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NUMERICAL ANALYSIS OF CYCLIC LOADED SHAPE MEMORY ALLOYS WITH AN ADAPTED ALGORITHM FOR ANSYS

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ABSTRACT

This work presents an adapted numerical model using as basis Ansys Mechanical solver to simulate the behaviour of a shape memory alloy (SMA) circular beam. The analysis includes quasi-static and traction-compression cyclic cases. Since the Ansys Mechanical solves mainly the first case, the other result is obtained using the adapted algorithm based in a developed theory. The final results show the superelastic behaviour through stress-strain diagram for the material and displacement-time curve of a free vibration system.

Keywords: shape memory alloys, superelasticity, numerical methods, dynamic response.

INTRODUCTION

The SMA are a kind of alloy classified as smart materials. It receives this rating because of two main characteristics, the shape memory effect (SME) and superelasticity (SE). The important material properties that produces the two characteristics mentioned are detailed in Lagoudas (2008). In the case of numerical simulations, there are different models that propose to predict the structure's behaviour. More details about them can be found in and Auricchio (2001).

The software Ansys uses the Auricchio's model to solve static problems, since the generated stress-strain diagram bring the hysteresis loop, when the material is used in a vibration system, there is a hysteretic damping condition, soon the adapted algorithm aims to simulate an adopted ideal free vibration system with only hysteretic damping based on multiple simulations in the commercial software and be able to present the material's properties caused by cyclic loadings as mentioned by Tobushi et al. (1992).

The routine consists in an Ansys's simulation with the system's initial condition, displacement and velocity, to obtain the stress-strain data for the movement first half-cycle that is used by Matlab's algorithm to calculate the hysteretic damping parameters and predict the next behavior of the second half-cycle. These steps are repeated until the system reach a steady-state condition. The characteristics of the material are present in Table 1, being used to calculate the effect of the SMA application in a dynamic situation, with the dynamic system having a 1 [kg] mass coupled, the SMA element radius and length being 10^{-3} and 10^{-2} meters respectively and the simulation considering an environment temperature of 60 [°C].

RESULTS AND CONCLUSIONS

The displacement-time curve in Fig. 1a presents the vibration behaviour of the system studied and Fig. 1b shows the respective stress-strain that is caused by the movement. It is possible to

see the influence of the energy loss due to the hysteresis loop and the alteration in the hysteretic damper parameters produced over the cycles, including the changes in the characteristic's temperatures due to cyclic loading-unloading.

Table 1 – Adopted system parameters

Young's modulus [GPa]	Transformation temperatures [°C]	Transformation constants [MPa °C ⁻¹]	Transformation stress [MPa]	Maximum residual deformation
67	$M_F = 9$	$C_M = 8$	$\sigma_s^{crit} = 100$	$\epsilon_r = 0.067$
	$M_S = 18.4$			
	$A_S = 34.5$	$C_A = 13.8$	$\sigma_f^{crit} = 170$	
	$A_F = 49$			

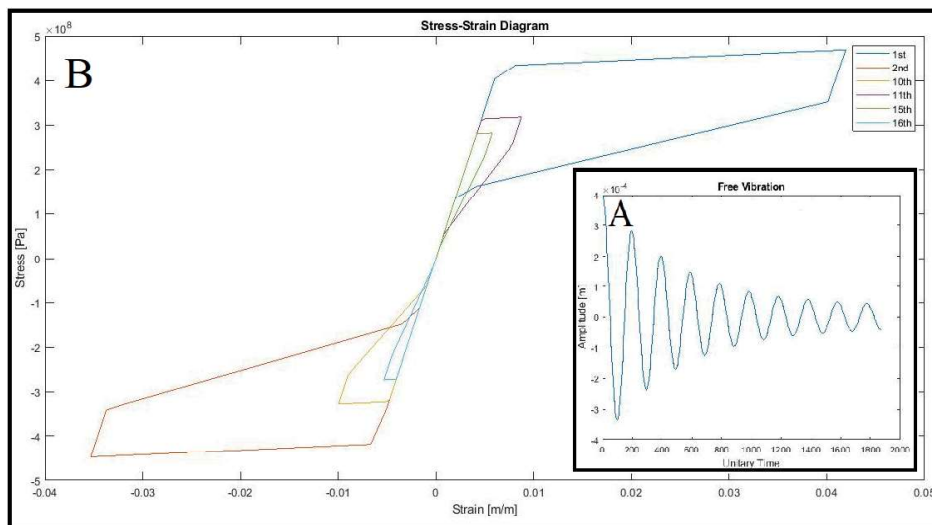


Fig. 1 – Results obtained with the adopted simulation procedure.

The presented research was developed with the goal to simulate the expected dynamic behavior of a shape memory alloy subjected to a free vibration system based on its stress-strain diagram obtained with Ansys. Future research is going to acquire experimental data to calibrate the model and obtain the dynamic behavior to validate the adapted algorithm utilized.

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