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Thermographic study of the preheating plugs in diesel engines

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ABSTRACT

The use of direct injection diesel engines has been widely applied during the past ten years. In such engines, the preheating plugs are a key element which has a significant contribution in the pollutant emissions.

In this paper, two different plug designs from Renault are analyzed. The new plug reduces substantially the required electrical consumption. Nevertheless, the pollutant emissions are higher (fundamentally CO and HCs) and hereby a thorough analysis is required to understand the possible reasons.

Firstly, an infrared thermography analysis of the plugs has been carried out. The new plug tip presents 100–200 °C higher temperatures than with the former design. Secondly, a thermal model has been developed and validated with temperature measurements. The latter model has helped to obtain the energy flow diagram. Finally, a thermography analysis of the head of the cylinders has been carried out. The results show that the higher exhaust emissions are related with an incomplete combustion process due to a thin air gap which surrounds the tip of the plug.

1. Introduction

In the past ten years, diesel engines have been widely used in the automotive industry in Europe [1] due to their higher efficiency, fuel economy and reliability.

Progressively, Direct Injection (DI) diesel engines have replaced the Indirect Injection engines. The main advantages are the reduction of the fuel consumption [2] and the favorable characteristic torque profile. Additionally, with the use of turbo-charging, a high performance is now achieved even for small and medium DI diesel engines, which now deliver specific brake powers close to those of spark ignition engines [3].

Nevertheless, the pollutant emissions are a key issue in the development of diesel engines given the recent restrictive legislations. Most of the pollutant emissions are produced during the engine start and warm-up [4–6], where the emissions of CO, HC and smoke are significant. These emissions are often caused by difficulties in obtaining a stable and efficient combustion under these conditions [3]. During the rest of the operation conditions from the engine, particularly for a constant charge and engine speed, the emissions are generally lower.

In order to start the operation of DI diesel engines, preheating plugs are mandatory to achieve the desired thermal conditions when the fuel is injected in the combustion chamber. Nevertheless, the preheating plugs require a considerably high electric energy consumption from the battery. Thus, the improvement of their design is a key issue to reduce both the energy consumption and the pollutant emissions.

In this paper, and for the first time, two different plugs of RENAULT have been characterized by means of infrared (IR) thermography. In comparison with other conventional measurement techniques such as with thermocouples or thermo-resistances, IR thermography presents the advantage of providing an instantaneous response to any temperature variations. Furthermore IR thermography is a non-intrusive tool [7] to characterize small elements such as the preheating plugs of a vehicle. Otherwise it would be hardly possible to measure the plug temperature under real operating conditions, as the insertion of thermocouples would modify the heat transfer conditions. Infrared (IR) thermography has already proved to be a useful technique in a wide variety of applications such as in the automotive sector [8–10], building inspections [11,12], HVAC installations [13,14] or in the characterization of heat exchangers [15,16].

2. Experimental set-up and methodology

2.1. Description of the preheating plugs

This paper analyzes the preheating system of a RENAULT Meganne III K9K engine. The main features of the engine are given in

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