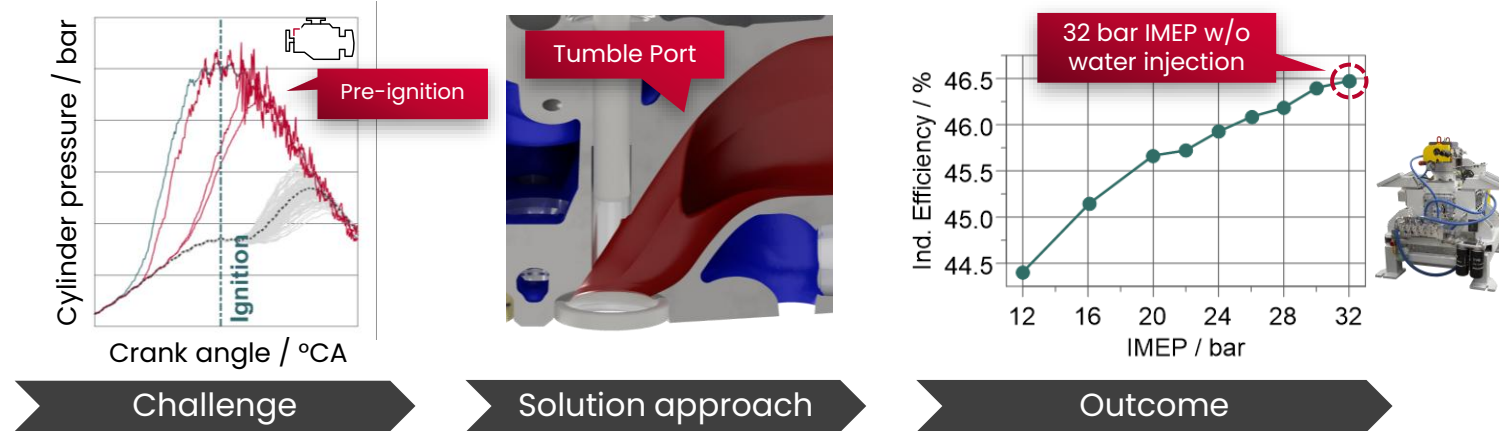


FEV Signature Solutions

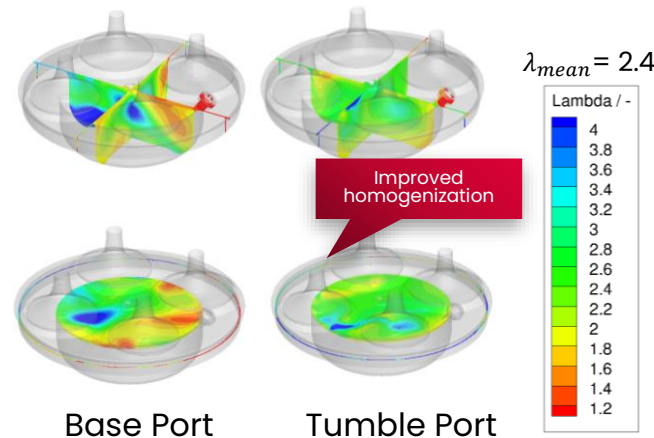
Flat Tumble Cylinder Head Design

Maximize your H2-ICE Performance!



FEV offers

- ▶ Cylinder head development based on FEV's unique holistic design process to ensure best results in class
- ▶ Includes cooling channel and port design, charge motion and mixture formation optimization by 3D CFD, cooling CFD and FEA
- ▶ One-stop for all the work, including testing on our in-house SCE for target validation

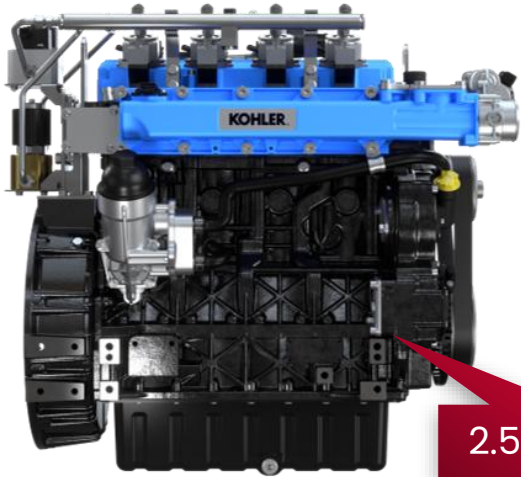


Why FEV

- ▶ **Proven expertise:** 45+ years of automotive engineering excellence, trusted by global OEMs and Tier-X suppliers to deliver innovative, production-ready solutions with deep domain expertise
- ▶ 10+ years of experience with hydrogen engine testing
- ▶ **Complete lifecycle support:** From concept to series maturity, including design, simulation, prototyping, testing, industrialization, and implementation
- ▶ **Customer-centric solutions:** Transparent and customizable, enabling you to extend, integrate, and scale your own development

Reference project FEV propulsion

DI injection & mixture formation optimization in flat cylinder head engines



2.5 L H2 DI ICE



MD H2 DI engine



15L HD H2 DI engine



9L HD H2 DI engine

- ▶ The generation of tumble motion via intake port adaptations in flat cylinder heads is the baseline for a H2 dedicated charge motion concept
- ▶ Piston bowl design and injector spray layout are further keys for an optimized mixture formation and the achievement of a high level of charge homogenization

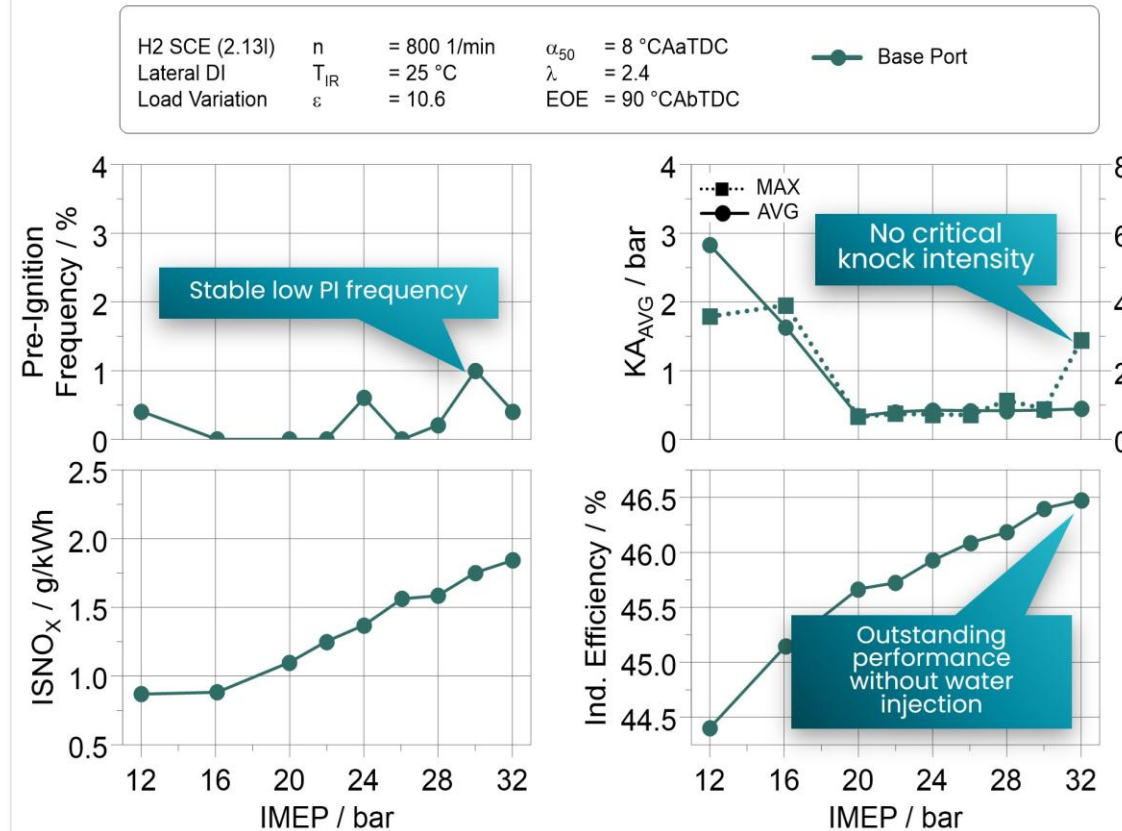
Reference project FEV propulsion

Thermodynamic testing on HD single-cylinder engine

FEV INTERNAL PROJECT SOPHIA

Results

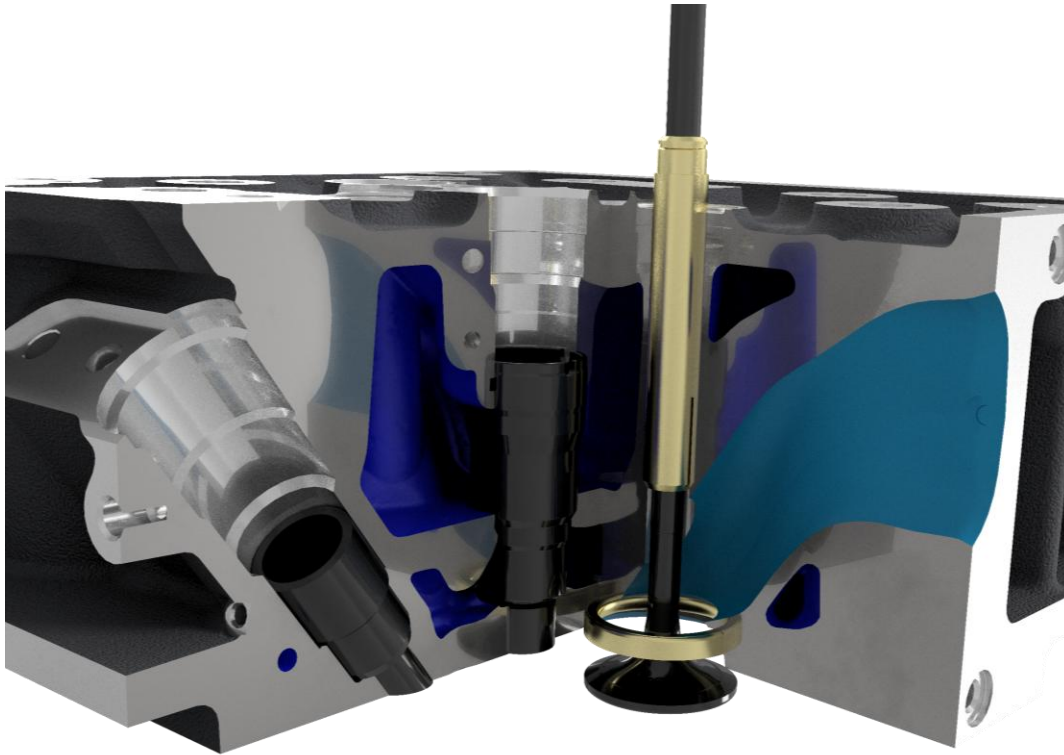
- FEV has identified vulnerabilities of hydrogen combustion engines and applied measures to counteract load-limiting abnormal combustion
- Realization of **IMEP = 32 bar** is a great **milestone** in H₂ combustion development
 - Abnormal combustion is still at an acceptable level
 - Hardware optimizations have high impact on feasible performance
- **ITE > 46 %** is an excellent value for CR 10.6




Dedicated hardware
Optimized mixture homogeneity
Pre-ignition and knock on acceptable levels

H2 ICE Flat Tumble Cylinder Heads

AS PART OF FEV'S H2 ICE DEVELOPMENT CONCEPT – BACKGROUND & BENEFIT



Background

Commercial engines are based on previous Diesel developments with corresponding flat cylinder heads designed w/o tumble or only swirl charge motion concepts.

Work Scope

The conversion of these engines towards H2 operations requires an adaption of the combustion process including a revised charge motion concept.

Challenge

The low ignition energy of hydrogen and wide flammability encourage the occurrence of abnormal combustion phenomena such as pre-ignition.

Solution

A tumble charge motion is beneficial to improve the mixture formation as well as to mitigate the pre-ignition probability. With FEV's tools a tumble intake port design can even be realized in flat cylinder heads.

Impact

A significant increase in performance and decrease in pre-ignition frequency. A further benefit of a refined mixture homogenization is the reduction of NOx emissions.

Get in touch with us for further information



[www.fev.com/en/
signature-solutions](http://www.fev.com/en/signature-solutions)