International MITHYGENE-ETSON benchmark

Lithuanian Energy Institute scientists participated in the international MITHYGENE-ETSON benchmark and provided simulations of hydrogen combustion.

In the case of a severe accident in a nuclear power plant, flammable gases can be produced during the transient. Hydrogen can be produced during an exothermal oxidation of fuel cladding and other overheated metallic surfaces. If during the accident reactor vessel integrity failed and corium migrated to the containment, an additional large amount of hydrogen would be produced, together with carbon monoxide and other gases during molten core – concrete interaction.

The accumulation of generated flammable gases could lead to the formation of locally combustible mixtures. Explosions of such mixtures could produce loads posing risks to the containment integrity. While it is possible to significantly reduce the risk of hydrogen explosion using safety systems, e.g. passive autocatalytic recombiners, this risk cannot be completely mitigated for the whole accident duration, especially for the phases with intense hydrogen generation.

In order to improve knowledge of hydrogen risk and how to manage it during a severe accident, an international MITHYGENE project was launched in France in 2013, funded by the French National Research Agency. Within the framework of MITHYGENE project, a new facility designed for turbulent flame acceleration experiments, named ENACCEF2, was constructed and put into operation in the ICARE (Institut de Combustion Aérothermique Réactivité et Environnement), Orleans. The ENACCEF2 facility was designed as a highly instrumented vertical acceleration tube with the possibility to insert different obstacles in the flame path. Using ENACCEF2 experiments it is possible to study the phenomena governing flame acceleration, deceleration and quenching.

In the frame of MITHYGENE project and with the support of ETSON (European Technical Safety Organizations Network), an international MITHYGENE-ETSON benchmark was organized for the computational codes used in safety analyses of hydrogen combustion in the containments of nuclear power plants. This benchmark was organized based on experiments performed in the new facility ENACCEF2.

The objective of the MITHYGENE-ETSON benchmark was to identify the contemporary level of the numerical tools in the area of hydrogen combustion simulation under the conditions typical of safety considerations for NPP.

Three experiments of vertical flame propagation with the obstacles in the homogeneous hydrogen-air mixture were provided for the benchmark participants to simulate. All of them were conducted using the same geometrical facility configuration and boundary conditions, but with different initial volumetric hydrogen concentrations – 11, 13, and 15%.

The benchmark was organized in three phases:

- **Open phase** with the main focus on studying the problems and ENACCEF2 facility conditions. The results of the simulations were not intended to constitute the subject of the detailed analysis. An experiment with 13% initial hydrogen concentration was selected for this phase, and its results were available for the benchmark participants while performing the simulations.
- **Blind phase**. Experiments with 11 and 15% initial hydrogen concentration were selected for the blind phase, their results were not available for the benchmark participants while performing the simulations.

- **Post-blind phase**. During this phase the participants could deliver the revised simulations performed after disclosure of the experimental data used during the blind phase.

There were 16 submissions from 8 countries in the benchmark. Both the lumped-parameter (LP) and computational fluid dynamics (CFD) codes were used in the benchmark. Participants of the benchmark and codes used are:

- The Nuclear Regulation Authority (NRA), Japan, openFOAM (CFD),
- The French Alternative Energies and Atomic Energy Commission (CEA), France, Europlexus (CFD),
- Gesellschaft für Anlagen- und Reaktorsicherheit (GRS), Germany, CFX (CFD),
- Air Liquide, France, FLACS (CFD),
- Institute "Jozef Stefan" (IJS), Slovenia, Fluent (CFD), ASTEC (LP),
- Paul Scherrer Institute (PSI), Switzerland, Fluent (CFD),
- Technical Research Centre VTT, Finland, Fluent (CFD),
- State Scientific and Technical Center for Nuclear and Radiation Safety (SSTC NRS), Ukraine, CFX (CFD), MELCOR (LP),
- Japan Atomic Energy Agency (JAEA), Japan, openFOAM (CFD),
- Institute for Radiological Protection and Nuclear Safety (IRSN), France, Fluent (CFD), P^2REMICS (CFD), ASTEC (LP),
- Lithuanian Energy Institute (LEI), Lithuania, ASTEC (LP),
- Foster Wheeler, UK, MELCOR (LP).

The results of the blind phase of the benchmark demonstrated the present ability of the most used codes to qualitatively predict the pressure evolution inside the experimental facility. However, the maximum value of the flame velocity was mostly overpredicted. This overprediction reveals that the combustion models used in different codes still need improvement in order to provide more accurate results. Possible areas for improvements are the chemistry part, the turbulent combustion model and the coupling between the two models.

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