Multi-scale numerical modeling of innovative sound absorption solutions for the reduction of the noise footprint of a shrouded rotor

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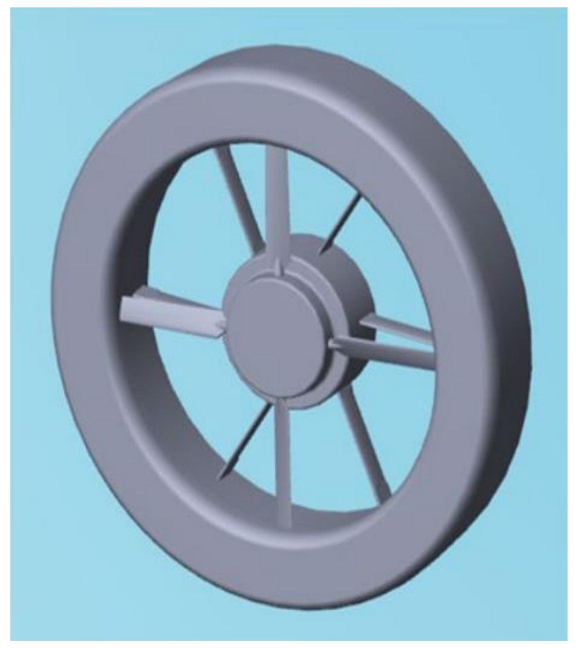
INTRODUCTION

- Exposure to environmental noise in urban areas has direct or indirect effects on the health and well-being of populations according to the World Health Organization (WHO).
- Sound absorption solutions are proposed to **reduce the noise footprint** of an Electrically Distributed Anti Torque (EDAT) helicopter tail rotor.
- A multi-scale numerical modeling approach is being developed for designing sound absorption solutions to guide the design of an **optimal acoustic solution.**




OBJECTIVES

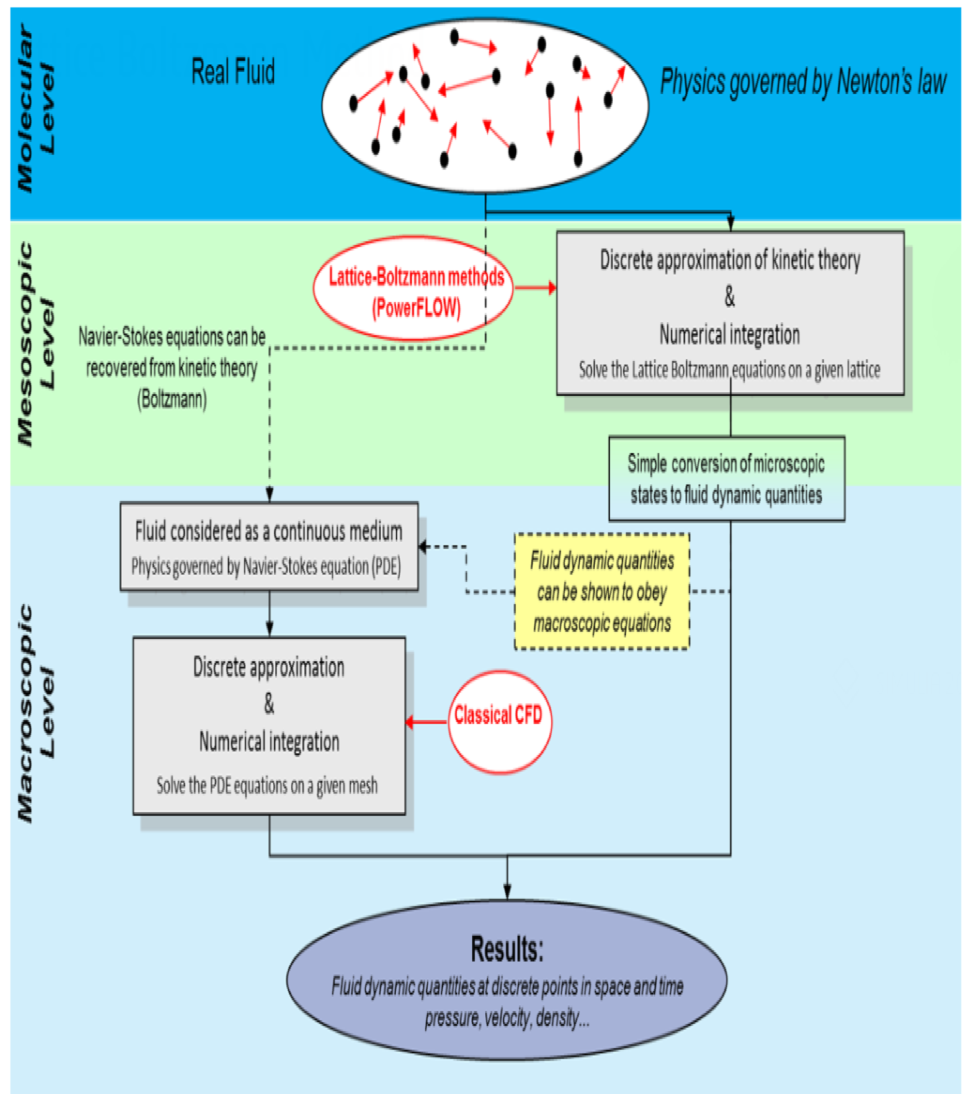
General objective:

✓ Establish a general research methodology to develop sound absorption solutions to reduce the noise footprint of shrouded rotors.

Specific objectives:

✓ Development of a numerical model for simulating the noise footprint of a shrouded rotor.
✓ Design and optimization of innovative sound absorption solutions using a multi-scale approach.
✓ Validation of the noise reduction obtained with the developed solution.

THE LATTICE BOLTZMANN METHOD (LBM)



Consider the Boltzmann equation in the form:

- $\partial_t f + \vec{\xi} \cdot (\vec{\nabla}_x f) = \Omega$
- $\Omega^{(BGK)} = \frac{f^{(eq)} - f}{\tau}$

Discretization

- Space and velocity space
  - $\partial_t f_i + \vec{\xi}_i \cdot (\nabla_x f_i) = \Omega_i$

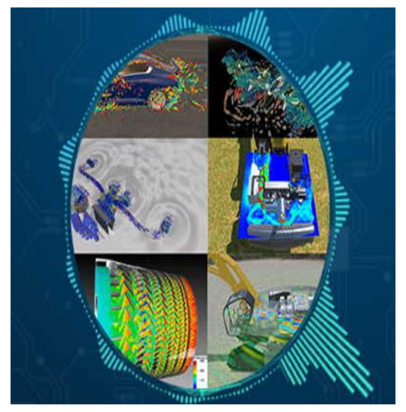
Using a Taylor expansion

$$\left(\frac{\partial fi}{\partial t} + \vec{\xi}_i \cdot \frac{\partial fi}{\partial \vec{x}}\right) = \frac{f_i(\vec{x} + \vec{\xi}_i \Delta t, t + \Delta t) - fi(\vec{x}, t)}{\Delta t} + O(|\Delta\vec{x}|, \Delta t)$$

- The discrete Boltzmann equation is then

$$f_i(\vec{x} + \vec{\xi}_i \Delta t, t + \Delta t) - fi(\vec{x}, t) = \Omega_i \Delta t + O\left((\Delta\vec{x})^2, (\Delta t)^2\right)$$

METHODOLOGY



Simulation of the flow and the acoustic field inside and outside of the shrouded rotor using PowerFLOW

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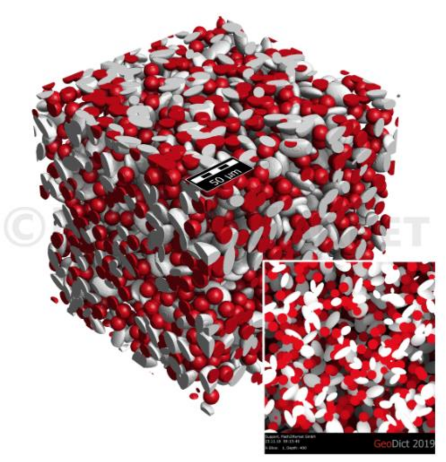

Numerical evaluation of selected concepts by commercial software Geodict and PowerFLOW as well as existing analytical models

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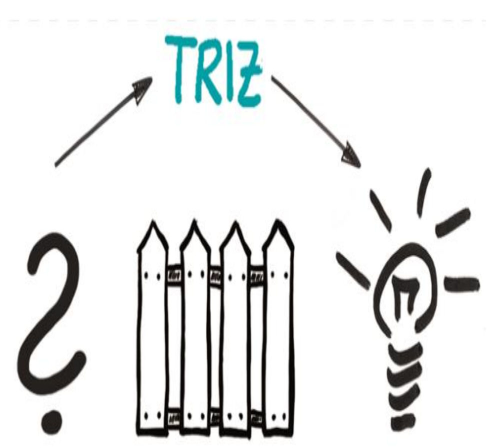

Multiscale simulation of selected acoustic solutions by the TRIZ/BioTRIZ method

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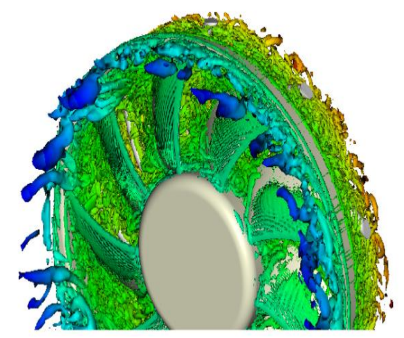

Simulation of the intermediate prototype on PowerFLOW

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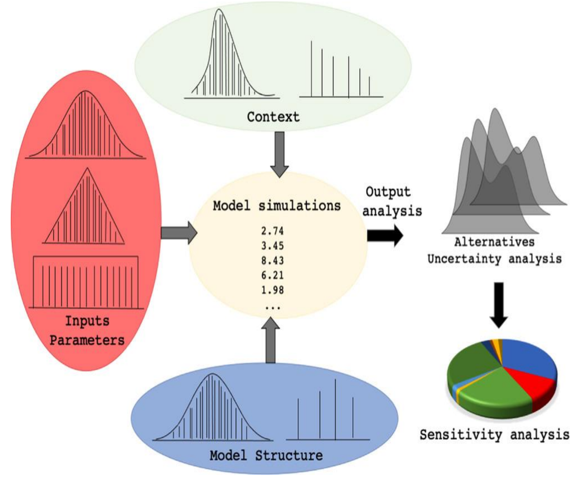

Sensitivity study by numerical simulation on final prototype

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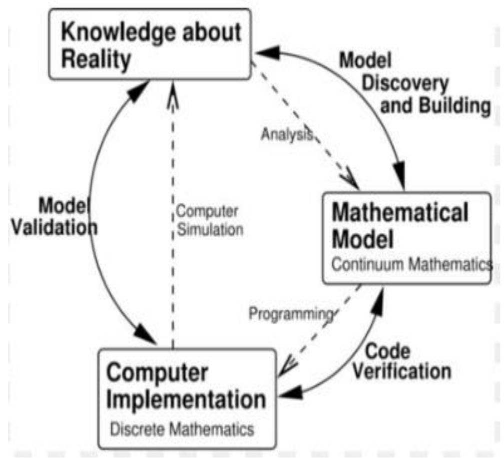


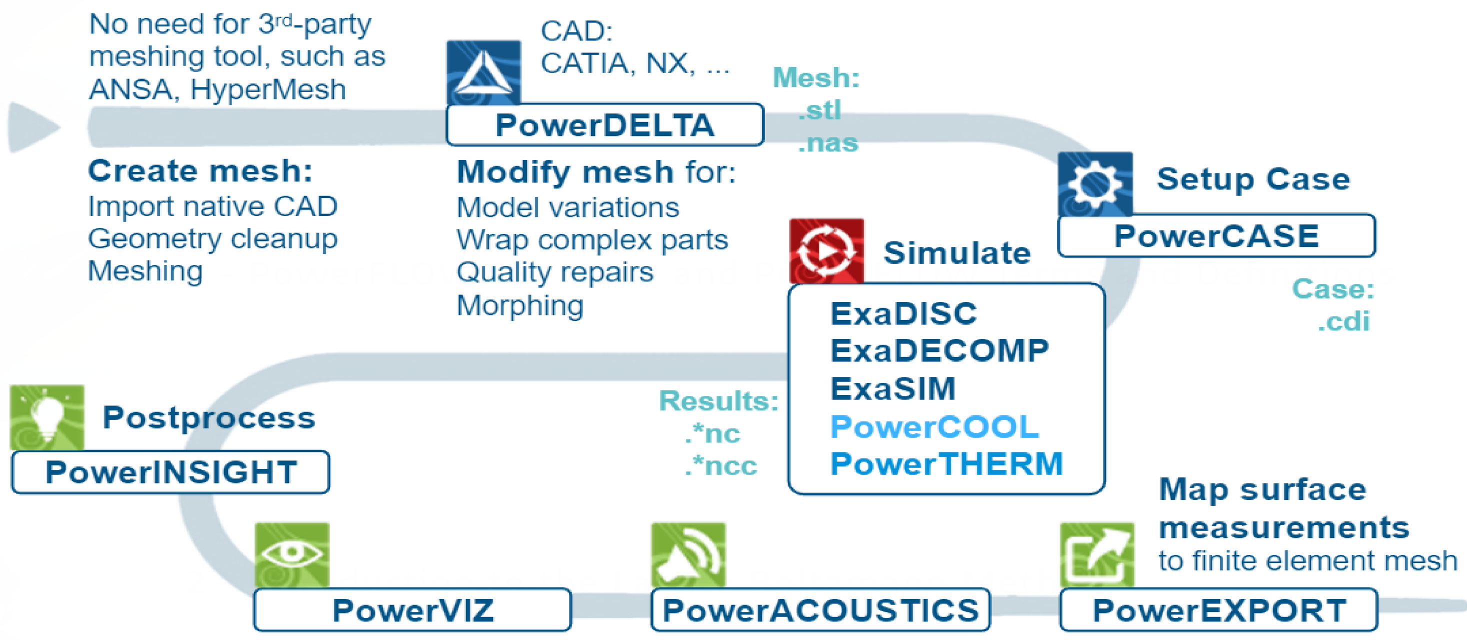
Validation of the numerical prediction by comparison with full-scale experimental prototype results

POWERFLOW SIMULATION

Three pillars of PowerFLOW

- Aerodynamics Simulations
- Thermal Simulations
- **Aeroacoustics Simulations**

Application Usage Flow



CONCLUSION AND UPCOMING STEPS

This project aims at demonstrating that it is possible to implement a design methodology to achieve a substantial overall noise reduction on a single rotor.

- ❑ Analytical models available in the literature and PowerFLOW numerical models will be used to predict the acoustic response of resonators and other acoustic solutions.
- ❑ To test the acoustic solutions before their fabrication, a campaign of multi-scale numerical simulations will be held.
- ❑ Multi-scale numerical simulation with PowerFLOW will allows us to validate the measurements of acoustic pressure fields in the near and far field with and without the addition of acoustic treatment.

NOMENCLATURE

f: Particle distribution function
ξ: Microscopic particle velocity
t: Time
τ: Relaxation time
Ω: BGK collision operator
feq: Distribution function at equilibrium

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