A Brief Introduction to "Mem-Models" in Engineering Mechanics Applications

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Abstract

A significant event happened for electrical engineering in 2008, when researchers at HP Labs announced they had found "the missing memristor", a fourth basic circuit element that was postulated nearly four decades earlier by Dr. Leon Chua, who was also instrumental in developing the mathematical theories of memristive, memcapacitive and meminductive systems, resulting in an entire class of "mem-models" that are the foundation of the present work. By applying well-known mechanical-electrical analogies, the mathematics of mem-models may be transferred to the setting of engineering mechanics, creating the mechanical counterparts of memristors, memcapacitors, etc. However this transfer is nontrivial; for example, a new concept and state variable called "absement", the time integral of deformation, emerges. We study these mem-models, which are characterized by a "zero-crossing" property that has interesting implications for nonlinear constitutive modeling, particularly hysteresis, and we identify some examples of "mem-dashpots" and "mem-springs", which include displacement-dependent and variable dampers, the superelasticity found in shape memory alloys, and the pinched hysteresis loops associated with self-centering structures. This work adds to the fast-growing body of literature on elements and systems labeled with "mem", which is a basic branch of study in nonlinear dynamics.