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New research assessing the effect of engine operating conditions on regulated emissions of a 4-stroke motorcycle by test bench measurements

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ABSTRACT

In the latest years the effect of powered two-wheelers on air polluting emissions is generally noteworthy all over the world, notwithstanding advances in internal combustion engines allowed to reduce considerably both fuel consumption and exhaust emissions of SI engines. Nowadays, in fact, these vehicles represent common means of quotidian moving, serving to meet daily urban transport necessities with a significant environmental impact on air quality. Besides, the emissive behavior of the two-wheelers measured under fixed legislative driving standards (and not on the local driving conditions) might not be sufficiently representative of real world motorcycle riding.

The purpose of this investigation is a deeper research on emissive levels of in-use motorcycles equipped with last generation SI engines under real world driving behavior. In order to analyze the effect of vehicle instantaneous speed and acceleration on emissive behavior, instantaneous emissions of CO, HC and NO_X were measured in the exhaust of a four-stroke motorcycle, equipped with a three-way catalyst and belonging to the Euro-3 legislative category. Experimental tests were executed on a chassis dynamometer bench in the laboratories of the National Research Council (Italy), during the Type Approval test cycle, at constant speed and under real-world driving cycles. This analytical-experimental investigation was executed with a methodology that improves vehicles emission assessment in comparison with the modeling approaches that are based on fixed legislative driving standards. The statistical processing results so obtained are very useful also in order to improve the database of emission models commonly used for estimating emissions from road transport sector, then they can be used to evaluate the environmental impact of last generation medium-size motorcycles under real driving behaviors.

1. Introduction

In order to estimate the environmental impact ascribable to road traffic sector and to delineate operative policy to safeguard air quality state in urban contexts, broad investigations are essential for policy makers and academics. In this context, significant publications (European Commission, 2010; Vasic and Weilemann, 2006; Ntziachristos et al., 2006) established that the two-wheelers vehicles in the last years are taking on an increasing chief role in private mobility with an immediate consequence on urban air quality of European countries, and the share of the emissions from mopeds and motorcycles to the total air pollution will increase in the next years if no remedial measures will be taken.

Two-wheelers class, in fact, are very utilized as widespread means of quotidian moving in the main European cities (Prati et al., 2011; Iodice and Senatore, 2015a; Mellios et al., 2006), in which motorcycles and mopeds represent an important share of motorized vehicles. Recently, in fact, these vehicles accounted for about 32 million vehicles in EU-28, so playing around 8% of urban vehicle fleet. For example, in Italy, parking difficulties and traffic congestion effect the real alternatives of urban transportation mobility, to the point that the percentage contribution of the motorized two-wheelers to the whole passenger mobility fleet is close 25%; with around 9 million vehicles, actually, Italian two-wheeler vehicle fleet contributes for about 28% to whole EU-28 figures (Iodice and Senatore, 2014, 2015b).

In the latest years, improvements in internal combustion engines, such as the use of better lubricants, the development of the common rail fuel system with electronic mixture control, and the adoption of three-way catalytic converter, allowed to decrease significantly both fuel consumption and pollutants emission of the last generation engines during the steady state performance. However, while the two-wheelers may have satisfactory emissive behavior during the Type Approval test cycles, on the other hand, under real driving conditions poor emissive performance may result in these vehicles possibly failing key emission tests. It is therefore prominent to make efforts in order to improve fuel

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consumption and emissive levels of this particular vehicular category under urban driving conditions.

The existing fixed legislative driving cycles don't consider particularly the emissive behavior of mopeds and motorcycles under the local driving conditions, so underestimating cycle dynamics. The emissive levels and emission factors calculated in these circumstances aren't adequately descriptive of real-world motorcycle riding, since the use of motorized two-wheelers befalls in urban contexts and then these vehicles are always driven under real driving conditions (Montella et al., 2014). Besides, while there are numerous data published in scientific literature on emissive levels from powered two-wheelers belonging to old legislative standards, little information is known about the exhaust emission of new sold motorcycles in real-world conditions (Hamada and Rahman, 2014). In view of all these concerns, it is clear that a consistent assessment of the emissive behavior of the last generation motorcycles in real urban conditions is extremely important.

For all these motives, an analytical-experimental study aiming on these concerns and based on roller test bench measurements was executed by the Department of Industrial Engineering (University of Naples Federico II) and by Istituto Motori (CNR-Italy). Emissions of CO (carbon monoxide), (HC) unburned hydrocarbons and NO_X (oxides of nitrogen) were measured in the exhaust emissions of a four-stroke motorcycle with an engine displacement of 280 cm^3. This motorcycle belongs to the Euro-3 type approval category and is equipped with a three-way catalytic converter for emissions abatement.

In order to better characterize the emissive levels of the newly sold motorcycles under urban driving conditions, and thus to analyze the influence of instantaneous vehicle speed and acceleration on emissive performance, the exhaust emissions of this motorcycle were calculated during different driving cycles: the legislative driving cycle for Europe "UDC + EUDC" (Urban Driving Cycle, Extra Urban Driving Cycle) and two real-world driving cycles, which are the Worldwide Motorcycle Test Cycle ("WMTC") and the "Artemis Urban Cold" driving cycle. Besides, further experimental tests were executed at constant speed, so removing the effect of the acceleration phases that generally have a strong influence on emission levels (Zamboni et al., 2011; Gkatzoflias et al., 2007). At last, the present study was focused also on the comparison between the statistical processing results achieved in this investigation and the emission factors attained by the existing emission models (Elst et al., 2006; Steven, 2003) for calculating emissions from road transport sector, obtaining interesting results.

2. Material and methods

2.1. The laboratory

Roller test bench measurements were executed in the laboratories of Istituto Motori (National Research Council, CNR-Italy); the motorcycle under investigation was tested on a two-wheeler chassis dynamometer (AVL Zollner 2000—single roller), which simulates road load resistance and vehicle inertia (Iodice and Senatore, 2015c). The bench (Fig. 1) is arranged to reproduce the road load conditions and to measure the exhaust emissions of the two wheelers during several dynamic speed cycles. By using this chassis dynamometer, it is also possible to carry out experimental tests in constant speed mode, constant acceleration mode, and constant tractive force mode. Besides, a variable speed blower, positioned in front of the vehicle, acted as the cooling wind on the road. A driver's aid displayed speed trace of the driving cycle to follow with a tolerance of ± 1 km/h.

Each experimental test was executed in cold-start conditions and, before each experiments, the motorcycle was kept at a quite constant temperature around 20 °C for at least 6 h. Generally, environmental stability conditions during emission gases determination are needed to obtain reliable results, characterized by very high repeatability during the cold start transient. Although in this laboratory it is not possible to set the room temperature, pressure and moisture (which can affect the cold emissions), no radical differences were detected in the laboratory environmental conditions; during emission gases determination, in fact, the test room temperature was always verified between 17 and 22 °C.

During the experimental tests the exhaust gases of the motorcycle are diluted with filtered ambient air by a CVS (Constant Volume Sampling) with Critical Flow Venturi unit: a dilution tunnel is positioned upstream the sampling for gas analysis, in order to guarantee stable flow condition. Depending on the test cycle to be driven and the available analyzer ranges, a fit range for tunnel flow is chosen in order to measure all exhaust emissions with sufficient accuracy.

A portion of diluted gases so obtained is sampled downstream the dilution tunnel in the sampling bag system for measuring the concentrations of regulated pollutants in the exhaust emissions, by a non-dispersive infrared analyzer (NDIR) for CO, a flame ionization detector analyzer (FID) for HC and a chemiluminescence detection analyzer for NO_X. The gases used in the calibration of these instruments are CO,

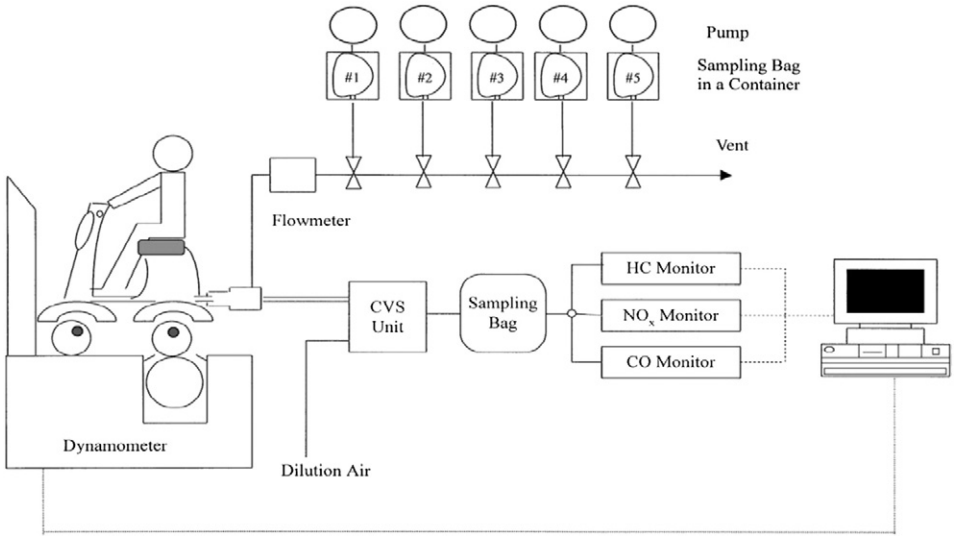

Fig. 1. The experimental apparatus.