

## CYCLIC INDENTATION TEST TO CHARACTERISE VISCOELASTIC BEHAVIOUR OF POLYMERS

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The Oliver & Pharr analysis of indentation data is generally acknowledged and used by research labs and industries to characterize the mechanical behaviour of metals at small scales. It is based on the Sneddon's contact model of a rigid indenter penetrating an elasto-plastic matter and is perfectly suitable for these materials. However, when the nanoindentation technique is used to study polymer behaviour, there is no general agreement on the procedure and analysis method to use. It is clear that getting the elastic and plastic parameters from the fitting of a single unloading is insufficient to fully characterize the time-dependent behaviour of these materials. The indentation methods applied on polymers are usually inspired by the well-known macroscopic mechanical tests and implemented with the nanoindentation equipment. For instance, a creep test is reproduced through nanoindentation at constant force, revealing a logarithmic behaviour similar to macroscopic one. When small oscillations are superposed on the static nanoindentation loading, a dynamical loss and storage moduli can be calculated by an analogy to the macroscopic DMA technique. The direct analogy between macroscopic static and dynamic behaviour, and microscale contact behaviour might be questionable due to many factors. Nevertheless, these methods are the only procedures available today to access the local mechanical properties of polymers with nanoindentation. In this work, we suggest a new cyclic indentation method and material behaviour analysis inspired by a macroscopic tension fatigue test. Our test consists of up to 1200 loading-unloading cycles after an initial holding period at low load to correct for a thermal drift. Each hysteresis loop is analyzed to obtain its area, the secant rigidity and mean (ratcheting) displacement similarly to the area, secant modulus and ratcheting strain characterizing the macroscopic test (see Figure 1). The frequency and load ratio effects on these three parameters are also studied. The cyclic indentation test is performed on two glasses, a titanium alloy and several polymers to make sure that the observed time-dependency is due to the material behaviour and not to the indentation technique itself. The results obtained on a high density polyethylene are discussed and compared with the macroscopic tension fatigue behaviour demonstrated by this material previously [1].

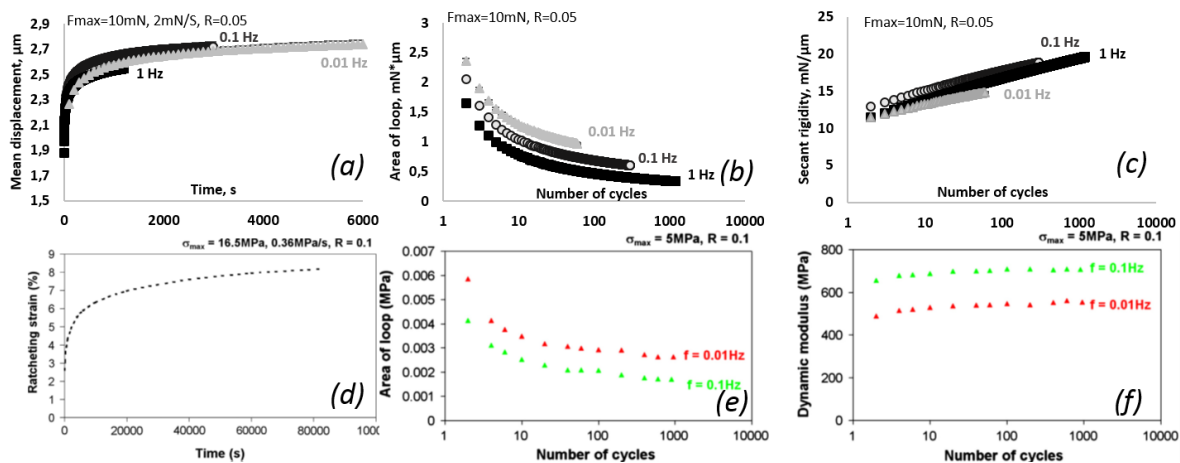


Figure 1 – HDPE behaviour by the new cyclic indentation test (a-c) and tensile fatigue test from [1] (d-f)

[1] S. T. T. Nguyen, S. Castagnet, J-C. Grandidier “Nonlinear viscoelastic contribution to the cyclic accommodation of high density polyethylene in tension: Experiments and modeling” *International Journal of Fatigue* 55 (2013) 166–17