# MINUTES OF MEETING



## FLACS USER GROUP MEETING

**Place:** Technopark, Meeting Room Fortran, Zurich, Switzerland
**Date:** 10 November 2006
**Prepared by:** Olav R. Hansen and Idar Storvik

**Participants:**

| | | |
|---|---|---|
| Vincent Marchand | ARKEMA | France |
| Pierre-Marie Sedat | ARKEMA | France |
| Malika Madoui-Barmasse | Gaz De France | France |
| Jerome Hocquet | IRSN | France |
| Thomas Vuillez | ODZ Consultants | France |
| Didier Batherosse | ODZ Consultants | France |
| Francesco Chille | Cesiricerca | Italy |
| Åmund Langelid | DNV | Norway |
| Ellen Østerbø | GexCon Consulting | Norway |
| Are Bratteteig | GexCon Consulting | Norway |
| Jan Roar Bakke | GexCon Consulting | Norway |
| Olav Roald Hansen | GexCon Software | Norway |
| Idar Storvik | GexCon Software | Norway |
| Trygve Skjold | GexCon Software | Norway |
| Ole Jacob Taraldset | GexCon Software | Norway |
| Stian Høiset | Norsk Hydro | Norway |
| Anette Urheim | Safetec | Norway |
| Brynhild Olsø | Safetec | Norway |
| Alexandre Brigadeau | Scandpower | Norway |
| Jens Kristian Holen | Statoil | Norway |
| Agnes Elin Hollund | Statoil | Norway |
| Andreas Obrist | SKS | Switzerland |
| Charlotte Higgins | BMT Fluidmechanics | UK |
| Michela Oliviero | BMT Fluidmechanics | UK |
| Chris Savvides | BP | UK |
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# 1. Industry Seminar November 9, 2006

The day before the FLUG meeting an open industry seminar "CFD Modeling of Risk" was held. Around 55 participants from 11 countries participated, and interesting presentations were given about dust explosion modelling, hydrogen safety, explosions in offshore oil and gas and onshore plants, use of virtual reality and more. The talks seemed to be well received among the audience.

# 2. Workshop on geometry import and blast propagation November 10

**Geometry import**
The FLUG chairman Chris Savvides, BP, wished welcome to the FLUG meeting. Ole Jacob Taraldset presented the status and development focus for the geo2flacs geometry import tool. Different formats that could be handled were described, as well as formats that GexCon plans to include. At the end Ole Jacob did a demonstration of CAD import.

Questions:
- Andreas Obrist asked about the possibility to import AutoCAD. Ole Jacob replied that some missing libraries were a main reason for missing AutoCAD import possibilities.
- Jan Roar Bakke asked about 2D and 3D representation in AutoCAD, and Ole Jacob confirmed that with old AutoCAD format the 2D/string representation was not possible, but with the new formats it could be possible to import.
- Didier Batherosse asked about how rotated objects were handled. Ole Jacob explained that geo2flacs would normally automatically align objects to the nearest axis. If the –r option is used when running geo2flacs, rotated objects are allowed (no alignment to axis is done inside geo2flacs). The resulting geometry can be imported by CASD, but the standard porosity program will not be able to handle the object file.
- Chris Savvides asked whether it could be possible to group objects even without a .drv file. It was concluded that some functionality for this should be considered to include, as this would accelerate the import process strongly in some cases. Some of the problems with this has already been removed in a recent development version, as objects (and "BClBBuu" string) are not redrawn for each object added.
- Andreas Obrist commented that a cylinder became a beam in the demo example. Ole Jacob explained that this may happen if geo2flacs does not recognize the way the object is described. For the particular example, the newest development version will recognize the cylinder (old version of geo2flacs was used for the demoexample).
- Andreas Obrist: Why is the geometry storage called database? This has historical reasons, until about 10 years ago Oracle or Ingres databases were used to store geometry information of up to 100 projects. Then a file database system was developed to replace these commercial databases.
- Charlotte Higgins commented that bounding boxes were made when a geometry object was not recognized, and that for instance when handling non-aligned objects such a bounding box could give a significant error. Didier Batherosse confirmed that in some cases there could be big discrepancies in geometry description. Ole Jacob responded that such problems may be seen (things are however improving), and that geometry verification is a very important part of the geometry work.
- Olav R Hansen concluded that the best way to improve geo2flacs is to communicate the problems and challenges to GexCon / Ole Jacob (ojt@gexcon.com or flacs@gexcon.com).

Michela Olivera presented some of their geo2flacs experiences. In a previous project they received partly dgn v7 files and partly v8 files. This gave a problem as only v7 is accepted, and geo2flacs stops with error every time a v8 file is read. It was quite work-intensive to find a workaround for this, and the import process did not complete after 48h due to too many individual objects. An effort was then done to group objects, and geo2flacs ran successfully in 3h. A method to group objects automatically (when no drv-file is present) was asked for.

Michela asked how to rename objects, Olav R Hansen answered that this could be done by defining a new object in CASD and choose ADD OBJECT.

Didier Batherosse commented that internal pipes were sometimes included in the CAD model, and could add extra objects. Are Bratteteig commented that these could be removed by the person generating the dgn-file, however, it was recommended to talk directly to this person as such details were seldom understood properly if communicated indirectly.

**Blast propagation**
Olav R Hansen presented simulations performed calculating far field pressure waves from full scale experiments. BFETS tests 1 (low congestion centre ignition), 2 (low congestion end ignition), 12 (high congestion centre ignition) and 7 (high congestion end ignition), as well as HSE-Phase 3A tests 1 (centre ignition), 2 (centre ignition), 3 (edge ignition), 4 (end ignition). For each test simulated internal explosion pressures as well as four external blast pressures (15m, 30m, 50m and 70m outside for BFETS, 6m, 12m, 24m and 48m for HSE-Phase 3A) were compared to experiments. All simulations were performed with both a 1m grid and a 0.5m grid resolution.

FLACS was able to reproduce the experimentally reported far field pressure waves reasonably well for the BFETS tests (tunnel geometry, venting from ends). A small grid dependency was seen, slightly better results were found for the 0.5m grid compared to the 1.0m grid.

For the HSE-Phase 3A geometry some of the results were good, whereas some of the experimental results, in particular in the near field (6-12m out) were not so well predicted. The main differences were that the experiments often had a significantly higher pressure peak (spike of very short duration), and for some of the tests the reported pressures were significantly higher than simulated.

Olav explained that much of the difference between simulation and experiments could be partly due to measurement techniques applied in the tests. So-called skimmer plates (30cm diameter plates) were vertically mounted along the main axis of the geometry. If the pressure waves are propagating nicely in parallel to these plates, one should expect to obtain a decent prediction of side-on pressure from the recordings. In reality one should expect asymmetries in the external explosion, in particular for HSE Phase 3A tests (with no confining walls to direct the explosion), so that blast waves may hit the skimmer plates at an angle, and reflected pressures rather than side-on pressures may be reported. For HSE test 3, which has unsymmetric edge ignition, this effect was more clearly observed than for the other tests. It was also indicated that the very thin spike in the measurements could be a local reflection phenomenon in connection to the blast waves reaching the sensors. For HSE test 4, it is believed that a DDT took place when the flame exited the geometry. As DDT is not picked up with FLACS, this may also lead to some deviation on the nearest sensors. With larger distance (48m observation) this deviation was reduced.

Jens Holen commented that the leading edge of the pressure shockwaves in the simulations is smeared compared to the experiments. Olav confirmed that this should be expected, and suggested that the guidelines from the multi-energy method could be used to get an indication whether one should expect a shockwave or not.

Francesco Chille commented that most of the pressure peaks modelled were of very short duration compared to natural frequencies of structures, which means that the exact pressure peak is not so important. The more important point is that the impulses are well predicted.

Charlotte Higgins presented some work from BMT looking into the prediction of blast waves in the far field. The same study was performed with a variation in grid resolution, including 1m and 2m uniform grids, as well as 2 scenarios with 1m grid in explosion region being stretched to 2m and 4m respectively outside the explosion region. The conclusion from the study was that the stretching of the grid to 2m (and to some extent 4m) did not change the predicted far field pressures significantly. A change from 1m uniform to 2m uniform grid had a more significant effect.

Olav R Hansen commented the study as very interesting. The difference between 1m uniform and 2m uniform could be understood, as the 2m uniform grid resolution is not satisfactory to resolve the explosion region according to FLACS guidelines, and this would also lead to a difference in time steps which could influence the results. The approach of simulating the inner explosion with a 1m grid (which is OK according to guidelines) and then stretch grid outside was very interesting. According to

the blast propagation grid requirements guidelines a maximum grid size of 10% of GASVOLUME$^{1/3}$ is recommended (which here will mean around 2m), but guidelines also state that grid resolution up to 20% of GASVOLUME$^{1/3}$ (here 4m) may give satisfactory results. This was confirmed in this study. The study may lead to modified guidelines from GexCon in future, in which the requirement of no stretching of grid when doing blast calculations may be modified to allow some increase of grid cell size outside the explosion region.

Stian Høiset asked how the panels were defined, if the panels were too large and along the propagation direction (e.g. roof panels) this would reduce the quality of blast predictions due to some smearing. It was confirmed that the panels were relatively small.

All simulations presented above used the new STEP = KEEP_LOW option in FLACSv8.1 to reduce smearing of pressure waves in the far field due to increased time step when explosion calms down.

Francesco Chille presented a study of shock wave propagation, using three different tools Abaqus, Plexis3C and FLACS. His conclusion was that the three tools produced similar results in shock-tube benchmark tests, and the results were also consistent with analytical solutions. A study for a 3D situation was also shown. Francesco concluded that results were similar, but the ease of using FLACS made this the more attractive alternative.

Alexandre Brigadeau asked whether the grid resolution should have been somewhat higher in the 3D case presented, and this was confirmed by Francesco Chille. Reason for low resolution was to be able to compare software output.

There was a brief discussion on alternative ways of setting up such simulations on, as well as choice of CFL number.

# 3. FLUG meeting part

**Minutes**
Chris Savvides went through the minutes from last meeting.

It was asked whether the FLACS training course job files could be uploaded to the FLUG web-pages, this was confirmed that could be done by GexCon.

Malika Barmasse-Madoui also commented on the need for regular bug-reports. Olav R Hansen responded that GexCon would aim for regular communication of this. Ways of communicating that would force the FLACS users to enter the web-site more frequently were suggested.

Minutes were accepted.

**FLACS porting to QT**
Idar Storvik presented activities on the porting of FLACS to QT. This would give the possibility to use FLACS both under Windows and under Linux operating systems. The porting process is ongoing, and GexCon is investing significant resources into this. Our subcontractor shall provide a ported version of FLACS interfaces by Easter time 2007, and it is expected that GexCon will provide a new release of FLACS based on this within June 2007.

Andreas Obrist asked about the possibility to exploit new 64-bit dual core processors. Idar responded that parallel computing is not utilized in FLACS, however in most cases a study will consist of several simulations, and in these cases two calculations can run side by side on a dual core processor. Idar also mentioned that it was not sure how quickly FLACS would be able to benefit from the faster operations available with 64-bit processors, however the potential higher efficiency was generally only of the order 20-30%.

Chris Savvides asked whether the existing users would get access to the windows version of FLACS when available. Olav R Hansen responded that existing users probably would prefer to continue with the Linux version due to expected higher flexibility, however, that the idea was that users should be able to choose between Windows version or Linux version. Exactly how the licensing of this would be organised would further depend on how well the Windows license manager could communicate with the Linux license manager. If this communication will be seamless, a user should be able to choose whether to access FLACS through Windows or Linux platforms, with less good communication between the platforms, the pricing of Windows would have to be different.

**Bugs**
Idar Storvik gave a presentation about reported bugs. The reported improvements in FLACSv8.1r2 released this summer were not discussed too much, as this was presented at the previous FLUG-meeting. It was mentioned that a bug in Pasquill-class A, B and C turbulence had been improved (but not distributed yet). Too high turbulence will be defined in current and previous versions for unstable Pasquill classes. A new option of the wind-gust was also implemented, which took into account higher sigma-theta values for unstable atmospheres, which gave more meandering of the wind for unstable compared to stable Pasquill classes.
Other bugs to be mentioned was the inert gas effect on combustion, in the current version a somewhat too high flame speed reduction effect will be predicted when diluting with nitrogen, water vapour or $CO_2$.
A bug in the leaks of FLACS-INERT and DESC has been repaired.
It was also mentioned that problems still exist with grid cells less than 1cm (too high turbulence generation), as well as other scenarios where turbulent length scale is significantly larger than grid cell sizes (e.g. refined grid in dispersion calculations).

**FLACS-II training course:**
Olav R Hansen mentioned that there had been several requests for a FLACS-II training course. He mentioned that the old FLACS-II training course was somewhat updated, parts of the training course was now included in the FLACS-I course, other parts were no longer relevant or recommended practice. It was concluded that GexCon should develop a FLACS-II training course including more advanced use of FLACS. Some of the training course could be “home-work” prior to the training course (e.g. Round-Robin tests in which GexCon define a scenario and ask the different participants to calculate blind and present results). It was decided to have a FLACS-II training course prior to the next FLUG-meeting in Bergen scheduled May 3-4 2007. The training course will likely start lunch-time May 2 or in the morning May 3, 2007.

**Presentations from Users:**
Jan Roar Bakke presented some work with dispersion calculations and evaluation of explosion pressure from dispersed clouds. He showed comparisons of explosions in actual cloud, in stochiometric “Q5”-cloud (now Q9 is recommended), in stochiometric cloud with same volume as flammable cloud, and finally with stoichiometric cloud with same volume as gas cloud above lower flammable limit. The study confirmed that the approach using a stoichiometric Q5 cloud gave a very comparable pressure prediction compared to exploding the dispersed clouds, whereas the conservatism was much higher when the flammable cloud volume or gas above LFL were replaced by stoichiometric gas clouds. This study was performed in a typical “tunnel” geometry from an oil and gas platform.

Chris Savvides presented a study in which AutoReagas simulations had been compared to FLACS simulations for a realistic onshore plant. The conclusion was that significantly higher overpressures were observed with AutoReagas than with FLACS. The geometry was “unconfined” with a limited degree of congestion. As a sensitivity study, the congestion level was gradually increased by adding pipes to the geometry. For AutoReagas, this led to practically no increase of explosion pressure (despite an increase of “pipe-length” of a factor of 6), whereas for FLACS the increased congestion had a significant impact on the explosion pressures.

Jan Roar Bakke commented that the trends seen for FLACS with higher pressure for centre ignition at low pressures, and opposite effect with higher pressures were consistent with observations from BFETS full scale project.

Olav R Hansen commented that he had heard of similar situations before, in which AutoReagas predicted much higher pressure than FLACS for low confinement/low congestion situations. Olav did not believe in the high pressure level or trends (no pressure increase with significant increase of congestion) seen with AutoReagas. He mentioned that some of the explosion experiments done with HSE Phase 3A rig were comparable in dimension and congestion level to the most congested example. And with a ceiling these experiments gave similar pressure values as the much less congested Autoreagas simulations did without a confining ceiling.

Olav R Hansen presented some simulations done in a recent project at GexCon. These were methane tunnel simulations. The client had wanted GexCon to perform blind simulations of previous tests in a tunnel system, and 6 different blind simulations of methane clouds from 3m to 18m length, with different ignition point and different tunnel complexity were modelled blind. Olav R Hansen presented overpressures curves from blind simulation and experiments, maximum pressures ranged from 0.2 barg to more than 1 barg in the different tests. He was very satisfied with the performance of FLACS as all these 6 different explosion test scenarios were blind predicted with an “error” in overpressure of less than 10%.

Olav R Hansen also presented current activities on dispersion modelling, including work with hydrogen jets and tracer releases at Manhattan. For very buoyant (and dense?) releases it was concluded that the FLACS guidelines that the expanded leak shall cover at least 50% of the control volume cell should maybe be made stricter. In some recent hydrogen tests simulated, it was necessary to refine the grid so that the leak covered 80-90% of the cell where it leaked in order to get good results, and for buoyant jets it may also be important to refine along the jet axis (not only across as stated in the main guidelines). This issue is mentioned in the FLACSv8.1 release notes from 2005. Another issue currently studied at GexCon is to what extent the mixing is underrepresented in high pressure jet releases with hydrogen. Recent simulations of some high pressure release experiments (40-200 barg) may indicate to high concentrations along the jet axis (i.e. too low spread of jet).

Aamund Langelid presented some work and tools of DNV, and how FLACS could be used in combination with DNV-Express for risk assessment work. He mentioned that one of the challenges with such risk assessments is the simulation time required for FLACS dispersion calculations.

Didier Batherosse asked for the inclusion of toxic dose exponents (k-factor). It was confirmed that this could be possible, but also concluded that these factors are not exact, and may vary from country to country, so that one would need a flexibility to define them at start of calculation.

Batherosse also asked about the possibility to plot line contours, and it was confirmed that this was possible, but it was indicated that Flowvis would not label the values at the contours (A check after returning home revealed that values at the contours can actually be obtained with Flowvis).

Due to time constraints, no discussion on future R&D priorities was performed, but opinions are always welcome to GexCon.

**Any other business:**
It was mentioned by some users that they would like to see an upgrade of the manuals. Olav R Hansen explained that currently one should look at the training course handout and examples (most of this can be downloaded from web-pages) first, and thereafter recent release notes and then the somewhat outdated manual. We have plans to include some guidance in the ported CASD version, however, this may not be in the first release. Olav mentioned that when prioritising between further development and bug-fixes or improving manuals, the latter has been given a lower priority. GexCon will however consider whether it is feasible to improve and update the manuals.

Olav R Hansen also mentioned that GexCon would be present at several conferences next spring, including US AIChE Spring meeting in Houston April 22-26, a Fire and Explosion Conference in

Edinburgh same week, the Loss Prevention Symposium in Edinburgh in May 22-24, and the International Conference on Hydrogen Safety in San Sebastian September 2007.

**Next meeting:**

- The next ordinary FLUG meeting will be held in Bergen, Norway, May 3-4, 2007. There will likely be a FLACS-II training course prior to the FLUG-meeting.
- There will also be a US FLUG meeting planned in Houston in connection to the AIChE Spring Meetings, the date for this is likely April 26, 2007.

**Actions:**

- GexCon should improve the communication to users about bugs, when required bug-reports should be issues.
- GexCon should upload simulation files from example cases of FLACS-I training courses at the FLUG area.
- GexCon will develop and organize a FLACS-II training course prior to the FLUG-meeting May 2-4, 2007.