



UiT The Arctic University of Norway

Exploring the Interconnected Realms of Multiphysics: Insights from My Research Journey

2nd April 2024

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Department of Automation and Process Engineering (IAP)
IR, Spectroscopy, and Numerical Modelling Research Group*

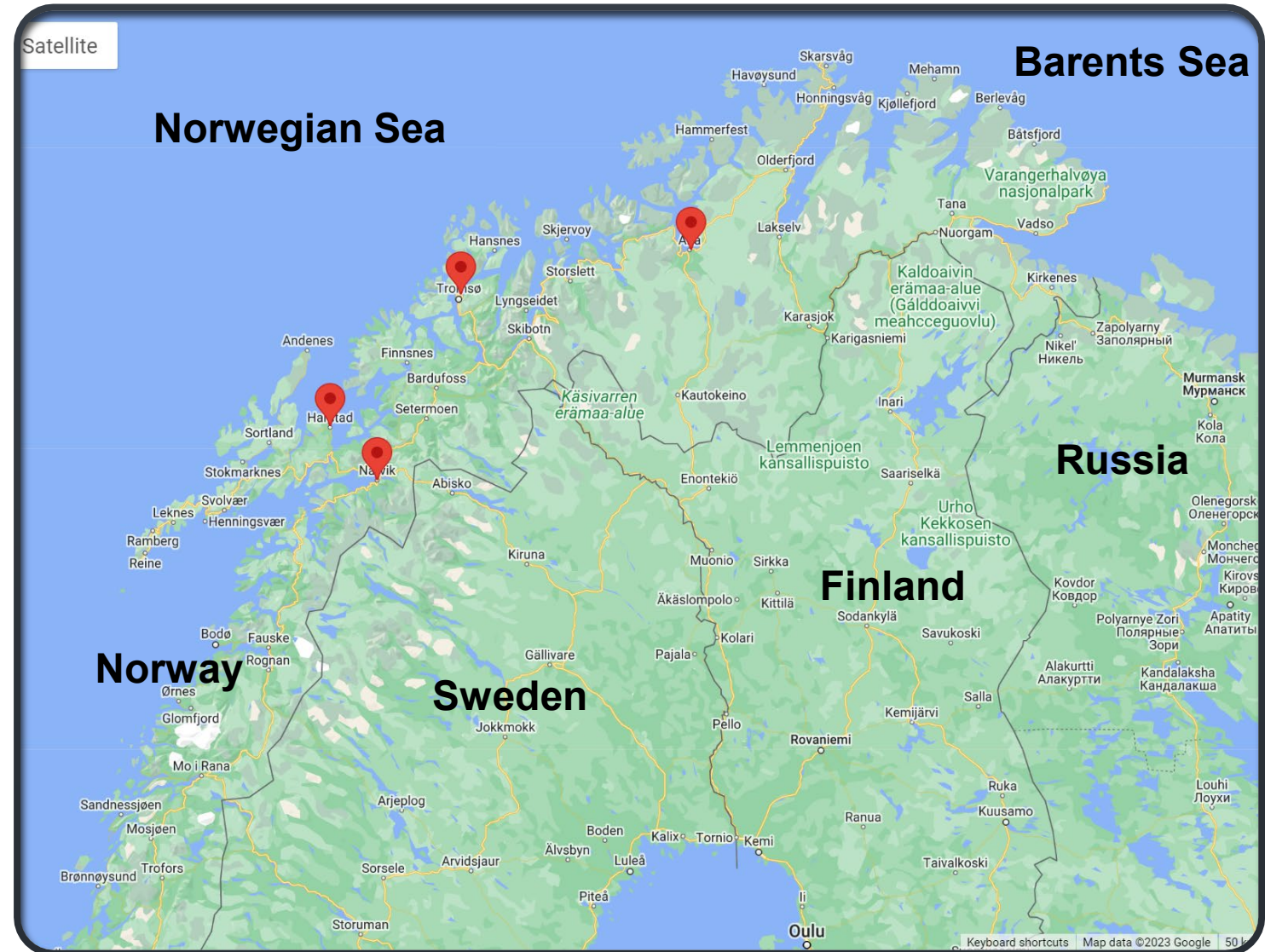
Collaborations with Chinese Universities

- Guest Lecturer - Zhengzhou University of Aeronautics (ZUA), March 2024
- Informal Discussions with Rao Adeel un Nabi and Prof. Wang Tie-Jun at SIOM, CAS, January 2024
- Guest Lecturer - Henan University of Science and Technology (HAUST), November 2023
- Invited by BIT to apply for 1000 Young Talents Plan as a Researcher, September 2019
- Conference Organizer - MULTIPHYSICS 2023 at Beijing Institute of Technology (BIT), Beijing, China, December 2017



UiT The Arctic University of Norway

4 campuses
70° north (latitude)
3500 staff (1700 academics)
17000 students



TROMSØ, NORWAY



Source: <https://www.visitnorway.com/places-to-go/northern-norway/tromso/>

Biography

Research Group Leader, UiT, Norway (2015-)

Associate Professor, UiT, Norway (2014-)

Post-Doctoral Researcher, UiT, Norway (2012-2013)

MPhil and PhD in Engineering, Cambridge, UK (2008-2012)

Bachelor in Aerospace Engineering,
NUST, Pakistan (2002-2007)



My Research Portfolio

Research Portfolio:

70+ Journal Publications

100+ Conference Presentations

10+ PhD Students Supervisions

20+ Master Students Supervisions

15+ International Funded Projects

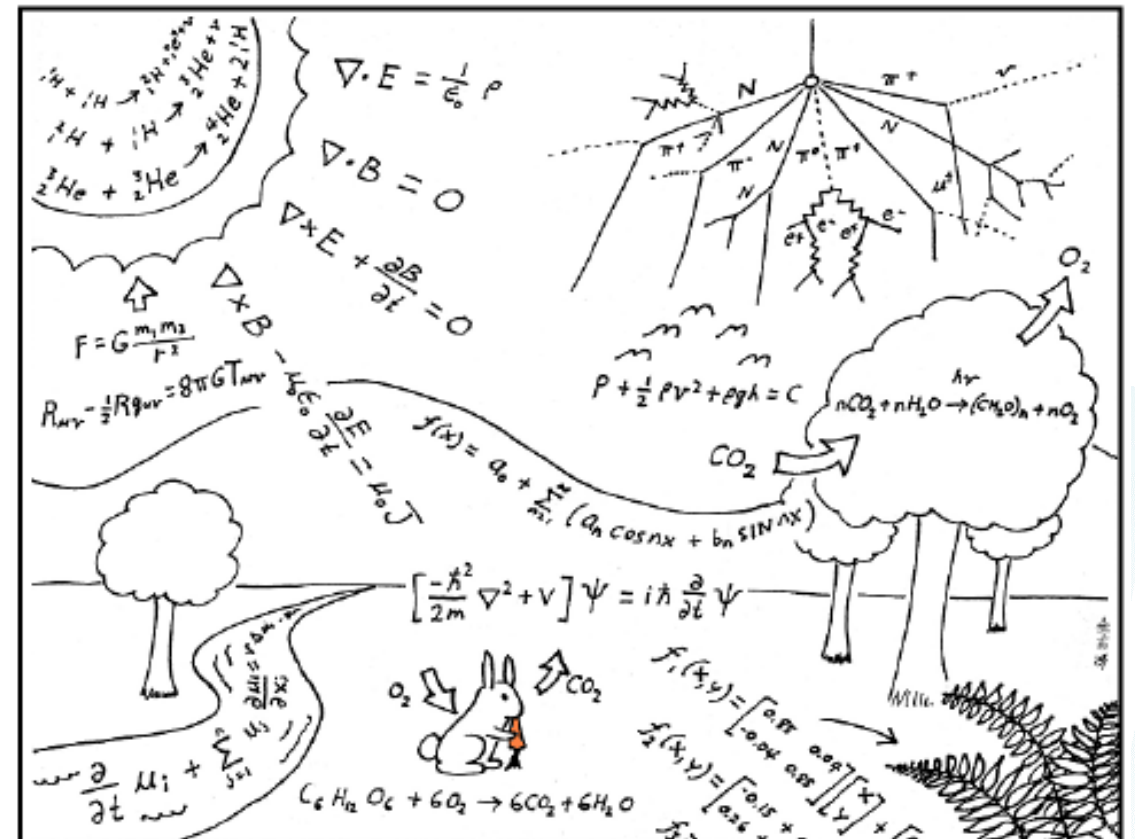
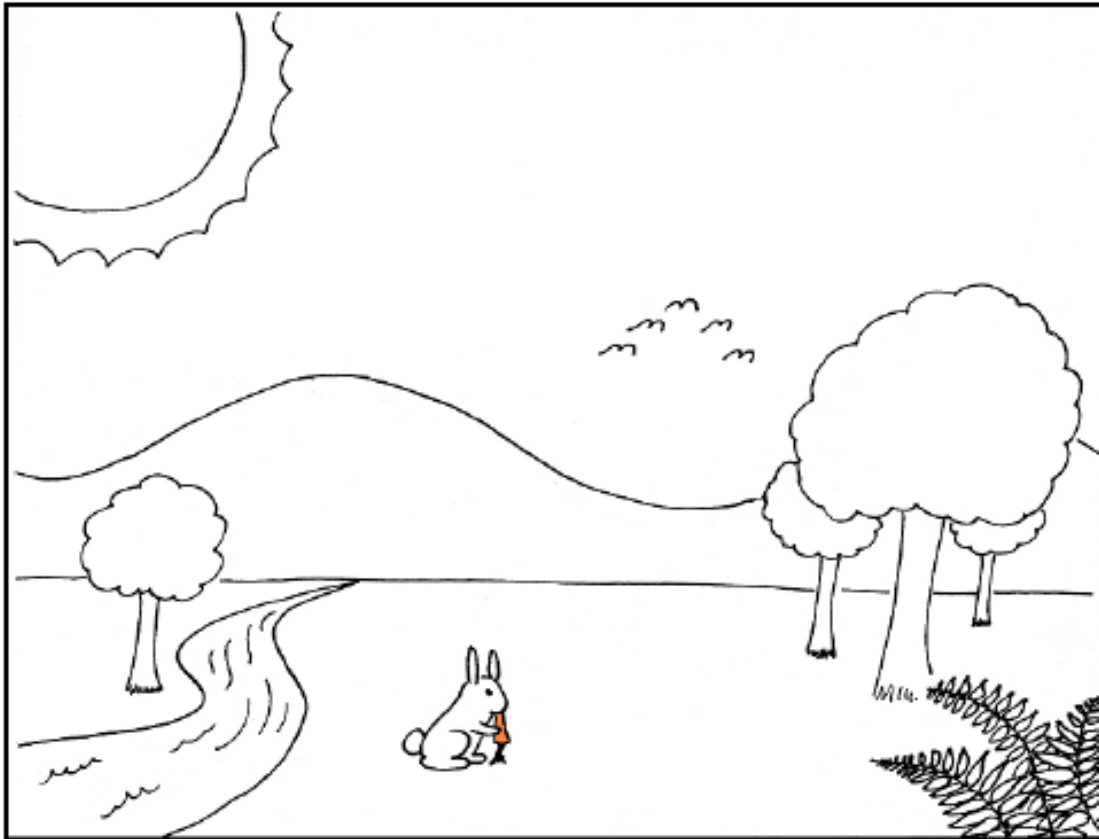
Developed Master/PhD courses:

- Multiphysics Simulation
- Thermography and Spectroscopy

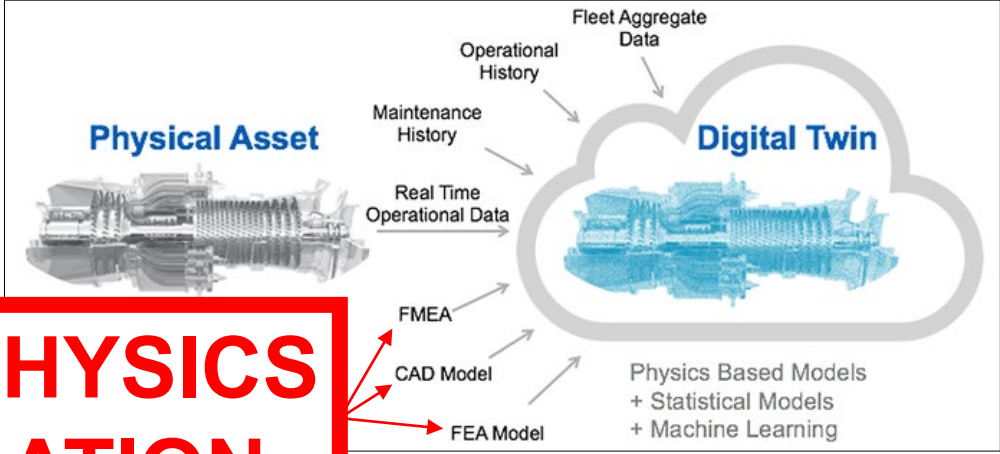
International Collaborations:

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

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.



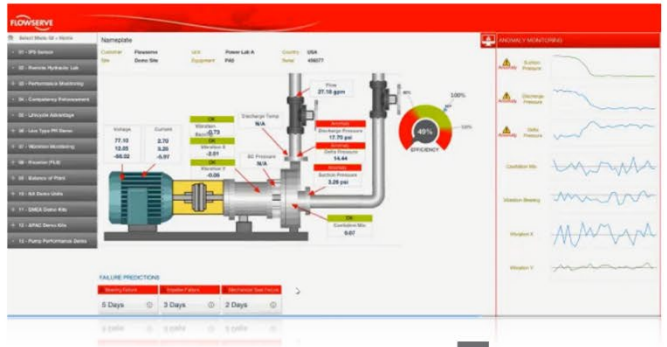
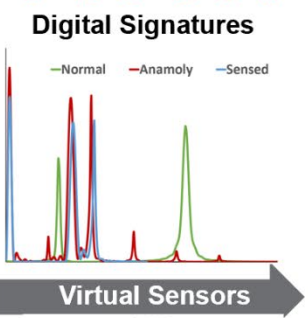
MULTIPHYSICS SIMULATION

DIGITAL TWIN

As Designed
MODEL-BASED ENTERPRISE & SYSTEMS ENGINEERING

As Operated
INTEGRATED IOT ASSETS & ECOSYSTEMS

FLUIDS
STRUCTURES
ELECTRONICS
SEMICONDUCTOR
EMBEDDED SOFTWARE



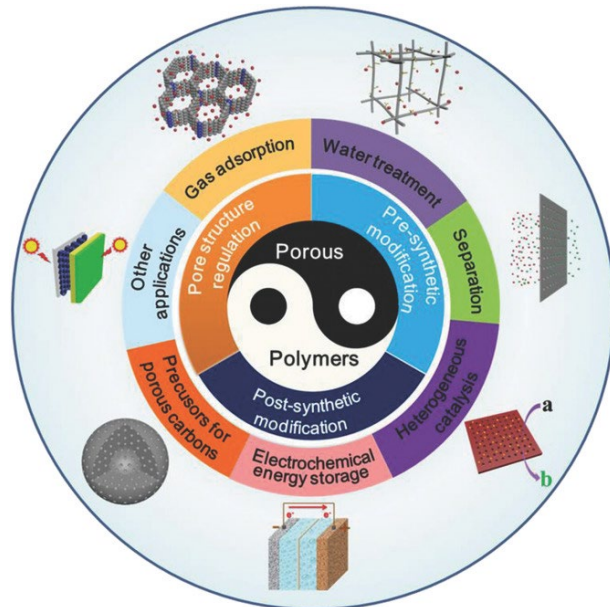
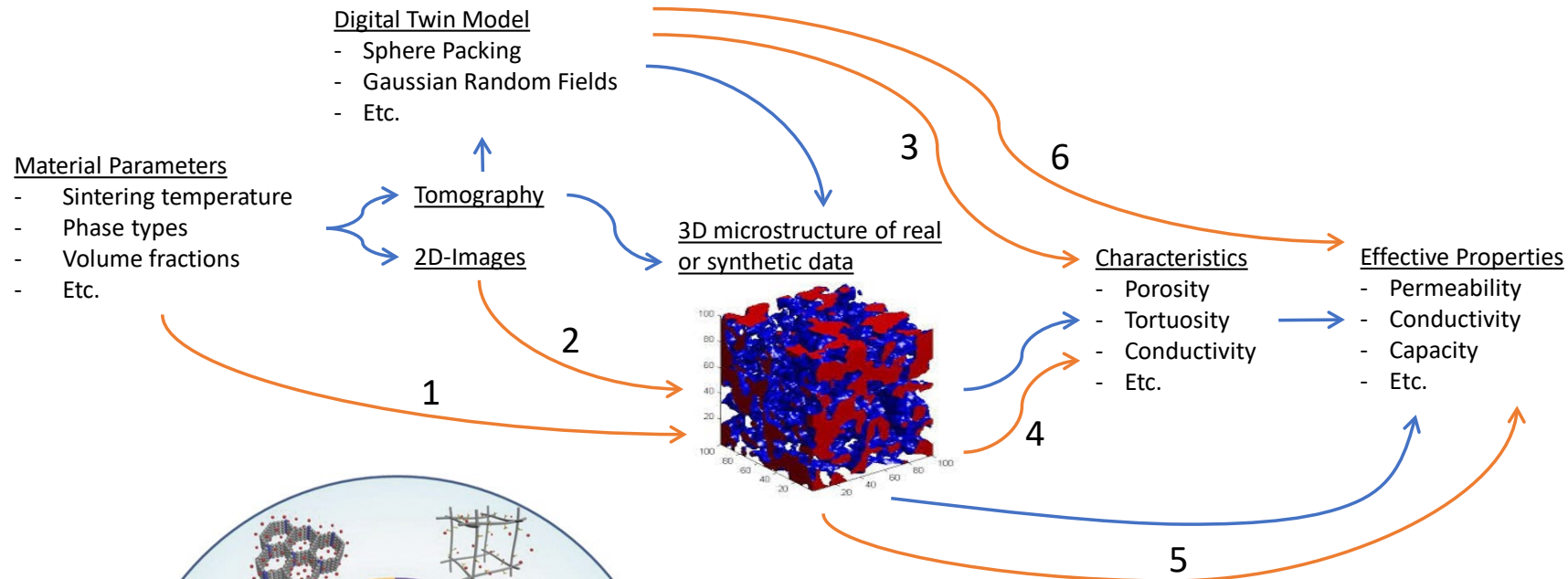
- Further improve:
- Cost
 - Weight
 - Efficiency
 - Robustness

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



Virtual Sensors

Microstructure Model – AI/ML Simulation



Ice Detection/Mitigation – CHT Simulation

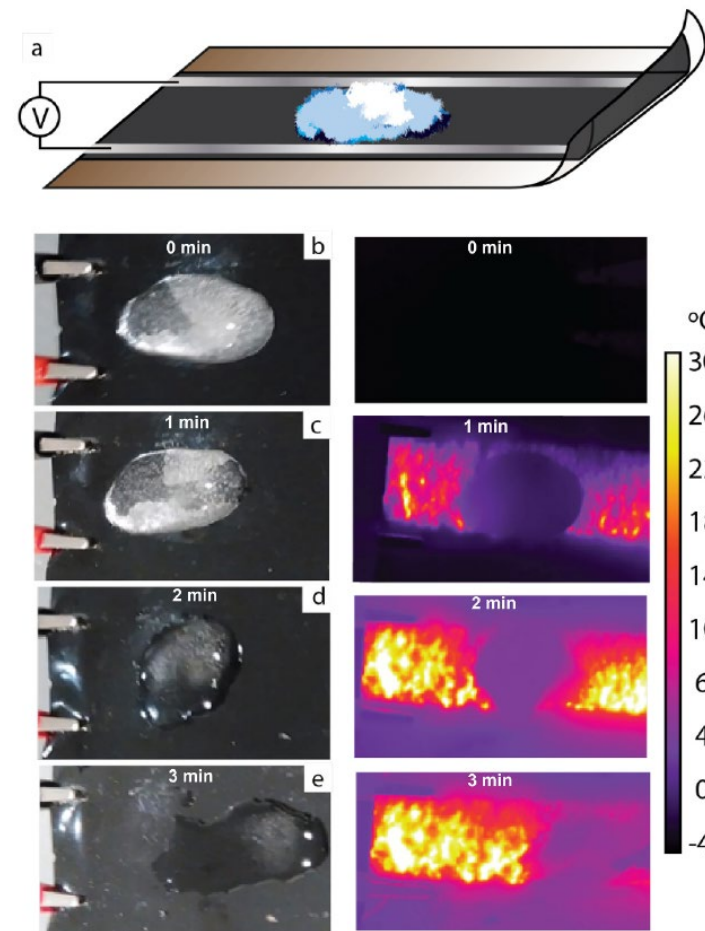
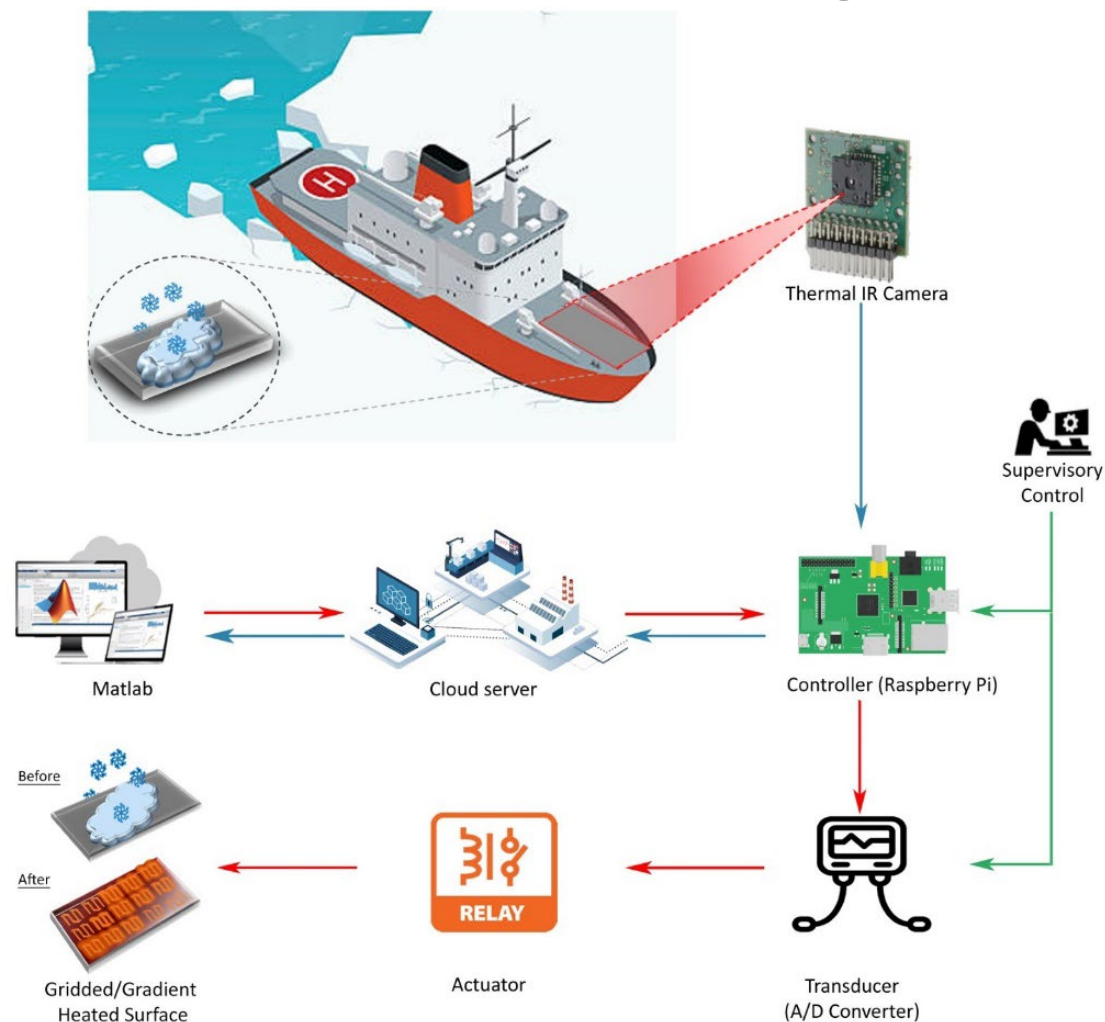
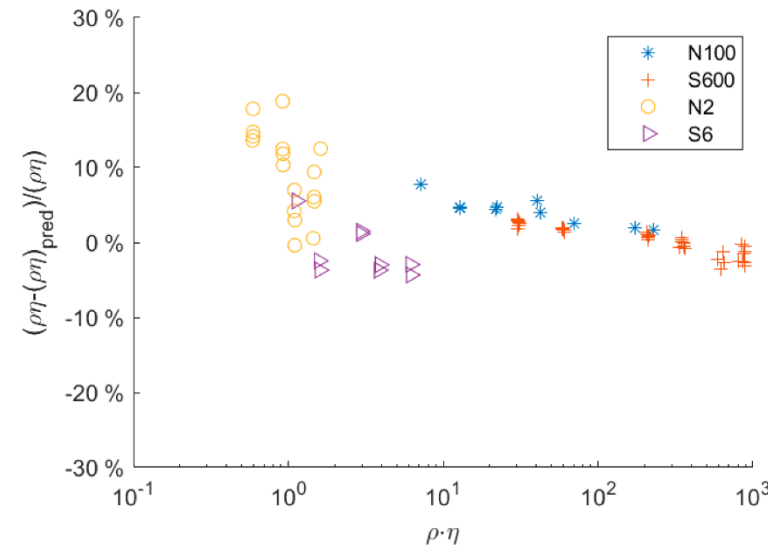
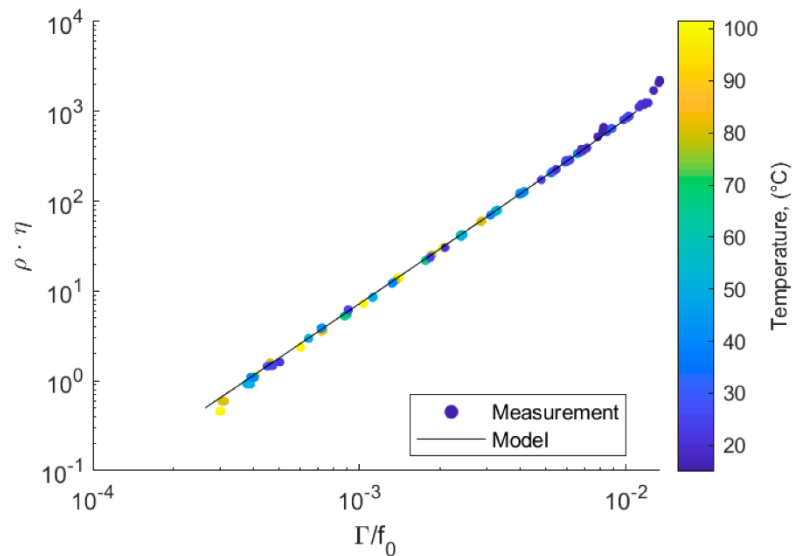
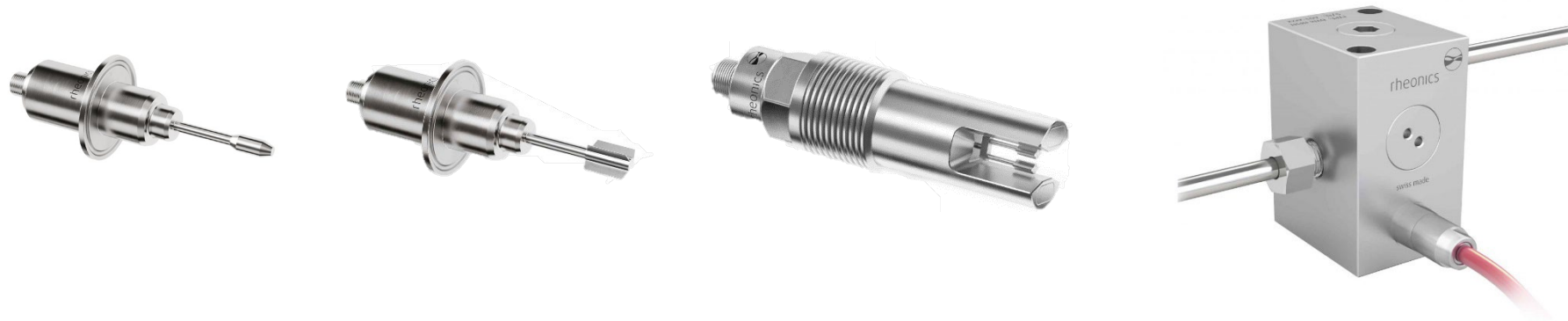


Fig. 4. De-icing demonstration of R2R CNT coated sheet (IR and colour images), when ice is frozen inside cold room at steady state temperature of -2°C .

Viscosity-Density Sensor – FSI Simulation

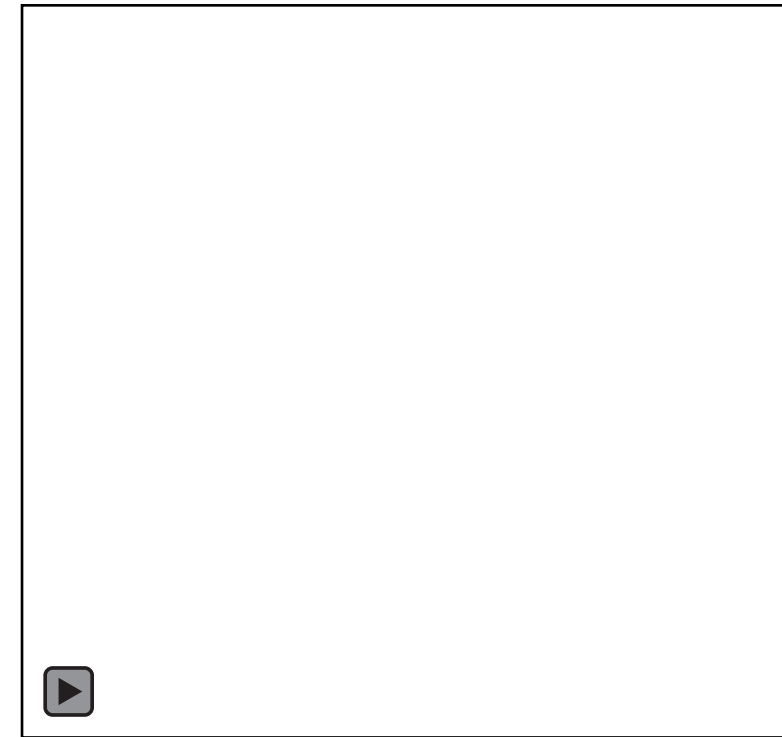
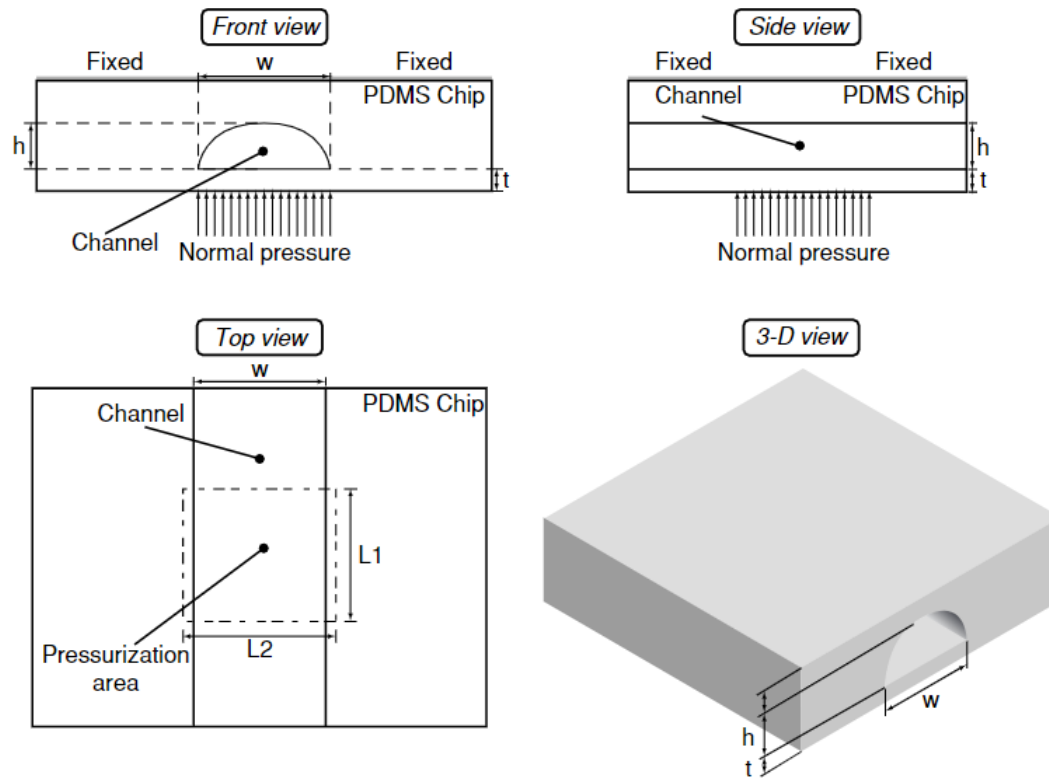


rheonics



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>

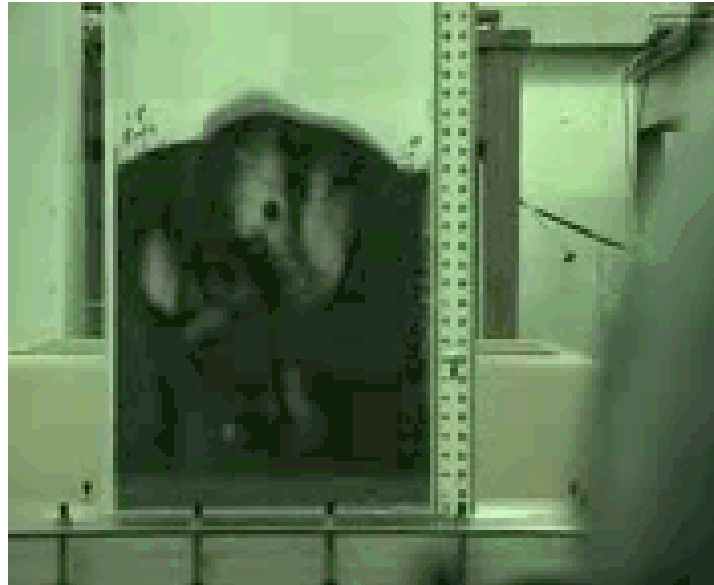
Micro-Fluidic Pump – FEM Simulation



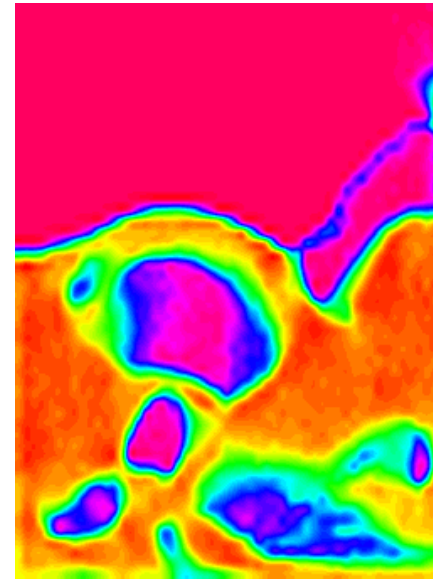
California Institute of Technology (CALTECH), USA

Hassan Khawaja et al. 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>

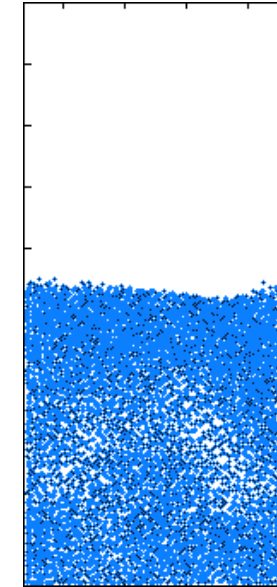
Fluidized Bed – CFD-DEM Simulation



Hopkinson Lab, University of Cambridge, UK



Fluid Inlet

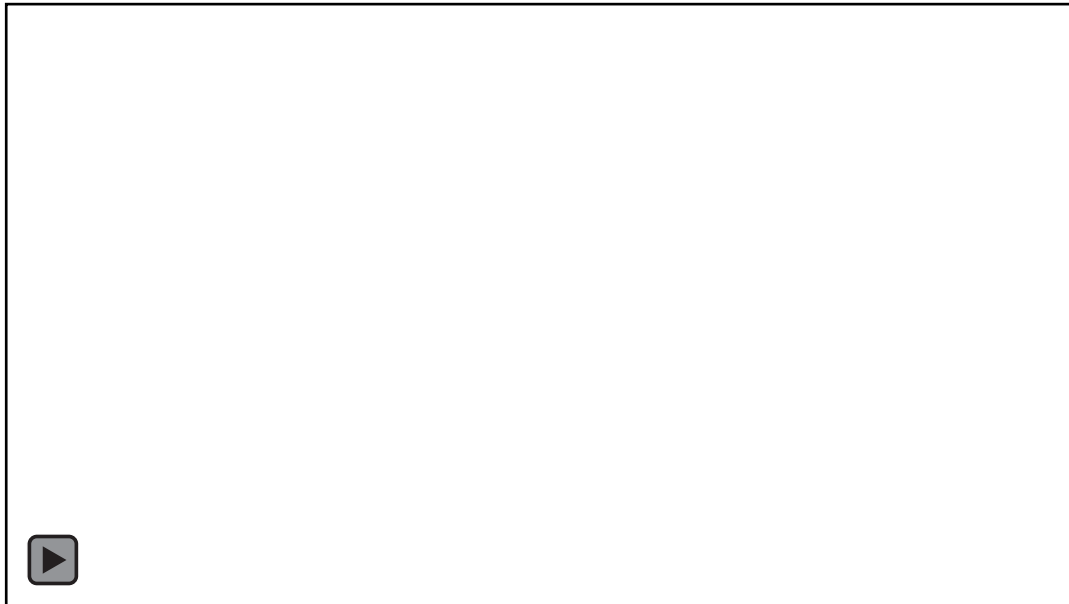


Fluid Inlet

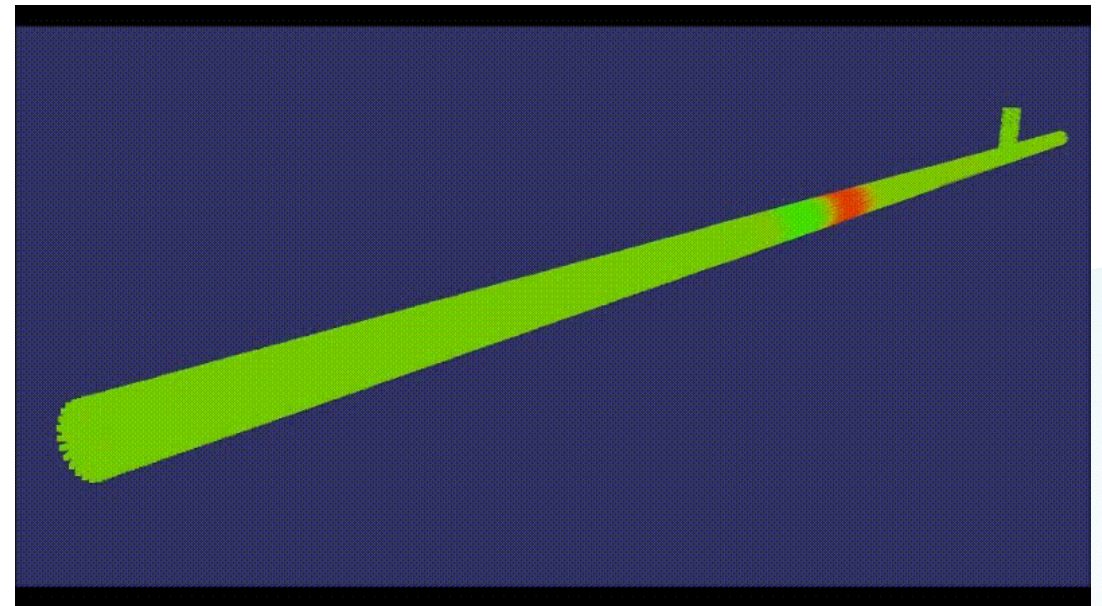
Hassan Khawaja et al. Multiphysics Modelling of Fluid-Particulate Systems. Academic Press, 2020, ISBN 978-0-1281-8345-8.

<https://doi.org/10.1016/C2018-0-02737-1>

Shock Tube – ALE CFD Simulation



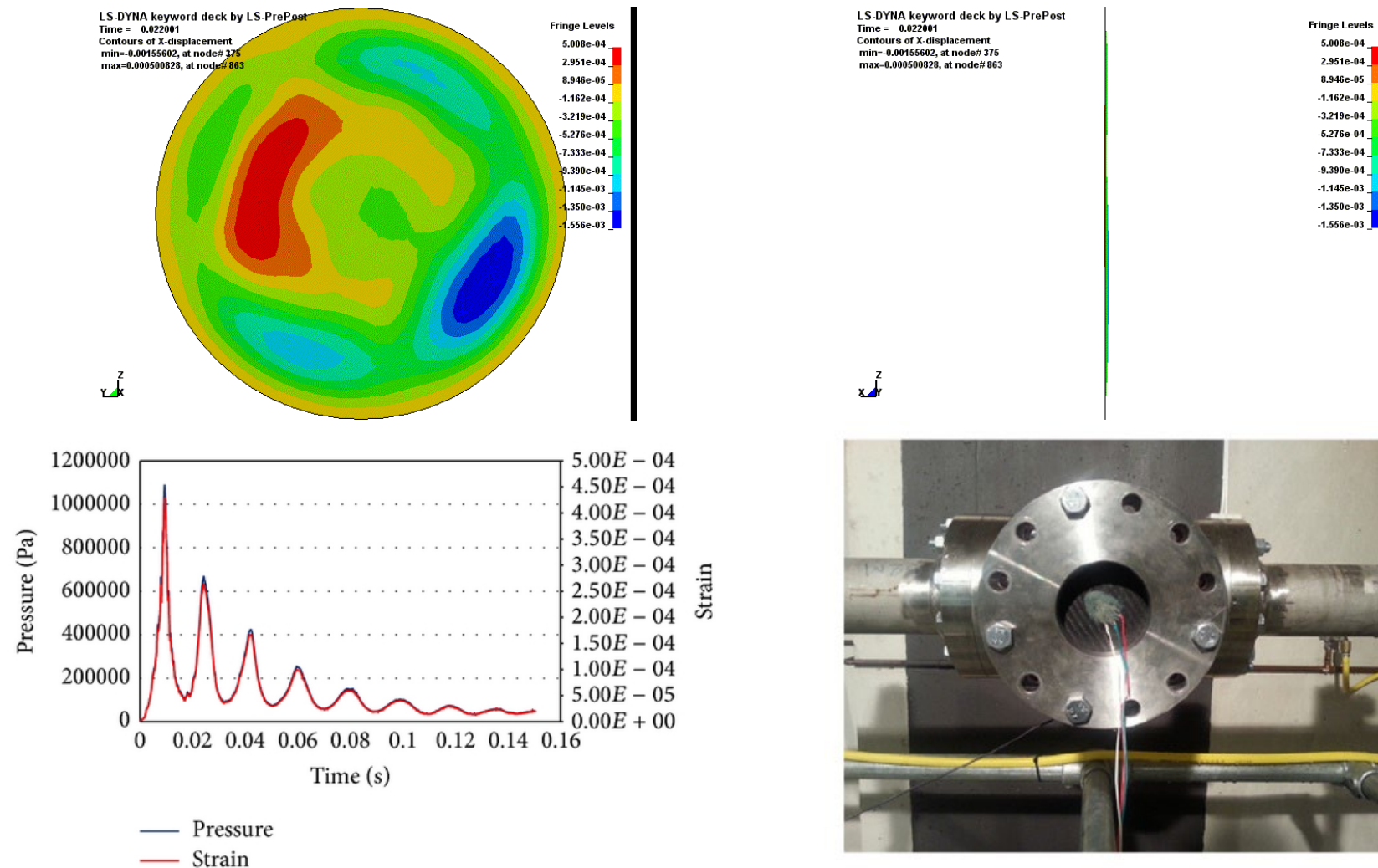
Shock Tube Research Facility at NBSK, Fjellidal, Norway



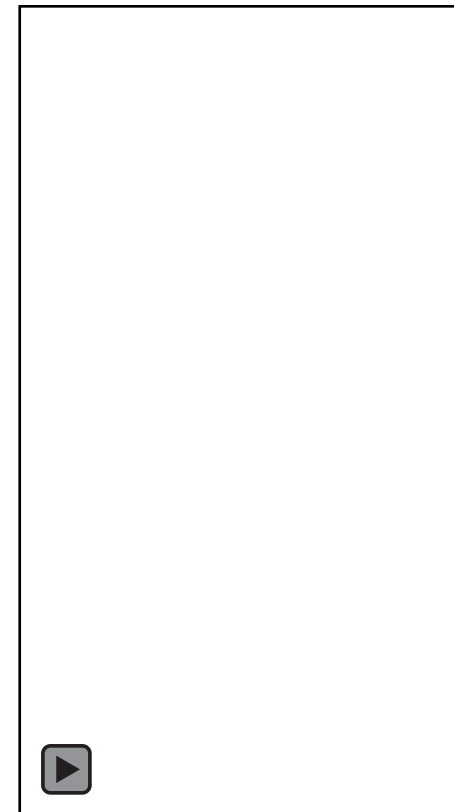
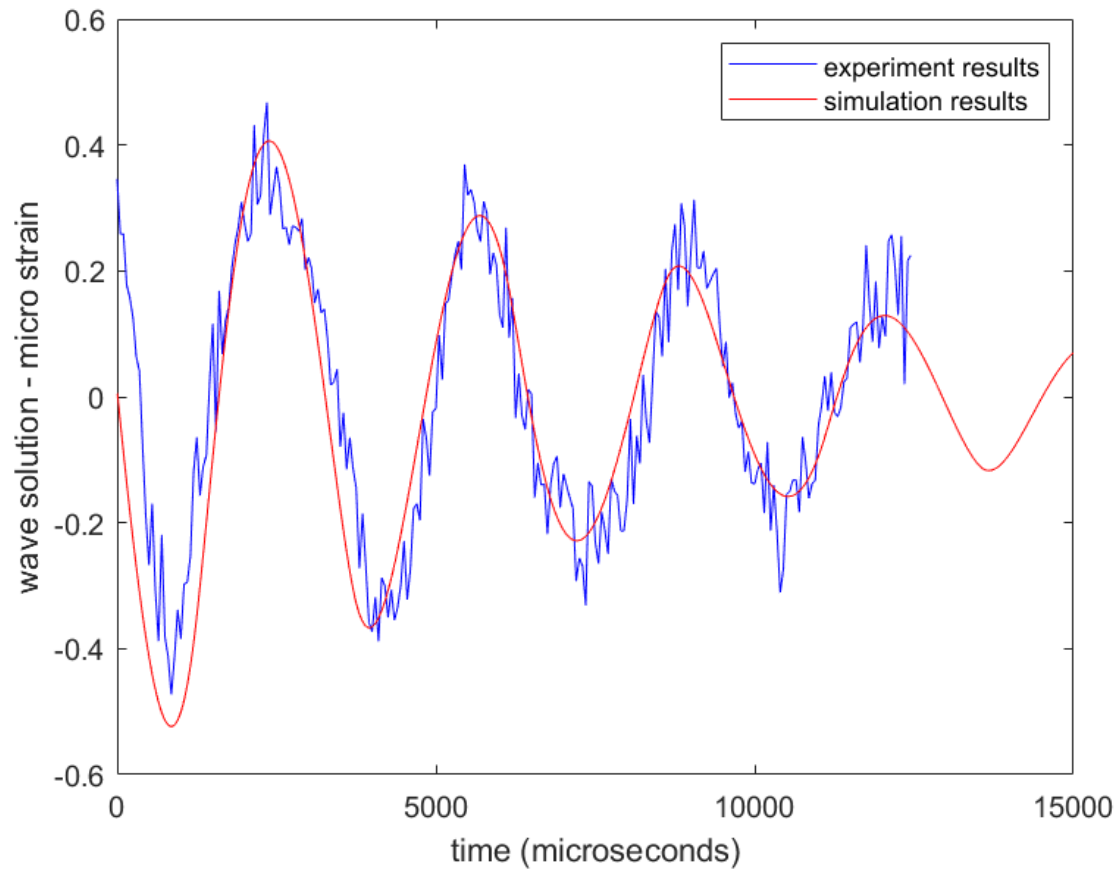
3D visualization of simulation results at ThinkLab, University of Salford, UK

Hassan Khawaja et al. Experimental and Numerical Study of Pressure in a Shock Tube. ASME Journal of Pressure Vessel Technology, 2016, 138(4): 041301. <http://dx.doi.org/10.1115/1.4031591>

Shock Tube – FSI Simulation



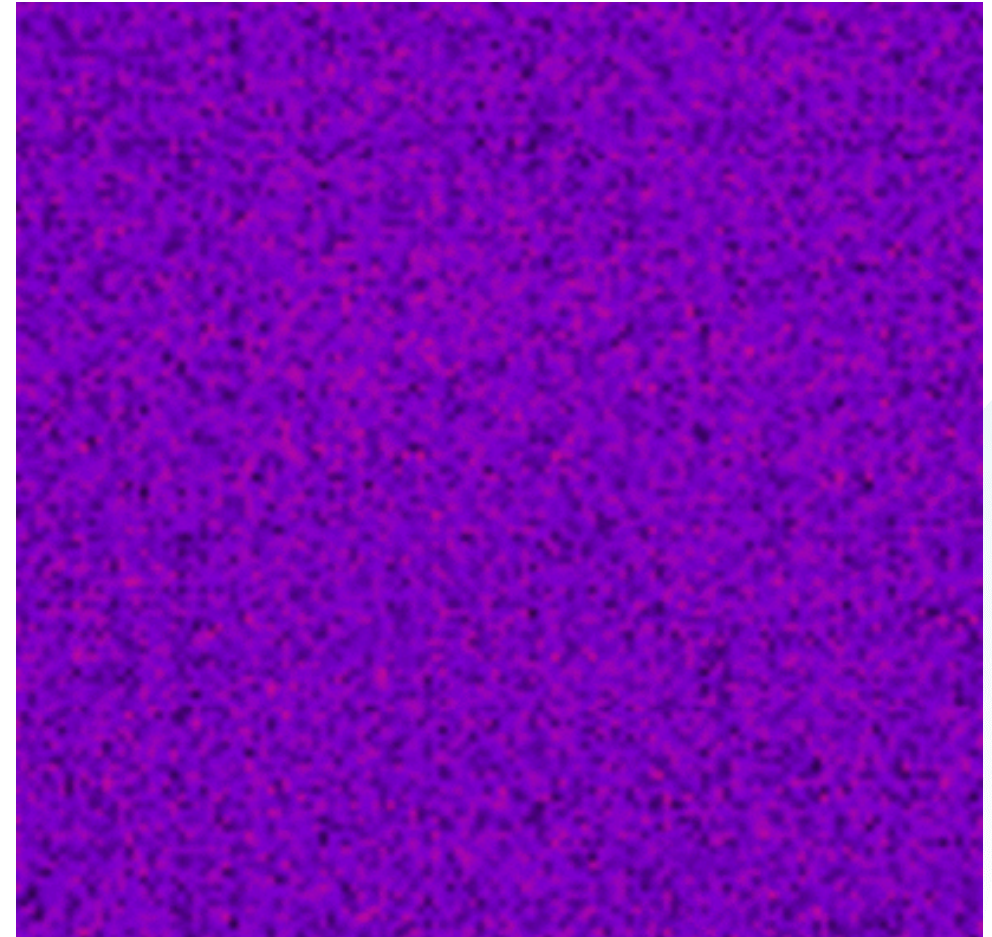
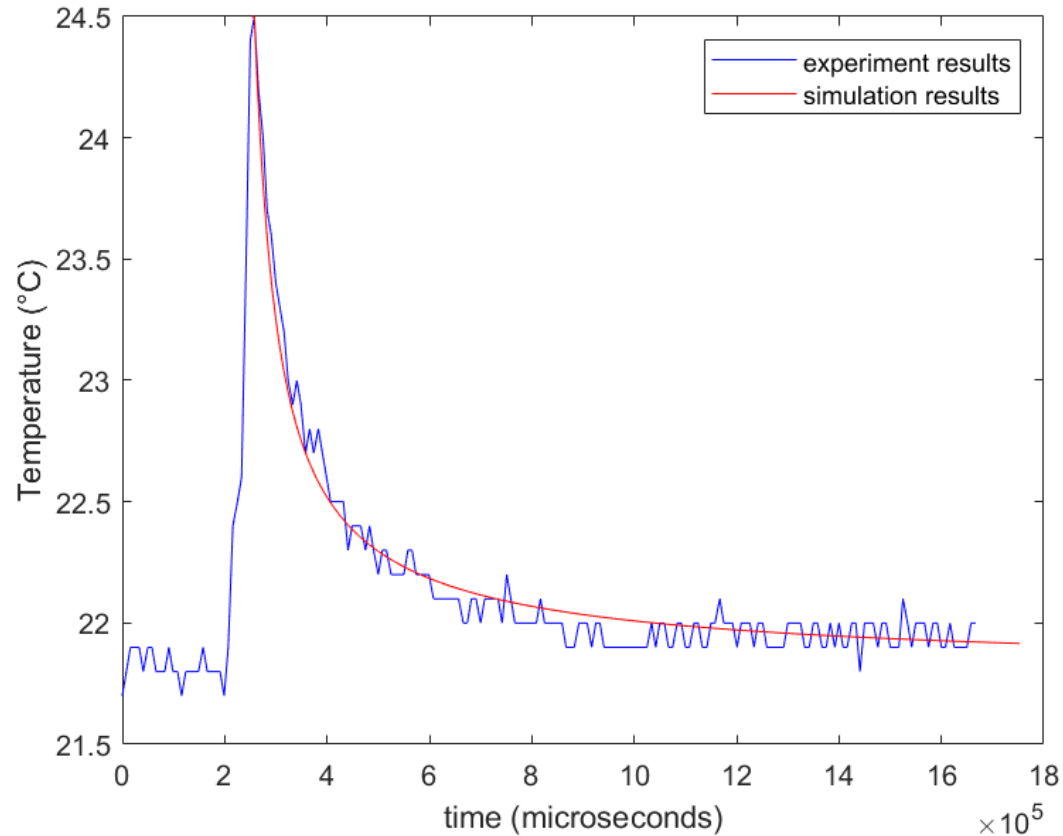
CFRP Impact – Strain Wave Simulation



Process Lab, UiT, Norway

Zahra Andleeb et al. Strain Wave Analysis in Carbon-Fiber-Reinforced Composites subjected to Drop Weight Impact Test using ANSYS®. The International Journal of Multiphysics, 2021, 15(3): 275-290. <https://doi.org/10.21152/1750-9548.15.3.275>

Thermography – CHT Simulation

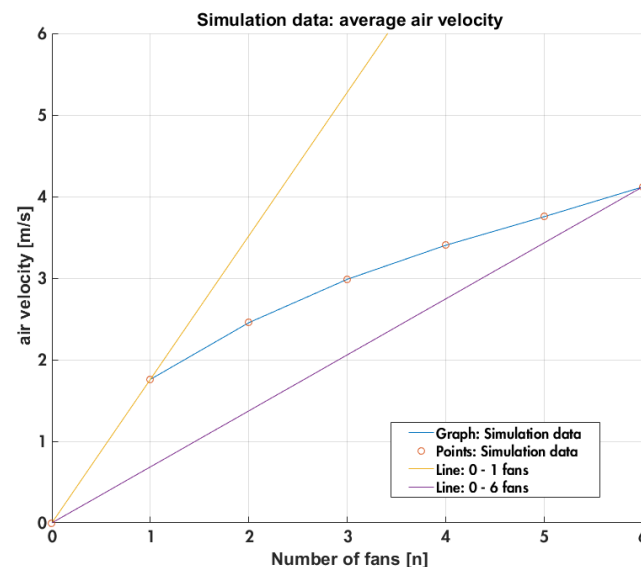
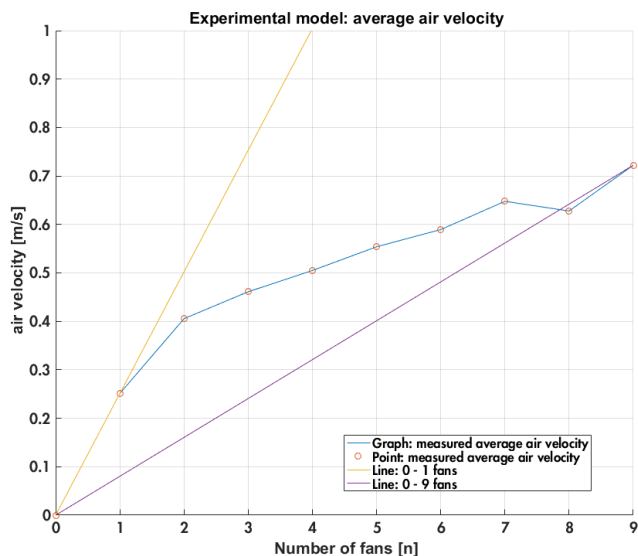
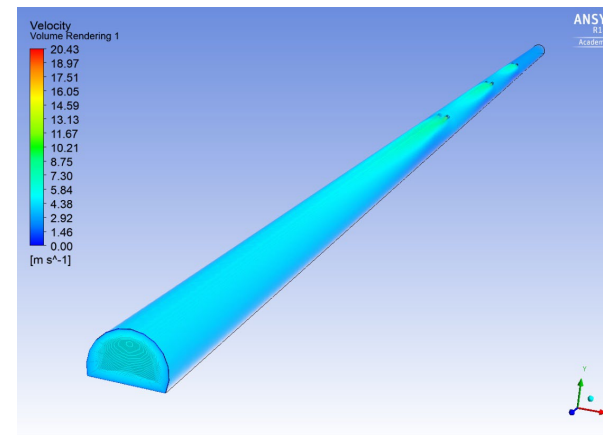


Zahra Andleeb et al. Thermoelastic Investigation of Carbon-Fiber-Reinforced Composites using Drop Weight Impact Test. Applied Sciences, 2021, 11(1): <https://doi.org/10.3390/app11010207>

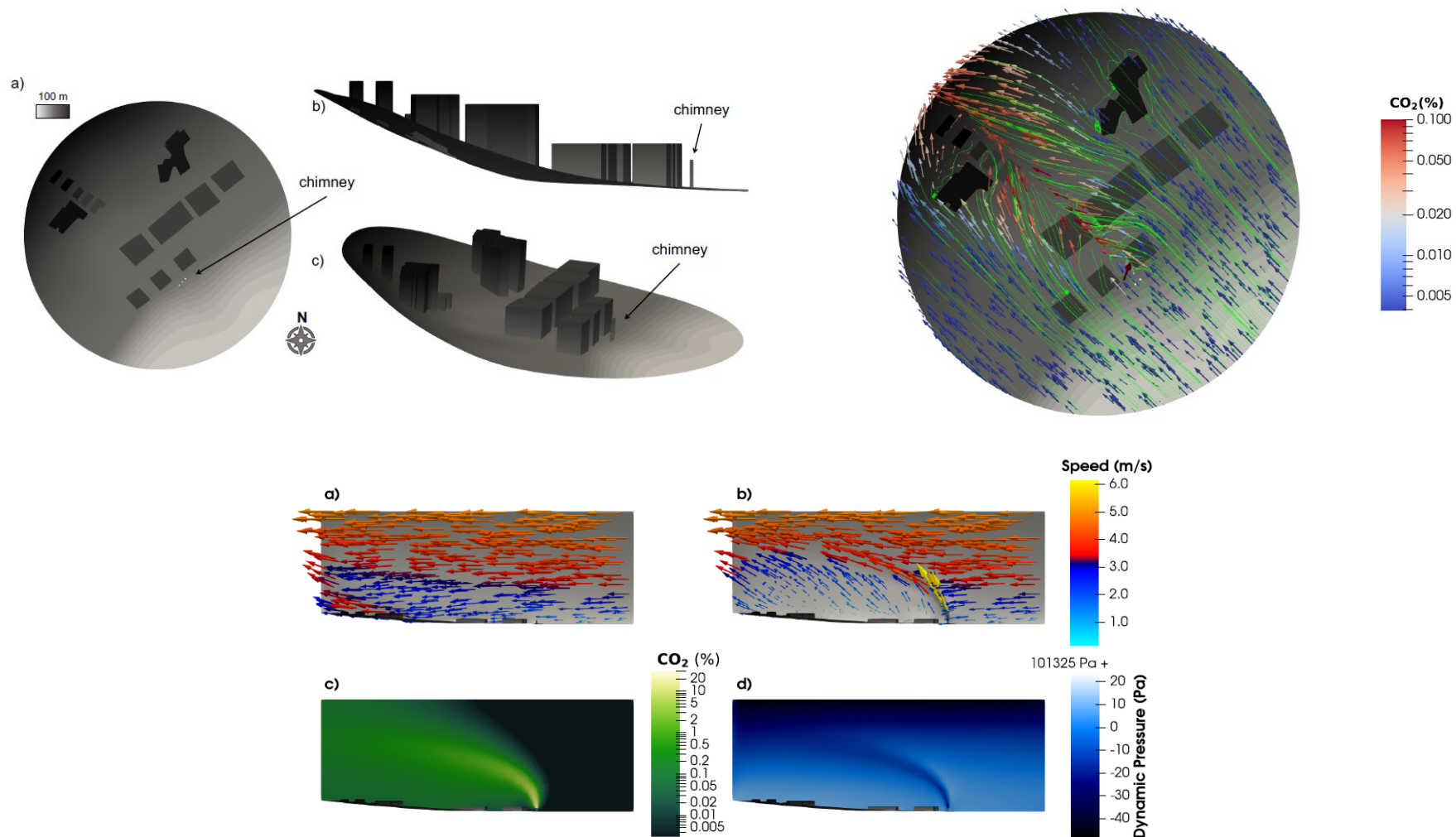
Flow in Highway Tunnel – CFD Simulation



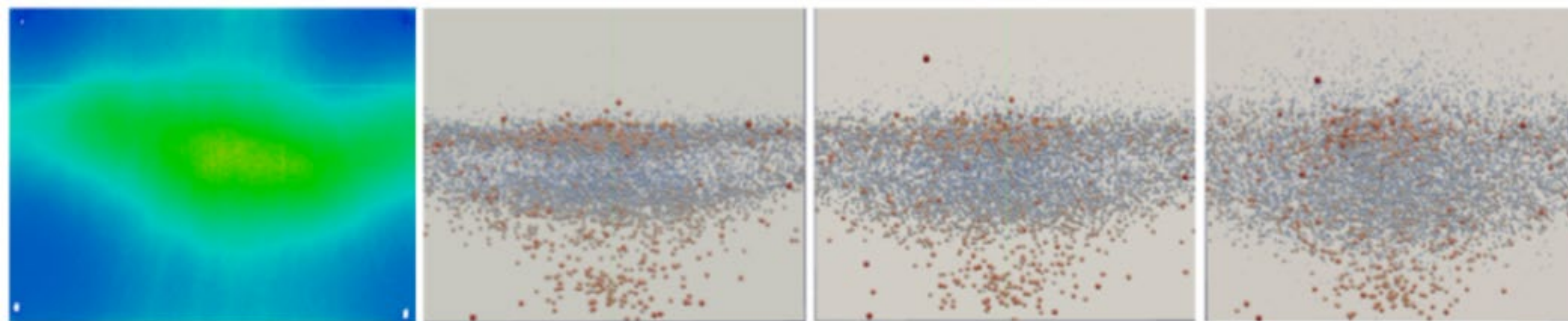
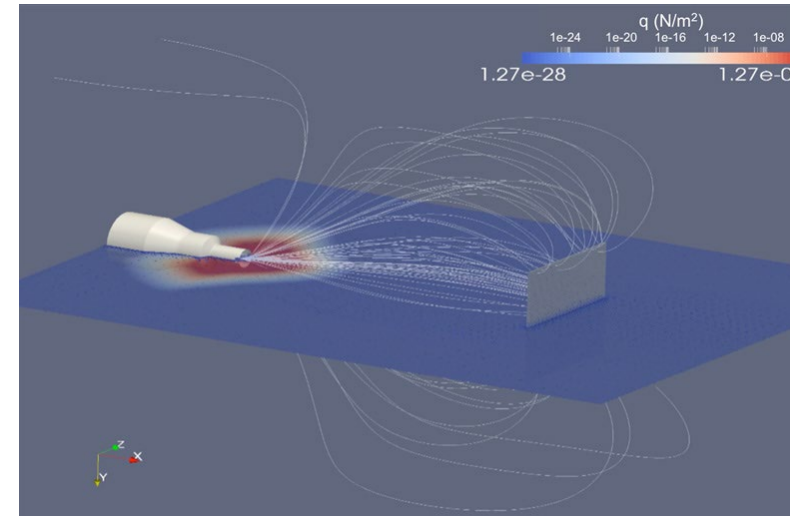
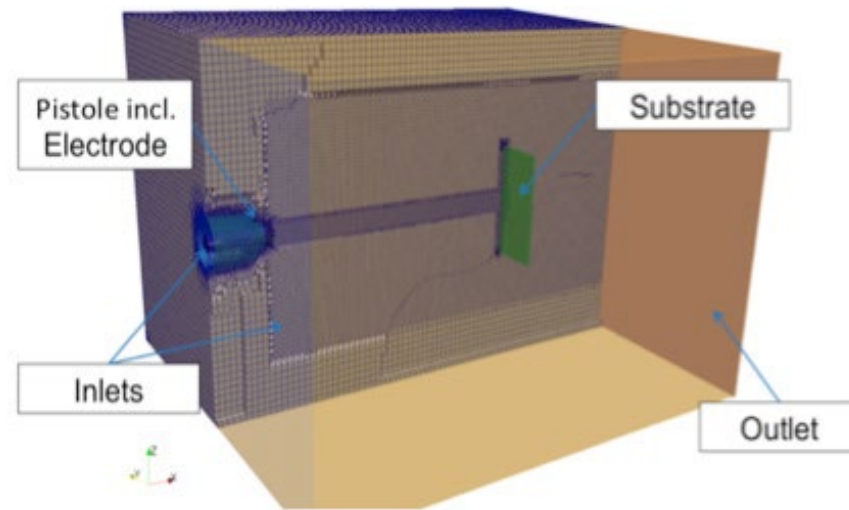
Lærdal Tunnel (24.5 km), world longest road tunnel



Emission Breivika Port – CFD Simulation



Powder ES Spray – CFD/ES/EM Simulation



Experiment

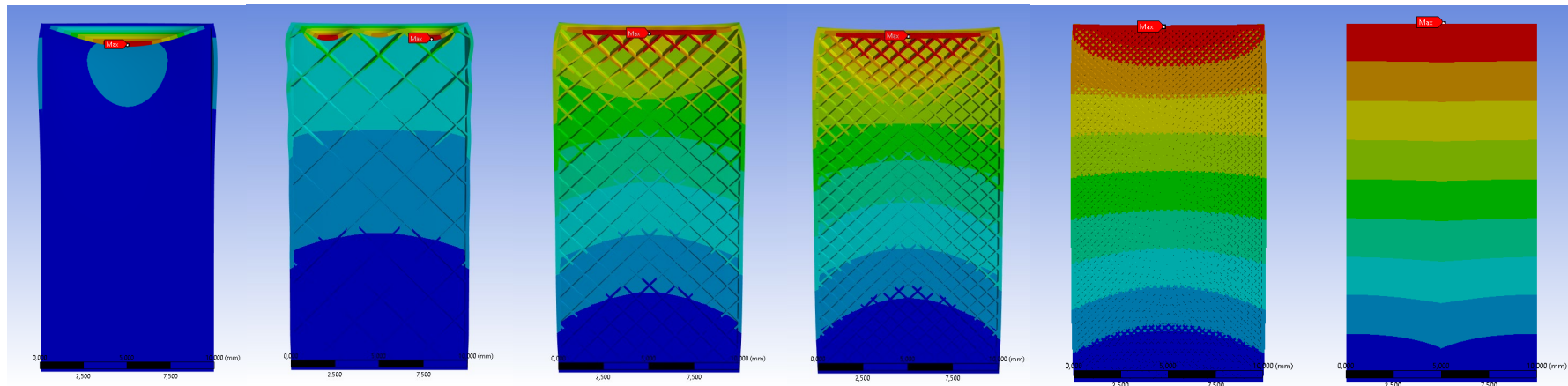
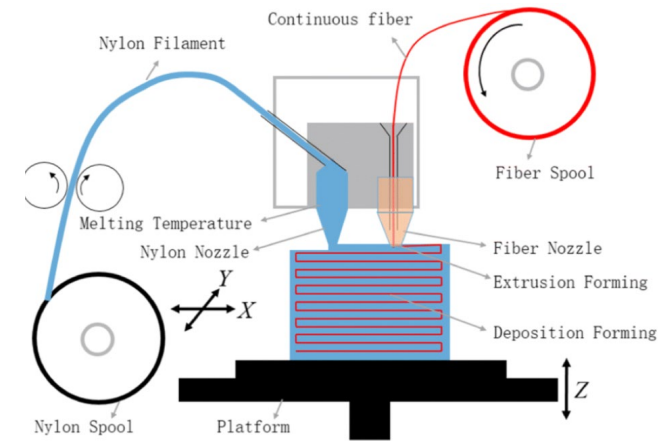
k-factor: 0.5

k-factor: 1

k-factor: 2

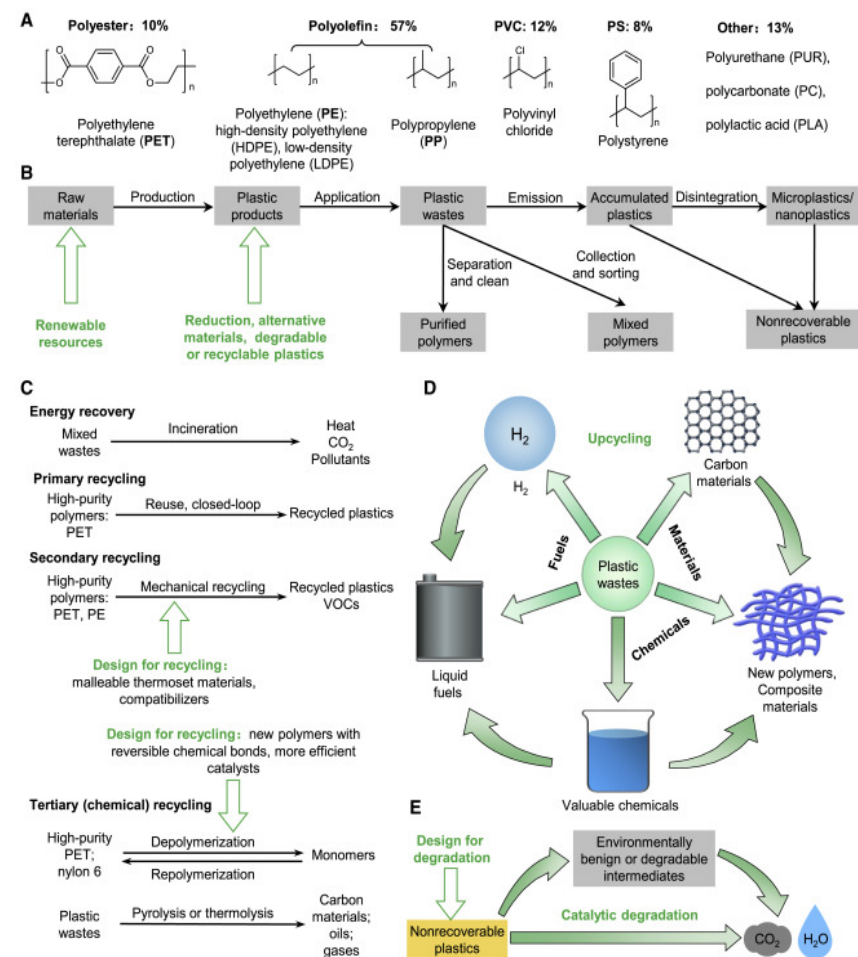
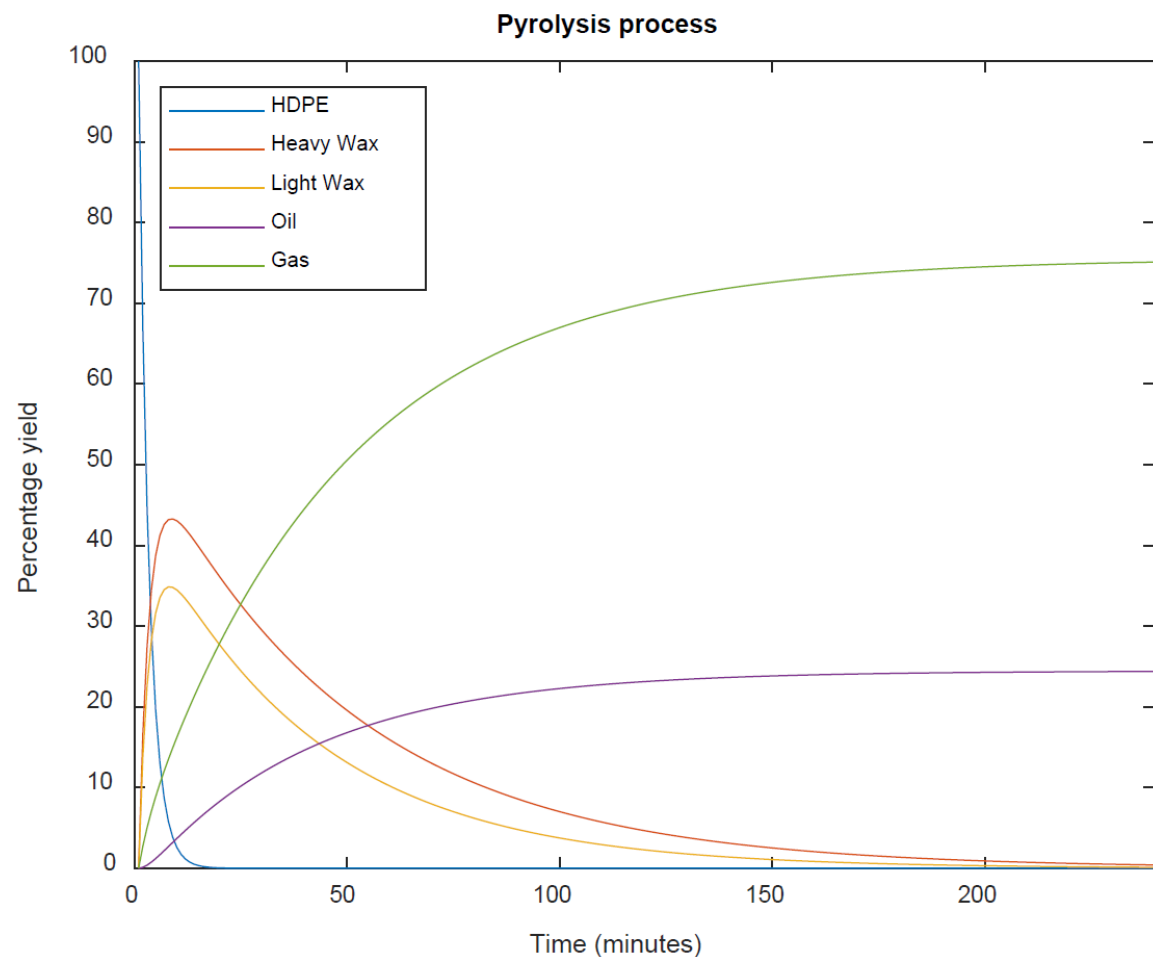
Gernot Boiger et al. Multiphysics Eulerian-Lagrangian Electrostatic Particle Spray Model for OpenFOAM® and KaleidoSim® Cloud-Platform. The International Journal of Multiphysics, 2020, 14(1): pp.1-16. <http://dx.doi.org/10.21152/1750-9548.14.1.1>

3D Print Structure Integrity – FEM Simulation



Zahra Andleeb et al. 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>

HDPE Pyrolysis – RK Simulation



Muhammad Irfan, Rao Nabi, Hammad Hussain, Muhammad Naz, Shazia Shukrullah, Hassan Khawaja, Saifur Rahman, Muhammad Farid. Statistical prediction and sensitivity analysis of kinetic rate constants for the efficient thermal valorization of high-density plastic into combustible oil and gases. *Heliyon*, 2023, 9(5), e16049. <https://doi.org/10.1016/j.heliyon.2023.e16049>



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Thank you and questions!

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