

Status and Perspectives of CFD

*Specialists Meeting on transient Thermal-Hydraulics in water cooled nuclear
reactors (SM-TH)*

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CFD in the field of Nuclear Reactor Safety

- T/H studies for NRS are still largely dominated by system codes (and “component” codes).
- The role of CFD has been increasing over the past 2 decades.
 - Interesting tool for configurations that involve 3D features, can provide a better understanding of some T/H issues
 - Can allow to go beyond certain conservatisms of more traditional approaches
 - Can be useful for upscaling
 - In some cases, CFD can partially replace costly experiments
 - But can never fully replace experiments !
- Before it can be used for NRS studies, CFD must be validated against high quality experimental results.
 - VV & UQ approaches needed.

Activity of the WGAMA CFD Task Group

- The CFD TG activity started in the early 2000's.
 - Animated by D. Bestion, G. Zigh, B. Smith, J. Mahaffy...
 - Phase 5 (2019-2021) animated by P. Ruyer & P. Freydier
 - CAPS proposed for Phase 6 (submitted to CSNI), to be animated by P. Ruyer, P. Freydier & S. Kelm.
- Redaction of reference documents:
 - BPG, Assessment of CFD codes, Multiphase flow document, UQ in CFD document.
 - CFD grade experiments (phase 4) ; TOP on the use of CFD for NRS (phase 5).
- Support to the organizers of CFD4NRS conferences.
- Support to the organizers of CFD benchmarks.
- The TG gathers CFD experts in the NRS field but still has little connection with system code activities; development of 3D capabilities in such tools may create opportunities for enhanced collaboration.

Benchmark Activity

- OECD/NEA-Vattenfall T-Junction Benchmark Exercise (high-cycle thermal fatigue),
 - OECD/NEA-KAERI Rod Bundle CFD Benchmark Exercise (turbulent mixing downstream of a spacer grid),
 - OECD/NEA-PSI CFD Benchmark Exercise (jet erosion of a stratified atmosphere based on PANDA),
 - OECD/NEA-PSI CFD benchmark with Uncertainty Quantification (turbulent mixing based on GEMIX),
 - OECD/NEA-TAMU Cold Leg Mixing Benchmark with Uncertainty Quantification, started in 2017.
 - OECD/NEA Fluid Structure Interaction benchmark started in June 2020, based on an experiment by OKBM).
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- Great opportunity to share expertise on an exercise with CFD-grade experiments, drive recommendations and illustrate CFD capabilities
 - Still many benchmark cases in «academical» configurations; too few applications of UQ methodologies, mainly due to costly computations; better results often associated with most complex computations (LES on fine meshes)
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- Next benchmark : selection process has shown largest interest to experimental configuration regarding the dead leg issue (Vattenfall) that is the closest to reactor application cases. Kickoff forecasted at beginning of 2023.
 - A proposal of DNS data based exercise on UQ / predictability of combined effects will be considered as a potential activity regarding development of UQ for CFD.

CFD4NRS conferences

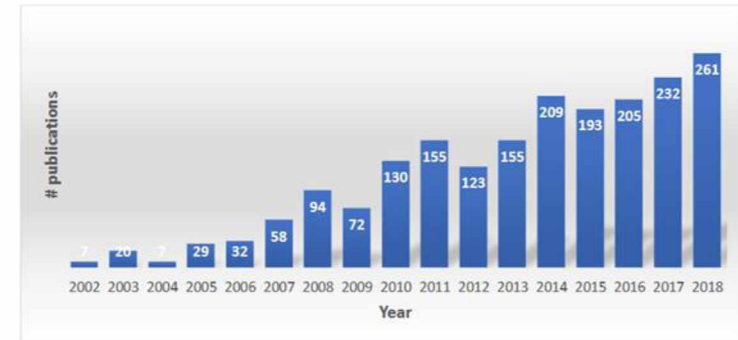
- The OECD/NEA CSNI CFD4NRS (Computational Fluid Dynamics for Nuclear Reactor Safety) workshop series started in 2006 in Garching, Germany.
- The CFD4NRS workshops ambition to be forums during which numerical analysts and experimentalists can exchange new information on the application of CFD to nuclear power plants safety and design issues.
- CFD4NRS-7 took place in 2018 in Shanghai, China.
- CFD4NRS-8 took place in 2020 (online due to the pandemic situation)
- CFD4NRS-9 postponed to early 2023, in College Station, Texas.
 - Suggestion: to open CFD4NRS to non-CFD T/H NRS community more largely than before.

BPG document

- Survey result : the BPG are the most widely used document produced by the TG.
 - Update of the BPG decided during Phase 5 of the CFD TG.
- The BPG are kept alive. Many important parts updated in 2021, including (non exhaustive list):
 - Wall condensation
 - Liquid metal systems, molten salt systems
 - 1D-3D multiscale coupling
 - Turbulence modelling for NRS applications
 - Heat transfer
 - FSI
 - V&V and UQ
 - Use of CFD for NRS studies in many different countries.
- Work finalized early 2022, with an important “introduction for beginners” part. Currently under review.

Technical Opinion Paper (1)

- Rapid progression of CFD use
 - Support studies, but also some studies directly used in the safety demonstration.
- Challenges still hindering a larger use.
 - Lack of qualified/accepted/established methodologies in certain cases
 - Access to information
 - Human factors
 - Cost



number of publications concerning CFD in the journals *Nuclear Engineering and Design* and *Annals of Nuclear Energy*

Technical Opinion Paper (2)

Perspectives

- Create and maintain a centralized entry point for CFD for NRS users providing links to validation databases, BPG's, selected publications...
- Extend benchmarking activities by code-to-code comparisons and even towards application-oriented comparative studies focusing on the prediction of safety criteria.
- Collect and summarize experience on UQ application to CFD in NRS. Support future work on UQ methods for CFD.
- Improve communication:
 - Write document to inform deciders and beginners about CFD capabilities and limitations with respect to NRS applications.
 - For CFD experts: a better knowledge of safety related issues and requirements for safety assessment is needed.
- Improving participation of system code users, TSO and regulators in CFD4NRS workshops.

Future Phase (phase 6) of the CFD TG activity

- CAPS submitted to the CSNI.
- Objective n°1 is to address the priorities identified in the TOP.
 - **Building an accessible (meta-) library of links for CFD for NRS related data**, including links to validation databases and to fundamental documents (BPG...), as well as an evaluation of such data.
 - **Writing a Technical Opinion Paper** (TOP) that first collects and summarizes existing work and/or perspectives **on the applicability of UQ methodologies for CFD to real industrial problems in the field of NRS**, and then consider proposals for a collaborative exercise on this subject.
 - **Help people communicate** : provide a few short, simple technical reports like “CFD for deciders”, “CFD for system code users”, “System codes for CFD users”.
- Objective n°2 is to continue promoting collaboration and exchange between CFD for NRS users (notably through **benchmarks and workshops**).

Conclusions

- Many expectations (CFD is quoted many times in the summary report) and already some uses in safety demonstration. CFDTG relatively very active within WGAMA: CFD should still evolve rapidly in short/mid term and have an increasing role in NTH.
- Before it can be used for NRS studies, CFD must be validated against high quality experimental results.
 - Need for “CFD-grade” experiments.
 - Access to such results : need for experimental databases.
- UQ methodologies have been proposed for NRS CFD studies, but are still not widely used for industrial studies.
 - Already used in academic problems (benchmarks).
 - Further work needed.
- Importance of the “user effect”.
 - Use and continuous updating of Best Practice Guidelines.
- A better integration of CFD studies in NRS may come from joint activities with 3D capabilities of system codes and/or coupling
- Particular case of two-phase flows: simulation relies upon many complex physical models.
 - DNS still out of reach in most practical cases.
 - Emphasizes the importance of validation.