Abstract

In recent years, the number of research focused on the development and study of new modes of premixed low-temperature combustion within the framework of the compression-ignition engines has been enormous. These modes have certain advantages over conventional Diesel diffusion combustion modes, mainly in terms of reduction of pollutant emissions, especially in NOx and soot characteristics of these engines. However, these new concepts also have various problems that remark so far unresolved. Fundamentally, they are derived from the control over the combustion process, because only thermodynamic conditions within the combustion chamber are that determine the ignition timing and therefore the performance and emissions associated therewith. This involves serious problems regarding the control of the ignition and the energy release in the engine cycle, as well as a narrow range of operating modes where the low temperature partially premixed combustion is functional.

In order to mitigate and reduce these limitations, this thesis proposes as main objective to contribute to the reduction of the various disadvantages arising from the control of partially premixed combustion processes and to improve the knowledge of the physical-chemical processes involved.

First, the extension of current knowlege regarding the modification of fuel reactivity in partially premixed combustion as a strategy to enhance the control and modulation of combustion is presented. For this purpose, a study on the characterization of the main phenomena (injection, mixing and autoignition) involved when using gasoline in compression-ignition engines with high-pressure common rail injection system is presented. As a result, the main differences found between Diesel and gasoline are mainly due to differences in density and viscosity. On the other hand, differences in terms of spray momentum flux, spray penetration and cone angle are minimal, compared to large differences found in terms of liquid length in evaporative conditions. The study of the mixing process shows how similar results are obtained for both fuels under partially premixed conditions, where transient effects on the injection process are important. In the same part of the work, combustion results show the potential of using low reactivity fuels in partially premixed combustion modes. An improvement in mixture homogeneity is shown, which is mainly due to the increased ignition delay. This facts reduces sensibly the amount of needed EGR, and also improves combustion phasing in the engine cycle.

In a second step, a new combustion mode based upon the assistance of a spark plug, namely the so-called Spark Assisted Partially Premixed Combustion (SAPPC)

is presented, which improves control of both start of combustion and combustion phasing. This part of the work shows the main features of the effect of spark assistance with a complete phenomenological, spatial and temporal description of the new combustion mode combining cylinder pressure signal and combustion images of the process. In this section are evaluated the effect of variations of different variables on both the engine combustion mode and the influence of the spark assistance with respect to these. Finally the main trends found in terms of emissions and combustion performance of SAPPC combustion mode are presented. Thus, the results show that the new spark assisted combustion mode increases developed combustion control in general. It allows direct control of the start of the same over the entire range tested, even at very low load condition which is a problem in these combustion modes. Furthermore, the combustion phasing as well as dispersion between cycles significantly improves. At the same time, the combustion process reduces the pressure gradients and noise derived.

SAPPC combustion process shows two different phases, a first phase with flame front propagation, which begins after spark discharge, and a second phase based on a controlled autoignition mainly controlled by pressure, temperature and mixture generated in the combustion chamber during the first phase. Different parametric studies allow insight into how they are affected and modified combustion phases by changing conditions and therefore proposed combustion mode. Finally, emission results show two clear scenarios: one of low NOx emissions with a lower efficiency of the combustion process, and a second one with high efficiency but with significantly higher NOx levels, too. In both scenarios soot levels are negligible.

Thus, based on the results from this research it is possible to say that the spark assistance in partially premixed combustion modes is a strategy that has great potential in terms of controlling the start of combustion, combustion phasing in a wide range engine operating conditions and reducing high pressure gradient. However, it is necessary to further deepen in the assessment of local conditions in the combustion chamber, experimentally or by means of 3D CFD modeling to improve the results of NOx emissions and maximize the efficiency of the combustion process.