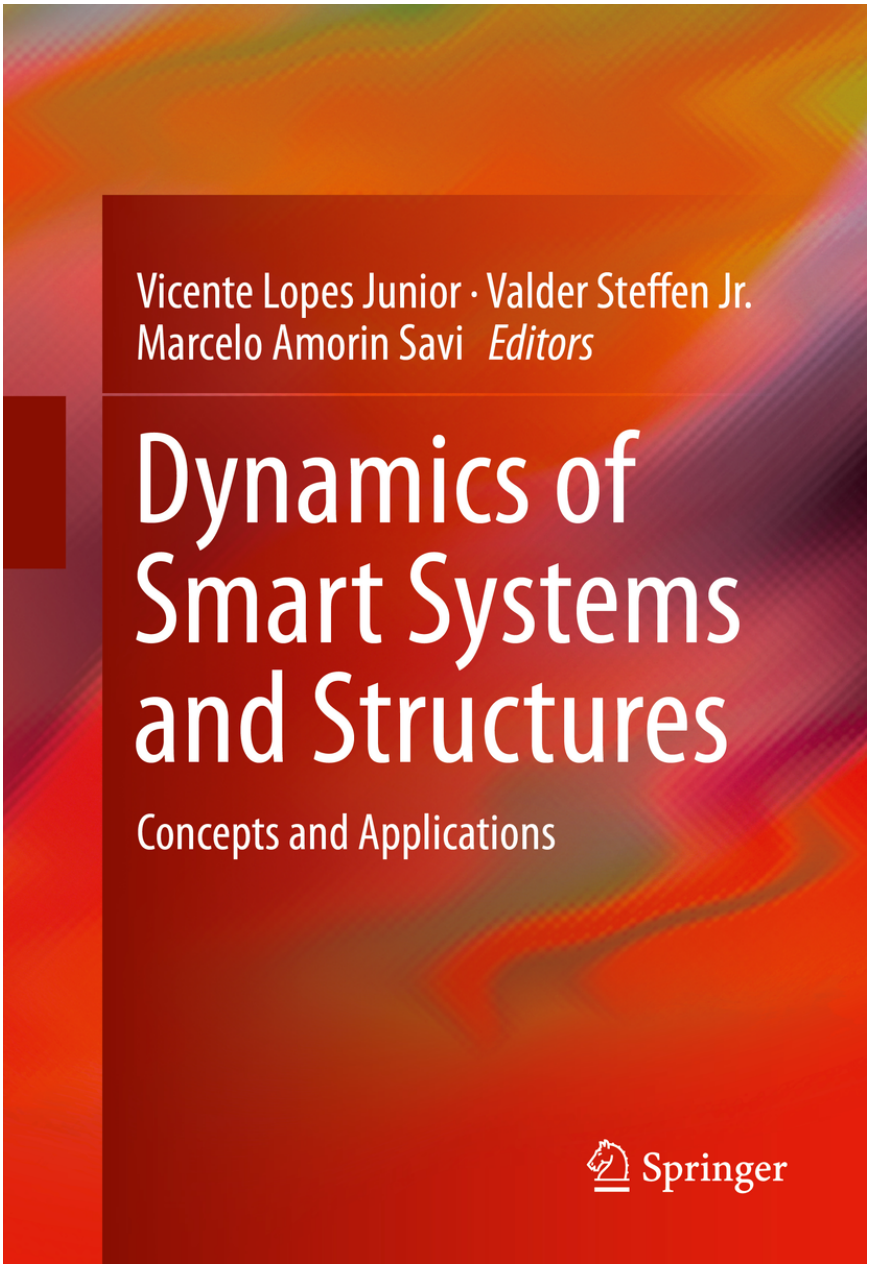

Lopes, V., Steffen, V., Savi, M.A. (2016). Introduction. In: Lopes Junior, V., Steffen Jr., V., Savi, M. (eds) ***Dynamics of Smart Systems and Structures***. Springer, Cham. https://doi.org/10.1007/978-3-319-29982-2_1

Chapter 1
Introduction

Vicente Lopes Jr.[1], Valder Steffen Jr.[2] and Marcelo A. Savi[3]

Nature should be the essential inspiration for researchers and engineers that try to develop systems and structures. The main inspirational point is certainly the adaptive behavior that provides the self-regulation ability. Through the history, human technology is always related to different materials and it is possible to recognize ages defined by some material invention: stone and metal, for instance. Recently, smart materials should be identified as the stimulus of a new age. Basically, smart materials have a coupling between mechanical and non-mechanical fields that confers the material a special kind of behavior. In this regard, it is possible to imagine numerous applications due to the coupling of fields that usually are not connected. The smart material age tries to exploit the idea to construct systems and structures with adaptive behavior that have the ability to change properties due to environmental changes and repairing themselves when necessary.

Besides the term smart materials, it is also usually employed intelligent, adaptive, multifunctional or active materials. Lagoudas (2008) defined active materials as a subgroup of multifunctional materials exhibiting sensing and actuation capabilities. However, in general, it is possible to use the term smart or intelligent materials in order

[1] UNESP – Universidade Estadual Paulista
Department of Mechanical Engineering
Ilha Solteira – SP – Brazil
E-Mail: vicente@dem.feis.unesp.br

[2] Federal University of Uberlândia
School of Mechanical Engineering
Uberlândia – MG – Brazil
E-mail: vsteffen@mecanica.ufu.br

[3] Universidade Federal do Rio de Janeiro
COPPE – Department of Mechanical Engineering
Center for Nonlinear Mechanics
21.941.972 – Rio de Janeiro – RJ – Brazil, P.O. Box 68.503
E-Mail: savi@mecanica.ufrj.br

to express the materials that presents couplings among different physical fields, and therefore, have adaptive characteristics that can be employed to adequate themselves to environmental changes.

Nowadays, the most used smart materials are the shape memory alloys, the piezoelectric materials, the magnetostrictive materials and the electro- and magneto-rheological fluids. These materials have the ability of changing their shape, stiffness, among other properties, through the imposition of electrical, electro-magnetic, temperature or stress fields. Variations of this kind of materials have been created, increasing even more the applicability of smart materials. In this regard, one could mention the ferromagnetic shape memory alloys, shape memory polymers, optical activated polymers and optical fibers. Besides, it should be highlighted the combination of different kinds of materials in hybrid composites, promoting a synergistic use of smart materials. Recently, there is a tendency for the reduction of smart devices to micro and nano-scales with the so-called MEMS and NEMS (micro-nano-electronic mechanical systems).

Smart materials are usually employed as sensors and actuators in smart structures. The choice of proper material for each application depends on many factors and two design drivers need to be highlighted (Lagoudas, 2008): the actuation energy density and the actuation frequency of the material.

Shape memory alloys (SMAs) present a mechanical-temperature coupling in such a way that they have the ability of recover a shape previously defined, when subjected to an appropriated thermomechanical loading process. When there is a restriction to the shape recovery, these alloys promote high restitution forces. The remarkable properties of SMAs are associated with phase transformations responsible for different thermomechanical behaviors of these alloys. Two different phases are possible in SMAs, namely austenite and martensite. Austenitic phase is stable at high temperatures and stress-free state presenting a single variant. On the other hand, martensitic phase is stable at low temperature in a stress-free state, being related to numerous variants. Phase transformation may be induced either by stress or by temperature.

Piezoelectric materials present a reciprocal electro-mechanical coupling and, once an electrical field is applied, the material exhibits a mechanical deformation; on the other hand, when the material undergoes a mechanical load, an electrical potential is generated. This reciprocity enables this kind of material to be used either as sensors or actuators in smart structures.

Magnetostrictive materials present a coupling between mechanical and magnetic fields. They can be defined as materials that present a shape change due to an application of a magnetic field. Magnetostriction was originally identified as a length change in an iron sample subjected to a magnetic field. This effect became known as Joule effect, being the most common mechanism employed in magnetostrictive actuators. The reverse effect, when a mechanical field causes the sample magnetization, is known as Villari effect, being usually employed for sensors.

Electro-rheological (ER) and magneto-rheological (MR) fluids are known as controllable fluids. They present a coupling between mechanical and electro or magneto fields. Therefore, a change in an electro-magneto fields cause a change in mechanical rheological behavior. An ER-MR fluid is a solid suspension that presents drastic changes in rheological properties due to structural arrangements in the suspension. Before the application of the electro-magnetic field particles are distributed in a random way, presenting a Newtonian behavior. The application of the electro-magnetic field causes an orientation of the particles that changes the fluid viscosity, presenting a nonlinear response.

Dynamics of Smart Systems and Structures presents a general overview of smart material systems and structures. It is split in three parts: I – Fundamentals; II – Smart Materials; III – Applications. In Part I – Fundamentals, several concepts of smart materials are presented. Continuum Mechanics, Wave Motion in Elastic Structures, Passive and Active Structural Vibration Control; and Nonlinear Dynamics and Chaos are the main subjects presented in the first part of the book. Part II presents the Smart Materials: Piezoelectric Materials; Shape Memory Alloys; Electro-Magneto Rheological Materials; and Composite Materials. Part III discusses some applications. It is discussed Piezoelectric Energy Harvesting; Impedance-Based Structural Health Monitoring; and Damage Monitoring in Aircrafts.

References

Lagoudas, D.C. (2008), *Shape Memory Alloys: Modeling and Engineering Applications*, Springer Pub. Co.

Oliveira, S.A. & Savi, M.A. (2013), “Os Materiais Inteligentes e suas Aplicações”, *Revista Marítima Brasileira*, v.133, n.10-12, pp.39-56.