

CHARACTERIZATION OF THE FRACTURE BEHAVIOR OF HYDROGELS

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Summary: *Hydrogels are attractive materials for many demanding applications (i.e. medical, scaffolds for soft tissue engineering, organic electronics and optics). One of the recent developments in this field is the fabrication of super tough hydrogels by using several modifications of the double-network concept. These hydrogels can show several hundred percent strains without failure under uniaxial tensile loading condition and reveal excellent fracture toughness and notch sensitivity. The measurements have been done with two different types of nanoparticle filled hydrogels which also showed a variation on the percentage of added nanoclay over a range of 2% to 15%.*

Keywords: *fracture, displacement controlled loading, crack tip blunting*

1 Introduction

Standard hydrogels consist of hydrophilic polymer chains which form a network and can absorb high amounts of water (over 90%). Besides these common hydrogels, at least three different major types of ultra strength hydrogels exist. First, there are polyacrylamide/alginate hybrid hydrogels which consist of ionically cross-linked alginate chains interpenetrated with the covalently cross-linked polyacrylamide [1]. Furthermore, there are double-network hydrogels where the minor component is tightly cross-linked polyelectrolytes and the major component comprises of poorly cross-linked neutral polymers such as polyacrylamide [2]. The last type are nanocomposite hydrogels which contain a variety of clay minerals with layered crystal structures that is easily exfoliated in water and act as a cross-linker [3].

2 Preparation and Setup

Pure shear specimens were produced by casting in combined Al and PTFE forms and then conditioned either as dry or in water, under constant temperature conditions before testing. These specimens were tested under monotonic, semi-cyclic and cyclic loading conditions using a BOSE Electroforce TestBench testing system including an extra sensitive 20 N load cell, a temperature chamber and a mounting system with different clamp sizes. Latter are necessary due to the varying swell of the hydrogels with nanoclay content.

3 Testing methods

3.1 Hysteresis tensile test

We assumed a strong dependence of mechanical properties on the nanoclay content. Hence, two different modifications of the nanocomposite hydrogels, termed as XLS (sole grade laponite gel) and XLG (gel grade laponite gel) have been prepared over a range of 2% to 15% added nanoclay. Stress- strain curves for the XLG grade hydrogels with varying nanoclay content are shown in figure 1.

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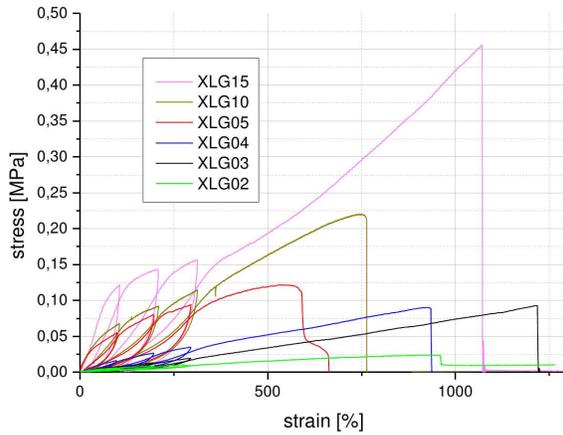


Figure 1: Stress-strain curves of XLG nanoparticle filled hydrogels with varying nanoclay content under dry test conditions.

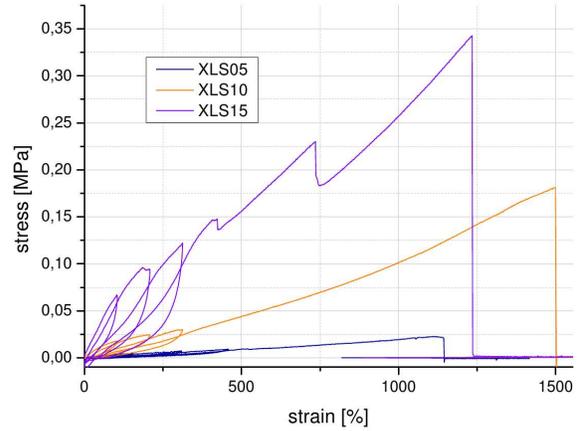


Figure 2: Stress-strain curves of XLS nanoparticle filled hydrogels with varying nanoclay content under dry test conditions.

It is also shown that these specimens have been tested under displacement control up to three different strain levels, namely 100 %, 200 % and 300 % and then stretched up to break. One can see that the degree of added nanoclay is proportional to degree of hysteresis and mechanical properties such as Young's modulus and tensile strength but there is no clear relationship between the nanoclay percentage and fracture strain. With increasing nanoclay content the hydrogels are stiffer and reveal higher fracture strength.

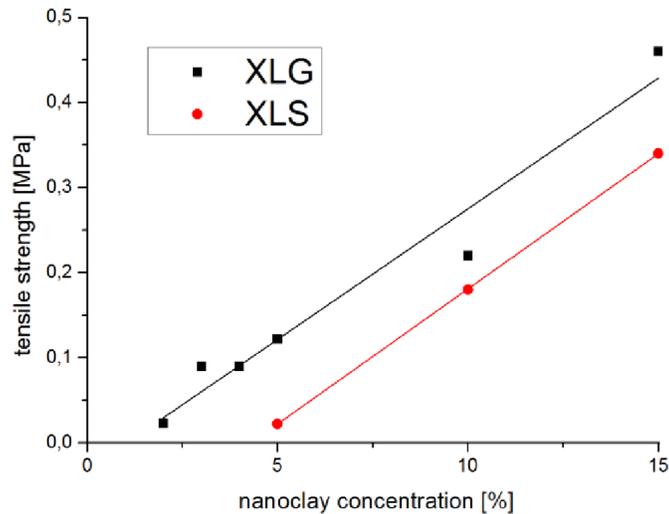


Figure 3: Impact of nanoclay concentration on tensile strength for both, XLS and XLG.

In the case of XLS we observed similar mechanical properties regarding the added nanoclay content. The big difference in contrast to the XLG gels is the 25 – 35 % lower fracture strength (always compared to the XLG gel with equal amount of nanoclay) but significantly higher fracture strain values (XLG from 500 to 1000 % and XLS is from 1000 to 1500 %). The dependence of the tensile strength on the nanoclay content both for XLG and XLS grades is shown in figure 3.

While XLG grades revealed higher tensile strength with a distinct data scatter, the XLS grades shown lower tensile strength values and low data scatter.

3.2 Comparison of "dry" hydrogels vs. hydrogels stored 24h in water

Furthermore, hydrogel specimens from the same batches have been stored 24 hours in water under constant temperature conditions and the previous tests have been repeated. A clear reduction of the stress level and an even more significant decrease of tensile strength just due to the 24h storage in water is shown in figure 4. Moreover, a nanoclay content dependent decrease of the tensile strength was observed (20 % to 350 %) and this tendency is shown in figure 5. In spite of this high data scatter, a clear trend was noticeable, that is, the wet hydrogels revealed significantly lower tensile strength.

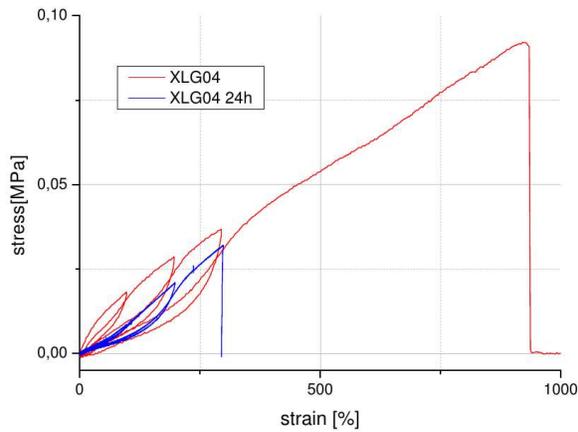


Figure 4: Dry-wet comparison for XLG4.

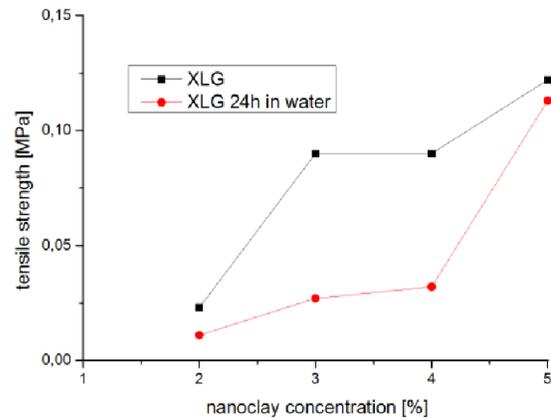


Figure 5: Dry-wet comparison for tensile strength.

3.3 Notched hydrogels

The pure shear specimens were subsequently notched in the next test series with a razor blade up to 3 mm length (1/10 of total length) and the same tests were performed as before. In figure 6, stress- strain curves of the notched specimens are shown for XLS under dry test conditions.

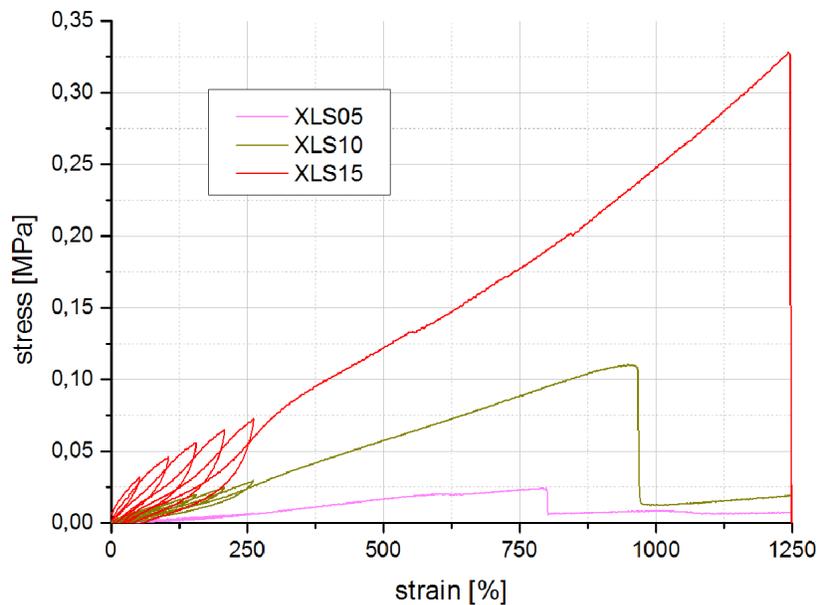


Figure 6: Stress-strain curves of 3 mm notched XLS nanoparticle filled hydrogels under dry test conditions.

The results are surprising in the way, that tensile strength for notched XLS hydrogels nearly remained at the same level for every nanoclay variation of the gel. Similar results were observed for XLG hydrogels too. Hence, all types of hydrogels exhibit really good notch sensitivity.

4 Outlook

One part of future work is focusing on fatigue in general and fatigue crack growth propagation, while another part will be the study of self-healing properties and property changes due to different temperature regions.

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