# TUTORIAL

## "Piezo-Electric drives: design, modelling and control"

### EPE-ECCE 2011

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## PIEZO-ELECTRIC MOTORS

The intrinsic properties of piezo-electric material allow many piezo-motor design. Thus, they may be adapted and developed for typical applications, where classical electromagnetic devices are not accurate. In particular, in the field of small power actuators, piezoelectric motors are good challengers because they offer higher efficiency than electromagnetic motors for the same output power. Moreover, they belong to the category of high force – low speed motors. Thus, they often drive the load directly, and don't need any speed reducer or gear sets. This property helps to reduce the weight or the size of mechanisms.
But many issues exist for the design, the power supply, the modelling, the optimisation and the control of such motors. Can we re-use early concepts like phasors, rotating reference frame, to attain a practical and comprehensive description of the motors, as for electromagnetic machines? Can we control the torque by controlling an electrical value, like the current or the voltage applied to the motor? What is the electrical to mechanical conversion principle in piezoelectric motors?

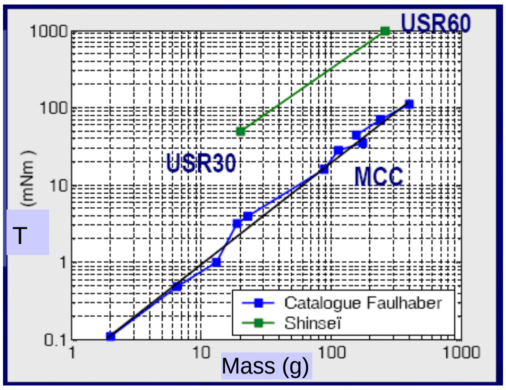


*Fig. 1: Torque-weight ratio comparison for electromagnetic motors (blue) and piezo-motors (green)*

## TUTORIAL OBJECTIVES AND CONTENTS

This tutorial addresses these questions. The tutorial objective is to highlight the similarities and differences between electromagnetic and piezo-electric devices, on the levels of power supply, energy conversion and control strategies.
After introducing the principles of piezo-electricity and the energy range of such actuators, some examples of piezo-electric motors are presented and key equations are laid down, showing how electrical energy is converted into mechanical energy (part 1).
Then, an optimisation approach is detailed for a particular piezo-motor application. Experimental examples are given (part 2).
Last, the modelling of Travelling Wave Ultrasonic Motors (TWUM) is presented in order to highlight differences and similarities with classical electromagnetic machines. Then, basic control laws and estimation of some internal variables can be deduced (part3).

## CONTENTS OF THE TUTORIAL: SCHEDULE

The tutorial is composed of three parts during **4h**

The first part will be dedicated to a general overview of the piezo-electricity and its applications: (1h)

- Piezo-electricity principle (direct and reverse effect)
- Piezo-electricity equations
- Typical forces and deformations
- Elementary piezo-actuators
- Piezo-motors: quasistatic and resonating
- Application, advantages and drawbacks

The second part will address the optimisation of piezo-motors and some particular high performance applications (1h))

- Modelling approach
- Optimisation approach
- Examples of piezo-motor design and applications

The third part will be focused on the modelling and control of the travelling wave motors, as it is the most famous one at an industrial stage. (1.45h)

1) Operating principle and modelling of the TWUM (Travelling Wave Ultrasonic Motor)

- The resonating stage
- The torque production at the rotor/stator interface
- Causal modelling using the concepts of phasors and rotating frame

2) Control principles

- Control in a rotating reference frame, avoiding the pull-out phenomena
- Torque control in a force-feedback application
- Position control of the motor's shaft
- Efficiency improvement: some solutions.

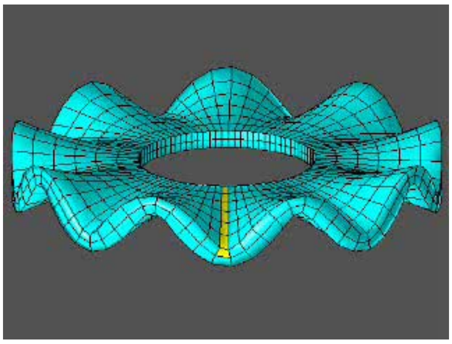

*Fig. 2: TWUM: stator vibration*

*Fig. 3:Optimised piezo motor (M. Fluckiger PhD)*

## AUDIENCE:

Basic knowledge on modelling and control of electrical machines is appreciated.

## SOME REFERENCES OF THE SPEAKERS

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