Proposal of Minisymposium for ECCOMAS Congress in Oslo on 5-9 June 2022.

*Title*: **Advances in Numerical Methods for Fluid-Structure Interaction**

*Topics*: CFD and CSM

*Organizer*:

Bernhard Müller, Norwegian University of Science and Technology (NTNU), Norway, <https://folk.ntnu.no/bmuller/>.

*Co-organizers*:

Wolfgang Schröder, RWTH Aachen University, Germany, <https://www.aia.rwth-aachen.de/en/der-lehrstuhl/lehrstuhlleitung/>;

Arthur Rizzi, Royal Institute of Technology (KTH), Sweden, <http://www.cambridgeblog.org/author-profile/arthur-rizzi/>;

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Stein Tore Johansen, SINTEF Industry, Norway, <https://www.sintef.no/en/all-employees/employee/252/>, and Norwegian University of Science and Technology (NTNU), Norway, <https://www.ntnu.edu/employees/stein.t.johansen>.

**Overview**:

Advances in discretization methods and new coupling techniques for fluid-structure interaction (FSI) are addressed. Novel cut-cell methods for the compressible and incompressible Navier-Stokes equations on collocated and staggered grids, respectively, are presented for simulating the interaction of compressible and incompressible flow with particles and other solid objects. Thereby, the interaction of turbulent compressible flow with thousands of particles is resolved by direct numerical simulation employing adaptive mesh refinement and a novel Runge-Kutta method in space and time, respectively. The interaction of water waves with a floating object also involves the computation of the free water surface using a volume of fluid (VOF) – level set (LS) method. A novel immersed boundary method is developed for the interaction of compressible flow in the human upper airways. The flow variables at ghost point are determined by using the no-slip boundary conditions at the elastic structure and interpolated flown variables at mirror points. For explicit methods for compressible flow, fluid flow and structure displacement are coupled explicitly via the kinematic and traction boundary conditions at the fluid-structure interface. For incompressible flow, the acceleration of quasi-Newton methods efficiently using various types of surrogate models is presented to couple black box solvers. The choice of computational software for FSI is addressed in the modular programming approach for aeroelasticity in the aerodynamic design of aircrafts.

Applications of the novel methods for FSI involve aerodynamics, marine engineering, process engineering and biomechanics.

**Preliminary program**:

1st. contribution and keynote (40 minutes):

Wolfgang Schröder (RWTH Aachen University, Germany):

*Direct particle-fluid simulation of fully resolved turbulent flow around thousands of particles*

2nd contribution (20 minutes):

Arthur Rizzi and Jesper Oppelstrup (KTH, Sweden):

*Modular programming approach to FSI applied to aircraft aeroelasticity*

3rd contribution (20 minutes):

Nicolas Delaissé and Josis Degroote (Ghent University, Belgium):

*Accelerating quasi-Newton methods using various types of surrogate models*

4th contribution (20 minutes):

Elena-Roxana Popescu, Son Tung Dang and Stein Tore Johansen (SINTEF Industry, Norway):

*Computation of ship motion in waves using Cartesian cut-cells*

5th contribution (20 minutes):

Frederik Kristoffersen and Bernhard Müller (NTNU, Norway):

*Novel immersed boundary method for fluid-structure interaction of compressible flow in the human upper airways*

**References**:

[1] Schneiders, L., Meinke, M., and Schröder, W. (2017). Direct particle–fluid simulation of Kolmogorov-length-scale size particles in decaying isotropic turbulence. *Journal of Fluid Mechanics,* *819*, 188-227.  <https://doi.org/10.1017/jfm.2017.171>

[2] Rizzi, A. and Oppelstrup, J. (2021). Aircraft Aerodynamic Design with Computational Software. Cambridge University Press. <https://books.google.no/books?id=4zorEAAAQBAJ&printsec=copyright&redir_esc=y#v=onepage&q&f=false>

[3] De Moerloose, L., Taelman, L., Segers, P, Vierendeels, J., and Degroote, J. (2019). Analysis of several subcycling schemes in partitioned simulations of a strongly coupled fluid-structure interaction. *International Journal for Numerical Methods in Fluids,* 89(6), 181-195. [**https://doi.org/10.1002/fld.4688**](https://doi.org/10.1002/fld.4688)

[4] Dang, S.T, Meese, E.A., Morud, J.C., and Johansen, S.T. (2019). Numerical approach for generic three-phases based on cut-cell and ghost fluid methods. *International Journal for Numerical Methods in Fluids,* [**https://doi.org/10.1002/fld.4758**](https://doi.org/10.1002/fld.4758)

[5] Khalili, M.E., Larsson, M., and Müller, B. (2018). Immersed boundary method for viscous compressible flows around moving bodies. *Computers & Fluids*, 170, 77-92. <https://doi.org/10.1016/j.compfluid.2018.04.033>