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Numerical analyses of EGR techniques in a turbocharged spark-ignition engine

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A R T I C L E I N F O

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A B S T R A C T

Exhaust Gas Recycle (EGR) is an interesting technique, which is more and more adopted in spark-ignition engines in order to reduce both NOx emissions and fuel consumption in certain engine operating points. A fraction of exhaust gases recycled to the intake produces a significant charge dilution which decreases the combustion chamber temperature and, as a consequence, the NO formation rates. Furthermore, charge dilution allows reducing pumping losses at part load and heat losses through the walls increasing the engine efficiency.

In this paper, numerous numerical analyses have been carried out in order to widely estimate the potential of exhaust gas recycle in a downsized, turbocharged spark-ignition engine. Many engine operating points have been examined, at different speed and load. Major attention has been paid to the portion of the engine map characterized by low rotational speed and WOT operation. Thus, the most severe conditions for knock onset have been deeply investigated.

The combustion process has been modeled by means of a three-dimensional computational code. In particular, an in-cylinder analysis has been carried out to evaluate the effects of charge dilution on flame propagation, knock resistance and exhaust gas temperature distribution.

Furthermore, adopting EGR, main engine control parameters (fuel to air ratio, spark advance and boost pressure) have been recalculated and the overall performances have been computed by a one-dimensional model. In this case, a simplified combustion model, tuned by means of 3-D computations, has been utilized. The models here presented have been validated by several comparisons with experimentally obtained results.

The optimization of engine parameters, together with the evaluation of knock risks, allowed recovering, at some extent, the engine performance in absence of exhaust recycle. At the same time, reductions in both fuel consumption and pollutant emissions have been obtained.

1. Introduction

Nowadays, the attention to climate changes imposes a strong reduction in CO_2 emissions coming from hydrocarbon combustion processes. Thus, the reduction of engine fuel consumption has become a mandatory goal in designing new proposals for the world passenger car market.

Talking about Europe, the present target for CO_2 emissions is 120 g/km (fleet average), while, as a long term target, average new car CO_2 emissions should fall to 95 g/km in 2020. This is an ambitious target and the challenge could be taken up by using hydrogenated fuels and by significantly reducing fuel consumption. Dealing with the latter point, a lot of new technologies are recently appearing in the market of both Diesel and Spark-ignition engines. An interesting point of view is focusing the attention on the improvement of engine efficiency at least within a specific portion of the engine operating map. In particular, improving efficiency at partial load operation, means improving efficiency in a region of the operation field of an automotive engine that is very widely exploited during the engine lifetime, particularly in urban areas. Thus, this kind of improvement could allow substantial reductions in fuel consumption and CO_2 emissions of car engines mainly used in urban or sub-urban areas.

Talking about spark-ignition engines, it is well known that, due to the added losses introduced by the traditional load control systems, the engine efficiency dramatically decreases at part load operation. It is also clear that at a given torque value, small swept volume engines permit, in general, to limit some typical engine losses (above all pumping and friction losses). Naturally, correct comparisons between small and large displacement engines can be made just at the same power output. Today trend in developing fuel saving engines is aiming at high specific power engines, that is

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