Magnetically assisted self-healing: modelling and experiments

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Abstract

Magnetic composites and self-healing materials have attracted considerable attention in their respective fields of application. Magnetic fillers enable the tunning of the properties of materials, as well as the change of shapes and motion when external magnetic fields are applied to them. Self-healing materials have the ability to repair structural damage and consequently restore their functional properties during the healing process. The fusion of these two unique features results in remarkable advances in both fields. This study explored the magnetically assisted self-healing behaviour of magnetic polymer composites (1) by combining an experimental characterisation with numerical modelling to provide insights into the understanding of the healing process under magnetic fields. The numerical framework was based on a finite element implementation of the magneto-mechanical problem coupled with phase-field fracture and diffusion-based healing to reproduce the fracture-healing behaviour of the polymer and the influence of magnetic fields. This model allowed for the prediction of inter-chain diffusion healing mechanisms under varying magnetic fields and temperature conditions, providing insights into healing efficiency and the overall mechanical performance of the material under applied magnetic fields. Moreover, a customised experimental setup was developed to precisely control the magnetic field and thermal conditions during the self-healing process on pre-damaged samples. The material under study was a composite of magnetic nanoparticles embedded in an elastomeric matrix. After healing, the mechanical testing revealed the recovery of tensile strength and elasticity, showing enhanced self-healing capabilities in the presence of magnetic fields. A good agreement was observed between numerical simulations and experimental data of analysed self-healing properties and good predictability. This combined experimental and numerical approach offers a comprehensive understanding of the self-healing mechanisms, lays the foundation for further development, and has significant implications for applications in magnetic soft robotics where autonomous damage repair implies a potential improvement (2).

References

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