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Ph.D. thesis (2019-2022)  
LGP2 (R. Passas; C. Martin)

# Understanding of the wrinkles formation during the coating functionalization of low grammage fibrous materials: a multiscale approach.

*Compréhension des phénomènes physiques relatifs à l'apparition de plis générés lors de la fonctionnalisation de surface par enduction des matériaux fibreux de faible grammage : une approche multi-échelles.*

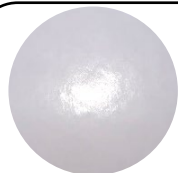
## Context

### Paper industry :

- Reduction of grammages with constant mechanical properties.
- Functionalization of papers in order to obtain specific surface properties and for new applications for thin paper.

But, it is mandatory to keep the quality of the paper:

- Wrinkles may appear during functionalization of low grammage papers.
- Non-conformities and downgrading of the products.



Conformed paper



Wrinkled and non-conformed paper

### Objectives:

- Obtaining fibrous supports with known characteristics.
- Development of multi-scale techniques for wrinkles characterization.
- Process simulation – modeling.

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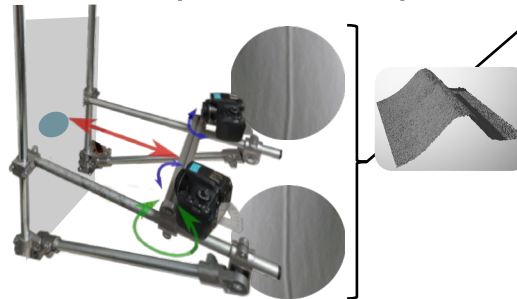
## Methods

### Paper - coating characterization:

- Mechanical properties, rheology and sedimentation studies.

### Understanding of the wrinkles formation:

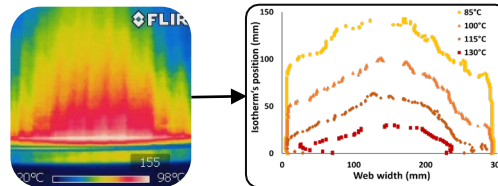
- Microscopic and macroscopic tools.



Digital Images Correlation (DIC) system

### Modelling and simulation:

- Understand the relationship between water absorption and paper mechanical properties.
- Study of temperature heterogeneity.



IR picture after drying and temperatures isotherms

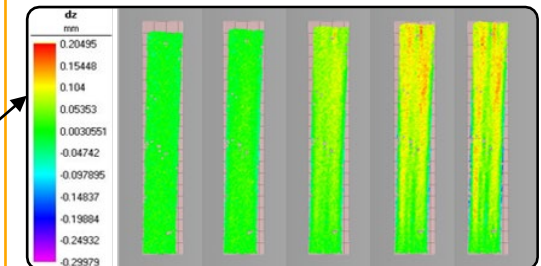
### Process analysis:

- Process monitoring.
- Database with all process parameters.

## Results

### Understanding of the wrinkles formation:

- DIC system to see wrinkles formation.

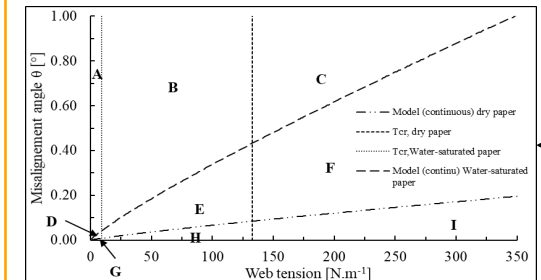


Out-of-plane displacement  $dz$  during a tensile test

- Impact of critical web tension  $T_{cr}$  and misalignment angle  $\theta$  on wrinkle appearance:

$$T_{cr} = \frac{2t_f^2}{\mu L} \sqrt{\frac{E_x E_z}{3(1-\nu_x \nu_z)}} \quad \theta = \frac{6\tau_{cr} a^2}{E_x L^2}$$

### Process control and monitoring:



Highlighting of 9 areas to facilitate coating process control (from A to I).

### Conferences:

Le Gallie & al, 25<sup>th</sup> TECNICEPA, Coimbra, Mar. 2021.  
Le Gallie & al. 7<sup>th</sup> EPNOE International congress, Nantes, Oct. 2021.