Piezoelectric Crystals Application on Landing Gears for Harvesting Energy

José Carlos de Carvalho Pereira
and
João Victor Pereira da Silva

Presented by Lie Pablo Grala Pinto

Summary

- **Introduction**
- **The Mathematical Formulation of the System**
- **Results and Discussion**
- **Conclusion**

Introduction

Introduction

- Nowadays piezoelectric materials are used as sensors and actuators in vibration control systems.
- It can measure the output vibration of a structure and act through introducing a restored force and/or affecting the damping.
- In days when new resources of energy are being studied, it can be a powerful tool in energy conversion for lower power applications.
- The employment of piezoelectric crystals has been studied in UAVs.
- This study aims to evaluate the generation in a comercial passenger aircraft and compare different piezoelectric crystals.

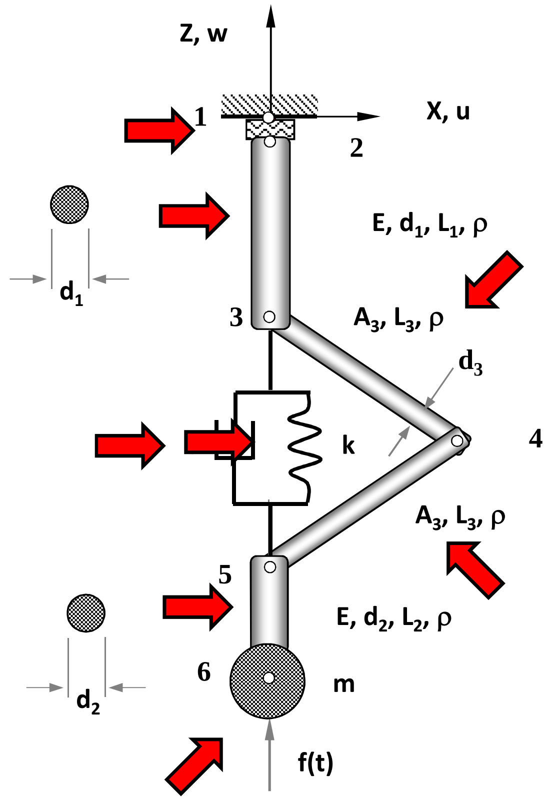
The Mathematical Formulation of the System

The Mathematical Formulation of the System

- The landing gear model considered in this study is, as follows.

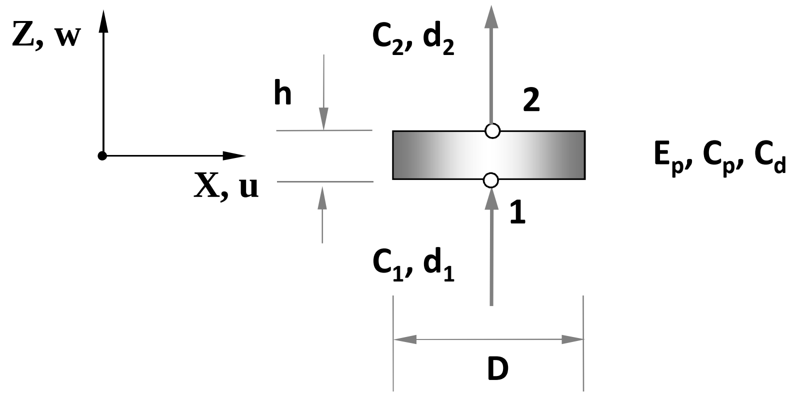
- It consists of:

  - Two rigid rods
  - Two bar elements
  - One spring element
  - One damping element
  - One piezoelectric disc
  - One lumped mass



The Mathematical Formulation of the System

- The piezoelectric disc is modeled as an uniaxial finite element.
- It is described by the dieletric constant C_d, piezoeletric constant C_p and Young's modulus E_p.
- The basic equations are:



$$\sigma = E_p.\frac{\partial w}{\partial z} - C_p.\frac{\partial V}{\partial z}$$

$$Q = C_p.\frac{\partial w}{\partial z} + C_d.\frac{\partial V}{\partial z}$$

IEEE Standard on Piezoelectricity

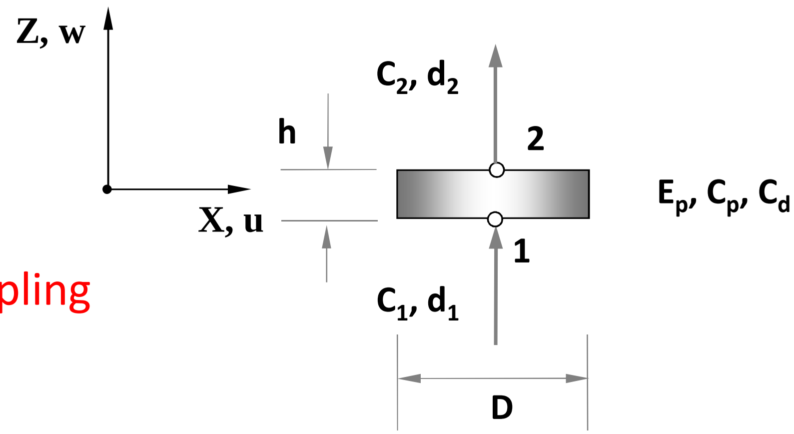
The Mathematical Formulation of the System

- Hence, by using the Lagrange equations:

$$[k_m] = \frac{E_p . S_p}{h} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$ Mechanical stiffness matrix

$$[k_{m\_el}] = -\frac{C_p . S_p}{2.h} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$ Electromechanical coupling stiffness matrix

$$[k_{el}] = \frac{C_d . S_p}{h} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix}$$ Electric stiffness matrix



The Mathematical Formulation of the System

- With the elementar matrices defined, the differential equation of motion is:

$$[M]\{\ddot{P}\}+[C]\{\dot{P}\}+[K]\{P\}=\{F(t)\}$$

- The load is an impulsive force applied on the lumped mass and it is converted as a velocity initial condition. The conditions are: F_o = 400N in Δt = 1s.

- The modal method is used to obtain the time domain response.

Results and Discussion

Results and Discussion

- The geometrical properties are of a comercial Boeing 747.

- Dimensions and masses obtained through the manufacturers.

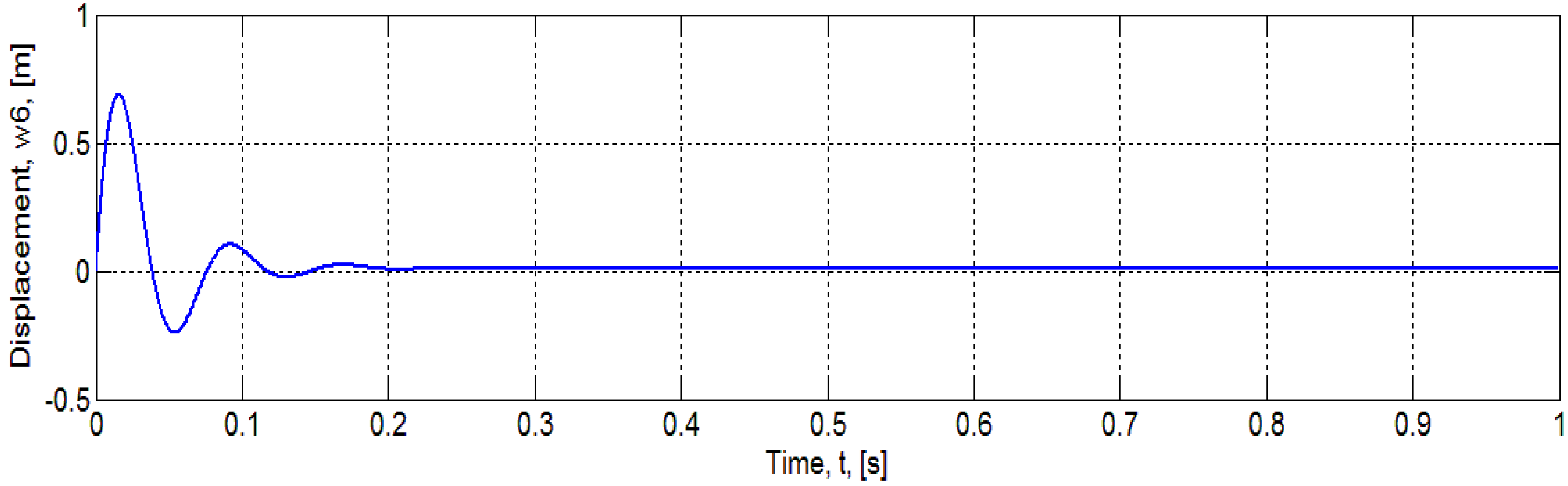
Results and Discussion

- The properties of the piezoelectric crystals analyzed.

	BaTiO3	PbTiO3	PbZrTiO3	PZT-5A	PZT-5H
Piezoelectric constant – C_p [C/m^2]	17,5	2,96089	10,5714	15,08	23,3
Dielectric constant – C_d [F/m]	$1,12 \times 10^{-8}$	$1,24 \times 10^{-9}$	$2,39 \times 10^{-9}$	$7,35 \times 10^{-9}$	$1,30 \times 10^{-8}$
Density – ρ [kg/m^3]	5700	7870	7700	7750	7500
Young's modulus – E_p [GPa]	150	143,3	160,9	121	126

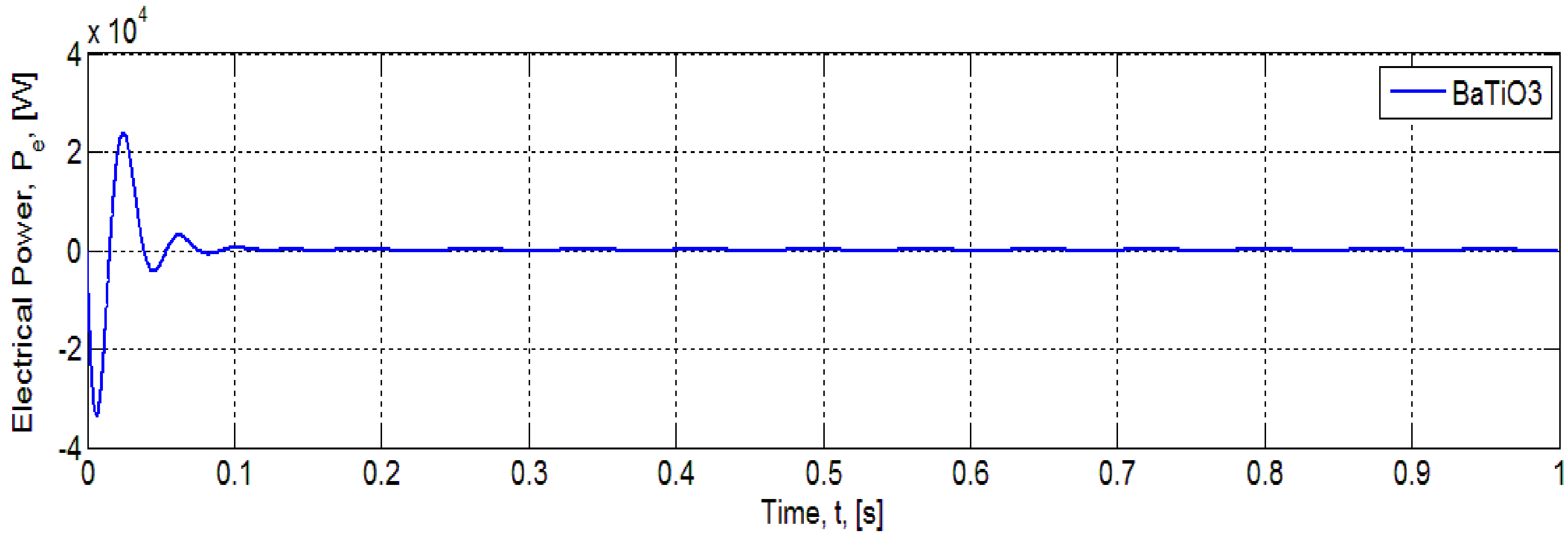
Results and Discussion

- The time domain response in respect to the displacement of the lumped mass:



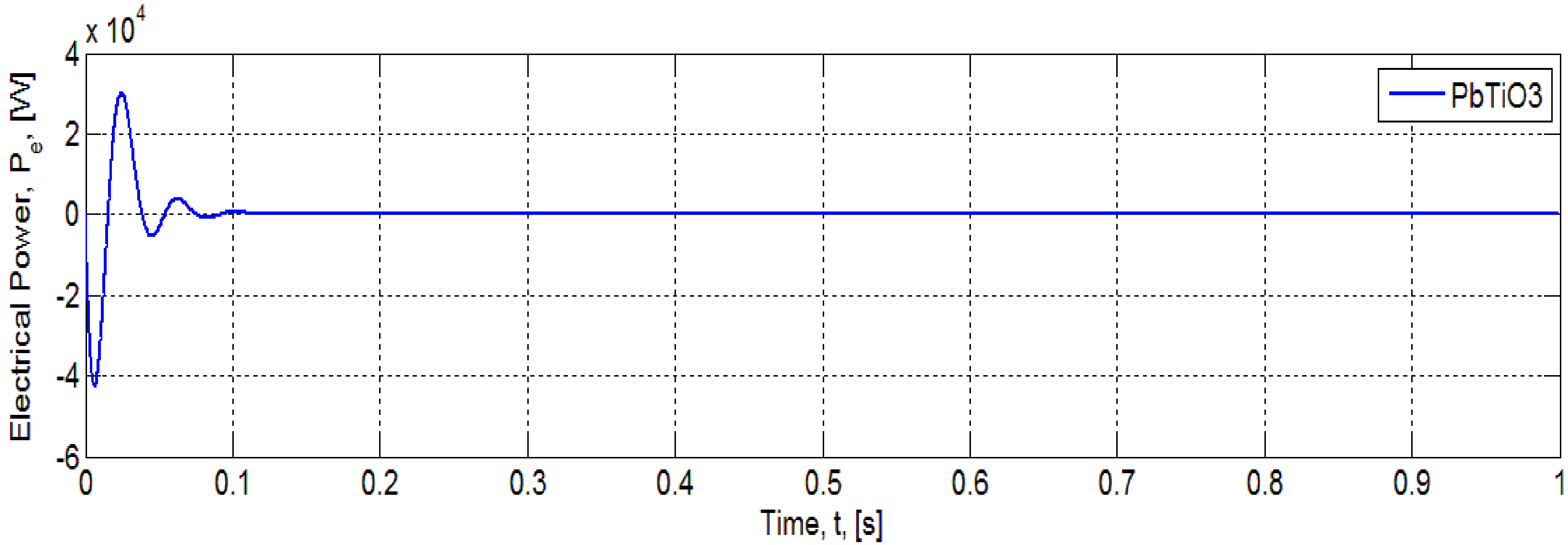
Results and Discussion

- The electrical power generated by **BaTiO3**:



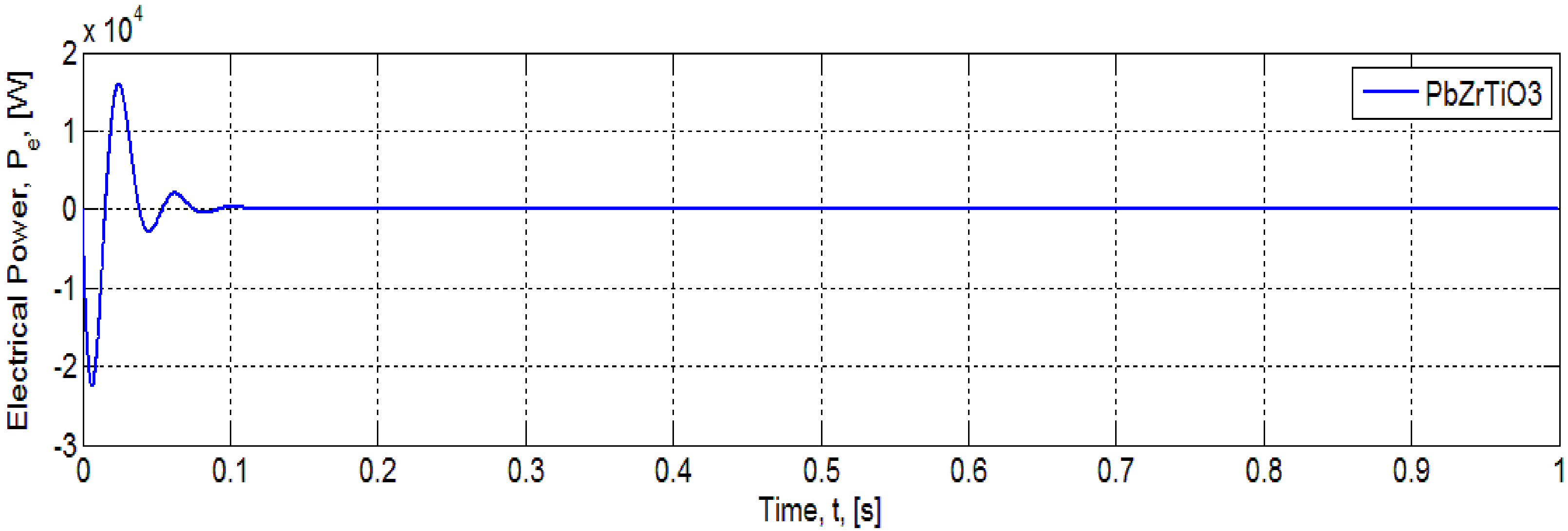
Results and Discussion

- The electrical power generated by **PbTiO3**:



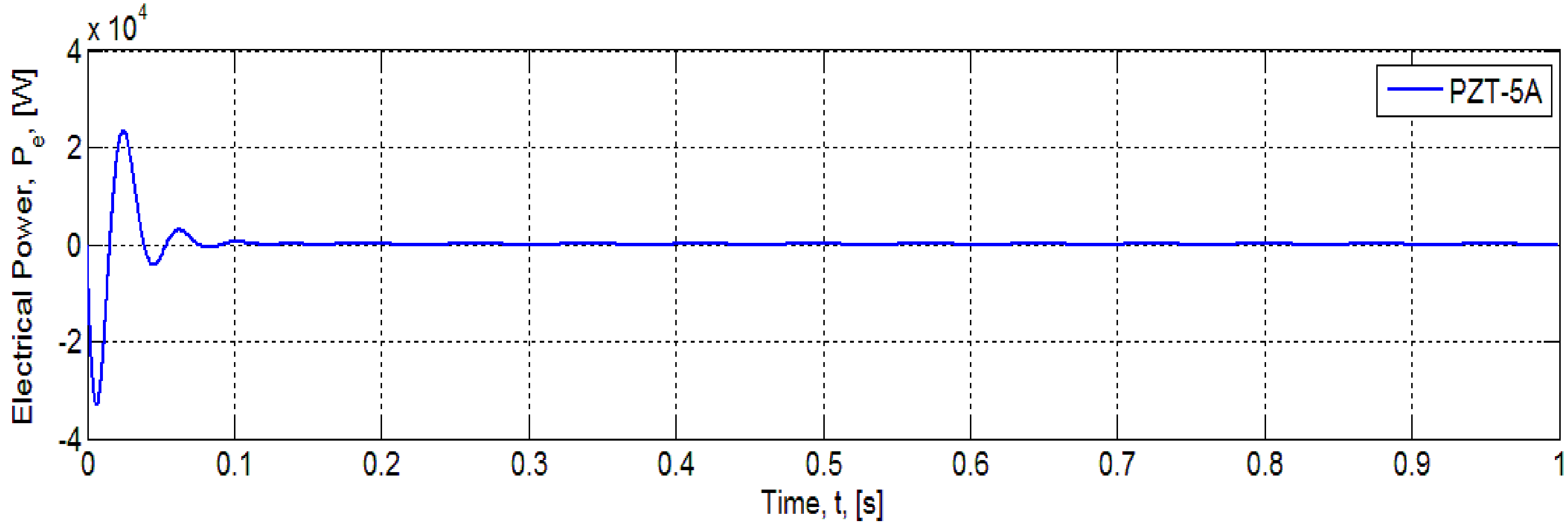
Results and Discussion

- The electrical power generated by **PbZrTiO3**:



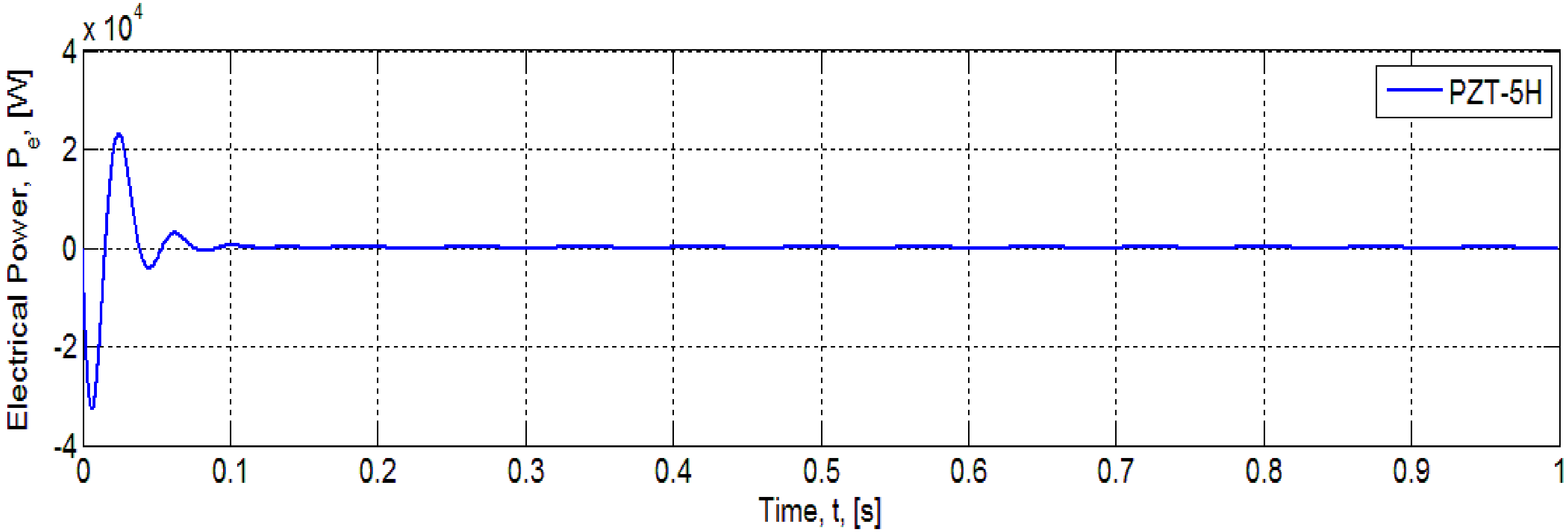
Results and Discussion

- The electrical power generated by **PZT-5A**:



Results and Discussion

- The electrical power generated by **PZT-5H**:



Conclusion

Conclusion

It is possible to infer:

- The energy generated can be highly beneficial for use in on-board devices that do not have great power demands.
- It can also be used for control systems, as a sensor and providing partial power.
- The difference between the power generated can reach up to 70% in the first peak in diferente materials.

The end