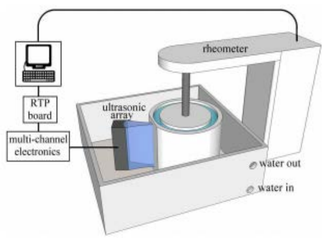
How natural rubber latex gels deform under stress: a study using a rheo-ultrasonic technic

Guilherme de Oliveira Reis[1], Paul Menut[1], Thomas Gibaud[2], Mathieu Leocmach[2], Laurent Vaysse[1], Fréderic Bonfils[1], Sébastien Manneville[2] and Christian Sanchez[1]

[1] UMR IATE : UM2-CIRAD-INRA-SupAgro, Montpellier, France; [2] Physics Laboratory, Ecole Normale Supérieure de Lyon, France

Context

Natural rubber latex (NRL), extracted from *Hevea brasiliensis* tree, coagulate by addition of an acid and formed a **colloidal gel**. Such gels present a **strain hardening** behavior if submitted to large amplitude oscillatory deformation. Whether this irreversible strain hardening occurs homogeneously in the entire material or propagate from the rotor to the stator is an open question. Here, we used conventional rheometry coupled with **2D ultrasonic speckle velocimetry (USV)** to study the displacements fields inside the gel during the strain hardening.



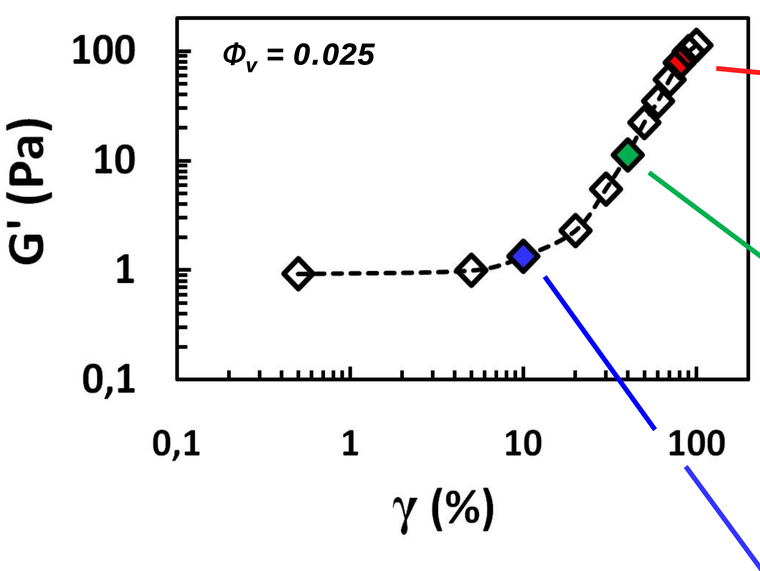
Materials & Methods

A prevulcanized **NRL** suspension (ϕ = 0.025) was acidified by addition of Glucono-δ-lactone. Oscillatory measurements were performed in a commercial rheometer (TA Instruments ARG2) using a PMMA Couette geometry (R_e =25 mm, R_i =23 mm, h =60 mm) to allow USV measurements with a **Ultrasonic 2D-scanner** (20 sequences of 3000 pulses sent at 350Hz). Polystyrene particles (Dynoseed TS20µm) were added in the suspension (1%wt) as ultrasonic contrast agent, without any impact on rheological properties. The **gel** was **formed *in situ*** and its **viscoelastic properties were monitored for 30 min at f =1Hz and γ =0.5%.** Then the **gel was submitted to increasing oscillatory deformation step by step**.

Material response to an oscillatory strain

NRL gels present a **irreversible strain hardening** under large stress (or strain), and eventually fracture. This behavior is characterized by a increases of G' and G" with the strain *.

** Poster P0100 : Study of Irreversible Strain hardening in Hevea brasiliensis latex gels*



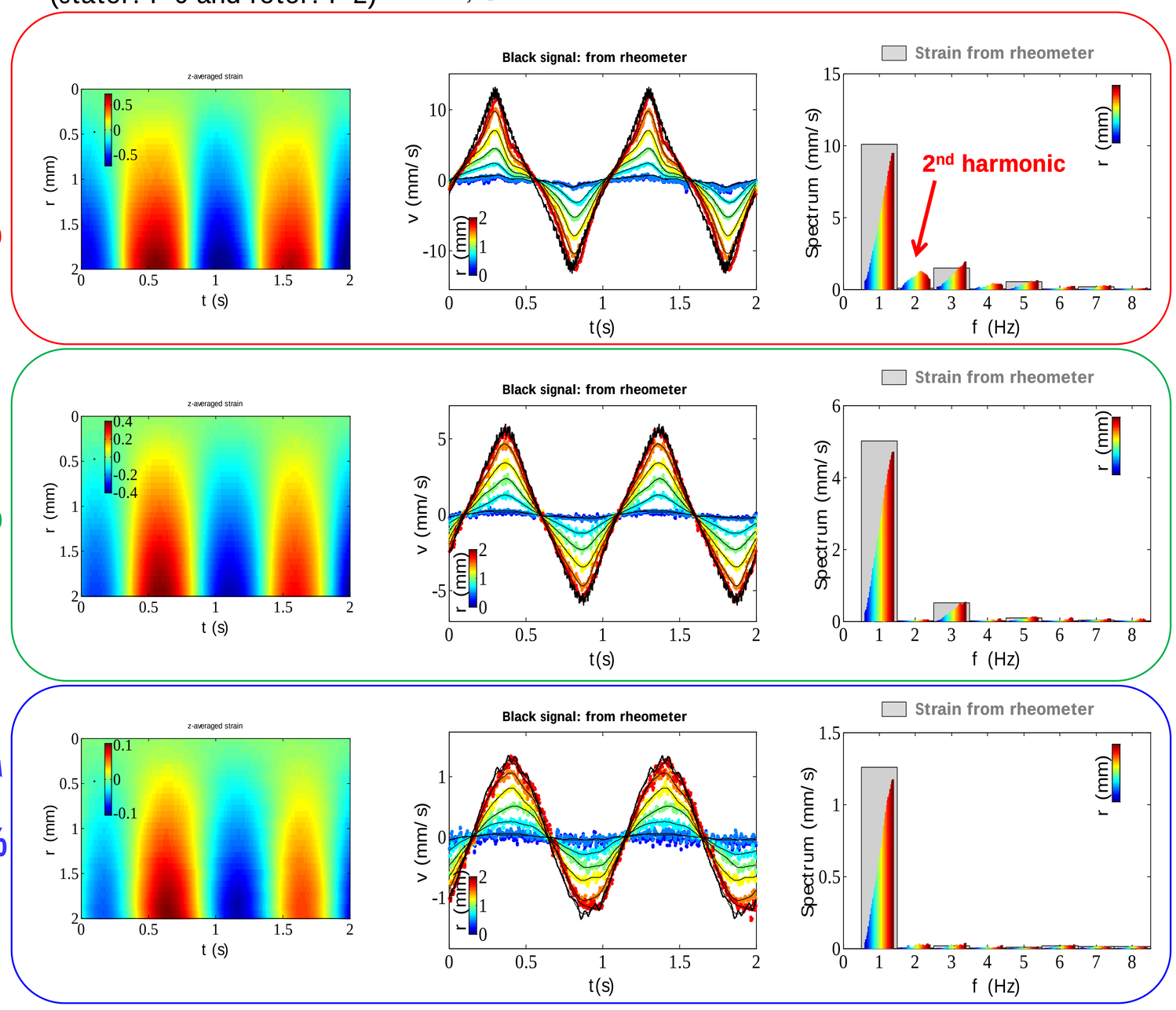
Oscillatory rheology of a NRL gel: G' during the increase of strain step by step

Displacements fields inside the gel during the oscillations (stator: r=0 and rotor: r=2)

Velocity profile obtained from USV during the oscillations

$$v = \sum_{f=1}^{8} v_f \sin(2\pi f t - \varphi_f) \quad \text{with} \begin{cases} v_f > 0 \\ \pi > \varphi_f > -\pi \end{cases}$$

Harmonics obtained from Fourier decomposition of the local velocity *vs* time



Three different **velocity profile :**

Sinusoidal (for **γ < 10%**):
(**1st** harmonic alone)

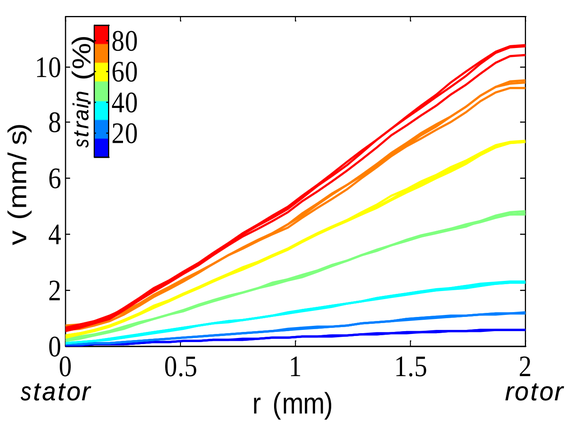
Triangular (for **10% < γ < 80%**):
(**1st - 3rd - 5th** harmonics)

Second harmonic (for **γ > 80%**):
(**1st-2nd-3rd** ,... harmonics)

Velocity Profiles

Linear displacements fields inside the gel are observed whatever the strain.

There is no apparent transient evolution once a new strain is imposed.



Velocity profiles inside the gel obtained from USV data

Conclusions

The macroscopic strain hardening behavior is associated with local rearrangements at a microscopic scale.

Local rearrangements are quasi-instantaneous upon strain increase, and homogeneously distributed in the sample.

At high strain deformations, while approaching rupture, the emergence of second harmonics in the signal might be the characteristic of preliminary disruption events.

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guilherme.de_oliveira_reis@cirad.fr