# Study of zero-carbon fuel for internal combustion engines (ICEs) – Ammonia Injection

## Introduction

- Addressing climate change involves reducing greenhouse gas emissions. Hydrogen, a carbon-free energy carrier, is popular but its storage and use in ICEs are controversial due to its properties.
- Ammonia ($NH_3$), with its high hydrogen content, existing production infrastructure, and easy liquid storage, is a promising ICE fuel. However, its unique characteristics, such as high auto-ignition temperature and narrow flammability range, require further research.
- Direct injection (DI) of liquid $NH_3$ into ICEs can improve combustion and emissions control. And allow co-injection with other fuels like biodiesel. However, the rapid phase change phenomena of liquid $NH_3$, namely cavitation and flash boiling, which are more likely to happen in this approach, need more experimental data and precise numerical models.

## Numerical Approach

- Most cavitation models, using volume of fluid, treat the phenomenon as isothermal, with mass transfer rates calculated based on pressure differences between phases, i.e. mechanical effect. However, if the superheated liquid nears its boiling temperature, this approach may fall short, necessitating the inclusion of thermal effects, which would be the case for thermal fluids like ammonia.
- The methodology for this project includes implementation of a new thermodynamic cavitation model and a non-isothermal cavitation solver in OpenFOAM, to simulate ammonia's cavitation and flash boiling inside the injector.

## Experimental Approach

- There is a notable lack of comprehensive data pertaining to the characterization of ammonia injection and spray. To address this, it is crucial to conduct experimental characterizations alongside numerical simulations. This dual approach will facilitate subsequent validation and comparative analysis of the results.
- The methodology for this project incorporates the utilization of a well-established experimental technique known as momentum flux measurements. This is complemented by high-speed imaging to effectively characterize the injection and spray of ammonia.

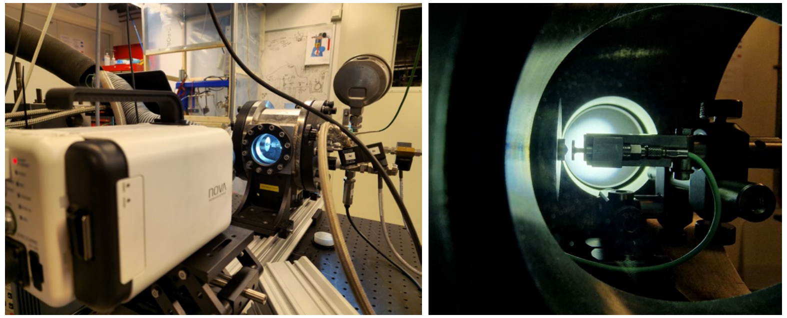

Fig. Experimental Setup

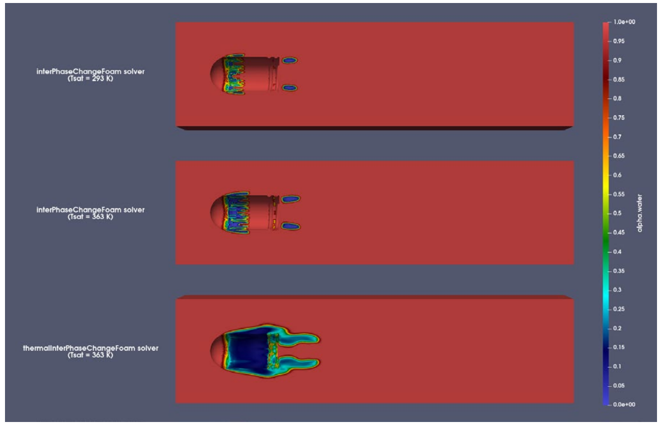


Fig. Initial numerical results, i.e. comparison between models


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Starting with Aerospace Engineering, I found my passion in addressing energy and environmental issues. My bachelor's project simulated a new wind turbine design, and my thesis developed an innovative natural gas burner. In my master's in Norway, I delved into hydrogen research, focusing on safety aspects of compressed gaseous hydrogen, including auto-ignition of leakages and hydrogen-air mixing. My PhD research is on practical applications of zero-carbon fuels in ICEs, with a special focus on ammonia behavior.

## *Estimated progress of the PhD project:*

| Just started ... | < 50 % | > 50 % | Almost done ☺ |
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## Publications


- K. Afshar Ghasemi, "Implementing a non-isothermal interPhaseChangeFoam solver with a thermodynamic cavitation model," In Proceedings of CFD with OpenSource Software, 2023, Edited by Nilsson. H., doi: http://dx.doi.org/10.17196/OS_CFD#YEAR_2023.



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