The Argon Power Cycle

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Exploring DI-H_2 and DI-O_2 injection strategies using CFD

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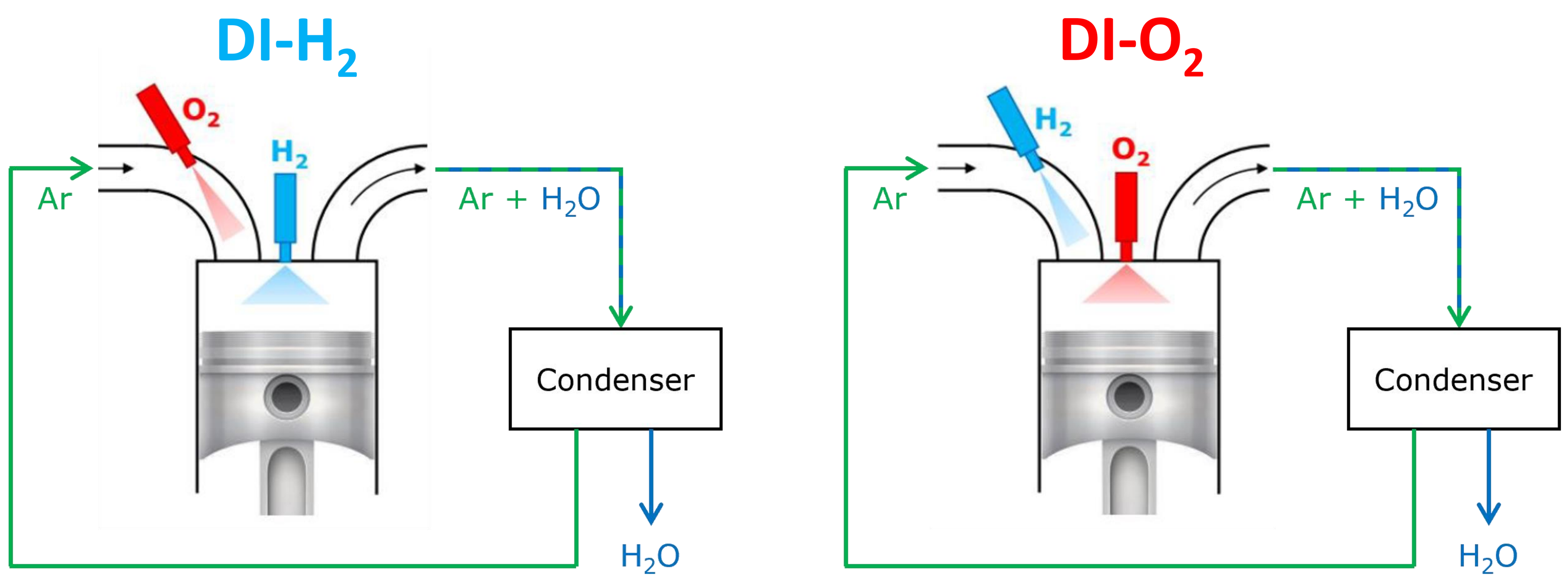
Why Argon Power Cycle?

Internal Combustion Engines (ICEs) can counteract the intermittent nature of renewable energy sources thanks to their ability to dispatch power rapidly. Challenges for ICE development are their relatively low efficiencies (<55%) compared to fuel cells, emissions, and pollutants. The Argon Power Cycle (APC) can overcome these challenges:

- Using argon as working fluid: ~25% efficiency gain, no NO_x;
- When hydrogen fuelled: no carbonaceous emissions;
- Closed-loop configuration: stoichiometric consumption, recyclability of Argon and unburned O_2 and/or H_2.

The APC allows to explore multiple injection strategies, since both hydrogen and oxygen need to be injected. This work presents the first tries of the DI-H_2 (left) and DI-O_2 (right) strategies.



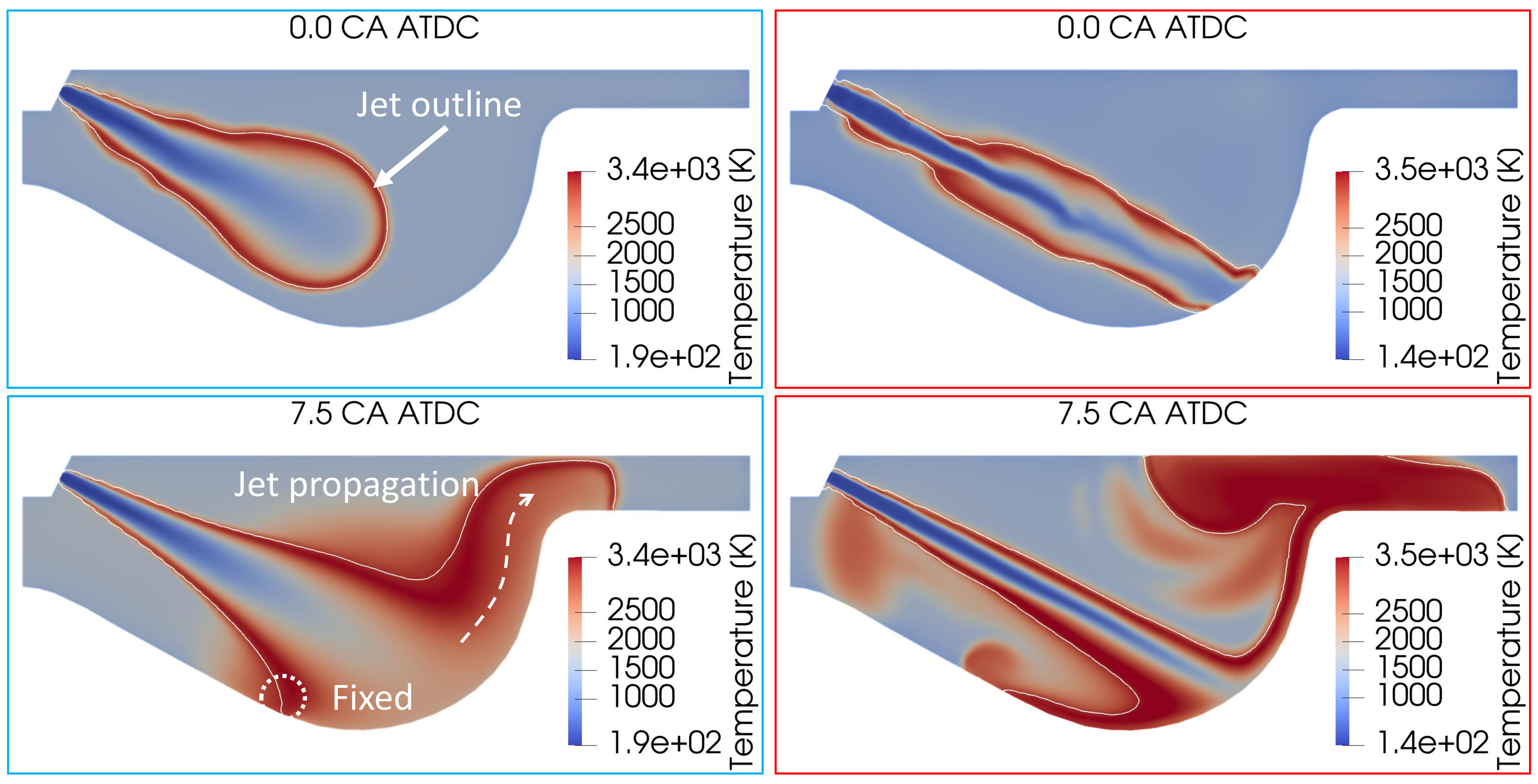
CFD environment setup

- Software program CONVERGE
- Closed-valve cycle
- 60° sector mesh
- Grid aligned with injection direction
- Sonic injection through inflow boundary, resulting in an under-expanded jet.
- Equal fuelMEP and λ requires different nozzle diameters in both cases due to oxygen-to-hydrogen ratio.

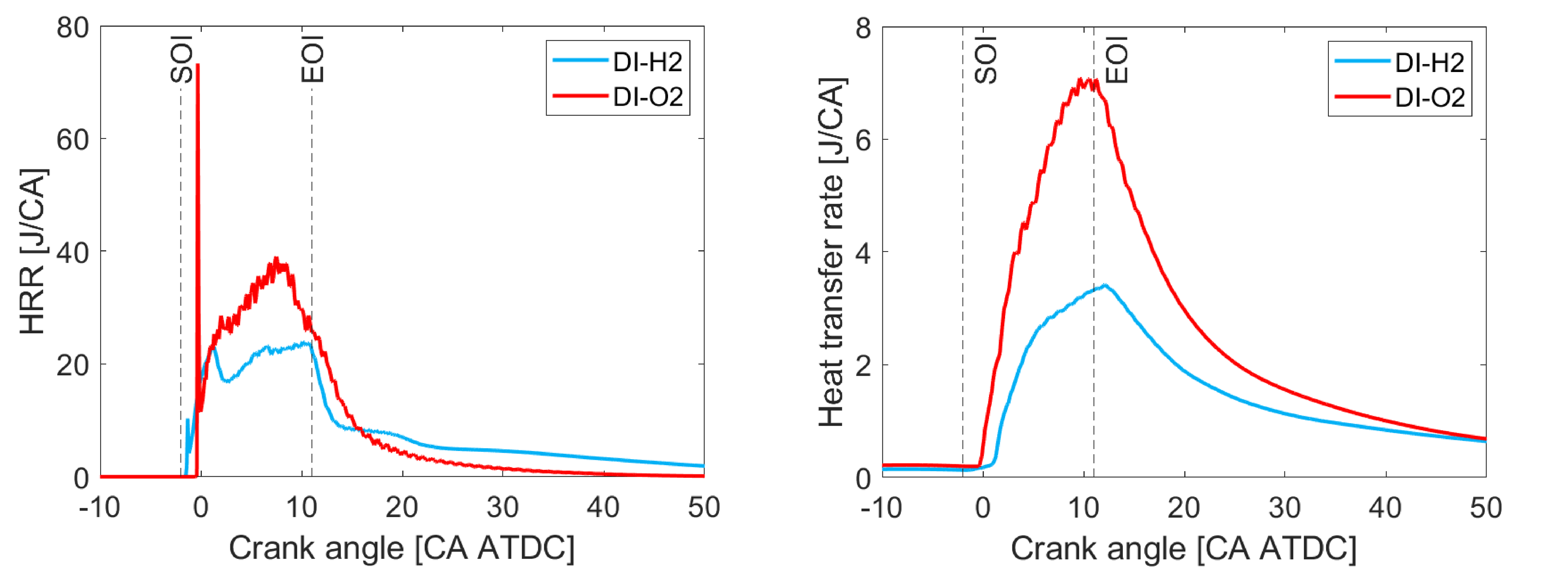
Engine specifications

Swept volume per cylinder	1.47 L
Bore / Stroke	112 / 149 mm
Compression ratio	16.1 : 1
Number of injector nozzles	6
Injection angle (w.r.t. vertical)	62°
Engine speed	1800 RPM
fuelMEP	19 bar

DI-H_2		DI-O_2
300	*Injection pressure [bar]*	300
1228	*Sonic velocity [m/s]*	308
3.6	*Injection rate [mg/s]*	28.2
-2 / 11	*SOI / EOI [CA ATDC]*	-2 / 11
0.50	*Nozzle diameter [mm]*	0.65



Snapshots of DI-H_2 (left) and DI-O_2 (right) simulations.



Chemical heat release rate and heat transfer rate through the boundaries.

Conclusions

- Low momentum of H_2 jet requires revised combustion chamber design which allows better free-jet turbulent combustion.
- About 25% of injected hydrogen is trapped in squish volume resulting in a long combustion tail.
- DI-O_2 has a predominant global mixing combustion phase, similar to diesel combustion, thanks to the high jet momentum.
- DI-O_2 has more heat loss due to properties (viscosity and conductivity) of the premixed H_2-Ar charge (as opposed to the O_2-Ar charge in the other case).

Future work

- Revise combustion chamber design for DI-H_2.
- Quantitative analysis of energy flows and thermal efficiency.
- System analysis of APC using 1D CFD to find suitable operating conditions.

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