MINUTES OF MEETING

FLACS User Group (FLUG)

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FLUG meeting 31 May – 1 June 2016

FLUG chairman: Olav Sæter (Statoil)

Day 1: 31 May 2016

Welcome

Erik Aadland (Gexcon) welcomed the participants to the twenty-seventh FLACS User Group (FLUG) meeting. He mentioned the challenges many companies experience at the moment, and commented that this situation also can trigger new and interesting developments. For Gexcon, the new software products FLACS-Risk and FLACS-Fire, as well as strategic partnerships, contribute towards opening new markets and creating value for the customers.

Agenda

Olav Sæter (Statoil) summarized the agenda for the two-day meeting. There were no comments to the agenda from the audience.

Update from the last FLUG meeting in China

Bin Xie (Gexcon China) reviewed the twenty-sixth FLUG meeting, which was hosted by China Classification Society (CCS) in Shanghai on 3-5 November 2015. The meeting was well-received, with about 120 participants and more than 100 people on the waiting list. Bin gave an overview of the topics presented during the meeting and related them to ongoing Gexcon projects for Chinese customers, for example an experimental campaign on LNG releases. The Chinese FLACS customers have established considerable application expertise in a relatively short time.

Bin also presented other initiatives on safety in China, and invited the participants of the FLUG meeting to the Sixth World Conference on Safety of Oil and Gas Industry (WCOGI 2016), which will be hosted by the University of Petroleum in Beijing, China, on 26-29 October 2016.

Olav Sæter (Statoil) inquired about the general acceptance of CFD in China. Bin explained that there are many CFD tools available in China, but the other tools do not focus on safety applications and validation in the way FLACS does. Chris Savvides (BP) asked whether the Chinese regulators require CFD for safety studies. Bin answered that it is not allowed to mention foreign software in the regulations, but requirements on safety studies are such that CFD tools have to be used.

Gexcon R&D – Activities and prospects

Trygve Skjold (Gexcon) presented an overview of the activities at the R&D department in Gexcon. He mentioned the ongoing Joint Industry Project (JIP) “Modelling Escalating Accident Scenarios and the Use of Risk-reducing technology for Explosion safety” (MEASURE), which focuses on fundamental aspects of turbulence and combustion modelling. Trygve acknowledged the support from the sponsors: Total, Statoil, ENGIE, GL Industrial Services UK Ltd. (DNV GL), ExxonMobil and BP, and mentioned that more details from the projects can be presented at the next FLUG meeting.

Trygve mentioned the ongoing process of evaluating FLACS v10.3 against the LNG Model Evaluation Protocol from the Federal Energy Regulatory Commission (FERC). This process has taken longer time than expected, partly due to revised procedures and changes in the underlying database, and partly due to significant differences in model performance between wind tunnel experiments and large-scale field experiments. The insights from the approval process are valuable for the development of the validation framework for FLACS, as well as for prioritizing further improvements to the model system. The fact that Gexcon has released FLACS v10.5 before the evaluation of v10.3 is complete highlights the necessity to shorten the approval process.

Trygve mentioned that Gexcon R&D has four active industry PhD projects, and described how these activities are linked to other strategic development initiatives, including a coordinated effort to improve the modelling of particle- and droplet-laden flows.

The 2020 vision for the Software division in Gexcon is the realize the 3D Risk Management (3DRM) approach. Trygve showed an example for how this could be done for a hypothetical hydrogen filling station. This work is part of the Hy3DRM project, supported by the Research Council of Norway (RCN) under the ENERGIX program, and is also part of the International Energy Agency (IEA) Hydrogen Implementation Agreement Task 37 on Hydrogen Safety. The main obstacle with respect to realizing

3DRM is to identify a dedicated end-user that is willing to invest time and efforts into an actual implementation.

Gexcon coordinates the EU-funded project "Improving Hydrogen Safety for Energy Applications through pre-normative research on vented deflagrations" (HySEA). The project started on 1 September 2015, and runs for three years. As a part of HySEA, Gexcon has recently distributed an open call for a blind-prediction study to partners in HySafe, IEA HIA Task 37, as well as to the FLUG list. The HySEA project receives funding from the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) under grant agreement No 671461. This Joint Undertaking receives support from the European Union's Horizon 2020 research and innovation programme and United Kingdom, Italy, Belgium and Norway. Further information is available on the project webpage: www.hysea.eu

Trygve mentioned two new JIP initiatives: "Development Of Water Spray Explosion Suppression" (DOWSES), coordinated by DNV GL, and "Assessing the Influence of Real Releases on Explosions" (AIRRE) coordinated by Gexcon and ENGIE.

As a comment to the ongoing discussions regarding a renewal of the methodology for performing quantitative risk assessments, Trygve pointed out the importance of embracing automated processes wherever that can save manual labour without lack of quality in the analysis, and at the same time preventing that the process of performing a risk analysis turns into a ritual with primary focus on demonstrating compliance, rather than understanding and improving the system. He mentioned an initiative by Gexcon, AVEVA and AKER where the aim to establish a JIP or similar that will focus on the workflow and associated methodologies as a project develops through the various phases of design and into operation.

The work on the development of the next generation of the numerical solver for FLACS (Flacs-3) continues. Antoine Dutertre (TOTAL E&P) inquired regarding the expected release date for the new solver. Trygve answered that an internal beta version is scheduled for Q4 2016, but it is too early to indicate a date for an external release. There is significant potential for shortening the simulation time and at the same time increasing the accuracy of the simulations, but there are still several technical issues that must be solved before the new solver can replace the old Flacs-2 solver in the commercial product. Olav R. Hansen (Lloyd's Register Consulting) asked whether validation receives sufficient focus in all the R&D projects. Trygve replied that validation remains the number one priority for FLACS as a software product, and that this is the main reason for the significant time and efforts Gexcon invest in the new validation framework.

Olav Sæter (Statoil) enquired how the results from JIP MEASURE would be made available to the community. Trygve answered that this depends on the Steering Committee for the MEASURE project. Regarding the LNG approval, Olav wanted to know whether there was no benefit of having been approved before. Trygve replied that the evaluation criteria had been modified, and all the work had to be redone with the new version.

FLACS v10.5 release

Djurre Siccama (Gexcon) introduced the new version of FLACS, v10.5r1. It includes the following new features: AVEVA® RVM import, cc-file support in CASD, Quick Grid GUI improvements, new co-file2 geometry counting tool (beta version), Flowvis 5: plot linking and legend in sidebar, improved video and image export, aggregation function and terrain import. All of these features are described in the release notes and the FLACS User's manual. Djurre stressed that future versions of FLACS, beyond v10.5, the packages will be made available for 64 bit architectures only. Hence, v10.5 is the last release where 32 bit packages are available without specific requests. Etienne Guinot (SAIPEM) enquired about the magnitude difference between the counting functionality in co-file and co-file2. Tommy Lea (Gexcon) answered that this depends on the geometry, since the new overlap detection will lead to lower results when many overlapping or nested objects are present in a geometry.

Olav R. Hansen (Lloyd's Register Consulting) commented about the validation of the terrain import. In his opinion, Burro 8, which have less wind, would be a more interesting test case. He also enquired about the challenges with the steps in the porosity and whether they lead to longer or shorter tails in gas dispersion. Djurre responded that Gexcon will follow up on the validation of terrain. In response to a question regarding the boundary conditions used for scenarios with terrain, Lorenzo Mauri (Gexcon) answered that Gexcon is aware of the possible effect of the stratification, and he gave some advice on limitations based on the Richardson number, which in the current guidelines is given quite conservatively.

Modelling dust explosions in the process industries

Maryam Ghaffari (Gexcon) introduced her PhD project on dust explosions. It represents a continuation of previous work at Gexcon, and includes the following four main activities: [1)] populating the validation framework with dust explosion experiments, [2)] performing laboratory-scale experiments at University of Bergen (UiB) and possibly Gexcon, [3)] completing a literature study to identify numerical methods for simulating turbulent particle-laden flows and combustion, and [4)] implementing improved models for particle-laden flows and flame propagation in dust clouds in FLACS-DustEx. The project entails cooperation with Forschungsgesellschaft für angewandte Systemsicherheit und Arbeitsmedizin (FSA) in Germany, and Gexcon aims at revitalizing the User Group meetings for users of FLACS-DustEx in 2016. Olav R. Hansen (Lloyd's Register Consulting) asked whether it was intended to extend the model to metal dust. Maryam replied that this was not defined as a goal for her PhD project.

Investigation of mist explosions

Laurence Bernard (Gexcon) presented results from experimental investigations of flame propagation in gas and mists that she has performed as part of her PhD project. The experiments will be followed by modelling in FLACS. Laurence described the experimental rig she had used at Cardiff University, and showed Schlieren images of hexane flames. Laurence concluded by summarizing different approaches for modelling droplet-laden flows, including the homogeneous equilibrium model (HEM), the Euler–Euler approach used in the Oil-Mist version of FLACS, and the Euler–Lagrange model that was implemented by Mathieu Ichard as part of his PhD thesis.

Olav R. Hansen (Lloyd's Register Consulting) commented about the inconsistencies in the data and sources of uncertainty. Olav Sæter (Statoil) inquired about the importance of the droplet size distribution on the combustion process, and indicated that this could have implications for the choice of modelling approach.

FLACS-Fire – validation and further development

Djurre Siccama (Gexcon) summarized the latest developments regarding FLACS-Fire. The user-base for FLACS-Fire has grown steadily, approaching 20 licences, and the feedback from the users is very positive. Gexcon prioritizes support of these users, since the Fire simulator is a relatively new product. Among the new developments and improvements during the preceding year, Djurre mentioned partial porosities, work on hydrogen jet fires, improvements regarding the convective radiation in monitor points, recommendations regarding pseudo-components for pool fire mixtures, recommendations and validation for trench fires, as well as general validation work. He continued the presentation with some results from the validation of vertical and horizontal jet fires, as well as hydrogen dispersion cases. Djurre also listed the improvements that are next on the list for the development team. For the next half to two years, and he stressed that the primary goal is to prepare the first version of the validation report.

Olav R. Hansen (Lloyd's Register Consulting) commented about the horizontal jet fires. He had modelled hydrogen jet fires using a smaller area for the jet program, which improved the results. Djurre assumed that similar settings were used in the recent simulations, and this has later been confirmed. Olav Sæter (Statoil) speculated whether the lack of momentum could be the reason for the deviation between simulations and experiments for horizontal hydrogen flames. Djurre agreed that this could be a contributing factor. In response to a question regarding LNG pool fires, Djurre replied that validation has been done for the two pool models included in the software, and for trench fires.

FLACS-Risk

Djurre Siccama (Gexcon) presented an update on the ongoing development of FLACS-Risk, Gexcon's software solution for calculating and visualizing 3D risk. The new software will allow risk-owners to design facilities that are significantly more cost effective, while still maintaining the required high safety levels, and avoid the hassle of developing own tools around the consequence simulator. Djurre stressed the importance of 3D visualization of risk as a means to efficiently communicating and improving the risk-owners' understanding of safety issues. FLACS-Risk will improve workflow and can contribute towards standardizing some of the methodology for safety studies.

The first release of FLACS-Risk is scheduled for Q4 2016. This version will not be a full QRA tool, but it will include ventilation, dispersion, and fire modelling. Support for explosion modelling will be added in one of the follow-up releases. Djurre showed new plot types, e.g. box plots for accumulations and mentioned different possible extension modules that could be developed in the future. He continued by demonstrating the user interface and an example of the application of FLACS-Risk, based on a hypothetical hydrogen fuelling station. Finally, Djurre introduced the early adopter programme for FLACS-Risk.

Etienne Guinot (Total) enquired about the availability of a release frequency database. Djurre pointed out that release frequencies are user input. Furthermore, anticipated congestion will not be provided by FLACS-Risk, at least not in the first version. Graham Morrison (Gexcon UK) asked whether there is an immediate plan to include personnel risk. Djurre replied that this is not implemented so far, and that one would need to investigate how many simulations are required for such a risk analysis. Being asked about the time saving with FLACS-Risk, Djurre elaborated that it depends on the efficiency of the consultants in their traditional way of working, but in most cases FLACS-Risk will allow shorter delivery times for results of at least equal accuracy.

Olav R. Hansen (Lloyd's Register Consulting) pointed out that 3D risk contours for drag or overpressure can be misleading, e.g. when the local maximum pressures come from different simulations. Olav Sæter (Statoil) commented on the evolution of Gexcon from a provider of consequence models to a provider of tools for risk analysis and risk management. This was followed by a discussion on the definition of risk. Trygve (Gexcon) mentioned that 'risk' previously was defined as a function of probability (e.g. the expectation values of event frequencies) and consequence, whereas modern definitions tend to also focus on the uncertainty in the estimates of frequency and consequence. Olav mentioned that the Petroleum Safety Authority of Norway (PTIL) has changed their definition of risk ("risk can be defined as the consequences of an activity with the associated uncertainty"), and that risk owners currently seek simpler approaches.

Graham Morrison added that also UK regulators are moving away from excessive focus on numbers, and pay more focus on barrier management, i.e. what is done about the risk and which procedures are in place to counter it. Ronan Abiven (Gexcon SW) stressed that FLACS-Risk aims at visualizing the risk picture, and thereby give a global view of the analysis and the contributors to the overall risk. This will provide much more value to the risk study than can be expressed in a single exceedance curve.

Virtual reality safety training

Chad Jarvis (CMR/Gexcon) mentioned that 2016 has been proclaimed the year of virtual reality (VR). He explained how VR functionality can be realised by combining FLACS simulations and use of a virtual reality headset in a modern gaming environment. This activity builds on the experience CMR and Gexcon developed during the project VR Safety, sponsored by Statoil, which started in 2004. Today, hardware devises such as Oculus Rift HMD and HTC Vive HMD cost less than 1000 USD, and computers with high-end GPUs cost less than 2000 USD. On the software side, all major game engines are now open source or very inexpensive.

Chad demonstrated a VR prototype that he had implemented for a Chinese client. The scenario included user interaction within a tank facility with fires and explosions. Olav Sæter (Statoil) asked whether the visualized fire was based on simulations or purely invented. Chad answered that the VR tool reads pre-simulated results from FLACS simulations. It is not feasible to trigger new simulations from the VR environment and compute them in real-time, in the same way as in VR Safety.

Cristina Zuliani (Saipem) enquired how long it had taken to make the training video. Chad answered that he had used about 2.5 months from he first started using this particular game engine. This was followed by a discussion about models that would enable the avatars to respond to surrounding conditions. The feature was not relevant for the current project, but it is possible to extend the functionality in that direction. Pascal Le Gal (Gexcon ME) wondered how one could exploit the same technique for training personnel with respect to risk awareness related to toxic clouds. Dag Magne Ulvang (CMR/Gexcon) replied that clouds can be equally well visualized by volume rendering. Etienne Guinot (Total) asked how many people could interact in the VR environment. Chad answered that currently this was limited to a single actor, but it is straightforward to extend this.

Finally, Chad elaborated on the motion sickness people experience when using 3D goggles, and mentioned possible solutions or mitigating measures for this problem.

Ignition modelling: are our approaches aligned?

Lars Rogstadkjernet (Gexcon) shared his experiences as a third-party reviewer for probabilistic analyses, and highlighted areas where the methodologies differ, mostly with respect to dispersion and ignition modelling. His goal was to initiate a discussion, since Gexcon, as provider of the consequence simulation tool, would like its users to be successful, and inconsistent results do not benefit anyone. NORSOK Z-13 contains detailed guidance for explosion risk analysis, and is widely adopted. Lars went into geometry modelling in more detail, and highlighted the use of difference congestion measures and treatment of incomplete models during early stages of design. Next, Lars described the normal approach to a dispersion study, and stressed that the number of dispersion simulations varies significantly between different consultancies. He gave an example of a leak scenario where just by changing the

orientation of the leak, the produced cloud-size and resulting risk was extremely different. Similarly, both wind and geometry can affect the composition and size of the cloud significantly. This initiated a discussion concerning the underlying assumptions for the different studies, e.g. as a result of short deadlines for the projects. Graham Morrison (Gexcon) emphasized that companies have different approaches to e.g. ignition modelling. Olav R. Hansen asked Lars how many companies use pre-ignition turbulence? Lars could not give an answer to this question, and remarked that his presentation focused on dispersion. Chris Savvides (BP) revisited the point regarding how many scenarios are needed for a proper QRA. Rather than being able to specify a fixed number, he argued that this should be up to the judgement of an experienced analyst.

Explosion test demonstration

The participants travelled to the upgraded and extended test site at Sotra and witnessed a propane explosion in the 50-m^3 M24 module. Engineers from Gexcon Laboratories also showed other experimental facilities.

Day 2: 1 June 2016

Hydrocarbon leak on the Gudrun platform on 18 February 2015

Olav Sæter (Statoil) presented the accident investigation after the release of condensate on the Gudrun platform in February 2015. His goal was to explain the chain of events and identify the root cause, and to show how FLACS could be used to understand selected aspects of the accident. The release of condensate occurred in the process area, on a bypass line directly after the first stage separator. The flammable cloud was not ignited, no people were harmed, and most of the barriers worked as intended.

Olav described two methods for establishing the mass flow rate and concluded that the leak rate probably was about 8 kg/s, of which approximately 50 % gas. The root cause was fatigue fracture of the bypass line, caused by mechanical vibrations.

Olav showed gas dispersion maps recreated from gas detector data and an investigation of the wind field in the process area. He commented on the observed dispersion perpendicular to and upstream relative to the prevailing wind direction. The largest volume of the gas cloud was estimated to about 3000 m^3, corresponding to about 500 m^3 stoichiometric mixture. Olav acknowledged that if the crack had developed into a full rupture, the leak rate could have approached 140 kg/s, which would have been a major accident. He stressed the importance of deluge, since water is the only measure that can mitigate the consequences effectively.

The discussion that followed touched on the significant of stratification, how the leak rate may have evolved over time, and the validity of the various equivalent cloud approaches.

Optimisation of gas detectors

Asmund Huser (DNV GL) presented several JIP initiatives from DNV GL and outlined a new risk-based approach for optimizing the number and location of gas detectors in complex geometries. The new scenario-based approach entails hundreds, or possibly thousands, of CFD simulations. Asmund emphasized that it is still open how many simulations one needs for achieving “convergence”. He showed 3D frequency maps for gas dispersion. Compared with the geographic approach (regular grid), the new scenario-based approach typically ends up with less detectors. To estimate the optimal number of detectors, it is straightforward to extend the dispersion study with a cost-benefit analysis.

Antoine Dutertre (TOTAL E&P) inquired commented that the methodology should consider the size of the largest undetected clouds, and the consequences of igniting such clouds.

HPC-cloud service for optimising gas and flame detector layouts

Lars Pesch (Gexcon) presented the Fortissimo II project, in which Gexcon, together with the Edinburgh Parallel Computing Centre (EPCC) and Micropack develops a part of FLACS-Risk that will allow users to evaluate and optimize detector layouts based on CFD simulations. Based on previous work in Gexcon, and a description of the methodology, he showed what was required to facilitate CFD-based detector layout. Large parts of the simulations for such a study can be reused from a general risk assessment, thus increasing the value for the customer. Lars continued by introducing the EU Horizon 2020 project Fortissimo II and Gexcon’s part in it. He introduced the project partners, EPCC and Micropack and their roles in the project.

Breaking down the objectives into project milestones, Lars showed how and when the functionality is intended to be delivered and how the user interface will look like. Olav R. Hansen (Lloyd's Register Consulting) wondered what a study with hundreds or thousands of simulations will cost on the HPC hardware. Erik Aadland (Gexcon) replied that some of Gexcon's customers run studies on the EPCC cluster routinely, and interested parties can contact Gexcon to learn more about the offering.

Hot plume dispersion from ground flares in an LNG plant: comparative study FLACS vs. FLUENT

Cristina Zuliani (Saipem) presented a study of ground flares and particular safety issues associated with such systems. Ground flares are an alternative to elevated flare towers that give less visual impact, e.g. in LNG plants. An installation may include hundreds of burners, and have the size up to a football field. With respect to safety, the main concern is the large amount of hot gases generated in the burners.

Cristina described the modelling approach and the CFD models used in her project: FLUENTv12 and FLACS. She compared iso-surfaces of temperature, and plume temperature profiles. Based on a threshold of 70°C for personnel risk, neither FLUENT nor FLACS indicated a definite hazard. However, the threshold for equipment such as heat exchanges for air conditioning systems is quite narrow, +/- 2° C, and for this parameter FLACS predicts a much larger hazard zone compared to FLUENT. Cristina suspected that the reasons for this differences were: (i) different turbulence models (different constant in buoyancy term), (ii) different inlet wind/turbulence conditions, (iii) different grid resolution in the far field (e.g. stretching of the grid in FLACS).

She concluded with an additional study with FLACS of multiple flare pits. This investigation showed that when the burners are located close to each other, the flare pits merge, while when further apart they are less coupled. Asmund Huser (DNV) wondered whether such an installation was available somewhere, so that one could obtain measurements. Cristina was not aware of an installation of the examined size and possibly double ground-flare constellation. Chris Savvides (BP) mentioned that earlier experience from multiple-burner ground flares in the UK indicate that the burners may melt due to the recirculation induced by individual burners. Franz Zdravich (Gexcon) enquired about the details of the inlet boundary conditions set in FLUENT, which solver had been used, and he commented on the grid stretching in FLACS.

The modelling of blast waves from BLEVEs

Malte Kjellander (Lloyd's Register Consulting) presented a study aimed at modelling the effects of BLEVEs with FLACS. He described the phenomenon of BLEVEs, and stressing that it is possible to get a BLEVE even below the boiling point. The damaging effect of BLEVEs include initial pressure wave, projectiles, and, for ignited BLEVES, fireball and blast waves. Empirical methods exist for estimating these effects. Malte concentrated on the first effect, the pressure wave caused by (1) the sudden release of the vapour overpressure, and (2) the boiling liquid. He then described how these could be modelled in FLACS: the physics of the vapour overpressure release is captured by FLACS, but the liquid expansion is not captured. Hence, reliable estimates require an empirical pseudo-source for the fraction of energy released in the blast. Malte described the simulation setup, which entailed about 1000 CPU hours per second of simulated time (with about five million cells in the domain).

A comparison with experiments carried out at the Spadeadam test site showed that FLACS gives conservative results, with simulated pressures typically 100-200 % above the measured ones. After the validation exercise, Malte compared simulated BLEVEs in the open and in a tunnel. In the 1D confined environment, the BLEVE forms a shock wave that travels through the tunnel.

Potential for major explosions from crude oil pipeline releases in varied terrain

Olav R. Hansen (Lloyd's Register Consulting) mentioned risks from transport of oil by ship, rail and pipeline. He used statistical data for annual leaks per 1000 km pipeline from Concawe (a division of the European Petroleum Refiners Association) to estimate leak frequencies, and discussed whether crude oil releases will explode. Buncefield, and a similar accident in Puerto Rico in 2009, were cited as examples. Olav argued that the traditional consequence assessments overestimate the dimension of the pool fires and neglect the risk of explosions. To arrive at a more refined, but still conservative estimate, he assumed that 5 % by weight of the oil would vaporize. With dense vegetation or trees in the cloud there is also significant risk of DDT. These risk factors are not identified in standard QRAs for pipelines. Upon a question regarding the type of oil, Olav commented that the described risks are relevant for any type of standard stabilized oil. Cristina Zuliani (Saipem) enquired about the risk picture for a buried pipeline. Olav Sæter (Statoil) wondered to what extent this hazard is manifested in actual accidents, given the extensive network of pipelines in Europe. Olav R. Hansen replied that the

quantitative example was for a particular case in a valley, and cannot be generalized. His main point was that the risk – especially of explosions – is neglected in current practice.

Comparison of detailed CFD simulations and pseudo-source models for jet leaks

Knut Erik Giljarhus (Lloyd's Register Consulting) has investigated the difference in pseudo-source modelling of jet releases between KFX and FLACS. He commented that the derivation of the pseudo-source models is similar, but that KFX and FLACS tools use different states as input to the CFD solver.

He continued by noting the excellent agreement between detailed entrainment simulations carried out with OpenFOAM and experimental results. For the cases without geometry, FLACS gives longer hazardous distances due to less turbulent mixing, whereas KFX appears to be in better agreement with the detailed CFD simulations.

Knut Erik also compared the entrainment models in KFX and FLACS, and found them to give very good results compared to the respective pseudo-source models when used in an idealized geometry. In complex geometry, FLACS shows good agreement between the pseudo-source model and the entrainment model, while he observed large differences for KFX. These differences could not be explained solely by the pseudo-source model.

Knut Erik suggested that further work should be done to understand the differences in complex geometries, and that the comparison should be extended to multi-component mixtures, real gas effects and condensation in the detailed CFD model.

Lorenzo Mauri (Gexcon) commented that the diameter in the entrainment in the under-expanded jet case should not be the orifice diameter but the expanded jet diameter, since the entrainment model is applied after the expansion. This may explain one of the larger differences observed by Knut Erik. Lorenzo added that the large differences between the pseudo-source models suggests that there still is controversy about what is the best model.

Geometry modelling and blast loads

Lars Rogstadkjernet (Gexcon) showed how sensitive simulation results can be with respect to different representations of the geometry. Such differences can for example arise from the way beams are constructed, or the conversion between different CAD tools. He showed the impact on geometry counting measures and explosion overpressures. Lars emphasized that it is of vital importance to pay attention to the import of the geometry model. Olav Sæter (Statoil) remarked that it was good to be reminded of such effects.

Comparison of FLACS and EXSIM for probabilistic explosion analysis

Knut Erik Giljarhus (Lloyd's Register Consulting) summarized the history of KFX, FLACS and EXSIM. The study had been initiated by ComputIt approaching LRC to get an initial impression of the usability of EXSIM for probabilistic explosion analysis. To this end, Knut Erik had set up a study with EXSIM based on earlier work with FLACS. The results showed similar trends for explosion pressures obtained with EXSIM and FLACS. For smaller gas clouds, FLACS produced somewhat smaller overpressures. Large differences were observed for open areas, and Knut Erik showed an idealized stress test that exposed a problem with EXSIM. This problem could be fixed by overriding the automatic routine for generating the computational mesh, and using a finer mesh instead.

Knut Erik's conclusion was that EXSIM is straightforward to use in the target context, but that large discrepancies for smaller clouds in more open areas occur. In addition, one should use EXSIM's grid optimizer with care. Helene Hisken (Gexcon) asked whether Knut Erik had compared results from the two models with experimental results. Knut Erik replied that this has been done previously, e.g. in the PhD thesis of Olav Sæter, and he had not redone such work. Chris Savvides asked how the grid for FLACS had been defined. Knut Erik assured that the grid guidelines had been used. Lars Rogstadkjernet (Gexcon) wanted to know how the grid optimizer works in the presence of solid surfaces. Knut Erik answered that the routine tries to find the walls and align the grid to them. Chris Savvides enquired how the interplay between KFX and EXSIM was. Apparently the way reactions are modelled in KFX and EXSIM is quite similar, so it might be possible to merge the two.

Increasing spatial and directional accuracy for reporting dimension drag loads with FLACS

Nicolas Salaün (Gexcon) motivated his presentation by the demand for cost reduction by smarter and sometimes less conservative designs, which may imply that one has to make more out of the data obtained in a risk study. As an example, he presented a study that involved cost-effective design against drag loads.

Nicolas explained the definitions for drag forces and the common practice to report a single value on an area basis (for a module or deck), which is then applied to all objects in the module etc. This approach is straightforward, since it is based on a single exceedance curve, but the disadvantage is that it can lead to excessive design in areas which are not exposed. The goal for the presented method was to determine a distribution of drag loads within a module, and to identify the (few) areas that experience high drag loads. The method does not require any rerunning of jobs, just additional post-processing. For the module used in the example, only limited parts of the geometry experience high drag forces, and most regions experience much smaller loads. In addition, directional drag can be retrieved, e.g. for pipe routing purposes. Nicolas stressed that the approach does not necessarily lower requirements, but brings added value on prevailing directions, and shows that systematic use of the maximum design accidental load (DAL) in all directions is not necessary. He demonstrated some ideas about improving graphical reporting with 3D field views of the loading. This allows the analyst to identify regions of high drag, and to understand the mechanisms behind the distribution. Olav R. Hansen (Lloyd's Register Consulting) asked Nico to explain the conventional approach, and to clarify the scaling applied per cell.

On the use of one-to-one coupling for probabilistic assessments

Steve Howell (Abercus) presented applications of the EXCGEN tool from Abercus for handling results from numerous simulations. This tool facilitates, for example, the automatic extraction of exceedance curves and mapping of CFD results to the CAD geometry. Also, sensitivities to ignition frequencies etc. can be shown and may trigger questions from designers. It is also possible to visualize the Q9 equivalent stoichiometric volume vs. the total flammable volume. Steve talked about current trends in 3D risk assessment and how HPC will offer new opportunities in the future, not just shortening the lead times, but rather giving a better risk picture. For instance, the 10^{-4} events may be wrongly interpreted, if the triggering event is not correctly identified. With respect to the coupling between CFD and FEA, he argued that computational costs are no longer prohibitive.

Update from support

Lene Sælen (Gexcon) presented the KPIs for FLACS support. The user feedback is generally very positive, and the targets have been reached or exceeded in all except one month since the start of 2015. She continued by presenting the new user portal as a single source of documentation, resources and support for all FLACS users. The content includes the knowledge base, i.e. a collection of self-contained articles about typical problems and questions. The handling of issues reported to flacs@gexcon.com will also be moved to the new portal, and it is possible to include forums for user discussions in the future. Finally, it is a target to move the FLUG pages to the same portal. The user portal will be gradually developed and filled with content, starting in the summer of 2016. Ultimately it should become a digital environment for exchange and learning. The second big news to be released this summer is the certification programme for FLACS. Lene described the requirements of the Level 1 certification and assured that when launching the programme there will be a free registration period for a single purchase without FLACS I training. Later the training will be included in the price for the FLACS I course.

FLUG wishes

Lars Pesch (Gexcon) mentioned the FLUG wishes that had been solved in FLACS v10.5, and pointed out the growth in the number of wishes since the last meeting. Three customers added new wishes:

- Laurent Paris (Technip) suggested an import filter for removing objects smaller than a certain size, such as nuts and bolts.
- One user suggested to add a function for automatically adding monitor points in a cone region, e.g. to monitor the flow out of a jet leak. It turns out that this functionality is already included, but Gexcon will include an example in the FLACS User's Manual.
- Another user suggested that Flowvis 5 should include an option for not visualizing the monitor points located above a cut plane.

Next FLUG meeting

In the aftermath of the FLUG meeting in May/June, it has been confirmed that the next FLUG meeting will be hosted by Technip in Paris on 8-9 November 2016. The address for the venue will be announced in due time.

Closing

Olav thanked Erik for hosting the meeting and summarized the two days. He thanked the participants for their contributions and closed the meeting.