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Thermomechanical properties of $Ni_{49.8}Ti_{50.2}$ under shear stress for solid-state cooling applications

E. O. Usuda[1*], C. C. S. Silva[1], F. C. Colman[2], J. Otubo[3], C. S. Alves[2], L. O. Péres[1], R. A. G. da Silva[1] and A. M. G. Carvalho[1,2,4]

[1]Universidade Federal de São Paulo, [2]Universidade Estadual de Maringá, [3]Instituto Tecnológico de Aeronáutica, [4]Universidade do Estado do Rio de Janeiro

*erik.usuda@unifesp.com

Introduction

Conventional vapor-compression cooling systems rely on greenhouse gases and account for ~30% of global energy consumption [1]. Solid-state refrigeration based on ***i*-caloric materials—which convert external stimuli into thermal energy—** emerges as a sustainable alternative. Within mechanocaloric effects, shear-stress-induced responses (torsiocaloric effect) remain largely unexplored yet promising, achieving significant thermal changes under relatively low stresses [2, 3]. Nitinol alloys have become promising materials for studying the mechanocaloric effect due to their shape memory effect and superelasticity around room temperature, which have been extensively studied under uniaxial stresses [1]. **However, the application of pure shear stresses in these alloys remains underexplored regarding the *i*-caloric effect.** To fill this gap, here we investigate the torsiocaloric properties of a $Ni_{49.8}Ti_{50.2}$shape memory alloy, intending to explore the reversible shear-induced martensite-austenite transformation for eco-friendly cooling and energy conversion technologies.

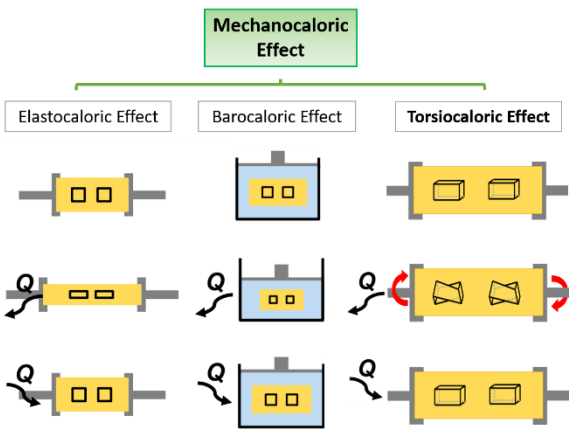


***Figure 1**. Scheme for mechanocaloric effects. Adapted from ref. [4]*

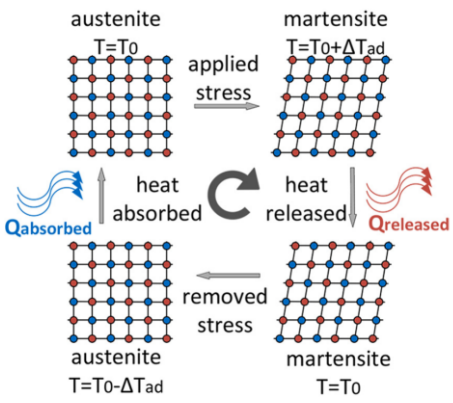


***Figure 2**. Mechanisms of mechanocaloric effect in Ni-Ti alloy (adapted from ref. [5]).*

Materials and Methods

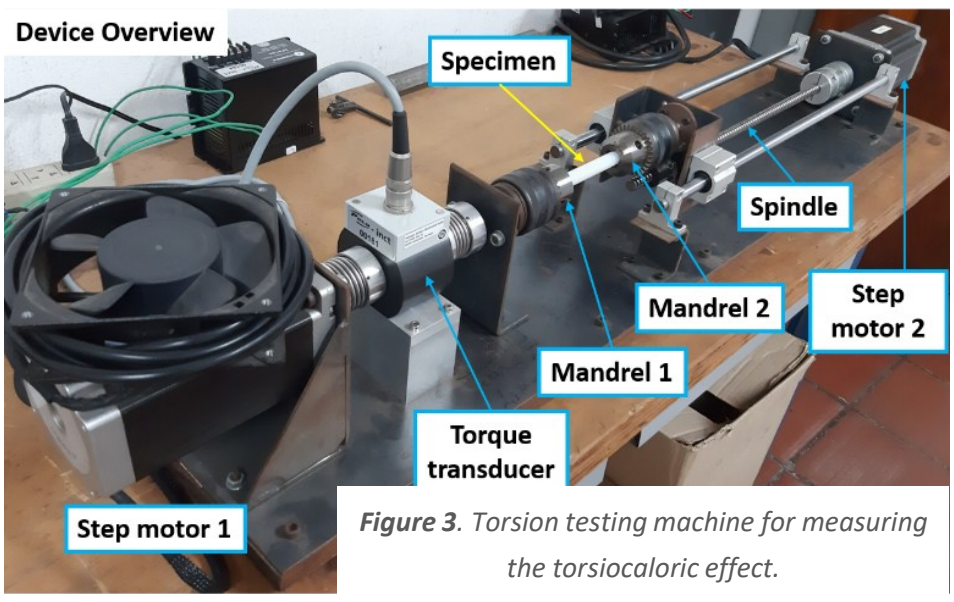
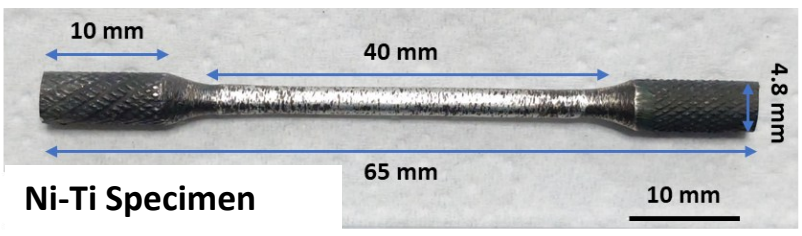


***Figure 3**. Torsion testing machine for measuring the torsiocaloric effect.*



SAMPLE PREPARATION

Sample	Cast method		Heat treatment
$Ni_{49.9}Ti_{50.2}$	Vacuum induction furnace followed by Rotary swaging	Machined into desirable geometry for the production of test specimen	2h @ 900 ºC Water quenching

Results

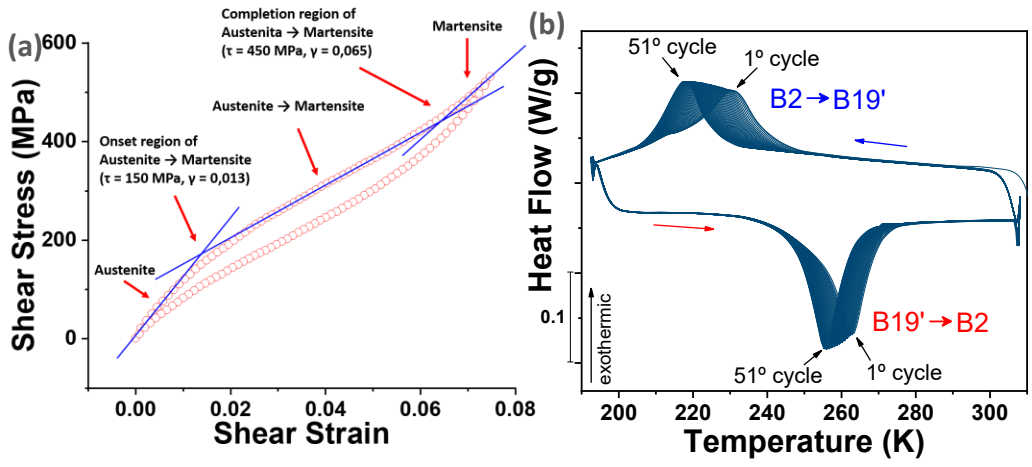


***Figure 4**. (a) Shear stress-strain curve of $Ni_{49.9}Ti_{50.2}$.(b) DSC curve for multiple cycles.*

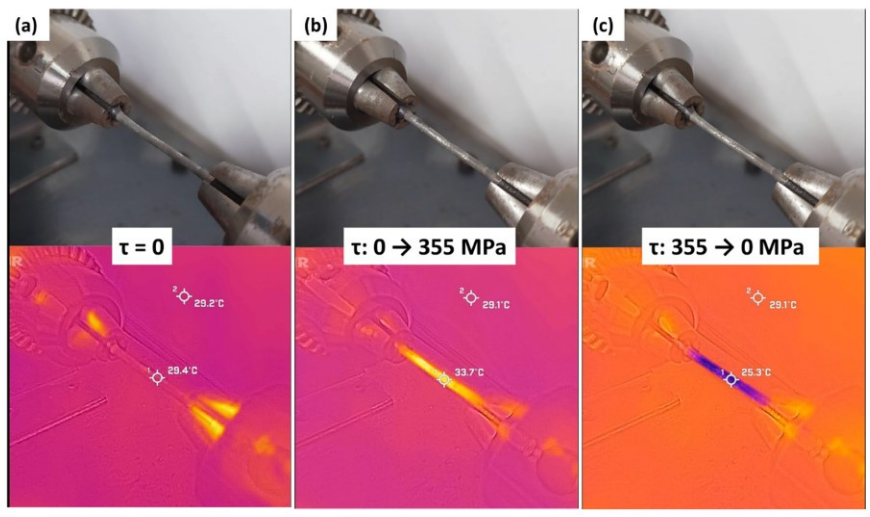


***Figure 5**. Temperature change (ΔT_{ad}) captured with a thermal imaging camera.*

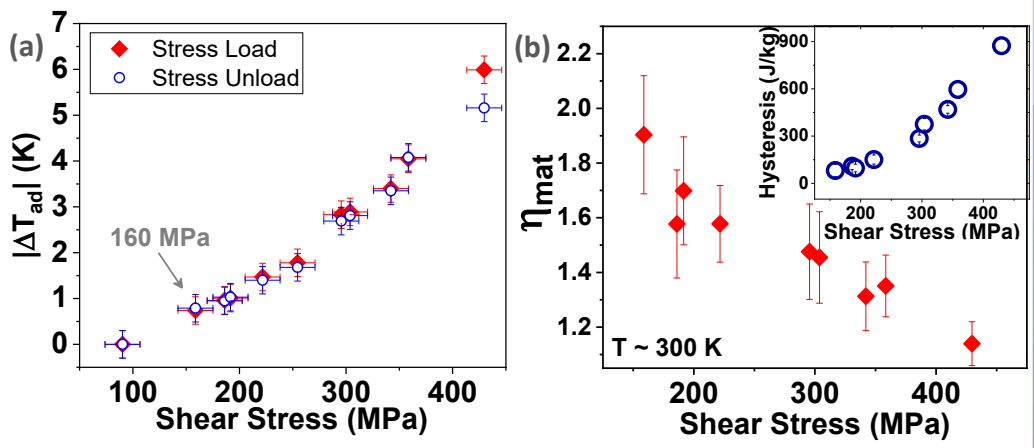


***Figure 6**. (a) ΔT_{ad} vs. Shear Stress at ambient temperature. (b) Material efficiency vs. shear stress (inset shows the corresponding mechanical hystesis).*

Conclusions

$Ni_{49.9}Ti_{50.2}$ operates in the austenitic ($B2$) phase at room temperature, undergoing a reversible, gradual $B2 \leftrightarrow B19'$ transformation between ~ 150 and 450 MPa with a characteristic S-shaped stress–strain profile.

Direct temperature change measurements shows a linear ΔT_{ad} increase above 160 MPa, reaching $+6.0$ K (loading) and -5.2 K (unloading) at 430 MPa ($T \sim 300$ K).

Material efficiency (η_{mat}) peaks at 1.9 (160 MPa) and drops to 1.14 (430 MPa) due to higher hysteretic dissipation, establishing pure shear in Ni-Ti as a viable route for solid-state cooling.

References

[1] P. Lloveras & J. L. Tamarit, MRS Energy & Sustainability 8, 3-15 (2021). **[2]** Wang, Run, et al., Science 366, 6462, 216-221 (2019); **[3]** E. O. Usuda et. al., Measurement Science and Technology 36, 085901 (2025). **[4]** S. Crossley, N. D. Mathur, X. Moya, AIP Adv. 5, 067153 (2015); **[5]** Tušek, J., et al., Journal of Applied Physics 117, 12 (2015).

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