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Machine Learning Approaches to Analyzing Atomic Force Microscopy Images of Cross-Linked Polyethylene Pipes

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We use atomic force microscopy-force spectroscopy (AFM-FS) to measure the morphology and mechanical properties of cross-linked polyethylene (PEX-a) pipe. PEX-a pipe is being increasingly used to replace metal pipe for water transport and heating applications, and it is important to understand ageing, degradation and failure mechanisms to ensure long-term reliability. AFM-FS measurements on the PEX-a pipe surfaces and across the pipe wall thickness allow us to quantify changes in the morphology and mechanical properties from high resolution maps of parameters such as stiffness, modulus, and adhesion. Measurements performed on pipes subjected to different processing and accelerated ageing conditions generate a substantial amount of data. To classify and correlate these images and the associated properties, we have used machine learning techniques such as k-means clustering, decision trees, support vector machines, and neural networks, revealing distinctive changes in the morphology and mechanical properties with ageing. Our machine learning approach to the analysis of the large body of AFM-FS data complements our deep generative modeling of infrared images of the same pipes [1], providing additional insight into the complex phenomena of ageing and degradation.

[1] M. Grossutti et al., ACS Appl. Mater. Interfaces 15, 22532 (2023).

Keyword-1

Atomic Force Microscopy

Keyword-2

Machine Learning

Keyword-3

Microscopy

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