Experimental and Numerical Study of Hydrogen Gas Explosions with a Focus on Deflagration-to-Detonation Transition

Introduction

The global shift to ***low-carbon energy*** is vital for addressing ***climate change***, with ***hydrogen*** playing a key role in the deep ***decarbonization*** of sectors such as electricity production, industrial manufacturing, and transportation. However, ***accidental explosions*** remain a major ***safety*** concern in hydrogen systems, potentially causing severe damage or loss of life. Understanding the physics of such events is essential for implementing safety measures. Since large-scale testing is expensive and resource-intensive, ***Computational Fluid Dynamics*** (CFD) offers an effective alternative for ***assessing explosion consequences***.

Objectives and Methods

- ***Experimental***: Conduct ***systematic experiments*** on gas ***explosions*** using homogeneous ***hydrogen-air*** mixtures in a ***lab-scale*** explosion channel to study ***DDT.***
- ***Numerical***: ***Develop*** a ***numerical solver*** within the ***OpenFOAM*** framework that accurately ***simulates DDT*** on relatively ***coarse computational meshes***.

Research Results

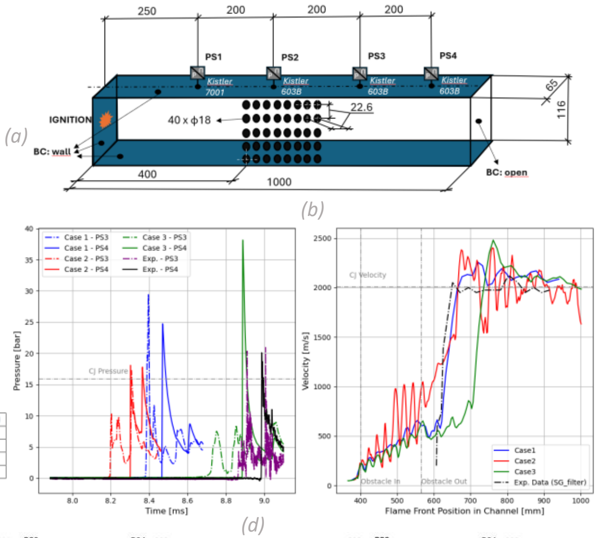
OpenFOAM solver: ***MMXFoam***

Combustion Model:

$$\frac{\partial(\rho b)}{\partial t} + \nabla\cdot(\rho \mathbf{u} b) - \nabla\cdot\left(\frac{\mu_t}{Sc_t}\nabla b\right) = \begin{cases} \rho_u S_u \Xi |\nabla b|, & \tau < 0.99, \\ \rho \frac{1-b}{\Delta t}, & \tau \geq 0.99. \end{cases}$$

DEFLAGRATION
AUTO-IGNITION
DETONATION

$$\frac{\partial(\rho\tau)}{\partial t} + \nabla\cdot(\rho \mathbf{u} \tau) - \nabla\cdot\left(\frac{\mu_t}{Sc_t}\nabla \tau\right) = \frac{\rho}{t_{ind}}$$



Case	Mesh	AMR	Base/Min. Mesh (mm)	Run Time (h)	DDT	$p_{3,max}$ (bar)	$p_{4,max}$ (bar)
1	26 152	Yes	2 / 0.5	21	Yes	29.5	24.7
2	116400	No	1 / 1	40	Yes	17.3	18.1
3	26 152	Yes	2 / 1	5	Yes	9.0	38.1
4	26 152	No	2 / 2	0.75	No	6.4	6.6

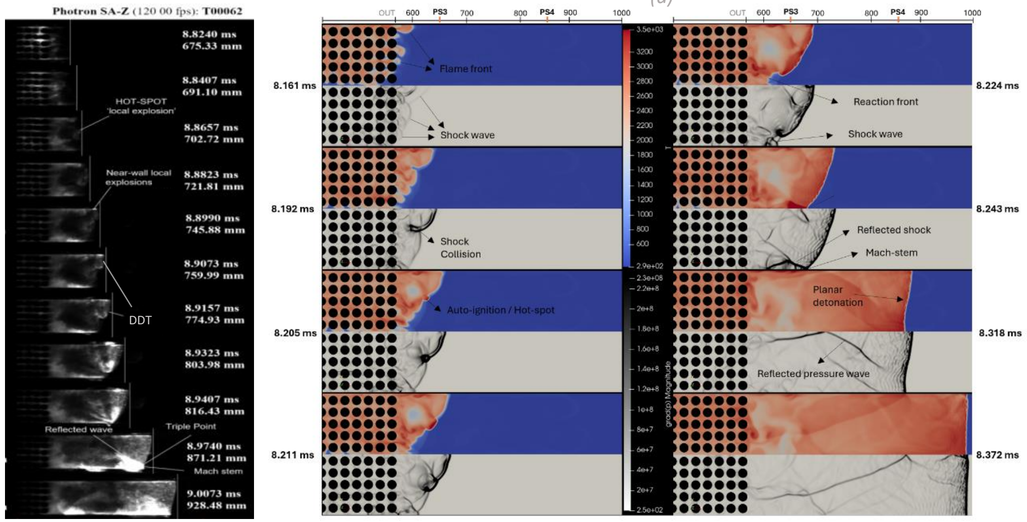


Figure: DDT Study *- (a) Explosion Channel (b) p-t and v-x plots, (c) experimental and (d) numerical results Case 2*

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Related projects: **FME HYDROGENi**

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Mechanical Engineer with a Master's degree from the University of Split, Croatia and currently pursuing a ***Ph.D.*** in ***hydrogen safety*** at the ***University of South-Eastern Norway*** (USN). My research focuses on the ***physics and dynamics of hydrogen gas explosions***, employing both ***experimental*** and ***numerical*** analysis to enhance the safety of hydrogen systems. With expertise in ***computational engineering***, ***simulations***, and ***testing***, I develop and implement ***consequence analysis tools*** to enhance ***safety***.

Estimated progress of the PhD project:

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

Publications

- Bosnic, P., Henriksen, M., Bjerketvedt, D., & Vaagsaether, K. (2025). *Modeling of Flame Acceleration and DDT in Open-Ended Channel with Homogeneous Premixed H_2-Air Mixture*. The 30th International Colloquium on the Dynamics of Explosions and Reactive Systems (ICDERS), Ottawa, Canada.
- Bosnic P., Henriksen M., Vaagsaether K. *Flame acceleration and DDT of homogeneous premixed hydrogen-air mixture in obstructed channel: A numerical study using OpenFOAM*. European PhD Hydrogen Conference 2024.
- Penga Z., Tolj I., Bosnic P. et al. *Combined numerical and experimental analysis of liquid water distribution inside PEMFC flow fields*. World Hydrogen Energy Conference 2022.

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