Evolution of residual stresses in polymer composites having porosity

Deepak Panda[1,*] **and Harini Subramanian**[1]

[1]Department of Mechanical Engineering, Indian Institute of Technology Gandhinagar, Palaj, Gandhinagar-382355, Gujarat, India
e-mail IDs: deepakmechiter@gmail.com, harini.subramanian@iitgn.ac.in

KEYWORDS: *Polymer composites, Porosity, Homogenization, Residual stress*

Polymer composites are often produced by curing an uncured liquid monomer, which gradually transforms into a cross-linked solid polymer that bonds the fibers. The development of residual stresses in polymer composites during curing is well reported [1]. The widespread usage of these materials demands an efficient and defect-free curing process. Pores may form during the curing process due to trapped gases or air bubbles in the matrix. As complete elimination of pores in the matrix is extremely expensive and unrealistic, it is essential to understand the influence of porosity on curing-induced residual stresses. The effect of porosity on residual stress evolution in a pure polymer system has been reported by modelling the material as linearly elastic [2]. However, polymer exhibits a viscoelastic constitutive response, and the magnitude and nature of residual stresses in polymer composites are very different from those generated in an isotropic polymer system. Hence, the present study aims to understand the effect of porosity on the evolution of residual stresses in polymer matrix and the laminated polymer composites, capturing their viscoelastic constitutive response. The effective viscoelastic properties

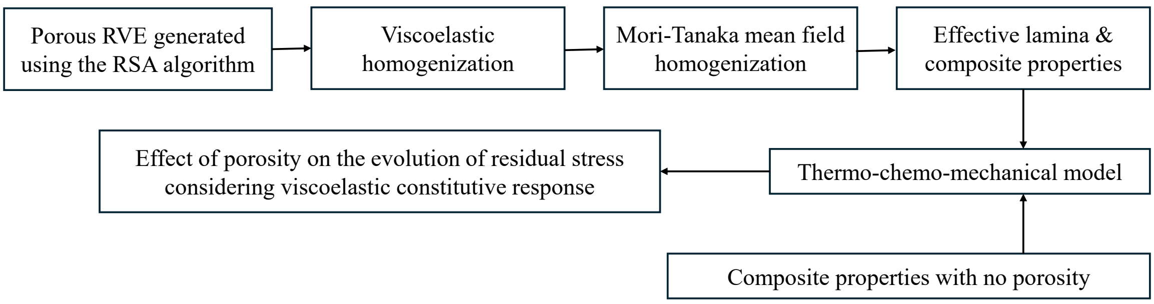

Figure 1. A schematic diagram illustrating the workflow.

of the polymer matrix composite are characterized by using a generalized Maxwell model. A two-step homogenization approach is adopted to calculate the effective viscoelastic properties, which comprise the elastic constants and relaxation times of the porous polymer composite. Firstly, the properties of the porous polymer are determined using a finite element (FE)-based computational homogenization technique. A representative volume element (RVE) of the porous matrix is created, and the homogenization is performed based on the Hill-Mandel macro-homogeneity condition. Appropriate periodic boundary conditions are applied to simulate the relaxation response of the RVE. Finally, the effective properties of the polymer composite are determined using the Mori-Tanaka method. An FE-based thermo-chemo-mechanical model is developed to predict the evolution of the temperature field, curing fraction, and residual stresses. The influence of porosity on the evolution of temperature and cure fraction is investigated. The complete computational workflow is shown in Fig. 1. The evolution of residual stresses in the domain is compared for the porous and non-porous cases, considering both isotropic matrix and orthotropic laminated composite cases.

[1] Yuan, Z. *et al.*, *Mech. Compos. Mater.*, **155**, 49–61, 2018. https://doi.org/10.1016/j.compositesb.2018.08.012

[2] Dewangan, B., & Chakladar, N. D., *Mater. Today Commun.*, **35**, 105711, 2023. https://doi.org/10.1016/j.mtcomm.2023.105711