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## Finite Element Simulation of Nuclear Blast Waves with Time-Varying Source Energy: Mathematical Modeling, Algorithm, and 3D Visualization

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This research paper introduces a finite element simulation approach to investigate the characteristics of nuclear blast waves, considering time-varying sources. The simulation methodology is founded on the blast wave equation and employs numerical techniques to solve for the temporal evolutions of pressure distribution. Notably, the model incorporates a time-varying source term denoted as  $S$ , facilitating the simulation of nuclear explosions with dynamically changing intensity within a localized range around the epicenter. This capability allows for the estimation of the blast's destructive potential by examining the resultant vacuum formation. The paper offers a comprehensive exposition of the mathematical formulation underlying the simulation model, accompanied by its implementation algorithm in Python using finite element computation. Moreover, the study encompasses a numerical calculation that explores the blast energy as a function of the source term, enhancing the understanding of blast dynamics. The results are presented as 3D color-coded plots, enabling a clear visualization of the pressure distribution across a defined distance and its temporal evolution. Notably, the plot provides insights into the formation of a vacuum in the vicinity of the blast epicenter. Furthermore, the discussion section critically examines the scope and limitations of the computational process, offering valuable insights into the accuracy and applicability of the model. This thorough evaluation enhances the understanding of the model's capabilities and computational constraints. By offering a powerful simulation tool for comprehending the behavior of nuclear blast waves, this study contributes to the field of disaster response and preparedness. It equips researchers and practitioners with valuable insights that can inform effective strategies and decision-making in mitigating the impact of nuclear incidents.

**KEYWORDS:** Index Terms—blast wave, finite element method, nuclear blast, pressure disturbance, simulation, time-varying sources, wave equation.

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