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Soot particles experimental characterization during cold start of a micro car engine

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Abstract

Substantial amount of pollutants is emitted during the vehicle start-up, since the engine has not reached its optimal operating temperature.
In urban traffic environment, the engine emissions during its warming up until it reaches a hot stabilized mode are an important source of major air pollutants.
Existing literature indicates that:
- in recent years the vehicle emissions have been reduced significantly, while those related to engine cold starts still remain high;
- emission levels during engine start-up are deeply influenced by the vehicle characteristics.
Most of studies are related to diesel engines equipped with high efficiency DPFs, gasoline port fuel injected and gasoline direct injected engines equipped with three-way-catalysts.
This paper aims at characterizing pollutants and solid particles emissions from a low displacement two cylinder diesel engine, whose main application is in city cars and urban vehicles. During tests, measurements started at the time of the engine cold start-up; transient conditions of load and speed were imposed to the engine. A characterization of solid particle was performed, in terms of particle number and size distribution for three engine thermal conditions: cold, warm and hot starts.

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Keywords: Diesel engine, cold start, warm start, particulate matter

1. Introduction

In urban traffic environment, vehicle cold/ warm start and transient conditions occur very frequently. Substantial amount of pollutants is emitted during these engine operations, since the engine has not reached its optimal hot

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stabilized mode. Particulate emissions along with NOx are an important source of major air pollutants and they have become the focus in diesel engine control technology.
In recent years, the total vehicle emissions have been reduced significantly, while those related to engine cold starts still remain very high and represent key issues in order to satisfy the continuous tightening of worldwide regulations limiting emissions of harmful compounds in the exhaust gas [1, 2, 3]. Since the final result of driving tests is significantly affected by the percentage of emissions during cold phase, research activity is devoted to develop strategies able to eliminate or reduce the harmful compounds in the exhaust gas during these periods.
Literature presents the results of investigations aimed at developing potential strategies able to shorten the cold phase of the engine and at reducing pollutant emissions during engine start-up. [4] presents the results of an experimental analysis carried out in order to understand the behavior and the stability of the combustion process when multiple injection strategies are applied in the idle phase after the cold start of the engine. In [5, 6], an intake heating strategy is presented and its effect on reducing the gaseous and particulate emissions is analyzed.
Research activity has been devoted to investigate the exhaust emission during engine transient operation and during cold and warm start. [7] presents the results of emissions measurements in a turbocharged diesel engine in the first period after its start. [8] compares the emissions from a diesel engine in the initial period following the start-up phase in cold and warm start mode, once cooling water and lube oil have reached a state of equilibrium. [9] and [10] compare solid particle number and size distribution during engine start-up of various light duty engines and highlight the need of control strategies able to reduce particle emissions during engine start-up. [11] investigates the exhaust emission characteristics of a six-cylinder direct injection diesel engine during cold and warm start. [12] presents an investigation of the operating conditions effect on nano-particle emissions from a turbocharged diesel engine. [13] evaluates the impact of cold ambient conditions on cold start and idle emissions of a diesel engine.
Literature highlights that :
- the emission levels during cold engine start-up are higher than those after stable thermal conditions are reached, since fuel atomization, mixture formation and combustion process are penalized and, moreover, facilities used for exhaust treatment and cleaning do not work properly, yet;
- the emissions are deeply influenced by the vehicle characteristics; most of literature is related to diesel engines equipped with high efficiency DPFs, gasoline port fuel injected and gasoline direct injected engines equipped with three-way-catalysts;
- investigations about PM emissions during engine cold start and transients by using advanced instrumentation are limited.
This paper aims at characterizing pollutants and solid particles emissions from a low displacement two-cylinder diesel engine, whose main application is in city cars and urban vehicles. Steady state conditions have been investigated in a previous research activity, in which performance and emissions were analysed in the engine complete operative field [14]. The results here presented are related to dynamic tests: measurements started at the engine idle, then transient conditions of load and speed were imposed. Cold start-up, warm-up and hot period were investigated. The exhaust emissions were analyzed and a characterization of solid particle was performed, in terms of particle number and size distribution by means of Cambustion differential mobility spectrometer.

Nomenclature

D_p	particle diameter
N/cc	concentration of particles per cubic centimeter

2. Experimental system and tests

2.1. Test engine and facilities

Tests were conducted on Lombardini LDW442CRS, a two-cylinder diesel engine equipped with a common rail fuel injection system. Engine specifications are given in Table 1.
The engine was coupled with an asynchronous motor SIEMENS 1PH7. Figure 1 shows the engine test bench.
A software in Labview10 environment was used to manage stationary and transient tests. During transient tests, in order to guarantee the perfect repetition of a specific set of conditions, the input values were managed by a previously compiled data file.