Dynamic characterization of synthetic and plant fibers

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Objective: go further in structural and multifunctional applications
- to master the natural resources
- to control the mechanical properties in a specific environment
- to optimize the architecture of the composite

Bio-based composite: application in the field of sports

Loss-modulus map from literatures

- Natural fiber
- Synthetic fiber
- Polymer
- Composite
- Metal

\[ \eta \frac{E}{E} = 1 \]

Renewable

Bio-based composites

Market demand

Natural fiber resources

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Dynamic tests on fibers
Dynamic tests on fibers

Damping: macroscale analysis

- Dynamic Mechanical Analysis (DMA tests)
  - Storage modulus: 18 GPa in glassy state to 3.8 GPa in rubbery state
  - Loss factor: 2.5 to 24% according to the temperature and the frequency

- Modal analysis
  - Loss factor: 1.3 to 2.5% according to the frequency

UD flax composite

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Impact of flax fibers reinforcement polymer composite on:
- **stiffness**: the storage modulus increases
- **damping**: the loss factor evolution is depending on the matrix...
Energy dissipation could come from:
- fiber properties: polymeric and hierarchical
- interface fiber/matrix
- interface in fiber bundles (friction)
- damage
- matrix properties

Difficulties to study bio-based material:
- variability
- hierarchical
- sensitivity

Environment influence:
- humidity
- temperature
- frequency
- fiber type

Fiber-scale dynamic tests
Outline

Context and motivations

State of the art on fiber-scale tests

Dynamic tests on elementary fiber

First measurements and discussions
Modulus at the fiber-scale

DMA tensile tests
Placet et al. 2009
hemp fibers

Mounier et al. 2012
Determination of the transverse elastic properties of glass fiber and carbon fiber

Single fiber transverse compression testing
Wollbrett et al., 2015
aramid fibers

Nanoindentation test: modulus identification
Perrier, 2016
hemp fiber

Determination of the elastic moduli of glass by forced vibrations
Perrin et al. 2007

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Dynamic tests on fibers
Damping at the fiber-scale

Placet et al. 2014

Adams et al. 1975

Philips, 1987

Yu, 2016

DMA tests on elementary hemp fiber

Key points to measure the damping at the fiber-scale:
• To quantify the aerodynamic effect (vacuum)
• To control of the limit conditions:
  ○ Clamp design
  ○ Measure method
  ○ Excitation mode
• To know the sample (geometry, density...)
Outline

Context and motivations

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First measurements and discussions
Dynamic test on fiber: concept

Objective: develop an **experimental method** to characterize the **damping** at the fiber scale.

1450 $m^3/kg – 75$ GPa

Vibration modes 5mm flax-fiber

Signal post-processed

frequency and modal damping

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Elementary fiber

Fiber preparation

Clamp

Flax fiber dimensions

Hair: 50 to 100 µm

Flax fiber dimensions

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Experimental setup

Microscale measurement in **MEMS room**:
- camera and microscope isolated from vibrations
- excitation with an electrical probe

- caméra Phantom V710
- microscope 5x
- clamp + fiber
- probe
Vidéos types obtenues

Glass fiber

Flax fiber

probe - excitation

fibre
Outline

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Data analysis

Recorded image

Modified image

Subtraction and binarization

Track the largest object

Fiber displacement – processed data

Isolation of the area of interest (time and spatial)

Fiber displacement – raw data
Mechanical properties analysis

Model approximation

\[(A_1 \cos(\omega t) + A_2 \sin(\omega t))e^{-\xi \omega t}\]

Amplitude [px]

Time [s]

Determination of the resonance frequency and of the modal damping

\[E' \text{ and } \tan(\delta)\]

Uncertainty about:
- the clamp
- the excitation
- the geometry of the fiber \((S, L, \rho)\)
- the aerodynamic effects

On going work!
Work on:
- the clamp
- the excitation
- the environment effects
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