A Novel Approach to Describe the Constitutive Behaviors of SMAs by Redefining Martensite Internal Variable

Longfei Wang[1], Ying Wu[1*] and Zishun Liu[2]

[1]State Key Laboratory for Strength and Vibration of Mechanical Structures, National Demonstration Center for Experimental Mechanics Education, Shaanxi Engineering Laboratory for Vibration Control of Aerospace Structures, School of Aerospace Engineering, Xi'an Jiaotong University, Xi'an, China

[2]International Center for Applied Mechanics, State Key Laboratory for Strength and Vibration of Mechanical Structures, School of Aerospace Engineering, Xi'an Jiaotong University, Xi'an, China

[*]Corresponding author: wying36@xjtu.edu.cn

Abstract
Shape memory alloys (SMAs) are types of shape memory materials possessing the capability to retain their previous shape when subjected to certain stimulus, e.g., the thermomechanical variations, which makes them to be highly concerned in recent years in a broad range of commercial applications. Since the significant characteristics of SMAs, involving the shape memory effect and the pseudo-elasticity, are deeply effected by internal variables in SMAs, accurate descriptions of the variation of these variants are quite important. Therefore in this study, we redefine the internal variables in SMAs including the martensite phase and the R-phase based on the Brinson model, and propose a constitutive model for SMAs considering the inelastic strain caused by the martensitic or R-phase transformations. The results show that the proposed constitutive model is capable to reveal the behaviors of SMAs, including the pseudo-elasticity, the shape memory effect, and the internal sub-loops due to the incomplete phase transformations. In addition, we also extend the novel model to ones reflecting tensile-compressive asymmetry behaviors, ratchetting deformations and even the rate-dependent behaviors of SMAs, which make them widely used in engineering applications. It is also demonstrated that the numerical results show good agreements with the experimental results, which confirms the feasibility of these SMA constitutive models.

Keywords ratcheting deformations, phase diagram, phase transformation, R-phase, shape memory alloys

Acknowledgments
This work was supported by grants from National Natural Science Foundation of China Grant (Nos.11772242, 11572236 and 11820101001).

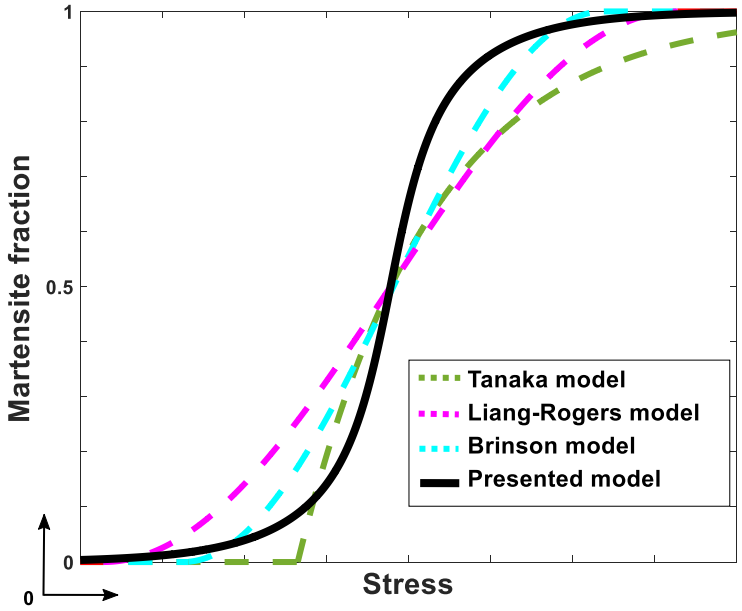

Fig. 1 Qualitative analysis of martensite fraction ξ in SMAs for martensitic transformation.

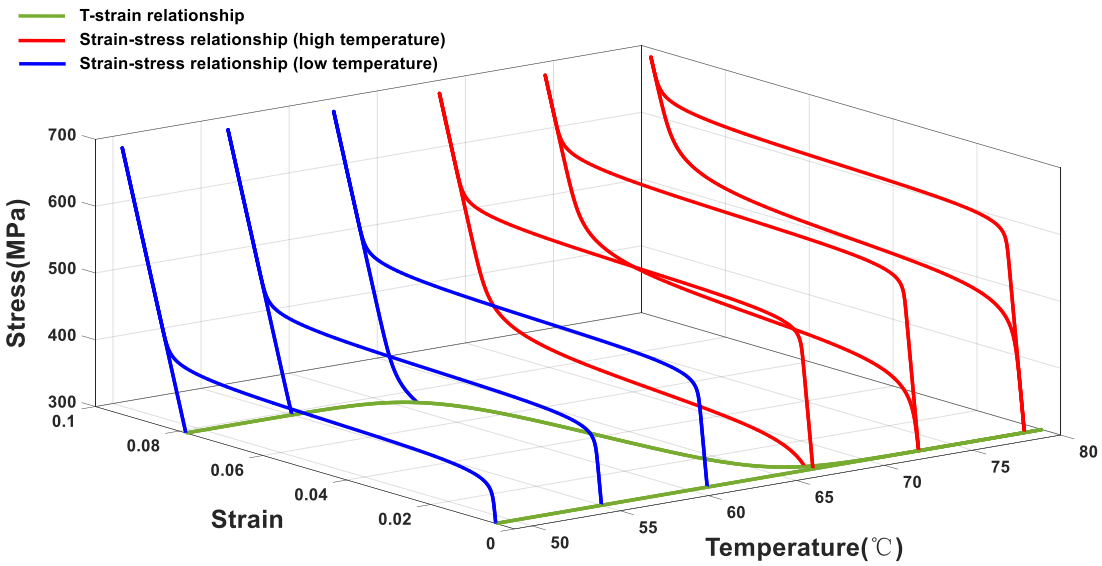

Fig. 2 The temperature-strain-stress relationship of SMAs with martensitic transformation in a complete mechanical cycle.