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One Dimensional Modeling of the Shape Memory Effect

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ABSTRACT

This paper aims to build a constitutive model intended to describe the thermomechanical behavior of shape memory alloys. This behavior presents many facets, among them we have considered the simple way of shape memory, which is one of most important properties of shape memory alloys. Because of numerous stages of this effect, the subject was divided into three independent parts. For each part, we built the corresponding thermodynamic potential and we deduced the constitutive equations. To make this model workable, we have developed an algorithm. The simulation was performed using the NiTi as shape memory alloy.

Keywords: Shape; Strain; Detwinned Martensite; Region

1. Introduction

The known behavior of conventional materials has allowed their use in many applications but the discovery of new properties, coming from a singular behavior of materials known as shape memory alloys, opened a way for other applications from medical to aerospace.

This unusual behavior has attracted a significant attention of scientists and researchers. Therefore, various models were proposed.

These models are based on thermodynamics laws and frameworks theories as generalized standard materials. Halphen and Nguyen [1] used by Lexcellent and Licht [2], Edelen's formalism [3] used by Tanaka and Nagaki [4].

These models can be classified as follows:

1) Macroscopic models: Built of the thermomechanical behavior, they are generally simpler in formulation and geared more towards engineering applications. Thus, the detailed physics of phase transformation are usually not rigorously addressed.

2) Micromechanical models are based on the micromechanics of a single crystal. Chu and James [5]; James *et al*., [6]; Lexcellent *et al*., [7]; Govindjee and Hall [8]; Berveiller *et al.* [9]; Patoor *et al.* [10]. Generally, this class of model was derived from more fundamental thermodynamic principles and the shape strains of different martensite variants are included.

In this paper, we focus on the effect of simple way shape memory which is the first property discovered. The adopted approach is based on the sharing of the study on three following steps:

1) Orientation of twinned Martensite;
2) Heating for austenite;
3) Cooling for detwinned Martensite.

2. Methods

2.1. Presentation of the Subject (Figure 1)

The thermomechanical cycle to the memory effect of a simple shape is defined the following:

1) Applying a mechanical load under Temperature T_1 lower than M_f^0 (Temperature of transformation start of Martensite): The material is deformed first elastically, followed by an important deformation due to twinned Martensite orientation. When the load is cancelled the deformation is not fully recovered, only elastic part is recovered.

2) Heating to a temperature above A_f^0 (Temperature of transformation finish of Austenite): When the temperature reaches A_s^0 (Temperature of transformation start of Austenite) the deformation begins to recover.

3) Cooling to T_1: Austenite begins to transform to Martensite and finally the material is at the origin of the cycle.

2.2. Definition of Regions (Figure 2)

The study will concern three regions which are planes (ε,

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