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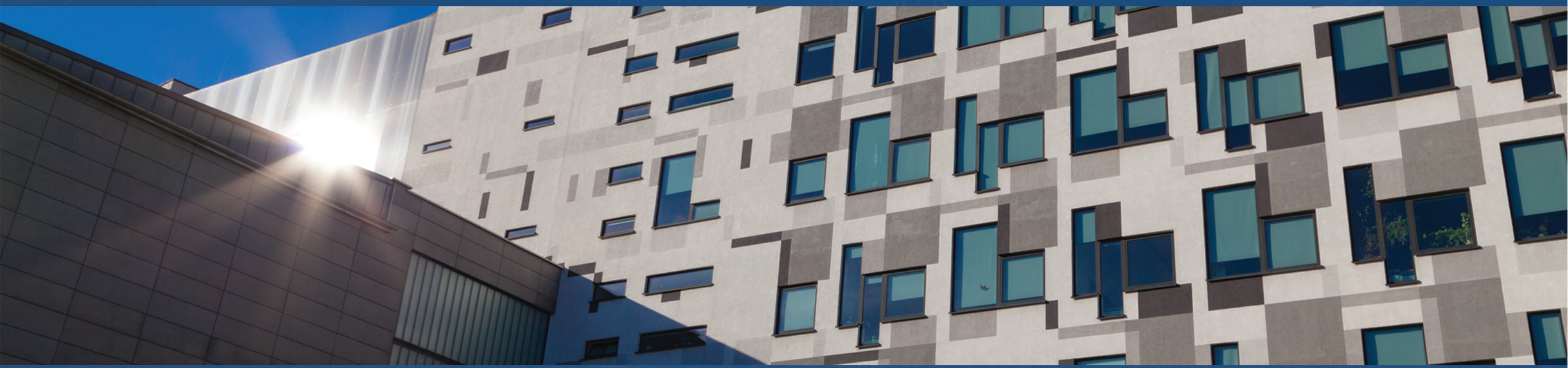

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STRESS RELAXATION EFFECTS IN TiNi SMA

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1. Introduction

Experimental and numerical results of thermomechanical effects related to phenomena of stress relaxation investigated in TiNi SMA subjected to modified program of strain-controlled tensile loading at room temperature are analyzed. More details related to thermo-mechanical coupling approach can be find in [1, 2].

2. Experimental procedure

The experiments were carried out on belt type specimens cut off from TiNi SMA strip. The specimens were subjected to displacement-controlled tension with strain rate $5\times10^{-2}s^{-1}$. The loading and unloading processes were executed in two following way: loading up to strain equal to 4%; maintaining the strain value during 3 minutes; reloading up to the strain of 7% and unloading to zero stress. In the experiment, a monotonic stress drop of 170 MPa and specimen temperature increase of cca. 15 K were observed.

3. Thermo-mechanically coupled SMA constitutive model and numerical modeling

Details of the SMA phenomenological model [3], implemented into the software for structural analysis PAK based on Finite Element Method (FEM) were given in the previous paper of the authors [1, 2]. To realize the thermo-mechanical coupling [2] in the partitioned approach [4], the FEM programs for structural (PAKS) and heat transfer analysis (PAKT) were connected using the Component Template Library (CTL), developed by Niekamp [5]. The heat transfer program PAKT enabled computation of a temperature change in solids. The elementary dissipative energy q_{dis} of the martensitic phase transformation can be expressed as [2, 3]:

$$q_{dis} = \eta\left(\Pi - \rho\Delta s_0 T\right)\dot{\xi}\,,$$

where η denotes the dissipative factor, Π is the thermodynamic force, $\rho\Delta s_0$ describes the stress sensitivity coefficient, $\dot{\xi}$ is the rate of martensitic volume fraction and T is the SMA temperature [3]. The TiNi belt type specimen has been modeled by the FEM 3D elements [1, 6]. It was assumed that the specimen ends have the same and constant temperature, because the grips of the testing machine are very large in comparison to the specimen thickness. The rest of the specimen model enabled free convection.

4. Results and conclusions

Comparison of the experimental and numerical results in the form of the stress and average temperature variations vs. strain is shown in Fig 1 for the TiNi SMA subjected to the loading program described above.

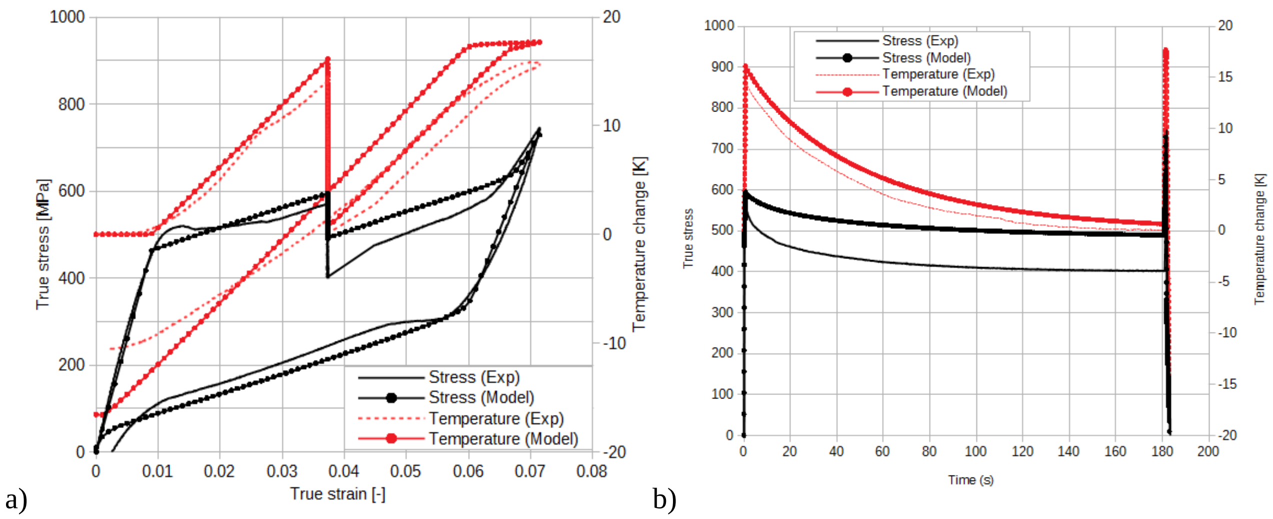

Figure 1. TiNi tension at strain rate of $5\times10^{-2} s^{-1}$ with 3 min loading break induced at advanced stage of martensite transformation - experiment and model. Stress and temperature variations vs.: strain (a); time (b).

The numerical approach proposed confirmed decrease of the stress when the strain was kept constant during the SMA loading (Fig. 1). A monotonic stress and the temperature drops were observed. Large stress relaxation reduction was observed for the strain rate applied. After the relaxation stage was completed, the transformation processes develop in typical manner. The exothermic character of the martensitic forward transformation was demonstrated, as well as decrease of the specimens temperature during the reverse transformation. Even a temperature decline below the initial level was confirmed by the model.

Acknowledgements

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