CATASTROPHIC DOMINO EFFECT DUE TO PROJECTION OF STRUCTURAL FRAGMENTS GENERATED BY INNER EXPLOSIONS OF TANKS AND VESSELS

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The domino effect related to the projection of fragments in an industrial environment occurs when an element of a system, such as a chemical vessel, undergoes catastrophic fragmentation as the result of an explosion. The high-velocity fragments then impact and damage neighboring systems, which then leads to other dangerous scenarios such as loss of containment, fires or even other explosions. Of all industrial accident scenarios, those involving throwing of fragments have the greatest range from the accident point, well over 1 km. This process has been seen in several major accidents worldwide. In this work, this domino effect scenario was studied in three steps: fragment generation, trajectory calculation and impact damage. In the first step, fragmentation patterns were studied using numerical simulations. For this, the inner explosions of 100 stainless steel 304 vessels, with spherical geometry, diameters between 1 m and 20 m and thickness in a range of 10 mm to 90 mm, were simulated with the software of material dynamics modeling ANSYS-AUTODYN. In this step, the burst pressure of each vessel was estimated with Svvenelson’s equations, likewise, the explosion energy was calculated using Baum’s equations; with this information, the explosion was modeled with an equivalent quantity of TNT. The detonation was simulated using Smoothed-Particles Hydrodynamics (SPH) method and the tank were meshed with a 3D Lagrangian grid. In addition, Mott’s stochastic fragmentation model was implemented in order to simulate a material with heterogeneous microstructure. The probability density functions of mass, velocity and number data of the fragments were obtained as a result of this step. These data were used as input in the second step, trajectory calculation. In this step, 3D kinematics equations were employed to calculate the fragments paths during their flight and the feasible impact regions taking into account aerodynamic characteristics such as drag and lift coefficients. Additionally, the impact probability was estimated for different targets (cylindrical and spherical tanks of several sizes) located at multiple points from the source tank. Finally, in the step of fragment impact damage, Monte Carlo simulations were implemented using an analytic penetration model in order to estimate the damage probability due to one or more fragments that impact a target. The results of this work could be used in the inherently safe design (ISD) of plants and industrial areas in order to minimize the effects of this kind of scenarios inside the plant, in surrounding communities and in the environment.

Key words: Explosion, Inherently Safer Design