Mitigation of hydrogen explosions

Introduction

Hydrogen is considered to be an important part of the energy supply of the future and a major driver of the green shift. However, hydrogen is a highly explosive gas. Therefore, safe use of hydrogen is an important research topic.

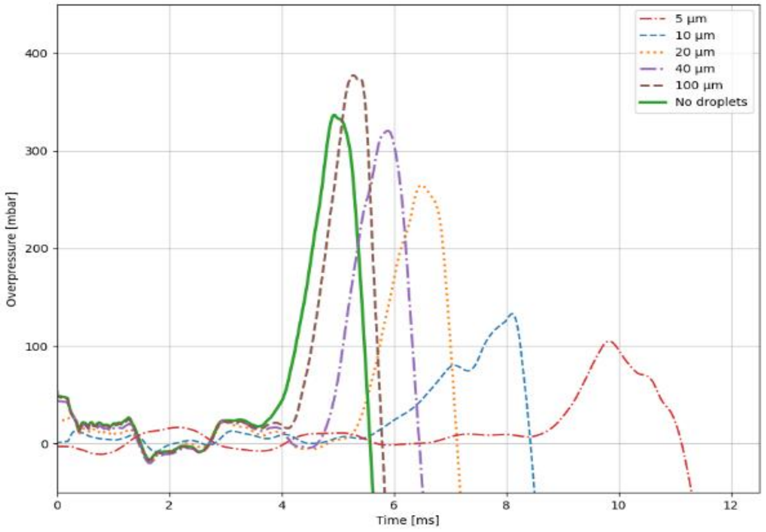
Water spray systems are a possible active fire protection method for mitigation of hydrogen explosions. If water spray is released when leakage of hydrogen is detected, it might prevent explosion pressure build-up. However, models of this are generally not validated, and more research should be conducted. Studies have shown divergent results because of the complex flow of gas explosion interacting with water droplets.

Primary objective

- The main objective is to determine the effect of a distribution of water droplet sizes (polydisperse) on a hydrogen explosion in a computational fluid dynamics (CFD) simulation compared to a monodisperse assumption.

Secondary objectives

- The Open-Source CFD simulation software OpenFOAM and the chemical kinetics software Cantera will be used for the simulations.
- As part of the research project, water droplet injection in the post-flame region will also be investigated.



In the submitted conference paper for ISFEH 2025, monodisperse water spray in a premixed lean hydrogen-air deflagration was modeled in OpenFOAM. The aim was to investigate how droplets of different sizes affect the deflagration pressure and velocity. The model is 2D, the solver is multicomponentFluid, the turbulence model is k-epsilon and the combustion model is Partially Stirred Reactor. The premixed gas cloud is modeled as Eulerian and the water droplets as Lagrangian particles. First, the numerical combustion model was validated against experimental data. Then, droplet sizes ranging from 2-100 µm were injected into the model to explore the effect on flame position and overpressure. The overpressure results are shown in the figure above and revealed that the droplets in the range of 2-40 µm had a mitigating effect on the deflagration, with droplets sized 2-10 µm being the most effective. Droplets sized 5-10 µm increased the flame propagation time and increased the overpressure significantly, while the smallest droplets of 2 µm prevented ignition. Droplets sized 100 µm did not have a mitigating effect, but slightly increased the overpressure.

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- BSc in Mechanical Engineering from Høgskulen på Vestlandet (HVL)
- MSc in Process Technology from USN
- Experience with CFD on both Master's Thesis and Research Project

Estimated progress of the PhD project:

Just started ... **< 50 %** **> 50 %** **Almost done ☺**

Publications

- A. M. Lande, J. Lundberg and M. Henriksen, "Modeling Monodispersed Water Droplets in Hydrogen Deflagration Using OpenFOAM ," The International Seminar on Fire and Explosion Hazards (ISFEH), Rome, Italy, 2025
- A. M. Lande and J. Lundberg, "Summary of mechanisms of water droplets in hydrogen deflagration," Nordic Flame Days 2023, Trondheim, Norway, 2023

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