**Influence of swelling on the fatigue behaviour of a composite hydrogel for disc implant**

C. Wyss¹, A. Khoshabeh², B. Caglar¹, D. Pioletti², P.-E. Bourban¹

¹ Laboratory of Polymer and Composite Technology, ² Laboratory of Biomechanical Orthopedics
Ecole Polytechnique Fédérale de Lausanne (EPFL)
celine.wyss@epfl.ch

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**Introduction**

One of the most recent treatment proposed for discogenic lower back pain is to permanently replace the Nucleus Pulposus (NP).

PEGDM hydrogel reinforced with cellulose fibres is proposed as a replacement biomaterial that is injected directly into the degenerated IVD in the liquid form and cured in situ via UV-light irradiation [1].

The reliability of this composite hydrogel under long-term fatigue loading is investigated this study.

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**Objectives**

- Study and quantify the long-term behaviour of the composite hydrogel under cyclic loading.
- Develop a microscopy method to compare qualitatively the NFC fibres morphology into the composite hydrogel at different loading and swelling conditions.

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**Materials & Methods**

**Materials**

Composite hydrogel: 10 wt.% of 20 kDa Poly(Ethylene Glycol) DiMethacrylate (PEGDM) reinforced with 0.5 wt.% of Nano-Fibrillated Cellulose (NFC)

Neat hydrogel (as a representative of the composite hydrogel's matrix): 10 wt.% of 20 kDa PEGDM

**Mechanical testing**

Glass container

Transcranial Ultrasound

Sample

Synthesis

0.1 g/mL Isgacure 2959

10 wt.% PEGDM

0.5 wt.% NFC

NFC

Neat

Composite

PBT

UV-light

20 min

30 min

**Results & Discussion**

**High-cycle fatigue test**

20% maximum applied strain at 60 Hz

The composite hydrogel withstands the required 10 million cycles.

Addition of NFC fibres provides an increase in elastic modulus by reduction of 10% in the first 10 cycles.

**Effect of hydrogel’s hydration state**

1. Stiffening induced by swelling: The lower swelling ratio of the composite hydrogel indicates that the NFC network is pre-strained due to swelling. The latter participates in a formation of a more elastically active network that provides an increase of the elastic modulus.

2. Reduced softening in the as-prepared state: NFC fibres into the hydrogel at the as-prepared state are less constrained in the 3D-direction resulting in a decrease of the softening.

(A) A global expansion of the NFC network could be observed at a microscopic scale. Some fibres are slightly extended and their respective surface flattened.

**Effect of relaxation**

**NFC Morphology**

A large diversity in size and morphology of NFC fibres reflects the preparation history.

(1) The NFC fibres are composed of bundles of nano-fibres that were not perfectly debranched.

(2) The clouds of NFC are probably constituted of tightly entangled and randomly oriented NFC fibres.

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**Conclusions**

- The composite hydrogel withstands the required 10 million cycles. The partially recoverable softening behaviour similar to the Mullins effect is associated with a gradual disintegration and re-arrangement of the nano-fibrillated cellulose (NFC) network.
- The swelling pre-strains the NFC network and thus participates to the formation of a more elastically active network providing an increase of the apparent elastic modulus.
- An imaging method was developed that enables to observe the NFC fibres morphology into the composite hydrogel at its different stages that it is faced during the mechanical testing.

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**Perspectives**

- Confined mechanical testing
- Effect of drying rate and dryness degree
- Effect of multiple re-hydration cycles
- Effect of NFC fibres dispersion

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**References**


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