

Smart Structures Project 3

Lecturer: Morteza Karamooz

Problem: Consider an SMA NiTi wire with the material properties of the SMA listed in Table 1.

- a) Obtain the stress–strain response of the NiTi under uniaxial partial tension test at different temperatures:

The specimen in the temperature 253 K is first loaded to achieve 4% strain and then unloaded which leads to a residual strain at the end of the first cycle. Once again, the load increases up to 8% strain. Finally, unloading to zero stress yields to a residual strain. Similar processes are adapted as shown in Fig. 2b and c, respectively, for temperatures 283 K and 293 K but unloading stage in the first cycle is restricted to 2% strain. Your results should be similar to green lines in Fig. 2. the SMA material is assumed to be initially in parent phase ($\xi_S = \xi_T = 0$) for temperatures $T \geq M_s^0$.

- b) In order to analyze geometrically non-linear transient (dynamic) response of an SMA composite beam under impulsive loads, a fully clamped composite beam with length 200 mm, width 20 mm and total thickness $H = 5$ mm is considered, as shown in Fig 1. It is assumed that the elastic layer is made of Aluminum ($E_e = 70 \text{ GPa}$, $\rho_e = 2707 \text{ kg/m}^3$). In order to activate the SMA layer, it is heated and its temperature is uniformly distributed. On the other hand, it is assumed that the temperature of elastic layers remains in the reference temperature as a generally well-known assumption since the effect of elevated SMA temperature on adjacent elastic layers is negligible. In all dynamical simulations, it is assumed that the structure is subjected to an incremental impulse point load with the magnitude of 200 kN and loading duration $s = 1$ ms which is imposed upward (z direction) on the center of the structure.

Moreover, in all computations, 50 elements in the axial direction with 5 through-the-thickness Gauss points pre-element were used to obtain the converged results up to four significant digits. Obtain the central transverse displacement and detwinned martensite fraction time histories of a single SMA beam at different temperatures as shown in Fig 3. Fig. 3b and c shows that detwinned martensite fractions at top and bottom surfaces have no identical value at loading step which is due to the geometrical non-linearity. As shown in Fig. 3a, the temperature has a significant effect on the response of the SMA beam so that high permanent displacement remains in the structure after unloading at temperatures below A_f^0 .

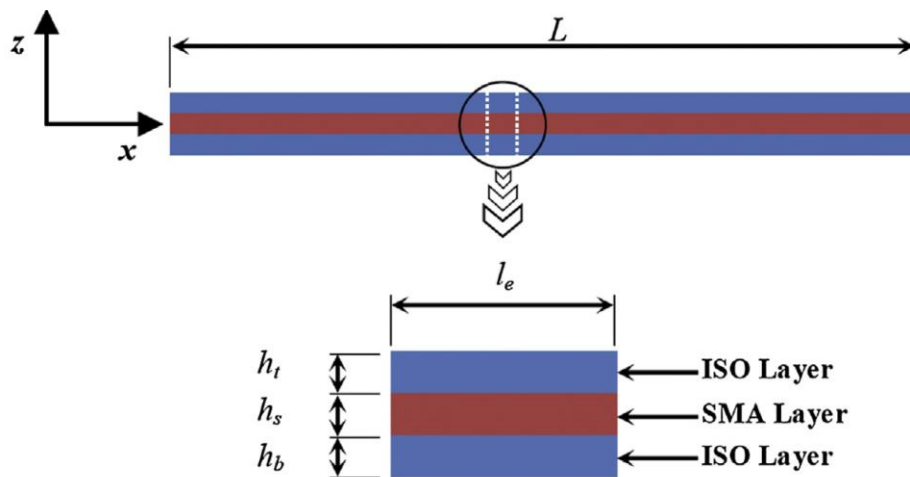


Figure 1. Material properties of the SMA.

Parameter	Case A	Case B ^a	Unit
E	40,000	68,400	MPa
ν	0.33	0.36	–
ρ	6500	8000	kg/m ³
ε_L	0.060	0.038	–
Δu_0	11,585	14,725	J/kg
Δs_0	46.15	47.50	J/kgK
H_s	9.23	100	J/kg
Y_{s0}^f	240	88.92	MPa
Y_{s1}^f	379	173.44	MPa
Y_{s0}^r	45	90	MPa
Y_{s1}^r	26	91.05	MPa
Y_{T0}^r	1.5	2.66	MPa
c^f	92.31	190	J/kg
c^r	184.61	95	J/kg
M_f^0	249	306	K
M_s^0	251	310	K
A_s^0	256	317	K
A_f^0	260	319	K

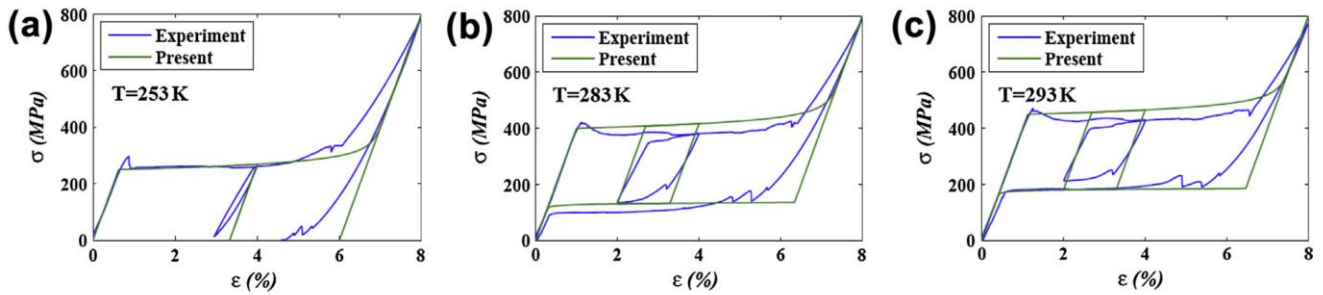


Figure 2. Model predictions compared to the experiment [1] for partial tension test at different temperatures.

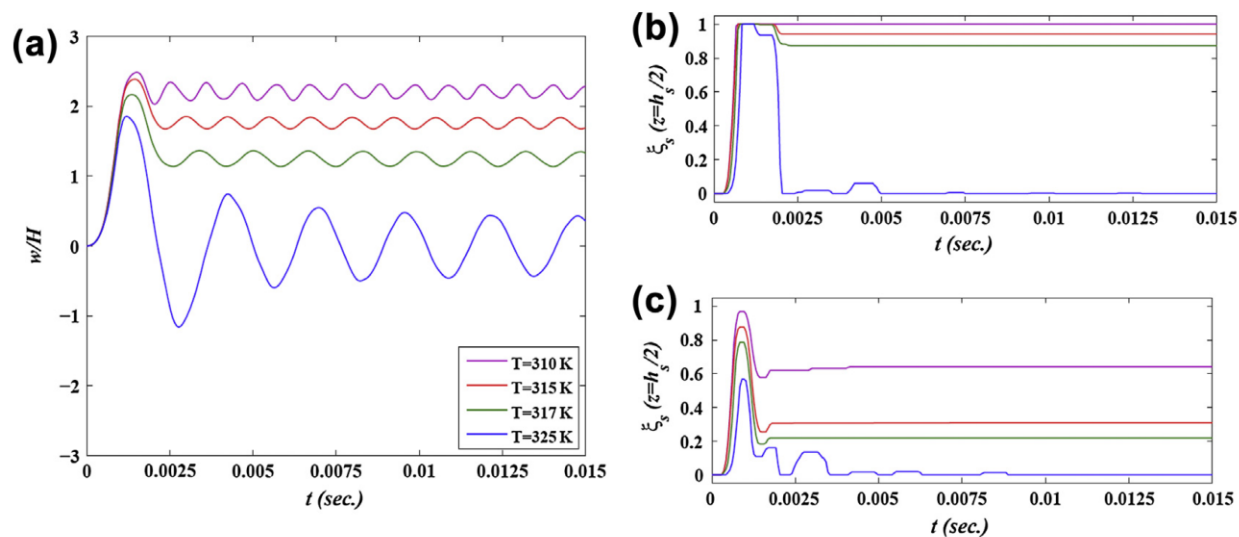


Figure 3. The time-histories of the central deflection (a), detwinned martensite fraction at top point of beam mid-span (b) and detwinned martensite fraction at bottom point of beam mid-span (c) for an SMA beam at different temperatures.

[1] Šittner P, Pilch J, Heller L. 2009. <<http://ofm.fzu.cz/ofm/index.php/en/roundrobin>>.