Synthesis

Under the proposed Green Deal program, the European Union (EU) will aim to achieve zero net greenhouse gas (GHG) emissions by 2050. To shift the mobility of the future towards a zero-emission scenario, besides the fostering of powertrain electrification, which represents the most promising solution to improve the air quality in highly congested urban areas, the Green Deal also supports the development and the production of sustainable alternative fuels capable to achieve a zero impact in their entire life cycle. Among them, hydrogen (H2) has recently become a highly attractive solution since it could be produced from renewable energy sources, and its combustion generates almost zero GHG emissions. It is well known that H2 can be used with both internal combustion engines (ICEs) and fuel cells (FCs). However, hydrogen-fueled ICE represents a robust and cost-efficient option to be quickly implemented under the current production infrastructure. H2 engines are usually run ultra-lean to avoid abnormal combustion phenomena, limit the exhaust gas temperatures, minimize the emissions of nitrogen oxides (NOx) and achieve high conversion efficiencies. However, the exploitation of excess-air makes the power density very low, creating also huge challenges for the design of the charging system. In this framework, this manuscript focuses on the conversion of a high-performance 3.0L V6 Direct Injection (DI) gasoline engine in a hydrogen-fueled one. The H2-ICE is supposed to run in ultra-lean conditions at low loads, adjusting the power output by solely varying the relative Air-Fuel ratio. On the other hand, at high loads, the engine switches from ultra-lean to stoichiometric operations where, to mitigate knock and limit the exhaust gas temperature, Port Water Injection (PWI) is exploited. Before preliminarily evaluating the potential of the converted ICE, a comprehensive analysis on water injection was carried out. In particular, by exploiting a huge set of experimental data collected on a small displacement gasoline engine in dry and wet conditions, a proper methodology to simulate Port Water Injection technology was defined, analyzing in detail its knock mitigation potential and the effect of water content on the combustion process. Afterwards, due to the lack of H2-ICE experimental data, this methodology was adapted to simulate hydrogen combustion. The H2 combustion model, together with a dedicated knock model, was then integrated into a complete H2 engine model, paving the way for a preliminary definition of displacement, Compression Ratio (CR) and turbocharger (TC) size with the aim to achieve a demanding full-load performance target, minimizing the water demand. Finally, in the process of building up a virtual engine dedicated for hydrogen development, a 3D-CFD methodology to preliminary assess the H2-air mixture formation considering different injector positions was also developed.