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# Computational Analysis of Injection-Velocity Effects on Dynamic Parameters of Unconfined Fuel-Vapor Clouds

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**A computational investigation is performed to study the effects of injection velocity on the main dynamic parameters of the fuel cloud released into the open atmosphere. The volume, shape, and growth rate of the cloud, turbulence intensity, as well as the distribution of fuel concentration, temperature gradient, and self-ignition induction time are the most important parameters determining the mode of combustion that propagates through the cloud. A modified KIVA-based program is employed to fulfill the calculations. Systems of equations are solved by a finite-volume method. The $k$–$\varepsilon$ model and discrete droplet model are applied for modeling gas-phase turbulence and liquid spray, respectively. The fuel-injection velocity is shown to have a major effect on turbulence intensity and uniformity of the cloud. With increasing injection velocity, the detonable part of the cloud rotates sooner and faster, and there is less time for ignition. A comparison with experimental results is performed for validation.**

**Key words: numerical simulation, two-phase flow, injection velocity, fuel–air cloud, detonation.**

## INTRODUCTION

The large number of vapor-cloud explosions in the past, which involved severe damages, clearly indicates the need to consider this problem. Despite much valuable information that has been obtained, many problems still remain unresolved, and there are a lot of serious explosions every year. Preventing such events from happening requires a good knowledge of gas explosion and the way of reducing the frequency and consequence of its occurrence.

One of the best ways of indicating the detonability of a fuel–air mixture is to study unconfined detonation. Special devices are applied to produce and ignite unconfined clouds. They employ small explosive charges to disperse a liquid, or solid, fuel into the open atmosphere (Fig. 1a). When the cloud reaches a suitable size and fuel concentration, it can be detonated by a secondary ignition. A possibility of initiation and propagation of detonation depends strongly on the reactivity of the cloud. Some parameters of the cloud, such as its volume, shape, and growth rate, as well as the fuel type and concentration in the cloud, turbulent flow scales, temperature gradient, and induction time distributions, have a great influence on the degree of reactivity and, hence, on the mode of the propagating combustion wave. In addition, the location of the ignition point and the power and type of the ignition source play a significant role in detonation initiation.

The fuel-dispersion process plays a key role in determining the main parameters of the cloud and, hence, its reactivity. The dispersion mechanism and dynamic behavior of the cloud have to be studied.

Based on the relative magnitude of the inertia and aerodynamic forces acting on the fuel, the dispersion process can be divided into three phases [1, 2]. The first phase is the ejection regime in which the inertia forces dominate over the aerodynamic forces. The sec-

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