COST Action - FP1005

joint

6nd MC/WG Meeting

6th ERCOFTAC SIG43 Workshop

"Fibre suspension flow modelling - a key for innovation and competitiveness in the pulp & paper industry"

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PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

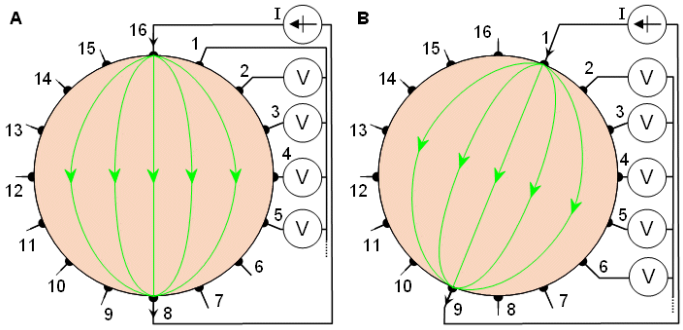
DEEC/FCT and DEQ/FCTUC
University of Coimbra
Portugal

Presentation Outline

- Brief Introduction to Electrical Impedance Tomography.
- Pilot Rig testing:
  - A) eucalyptus fibers.
  - B) Rayon fibers.
- Flow velocity estimation: first steps.

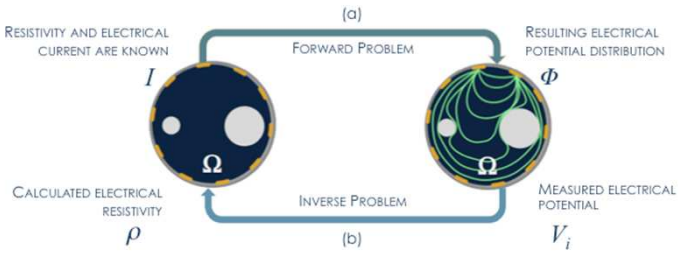
Electrical Impedance Tomography overview

In the development of accurate models for suspension related processes, prior knowledge of several flow characteristics is essential, such as spatial distribution of phases, flow regimen, interfacial area, and relative velocity between phases, amongst others.



Mathematical Formulation

Complete Electrode Model (CEM)



Regularized Gauss-Newton algorithm

For all described tests a mesh with 2304 triangular elements and 1201 nodes was used.

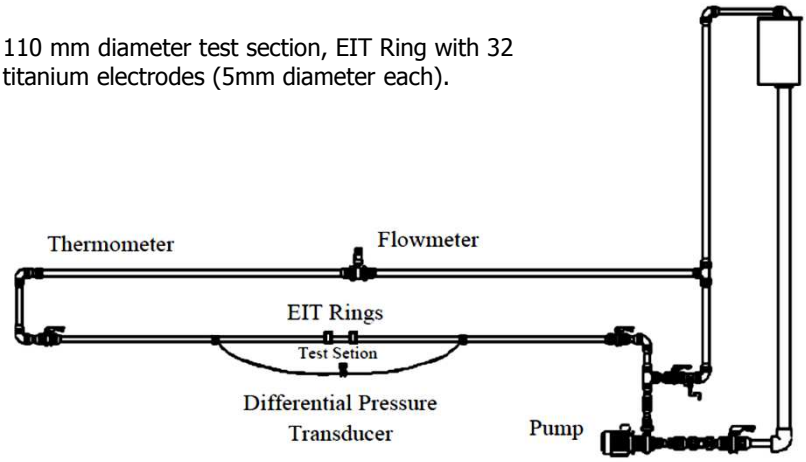
Majorly opposite injection and adjacent measuring was used.

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Experimental Setup I

PILOT RIG overview (DEQ-FCTUC)

110 mm diameter test section, EIT Ring with 32 titanium electrodes (5mm diameter each).

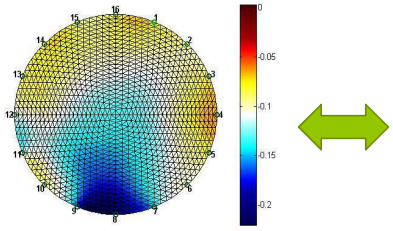


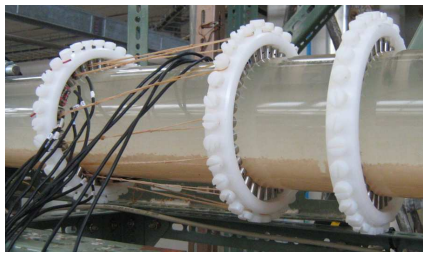
PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

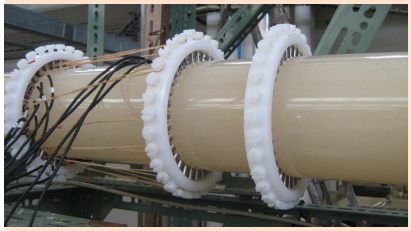
Experimental Setup I

Pilot Rig testing.

Flow speed: 0 m/s (adjacent injection and measuring only for this zero flow situation).







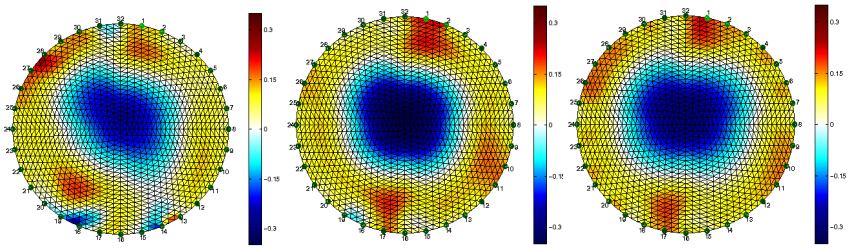
Flow speed: 0.7, 1.6 and 2.6 m/s. Eucaliptus short fibers, with a lenght of 0,706±0,03 mm, and with a concentration of ± 2.8% (w/w).

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Experimental Setup I

Pilot Rig testing.

Reference medium: NaCl doped water (conductivity 1.705 mS/cm).



Velocity = 0.7 m/s | Velocity = 1.6 m/s | Velocity = 2.6 m/s

Applied excitation: $2V_{pp}$ at 10KHz

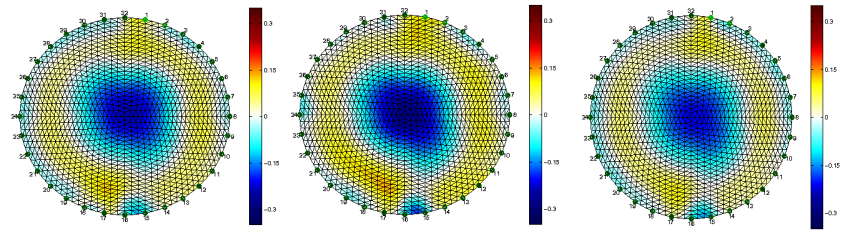
PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Experimental Setup I

Pilot Rig testing.

Applied excitation: $2V_{pp}$ at 10KHz

Reference medium: NaCl doped water (conductivity 1.440 mS/cm).



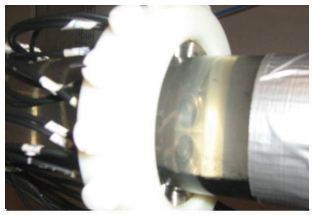
Velocity = 0.7 m/s | Velocity = 1.6 m/s | Velocity = 2.6 m/s

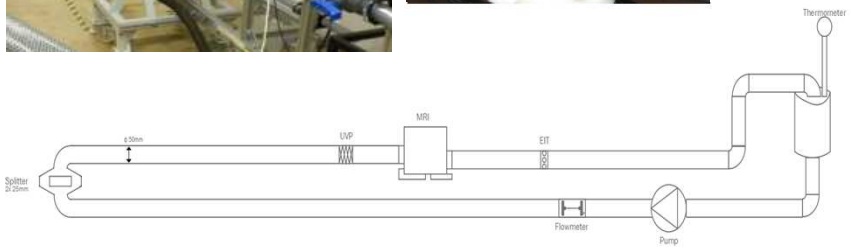
Results brief analysis – we can observe in the EIT images the fibers plug dimension change with the velocity: when it increases from 0.7 to 1.6 m/s the plug starts to get more "dense" (fibers are more agglomerated), noticeable by the growth of the darker blue region in the images; when going from 1.6 to 2.6 m/s, and, supposedly, all the suspension is already flowing, the darker blue region decreases, indicating a gradual destruction of the central fibers plug.

Experimental Setup II

PILOT RIG overview (KTH)

50 mm diameter test section, EIT Ring with 16 titanium electrodes (5mm diameter each).





PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Experimental Setup II

Pilot Rig testing.

Flow speeds of 0.5, 1 and 1.5 m/s. Rayon fibers (average fiber length: 2mm; average fiber diameter: 60 μm; fiber aspect ratio, L/d=33), with concentrations (nL^3) of 5, 10, 13, 16 and 20.

All experiments performed using:

- an applied excitation: $2V_{pp}$ at 10KHz;
- a reference medium: NaCl doped water (conductivity 1.6 mS/cm).

Data analysis

Velocity change behaviour

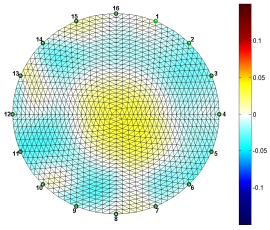
Concentration change behaviour

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

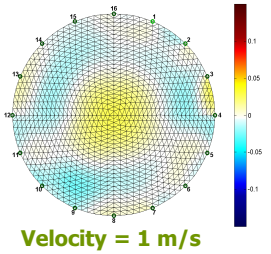
Experimental Setup II

Pilot Rig testing.

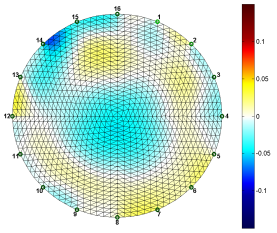
Fibers concentration $nL^3 = 5$



Velocity = 0.5 m/s



Velocity = 1 m/s



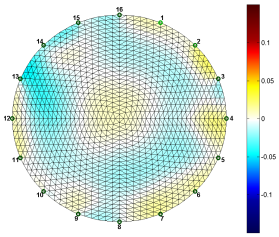
Velocity = 1.5 m/s

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

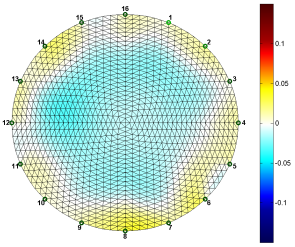
Experimental Setup II

Pilot Rig testing.

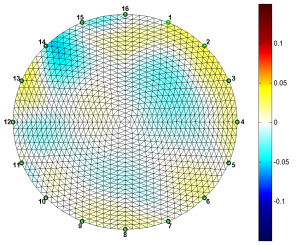
Fibers concentration $nL^3 = 20$



Velocity = 0.5 m/s



Velocity = 1 m/s



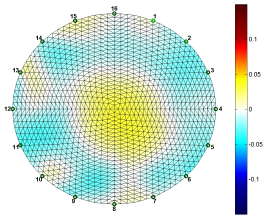
Velocity = 1.5 m/s

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

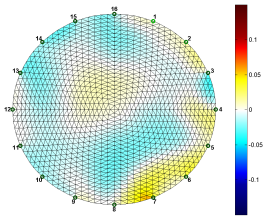
Experimental Setup II

Pilot Rig testing.

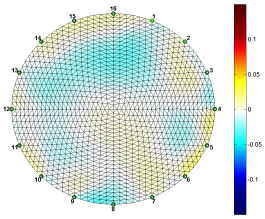
Flow velocity = 0.5 m/s



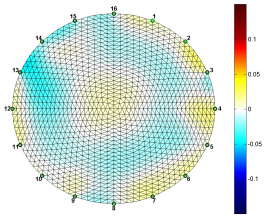
Fibers concentration: $nL^3=5$



Fibers concentration: $nL^3=10$



Fibers concentration: $nL^3=13$



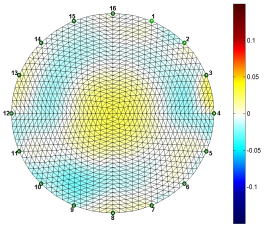
Fibers concentration: $nL^3=20$

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

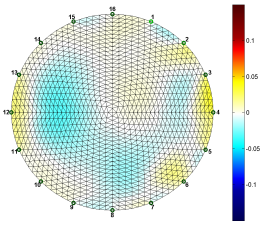
Experimental Setup II

Pilot Rig testing.

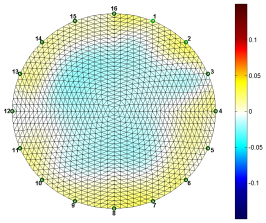
Flow velocity = 1 m/s



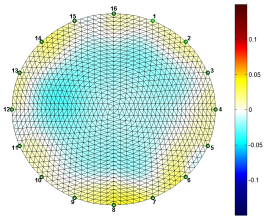
Fibers concentration: $nL^3=5$



Fibers concentration: $nL^3=10$



Fibers concentration: $nL^3=13$



Fibers concentration: $nL^3=20$

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Experimental Setup II

Pilot Rig testing.

Results brief analysis:

- a) regarding a fixed fibers concentration. For the lowest velocity it is observable that the fibers are to disperse: when the velocity rises from 0.5 to 1 m/s it is noticeable a decrease of the fibers dispersion, which is further evident when the velocity is raised to 1.5 m/s, for the lowest concentration, $nL^3=5$, while for $nL^3=13$, the fibers seem to start to disperse along the tube section.

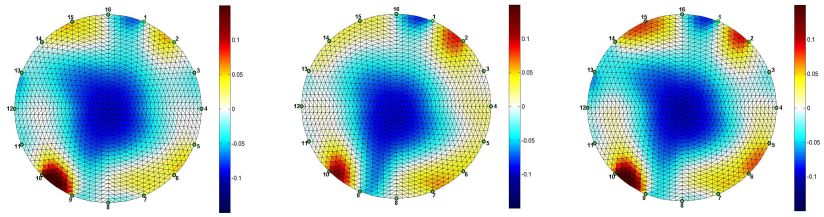
- b) regarding a fixed velocity. When the concentration of the fibers is equal to $nL^3 = 5$ they seem to be to much dispersed. As the concentration is raised it is observable that the blue area inside the section growths and gets more intense, indicating the existence of a larger quantity of fibers inside the section.

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Flow velocity estimation: Offline testing

Marker strategies addressed: non conductive solid markers, conductive solid markers and inline marker injection.

Reference images for solid markers use: cotton lint contains only washed and squeezed fibers.



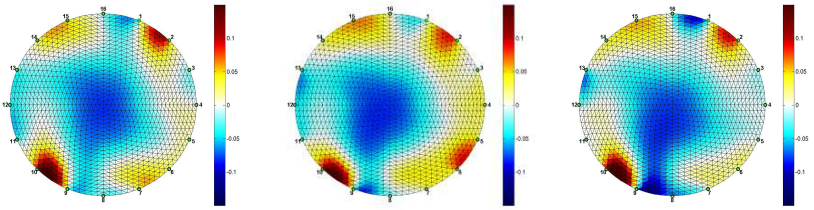
reference medium: NaCl doped water (conductivity 1.7 mS/cm).

Applied excitation: $2V_{pp}$ at 10KHz

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Flow velocity estimation: Offline testing

Non-conductive solid markers: cotton lint contains washed and squeezed fibers + glass spheres with 3mm diameter.



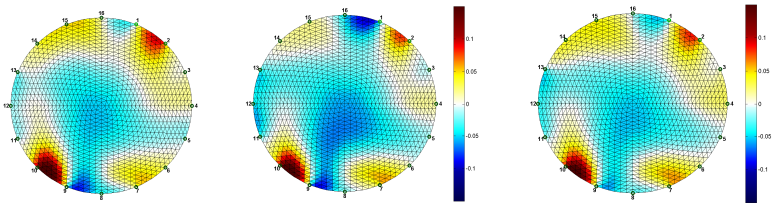
reference medium: NaCl doped water (conductivity 1.7 mS/cm).

Applied excitation: $2V_{pp}$ at 10KHz

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Flow velocity estimation: Offline testing

Conductive solid markers: cotton lint contains washed and squeezed fibers + gold coated glass spheres with 3mm diameter.



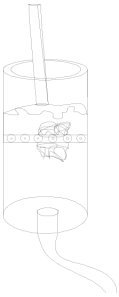
reference medium: NaCl doped water (conductivity 1.7 mS/cm).

Applied excitation: $2V_{pp}$ at 10KHz

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Flow velocity estimation:

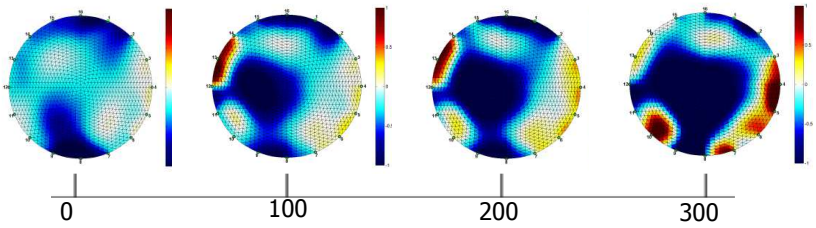
Inline marker injection.



Initial Reference medium: tap water (conductivity 0.1 mS/cm); Injection of NaCl doped solution (conductivity 4.4 mS/cm); Final solution conductivity 0.7 mS/cm; Washed and squeezed fibers inserted in a cotton lint (simulated plug).

Applied excitation: $2V_{pp}$ at 10KHz

Acquired images time sequence (ms)

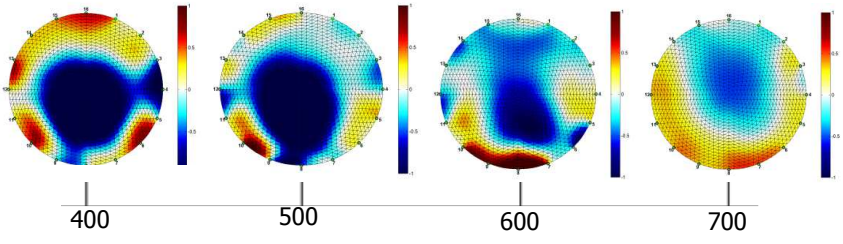


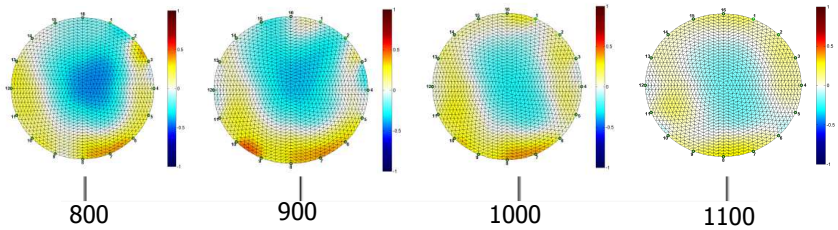
PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Flow velocity estimation:

Inline marker injection.

Inline solution injection seems to be the most adequate approach.





Next steps

- Further tests in pilot rig regarding velocity and concentration changes using eucalyptus and other fibers (natural ones: pine; synthetic ones: rayon).
- Flow velocity estimation first tests will be made as soon as the pilot rig injection system is on place using two EIT sections and two EIT hardware units, working in an interleaved and synchronized mode.

PILOT RIG FIBERS SUSPENSIONS CHARACTERISATION USING ELECTRICAL IMPEDANCE TOMOGRAPHY: SOME TEST CASES.

Thank you for you attention