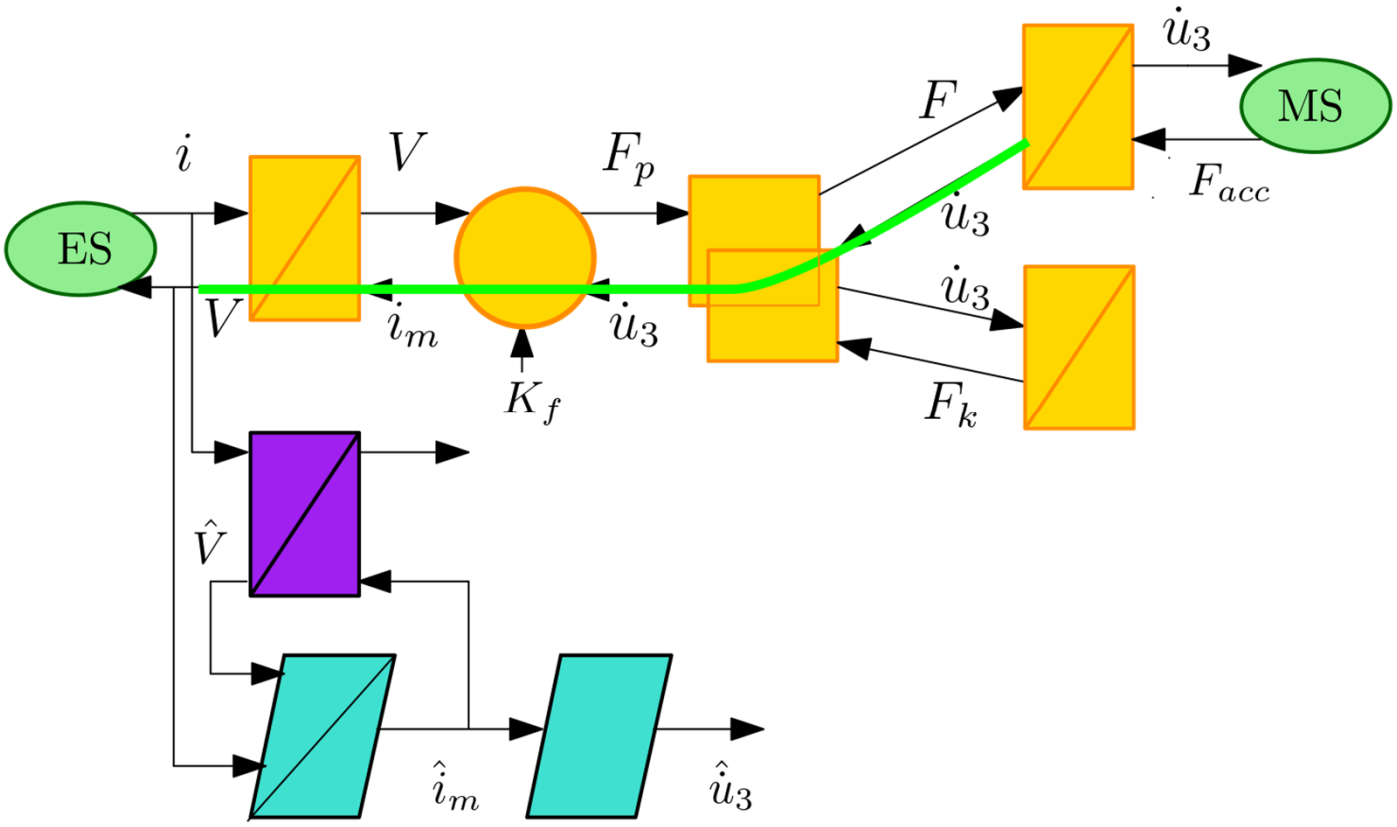
conversion



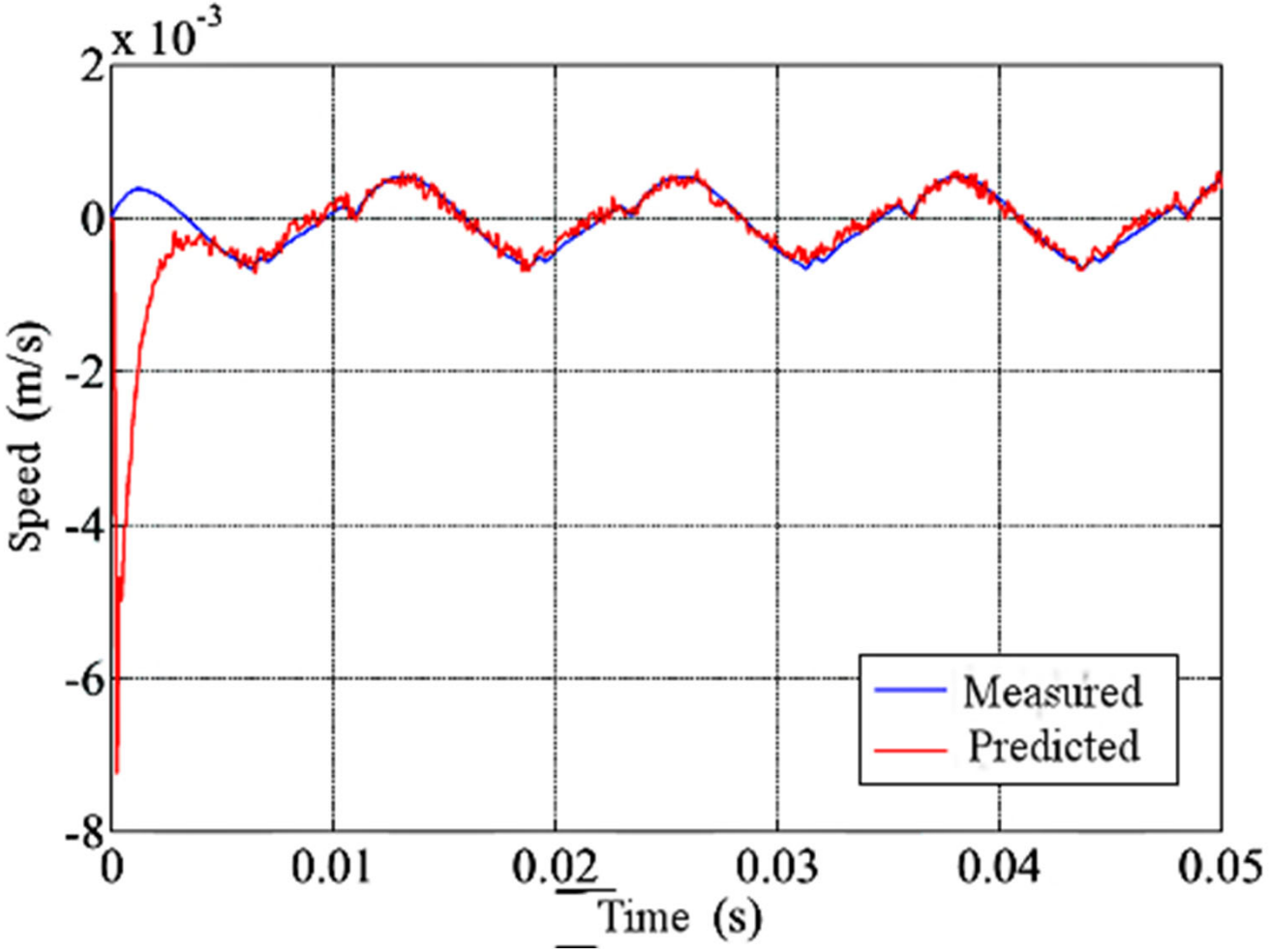
The path from the speed toward a measurable electric variable is found using the EMR of the system [Giraud-Audine 11]



The motional current is then estimated by matching the voltage of model of the blocked capacitance (purple block) to the actual voltage using a closed loop



The estimator is able to track the speed accurately.



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