Hydrogen is regarded as a future energy carrier. Within the H2BVplus research project sponsored by the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT), a high-efficiency combustion system has been developed for passenger car hydrogen engines by the Institute of Internal Combustion Engines and Thermodynamics of Graz University of Technology in collaboration with BMW Group Research and Technology. The conventional diesel combustion process served as a template.
1 INTRODUCTION

Climate change and the finite nature of fossil fuels, combined with political interdependencies, require us to make increasing use of renewable energy. In this context, we should not allow today's oil monopoly to be replaced by some new dependency. Sustainable mobility requires a broad base of distinct energy sources, whilst avoiding the potential consequence of increasing the number of pumps at fuel stations. In a manner similar to electricity, hydrogen is suited for use as a carrier of energy from a variety of sources and, when used for internal combustion engines, it offers important advantages such as rapid tank filling and high power density at an affordable price.

In the European-sponsored HyICE project [4] it has already been demonstrated that a hydrogen engine with typical spark ignition (SI) layout and internal mixing can actually surpass current gasoline engines in terms of power density and efficiency. In order to achieve a better understanding of mixing and combustion processes, in addition to classic thermodynamic investigations on a single cylinder research engine, this work included visual measurements using an injection chamber and a transparent engine. Substantial development activities in the area of 3D-CFD mixing and combustion simulation had been verified optically for the first time, 1.

In order to achieve a further increase in efficiency, the H2BV-plus project was set up to demonstrate the advantages of the conventional diesel compression ignition (CI) process compared with the SI process with a hydrogen engine. The motivation for Graz University of Technology in collaboration with BMW Group Research and Technology was driven by the higher compression ratio in combination with good ability for supercharging, through the absence of knocking, and minimised wall heat transfer due to charge stratification.

The aim was to demonstrate whether a diesel-like hydrogen combustion system — henceforth referred to as H2 diesel combustion system — was possible for passenger car application. Concepts involving both auto-ignition and externally supplied ignition were to be investigated in order to reveal the potential with regard to efficiency and power density.

2 ENGINE DESIGN

The auto-ignition temperature of hydrogen is 860 K [1], which is significantly higher than the 520 K of conventional diesel fuel. However, the principal parameter influencing combustion chamber design for H2 auto-ignition was the requirement for a final compression temperature of at least 1100 K [6] in order to achieve ignition delay below 1 ms.

Using 0D engine cycle calculations, various combinations of compression ratio and intake air pre-heating were investigated and demonstrated the capacity to achieve the required final compression temperature. Two concepts were pursued for 3D-CFD design work on the combustion chamber and jet pattern: compression ratio (CR) of 22 with low-level intake air pre-heating and CR = 18 with high-level intake air pre-heating.

2.1 COMBUSTION CHAMBER DESIGN WITH 3D-CFD

The combustion chamber was designed using Fluent 3D-CFD software. Targeted was a layout for which the peripheral region of the injected hydrogen jets mixed as well as possible with the surrounding air in the combustion chamber whilst remaining clear of the comparatively cool walls within the target maximum ignition delay of 1 ms.

The combustion chamber design process is shown in 2. Starting from a known combination of injector jets and piston bowl shape from a conventional car diesel engine, both were varied in a comprehensive trial of variants and optimised to the point where a configuration was found to achieve the requirements stated above. The optimum for good mixing and ease of manufacture proved to be a slightly 6-shaped piston bowl with central injector and 16 x 0.3 mm nozzle geometry, 2, right.

2.2 DESIGN OF THE TEST DEVICE

The single-cylinder research engine with typical diesel layout for passenger car-size application shown in 2 served for testing. A new