Acoustic measurements on the Hole Erosion Test

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Charline Jeanniot - Irstea

Stéphane Bonelli (Irstea), Pierre-Olivier Mattei (LMA), Fabien Anselmet (Irphe), Naïm Chaouch (Irstea)

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Context

→ In France : 1 dike break/year ~ 100 M€

→ In the world : 46 % of dike break is caused by internal erosion

Outline

I Context of thesis research and experimentations

II Experimental results

III Next steps and perspectives

→ Is acoustic detection an effective method for dyke monitoring ?

I - Digue2020 (ERDF)

Marine submersion protection dike research platform

- Quantifying the actions of the sea on a dike and its durability (soil-lime dike),
- Asses the perception of the risk of marine submersion and protective measures,
- Interdisciplinary approach : natural sciences, engineering, history and psychology.

Camargue Dike © Irstea

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I – Hydro-acoustic modelling of internal flows with application to dikes and levees – Thesis

Objectives

- Study the potential of acoustic detection,
- Develop new theoretical models and numerical tools for the emission and propagation of acoustic waves.

Subject

→ Acquire and interpret the acoustic signals characteristic of internal flows and the erosion phenomenon via :

- Lab experimentations (Hole Erosion Test bench),
- In situ tests.

→ Model and simulate internal flows studied and compare theoretical and experimental acoustic responses using COMSOL Multiphysics, MATLAB and Mathematica softwares.

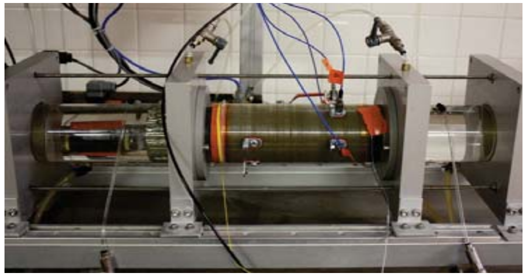
I – Acquisition of acoustic signals characteristic of internal flows – Hole Erosion Test bench

Soil-lime test tube	D_1=6mm	D_2=10mm
Accelero-meters	Measure 1	Measure 2
Optical Fiber	Measure 1	Measure 2

→ several levels of flow

Acoustic measurements with accelerometers and optical fiber.

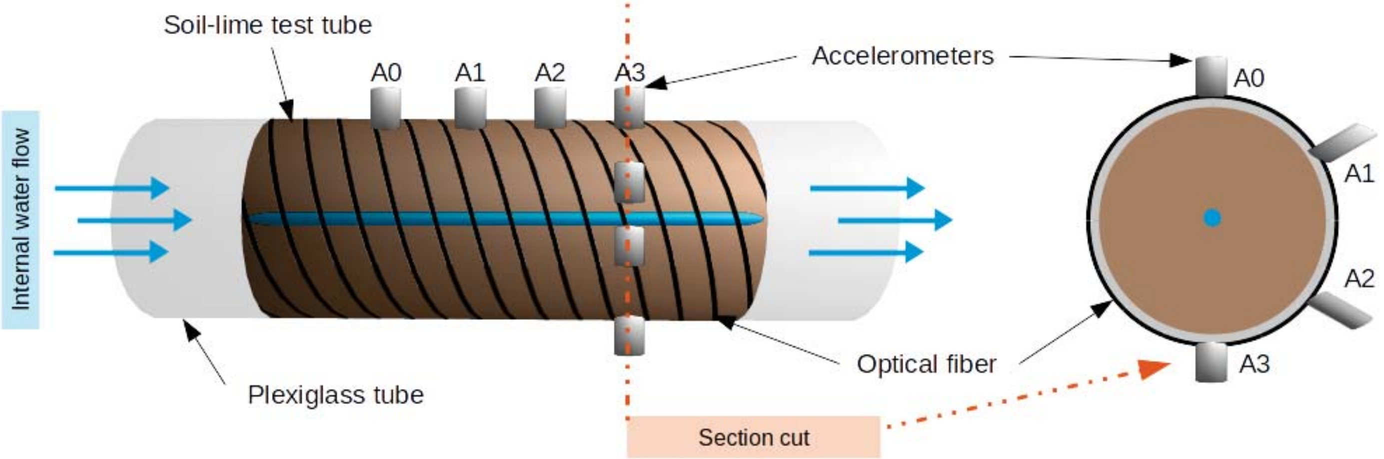
Acoustic measure device – Hole Erosion Test



Test bench Hole Erosion Test © Irstea

Longitudinal layout

Transversal layout



I – Theoretical model of the acoustic emission of an internal pipe flow

System response to an internal turbulent excitation

- System equation : harmonic state $[\Delta - K^2]\, p(n) = F(n) \qquad n \in \Omega_p$
- Boundary conditions
  - Neumann condition (housing)
  - Dirichlet condition

$$\partial_n p(n) = 0 \qquad x = 0, L_p \qquad \forall r, \theta \in [0, R_p], [0, 2\Pi]$$
$$p(n) = 0 \qquad r = R_p \qquad \forall x, \theta \in [0, L_p], [0, 2\Pi]$$

Green's representation

→ a representation of a pressure field which describes the direct fields and those diffracted by the boundaries.

Vibration modes

$$f_n = \frac{n c_0}{2 L_p}$$

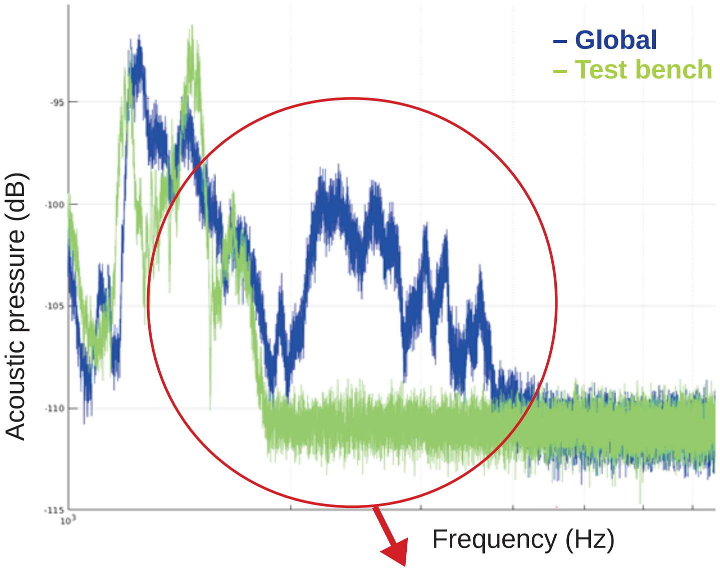
- f_1 = 2500 Hz
- f_2 = 5000 Hz

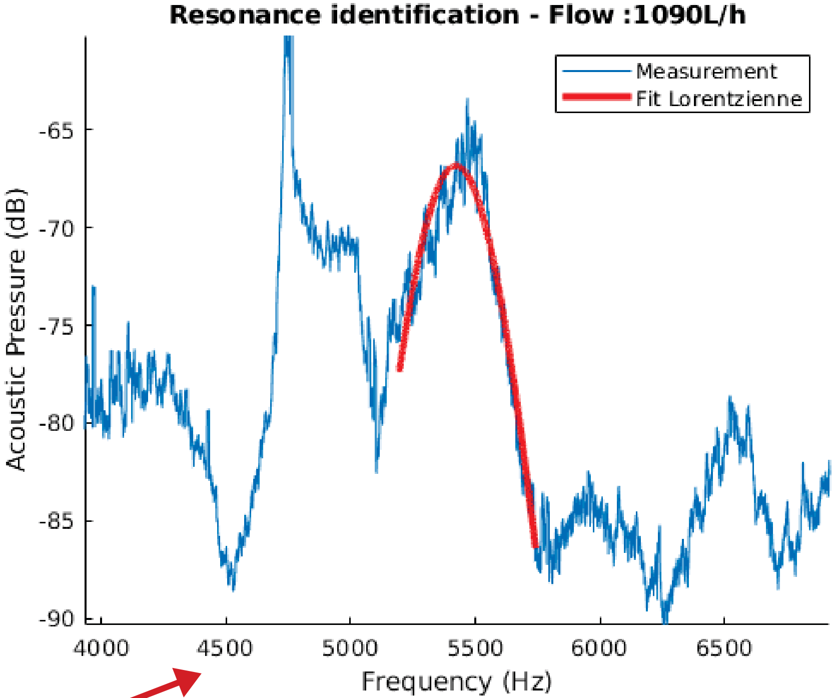
→ Theory vs experimentations ??

n : mode number – c_0 : acoustic wave celerity (1500m/s) – L_p : test tube length (30cm)

II – Acquisition of acoustic signals characteristic of internal flows – Acoustic measurements with accelerometers

Fourier Transform → **Frequency filter** → **Lorentzienne identification** → **Trends (Flow rate, Velocity, Reynolds Number)**





- Characteristic signal of the test bench is below 1kHz → Lorentzienne identification between 1-10kHz
- Resonance peaks ~ 2340 Hz and 5470 Hz

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II – Acquisition of acoustic signals characteristic of internal flows – Acoustic measurements with accelerometers

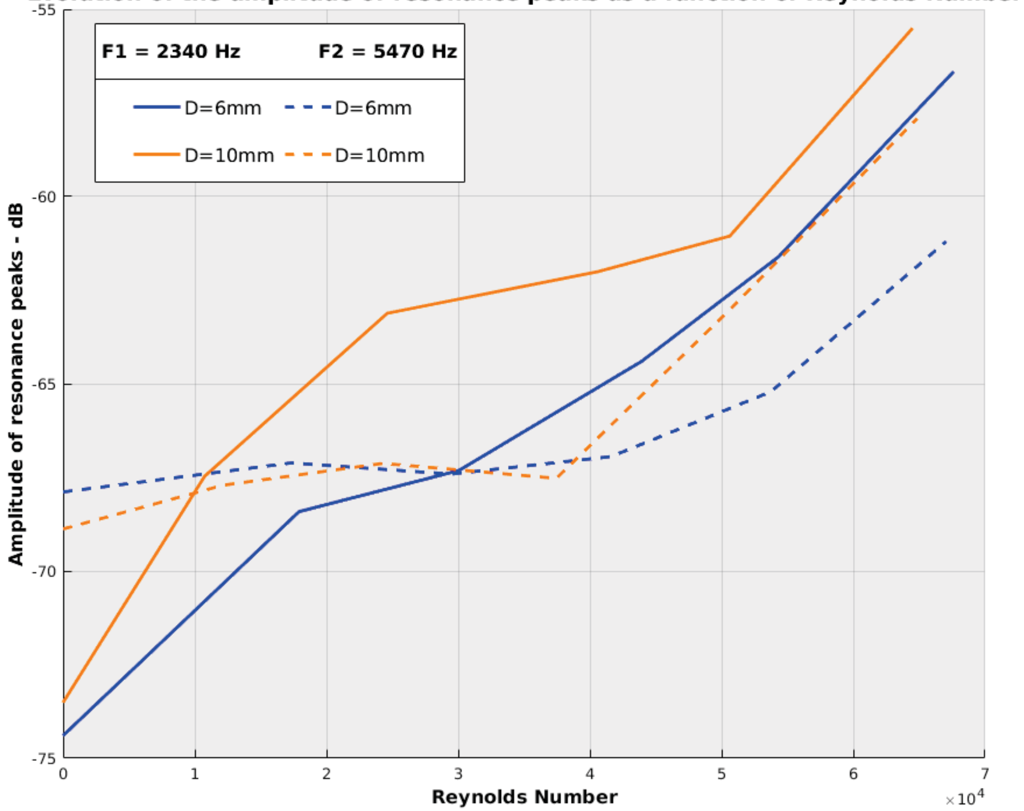
Fourier Transform → Frequency filter → Lorentzienne identification → Trends (Flow rate, Velocity, Reynolds Number)

Reynolds Number

- Resonance frequencies
- Trends independent of the diameter
- Bernoulli's law $p + \frac{1}{2}\rho v^2 = cst$

→ dB gain ~ 1-10dB between each point

Evolution of the amplitude of resonance peaks as a function of Reynolds Number



III – Next steps and perspectives

Next steps

- New measurements on the same test bench with more soil test tubes (D_1, D_2, D_3, D_4) and more flow rates.

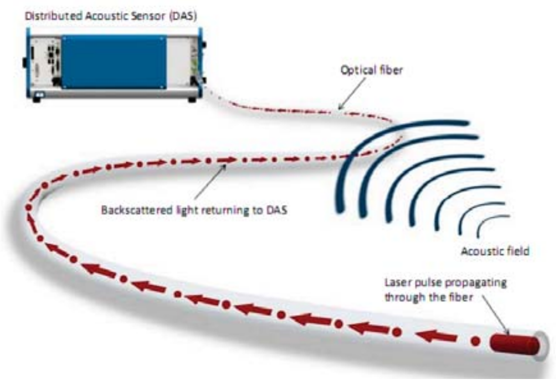
  → Refine previous trends

- Insert and characterize acoustically the internal erosion

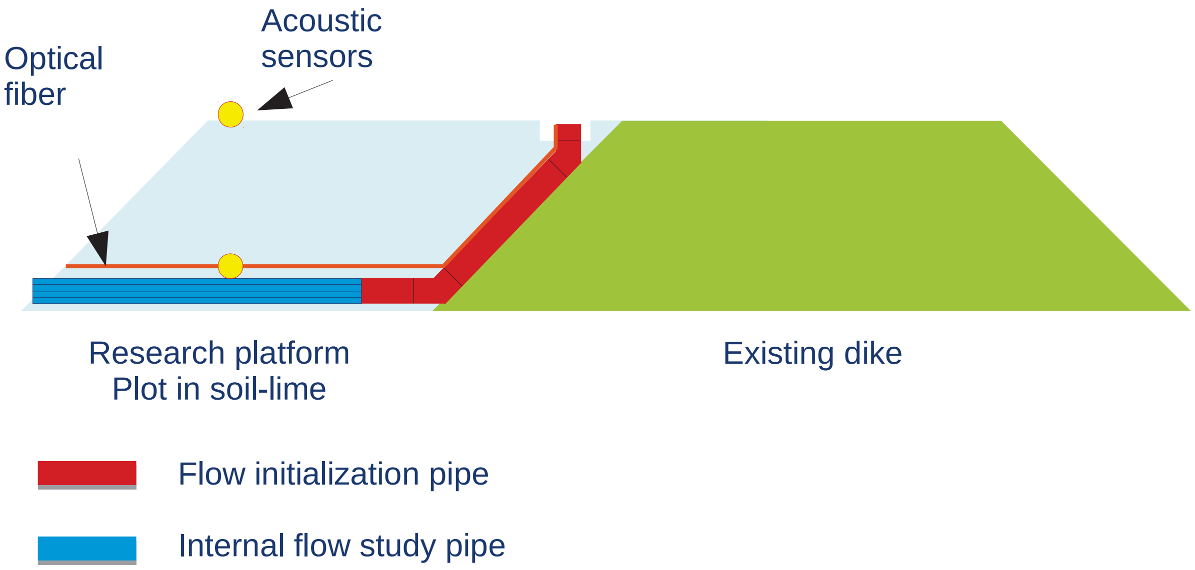
Perspective

- Develop acoustic measurements by optical fiber (Digue2020)

III - Internal flow tests in situ – Digue2020



Acoustic measurements by optical fiber, in collaboration with Cementys (SMB).



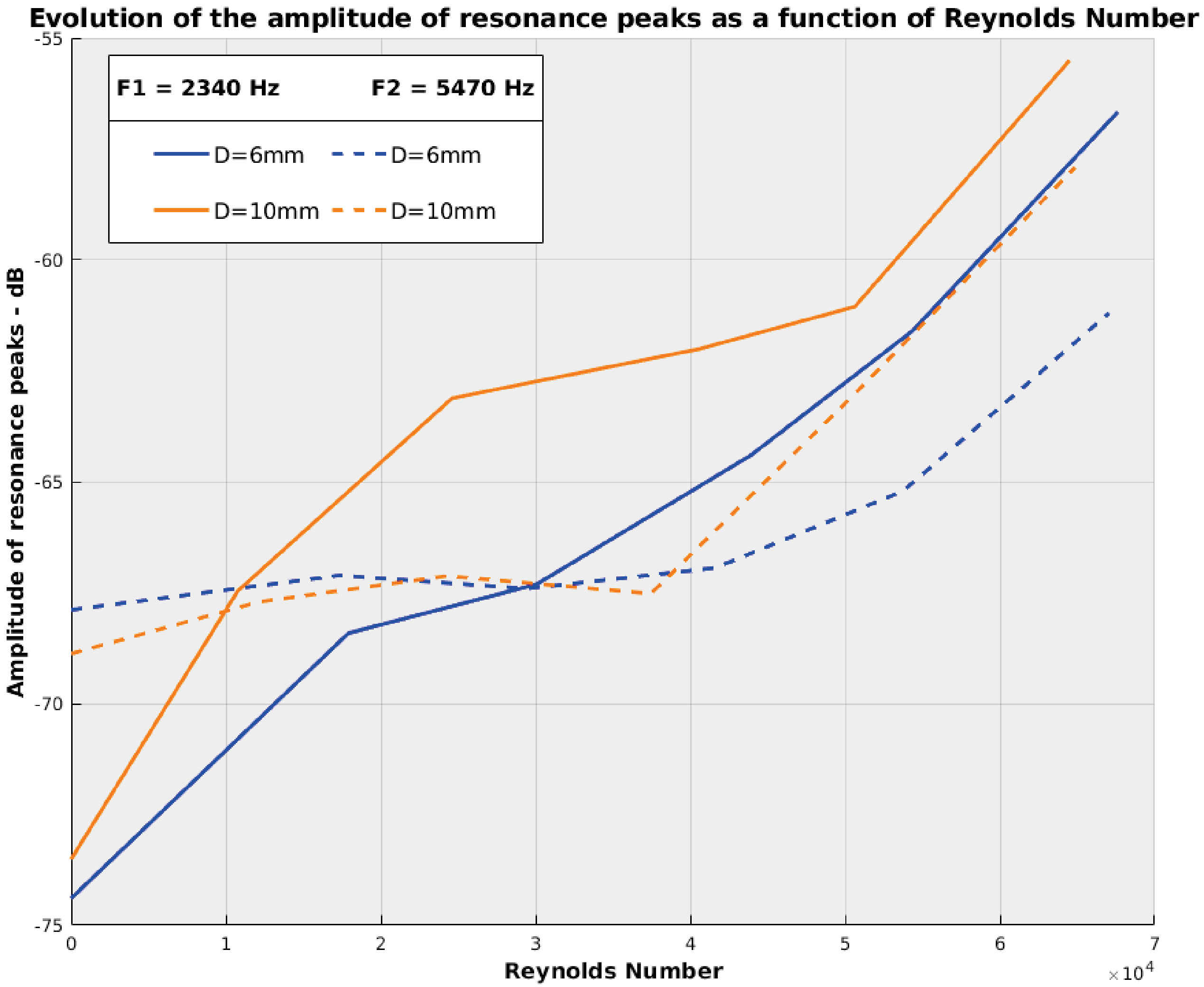
- Two internal pipes will be realized and instrumented during the construction of the research platform.
- Internal flow tests consist of studying acoustic emissions characteristic of an internal flow in a dike type hydraulic structure.

→ Results confrontation

Thank you for your attention

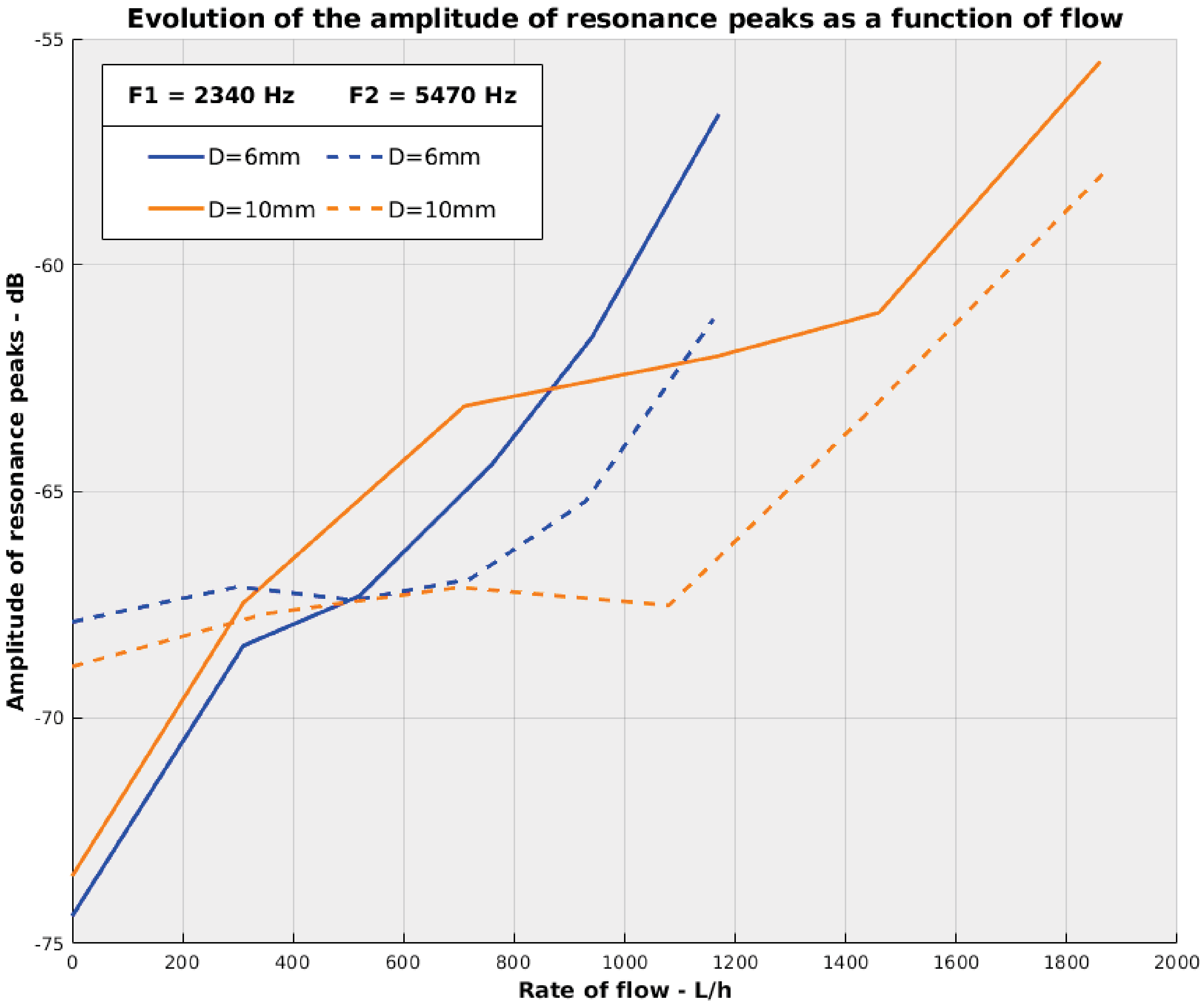
II – Acquisition of acoustic signals characteristic of internal flows – Acoustics measurements with accelerometers

Reynolds Number



II – Acquisition of acoustic signals characteristic of internal flows – Acoustics measurements with accelerometers

Rate flow



II – Acquisition of acoustic signals characteristic of internal flows – Acoustics measurements with accelerometers

Velocity