Direct Injection H_2 Engines

Optimization of Hydrogen Combustion Towards 45% Efficiency Target

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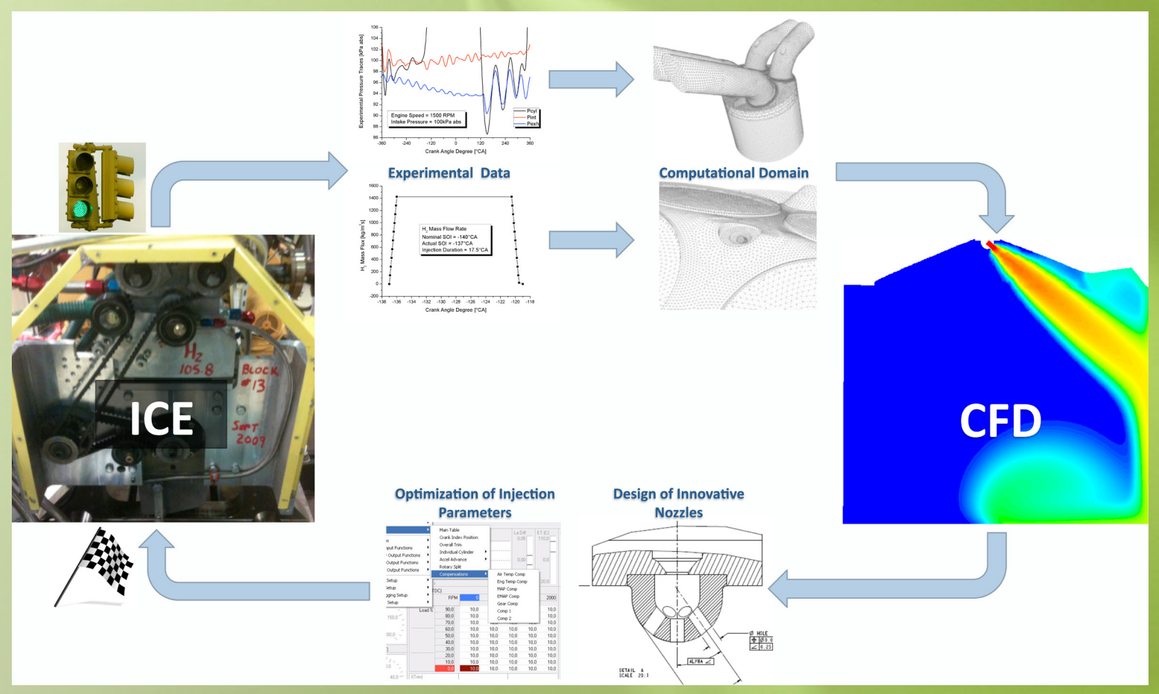
Opportunity

Hydrogen-fueled internal combustion engines (H_2 ICEs) have significant potential as a bridging technology toward a large-scale hydrogen infrastructure. The U.S. Department of Energy (DOE) has set challenging goals for H_2 ICEs including 45% brake thermal efficiency, NO_X emissions of 0.07 g/mile, and power density comparable with gasoline engines.

Direct Injection (DI) has proven to be a promising approach to help meet these objectives. However, both geometrical and operational injection parameters need to be properly set to achieve optimal mixture stratification in the combustion chamber.

Solution

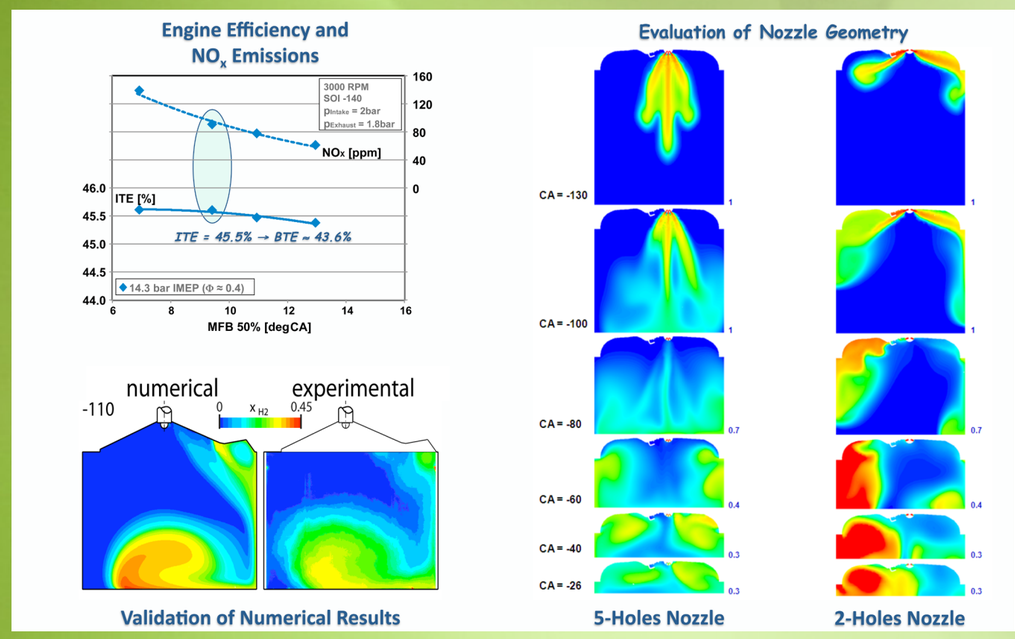
Argonne engineers are investigating advanced mixture formation concepts to improve the engine efficiency of DI H_2 ICEs while reducing exhaust emissions. Complementary to experimental data, researchers use computational fluid dynamics (CFD) simulations for engine diagnosis, and as an effective cost-efficient development tool. Sandia National Laboratories (optical data), Ford (technical support) and Westport (H_2 injectors) are Argonne's main partners in this research project.



The interaction between experiments and modeling at Argonne is a key factor to improve the engine efficiency.

What We've Achieved

Argonne's DI-H_2 single-cylinder engine has been significantly modified with a higher compression ratio and a piezo injector. Conditions with simulated turbocharging (higher intake and exhaust pressure) have been analyzed, resulting in 43-44% brake thermal efficiency at high engine load and speed (14.3 bar @ 3000 RPM), and emissions levels less than 100 ppm. Numerically, the CFD code has been intensively validated against optical data from Sandia National Laboratories, providing remarkable agreement in terms of H_2 jet evolution. New nozzle geometries have been numerically evaluated to improve the mixture stratification process and have been manufactured upon request.



Benefits

- Domestically produced alternative fuel will help reduce the nation's dependence on foreign oil
- Meet DOE targets of higher engine efficiency and reduced NO_X emissions for hydrogen engines

Future Work

- Extend the code validation to multi-hole nozzles
- Design and testing of optimized nozzle configurations
- Numerical simulation of combustion and pollutant formation

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