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FIRE MODELING WITH CAD/GE1 TECHNIQUES

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ABSTRACT

Innovative building designs have been implemented in many Asia Pacific countries over the past two decades, such as airports, exhibition centres, large scale shopping malls, subway stations, etc. In particular, large scale or special projects might not be complied with local building / fire safety codes or practices. Fire engineering is an acceptable approach to justify fire and life safety design safety in comparison with code compliance cases. Fire Dynamics Simulator (FDS) is one of the Computational Fluid Dynamics (CFD) codes that are widely accepted by many local fire authorities in this region for smoke control study purpose. The 3D FDS simulation result visualization could give the general idea of smoke behaviour under different fire scenarios to the stakeholders. Nevertheless, due to the use of Cartesian grid, the 3D model used may appear a bit rough and difficult for the general public to understand, in particular on minor architectural details such as the features geometry of buildings roof. Increasing the grid density to capture such geometrical details could improve the visualization but would undoubtedly result in a huge demand on computational resource requirements.

To balance the visualization demand and simulation resource, starting from FDS Version 4, 3D CAD/GE1 model could be embedded directly in Smokeview to enhance the result visualization. However, information provided in the FDS manual regarding this approach is limited. Based on years of research, testing and project experience, by using the same 3D CAD files, a systematic approach has been developed for the 3D CAD/GE1 model and computation grid generation. This paper outlines this approach by using PyroSim. Several project examples in the Asia region will also be included to illustrate the benefits of the method.

INTRODUCTION

In Asia Pacific Region, many new infrastructure and development projects are under construction or design. Some of them have spectacular architectural design and some of them have huge coverage. Due to their own design nature, these new projects may not fully comply with the local building / fire safety codes. Fire engineering approach is an acceptable way to justify the project's fire and life safety provisions. In most cases, smoke control analyses should be provided. Fire Dynamics Simulator (FDS) is one of the well accepted CFD codes for simulating the smoke behaviour and the tenable environment during fire scenarios. FDS is probably one of the easiest tools to use and the CFD codes are available for free. It has been widely adopted in fire engineering analysis since its first release in 2000.

Visualization and post processing are a critical process for CFD result interpretation. General public can only understand the CFD results from the output after post processing. This is particular difficult for large scale projects with complicated geometries.

Currently, Building Information Modelling (BIM) is getting popular for the owners in Asia Pacific regions. BIM includes a 3D Computer Aided Design (CAD) models and a lot of useful data for the projects. Simulation analysis could enhance the designs. BIM can deliver the designs to different parties in virtual 3D environment. It improves the communication during design stages and avoids service crashes during the construction stages. The owners can save costs from better design and shorter construction period. Authorities can also make use of these 3D images to conduct public consultations. BIM provide additional information for many simulation analysis. Thus modifying directly the 3D BIM model to fit simulation analysis software is much easier than transfer 2D drawings to 3D models. On the other hand, owners and authorities are requesting more geometrical details to be included in the analyses models to improve the realistic level.

The Cartesian grid system used in FDS cannot capture curves or detailed geometries in great details or else very fine mesh would be needed, which makes computer hardware and simulation time become the bottle neck. To achieve a timely project delivery for FDS simulations and the good visualization of the results, using 3D CAD/GE1 (Smokeview geometric description file) model to display the 3D model in the post processing program Smokeview, is one of the suggested solutions.

In this paper, the outline approach of using 3D CAD/GE1 for post processing will be introduced. Samples from several fire engineering projects in Asia Pacific Region will be used for demonstration. They cover road tunnel, transit tunnel / station, and a museum.

3D CAD/GE1

Converting CAD to FDS

3D models of buildings or infrastructures can be created from BIM programs, such as Google SketchUp or various CAD programs. Programs for converting 3D model to FDS model could be used, namely "3dsolid2fds", "acad2fds", "dxf2fds", PyroSim, etc. The meshing process will generate the Cartesian grid based on the 3D CAD model. The grid arrangement is a major issue for the accuracy of FDS simulation.

According to the User's Guide for FDS, Kelvin M *et al.* (2010), the accuracy of the grid is given by the non-dimensional expression D^* / δ_x where D^* could be found in following equation:

$$D^* = \left(\frac{\dot{Q}}{\rho_\infty c_p T_\infty \sqrt{g}} \right)^{\frac{2}{5}} \quad (1)$$

Form the above equation, the grid resolution sensitivity depends on the fire source instead of the architectural length scale. Therefore, there is not necessary to adopt an extreme fine grid to capture the non-essential architectural details which would have no effect on the simulation result. For proper FDS analysis, appropriate grid arrangement based on proper the level of geometrical details must be adopted.

3D CAD/GE1 Model

In the Smokeview User's Guide, Glenn.P *et al.* (2011), realistic geometric data can be represented in CAD/GE1 file. The CAD/GE1 file is in ASCII text format. It uses FORTRAN code segments for naming convention of associating variables. The program "dxf2fds" was written by David Sheppard of the US Bureau of Alcohol, Tobacco and Firearms (ATF). When converting a "dxf" format CAD file to a FDS version 4 input file, it will also generate a Smokeview geometric description file (.GE1). The GEI file has the same geometric details as the CAD file and independent to the FDS mesh. It is a "dummy" geometry file. The CAD/GE1 can be displayed in Smokeview under manual "Show" → "Geometry" → "Obstacles" → "Locations: CAD". In fact, the detailed buildings geometries can be included in GE1 models with no relation with the FDS computational domain.

Creating a GE1 file is not easy because all geometry coordinates need to recode in text format. There is an example in Smokeview User guide which showing the x, y and z coordinate of a quadrilateral obstruction. The four corners of the quad must lie in a single plane and they should be ordered in counter-clockwise direction. Preparing the 3D model in a computer graphical environment and convert it to GE1 format should be a more practical way for the complex geometries for projects.

"dxf2fds" can converts FDS input file to GE1 files. However, some extra efforts for "repairing" the 3D model are needed because some extra unoccupied surfaces will appear in FDS model and it will be more difficult to identify the individual surfaces in the FDS input file. Moreover "dxf2fds" only works for the FDS Version 4, but not in the latest version.

Today, PyroSim can fully convert the "dxf" file to FDS input file and GE1 model. Parsons Brinckerhoff Hong Kong Office has been using Pyrosim since 2007.

FDS Simulation and Post Processing

Making good CAD/GE1 models enhance the communication between the engineer and the client by presenting a more detail architectural geometries. The objective for FDS simulations is to analyze that smoke control system can provide a tenable environment during evacuation. Therefore, different fire scenarios or operations should be considered. In addition, Equation 1 should be applied to specified an appropriate grid size. The normal working flow for handling large scale complex geometry projects is shown as following:

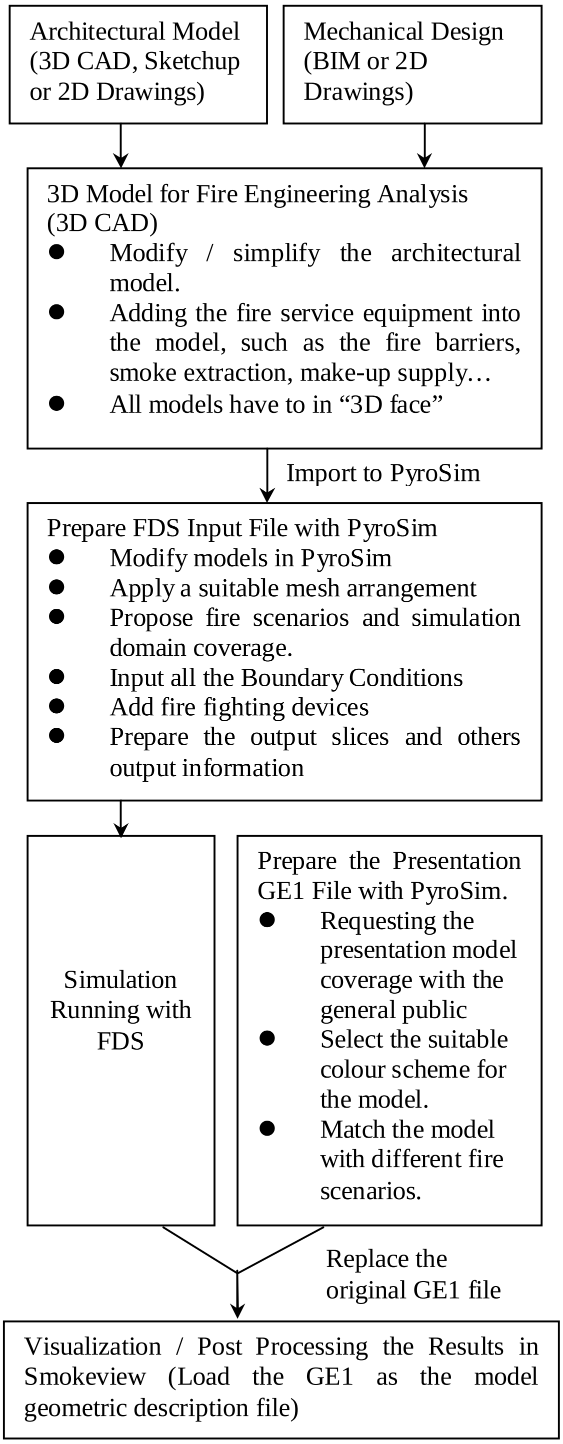

Chart 1, flow chart of a fire simulation construction process

From the above flow chart, there are two models for the simulation: FDS model for simulation and the other "dummy" CAD/GE1 model with all architectural details around the FDS model.

With this approach, the FDS simulation time will become manageable. "Dummy" CAD/GE1 model can be prepared during the simulation. It should be noted that both models need to use the same coordinate system. In addition, the GE1 file name needs to be included in FDS input file before the simulation starts. The GE1 file could be replaced and updated anytime when using Smokeview for post-processing.

PARSONS BRINCKERHOFF PROJECT REFERENCES

A Museum in Taiwan

A museum for displaying the Sarira was designed in 2006. 3D CFD simulation technique was used to analyze the HVAC (Heating, Ventilation, and Air Conditioning) system and fire services design for the main exhibition hall.

FLUENT was adopted for the HVAC system simulation and FDS was used for the fire simulation. The shape of the exhibition hall was like a sphere and the Sarira was located at the middle tower inside the sphere. A complete 3D Max model was provided for the analysis. Therefore the FDS geometrical model was generated with "dxf2fds". Figure 1 and Figure 2 illustrate the FLUENT and the FDS models, respectively.

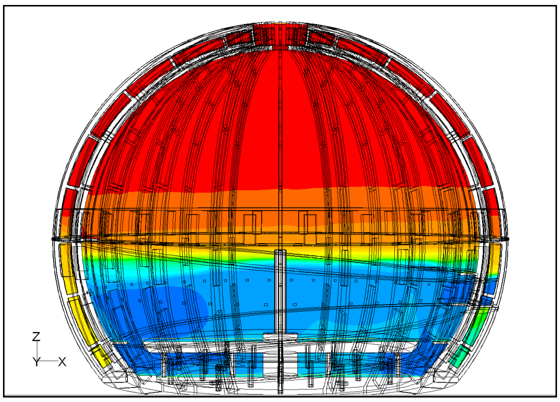

Figure 1, HVAC Analysis for a Taiwan Museum by using FLUENT

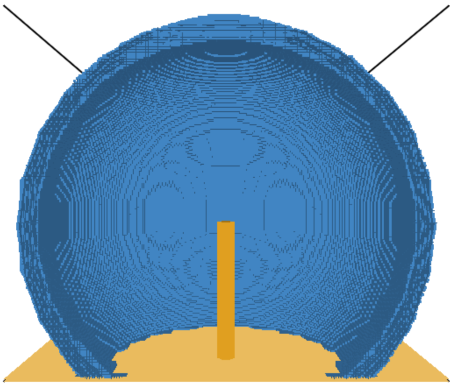

Figure 2 , FDS Geometrical Model for the Museum

Large Scale Hub Station in Hong Kong

Parsons Brinckerhoff was leading the building services system design for the expansion of a large interchange station in Hong Kong. The existing station concourse would be modified for the new line. The original concourses design could not fully comply with the current local fire safety codes. In order to demonstrate that the proposed fire safety provisions could achieve the fire and life safety objectives, over 15 fire scenarios have been analyzed.

The station was designed with the use of BIM. 3D BIM model with detailed architectural and engineering components were included. Figure 3 illustrates the station BIM model (exterior and interior).

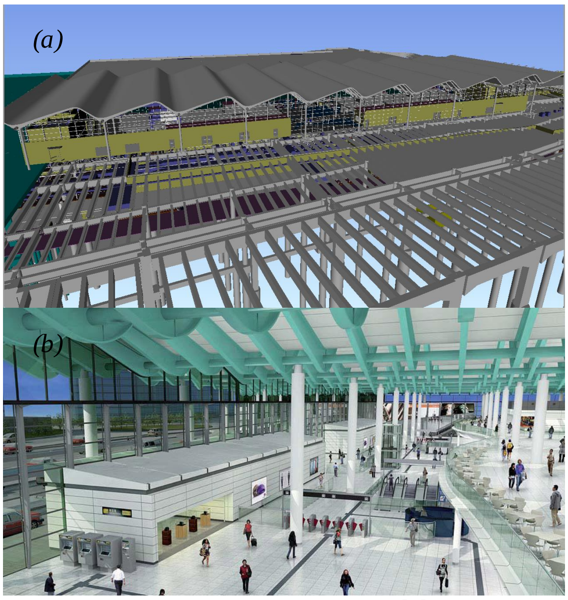

Figure 3, Station concourse BIM Model. (a) Exterior View; (b) Interior View

The coverage of the station concourse domain was approximately 160m x 120m x 15m. In the study, whole concourse needed to be covered by a FDS model. Detailed geometries including the roof features were included. From the smoke control point of view, the detailed curved shape of the existing roof is not a critical parameter. The FDS model only needed to capture the major architectural features.

In this project, 3D CAD was converted from the BIM model. The FDS and GE1 models were prepared by PyroSim. According to the design fire load, 0.4m x 0.4m x 0.4m grid cells were adopted. The total mesh number for each fire scenario was approximate 3.8 millions. The detail of the roof and some other architecture features were presented in the GE1 model. Figure 4a and Figure 4b are the comparison on the geometrical models between the FDS and "dummy" CAD/GE1. Obviously, the GE1 geometrical model was close to reality and one could correlate the fire scenario with the virtual BIM model.

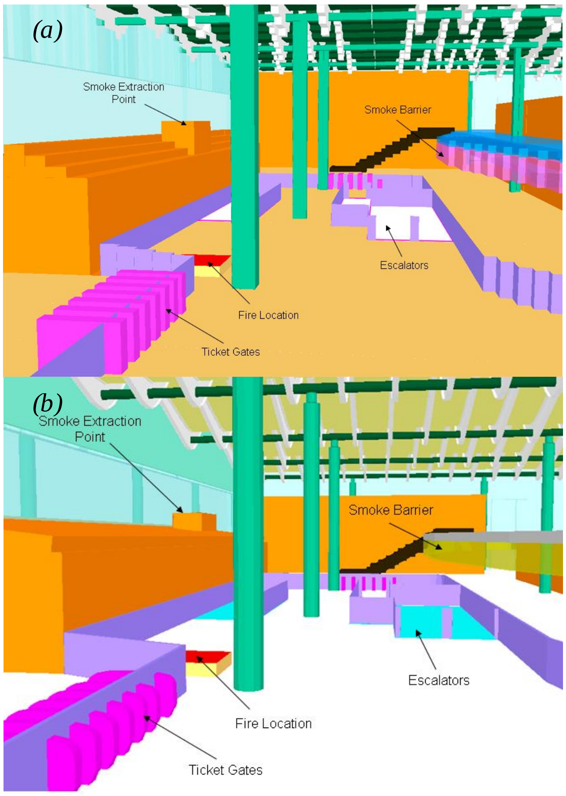

Figure 4, Station Concourse Model. (a) FDS Geometrical Model; (b) CAD/GE1 Geometrical Model

Smokeview can present the FDS simulation results with and without the CAD/GE1 model. The CAD/GE1 model also can be "clipped", "hidden" and edited in Smokeview. It is same as the normal FDS model. Figure 5 shows the comparison for 3D Smoke Soot Mass Fraction in both models.

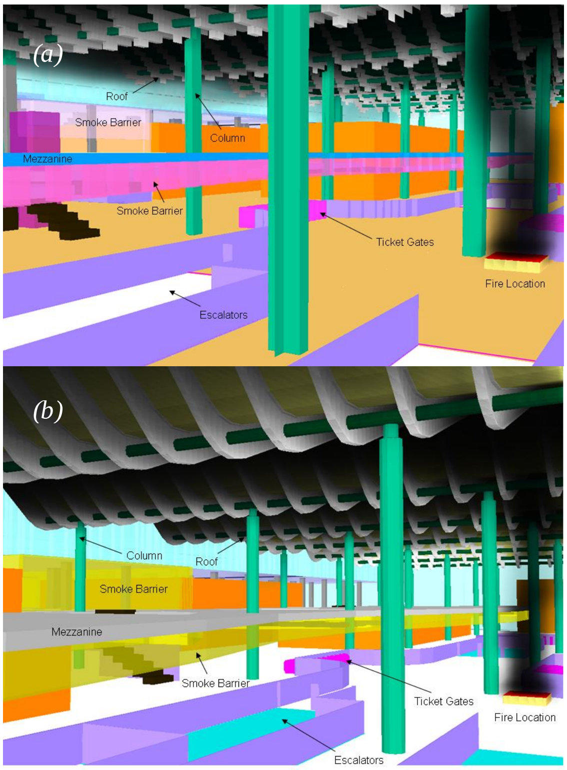

Figure 5 3D Smoke Presentations for HUH Station Concourse. (a) FDS Geometrical Model; (b) CAD/GE1 Geometrical Model

CAD/GE1 helped a lot in the successful delivery for this project. Without the "dummy" refinement model on the roof, the cost of simulation duration was going to be unreasonable. Also as the GE1 model had no relation with the real FDS model. It could be edited during or after the simulation. If the changes has no influences on the smoke control system, only GE1 model need to be modified. Time and cost can be saved without re-run the simulations.

<u>Platform and Fan Track Area For High Speed Railway</u>

In June 2011, Parsons Brinkerhoff conducted a fire engineering study to analyse the smoke control system for one of the largest multi-track underground platform and fan track area in Asia. The total area of track fan area and platform area is around 800m x 200m. Figure 6 illustrates the overall CAD/GE1 model for the platform and track fan area.

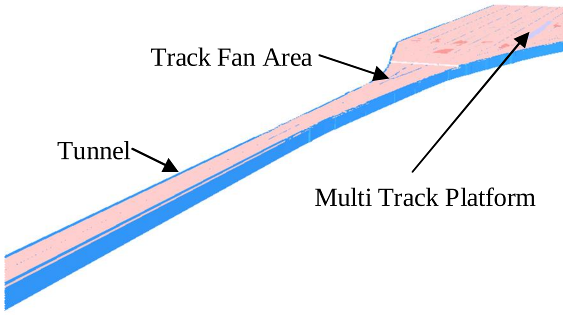

Figure 6, Overall Model for Platform and Track Fan Area

The fire simulation scenarios included a 22MW fire occurred on an Electric Multiple Unit (EMU) / train and the EMU was fully or partly occupied a station trackway. The smoke generated from the EMU fire should be captured by the smoke extraction points such that the passengers can be evacuated safely to station/tunnel. Fire scenarios also covered EMU stopped in different area inside the platform or track fan area. When an incident EMU stopped in Track Fan Area, extraction slots would capture the smoke. When the incident EMU stopped in platform, Over Track Extraction (OTE) would capture the smoke and Under Platform Supply (UPS) would provide addition make up air.

The FDS model for each scenario covered a full train length which is over 400m length. The width of the FDS model in each scenario depended on the fire compartment. The height of the track fan area and platform are around 10m. In each fire scenario simulation, there were two types of grid configurations. The size of grid around the incident fire region is 0.2 x 0.2 x 0.2m and the sizes of grid in other domains are 0.4 x 0.4 x 0.4m. The total mesh number for each scenario was less than 3.7 millions. The boundary condition was calculated with SES (Subway Environment Simulation) and matched the ECS (Environmental Control System) design. Also the arrangement inside the track fan area was complicated. There were track crossovers connect to different platforms. Therefore, a "dummy" GE1 model was applied for presenting the geometry model.

The FDS models look like something build with "Lego" in this project. The grid cell size will simplify all curvy geometries at the crossover. When grid cell size could not be refined further due to computational resource consideration, CAD/GE1 would be an option for better model presentation. Figure 7 & Figure 8 are the comparisons between FDS model and GE1 model.

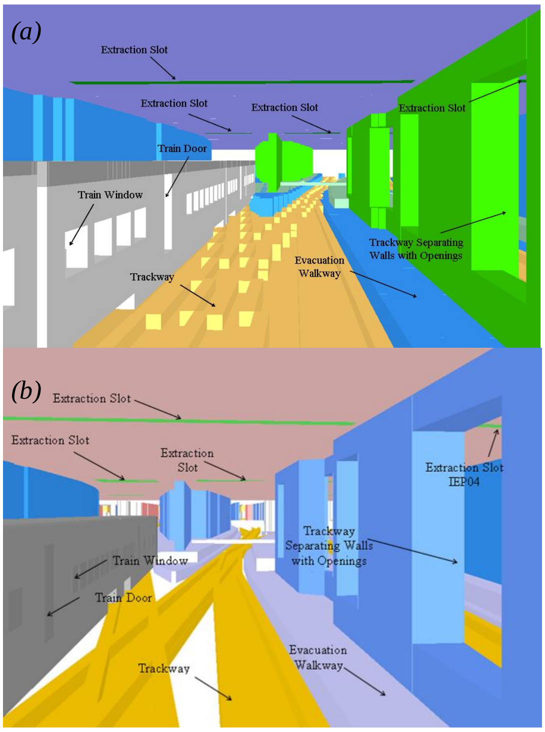

Figure 7, Crossovers in Fan Track Area. (a) FDS Mode; (b) GE1 Model.

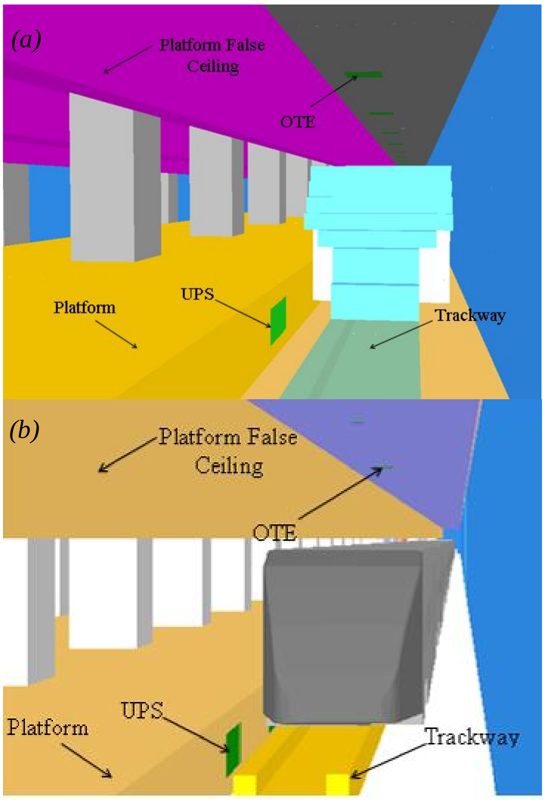

Figure 8, Platforms Fan Track Area. (a) FDS Model; (b) GE1 Model.

CONCLUSION

CAD/GE1 is not a new technique in engineering and simulations. It was introduced since FDS Version 4. 3D models for projects are currently very common. PyroSim provides a platform for converting 3D CAD to a "dummy" GE1 model which is independent from the FDS computational mesh. With GE1 model, the quality of geometrical model presentation would be improved significantly. And detailed architectural features could be presented in Smokeview. The GE1 model can be edited at anytime, so it can avoid spending computer time on re-running the FDS simulations due to updating unimportant geometrical details.

When a CAD/GE1 model is adopted into a FDS simulation, the following items are the key issues that might help to achieve project successes.

- Separate the major and minor features for the geometrical model.
- A proper computational mesh and domain.
- Add the GE1 file description inside the FDS input file before the simulation start.
- Make sure that proper model setting and Boundary Conditions of the FDS simulation are adopted.
- Using the same x, y, z coordinate with FDS model and CAD/GE1 model.

All in all the CAD/GE1 is a model that can display inside Smokeview. It cannot improve the FDS simulation accuracy but merely improve the geometric presentation. CAD/GE1 models help a lot on the communication between various parties. With the third party FDS per-processing software, PryoSim, CAD/GE1 can be generated automatically. CAD/GE1 is very helpful and user friendly during the post processing for the FDS analysis.

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