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# Development of a GUI-Based Simulation Tool for Overpressure Distribution Assessment of Explosions in Nuclear Power Plants

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## 1. Introduction

Following the Fukushima accident, the risk of hydrogen generation and explosion within nuclear containment buildings has become a central issue in nuclear safety. Hydrogen explosions generate high-energy shock waves in a short time, causing significant overpressures that may damage structures, disrupt safety systems, and trigger secondary accidents. For effective safety evaluation, it is essential to predict both the magnitude and spatial extent of overpressure propagation.

This study aims to address this need by developing a GUI-based simulation tool that evaluates the overpressure distribution of hydrogen explosions in nuclear power plants. By integrating simplified physical models into a user-friendly interface, the tool enables rapid assessment of hydrogen explosion impact ranges and provides valuable insights for safety design and emergency preparedness.

## 2. Methodology

### *2.1 Physical Model*

The combustion enthalpy of hydrogen (approximately 120 MJ/kg) was compared to the detonation energy of TNT (4.184 MJ/kg) to estimate the equivalent TNT mass. From this equivalence, the peak overpressure as a function of distance was calculated using a simplified surface burst scaling law. The temporal variation of the pressure was modeled by applying the Friedlander decay function, which reproduces the characteristic waveform of explosion-induced shock waves.

### *2.2 Simulation Framework*

The simulation tool was implemented in Python and features the following functions[Fig.1]:

(1) 1D Graphs: Instantaneous overpressure distribution and cumulative maximum overpressure as a function of distance.
(2) 2D Contour Maps: Overpressure contours on the XY plane, allowing visual analysis of spatial pressure gradients.

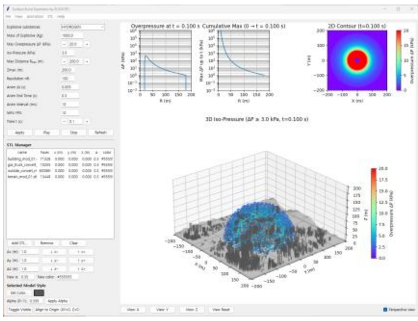


Fig. 1. User Interface (UI) Snapshot

(3) 3D Scatter Plots: Iso-pressure regions represented as point clouds for spatial evaluation.
(4) 3D Iso-Surfaces: Constant overpressure regions visualized as continuous surfaces for blast boundary identification.
(5) STL Integration: Import of building and terrain geometry through STL files, enabling impact assessment under realistic plant conditions.

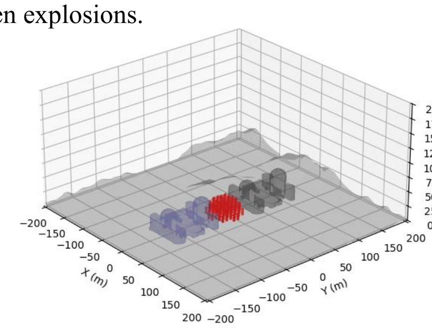
## 3. Results and Discussion

### *3.1 Temporal Evolution of Overpressure*

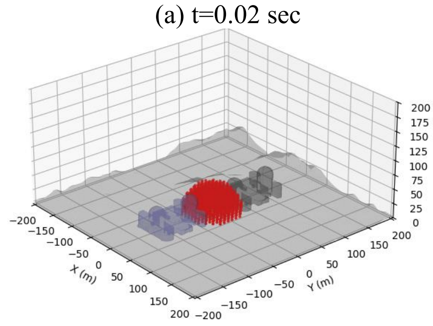
Figure 2 shows the propagation of overpressure with time after the explosion (Hydrogen mass: 1,000kg). At t = 0.02 s, a highly concentrated pressure field appears near the explosion center. By t = 0.05 s and t = 0.09 s, the shock wave has rapidly propagated outward, forming spherical fronts. Finally, at t = 1.5 s, the overpressure is significantly reduced, with only a few kilopascals observed at far-field distances.

### *3. 2 Instantaneous Overpressure Distribution*

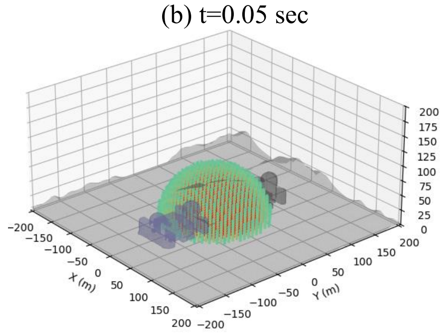
Figure 3 presents the instantaneous overpressure distribution as a function of distance. Within a few meters of the explosion center, overpressures exceeding several hundred kPa are observed, while the pressure decreases sharply with distance. These results provide insight into the localized yet intense destructive capability of hydrogen explosions.



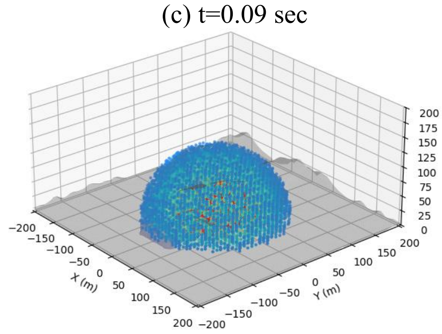

(a) t=0.02 sec




(b) t=0.05 sec




(c) t=0.09 sec




(d) t=0.15 sec

Fig. 2. Temporal propagation of overpressure

### *3.3 Maximum Overpressure Distribution*

Figure 4 shows the maximum overpressure recorded up to a given time for different distances. Peak values near the explosion center reach tens of megapascals (MPa), while distances of tens of meters still experience several kilopascals of overpressure. This information is critical for evaluating the structural safety margins of containment buildings and auxiliary systems in nuclear power plants.

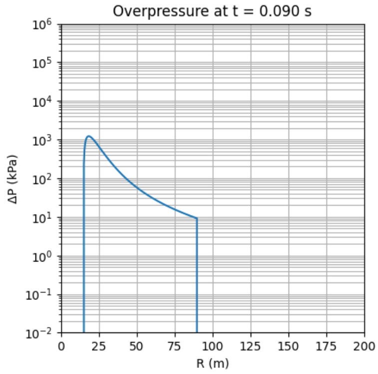
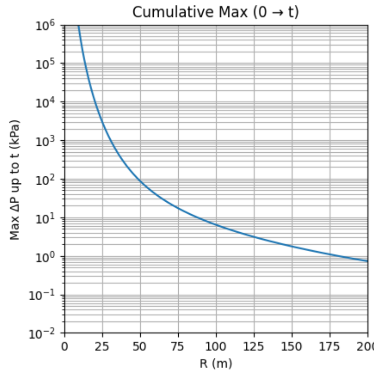



Fig. 3. Instantaneous overpressure distribution as a function of distance




3D Iso-Pressure (ΔP ≥ 3.0 kPa, t=0.220 s)

Fig. 4. Maximum overpressure distribution as a function of distance

## 4. Conclusions

This study developed a GUI-based simulation tool for the assessment of overpressure distribution resulting from hydrogen explosions in nuclear power plants.

Although based on simplified physical models, the tool provides fast and intuitive visualization of temporal and spatial overpressure characteristics. The ability to integrate STL geometry enables impact evaluation under realistic structural configurations, making the tool particularly useful for preliminary safety assessments and emergency response planning.

Future work will focus on validating the tool against experimental data and advanced CFD analyses to improve its reliability. Ultimately, the tool may serve as a practical decision-support system for hydrogen safety management in nuclear power plants.

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