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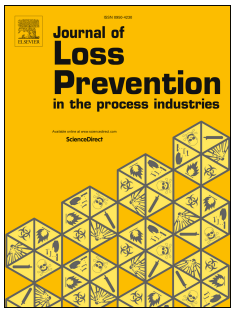

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Influence of Water Droplets on Propagating Detonations

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Abstract

In order to mitigate flame acceleration and detonation in hydrogen-air mixtures, which can lead to the release of harmful radionuclides in severe nuclear plant accidents, water spray systems are being considered. A series of experiments were conducted in a detonation tube filled with hydrogen-air mixtures. It was found that for a water droplet curtain with 215 μm droplets the detonation speed deficit was increasing with increasing size and density of the water droplet cloud, decreasing the speed below the speed of the detonation products. Moreover, as the initial pressure and equivalence ratio decreased, the speed deficit increased and, for the conditions tested, reached up to 16%. For most cases, 215 μm droplets quenched the detonation temporarily but the flow rapidly accelerated back to the initial detonation speed. It was concluded that the quenching effect for 215 μm droplets was limited by relatively fast evaporation time. However, this limitation was found to be partially overcome by the usage of additional injectors to reduce to injection time for a given injected mass of water. In contrast, nozzles giving water droplet diameters of 500 μm enabled complete detonation quenching.

Keywords: *detonation quenching, water droplets, hydrogen, flame suppression*

1. Introduction

In the case of severe accidents in nuclear power plants, an excessive amount of hydrogen can be accumulated as a result of oxidation of overheated zirconium alloy tubes. In order to mitigate flame acceleration and detonation of the hydrogen mixed with air and prevent the release of harmful radionuclides, the potential of water spray systems is investigated.

Water is a primary condensed-phase agent used in fixed fire extinguishing systems due to its thermal characteristics (Grant et al., 2000). The mitigating effect is mainly caused by the extraction of thermal energy via evaporation of the water droplets, which reduces the local flammability of the mixture by the vapor addition and causes a decrease in the oxygen concentration. Water mist fire suppression systems are highly dependent on the application rate and more importantly on the characteristic droplet size of the mist that has to be fine enough to evaporate within the combustion zone (Thomas, 2000).

Fire mitigation solutions incited the interest in the possible usefulness of water spray systems in providing a low-cost, environmentally safe and low maintenance reduction of the explosion overpressures (Catlin, 1993; Wingerden, 1995a). An important finding for the detonation quenching is that water droplet fragmentation under the influence of the impinging shock causes the creation of a rarefaction zone that reduces the shock intensity (Chauvin et al., 2011). However, in order to obtain a mitigating effect, water droplets have to be either very