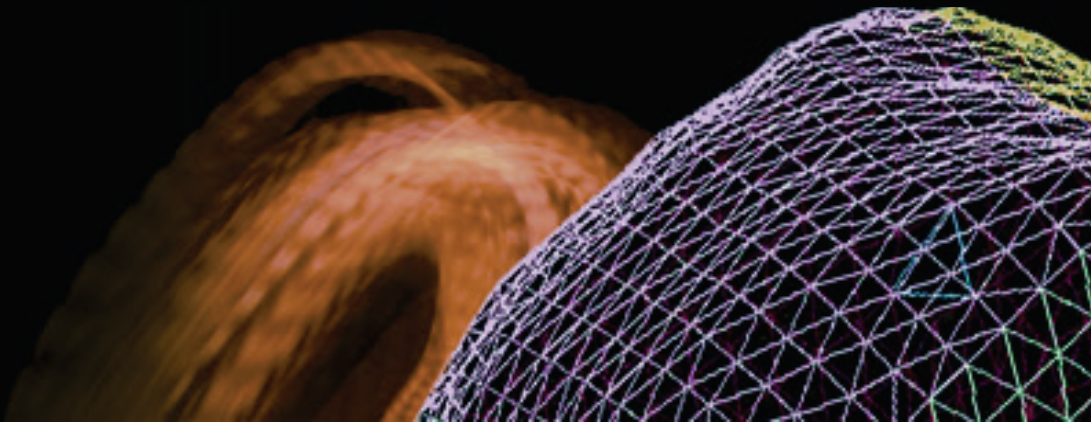


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# **MULTIPHYSICS**

# **2023**

**14 - 15 December 2023**  
**Graz, Austria**



# **MULTIPHYSICS 2023**

**14-15 December 2023**

**Graz, Austria**

## **Conference Board**

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## General Information

### Scope of Conference

Understanding real physics and performing Multiphysics simulation are extremely important to analyse complex systems in order to better design and manufacture engineering products.

The objective of the conference is to share and explore findings on mathematical advances, numerical modelling and experimental validation of theoretical and practical systems in a wide range of applications.

The scope of the conference is to address the latest advances in theoretical developments, numerical modelling and industrial application, which will promote the concept of simultaneous engineering. Typical combinations would involve a selection from subject disciplines such as Acoustics, Electrics, Explosives, Fire, Fluids, Magnetic, Nuclear, Soil, Structures, and Thermodynamics.

### Registration Pack – Collection Hours

Registration packs should be collected from the Registration Desk. Collection Hours are as follows:

Thursday, 14 <sup>th</sup> December	9:30-17:30
Friday, 15 <sup>th</sup> December	9:30-17:30

### Special Events

Thursday, 14 <sup>th</sup> December Group Photograph	11:00
Thursday, 15 <sup>th</sup> December Conference Banquette	19:30

### Timing of Presentations

Each paper will be allocated 20 minutes. A good guide is 15 minutes for presentation with 5 minutes left for questions at the end.

Good timekeeping is essential, speakers are asked to keep strictly to a maximum of 18 minutes per presentation.

### Group Photograph

A group photograph will be taken during the tea/coffee break on the first day of the Conference.

### Language

The official language of the conference is English.

### Audio-visual

The lecture room will be equipped with the following: one laptop, one LCD projector and cables, one projection screen, and one microphone.

Delegates are requested to either email their presentations to the Conference Coordinator Hassan or bring them in a memory stick.

### Paper Publication

Authors are invited to submit full-length papers for publication in The International Journal of Multiphysics (ISSN: 1750-9548) by 31<sup>st</sup> January 2023.

There is no Article Processing Charge (APC) for one article per registration.

### Sponsorship

The Conference Board would like to thank the sponsors for their support.

## **Keynote Speaker**

Prof. E AlBahkali  
Department of Mechanical Engineering  
King Saud University  
Saudi Arabia

## **BIOGRAPHY**

Prof. AlBahkali got his B.S. in Mechanical Engineering with first class of honors from King Saud University (KSU), Riyadh, Saudi Arabia, and joined the Department at KSU as a Teaching Assistant who later sponsored him to continue his graduate education. He got his master's and Ph.D. degrees from the Department of Mechanical Engineering at the University of Michigan - Ann Arbor, USA. Since that time, he has been a faculty member in the Department of Mechanical Engineering at KSU. Currently, he is ranked as a full Professor. During the past years, Dr. AlBahkali got training classes in interpersonal, strategic bases, and key skills for effective academic leadership and took courses in mastering management consulting. He became the Chairman of the Mechanical Engineering Department for four years. He taught different courses for both undergraduate and graduate students in the areas of Machine Design, Vehicle Structures, Mechanical systems, Optimization, and Simulation. He also worked in different academic committees such as student advisors, accreditation, reviewed and built several engineering programs. In addition, Dr. AlBahkali has very good experience in consulting, through his work with the Saudi Standards Metrology and Quality Organization and in the private sector as a technical advisor for Automotive Services. He provides consulting services in the areas of machine design, engineering systems simulations, maintenance, vibration, failure analysis, and life cycle. He also participates in engineering arbitration and settlement of differences between parties in disputes. His research interest is focused on the area of Machine Design, Vibration Analysis, Computational Mechanics, Multiphysics Simulations, Optimization, Redesign Mechanical Parts, and Design for Manufacturing. He is a member of the editorial board for The International Journal of Multiphysics.

**MULTIPHYSICS 2023****PROGRAMME**

<b>TIME</b>	<b>Thursday 14 December 2023</b>	<b>Friday 15 December 2023</b>
<b>09:00 - 09:30</b>	<b>Registration</b>	
<b>09:30 - 11:00</b>	<b>Keynote Address &amp; Synopsis</b>	<b>Session 2.1</b> <i>Fluid Structure Interactions</i>
<b>11:00 - 11:30</b>	<b>Break / Posters</b>	
<b>11:30 - 13:00</b>	<b>Session 1.2</b> <i>Aerospace and Marine</i>	<b>Session 2.2</b> <i>Modelling Techniques</i>
<b>13:00 - 14:00</b>	<b>Lunch</b>	
<b>14:00 - 15:30</b>	<b>Session 1.3</b> <i>Cold Climate Technology</i>	<b>Session 2.3</b> <i>Multiphysics Applications</i>
<b>15:30 - 16:00</b>	<b>Break / Posters</b>	
<b>16:00 - 17:30</b>	<b>Session 1.4</b> <i>Computational Fluid Dynamics</i>	<b>Session 2.4</b> <i>Posters</i>
<b>17:30 - 18:00</b>	<b>Closing Remarks</b>	
<b>19:30</b>	<b>Conference Banquet</b>	

**Full Programme**

**Thursday 14 December 2023**

**09:00 - 09:30      Registration**

**09:30 - 09:45      Conference Opening**

*T Rahulan, The International Society of Multiphysics*

**Welcome Address: The 18th International Conference of Multiphysics 2023**

*Dirk Wilhelm, Dean SoE School of Engineering, ZHAW Zurich University of Applied Sciences, Switzerland*

**09:45 - 11:00      Session 1.1  
Keynote Address & Synopsis**

*Chair: M Moatamedi, The International Society of Multiphysics*

**Keynote Address: Engineering Problems from the Prospective of Multiphysics**

*E AlBahkali, Department of Mechanical Engineering, King Saud University, Saudi Arabia*

**Synopsis Part 1: The International Journal of Multiphysics  
Synopsis Part 2: The International Conference of Multiphysics 2024**

*H Khawaja, The International Society of Multiphysics*

**11:00 - 11:30      Break / Posters**

**Thursday 14 December 2023**

**11:30 - 13:00      Session 1.2  
Aerospace and Marine**

*Chair: G Boiger, SoE, ZHAW Zurich University of Applied  
Sciences, Switzerland*

**Satellite Multitasking Fuzzy System for Attitude Control and Sun Tracking**

*YC Chak, R Varatharajoo  
Universiti Putra Malaysia, Selangor, Malaysia*

**Investigating the Effect of Leading-Edge Tubercles with Variable  
Intertubercular Distances on the Performance of Tidal Turbines**

*CJ Consing, RM Piamonte, LA Danao  
University of the Philippines Diliman, Philippines*

**A Novel Chain-to-Flowline Interface for Subsea Pipeline Anchoring Systems**

*M Haidarali, G Gerometta  
Subsea7, France*

**Effect of Surface Roughness on Dynamics of Laminar Separation Bubble  
along UAV Wing RG15 Airfoil - Numerical Case Study**

*M Muhammed, MS Virk  
UiT-The Arctic University of Norway, Norway*

**13:00-14:00      Lunch**



**Thursday 14 December 2023**

**14:00-15:30      Session 1.3  
Cold Climate Technology**

*Chair: AS Fallah, Oslo Metropolitan University, Norway*

**Ice Detection System Prototype and Lab Results**

*A Yousuf, H Khawaja, MS Virk*

*UiT-The Arctic University of Norway, Norway*

**Investigating Ice Nucleation and Heat Transfer Dynamics in Supercooled Liquid Water Using Thermography**

*H Khawaja<sup>1</sup>, S Keshavarzi<sup>2</sup>, M Manaf<sup>1</sup>, A Yousuf<sup>1</sup>, MS Virk<sup>1</sup>, D Harvey<sup>2</sup>, G Momen<sup>2</sup>*

*1. UiT-The Arctic University of Norway, Norway*

*2. University of Quebec at Chicoutimi, Canada*

**Icing Prediction Model for Transmission Line Conductor Using Environmental Parameters**

*X Han<sup>1</sup>, MS Virk<sup>1</sup>, X Jiang<sup>2</sup>, Q Hu<sup>2</sup>*

*1. UiT-The Arctic University of Norway, Norway*

*2. Chongqing University, China*

**Resistive Heating Application for Ice Mitigation of Railway Switch- a Multiphysics Case Study**

*A Lotfi, H Asif, MS Virk*

*UiT- The Arctic University of Norway, Norway*

**15:30-16:00      Break / Posters**

**Thursday 14 December 2023**

**16:00 - 17:30      Session 1.4  
Computational Fluid Dynamics**

*Chair: E AlBakali, King Saud University, Saudi Arabia*

**Multiphysics simulation-based investigation of electro-static precipitation phenomena in the context of coating standard automotive rims**

*G Boiger<sup>1</sup>, B Siyahhan<sup>1</sup>, A Schubiger<sup>1</sup>, M Hostettler<sup>1</sup>, AS Fallah<sup>2</sup>, H Khawaja<sup>3</sup>, M Moatamedi<sup>4</sup>*

- 1. SoE, ZHAW Zurich University of Applied Sciences, Switzerland*
- 2. Oslo Metropolitan University, Norway*
- 3. UiT-The Arctic University of Norway, Norway*
- 4. New York University London, United Kingdom*

**Multiphysics simulations of wet chemical processes for surface treatment of large-scale substrates used in microelectronic industry**

*M Kolitsch-Mataln, A Gleissner  
SEMSYSCO GmbH, Austria*

**Existence and Smoothness of the Navier-Stokes equations part 1: The velocity representation by a Green's boundary integral**

*E Chadwick  
University of Salford, United Kingdom*

**Existence and Smoothness of the Navier-Stokes equations part 2: The force impulse boundary integral**

*E Chadwick  
University of Salford, United Kingdom*

**A CFD Study of Preventing Snow Accumulations on Roofs using Airflows**

*A Sjøveian<sup>1</sup>, Z Andleeb<sup>2</sup>, H Khawaja<sup>1</sup>, M Moatamedi<sup>3</sup>*

- 1. UiT-The Arctic University of Norway, Norway*
- 2. Abyss Solutions, Pakistan*
- 3. New York University, London, United Kingdom*

**19:30              Banquet**

**Friday 15 December 2023**

**09:30 - 11:00      Session 2.1  
Fluid Structure Interactions**

*Chair: M Souli, Lille University, France*

**Blast-Loaded Cylindrical and Truncated Conical Shells**

*N Mehreganian<sup>1</sup>, Y Safa<sup>2</sup>, G Boiger<sup>2</sup>, AS Fallah<sup>3</sup>, M Moatamedi<sup>4</sup>*

- 1. Imperial College London, United Kingdom*
- 2. SoE, ZHAW Zurich University of Applied Sciences, Switzerland*
- 3. Oslo Metropolitan University, Norway*
- 4. New York University London, United Kingdom*

**Calibration and Numerical Modelling of a Peristaltic Pump for Accurate Fluid Transport in Complex Tube Setups**

*M Hostettler, G Boiger  
SoE, ZHAW Zurich University of Applied Sciences, Switzerland*

**A Semi Transient Methodology for Dual Time Stepping of Particle and Flow Field Simulations of an Eulerian-Lagrangian Multiphysics Solver**

*B Siyahhan<sup>1</sup>, G Boiger<sup>1</sup>, AS Fallah<sup>2</sup>, H Khawaja<sup>3</sup>, M Moatamedi<sup>4</sup>*

- 1. SoE, ZHAW Zurich University of Applied Sciences, Switzerland*
- 2. Oslo Metropolitan University, Norway*
- 3. UiT-The Arctic University of Norway, Norway*
- 4. New York University London, United Kingdom*

**A Neural Network Based Non-Intrusive Surrogate Modelling Framework for Fluid-Structure Interaction and Aeroelastic Simulation**

*D Fairchild  
University of Salford, United Kingdom*

**11:00 - 11:30      Break / Posters**

**Friday 15 December 2023**

**11:30 – 13:00      Session 2.2  
Modelling Techniques**

*Chair: E Chadwick, University of Salford, UK*

**Optimization of Horizontal Axis Wind Turbine for Small Generators Using Genetic Algorithm with Reduced Number of Design Variables**

*MP Lumbea, JI Encarnacion*

*University of the Philippines Diliman, Philippines*

**Synergistic Integration of Multiphysics Modelling and Control Engineering Paradigms: A Novel Approach to Dynamic Algorithm Formulation**

*V Buff, M Boldrini, G Boiger*

*SoE, ZHAW Zurich University of Applied Sciences, Switzerland*

**Improving the analytical estimation of conductive heat transfer by the development of a novel model**

*S Zoras, S Veranoudis*

*Democritus University of Thrace, Greece*

**Modeling and Analysis of The Unbalance Magnetic Pull Due to Static Eccentricity for The Double Cage Induction Motor in COMSOL Multiphysics 6.0**

*R Deore, K Kalita*

*Indian Institute of Technology Guwahati, Assam, India*

**13:00-14:00      Lunch**

**Friday 15 December 2023**

**14:00-15:30      Session 2.3  
Multiphysics Applications**

*Chair: M Kolitsch-Matain, SEMSYSCO GmbH, Austria*

**An analytical model to determine the premature and extended contact in polymer gears**

*S Vignesh, JA Mertens*

*National Institute of Technology Puducherry, Karaikal, India*

**The Extended Discrete Element Method (XDEM) as a Multi-Physics Simulation Platform in Green Steelmaking**

*B Peters*

*University of Luxembourg, Luxembourg*

**Non-destructive testing experiments and numerical simulations for defect detection with the use of laser spot thermography**

*M Sobczak, B Hyla, J Roemer*

*AGH University of Science and Technology, Krakow, Poland*

**How can a magnetic field control the acoustic wave?**

*VN Gorshkov<sup>1</sup>, V Kolupaieva<sup>1</sup>, G Boiger<sup>2</sup>, N Mehreganian<sup>3,4</sup>, P Sareh<sup>3,5</sup>, AS Fallah<sup>4,6</sup>*

*1. National Technical University of Ukraine, Ukraine*

*2. SoE, ZHAW Zurich University of Applied Sciences, Switzerland*

*3. University of Liverpool, United Kingdom*

*4. Imperial College London, United Kingdom*

*5. Newcastle University, United Kingdom*

*6. Oslo Metropolitan University, Norway*

**Multiscale-multiphysics model for novel ceramic solid oxide fuel cell electrodes**

*P Marmet, L Holzer, T Hocker, G Boiger*

*SoE, ZHAW Zurich University of Applied Sciences, Switzerland*

**15:30-16:00      Break / Posters**

**Friday 15 December 2023**

**16:00 - 17:30      Session 2.4  
Posters**

*Chair: T Rahulan, The International Society of Multiphysics*

**Prediction of marine icing incidents in cold regions using an IoT-based device**

*S Dhar, H Khawaja, M Naseri, T Zhu, K Edvardsen  
UiT-The Arctic University of Norway, Norway*

**Investigating RANS Turbulence Models for Predicting Airflow Dispersion in Enclosed Environments: Numerical Simulation and Experimental Validation**

*J Owolabi, H Khawaja, A Aganovic  
UiT-The Arctic University of Norway, Norway*

**Multiphysics Study of Thermal Properties of Neoprene and Natural Rubber for Wetsuit Applications**

*M Busvold, H Khawaja  
UiT-The Arctic University of Norway, Norway*

**Numerical Simulation of Liquid Nitrogen Flashing under Rapid Depressurizations**

*T Watanabe<sup>1</sup>, T Shiigi<sup>1</sup>, K Tokunaga<sup>1</sup>, K Shimojima<sup>2</sup>  
1. National Fisheries University, Japan  
2. Okinawa National College of Technology, Japan*

**Shock Loading as Pre-processing for Freeze-drying**

*T Watanabe<sup>1</sup>, K Tokunaga<sup>1</sup>, T Shiigi<sup>1</sup>, K Shimojima<sup>2</sup>, S Tanaka<sup>3</sup>, K Hokamoto<sup>3</sup>, S Itoh<sup>4</sup>  
1. National Fisheries University, Japan  
2. Okinawa National College of Technology, Japan  
3. Institute of Industrial Nanomaterials, Kumamoto University, Japan  
4. Institute of Shockwave Applied Technology, Japan*

**Effect of Cold Heat Shock Loading by usual freezing and Liquid Nitrogen to Parasite**

*T Watanabe<sup>1</sup>, T Shiigi<sup>1</sup>, K Tokunaga<sup>1</sup>, K Shimojima<sup>2</sup>  
1. National Fisheries University, Japan  
2. Okinawa National College of Technology, Japan*

Numerical and Experimental investigation of FEM and SPH Methods for FSI Applications

*R Lobosco<sup>1</sup>, M Souli<sup>2</sup>, E Elbakhali<sup>3</sup>, F Erchiqui<sup>4</sup>*

*1. Federal University of Rio de Janeiro, Brazil*

*2. Lille University, France*

*3. King Saud University, Saudi Arabia*

*4. Université du Québec en Abitibi-Témiscamingue, Canada*

**17:30 - 18:00      Close of Conference**

*SESSION 1.1*

**KEYNOTE ADDRESS &**  
**SYNOPSIS**

THURSDAY, 14 DECEMBER 2023  
09:30 – 11:00

CHAIR

M Moatamedi  
The International Society of Multiphysics



Thursday, 14 December 2023

09:30 – 11:00

## **Keynote Address**

### **Engineering Problems from the Prospective of Multiphysics**

*E AlBahkali  
Professor of Mechanical Engineering,  
Department of Mechanical Engineering,  
King Saud University  
Kingdom of Saudi Arabia*

Natural phenomena are of Multiphysics. Until today, most of the engineered solutions to these phenomena are not considered Multiphysics. Therefore, the quality and cost of an engineering system are affected, which have now become central issues of simulations for researchers and engineers. The focus of Multiphysics modelling from the prospective of material properties, boundary conditions, and system components is in situations where coupled phenomena occur that involve a combination of thermal, fluid, and solid mechanics. Practical problems were used to introduce and support the important fundamentals of various physics required in Multiphysics modelling. Advanced topics like contact deformation and fluid structure interaction were addressed. Frictional heating generated in sliding systems causes thermoelastic distortion, wind turbine simulation, and pipeline failures due to fluid induced vibration, solid body exposed to thermal heat are exemplified to be discussed in detail. A new idea of complex engineering problem is going to be elaborated. The importance of Multiphysics modelling issues to these examples was emphasized. In addition, solutions to problems, such as in linear and non-linear situations were addressed, as well as specific solutions for Multiphysics modelling of solid-solid to a thermoelastic body involving sliding speed and of fluid-solid to a fluid inside the pipeline and wind turbine exposed to air were provided. Conclusion and remarks to these problems were discussed.

## **Synopsis Part 1: The International Journal of Multiphysics**

*H Khawaja*

*The International Society of Multiphysics*

The International Journal of Multiphysics publishes peer-reviewed original research articles, review papers and communications in the broadly defined field of Multiphysics. The emphasis of this journal is on the theoretical development, numerical modelling and experimental investigations that underpin Multiphysics studies.

The scope of the journal is to address the latest advances in theoretical developments, numerical modelling and industrial applications which will promote the concept of simultaneous engineering. Typical combinations would involve a selection from subject disciplines such as Acoustics, Electrics, Explosives, Fire, Fluids, Magnetic, Soil, Structures, and Thermodynamics. This journal aims to publish high-quality findings of basic research and development as well as engineering applications.

The International Journal of Multiphysics is indexed in Elsevier® Scopus (SNIP, CiteScore, SJR), Elsevier® Engineering Village (EI Compendex), Clarivate Analytics® Emerging Sources Citation Index (ESCI), Clarivate Analytics® Web of Science, SHERPA RoMEO: Green, Directory of Open Access Journals. The International Journal of Multiphysics received Elsevier® Scopus CiteScore of 1.3 in 2022 (in comparison to 1.1 in 2021). According to the Clarivate Analytics® Web of Science, The International Journal of Multiphysics has an impact factor of 0.7 in 2022.

For more information, visit: [www.multiphysics.org/journal](http://www.multiphysics.org/journal)

## **Synopsis Part 2: The International Conference of Multiphysics 2024**

*H Khawaja*

*The International Society of Multiphysics*

The objective of The International Conference of Multiphysics is to share and explore findings on mathematical advances, numerical modelling and experimental validation of theoretical and practical systems in a wide range of applications.

The scope of the conference is to address the latest advances in theoretical developments, numerical modelling and industrial application which will promote the concept of simultaneous engineering. Typical combinations would involve a selection from subject disciplines such as Acoustics, Electrics, Explosives, Fire, Fluids, Magnetic, Nuclear, Soil, Structures and Thermodynamics.

In the past, Multiphysics Conferences have been organised Graz Austria, Oslo Norway, Dubai United Arab Emirates, Krakow Poland, Beijing China, Zurich Switzerland, London United Kingdom, Sofia Bulgaria, Amsterdam The Netherlands, Lisbon Portugal, Barcelona Spain, Kumamoto Japan, Lille France, Narvik Norway, Manchester United Kingdom and Maribor Slovenia. Researchers from all around the world participated in these events. The Organisers and the Management Committee are thankful to all attendees for making these events successful.

For more information, visit: [www.multiphysics.org/conference](http://www.multiphysics.org/conference)

**SESSION 1.2**

**AEROSPACE AND MARINE**

THURSDAY 14 DECEMBER 2023

11:30 – 13:00

CHAIR

*G Boiger*

*SoE, ZHAW Zurich University of Applied Sciences  
Switzerland*

**Satellite Multitasking Fuzzy System for Attitude Control and Sun Tracking**

*YC Chak, R Varatharajoo*

*Universiti Putra Malaysia, Selangor, Malaysia*

Reaction wheels are used in many high precision pointing satellites because they can produce a stabilizing torque in any chosen orientation. Without a redundant cluster of reaction wheels, any mechanical failure beyond repair could interrupt the mission. Almost all medium-to-large-sized satellites have solar array drive assemblies (SADAs) installed to position the solar array panels for power generation. Since SADAs are normally mounted on the pitch axis, they might potentially be exploited for an internal torque generation. Typically, linear state-feedback control strategies are sufficient to solve the nadir-pointing attitude control problem. In this work, a few fuzzy logic-based control schemes are proposed for the satellite combined attitude and sun-tracking control system (CASTS) to improve the attitude pointing accuracy. For disturbance rejection purposes, model reference adaptive control, active force control, and linear quadratic integral are synthesized with the fuzzy control. Numerical treatments of the proposed fuzzy-based CASTS control strategies are demonstrated. The performance comparison is made to identify the effectiveness of each control strategy. The results indicate that the proposed fuzzy-based CASTS control strategies are promising for regulating the satellite attitude and tracking the sun simultaneously in the presence of disturbance torques. It is concluded that the multitasking idea of the employing the SADAs as momentum exchange devices works to control the satellite attitude, and they may even serve as backups in the event of reaction wheel failure.

multitasking, attitude control, sun-tracking, fuzzy control, disturbance rejection

**Investigating the Effect of Leading-Edge Tubercles with Variable Intertubercular Distances on the Performance of Tidal Turbines**

*CJ Consing, RM Piamonte, LA Danao  
University of the Philippines Diliman, Philippines*

The use of leading-edge tubercles to improve the performance of turbines is a developing research trend, but the use of variable intertubercular spacing has not been explored. As such, the objective of the study is to investigate the performance of tidal turbines using sinusoidal leading-edge tubercles with variable intertubercular distances. A 120° rotating reference frame CFD mesh was used to evaluate the performance of a blade with variable intertubercular spacing in comparison to blades with uniform tubercles and no tubercles. The results showed that uniform tubercles perform better near and above the peak tip speed ratio, but variable tubercles perform better within the stall region. It was also observed that counter rotating vorticity appear to redistribute the area upon which the flow remains attached rather than purely improving flow attachment. This study aims to be an initial exploration of variable tubercle geometry.

tubercles, tidal turbine, vorticity

## **A Novel Chain-to-Flowline Interface for Subsea Pipeline Anchoring Systems**

*M Haidarali, G Gerometta  
Subsea7, France*

Anchoring systems for oil and gas pipelines laid on the seabed and subject to substantial loads are important features of subsea oil and gas projects and can be challenging in terms of effectiveness, risks, and costs. Anchoring systems generally consist of a suction pile, a chain system and, an interface solution between the chain system and pipeline, where the loads can be effectively transferred from pipeline to seabed through this arrangement. The selection of an appropriate chain-to-flowline interface is an important aspect in the design of anchoring systems, where different parameters with respect to fabrication and installation as well as the robustness and fit-for-purpose of the solution during different phases of its life are involved that complicate the choice of an effective, safe, constructable, installable, and economically viable solution for chain-to-flowline interface.

In this study, we developed a new robust solution for chain-to-flowline interface of pipeline anchoring systems. This solution that incorporates a special forging component integrated into pipeline onshore overcomes the high risks and costs associated with conventional solutions such as friction clamp when pipelines are subject to high axial loads. Since this forging solution is subject to reeling process during installation, the reelability of the forging component and its coating is a key aspect of design. The design by finite element analysis (FEA) was adopted for the forging component using the FEA software package ABAQUS. Material and geometric nonlinearities were incorporated into FE models. The forging component was verified against different failure modes during installation phase and throughout the service life using the acceptance criteria in the relevant ASME Boiler and Pressure Vessel, and DNV codes and guidelines.

Subsea Oil & Gas, Pipeline, Anchoring System, Reelability

**Effect of Surface Roughness on Dynamics of Laminar Separation Bubble along UAV Wing RG15 Airfoil - Numerical Case Study**

*M Muhammed, MS Virk  
UiT-The Arctic University of Norway, Norway*

The flow around the Unmanned Aerial Vehicle (UAV) operating at a low Reynolds number regime of the  $O(10^5)$  is predominantly laminar and it leads to the formation of Laminar Separation Bubble (LSB). The pressure, shear stress, and heat flux distribution are considerably affected by LSB, which affects lift, drag, and pitching moment values. The surface roughness of UAVs or aircraft wing is altered by the ice accretions, frost formation, dust accumulations, etc. The change in the surface roughness has a considerable effect on the dynamics of LSB along UAV wing profile (airfoil) surface. The distribution of pressure, shear stress and heat flux distribution on airfoil surface is also a function of the position and strength of LSB. Multi-shot computational fluid dynamics-based ice accretion simulations are performed using a quasi-unsteady approach, where the flow field is recalculated at specified intervals. During each shot the airfoil shape and its surface roughness characteristics are altered by the accreted ice mass and the dynamics of LSB is also affected by the surface modifications. Thus, it is important to understand the behavior of LSB with surface roughness. Computational fluid dynamics simulations are performed using the RANS based transition turbulence model to study the behavior of LSB on UAV airfoil RG-15 at various surface roughness values.

UAV, Airfoil, Laminar separation bubble, Transition turbulence models, low Reynolds number, surface roughness.





**SESSION 1.3**

**COLD CLIMATE**  
**TECHNOLOGY**

THURSDAY 14 DECEMBER 2023  
14:00 - 15:30

CHAIR

*AS Fallah*  
*Oslo Metropolitan University*  
*Norway*

**Ice Detection System Prototype and Lab Results**

*A Yousuf, H Khawaja, MS Virk*

*UiT-The Arctic University of Norway, Norway*

Icing on onshore and offshore infrastructure is a well-known problem in cold regions prone to adverse weather conditions, due to operational challenges and enhanced safety concerns. Infrared thermography can serve as a non-destructive, non-intrusive technique to monitor the surface condition of such structures in terms of temperature-based image analysis. This work presents a prototype using low-cost infrared cameras for thermal inspection of ice accreted on exposed surfaces. The preliminary results of this prototype setup tested in laboratory will be shared for feasibility studies. The proposed prototype is based on active infrared thermography technique to detect the ice presence, and image processing-based methods to identify ice shape footprint and location. In future, the proposed design shall be integrated with active ice mitigation system to anti-/de-ice the target structure.

Ice Detection, Infrared Thermography, Prototype, Lab Tests, Ice Mitigation System

## Investigating Ice Nucleation and Heat Transfer Dynamics in Supercooled Liquid Water Using Thermography

*H Khawaja<sup>1</sup>, S Keshavarzi<sup>2</sup>, M Manaf<sup>1</sup>, A Yousuf<sup>1</sup>, MS Virk<sup>1</sup>, D Harvey<sup>2</sup>, G Momen<sup>2</sup>*

*1. UiT-The Arctic University of Norway, Norway*

*2. University of Quebec at Chicoutimi, Canada*

This study delves into the intricate interplay of thermography, ice nucleation, and heat transfer during the phase change from supercooled liquid water to crystallized ice. The phenomena of ice nucleation and its subsequent growth have paramount importance in various fields, including cold climate engineering, atmospheric science, cryopreservation, and refrigeration systems. Our research aims to provide deeper insights into these fundamental processes. Utilizing high-resolution, high-speed infrared thermography, we captured real-time temperature data during ice nucleation events. By analyzing these temperature profiles, we gained valuable information about the dynamics of ice nucleation. Our findings reveal the crucial role of nucleation sites, their distribution, and their impact on the overall heat transfer process. This knowledge contributes to a more comprehensive understanding of ice nucleation mechanisms. Furthermore, we investigated the relationship between heat transfer and ice crystallization kinetics. Our results demonstrate that heat transfer plays a pivotal role in influencing nucleation rates and ice growth. This knowledge has implications for optimizing heat exchange processes in various industrial applications. One of the key highlights of our study is the observation of nucleation under supercooled conditions. We provide evidence of how supercooled liquid water transforms into crystalline ice, shedding light on the underlying physics and mechanisms involved. This phase change process is of significant importance in the context of cloud formation and freezing rain phenomena. In summary, our research integrates thermography, ice nucleation, and heat transfer dynamics to unravel the complexities of phase change from supercooled liquid water to crystallized ice. These findings have practical implications across multiple industries and can aid in the development of more efficient anti-/de-icing systems, refrigeration systems, improved weather prediction models, and enhanced cryopreservation techniques. Our study opens new avenues for further exploration in this field, ultimately advancing our understanding of these critical processes.

Ice Nucleation, Thermography, Heat Transfer Dynamics, Supercooled Conditions

## **Icing Prediction Model for Transmission Line Conductor Using Environmental Parameters**

*X Han<sup>1</sup>, MS Virk<sup>1</sup>, X Jiang<sup>2</sup>, Q Hu<sup>2</sup>*

*1. UiT-The Arctic University of Norway, Norway*

*2. Chongqing University, China*

Icing is a critical concern demanding close attention to ensure the stable and safe operation of transmission lines. The prediction of power line icing has consistently remained a prominent research focus both domestically and internationally. Presently, the majority of models used to forecast icing on power lines predominantly rely on four environmental parameters: wind speed, temperature, air's liquid water content, and the median volume diameter of water droplets. The challenge in obtaining the latter two parameters severely hinders the practical application and widespread adoption of wire icing models in engineering. This research work is centered around the "four-parameter" conductor icing model. It conducts a thorough analysis of the impact characteristics of these environmental parameters on the conductor icing growth process through multiphase numerical calculations. Based on these findings, a conductor icing prediction model is established, utilizing fundamental environmental parameters that can be easily obtained through standard sensors. The model's accuracy is then validated using real-world monitoring data on line icing. This enhancement significantly bolsters the practical utility of the conductor icing model in engineering applications and offers valuable insights for improving early warning systems for transmission line icing.

Icing, Transmission line, Simulation

## **Resistive Heating Application for Ice Mitigation of Railway Switch- a Multiphysics Case Study**

*A Lotfi, H Asif, MS Virk*

*UiT- The Arctic University of Norway, Norway*

The railway is an important source of logistics & transportation in cold regions, but icing can be challenging for uninterrupted railway operations. Icing on railway switches is a safety hazard and presently, the most common way of ice mitigation in the railway industry is the use of resistive heaters. These heaters consume a great amount of electricity leading to high financial costs in terms of operation and maintenance of railway tracks in ice-prone cold regions. This research work aims to investigate the heat transfer from the resistive heater to the rails and calculate the heat loss. In this regard, a multiphase Computational Fluid Dynamic (CFD) based numerical study and lab-based experiments are carried out to simulate the heat transfer, considering a section of stock rail, a switch rail, and a heating element. Results show a considerable loss of heat from the heater to the surroundings of the rail. CFD results also provided a good insight of heat transfer along railway section and temperature distribution is also compared with the IR thermal imaging from lab experiments. The study provided a good base for further optimization of resistive heating operations for ice mitigation along railway switches.

Icing, Railway, Rail Switch, CFD, Infra-Red



**SESSION 1.4**

**COMPUTATIONAL FLUID**  
**DYNAMICS**

THURSDAY 14 DECEMBER 2023  
16:00 - 17:30

CHAIR

*E AlBahkali*  
*King Saud University*  
*Saudi Arabia*



## **Multiphysics simulation-based investigation of electro-static precipitation phenomena in the context of coating standard automotive rims**

*G Boiger<sup>1</sup>, B Siyahhan<sup>1</sup>, A Schubiger<sup>1</sup>, M Hostettler<sup>1</sup>, AS Fallah<sup>2</sup>, H Khawaja<sup>3</sup>, M Moatamedi<sup>4</sup>*

*1. SoE, ZHAW Zurich University of Applied Sciences, Switzerland*

*2. Oslo Metropolitan University, Norway*

*3. UiT-The Arctic University of Norway, Norway*

*4. New York University London, United Kingdom*

In this extended study, electrostatic precipitation, a cornerstone technology in industrial coating applications, is examined with enhanced depth and breadth, targeting its applicability in coating standard automotive rims. Utilizing an advanced Eulerian-Lagrangian, Extended Discrete Element Method, Finite Volume solver constructed within the OpenFOAM CFD-framework, we present a holistic computational model that incorporates various facets such as airflow dynamics, coating-particle interactions, and intricate particle-substrate phenomena like blow-off and corona formation. Enabled by Massive Simultaneous Cloud Computing technology, our solver permits concurrent exploration of a wide array of industrially relevant conditions.

This research goes beyond earlier studies by encompassing not only variations in "Mean Powder Particle Diameters" and "Powder Particle Density," but also conducting a more expansive simulation sweep that incorporates changes in "Particle Diameter Deviation" and "Applied Voltage." This allows for a nuanced understanding of sensitivities and uncertainties linked to these parameters. We apply this comprehensive modeling approach to scrutinize single-burst powder coating on a typical metallic, automotive rim substrate. The study delivers intricate predictions and visualizations of coating patterns, efficiencies, and homogeneity across a range of conditions.

Our findings offer valuable insights for optimizing powder properties, which hold considerable implications for material suppliers in the coating industry. Despite these advances, certain limitations remain, underscoring the need for further research in this vital domain.

Simulation, Euler-Lagrange, XDEM, Electro-Static Precipitation, Coating, Automotive Rims; Massive Simultaneous Cloud Computing; Parameter Study; OpenFOAM;

**Multiphysics simulations of wet chemical processes for surface treatment of large-scale substrates used in microelectronic industry**

*M Kolitsch-Mataln, A Gleissner  
SEMSYSCO GmbH, Austria*

In the field of microelectronics, the processing of substrates plays an important role for manufacturing of electronic devices. The surface treatment is mainly carried out using wet-chemical equipment. Those processes extend from deposition of extremely thin metallic layers in the micro- to nanometer range to controlled etching of structures, comprising many multiphysical phenomena, such as turbulent fluid flow, flow of electric current for electrochemical deposition/etching, species transport of many different chemical components and metal ions, chemical reactions in fluids and so on.

To reach homogenous surface treatment, the challenges arise with the substrate size, especially for large scale substrates like panels to produce PCBs (printed circuit boards) or for manufacturing or packaging of micro-, nano- or other types of electronic devices. Due to the technical progress, the substrate dimensions of such panels are undergoing significant increases in their dimensions. Panels are already reaching single side lengths of significantly more than 1000mm and in some cases even more than 3000mm. For size reasons, the processing of such large-scale substrates is performed in specially designed vertical process chambers.

However, the technical progress in microelectronic industry, followed by customer requests, is leading to a demand for ever larger panel sizes from year to year. Therefore, the requirements on surface treatments are becoming increasingly complex. For example, for electrochemical deposition, the main challenges are the achievement of a uniform current density distribution over the substrate surface as well as a high-rate delivery of the electrolyte coupled with turbulent flow of electrolyte containing the ionic species to be deposited to the surface. For optimization purposes it is necessary to carry out simulations as the knowledge gain from experimental set-ups is limited due to limited access to the process site and the simultaneous occurrence of multiphysical phenomena. This talk will focus on selected multiphysical simulations for surface treatment of large-scale substrates such as panels.

Multiphysics simulations, microelectronic industry, wet chemical processes, large-scale substrates

## Existence and Smoothness of the Navier-Stokes equations part 1: The velocity representation by a Green's boundary integral

*E Chadwick*

*University of Salford, United Kingdom*

Consider the incompressible Navier-Stokes equations in an unbounded domain with no bodies or force fields present.

Let us assume that the velocity is given at an initial time everywhere in the domain by a smooth velocity flow field and has a Stokeslet decay in the far-field.

Then the velocity is represented by a boundary integral of NSlets in the space-time domain, where the NSlet is the fundamental solution Green's function, the boundary is the volume (spatial domain) at initial time, and the strength distribution is the initial velocity.

This result is obtained by using the standard Green's integral formulation for fluids, called the theory of hydrodynamic potentials, but applied to a space-time domain. Another important departure from the standard approach includes introducing a vector potential directed in the radial direction from its origin such that its divergence represents the non-linear terms. Near to the fundamental solution it is shown that the NSlet approximates to the Eulerlet, and far-from the fundamental solution it is shown that the NSlet approximates to the Stokeslet. Then, by considering the vector potential, the Green's integral contributions near-to and far-from the point are calculated to give the boundary integral velocity representation.

Navier-Stokes solution, existence and smoothness

## Existence and Smoothness of the Navier-Stokes equations part 2: The force impulse boundary integral

*E Chadwick*

*University of Salford, United Kingdom*

Consider the incompressible Navier-Stokes equations in an unbounded domain with no bodies or force fields present.

Let us assume that the velocity is given at an initial time everywhere in the domain by a smooth velocity flow field and has a Stokeslet decay in the far-field.

A conservative boundary integral (in the space-time domain) for the constant force impulse for the flow is presented. This is obtained by considering a boundary integral force impulse distribution, and flow either side of this boundary. Then, from part 1 the velocity is represented by a boundary integral distribution of force impulses. Taking the boundary to consist of a part near to the fluid point where the NSlet approximates to the Eulerlet, and a part far from the point where the NSlet approximates to the Stokeslet, then by using the Eulerlet and Stokeslet solutions, and knowing that the force impulse is bounded, by using the Cauchy-Schwarz inequality it is shown that the velocity and all its derivatives are bounded, leading to existence and smoothness of the solution.

Navier-Stokes solution, existence and smoothness.

**A CFD Study of Preventing Snow Accumulations on Roofs using Airflows**

*A Sjøveian<sup>1</sup>, Z Andleeb<sup>2</sup>, H Khawaja<sup>1</sup>, M Moatamed<sup>3</sup>*

*1. UiT-The Arctic University of Norway, Norway*

*2. Abyss Solutions, Pakistan*

*3. New York University, London, United Kingdom*

Today, there is an abundance of roof designs for buildings, each possessing distinct characteristics when subjected to snowy and cold conditions. Snow buildup on roofs poses various risks, including structural damage and personal injuries. Snow loads can lead to severe building damage or even collapse. The presence of intricate roof shapes and valleys exacerbates the potential harm caused by snow. Additionally, sloped roofs above lower levels can become hazardous if a substantial amount of snow accumulates before sliding off. Furthermore, the orientation of the roof site is crucial in relation to prevailing wind patterns and sunlight exposure.

The primary objective of this thesis is to explore the feasibility of utilizing airflows as a means to prevent snow accumulation on roofs. The goal is to introduce an innovative solution to mitigate snow buildup. The concept involves harnessing the drag force generated by wind speeds of both 3 and 27 m/s to dislodge various types of snow crystals, such as powder, needles, spatial, dendrites, rimed, and graupels crystals. By directing these airflows to remove snow crystals before they settle on the roof's surface, the intention is to make the process easier and safer compared to removing accumulated snow. The aim is to employ the appropriate wind velocity to effectively divert snow particles by generating sufficient drag force. After experimenting with various flow inclinations, an angle of 45 degrees was selected. To achieve this objective, the necessary airflow rates are calculated empirically, and different flow patterns are simulated using ANSYS® Workbench.

Icing, CFD, airflows, drag force, ANSYS®

*SESSION 2.1*

**FLUID STRUCTURE**  
**INTERACTIONS**

FRIDAY 15 DECEMBER 2023  
09:30 – 11:00

CHAIR

*M Souli*  
*Lille University*  
*France*

**Blast-Loaded Cylindrical and Truncated Conical Shells**

*N Mehreganian<sup>1</sup>, Y Safa<sup>2</sup>, G Boiger<sup>2</sup>, AS Fallah<sup>3</sup>, M Moatamedi<sup>4</sup>*

*1. Imperial College London, United Kingdom*

*2. SoE, ZHAW Zurich University of Applied Sciences, Switzerland*

*3. Oslo Metropolitan University, Norway*

*4. New York University London, United Kingdom*

Localised pulse pressure loads can pose a significant threat to structural elements as well as critical equipment. The impulse impinged upon the localised zone at the contact interface can exceed 80% of the total impulse that the charge can deliver to an infinite target, leading to potential perforation of the structural element. This necessitates devising superior designs capable of withstanding high overpressures. Hollow cylindrical and truncated conical shells depict enhanced torsional and shear resistance compared to beams and plates and are ubiquitously used in structures. Upon extensive localised blast, these elements undergo local and global deformation and failure. The detrimental damage to the shell depends on the stand-off and charge mass and is proportional to the emerged local dynamic stresses and inelastic deformations.

In this work, we examine large plastic deformations of hollow cylindrical and truncated conical shells subject to a range of pulse pressures emanated from high explosives at different proximities to the target source. Fluid-Structure Interaction (FSI) phenomenon was investigated using Finite Element (FE) models concerning the flexible and rigid targets corresponding to the coupled and uncoupled techniques, respectively. The Multiphysics (FSI) techniques were developed in each of these scenarios, to discern the characteristics of blasts at various stand-offs and to derive a number of dimensionless functions which linked the load parameters to structural, material, and geometric properties. The FSI results for the coupled and uncoupled techniques were also compared against the theoretical solutions in the literature which showed good agreements. A dimensionless impulse parameter was defined based on the Gaussian distribution function associated with the load shape, which renders calculable the probability of the impulse as the total impulse that can potentially be imparted to the target.

FSI, Localised blast, Plastic response, Stand-off distance

## Calibration and Numerical Modelling of a Peristaltic Pump for Accurate Fluid Transport in Complex Tube Setups

*M Hostettler, G Boiger*

*SoE, ZHAW Zurich University of Applied Sciences, Switzerland*

Peristaltic pumps play an indispensable role in transporting sensitive fluids, especially at low flow rates down to the milliliter per hour range. Considering complex and variable tube setups including various fluid dynamically active components, the calibration of these pumps poses significant challenges due to the intricate contributions of the components to pressure loss. This study addresses the challenge posed by the potentially innumerable setup combinations that could emerge in practical applications. Recognizing the impracticality of empirical calibration measurements for each possible setup and process condition, our team pursued the development and validation of a numerical modelling approach.

Given the importance of efficiency in practical applications, we diligently assessed the computational demand and efficiency of the numerical strategy. Initially, a 3D fluid-structure interaction (FSI) approach for multiphysics modelling was adopted. However, recognizing the excessive complexity and computational load, the strategy was streamlined to a more simplified yet effective methodology, relying on geometric displacement of the liquid due to the tube deformation within the peristalsis of the pump. Besides the viscoelastic behavior of the tube material, the characterization of the pressure loss behavior of each individual fluid dynamic component within the tube system was crucial. We undertook a series of rigorous fluid dynamic experiments to conduct these characteristics. The findings from these experiments were subsequently integrated into the solver development phase.

The final solver showcased reliable performance. We validated its efficacy through a series of tests, and it demonstrated consistent and accurate predictions. We are pleased to announce that this novel solver offers an innovative approach for calibrating peristaltic pump systems encompassing complex setups and varying process conditions.

peristaltic pumps, multiphysics simulation, validation, pressure drop



## **A Semi Transient Methodology for Dual Time Stepping of Particle and Flow Field Simulations of an Eulerian-Lagrangian Multiphysics Solver**

*B Siyahhan<sup>1</sup>, G Boiger<sup>1</sup>, AS Fallah<sup>2</sup>, H Khawaja<sup>3</sup>, M Moatamedi<sup>4</sup>*

*1. SoE, ZHAW Zurich University of Applied Sciences, Switzerland*

*2. Oslo Metropolitan University, Norway*

*3. UiT-The Arctic University of Norway, Norway*

*4. New York University London, United Kingdom*

Many industrial applications involve particles transported by a carrier fluid flow with additional multi-physical effects such as electromagnetics. The simulation of such processes is computationally expensive especially because of the diverse dimensional and time scales involved. In this study, the time scale for the fluid flow to be stably simulated is shown to be up to 2 orders of magnitude higher than the time scale for a spherical particle to assume carrier flow velocity. A semi-transient solution methodology has been devised, utilizing a dual time stepping approach for the flow and particle simulations. In this methodology, first the flow field is simulated with the larger time step, saving the resultant fields at regular intervals serving as snap shots of the flow. Then between each snap shot, the flow is treated as steady state, facilitating the calculation of the particle trajectory based on the resultant forces. This approach is especially suitable for applications where the particle cloud density is low enough not to have a significant effect on the flow field warranting a one way coupling. The accuracy of the method is established by comparing key performance parameters such as coating transfer efficiency and the homogeneity of the coating obtained from a fully transient simulation. The saving potential in terms of computational resources is also quantified.

Dual time stepping; Multiphysics simulation solver; Eulerian Lagrangian method; OpenFOAM; Semi transient methodology

## **A Neural Network Based Non-Intrusive Surrogate Modelling Framework for Fluid-Structure Interaction and Aeroelastic Simulation**

*D Fairchild*

*University of Salford, United Kingdom*

In recent years, research into the application of surrogate modelling techniques for Multiphysics analysis has gained significant interest. Surrogate modelling aims to reduce the computational time and complexity of the determination of the response of a system by constructing a simple model which approximates the input-output behaviour of the underlying model.

The application of a non-intrusive surrogate model, which required no a priori understanding of the underlying physics of the high order model, was investigated for the application to Multiphysics parametric non-linear simulations, specifically fluid-structure interaction and aeroelastic problems, as these generally require relatively complex simulations over a large range of system conditions, that can be time and computationally intensive.

In this paper, a proposed surrogate framework composed of a POD-NN (proper orthogonal decomposition based neural network) surrogate modelling scheme was implemented to several different fluid-structure interaction and aeroelastic high order simulations of increasing complexity. For these test cases, a series of high order model simulations were run, varying certain parameters between a given range. a Latin-hypercube sampling approach was then applied to the high order results, and POD analysis was then conducted to acquire a low order approximation of the entire system. The POD coefficients were then used to train a series of multilayer perceptron-based networks to learn the behaviour of the system. From this, generalised regression radial basis function networks were used to interpolate new system responses outside of the parametric training data points.

Surrogate modelling, Reduced Order Modelling, Artificial Neural Networks, Deep Learning, Radial Basis Function Interpolation, Fluid-Structure interaction, Aeroelasticity, Proper Orthogonal Decomposition, Multiphysics Simulation



***SESSION 2.2***

**MODELLING TECHNIQUES**

FRIDAY 16 DECEMBER 2022  
11:30 – 13:00

CHAIR

*E Chadwick  
University of Salford  
UK*

## Optimization of Horizontal Axis Wind Turbine for Small Generators Using Genetic Algorithm with Reduced Number of Design Variables

*MP Lumbera, JI Encarnacion*

*University of the Philippines Diliman, Philippines*

In response to the escalating energy demand and the imperative for renewable energy sources, the significance of developing small-scale wind turbines has grown substantially. This is particularly applicable in off-grid areas of the Philippines characterized by modest energy requirements and average wind velocities. Designing an optimized wind turbine capable of generating adequate power while minimizing energy costs presents formidable challenges. To tackle this, the utilization of a genetic algorithm (GA) in the design process of horizontal axis wind turbines was investigated. The GA facilitates the efficient generation of turbine configurations, accommodating low wind speeds and the need for high RPM values. The efficacy of the generated blades was assessed using a validated Python code that employs a simplified Blade Element Momentum technique. By employing a conic equation with a representative distribution coefficient to parametrize the chord and twist distribution, the design time was substantially reduced. Augmenting the number of parents, population size, and the maximum A-coefficient in the GA yielded superior fitness values, as calculated using normalized  $C_p$  and TSR parameters. When subjected to Philippine wind conditions, the performance of the optimized blade exhibited a decline; however, this drawback was mitigated by an increase in rotor diameter, which also enhanced its overall performance. The implementation of a direct-drive mechanism, eliminating the need for a gearbox, resulted in reduced Cost of Energy (COE) for the optimized blade, thereby contributing to increased power generation. In particular, the optimized 1-meter blade, boasting a rated power of 13.91 kW and a rated RPM of 496.56 under a wind speed of 4m/s, outperformed the base blade operating under 10m/s wind speeds.

genetic algorithm, blade element momentum, optimization, reduced number, turbine

## **Synergistic Integration of Multiphysics Modelling and Control Engineering Paradigms: A Novel Approach to Dynamic Algorithm Formulation**

*V Buff, M Boldrini, G Boiger*

*SoE, ZHAW Zurich University of Applied Sciences, Switzerland*

In contemporary control engineering, the nuanced amalgamation of multiphysics models into efficacious control frameworks remains a sophisticated challenge. This research endeavor was orchestrated to devise methodologies that adeptly transpose the stationary solutions inherent in 1D and 2D multiphysics models into dynamic control system models, with a specific inclination towards platforms such as Simulink. Concurrently, we embarked on the formulation of multiphysics models designed to seamlessly dovetail with advanced observer systems. These models allow to continuously estimate system states that enables the control engineer to increase reaction time based on model prediction. A paradigmatic and quintessential project will be elucidated during the presentation, serving as a testament to the enhanced capabilities engendered by this novel integration of multiphysics-modelling within control algorithm schematics.

Control Engineering, model integration, observer systems, synergetic integration, control algorithms

**Improving the analytical estimation of conductive heat transfer by the development of a novel model**

*S Zoras, S Veranoudis  
Democritus University of Thrace, Greece*

The purpose of this study is the development of an analytical solution based computational tool for heat transfer in solids. The proposed method extends the Dual Phase Lag theory by the introduction of the solid body that is considered as a pulsating thermal string whose oscillations correspond to temperature fluctuations. These oscillations give stationary thermal waves in every axis. The combination of the 3D Thermal Strings provided the ability to describe the temperature changes of solid bodies, the calculation of the relaxation time required towards equilibrium, and the thermal load required to keep a non-equilibrium state. The model is based on the analytical solution of the heat transfer equation in three dimensions, so it can deal for the whole solid body e.g., a wall element. It is proved that these oscillations are critical dumped ones and the model uses mathematical formulations to calculate the time required for an area to reach a "target temperature" which describes the final temperature. The solution depends on the initial and boundary conditions of the solid. For more complicated solids (with non - homogeneous structures) the "novel" modelling method made use of the introduced "reduced" length of the solid, based on the thermal conductivity of the materials of the solid which corresponds to the equivalent length that the solid would have if it was homogeneous. The validation and reliability of the Thermal Strings model were obtained by comparing the results of the proposed model against the classic heat transfer which found to be identical.

heat transfer, conduction in solids, analytical solution model

## **Modeling and Analysis of The Unbalance Magnetic Pull Due to Static Eccentricity for the Double Cage Induction Motor in COMSOL Multiphysics 6.0**

*R Deore, K Kalita*

*Indian Institute of Technology Guwahati, Assam, India*

The electric machine is used for domestic, commercial, and industrial purposes, especially induction motors are suitable for most industrial applications. However, these machines are operated at very high speeds and under heavily loaded conditions. During operations, many electrical as well as mechanical roots are responsible for the faults in the system. The faults in the induction motor are mainly associated with eccentricity-related faults. Eccentricity type faults are the cyclic type of faults, that produce an uneven air gap between the rotor and the stator which ideally should be concentric. Due to the eccentricity between the rotor and the stator, there is the formation of the extra pole pair along with the fundamental one. However, the nonuniform flux distribution in the airgap is responsible for an extra electromagnetic force on the rotor called the Unbalance Magnetic Pull (UMP). In this paper, a 2D model of 60 slots, 48 rotor bars, and a 4-pole, star-connected parallel type of electric circuit double cage induction motor has been modeled in the COMSOL Multiphysics 6.0 software. The effect of increasing static eccentricities in the rotor-stator airgap has also been investigated. The effect of the different static eccentricities has been compared with the concentric model. However, the numerical model has also been justified with the experimental results. The unbalanced forces, airgap flux density, torque, rotor coil current, stator coil current, and flux for the different static eccentricities for the same configurations are analyzed. The results were compared in the time domain and the frequency domain. Later this electromagnetic model has been coupled with MATLAB 2023 and the rotordynamic analysis for the rotor response in concentric as well as the static eccentricity has been investigated in the time and frequency domain.

Double Cage Induction Motor, Faults and Vibration, Static Eccentricity, Unbalance Magnetic Pull (UMP), COMSOL Multiphysics 6.0, FFT, Electromechanical Interactions, Rotordynamic, etc.





**SESSION 2.3**

**MULTIPHYSICS**  
**APPLICATIONS**

FRIDAY 15 DECEMBER 2023  
14:00 – 15:30

CHAIR

*M Kolitsch-Mataln*  
*SEMSYSCO GmbH*  
*Austria*

## An analytical model to determine the premature and extended contact in polymer gears

*S Vignesh, JA Mertens*

*National Institute of Technology Puducherry, Karaikal, India*

Polymer gears have effective vibration-damping characteristics, can operate without lubrication, and can be produced effectively using the injection molding technique. One disadvantage of polymer gears is their susceptibility to high temperatures and various failure modes that depend on the applied load. While thermal-induced plastic deformation is the principal cause of failure, there have also been reports of wear failure caused by elastic deformation at higher loads (Karimpour et al., 2010; Walton et al., 1994). In polymer gears, wear is caused by premature and extended contact phenomenon, in which the gear tooth makes contact with the subsequent tooth beyond the theoretically predicted path of action. This contact occurs between the pinion tip and gear flank in the path of approach region, whereas in the path of recess, contact occurs between the gear tip and pinion flank. The contact develops in a direction along the addendum circle radii of the meshing gears, i.e., perpendicular to the direction of the path of action. The consideration of extended contact in polymer gears is often neglected in fundamental design calculations, despite its significant influence on the load-carrying capacity of the gears. While many researchers have acknowledged the existence of this phenomenon, there is a lack of a proper analytical model to find the length of the additional contact. The research aims to develop an analytical model to determine premature/extended contact during the initial and final phases of engagement. Following this, a sequence of numerical simulations will be carried out for standard thermoplastic gears under different loading conditions. The derived analytical formula will be compared with the numerical outcomes, and the maximum load that can be applied to the given geometry without inducing premature/extended contact will be determined.

Polymer gears; analytical model; premature contact; extended contact; deflection

## **The Extended Discrete Element Method (XDEM) as a Multi-Physics Simulation Platform in Green Steelmaking**

*B Peters*

*University of Luxembourg, Luxembourg*

The current transition from grey steel from traditional blast furnaces via blue steel to green steel e.g., Mitrex and Energiron technologies is characterised by a complex interaction between a particulate phase and multi-phase fluid dynamics. Thus, it comprises a truly multi-physics environment including motion and thermodynamics of solid particles that exchange heat, mass and momentum with a chemically reacting multiphase flow. The objective of the current contribution is to introduce the extended discrete element method (XDEM) for resolving and consequently analysing the multi-physical processes in steelmaking. For this purpose, the iron-bearing material is considered as discrete particles that undergo a reduction process with a reducing agent of carbon monoxide or hydrogen while descending through the reactor. Innovative and fast algorithms determine the thermodynamic state i.e. reduction degree of each particle depending on the position in the reactor. The interstitial void space between the particles is described by reacting multi-phase computational fluid dynamics. Both, the discrete phase and continuum phase exchange intensively mass, energy and momentum and thus, resolving the multi-physics of the reactor in space and time. The predicted results determine the overall thermodynamic state of the reactor and a thorough analysis of these results unveils the underlying multi-physics. High-performance computing applying a hybrid approach of MPI and OpenMP allows generation results in moderate computational times. Hence, the XDEM simulation platform is excellently suited to support the design and operation of steelmaking reactors for a more sustainable environment.

Extended Discrete Element Method (XDEM), green steel

**Non-destructive testing experiments and numerical simulations for defect detection with the use of laser spot thermography**

*M Sobczak, B Hyla, J Roemer*

*AGH University of Science and Technology, Krakow, Poland*

Laser thermography is a sub-domain method in active thermography that uses a high-power laser as the thermal excitation source. Laser excitation gives the possibility to precisely control the inspection parameters such as laser power and pulse length. Therefore, this technique can be applied especially for fragile structures where testing conditions must be maintained precisely. A significant advantage of laser thermography is the capability to detect both delamination and cracks. The following work shows the demonstrator of a laser spot thermography technology that was designed and constructed at AGH UST. The paper presents laser thermography laboratory experiments and their corresponding numerical simulations along with the developed procedures for defect identification. Defect detection algorithms are based on regression methods and temperature distribution in the laser spot. In the presented approach a consistent image of the whole sample is obtained using the modified Thermal Signal Reconstruction (TSR) method. Additionally, on top of the temperature map, the vectors corresponding to the disturbance of the temperature field are shown allowing the operator to distinguish faulty regions. Moreover, the data clustering algorithm is used for the automatic indication of defect points. The methods are presented in the case of the additively manufactured sample containing prepared defects of known geometry.

NDT; defect detection; laser thermography; delamination; crack

## How can a magnetic field control the acoustic wave?

*VN Gorshkov<sup>1</sup>, V Kolupaiev<sup>1</sup>, G Boiger<sup>2</sup>, N Mehreganian<sup>3,4</sup>, P. Sareh<sup>3,5</sup>, A.S. Fallah<sup>4,6</sup>*

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The success in the flexible design of smart acoustic metamaterials is crucially contingent upon the degree of control over the parameters defining the spectrum of band-structure and morphology of dispersion surfaces. Using a magnetic field, a set of band gaps are formed and actively controlled in 3D metamaterials. In such acoustic structures the stiffness of the medium, in which unit cells are immersed, and the stiffness of their shells surrounding multi-particle cores depend on the induction of an external magnetic field. The results obtained are systematized through the qualitative scenario for the evolution of the frequency characteristics of the metamaterial in the direct process (when the induction increases). With an increase in the stiffness of the shells/medium, the wavelength of the shell's surface waves of relatively low frequencies is augmented, and, at some stage, the degree of uniformity of displacements of the shell particles relative to the centers of the cells mass noticeably increases. It is at this, dynamic, stage that significant heterogeneity develops in the motion of dispersion surfaces along the frequency axis upwards and band gaps are formed. The width of the corresponding band gaps creation region is limited by the frequencies of oscillation modes, in which each shell moves relative to its core (in phase or antiphase) as a whole. The gradual approach to incipience of such nearly homogeneous displacements of the shells corresponds to the quasi-stationary stage of the dynamics of the band gaps formed. We demonstrate that diverse options as variations of the unit cell morphology or the stiffnesses of shells and the environment, can lead to a wide range of scenarios of the dynamics of band gaps formed. The results obtained are in good agreement with the data presented in available experimental works.

active filtering, acoustic metamaterial, magnetorheological elastomer, band structure, multi-particle core, core-shell structure

## Multiscale-multiphysics model for novel ceramic solid oxide fuel cell electrodes

*P Marmet, L Holzer, T Hocker, G Boiger  
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Solid oxide fuel cell (SOFC) technology is a promising solution for the on-demand supply of electrical energy using synthetic gas or biogas (or natural gas) as input. To significantly improve on the unavoidable degradation of state-of-the-art anodes like Ni-YSZ, we elaborate on fully ceramic composite electrodes, which are based on mixed ionic and electronic conductors (MIEC) like doped ceria and perovskite (e.g., titanate) materials. To accelerate the development of these novel electrodes, a Digital Materials Design (DMD) framework for the systematic and model-based optimization of MIEC SOFC-electrodes is elaborated. In our DMD approach we combine stochastic microstructure modeling, virtual testing of 3D microstructures and a multiscale-multiphysics electrode model to explore the available design space by performing parametric studies. The multiphysics electrode model is thereby used to predict the impact of a virtual microstructure variation on the electrode performance. The model captures all the relevant physico-chemical processes involved like the transport of charge carriers in the two MIEC solid phases, transport of the gas species in the pore-phase (described by the dusty-gas model) and the reaction kinetics (calibrated to the experimental performance characterization of the cells). A special emphasize is laid to the appropriate description of the microstructure effects. Thereby, a 1D FEM continuum model implemented in Comsol Multiphysics is used to describe the electrode on a button cell level. The microstructure effects are then captured using effective transport and interface properties, determined from 3D microstructure data. The model results are validated on experimental performance characterizations of the button cells (e.g., EIS results). This model-based performance prediction enables to establish the relationship between materials choices and compositions, fabrication parameters, microstructure properties and cell-performance. This approach is thus capable to explore a much larger design space than it would be possible with experimental methods only.

multiphysics-multiscale modelling, effective microstructure properties, solid oxide fuel cell, porous ceramic composite electrode, mixed ionic and electronic conductor (MIEC)

**SESSION 2.4**

**POSTERS**

FRIDAY 15 DECEMBER 2023  
16:00 – 17:30

CHAIR

*T Rahulan*  
*The International Society of Multiphysics*



**Prediction of marine icing incidents in cold regions using an IoT-based device**

*S Dhar, H Khawaja, M Naseri, T Zhu, K Edvardsen  
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An IoT-based device is introduced, which is designed with the aim of enhancing safety and operational efficiency in environments prone to marine icing incidents. This device is equipped with a suite of sensors monitoring and analyzing crucial meteorological data in real time to predict the onset of icing conditions. It can track variables such as air temperature, wind speed, relative humidity, wave height, and seawater temperature in real-time, establishing the fundamentals for icing prediction. Notably, this device has a distinctive capability - the ability to detect the presence and amount of liquid water, an essential layer of analysis, given that not all sub-freezing conditions inevitably culminate in ice formation. The algorithm is designed with a threshold-based approach, which integrates defined values for each monitored parameter, promptly activating predictive capabilities upon meeting these thresholds. Furthermore, the device's trajectory includes the incorporation of neural networks for continual refinement of the algorithm to improve its predictive abilities. Practical applications include infrastructure protection for vessels and marine installations like offshore platforms, and aquaculture facilities. Its early warning system can play a role in mitigating ice-related damages and improving anti-icing systems, such as optimizing heating control. Additionally, it may contribute to environmental research by providing data on climate patterns and weather-related trends. Currently, in the construction phase, the device undergoes testing in a controlled cold room environment to assess feasibility and enhance algorithm performance for practical deployment.

marine icing, IoT, cold regions, meteorological data, neural networks algorithm

## **Investigating RANS Turbulence Models for Predicting Airflow Dispersion in Enclosed Environments: Numerical Simulation and Experimental Validation**

*J Owolabi, S Dhar, M Manaf, H Khawaja, A Aganovic, MS Virk  
UiT-The Arctic University of Norway, Norway*

The dispersion of respiratory aerosol particles in enclosed environments poses a significant challenge to understanding the transmission of airborne infectious diseases, mainly due to the influence of turbulence on the propagation of aerosol particles. Turbulence, with its complex and chaotic nature, is a prevailing phenomenon in a fluid flow. Four widely used Reynolds-Averaged Navier-Stokes (RANS) turbulence models—Standard k-epsilon, RNG k-epsilon, Realizable k-epsilon, and SST k-omega incorporate empirical relationships and assumptions to approximate turbulent quantities. This study investigates these models' applicability and limitations in airflow dispersion in an enclosed space. The study has two parts. Firstly, Particle Image Velocimetry (PIV) analysis in an enclosed domain will be conducted across a range of velocities. Secondly, a computational fluid dynamics model based on RANS with different turbulence models will be setup for simulation. By comparing the experimental data and numerical simulations, we aim to comprehensively examine the accuracy of RANS turbulence models in capturing the behavior of turbulent flows. This research serves as a preliminary study toward understanding the transmission dynamics of bioaerosols, such as virus-laden droplets, in ventilated indoor environments.

PIV, CFD, RANS turbulence models, Indoor airflow, Respiratory aerosol dispersion, Experimental validation

## **Multiphysics Study of Thermal Properties of Neoprene and Natural Rubber for Wetsuit Applications**

*M Busvold, H Khawaja  
UiT-The Arctic University of Norway, Norway*

Surfers daring the harshest waves, including the frigid arctic waters of Norway, rely on wetsuits for extended cold-water sessions. Understanding the thermal behavior of wetsuit materials is crucial for enhancing surfers' comfort and safety. In this study, we investigate the thermal properties of neoprene and natural rubber, the primary materials used in wetsuit construction, with a focus on conductive and convective heat transfer modes. To gain insights into these thermal properties, we conducted experiments using a FLIR T1030sc infrared camera to capture the thermal signatures of frozen neoprene and natural rubber samples in both dry and wet conditions. These experimental findings were then compared with simulations performed using MATLAB® and Ansys, based on the Heat equation. The Heat equation's approximate solution was discretized using the finite difference method and solved using the FTCS (Forward-Time-Central-Space) method within the MATLAB® software environment. Our results demonstrate a close agreement between experimental data and simulations for dry samples of neoprene and natural rubber. However, a noteworthy discrepancy was observed in the case of wet samples. This discrepancy highlights the significant influence of water within the material on its thermal properties, which is particularly relevant for wetsuit applications. Specifically, the presence of water compromises the thermal performance of the wetsuit material. This insight has significant implications for wetsuit design and material selection, as it underscores the importance of developing materials that maintain their insulating properties even when exposed to water. Such advancements could lead to wetsuits that offer improved thermal comfort and prolonged protection in cold-water environments. In conclusion, our multiphysics study provides a comprehensive understanding of the thermal properties of neoprene and natural rubber, essential materials in wetsuit construction. We have successfully estimated the conductivity and overall heat transfer coefficient of these materials through a combination of experimental data and simulations. This research contributes to the optimization of wetsuit materials, ultimately enhancing surfers' ability to conquer extreme waves in various cold-water environments.

Surfing, Cold Climate, Wetsuit, Neoprene, Natural Rubber, Thermography, FTCS, MATLAB, Ansys

## **Numerical Simulation of Liquid Nitrogen Flashing under Rapid Depressurizations**

*T Watanabe<sup>1</sup>, T Shiigi<sup>1</sup>, K Tokunaga<sup>1</sup>, K Shimojima<sup>2</sup>*

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Recently, a demand for cryogenic fluids as a coolant has been increasing because of the industrial development of low temperature technology. The purpose of this study is to clarify some fundamental features of the phase changes associated with the flashing of cryogenic fluid. Liquid nitrogen at low temperatures was used as the test liquid. Flashing experiment of liquid nitrogen in a pressure vessel was conducted under rapid depressurization rate. Observations of the explosive boiling behavior caused by quick opening of an electromagnetic valve were undertaken by using a video camera. Pressure and temperature changes in the vessel were measured. Experimental results showed that the initial temperature distributions and depressurization rates have more intrinsic influence on these flashing phenomena. Relationship between pressure undershoot and depressurization rate was obtained. The rate of pressure recovery was found to increase with the rate of depressurization, which also resulted in the increase of the increment of pressure recovery. Authors try to numerical simulation of this phenomena. Pressure change represented by two phase model, the calculated and experimental results were compared.

Numerical Simulation, Liquid Nitrogen, Flashing, Depressurization

**Shock Loading as Pre-processing for Freeze-drying**

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In the food industry, it is hoping for high value-aided product and the increase in efficiency of food processing. On the other hand, we get an experimental result that the load of the shock wave improves an extraction of food and soften food. We tried to examine the effectivity of the shock wave as pre-processing for freeze-drying from the result in permeation character seen in the radish and so on. In the case of freeze-drying, the object tends to be limited to the small or thin one with size, from the sublimability in processing, the performance in case of the restoration and the viewpoint of the cost performance ratio. Therefore, we used comparatively large beheaded shrimps and squids and attempted to review the effectivity of the shock wave processing about being freeze-drying. The improvement of the sublimation speed was gotten from the result that the pressure change during freeze-drying processing and the improvement of the reconstitution was gotten from the result using hot water. It was expected that the reconstitution of the freeze-dried food is improved and that a processing time is abridged, by shock wave loading as pre-processing for freeze-drying.

Shock Loading, Pre-processing, Freeze-drying

## Effect of Cold Heat Shock Loading by usual freezing and Liquid Nitrogen to Parasite

*T Watanabe<sup>1</sup>, T Shiigi<sup>1</sup>, K Tokunaga<sup>1</sup>, K Shimojima<sup>2</sup>*

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In Japan where people like raw food of the marine products, a problem of the parasite often occurs. A similar problem occurs for feed of the dolphin that is very popular in aquarium. A parasite is contained in marine disposal of waste and feed, the method of the management is a subject. There is a guideline of the Ministry of health, labour and welfare, the information that is detailed to the parasite isn't known well. We carried out the research on the actual condition of the parasite. We tried to check about the low temperature tolerance of the parasite for usual freezing and low heat shock by liquid nitrogen experimentally. We focused on the number of cold experiences and the total cold time.

Cold heat shock, Liquid nitrogen, Parasite, Low temperature tolerance

## Numerical and Experimental investigation of FEM and SPH Methods for FSI Applications

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Simulation of Fluid Structure Interaction FSI, problems become more and more the focus of computational engineering, where FEM (Finite element Methods) for structural mechanics and Finite Volume for CFD are dominant. For small deformation, FEM Lagrangian formulation can solve structure interface and material boundary accurately, the main limitation of the formulation is high mesh distortion for large deformation and moving structure. One of the commonly used approaches to solve these problems is the ALE (Arbitrary Lagrangian Eulerian) formulation which has been used with success in the simulation of fluid structure interaction with large structure motion such as sloshing fuel tank in automotive industry and bird impact in aeronautic industry. For some applications, including bird impact and high velocity impact problems, engineers have switched from ALE to SPH method to reduce CPU time and save memory allocation. In this paper the mathematical and numerical implementation of the ALE is described. From different simulation, it has been observed that for the SPH method to provide similar results as ALE or Lagrangian formulations, the SPH meshing, or SPH spacing particles needs to be finer than the ALE mesh. To validate the statement, we perform a simulation of a shock wave propagation generated by explosive detonation. For this simple problem, the particle spacing of SPH method needs to be at least two times finer than ALE mesh. A contact algorithm is performed at the fluid structure interface for both SPH and ALE formulations.

Fluid Structure Interaction, CFD, Lagrangian formulations



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