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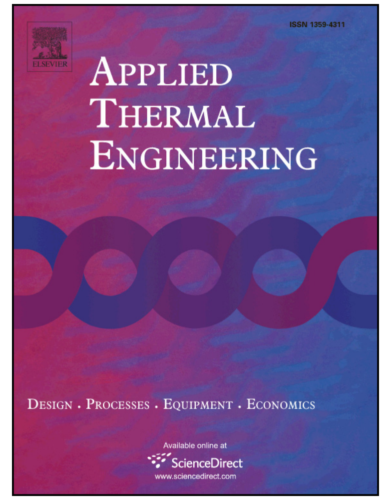

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Impact of the injector design on the combustion noise of gasoline partially premixed combustion in a 2-stroke engine

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Abstract

In this paper, a numerical Computational Fluid Dynamics (CFD) study is carried out with the purpose of understanding how the injector design may impact on the in-cylinder processes, which cause noise emission. This study is based on a combination of the gasoline partially premixed combustion concept with a new high speed direct injection 2-stroke engine, which emerges as a promising solution able to comply with nitrous oxides and particulate matter emissions standards, while ensuring combustion control and stability. The original engine configuration is varied by modifying the included spray angle and the number of injector nozzles in order to evaluate other design solutions for mitigating combustion noise. Results show that the maximum pressure time-derivative achieved during the combustion is the most influential parameter on the acoustic response of the in-cylinder noise source. However, they also evidence that for some operation conditions the resonance phenomena can enhance their contribution, thus playing a relevant role in the engine noise level. Further analysis allowed to identify three combustion-related parameters, which characterize this phenomenon and allow identifying key paths to minimize its levels.

Keywords: Gasoline PPC concept, 2-stroke engine, Combustion noise, Resonance, CFD Modelling

1. Introduction

In the last decade, adverse effects of the global warming have increased considerably, raising the concern about the environmental contamination and its consequences to life on Earth. In this context, at the Paris climate conference (COP21), 195 countries adopted a universal and legally-binding global climate deal [1]. Governments agreed on keeping the annual increase in global average temperature below 2°C. Consequently, they should scale up their efforts and support actions to reduce emissions, especially in terms of carbon dioxide (CO_2). In addition, other exhaust emissions, such as nitrous oxides (NOx) or particulate matter (PM), are strictly controlled for their negative impact on human health [2].

The transport sector represents nearly 26% of the total CO_2 emissions. In particular, the passenger cars segment is the largest source of both greenhouse and pollutant emissions in vehicles. Hence, the engine manufacturers have been forced to develop advanced systems to ensure fulfillment of the pollutant emissions standards, while improving engine performance, and therefore CO_2 emissions. Nowadays the advanced systems technology present in the compression ignition (CI) diesel engines and spark ignition (SI) engines for automotive applications have become really complex and expensive. In both engine concepts NOx and PM emissions can be mitigated by a combination of close control of the combustion process with the newest exhaust after-treatment solutions. However, these passive solutions worsen fuel consumption and increase engine costs, compromising both compliance with CO_2 emissions levels and customers' purchasing decision.

Advanced low temperature combustion (LTC) concepts arise as a solution to reduce after-treatment costs and fuel consumption. They have been thoroughly investigated for their advantage in reducing NOx and soot emissions simultaneously. In Diesel homogeneous charge compression ignition (HCCI) or premixed charge compression ignition (PCCI), fuel is ignited in highly premixed conditions to avoid soot formation, whereas NOx production is inhibited by decreasing the local temperatures with large amounts of exhaust gas recirculation (EGR) [3, 4]. The main issues with these concepts concern the over-mixed blend and the liquid fuel impingement on the cylinder/piston walls, which increase the unburned hydrocarbons (HC) and carbon monoxide (CO) emissions [5, 6]. Newest combustion concepts, such as gasoline partially premixed combustion (PPC) operate with partially premixed charges, between completely premixed and fully diffusive conditions. Investigations have confirmed the suitability of this combustion concept to achieve really low emissions of both NOx and soot particulates, while keeping the engine indicated efficiency. [7, 8].

The main drawback of the gasoline PPC concept resides in controlling the combustion phasing with the injection. Contrary to the conventional diesel combustion (CDC), the injection event alone does not ensure ignition, because the start of combustion mostly depends on the local thermodynamic conditions inside the chamber. This fact leads to a reduced load operation range between high-sharp combustions (knock) and unstable combustions (misfire). Nevertheless, there is evidence that

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