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- **The EAGLE project coordinated by IFP Energies Nouvelles (IFPEN)**, has been conducted by the European industry partners Renault, Vitesco Technologies, FEV and Saint-Gobain together with the technical universities of Naples, Aachen and Valencia.

- **Novel technologies** such as hydrogen boosting, ultra-lean pre-chamber ignition system, **and the use of new smart coating materials** for heat insulation were experimentally assessed and **showed promising results.**

- Furthermore, **tests performed** on the Renault multi-cylinder engine **validated the innovative electrified dual stage** boosting system and **provided a clear understanding of the after-treatment system** required to reach very **low tailpipe pollutant emissions.**

Coordinated and led by the French research organization IFP Energies Nouvelles (IFPEN), the industrial partners Renault, Vitesco Technologies GmbH (former Continental), FEV Europe GmbH, and Saint-Gobain Research Provence , together with the Università degli Studi di Napoli Federico II, the Institute for Combustion Engines (VKA) of the Technical University RWTH Aachen and the Research Institute CMT of Universitat Politècnica de València have developed a new highly efficient combustion system within the EU-funded project EAGLE (Efficient Additivated Gasoline Lean Engine).

In the frame of the H2020 Green Vehicles call GV-02-2016, the EAGLE project evaluated different advanced technologies to significantly improve the efficiency of an innovative gasoline engine for electrified powertrains in order to support a long-term fleet target of less than 50 gCO_2/km according to WLTP.

During the various phases of the project, the potential of different technologies was numerically assessed with advanced simulation tools, and experimentally explored on various prototype engines. Significant progress has been made on crucial topics for lean-burn combustion: hydrogen boosting, development of an ultra-lean high-efficiency ignition system, thermal insulation in different parts of the engine to reduce heat losses, and new materials for deNOx after-treatment devices.

Ultra-lean combustion allows reducing fuel consumption and pollutants but requires novel ignition technologies. One of them is the addition of small amounts of hydrogen to boost the combustion. This has been investigated by IFPEN, to determine the quantity that needs to be injected. Another one is a high energy ignition system. The VKA institute of RWTH Aachen performed advanced calculation studies to design a novel pre-chamber ignition system where a small amount of air-fuel mixture was ignited, and the flame jets injected into the main chamber through small holes. This was then developed, optimized, and tested together with FEV. Vitesco Technologies provided the injection system and the controls.

To improve engine thermal efficiency, smart coatings that allow reducing the heat losses in the combustion chamber were investigated for the project. CMT-Universitat Politècnica de València performed parametric studies and advanced calculations to define the main thermal characteristics of such smart coatings. Based on these, Saint-Gobain Research Provence and Saint-Gobain Coating Solutions developed a robust thermal sprayed coating, which was then applied on parts of two prototype research engines at IFPEN. Under some operation conditions, small gains were measured on break thermal efficiency without drawback on other combustion parameters.

In parallel, considering the new challenges posed by the lean-burn combustion, VKA-RWTH developed an innovative NOx storage catalyst (NSC) to fulfill the special aftertreatment conditions required. Several materials were tested, and the result was a catalyst with comparable NOx storage at low temperatures and lower oxygen storage capacity (OSC) than reference serial catalyst. The lower OSC leads to regeneration phases with better efficiency and hence to lower additional CO_2 production.

The technologies developed by the project partners (prechamber, injector, coatings…) were integrated in a single-cylinder research engine manufactured by Renault and tested at IFPEN. The experimental evaluation of the EAGLE concept yielded promising results in terms of efficiency, over 48%, close to the initial EAGLE target, and showed reduced engine-out NOx and particles emissions. It demonstrated that the ultra-lean burn combustion concept at high air dilution rates (?>2) is made possible with the fueled pre-chamber and can achieve very high efficiency.

Finally, a multi-cylinder engine demonstrator was designed and manufactured by Renault, considering the return of experience of prototype engine tests. For instance, Vitesco Technologies optimized the injection system for the demonstrator pre-chamber and developed a cylinder individual closed loop combustion control functionality. And Università degli Studi di Napoli Federico II contributed to the calibration and optimization of the multi-cylinder EAGLE engine at the test bench by developing an efficient energy management strategy for hybrid vehicles focused on the minimization of CO_2 emissions and fuel consumption.

The experimental investigations on the Renault multi-cylinder engine led by IFPEN validated the innovative electrified dual stage boosting system and provided a clear understanding of the after-treatment system required to reach very low NOx and particles (down to 10 nm) tailpipe emissions. Vehicle simulations performed by Università degli Studi di Napoli Federico II highlighted that the EAGLE PHEV application using the Renault E-Tech powertrain could achieve 50 gCO_2/km.

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Project website: https://www.h2020-eagle.eu

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The European research project EAGLE paves the way for a highly efficient gasoline engine
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