SUpport to Safety ANAlysis of Hydrogen and Fuel Cell Technologies

SUSANA
325386

Dr. Olaf Jedicke
Karlsruher Institute of Technology
www.support-cfd.eu

PROJECT OVERVIEW

- Call topic (SP1-JTI-FCH.2012.5.2)
- Application Area (Cross Cutting Activities)

Topic covered: Computational Fluid Dynamics (CFD) model evaluation protocol for safety analysis of hydrogen and fuel cell technologies

- 1st September 2013 – 31st August 2016
- Budget: 2.119.669 €, EU contribution: 1.159.124 € (54%)
- Consortium overview

KIT Karlsruher Institut für Technologie

JRC EUROPEAN COMMISSION

University of ULSTER

elementenergy

AREVA forward-looking energy

HEALTH & SAFETY LABORATORY

PROJECT OVERVIEW

- Short summary/abstract of project

critically review the state-of-the-art in physical and mathematical modelling of phenomena and scenarios relevant to hydrogen safety

compile a guide to best practices in use of CFD for safety analysis of FCH systems and infrastructures

update verification and validation procedures

generate database of verification problems

develop model validation database

perform benchmarking

Finally Achievement will be:

create the CFD model evaluation protocol built on these documents and project activities

PROJECT OVERVIEW

- Status of project

100%	critically review the state-of-the-art in physical and mathematical modelling of phenomena and scenarios relevant to hydrogen safety
75%	compile a guide to best practices in use of CFD for safety analysis of FCH systems and infrastructures
80%	update verification and validation procedures
60%	generate database of verification problems
50%	develop model validation database
60%	perform benchmarking

Final achievement 2016 will be:

create the CFD model evaluation protocol built on these documents and project activities

PROJECT TARGETS AND ACHIEVEMENTS

Programme objective/target	Project objective/target	Project achievements to-date	Expected final achievement
MAIP			
Development of databases to support fuel cells and hydrogen research	Technical structure of database Upload of protocols	100% 70%	Database of protocols for CFD modelling
AIP			
Capability of the CFD models of accurately describing the relevant physical phenomena	Development of database of protocols for CFD modelling and simulation on hydrogen safety aspects	70%	Providing of protocols

PROJECT TARGETS AND ACHIEVEMENTS

Programme objective/target	Project objective/target	Project achievements to-date	Expected final achievement
AIP			
Capability of the CFD models of accurately describing the relevant physical phenomena	development of database of protocols for CFD modelling and simulation on hydrogen safety aspects	70%	Database containing protocols
Capability of the CFD users of following the correct modelling strategy in CFD analysis	Accurate protocols	Available protocols at database up to 60%	FC contribution is missing according FC and difficult to compile due to technological difference

PROJECT TARGETS AND ACHIEVEMENTS

Programme objective/target	Project objective/target	Project achievements to-date	Expected final achievement
AIP			
Development of a model evaluation protocol for assessment of CFD models/codes accuracy for hydrogen and fuel cell technologies	Accurate protocols	Upload of protocols (actual status 70%)	Database containing protocols (aim 90%)
Number of data sets within the database	Datasets	80 < number of datasets < 100	Datasets added to database (90% due to missing FC data)

PROJECT TARGETS AND ACHIEVEMENTS

- SUSANA builds a database for model evaluation protocols beyond state of the art (first time)
- Advancements in comparing results from different applications and increasing of information value on modelling
- Accuracy of CFD models (codes) can get assessed by approved datasets based on real experiments
- Variety of datasets available for different problem-categories
- Next steps are:
  - To complete benchmarking exercises
  - To expand number of datasets
  - To in cooperate CFD modelling on FC
  - To finalize CFD model evaluation protocol

Laboratory Scale Experiments (<1 cubic meter)	Medium Scale Experiments (~10 cubic meter)	Industrial Scale Experiments (>100 cubic meter)
Gamelan_180, Gamelan_300, PRD, HYCOM-MC03, HYCOM-MC12, HYCOM-MC43, HYCOM-HC20, DDT_MINIRUT	Low Temperature Jet, GEXCON, SBEP_1, Ignition_Jet, Deflagration_shpere_vessel, HyInDoor_WP3, FZK-R 049809	SBEP_21, INERIS-6C, NASA-6, He_GARAGE, H2_HALLWAY, Open Deflagration, Vent_Deflagration_01, Vent_Deflagration_02, HYCOM-HYC01, HYCOM-HYC14, DDT_RUT, KI_RUT_hyd05, KI_RUT_hyd09, DDT_partial_confined_01-04

RISKS AND MITIGATION (1)

- Development of databases to support fuel cells and hydrogen research
  - difficult to compile relevant publications in case of use of Computational Fluid Dynamics (CFD) applied to hydrogen technology (number of reviewed papers limited)
  - Remedial actions difficult because availability of reviewed papers is a matter of facts
  - Nature of revision not needed, because the reduced number of datasets affects the general outcome (use of database) uncritical

RISKS AND MITIGATION (2)

- Capability of the CFD users of following the correct modelling strategy in applying correctly the CFD analysis
  - Computational Fluid Dynamics (CFD) is not widely used in case of modelling and simulation in fuel cells, because of different technological composition
  - Remedial actions by contacting FC community personally to receive information on reviewed papers useable to get developed as protocol
  - Nature of revision needed in concerns of number of useable protocols and datasets for model evaluation in case of modelling on fuel cell issues
  - Missing datasets will not hamper the use of SUSANA database in other applications than modelling FC

SYNERGIES WITH OTHER PROJECTS AND INITIATIVES

- Actually no further support by national programmes or other agencies
- Interaction with other European projects

FCH and FP projects	Description of complem… and/or joint ac… (if any)
FCH JU projects	
HyIndoor	Pre-normative research or… d hydrogen systems The generated knowledge… s. The experimental work will significantly enhance our understanding of hydrogen dispe… creased predictive ability of CFD modelling will … rticular settings without experimenta… information —… variety of potential applications
Other FCH-JU projects	It must be evalu… under FCH-JU could profit from SUSANA. A list of potential projects will be developed and contacted directly t… inform about SUSANA's general outcome and special results
FP projects	
H2FC European Infrastructure	H2FC European Infrastructure has several targets which … SUSANA aims: development of an e-infrastructure and … hydrogen and fuel cell research, mapping of European re… for fuel cells and hydrogen research, their capabilities … network of stakeholders and expert groups, special sessio… simulation on different conferences and workshops.
HySafe	HySafe NoE ends in HySafe association. Both of main interest for SUSANA because of networking on standards and pre normative research as well as HySafe is organizer of ICHS
Forthcoming projects under HORIZON 2020	It is planned to arrange a proposal concerning e-infrastructure for hydrogen and fuel cell research

International Conference on Hydrogen Safety

International Symposium Hydrogen & Energy

European Fuel Cell Conference

HORIZONTAL ACTIVITIES

- Forthcoming Seminar 2016
  - Dissemination seminar
    - A dedicated dissemination seminar will be organised to present the project outcomes to the FCH community
    - Following discussion at the previous progress meeting, this will take the form of a webcast seminar which will then be available to a wide audience
    - Potential venue is the offices of the Engineering Employers' Federation in central London

- Athens experts Work Shop
  - Themes covered most by safety, regulations, codes, standards
    - Contributions from Susana consortium members and experts
    - Session 1: Introduction and objectives
    - Session 2: Model Evaluation Protocols
    - Session 3: Best practice in numerical modelling
    - Session 4: Validation and verification techniques and methodology
    - Session 5: Industrial and commercial perspective

DISSEMINATION ACTIVITIES

- Experts and stakeholder work shop Athens
  - Eleven experts attended
  - From a number of European countries and USA
  - Representing a broad cross-section of industry and academia
  - Included world leading experts in their field (e.g. Bill Oberkampf, Sandia NL)
  - Also widened knowledge of and interest in Susana amongst researchers and practitioners
- Publications

- [1] Coldrick, S., Kelsey, A., Chernyavskiy, B., Makarov, D., Molkov, V., Baraldi, D., Melideo, D., Giannissi, S. G., Tolias, I. C. and Venetsanos, A. G. "A model evaluation protocol for Computational Fluid Dynamics (CFD) models used in safety analyses for hydrogen and fuel cell technologies", Submitted to the IChemE Hazards 25 conference, Edinburgh, UK.
- [2] Baraldi, D, et al. "Development of a Model Evaluation Protocol for CFD Analysis of Hydrogen Safety Issues – The SUSANA Project" Submitted to ICHS 2015.
- [3] D. Makarov, V. Molkov "FCH JU project "Support to safety analysis of HFC technologies" (SUSANA)" published in the second edition of e-Newsletter within H2FC project, available at: http://h2fc.eu/files/downloads/e-newsletter/H2FC_e-journal_2-2015_interaktiv(1).pdf
- [4] S.G.Giannissi, A.G.Venetsanos, N. Markatos, "Modeling of cryogenic hydrogen jets," Int. Conference on Hydrogen Safety, Yokohama, Japan, 19-21 October 2015.
- [5] I.C. Tolias, A.G. Venetsanos, "Comparison of convective schemes in hydrogen impinging jet CFD simulations," Int. Conference on Hydrogen Safety, Yokohama, Japan, 19-21 October 2015.
- [6] I.C. Tolias, A.G. Venetsanos, N. Markatos, C.T. Kiranoudis, "CFD evaluation against a large scale unconfined hydrogen deflagration," Int. Conference on Hydrogen Safety, Yokohama, Japan, 19-21 October 2015.
- [7] Olaf Jedicke; FCH-JU Review Days 2013, FCH JU Programme Review Days 2013, Brussels, 11 & 12 November 2013; General Presentation to the Project Status as POSTER to SUSANA
- [8] Olaf Jedicke; FCH-JU Review Days 2014, FCH JU Programme Review Days 2014, Brussels, 17 November 2014; General Presentation to the Project Status as POSTER to SUSANA
- [9] Olaf Jedicke; ICHS-4, International Conference on Hydrogen Safety, Brussels, 9th – 11th September.2013
- Presentations
- A presentation titled "Development and Application of Model Evaluation Protocols" by Adrian Kelsey (HSL) was given at a NAFEMS meeting on quality and reliability of CFD simulations:
- http://www.nafems.org/events/nafems/2014/q_rcfd/

DISSEMINATION ACTIVITIES

A model evaluation protocol for Computational Fluid Dynamics (CFD) models used in safety analyses for hydrogen and fuel cell technologies

S. Coldrick, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire, SK17 9JN, UK.

A. Kelsey, Health and Safety Laboratory, Harpur Hill, Buxton, Derbyshire, SK17 9JN, UK.

B. Chernyavskiy, Hydrogen Safety Engineering and Research Centre (HySAFER), Ulster University, Newtownabbey, BT37 0QB, Northern Ireland, UK.

D. Makarov, Hydrogen Safety Engineering and Research Centre (HySAFER), Ulster University, Newtownabbey, BT37 0QB, Northern Ireland, UK.

V. Molkov, Hydrogen Safety Engineering and Research Centre (HySAFER), Ulster University, Newtownabbey, BT37 0QB, Northern Ireland, UK.

D. Baraldi, European Commission Joint Research Centre, Institute for Energy and Transport, Westerduinweg 3, P.Box 2, Petten, 1755 ZG, Petten, Netherlands.

D. Melidoo, European Commission Joint Research Centre, Institute for Energy and Transport, Westerduinweg 3, P.Box 2, Petten, 1755 ZG, Petten, Netherlands.

S.G. Giannissi, Environmental Research Laboratory, National Center for Scientific Research Demokritos, Aghia Paraskevi, Athens, 15310, Greece

I.C. Tolias, Environmental Research Laboratory, National Center for Scientific Research Demokritos, Aghia Paraskevi, Athens, 15310, Greece

A.G. Venetsanos, Environmental Research Laboratory, National Center for Scientific Research Demokritos, Aghia Paraskevi, Athens, 15310, Greece

Abstract

Hydrogen and fuel cell technologies are seen as an increasingly important means of energy conversion and energy storage as European energy policies encourage transition to renewable sources, reduction of greenhouse gas emissions, and an increase in energy efficiency. This brings a corresponding move of these technologies out of the industrial domain, which is characterised by large quantities and a controlled environment, to the public domain which is characterised by a more diverse range of applications in typically less well controlled environments. The increase in demand brings an increasing need to carry out safety analyses and will therefore result in a more widespread deployment of modern numerical tools such as Computational Fluid Dynamics (CFD). This in turn has led to a requirement for a better understanding of the suitability of CFD models for each specific application.

Model Evaluation Protocols have been in existence for many years as a means of testing the quality of simulation tools mainly in the area of pollutant dispersion modelling. There have been several European initiatives for model evaluation covering dispersion, as well as fire and explosion modelling. The "SUpport to SAfety ANalysis of Hydrogen and Fuel Cell Technologies" (SUSANA) project aims to support stakeholders using CFD for safety engineering design and assessment of fuel cells and hydrogen (FCH) systems and infrastructure through the development of a new model evaluation protocol. The protocol covers all aspects of safety assessment modelling using CFD, from release, through dispersion to combustion and not only aims to enable users to evaluate models but to inform them of the state of the art and best practices in numerical modelling.

To achieve the aims, the project has seven work packages which are based upon a support strategy of collecting information from outside the project and disseminating this information to the user community. There are seven partners in the SUSANA consortium and each is responsible for a particular work package and coordinating the work of the other partners in that area. This paper gives an overview of the SUSANA project, the work packages and the main stages of the model evaluation protocol.

Keywords: Computational Fluid Dynamics, Model Evaluation Protocol, Hydrogen

Introduction

Strategic documents on European energy policies support a transition to renewable energy sources and diversification of the energy supply. The use of fuel cell and hydrogen (FCH) technologies would form an important part of this transition, as a means of flexible and efficient energy conversion. To date the main use of FCH systems and infrastructure has been in industrial applications, but with wider use, as part of a transition, they will move into the public domain and increasing numbers of the population will interact with FCH systems. Concerns about the level of safety of FCH installations could affect public acceptance of the technology. Already increasing numbers of FCH early market projects require a growing number of hydrogen safety experts who are able to make efficient use of available tools for safety engineering design, for example, Computational Fluid Dynamics (CFD). CFD can be used as a compliment to experimental studies and testing of FCH systems, and it is often the only affordable way to develop engineering solutions and safe strategies for their use.

SUSANA

SUpport SAfety ANalysis of Hydrogen and Fuel Cell Technologies

Duration:
36 months (starting date: 01/09/2013)

Application Area:
Cross-cutting Issues SP1-JTI-FCH-2012.5.2

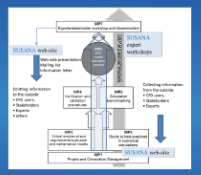
Budget:
Total Project budget: € 2.12 million
FCH JU contribution: € 1.16 million

Karlsruher Institute of Technology
University of Ulster
National Centre for Scientific Research Demokritos
Joint Research Centre EU
Health and Safety Executive
Element Energy LTD
AREVA SAS Renewable Energies

Scientific / main objectives of the project:
To achieve synergy and to consolidate the CFD excellence in application to safety design of fuel cells, hydrogen systems and infrastructure

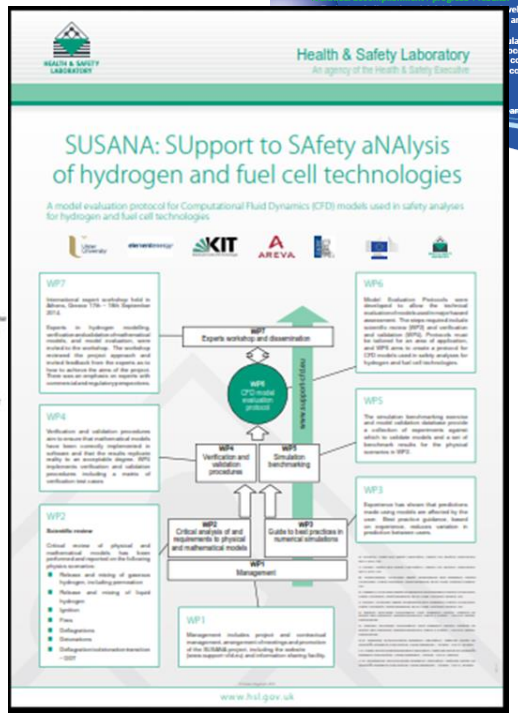
To support stakeholders using CFD for safety engineering design and assessment of fuel cells, hydrogen systems and infrastructure

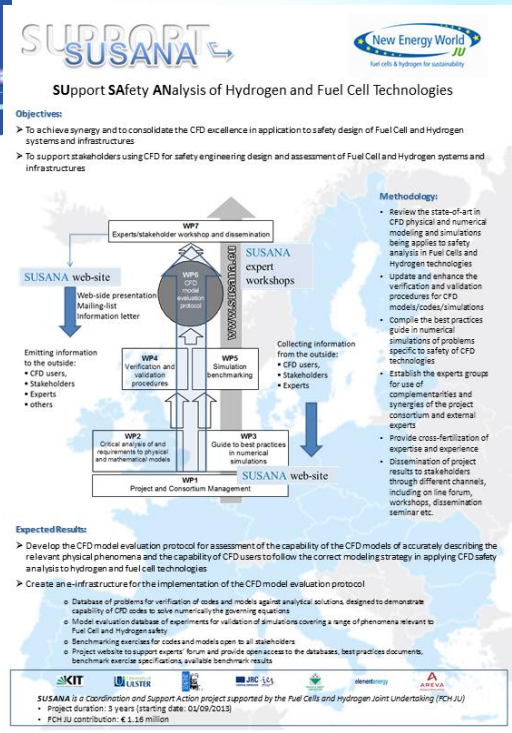
Technical accomplishment / progress / results:



Contribution to the Programme Objectives:
- Development of CFD model evaluation protocol for safety analysis for hydrogen and fuel cells technologies
- Pre-normative research of fire safety and pressure vessels made of composite materials
- Assessment of safety issues related to fuel cells and hydrogen applications

Conclusions, main findings and perspectives:
- Develop the CFD model evaluation protocol for assessment of the capability of the CFD models to accurately describe the relevant physical phenomena and ability to provide accurate engineering solutions
- CFD safety analysis of hydrogen and fuel cell technologies
- Create an e-infrastructure for the implementation of the CFD model evaluation protocol
  - Database of problems for verification of codes and models
  - Model evaluation database of experiments for validation
  - Benchmarking exercises for codes and models
  - Project website to support experts' forum and provide open access to the databases





EXPLOITATION PLAN/EXPECTED IMPACT

- Generally, effect and trust in the practicability of digital science to improve technological development
- FCH community using modelling and simulation methods to solve or discover potential problems in hydrogen technology can lean on common standards on model evaluation protocol for assessment of CFD models/codes
- Potential safety issues can get discovered accuracy and thus foster public awareness on recognizing hydrogen technology as a safe future technology
- Discover potential improvements of complete facilities and/or components by increasing application and accuracy of modelling and simulation
- Exploitation of project's results => as open access source
- Cross-cutting:
  - test standardisation (by model evaluation protocol)
  - safety assessment (by using CFD)
  - sustainability (by improving facilities based on results arising from digital science)

Thank you, for your kind attention!