Constitutive Modeling of Thermo-Mechanical Behavior of Shape Memory Polymers

H. Jerry Qi[1], Chris Yakacki[1], Robin Shandas[1], Ken Gall[2]

[1]Department of Mechanical Engineering
University of Colorado, Boulder, CO 80309
(qih@colorado.edu)

[2]School of Materials Science and Engineering
Georgia Institute of Technology, Atlanta, GA 30332

Shape memory polymers (SMP) are a group of polymers that are capable of recovering a predetermined shape after significant mechanical deformations. Typically, a SMP can be pre-deformed from an initial shape to a deformed shape by applying an external mechanical load at temperature T_d. A subsequently lowering down the temperature to T_s will maintain this deformed shape after the external mechanical load is removed. The shape memory effect is then activated by increasing the temperature to T_r, where the initial shape is recovered. In general, T_d and T_r are in the vicinity of the glassy transition temperature T_g, whilst T_s is below T_g. Recent advances in material science make it possible to vary the T_g by controlling chemistry or structure of SMP for a variety of applications, such as SMP based medical devices and microsystem actuation components. In these applications, it is highly desirable that the deformation history of SMP can be predicted and the recovery properties can be optimized. This, in turn, requires finite deformation constitutive models that capture the thermo-mechanical response of SMP polymers based on the fundamental understanding of structure-function relationships.

In this paper, we propose a three-dimensional constitutive model that describes the thermo-mechanical response of shape memory polymers. The model is based on the finite deformation theory and fundamental understanding of the structure-function relationship of SMP. Numerical simulations of a series of thermo-mechanical tests verify the efficiency of the model. Example for applying this model to complicated product design is presented.