MODELING OF SMA ACTUATORS IN SMART STRUCTURES

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Abstract. Compared to the other traditional active materials, such as piezoceramics and magnetostrictive materials, Shape Memory Alloys (SMAs) show superior performance as high energy density actuators. Due to their ability to develop large displacements and forces during martensitic phase transformation, SMAs constitute promising actuator candidates for large induced motions in vehicles and structures. Additional SMA advantages include simplicity of the actuation mechanism, silent actuation and low driving voltages. SMAs could be used as all-electric devices and can be used with little or no additional gear reduction or motion amplification hardware. These merits permit the realization of small or even miniature actuation systems in order to overcome space limitation restrictions. An important research issue that must be addressed is the low actuation frequency of SMA devices, which is due to limited heat transfer to and or from the environment. Conventional heat exchange mechanisms, such as resistive heating and especially convection cooling, have been found to be slow in terms of actuator frequency response. Special techniques are required for fast heating and cooling of the SMA components. Different solutions to these design issues, based on the use of active cooling systems will be discussed. In order to fully utilize the properties of SMA actuators and improve their design, it is imperative to develop and implement accurate models describing their behavior. Therefore, the current work will also focus on constitutive modeling of SMAs. In the center of the modeling effort is the formulation of Gibbs free energy and the identification of the internal variables, such as martensitic volume fraction and transformation strain. Constrains on the material behavior are derived using the second law of thermodynamic and constitutive equations are established. In addition, evolution equations for the internal variables are also proposed. The model is implemented numerically and results for various test cases, for both uniaxial and multiaxial loading are presented.