Project H2POWER

Hydrogen in fuel gas

air pollution | sustainable mobility

PROJECT DESCRIPTION

In a scenario in which the restrictions on emissions and consumption are increasingly restrictive and in which there is a tendency to search solutions for zero emission vehicles (ZEV - Zero Emissions Vehicle), investigations aimed at studying the possibilities offered by a mixtures of methane and hydrogen as fuel for internal combustion engines gain ground. The experiments carried out in recent years by various Institutes, Universities and research centers have shown that the use of hydrogen in the form of fuel gas injected, even if in small quantities, can make a significant reduction in CO_2 emissions. Most small and medium-sized municipalities have the need to develop strategies for sustainable mobility to reduce CO_2 emissions, while safeguarding the heritage of historic centers and the health of citizens. **H2Power** wanted to respond to these needs by experimenting the use of a mixture of hydrogen and methane as fuel for urban and extra-urban public transport. The H2Power project is based on 2 assumptions:

- the use of hydrogen fuel does not generate polluting emissions and emits only water vapor;
- hydrogen does not need to be transported but can be produced where necessary.

OBJECTIVES

The general objective of the project was to experiment the transformation of a vehicle for **urban and extra-urban public transport, in an urban context with significant differences in altitude**, from natural gas fueling into hydromethane (mixture of hydrogen and methane) fueling. H2Power sought to check the maximum percentage of hydrogen that can be mixed in a traditional engine, highlighting the complete compatibility and adaptability of the innovative fuel mixture. The tests were carried out in the engine testing laboratory of the Department of Industrial Engineering of the University of Perugia on a typical Otto engine running on natural gas. The analysis involved the use of several methane-hydrogen mixtures characterized by different concentration levels.

The decision to use hydrogen directly as fuel for heavy vehicles and not in fuel cells, was justified by the **considerable savings it would produce considering that it allows the optimization of the already obsolete vehicles**, transforming them into eco-friendly ones; while fuel cells would require a replacement of the existing vehicle fleet.

PROJECT PHASES

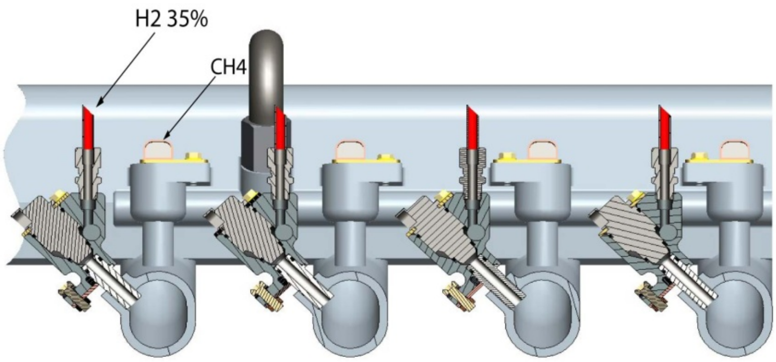
The project was structured in **two work phases, static and dynamic**, divided into 4 main actions with the aim of assessing the behavior of the electronic and mechanical system of the 2800 cc engine Iveco Daily and of the van, subject of the experimentation, fueled by the hydrogen-methane mix:

- assessment of the maximum percentage of hydrogen in the hydromethane mix;
- analysis and electronic optimization of the stoichiometric carburation process;
- retrofitting of the vehicle (a methane-powered van) to hydromethane system;

- statistical analysis of cost-consumption efficiency, procurement times, storage and supply at full capacity.

The **static phase** of the activity consisted of the study of the control unit and the sensors of the combustion process as well as of the fuel injection system.

The solution tested has identified the possibility of exploiting a separate dual-circuit fuel supply system so as to mix the two gases, varying the concentration according to the vehicle's power need: provision of hydrogen-methane mix or pure methane, according to the power required by the moving vehicle. The system consists of four injectors (Fig. 1) for methane and four for the mixture. The system is automatically managed by the electronic control unit by a purposely designed software. To make it possible to manage and control the engine supplied with the various mixtures and, in particular, to go in the direction of the leanest possible combustion, the control unit (ECU - Engine Control Unit) used on the vehicle (mod. "IAW1AF Magneti Marelli) was replaced by a new technology ECU (model EFI 4 Technology). The control unit allows, in addition to the possibility of variations of ignition timing, also the management of four additional injectors, in addition to the four original ones, which are part of the new design of the engine power supply.



Hydrogen has very different physical and chemical properties from methane: higher caloric power (143.0 MJ/ Kg), lower density (0.09 kg/ m3) and higher propagation speed (264cm). These different characteristics, require to be able to vary the injection times of the injectors, and the percentages of supply of the two gases, so as to obtain the required power and a torque capable of supporting a diversified route.

Another important change was related to the gas inlet manifold with four additional injectors and some sensors. In addition a new 60-pole cable to connect to the ECU, hydrogen gas supply pipes and a second hydrogen-methane pressure reducing valve have been wired, as well as the tank has been adapted for storing hydrogen-methane at 200 Bar.

After making all the changes, from the control unit to the carburation and injection system, in the **dynamic phase** of experimentation and tuning of the minibus engine, the following actions were implemented: adaptation of the body to house the instrumentation and the configuration of the sensors for monitoring the combustion parameters; installation of the serpentine pipes of the additional hydrogen-methane tank; and application of the double injector array as well as of the new ECU.

Engine prototype development activities and retrofitting of the existing system made possible due to the physical properties of hydrogen that make it less dangerous and explosive than methane, did not require complex modifications of reengineering, (pipes, valves and tank) but only some sealing precautions on the gaskets. During the monitoring carried out on the vehicle in movement, the torque power achieved in the urban contexts with significant differences in altitude as well as the CO2 and HC emissions were analyzed, compared also to those recorded in the static phase performed in laboratory. The road tests were carried out on a diversified route including parts of plain and challenging up- and downhills, so as to be able to detect the behavior of the vehicle in the various loading phases both when powered by 35% hydromethane mixture and by 100 % methane.

The dual fueling circuit has allowed to extend the overall quantity of the used hydrogen to higher percentages than those which could have been obtained with a fixed fueling system. The switching action between the pure methane circuit and the hydromethane mixture has made it possible to use a torque adequate to support the loads in the different routes. The switching of the dual fueling system did not show any misfiring phenomena (lack of ignition due to particular substances containing sulfur, which are deposited on the spark plug) in the combustion or of "stop and go" in any of the tests carried out. Hydrogen, due to its diffusion and propagation speed, makes the combustion homogeneous and well distributed throughout the combustion room. The engine was tested under partial load conditions at 2000 rpm and 4.5 bar. In all test series, after a period of preheating, the engine temperature remained at about 85 ° C ± 2 ° C.

PROJECT RESULTS

The experimentation was completed with the data monitored on the vehicle in a city circuit. The data obtained from monitoring are the average of the four measurement points (steep uphill, downhill, plain, maximum speed). The overall average is obtained on the basis of a fuel setting using hydrogen in maximum mixture when the required torque is compatible with routes in plain and fueling pure methane when the torque demand is more relevant. The tested fuels were of three types:

1 – pure methane (100% CH4);

2 – hydro-methane mixture, where hydrogen is 20% of the volume;

3 - hydro-methane mixture, where hydrogen is 35% of the volume.

The possibility to use hydrogen mixed up to 35% on plain routes with a moderate effort of the torque, makes the used technological solution of the dual circuit able to achieve the following results:

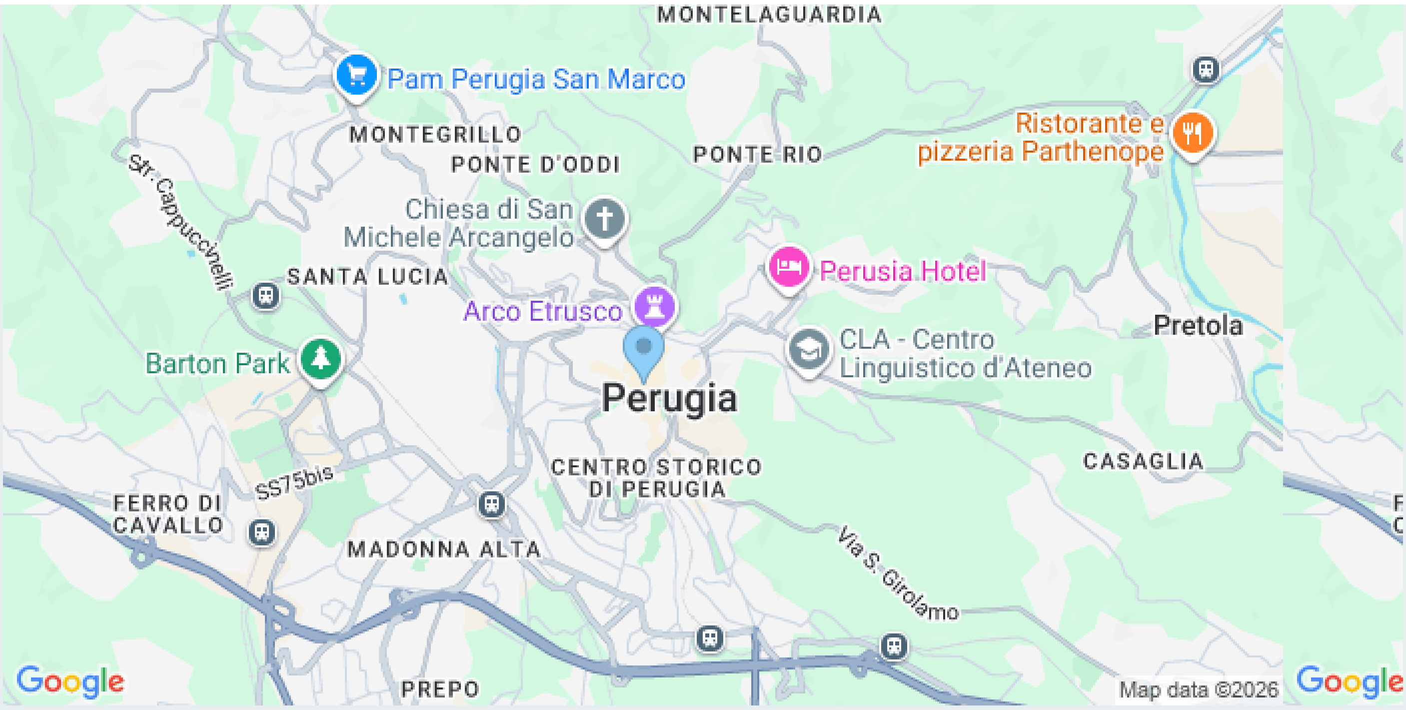
- The control unit has made it possible to mix the two gases that led to an **average 80%- 90% of carbon monoxide reduction, depending on the route (uphill, downhill, plain), and an average 20%-40% of carbon dioxide reduction** compared to the emissions of the pure methane fuel. **In addition there was a fuel saving of 30% in mass, equal to 7% in volume**;
- a **maximum 47% carbon dioxide reduction** compared to fueling exclusively by methane;
- from the economic point of view, an **18% overall reduction in fuel consumption**.

Approximately **100,00 km traveled** for the road testing of the van, **50 days of road testing** for the engine trial, **41 days of official tests** for the configuration of the maximum mixing limit of hydrogen and methane. The experimented technology of the dual supply system found to be much more performing than the supply of a fixed mix, able to achieve a maximum reduction of greenhouse gas emissions around the 50% threshold, as far as the efficiency of the system reduces the amount of methane that normally remains unburned (it's also a greenhouse gas), which then adds up to the percentage of saved CO2. The reduction in fuel consumption, equal to 18% of methane, is able to bear the amortization of the installation cost.

The technologies developed within the project have a high potential of transferability to municipal companies of urban public transport, companies with internal fleets, vehicles of public utility, urban mobility with heavy urban and extra-urban routes in other places in Europe with similar geographical and urban problems and characteristics. The most important documents for the replicability of the technological solution are:

- ***Guidelines for the implementation of the hydrogenmethane fuelled bus***;
- ***H2 Power Handbook***;
- ***Political Guidance***.

In the frame of the communication and dissemination activities a **video** on the H2POWER project's results and on sustainable mobility was realized.



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Acronym
H2POWER

Number of reference
LIFE09 ENV/IT/000216

Reference Programme
LIFE

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EU contribution
633.943

Call Year
2009

Start Year
2010

End Year
2013

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Description

Umbria - Municipality of Perugia