20th European Mechanics of Materials Conference - EMMC20
Florence, Italy | May 27th-29th, 2026
www.emmc20.unifi.it

Towards a fracture mechanics-based assessment of fatigue in non-woven biodegradable polymeric scaffolds

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Paper ID: 72
Symposium S8: Fracture, and damage of materials

Abstract

Electrospun, non-woven biodegradable polymeric scaffolds are widely employed in tissue engineering and regenerative medicine due to their ability to mimic the architecture of the extracellular matrix of soft tissue and promote cell infiltration. In addition to matching macroscopic mechanical properties such as stiffness and relaxation, these scaffolds must also maintain their structural integrity under the cyclic loading generated in physiological environments. Prosthetic aortic valves, for example, are subjected to millions of loading cycles annually, combining tensile, bending, and shear induced by the complex motion of the heart and the resulting hemodynamic flow [1]. From a mechanical perspective, electrospun synthetic polymers exhibit a strongly nonlinear macroscopic response, combining inelastic and rate-dependent phenomena with relevant anisotropy [2]. In contrast to other soft elastomers, their fibrous structure at the micrometer scale leads to a strong coupling between architecture and mechanics, making microstructural deformation and damage a central factor in their dissipative response. This work presents a fracture mechanics-based framework for assessing the fatigue of electrospun polycaprolactone-based meshes. Classic mechanical tests on uniaxial and pure shear specimen configurations, which are widely used in the fracture assessment of elastomers, are complemented by digital image correlation (DIC) and confocal laser scanning microscopy (CLSM). This integrated approach allows the correlation of macroscopic behavior with the local

analysis of microstructural changes under load and highlights relevant sources of intrinsic and extrinsic toughening [3]. These mechanisms depend in particular on the loading direction relative to the preferential fiber orientation that arises during electrospinning. Furthermore, our study highlights the advantage of a fracture mechanics perspective over the total-life approaches currently prescribed in standards for assessing the durability of tissue-engineered constructs [4].

Keywords:

soft materials fatigue fracture mechanics polymers electrospinning

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