UiT The Arctic University of Norway

Multiphysics: Paving the Future of Engineering

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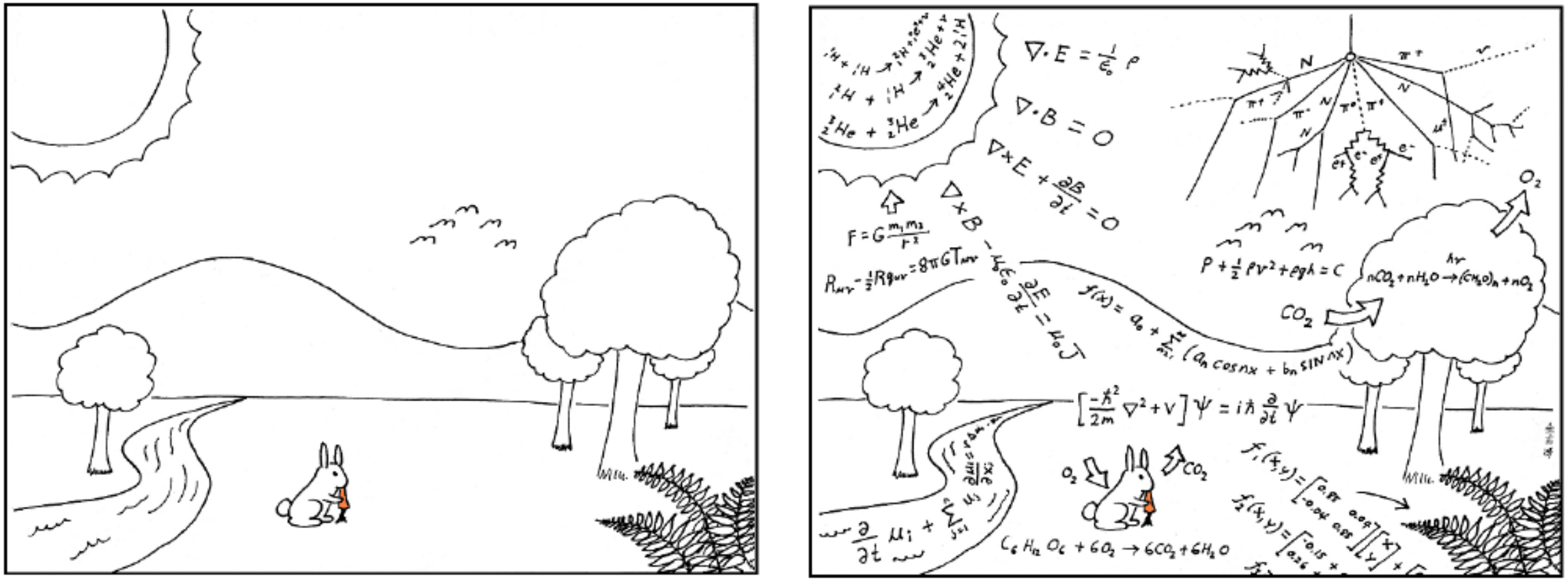
IR, Spectroscopy, and Numerical Modelling Research Group

Presentation Overview

- What is Multiphysics?
- My Research Portfolio
- Digital Twin (Future of Engineering)
- Key Examples
  - Porous media
  - Ice detection/mitigation
  - Microfluidic pump
  - Fluidized Bed
  - Shocktube
  - Conjugate heat transfer sensor
  - Fluid viscosity-density sensor
  - Flow in the highway tunnel
  - Marine emission Brevika port
  - Powder spray
  - 3D printing
- The International Society of Multiphysics

What is Multiphysics?

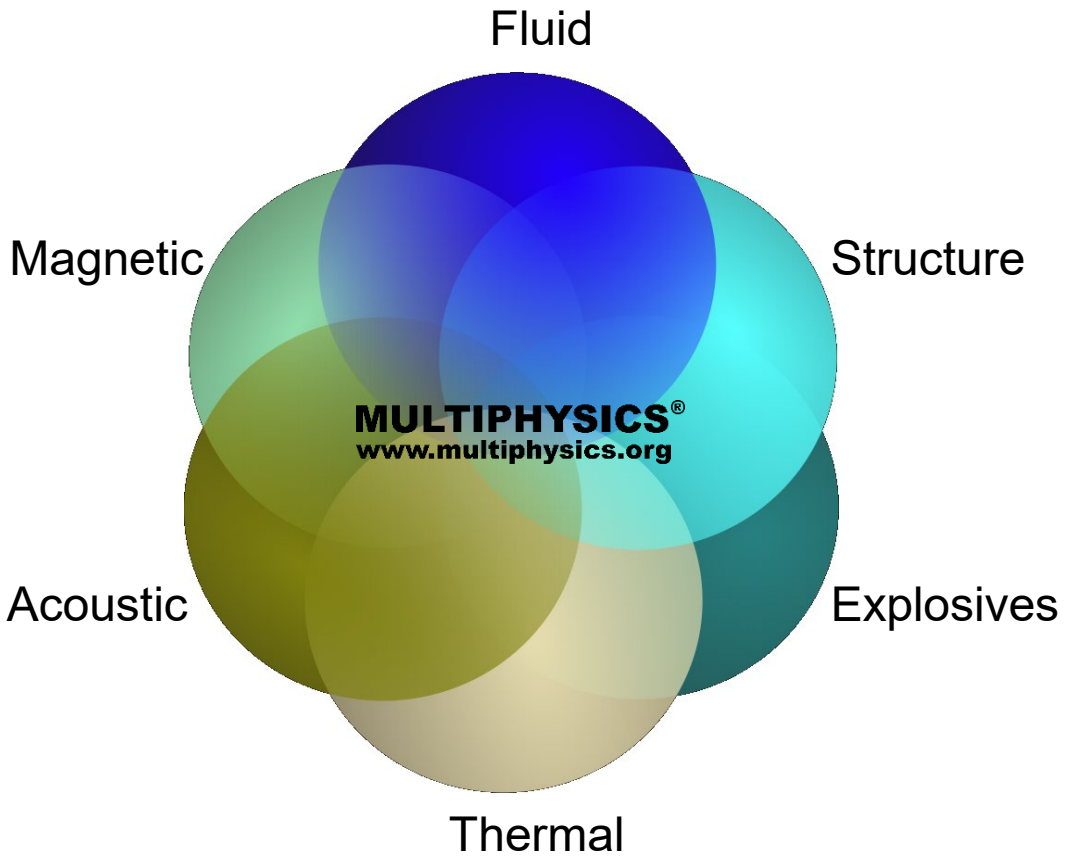


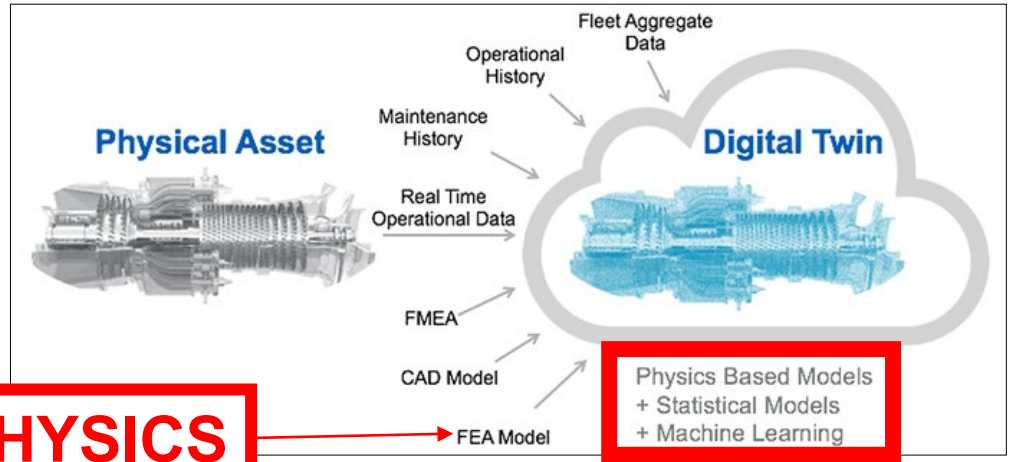
The interdependence between different physical models result in a complex-coupled system, referred to as multiphysics, where the outputs of one or more models becomes the inputs for the others.

My Research Portfolio – Multiphysics

70+ Research Publications
10+ PhD Students Supervisions
20+ Master Students Supervisions
15+ International Funded Projects

Past Collaborations: Canada, China, Ethiopia, France, Norway, Pakistan, Philippines, Poland, Russia, Sweden, Saudi Arabia, Switzerland, United Arab Emirates, United Kingdom, and United States



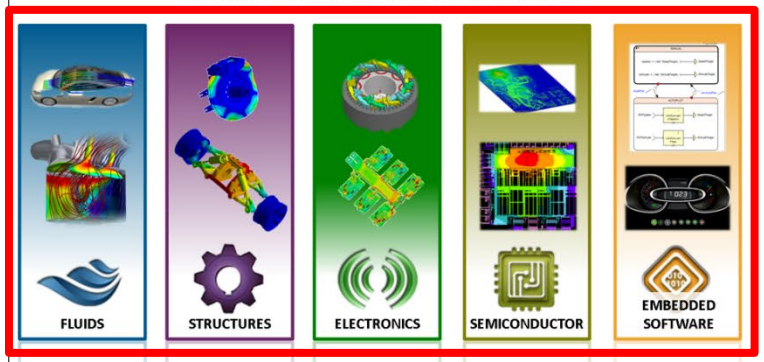


MULTIPHYSICS

DIGITAL TWIN

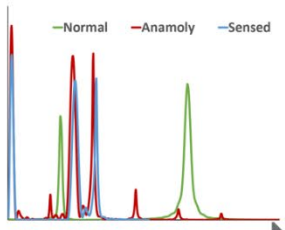
As Designed

MODEL-BASED ENTERPRISE & SYSTEMS ENGINEERING



Further improve:
- Cost
- Weight
- Efficiency
- Robustness

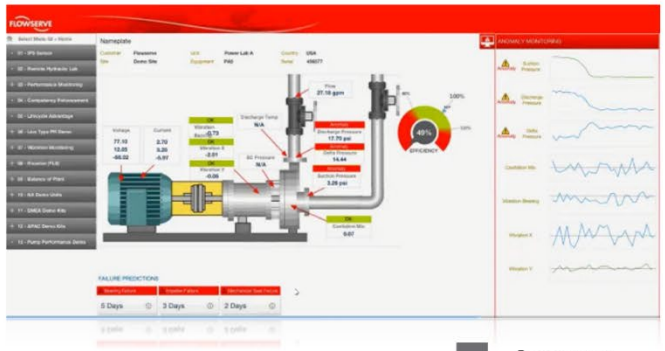
Digital Signatures



Virtual Sensors

As Operated

INTEGRATED IOT ASSETS & ECOSYSTEMS



Assess:
- Performance
- Life / Durability
- Diagnostics
- Optimization

Microstructure Characterization – AI/ML

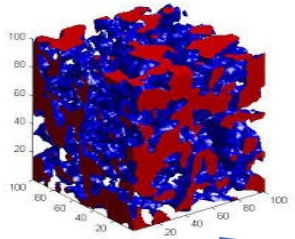
Digital Twin Model
- Sphere Packing
- Gaussian Random Fields
- Etc.

Material Parameters
- Sintering temperature
- Phase types
- Volume fractions
- Etc.

Tomography

2D-Images

3D microstructure of real or synthetic data



Characteristics
- Porosity
- Tortuosity
- Conductivity
- Etc.

Effective Properties
- Permeability
- Conductivity
- Capacity
- Etc.

1

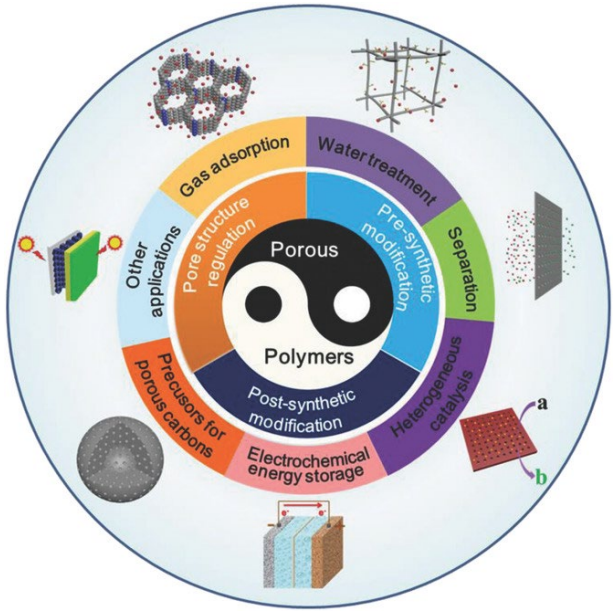
2

3

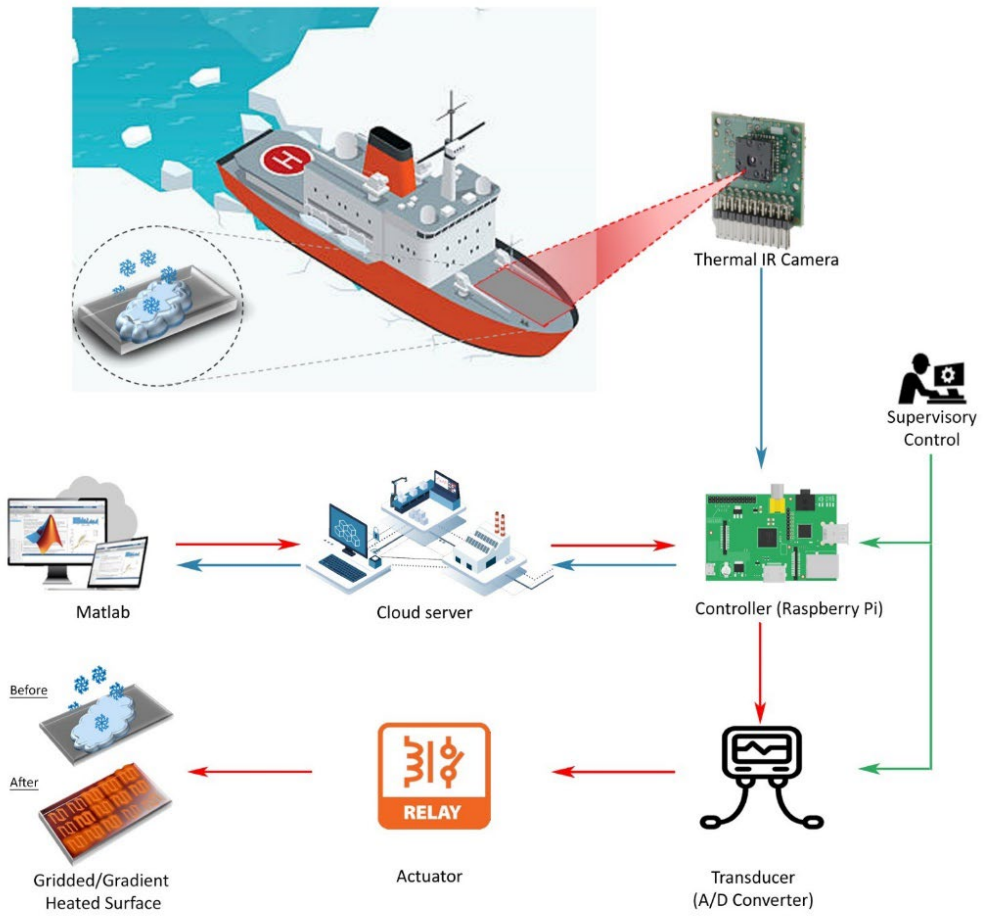
4

5

6



Ice Detection & Mitigation



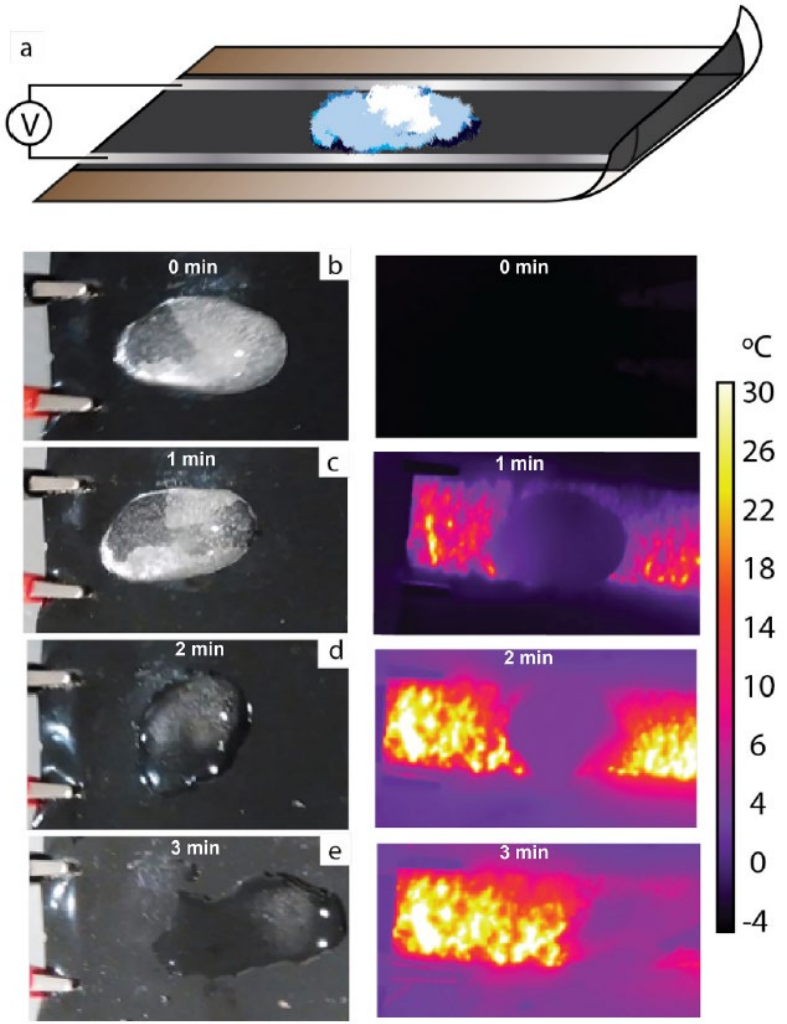
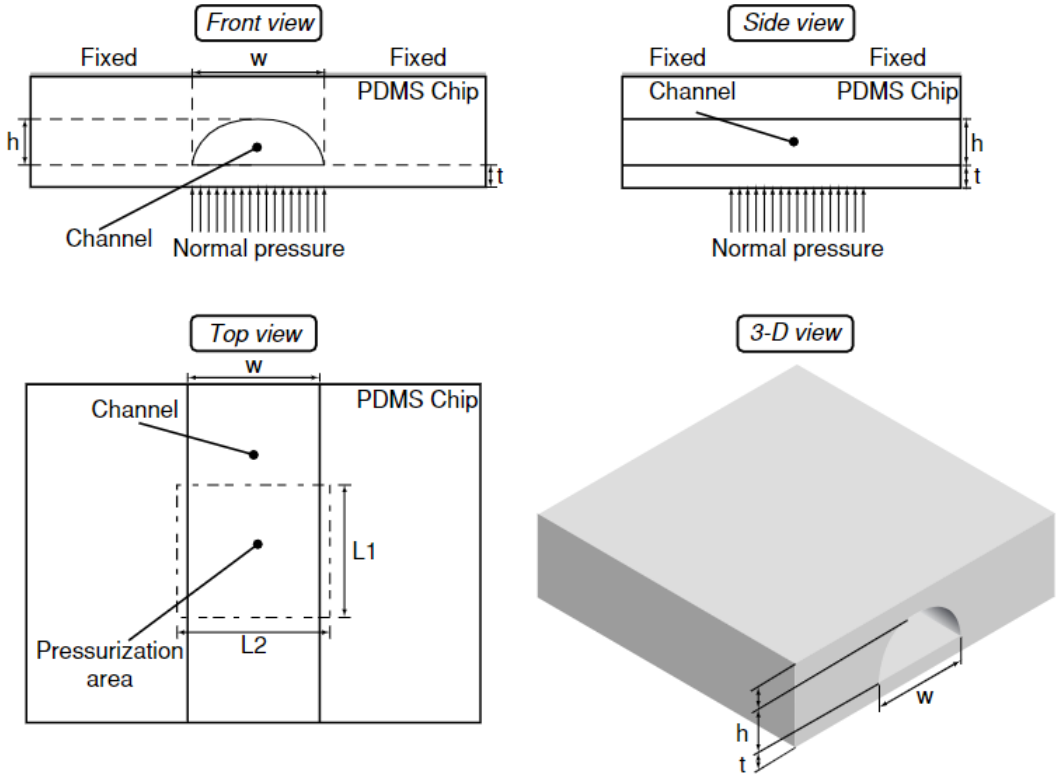
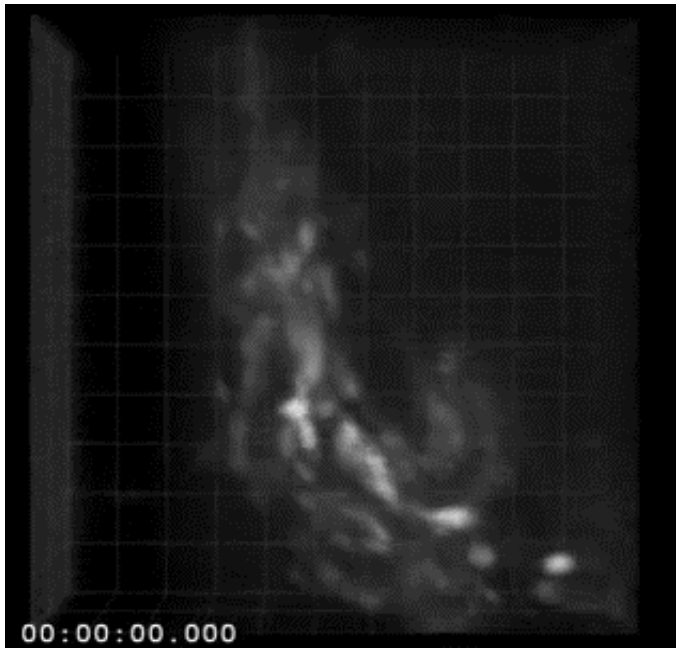


Fig. 4. De-icing demonstration of R2R CNT coated sheet (IR and colour images), when ice is frozen inside cold room at steady state temperature of −2 °C.

Adeel Yousuf, Hassan Khawaja, Muhammad Virk. Conceptual Design of Cost-Effective Ice Detection System Based on Infrared Thermography. Cold Regions Science and Technology, 2023, 215, 103941. https://doi.org/10.1016/j.coldregions.2023.103941

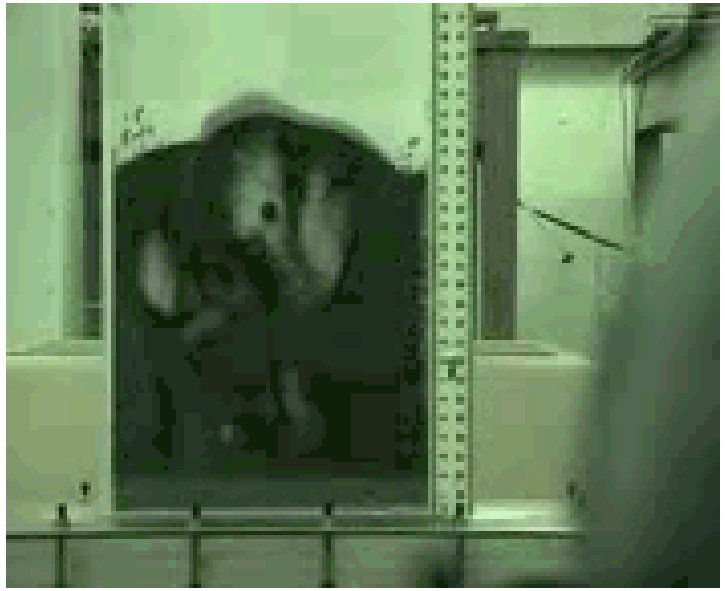
Micro-Fluidic Pump – Design Simulation

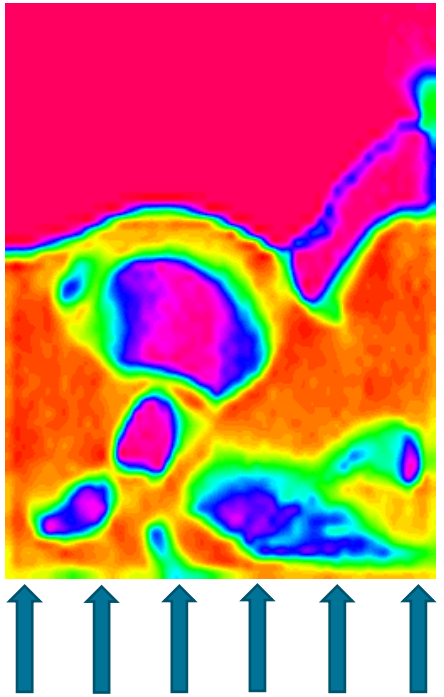


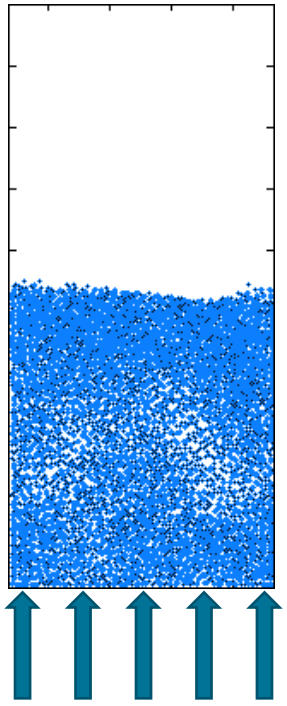


H Khawaja, I Raouf, K Parvez, A Scherer. Optimization of elastomeric micro-fluidic valve dimensions using nonlinear finite element methods. The International Journal of Multiphysics, 2009, 3(2): pp. 187 - 200. http://dx.doi.org/10.1260/175095409788837847

Fluidized Bed – Bubbles Simulation



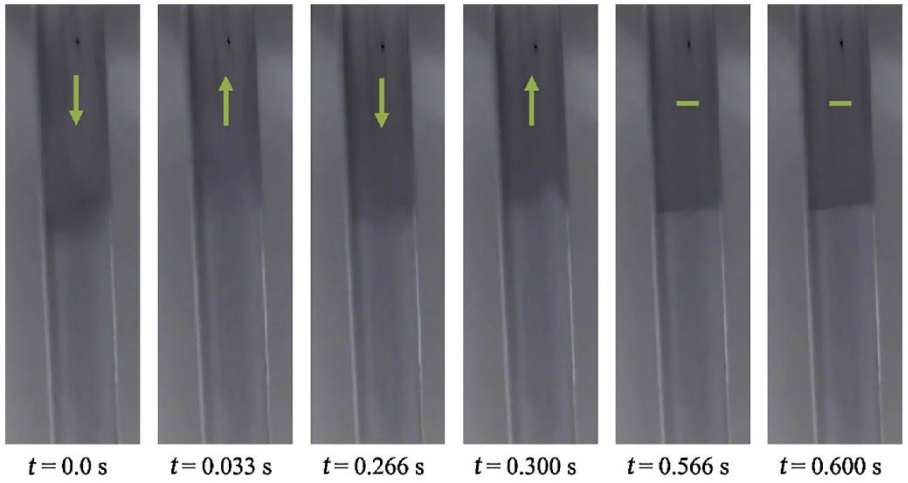


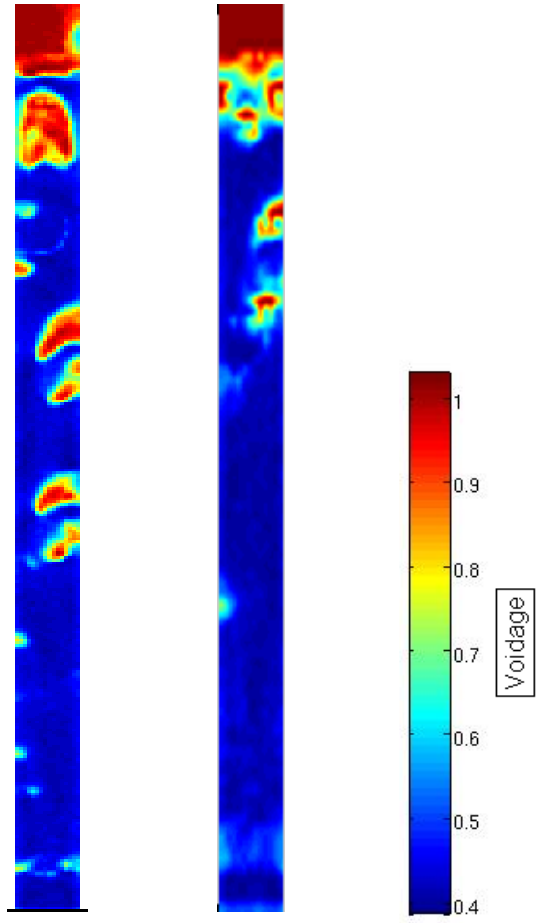


Fluid Inlet **Fluid Inlet**

H Khawaja, M Moatamedi. Multiphysics Modelling of Fluid-Particulate Systems. Academic Press, 2020, ISBN 978-0-1281-8345-8.
https://doi.org/10.1016/C2018-0-02737-1

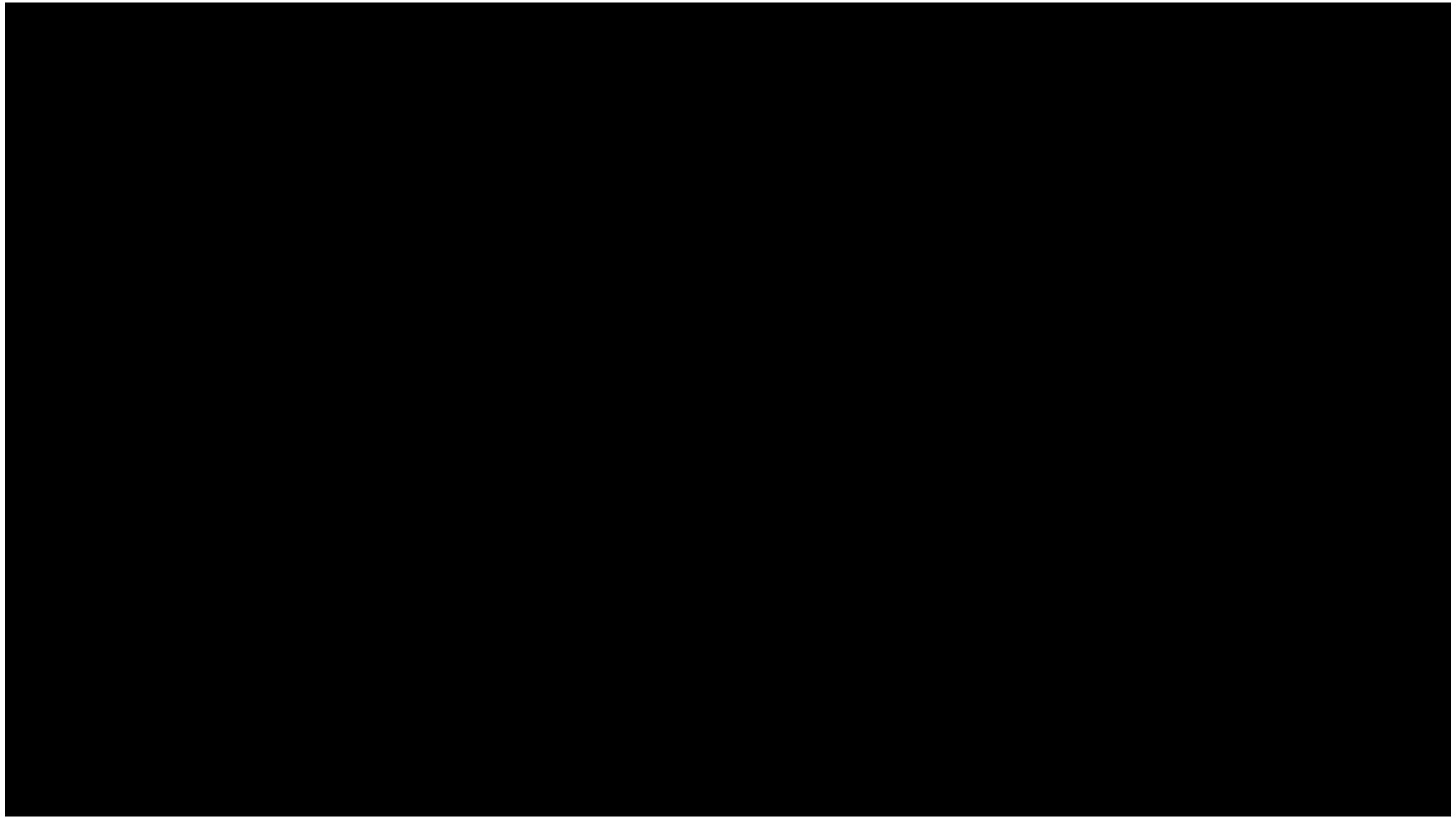
Fluidized Bed – Speed of Sound





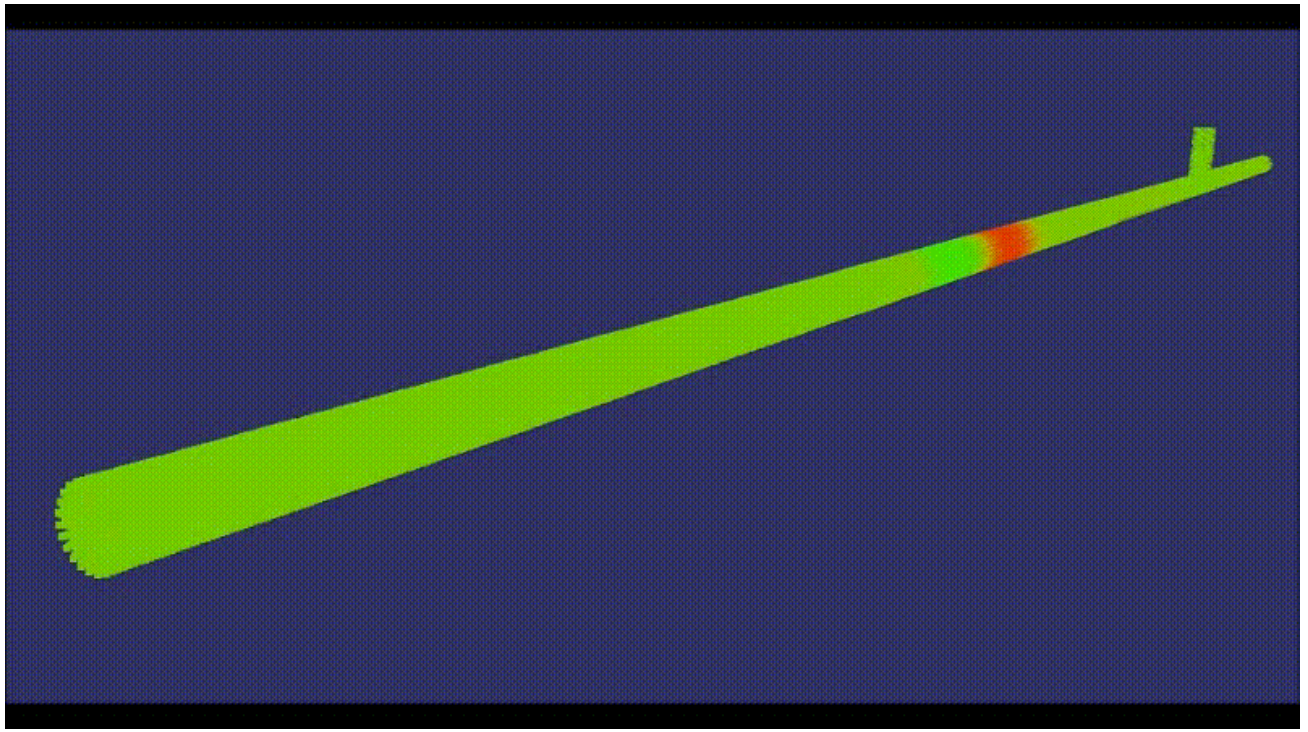
H Khawaja. Study of Sound Waves in Fluidized Bed using CFD-DEM Simulations. Particuology, 2017, 38: pp.126 - 133. https://doi.org/j.partic.2017.07.002

Shock Tube – Pressure Propagation

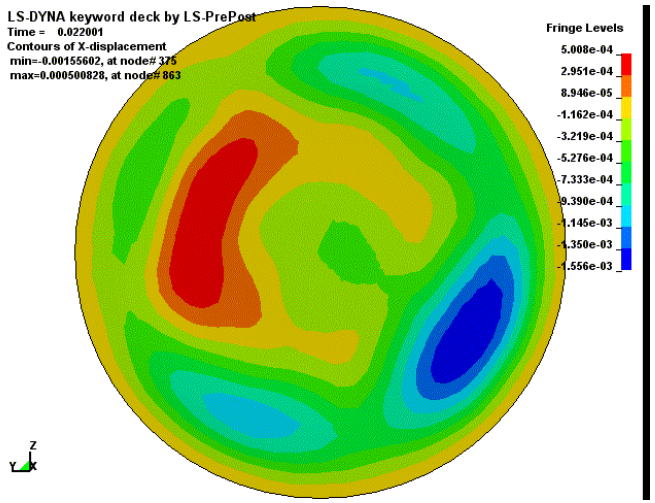


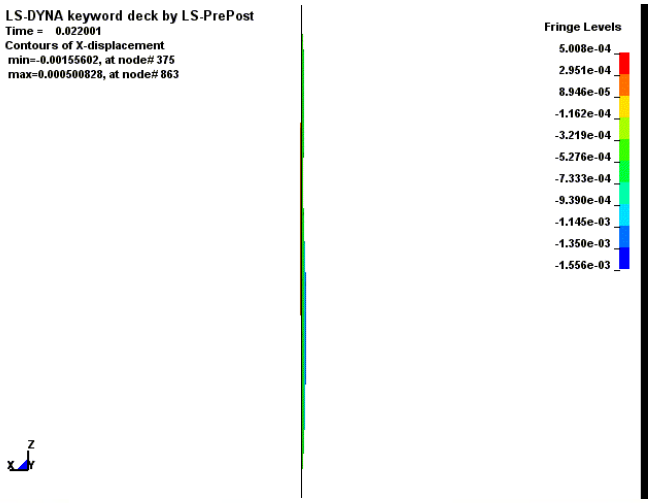
H Khawaja et al. Experimental and Numerical Study of Pressure in a Shock Tube. J Press Vess-T ASME, 2016, 138(4): 041301.
http://dx.doi.org/10.1115/1.4031591

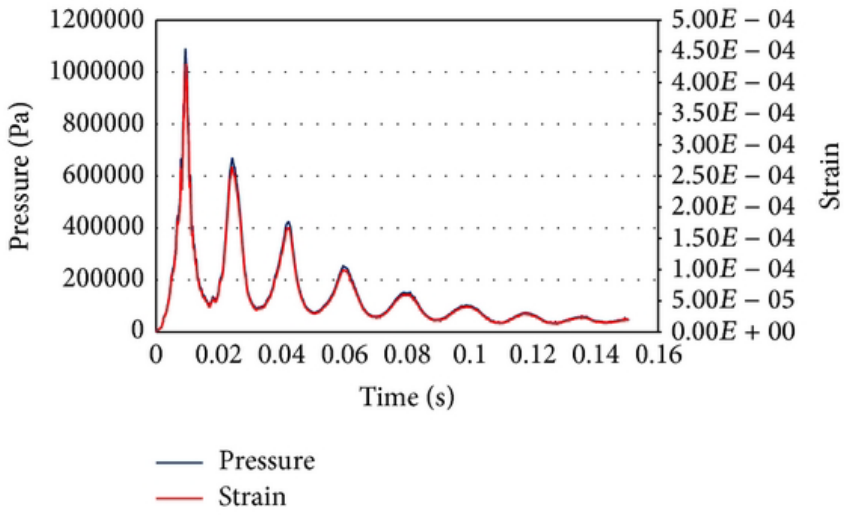
Shock Tube – ALE & FSI Simulations

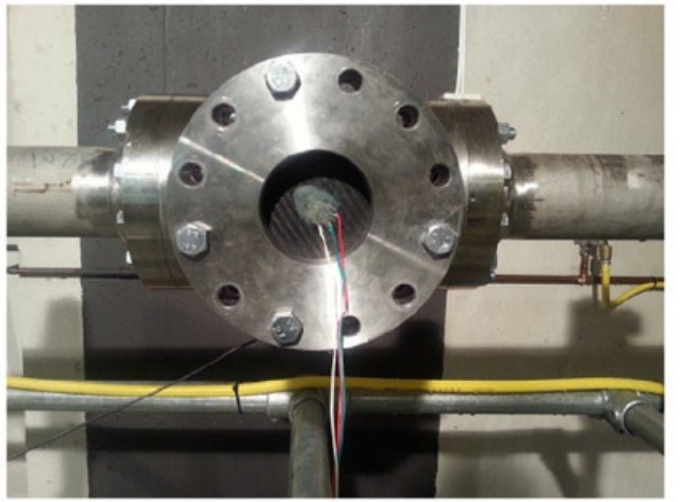


H Khawaja et al. Experimental and Numerical Study of Pressure in a Shock Tube. J Press Vess-T ASME, 2016, 138(4): 041301.
http://dx.doi.org/10.1115/1.4031591



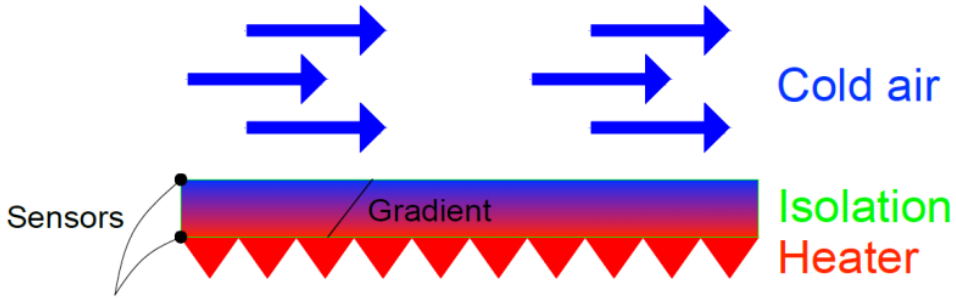


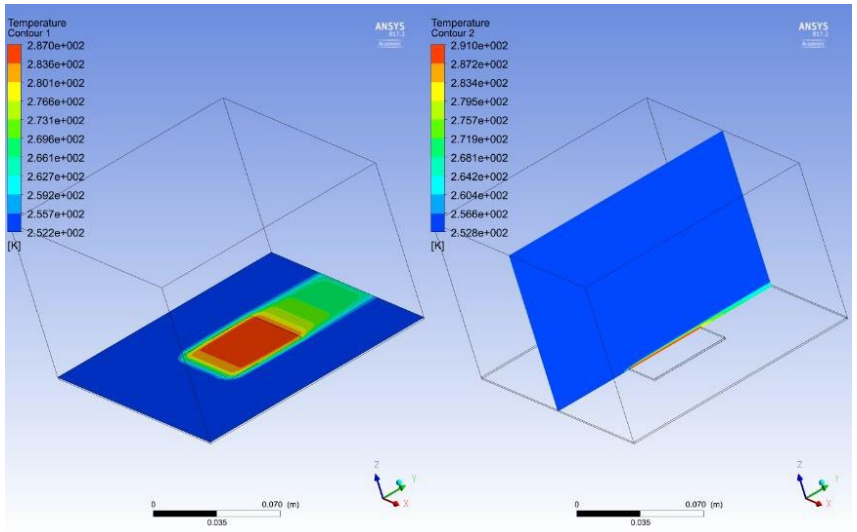




H Khawaja et al. Study of CRFP Shell Structures under Dynamic Loading in Shock Tube Setup. Journal of Structures, 2014. http://dx.doi.org/10.1155/2014/487809

Cold Exposure Sensor – CHT Simulation



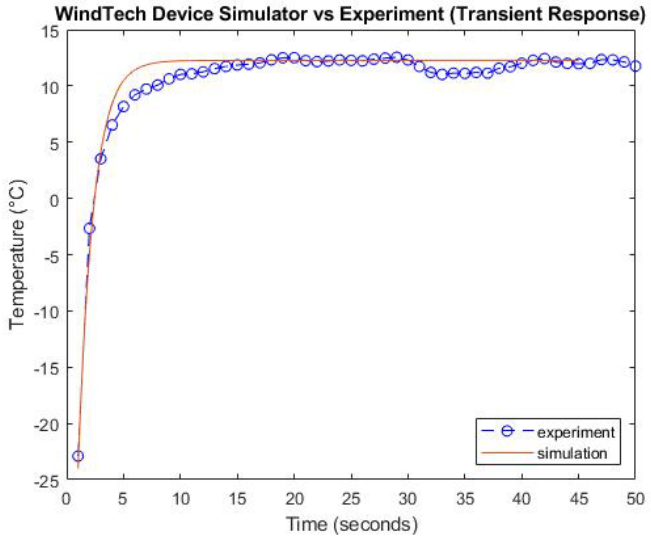


WindTech
WE DEVELOP COLD CLIMATE TECHNOLOGY

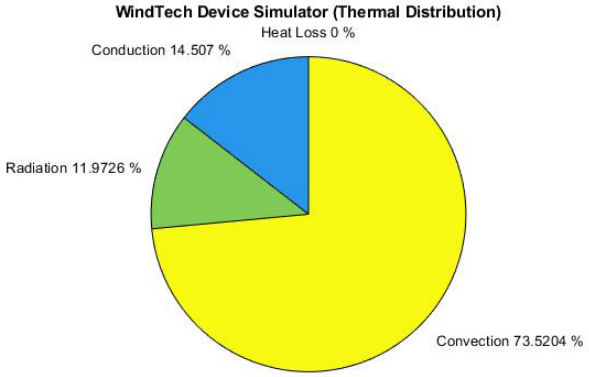
H Khawaja, D Swart, S Antonsen @ Windtech AS. Measuring Environmental Exposure. UK Patent GB 2588580. Link

Temperature = -23°C, Relative Humidity = 72%

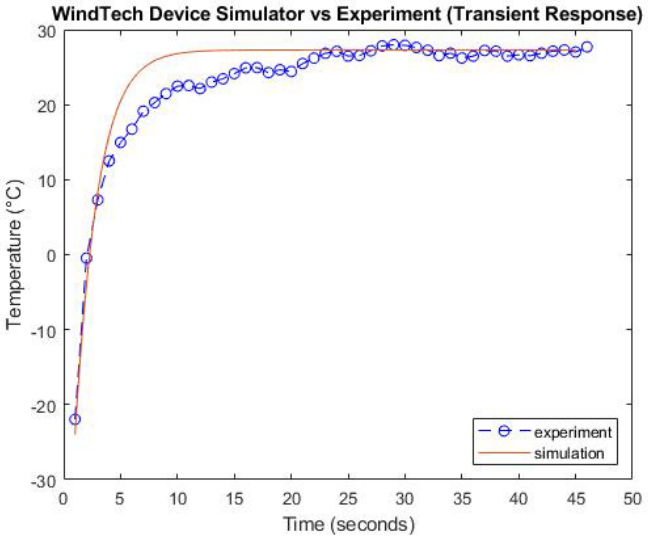
Wind Velocity = 8 m/s



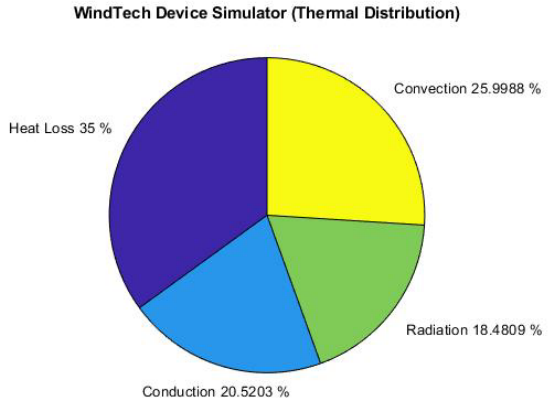
Heated Temperature = 12.1°C



Wind Velocity = 0.5 m/s

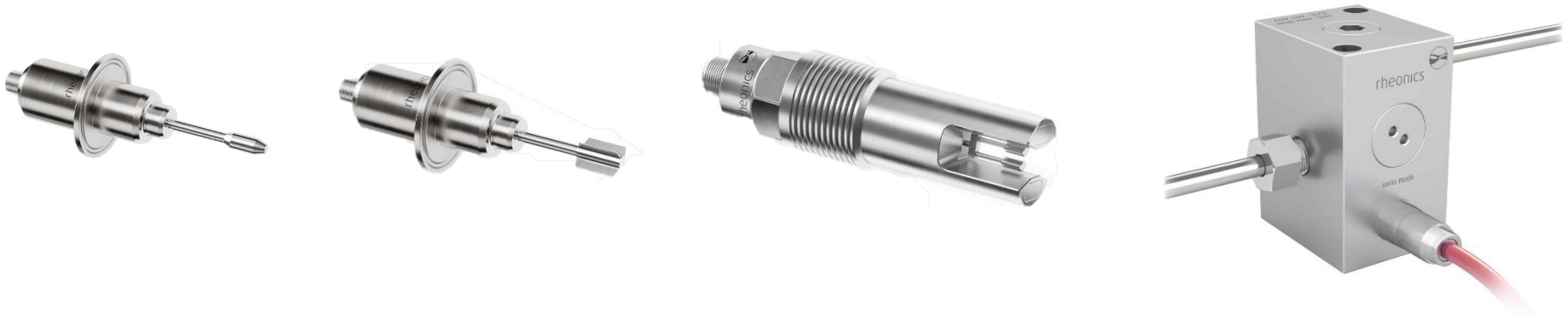


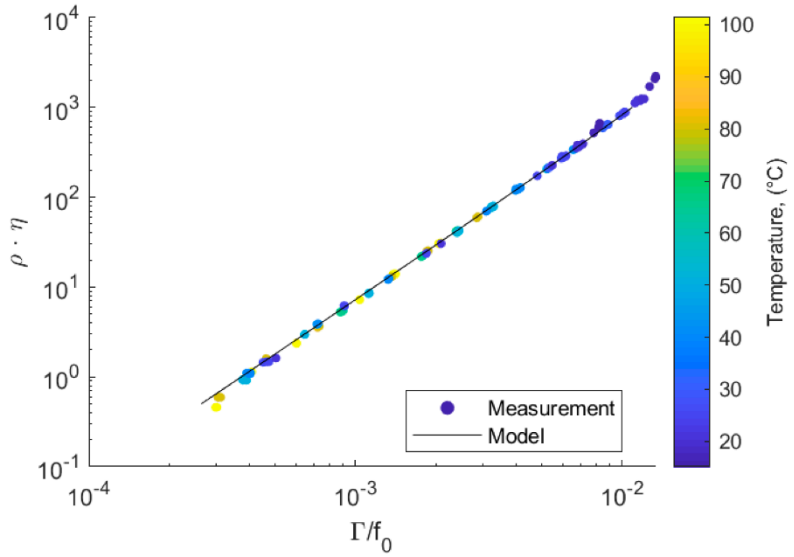
Heated Temperature = 26.9°C

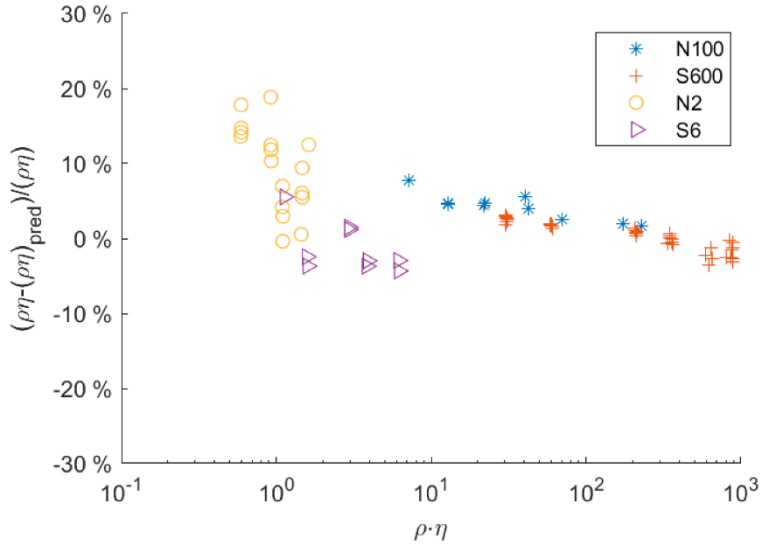


H Khawaja, D Swart, S Antonsen @ Windtech AS. Measuring Environmental Exposure. UK Patent GB 2588580. Link

Fluid Viscosity-Density Sensor



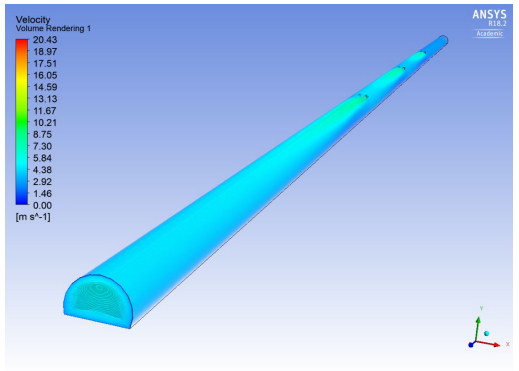


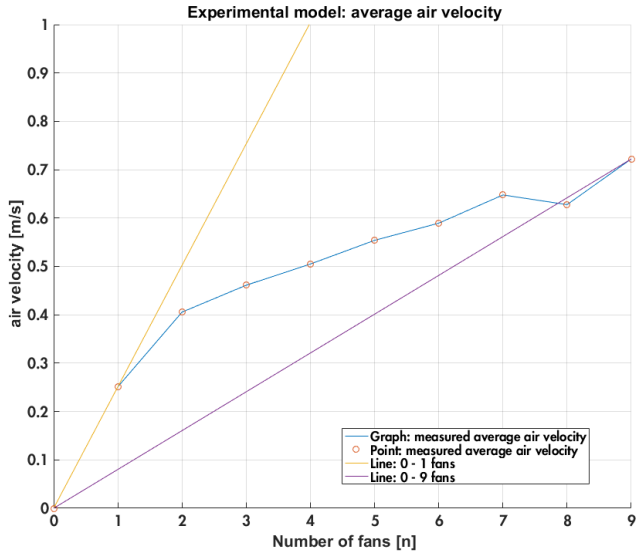


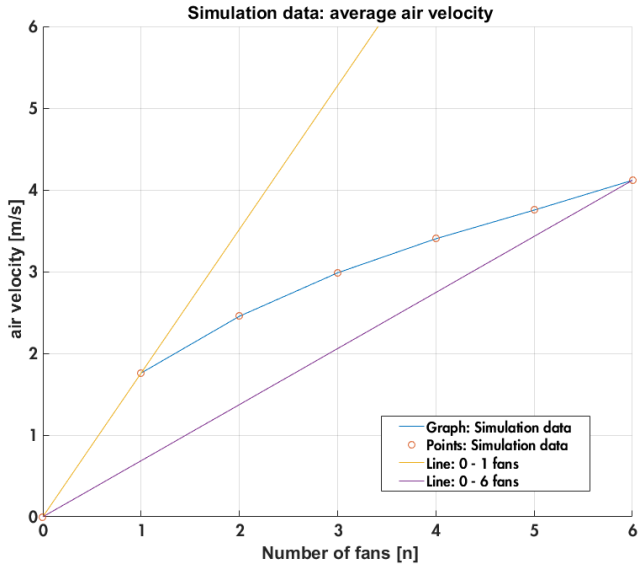
rheonics

Daniel Brunner, Joe Goodbeard, Klaus Hausler, Sunil Kumar, Gernot Boiger, Hassan Khawaja. Analysis of a Tubular Torsionally Resonating Viscosity–Density Sensor. Sensors, 2020, 20(11). http://dx.doi.org/10.3390/s20113036

Flow in Highway Tunnel – Simulation

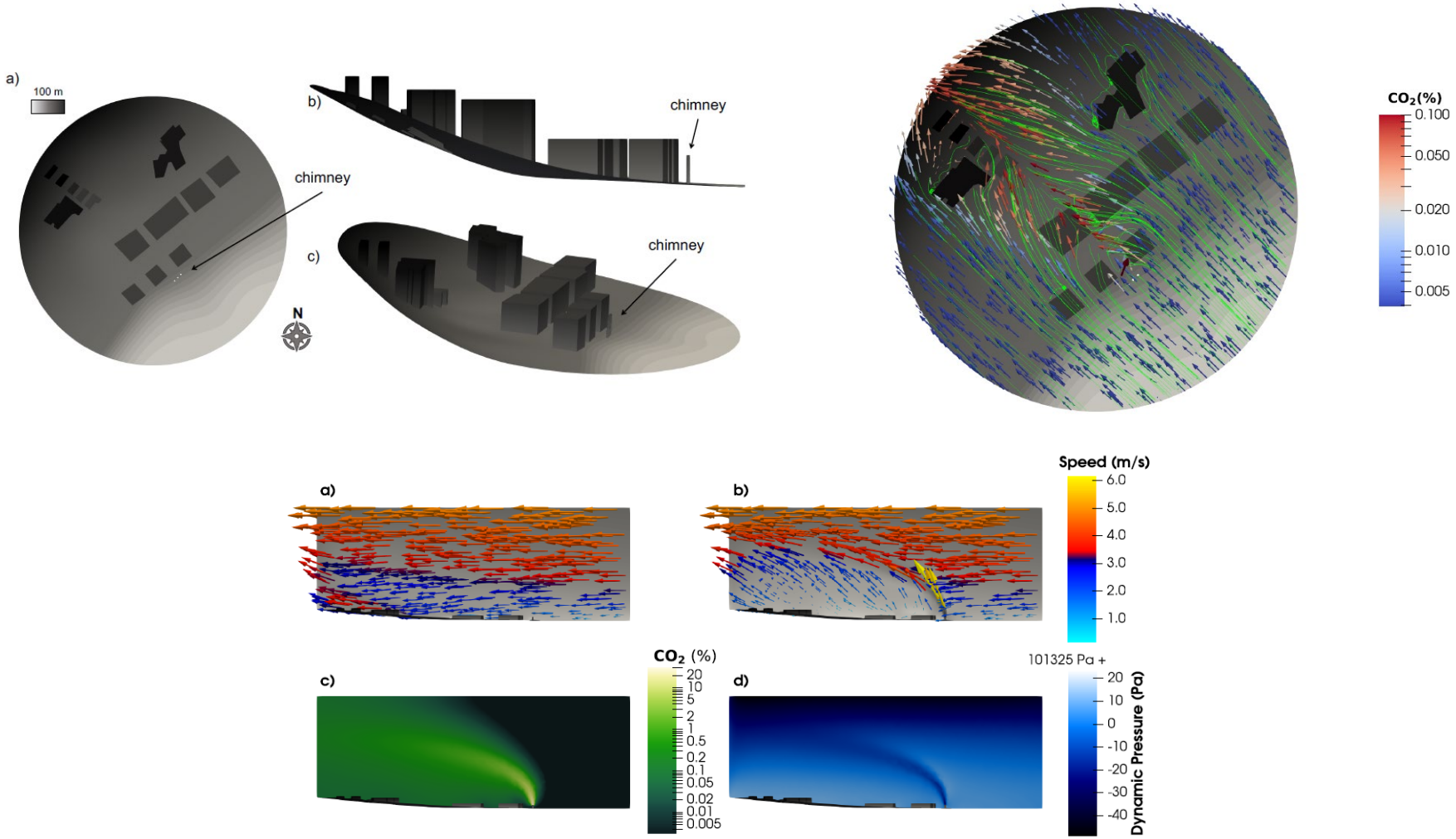






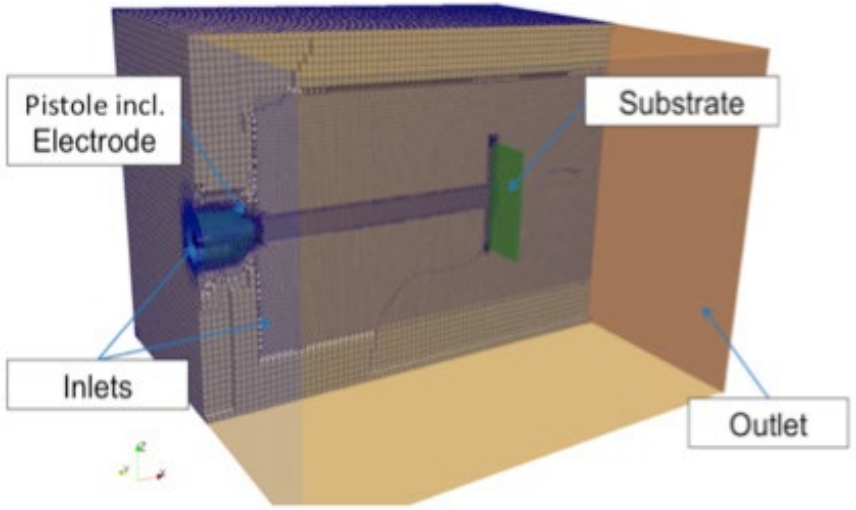
Torgeir Myrvang, Hassan Khawaja, Validation of air ventilation in tunnels, using experiments and computational fluid dynamics. The International Journal of Multiphysics, 2018, 12(3): pp. 295 - 311. http://dx.doi.org/10.21152/1750-9548.12.3.295

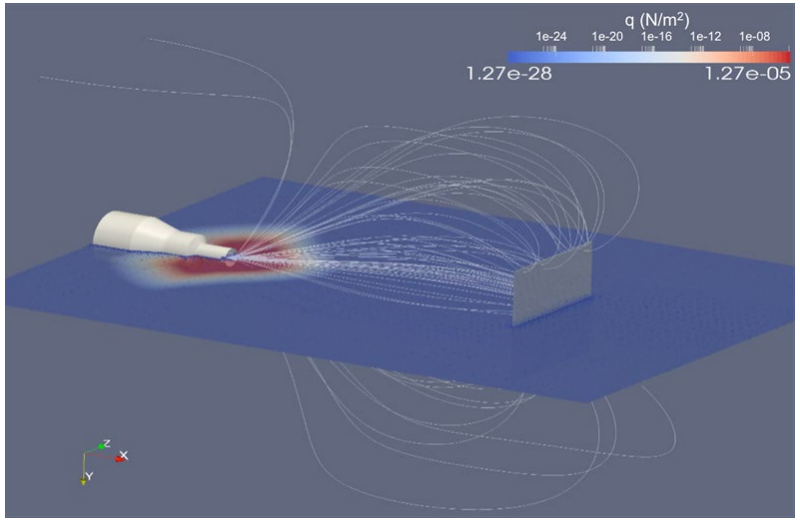
Emission Breivika Port – Simulation

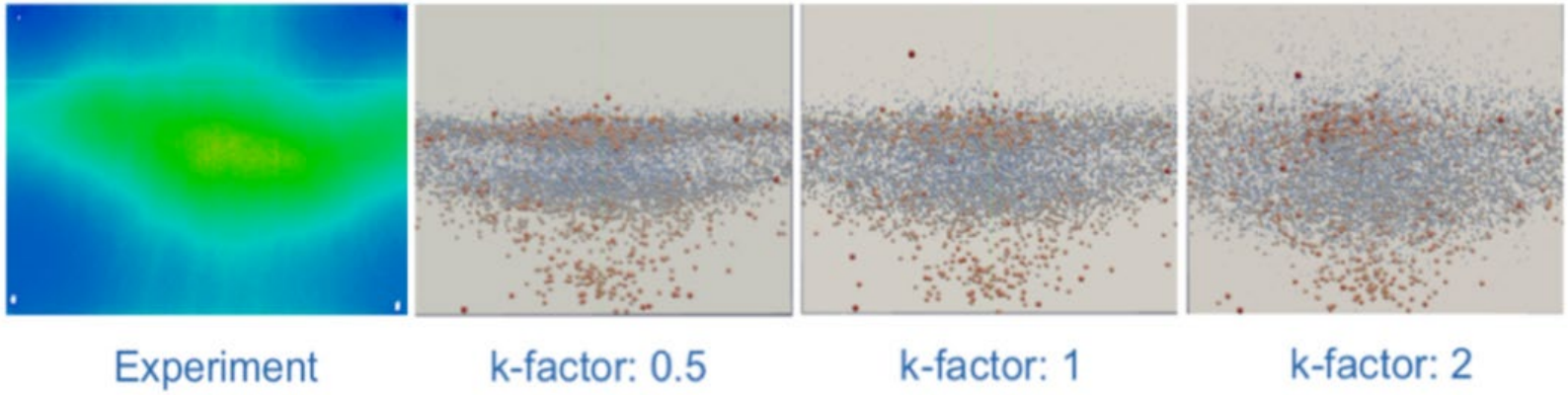


Asier Zubiga, Synne Madsen, Hassan Khawaja, Gernot Boiger. Atmospheric Contamination of Coastal Cities by the Exhaust Emissions of Docked Marine Vessels: the case of Tromsø. Environments, 2021, 8(9), 88.
https://doi.org/10.3390/environments8090088

Powder Spray – EM Field Simulation

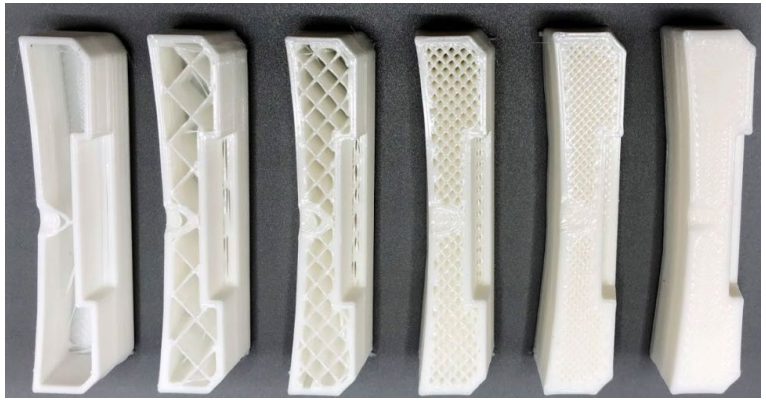


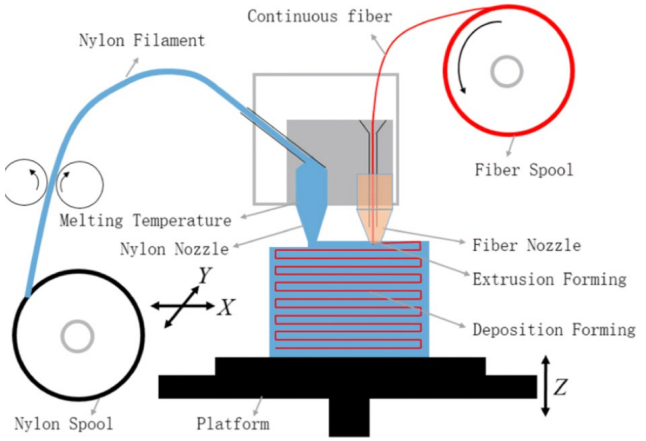


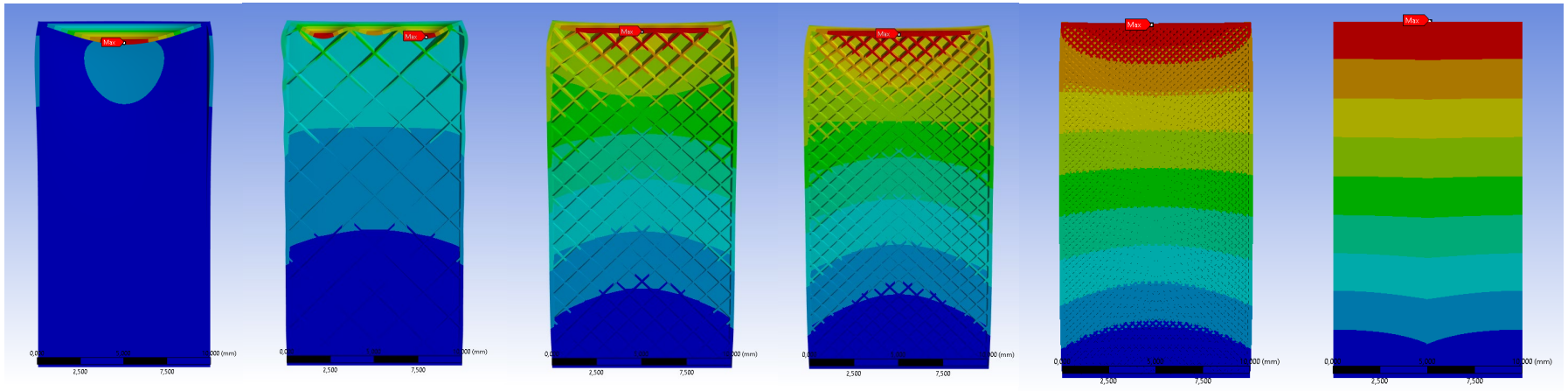


Gernot Boiger, Marlon Boldrini, Viktor Lienhard, Bercan Siyahhan, Hassan Khawaja, Mojtaba Moatamedi. Multiphysics Eulerian-Lagrangian Electrostatic Particle Spray Model for OpenFOAM® and KaleidoSim® Cloud-Platform. The International Journal of Multiphysics, 2020, 14(1): pp.1-16. http://dx.doi.org/10.21152/1750-9548.14.1.1

3D Print – Structure Integrity Simulations

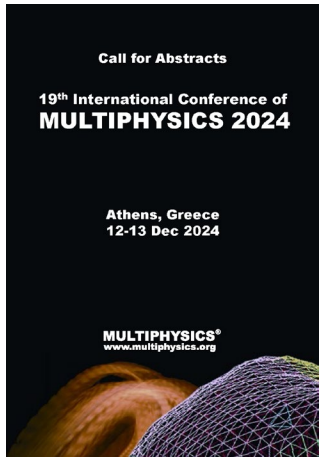


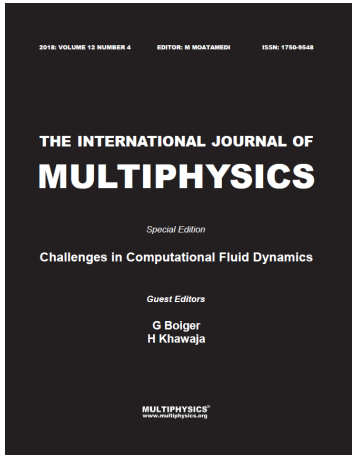


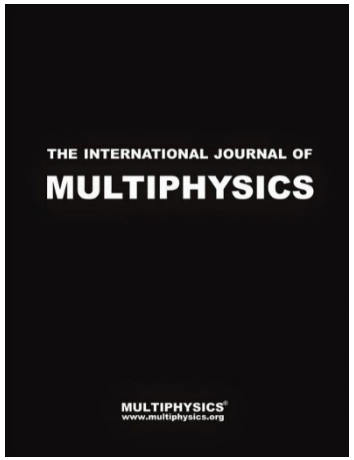


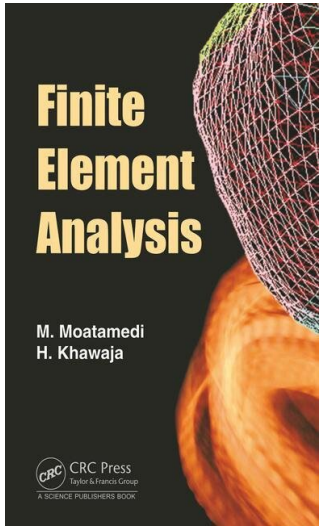
Zahra Andleeb, Hassan Khawaja, Kristian Andersen and Mojtaba Moatamedi. Finite Element Analysis to determine the impact of Infill density on Mechanical Properties of 3D Printed Materials. The International Journal of Multiphysics, 2022, 16(3), pp. 317-335. https://doi.org/10.21152/1750-9548.16.3.317

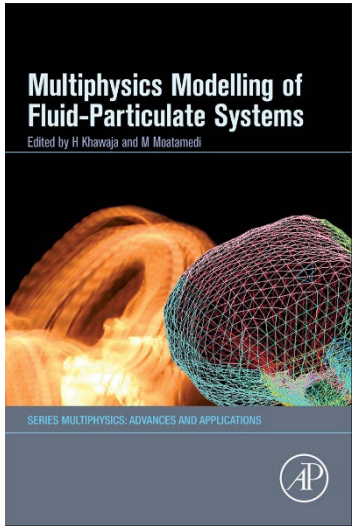
The International Society of Multiphysics

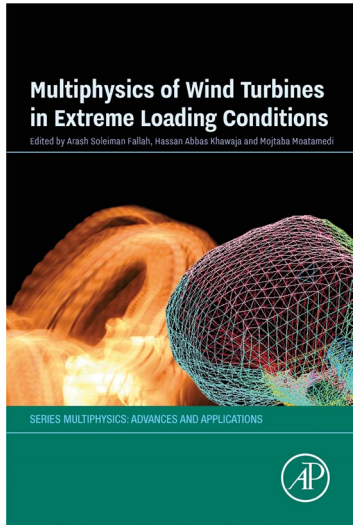


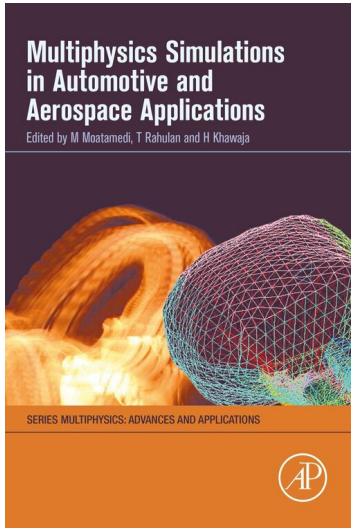












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Thank you and questions!

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