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Cold start emissions of a motorcycle using ethanol-gasoline blended fuels

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Abstract

The object of this study is to investigate the effect of ethanol–gasoline blends on CO and HC cold start emissions from a four-stroke motorcycle. Nowadays, due to catalyst improvements and efficient electronic mixture control, a significant part of the total emissions during a trip takes place during the cold phase. The employ of alternative fuels could be one of means to lessen the cold-start emissions from two-wheeler engines: ethanol is known as potential alcohol alternative fuel for spark ignition engines, which can be blended with gasoline to increase oxygen content and then to decrease CO and HC emissions.

From this considerations, an experimental-analytical investigation was performed on the exhaust cold extra emissions of one motorcycle belonging to the Euro-3 legislative category. The study explains a calculation procedure to model the cold start transient behavior of motorcycles in order to evaluate the impact of ethanol addition (10, 20 and 30 vol.%) on cold start emissions compared with a reference commercial gasoline. Results of the tests indicate that CO and HC cold start extra emissions by using ethanol–gasoline blended fuels decrease compared to the use of unleaded gasoline. Emission factors during the cold start transient were quantized as a function of the ethanol percentage in the blended fuels.

Keywords: ethanol–gasoline blend; cold start emission; two-wheelers emission

1. Introduction

Due to the increasing demand for energy and strict air pollution regulations, nations worldwide are actively studying and developing alternative clean fuels. Among alternative fuels, the employ of ethanol could be one of means to lessen carbon monoxide and total hydrocarbon emissions from two-wheeler engines and to reduce the

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depletion of petroleum fuels simultaneously. Emissions of pollutants into atmosphere from two-wheelers are becoming more and more concern in an industrialized society, especially for CO and HC [1,2,3]; due to attractive qualities, such as high maneuverability, parking simply, and inexpensive, motorcycles and mopeds are one of the main modes of carrying in major cities of southern Europe, particularly in Italy where the share of the two-wheelers to the total passenger vehicle fleet is around 25% [4]. Since catalysts are efficient only at high temperature, emissions are far more significant during the first part (cold phase) of a trip, when engine and catalyst are cold; for newly sold motorcycles equipped with a catalytic converter and electronic mixture control, cold-start emissions correspond to an important proportion of total emissions, with an evident consequence on air quality because of their prevailing use in urban environments [5]. For this reasons, studying the influence of ethanol on the pollutant emissions and performance of an engine is of great interest for many years. However, for newly sold motorcycles now few data are available for showing the effects of ethanol–blended gasoline on exhaust emissions, especially relating to the cold start transient and the warming up process; an expansion of the relevant cold emission factors was deemed necessary.

Taking into account all the previous considerations, a reliable evaluation of the cold emissive behaviour of motorcycles fuelled with ethanol-gasoline mixtures is of the greatest importance. An experimental-analytical investigation on the exhaust cold extra emissions of one motorcycle belonging to the Euro-3 legislative category, of 998 cm^3 swept volume, was jointly performed by Istituto Motori of the National Research Council (IM-CNR) and the Department of Industrial Engineering of the University of Naples Federico II. The first result of the study is the development of a calculation procedure for cold transient modeling, focused on the estimate of cold emission as a time-dependence function; processing measured data allows to quantify the cold transient duration and the emitted quantities during the cold phase. This methodology also analyses the influence of different driving cycles on motorcycles emission behavior during the cold-start. The second phase of the study was undertaken to evaluate, by using the same procedure, the impact of ethanol addition (10, 20 and 30 vol.%) on motorcycle cold start emissions compared with a reference commercial gasoline. Results of this analysis indicate that CO and HC cold start extra emissions by using ethanol–gasoline blended fuels decrease compared to the use of unleaded gasoline; emission factors during the cold start transient are quantized as a function of the ethanol percentage in the blended fuels.

1.1. Ethanol as fuel for SI engines and for motorcycles

The use of alternative fuels has received considerable attention due to increased demand for energy and more rigorous emission regulations [6]. Among alternative fuels, ethanol is very attractive and employed most generally for SI engines, having the following advantages over gasoline:

- Ethanol is a renewable fuel because it can be produced from agricultural feedstock such as sugar beet and wheat, corn and sugar cane, through biochemical processes [7] based on commercial technologies, or even from ligno-cellulosic materials but with technologies that are still under industrial demonstration.
- Ethanol is a chemical compounds composed of an ethyl group and a hydroxyl group bonded to the carbon atom: the high oxygen content in ethanol favors the further combustion of blended fuels within engine cylinders and then reduces the emissions of CO and HC [8].
- Ethanol is characterized by high octane number and the ability to withstand high pressures and temperatures without uncontrolled ignition. As the efficiency of SI engines depends on the compression ratio and high-octane fuels are particularly suitable for high compression ratios, the use of ethanol can offer higher energy efficiency.
- The latent heat of evaporation of lower molecular weight alcohols, such as ethanol, is higher than that of gasoline; this makes the temperature of the intake manifold lower, then increasing the volumetric efficiency [9].

Since using ethanol–gasoline blended fuels can reduce the emissions of pollutants and the depletion of fossil fuels at the same time, many researchers for many years have been dedicated to studying the influence of these fuels on the performance of an engine and on pollutant emissions. However, the correlations between ethanol-gasoline blended fuels and pollutant emissions have mostly been analyzed with passenger cars, while few studies in the literature investigate the effects of ethanol-blended gasoline on pollutant emissions from motorcycles, especially concerning the cold start transient.

Jia investigated the effect of using an ethanol– gasoline blend fuel (ethanol 10 vol.%) on exhaust emissions of a four-stroke motorcycle (125 cm^3 without catalytic converter) using chassis dynamometers. The results indicate reductions in CO and HC emissions as compared to the use of unleaded gasoline, with an insignificant effect of ethanol on NO_X emission. Furthermore, it was found that the ethanol-gasoline fuelled motorcycle engine produces more ethylene and acetaldehyde emissions than unleaded gasoline engine does [8]. Also Yao studied the effect of ethanol-gasoline blends on criteria air pollutant emissions in a four-stroke motorcycle with a displacement of 125 cm^3 and without a catalytic converter. The ethanol was blended with unleaded gasoline in four percentages (3, 10,15, and 20% v/v) and controlled at a constant research octane number, RON (95), to accurately represent commercial gasoline. In general, the exhaust CO and NO_X emissions decreased with increasing oxygen content in fuels. In contrast, ethanol added in the gasoline did not reduce the THC emissions for a constant RON gasoline. The 15% ethanol blend had the highest emission reductions relative to the reference fuel. The high ethanol–gasoline blend ratio (20%) resulted in a less emission reduction than those of low ratio blends (<15%). This may be attributed to the changes in the combustion conditions in the carburettor engine with 20% ethanol addition [7]. Yang investigated the emission characteristics of regulated air pollutants and carbonyls from nine four-stroke motorcycles using gasoline blended with 3% ethanol. All motorcycles had the same after-treatment device, a two-way catalytic converter, the fuel systems are all carburettor systems, while the displacement volumes were from 100 cm^3 to 150 cm^3. The results show that average emission factors of CO and THC decreased by 20.0% and 5.27% using ethanol-gasoline blend fuel, while NOx and CO_2 emission increased by 5.22% and 2.57% [10].

2. The vehicle and the experimental apparatus

In these experimental tests, a vehicle with a displacement of 998 cm^3 was employed: the motorcycle "Aprilia RSV". Its technical characteristics are reported in Table 1. This motorcycle is fitted with a very efficient electronic fuel injection systems, allowing the control of fuel feeding and enhancing catalyst efficiency also in cold transient; the on-board central unit controls the fuel injection strategy with feedback signal from the oxygen sensor placed in the exhaust pipe. The technologies to meet the latest emissive standards are a three way catalytic converter, the lambda probe oxygen sensor and a carbon canister.

Table 1. Technical specifications of the tested motorcycle

Category	Motorcycle
Engine principle	4-stroke
Cubic capacity [cm^3]	998
Fuel system	Integrated electronic engine management system
Cooling system	Liquid cooling with three way pressurized circuit
Max power [kW] @ 10000 rpm	105.24
Dry weight [kg]	189
After-treatment system	Three way catalytic converter - lambda probe oxygen sensor
Legislative category	Euro-3

In the Istituto Motori emission laboratory (Fig. 1) the motorcycle was tested on a chassis dynamometer (AVL Zollner 20" - single roller) that enables simulation of vehicle weights from small mopeds up to heavy two-wheel vehicles (range 80-450 kg). This bench is designed to simulate the road load (including vehicle inertia) and to measure the exhaust emissions during dynamic speed cycles. The chassis dynamometer was set by using the running resistance table according to the procedures laid down in Directive 97/24/EC: the equivalent inertia mass was set to 280 kg, the rolling resistance of front wheel 'a'= 24.6 N and the aerodynamic drag coefficient 'b'= 0.0242 $N/(km/h)^2$. A variable speed cooling blower was positioned in front of the motorcycle so as to direct the cooling air in a manner which simulates actual operating conditions; the blower speed was such that the linear velocity of the air at the blower outlet was within ±5 km/h of the corresponding roller speed. Before each test in cold start conditions, the motorcycle was kept at constant temperature between 20 °C and 25 °C for at least 8 hours. During the tests the exhaust gases were diluted with purified ambient air by a Mixing Unit connected to a Constant Volume Sampling with Critical Flow Venturi unit (AVL CFV-CVS). During the tests a continuous sample flow of the mixture were measured with an exhaust gas analysis system (AVL AMA 4000) so that concentrations of CO and HC were determined: the exhaust pollutants were sampled from the dilution tunnel and analyzed at 1Hz resolution. The exhaust concentration of HC and CO were measured, respectively, by a flame ionization detector (FID) analyzer (range: 0-5000 ppm) and a non-dispersive infrared (NDIR) analyzer (range: 0-5000 ppm). The signals were corrected for the time delay respect to the speed [5].

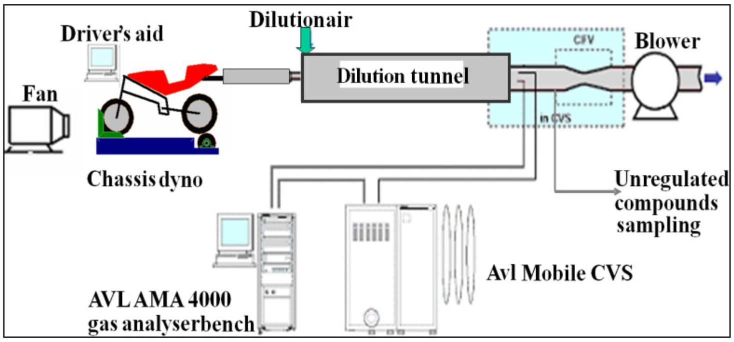

Fig. 1. Experimental apparatus

3. Experimental-analytical investigation on cold star transient

3.1. Warming up process

An increasing share of the newly sold motorcycles comes with fuel injection and does have electronic mixture control, in combination with the three-way catalyst; this clearly indicate that a cold start often results in elevated emissions compared with those of a start with a warm engine or driving with a warm engine. The cause may be attributed to various factors. First, the cold engine requires a rich mixture to compensate for the fuel that does not contribute to the combustion because it condenses at the cold internal parts of the engine or for the fuel that has not yet vaporized. Second, the catalyst has to warm up and during this period catalyst efficiency increases rapidly and - mainly during the early moments after a cold start - the fuel that is not combusted, or only partially, passes the catalyst untreated as HC and CO.

The current emission models available in Europe for calculating emissions from road traffic are widely used to calculate emissions of motorcycles. However, they do not take into consideration in detail the warm-up behavior of motorcycles: the emission factors measured in such conditions might not be sufficiently representative of real-world motorcycle riding, because it is assumed that most cold starts of powered two-wheelers occur in an urban environment and thus are driven under urban driving conditions after the start.

3.2. Modeling and results using commercial gasoline

In this section a calculation procedure is presented to model the cold-start transient. Extra emissions during operation of the cold-start engine can be represented by a cold instantaneous emission factor $f_{cold}(t)$ [11,12], expressed in terms of mass per time unit, with the help of the following considerations. Evolution of the cold instantaneous emission $f_{cold}(t)$ along time, for a given pollutant, can be summarised into a first phase characterized by the highest cold emissions due to the low temperatures of engine and catalyst and to the high enrichments of the air-fuel mixture, a second phase with decreasing cold emissions for the progressive increase of engine and catalyst temperatures and for the lower enrichments, followed by a quite stable phase with the minimum cold emissions when the normal temperatures are reached and the mixture is very close to the stoichiometric ratio. The function, then, must be such as to take zero value at the instant T_{reg}, that is the cold transient duration (1); it is also plausible to assume that the function is decreasing during the transient, and that the first derivative of the function takes zero value at the final time of transient (2). A functional expression that fulfil these two boundary conditions is represented by (3), expressed through two parameters ("T_{reg}" and "f_0") [5].

$$f_{cold}(T_{reg}) = 0 \tag{1}$$

$$f'_{cold}(T_{reg}) = 0 \tag{2}$$

$$f_{cold}(t) = f_0\left(e^{\frac{t}{T_{reg}}} - e\cdot\frac{t}{T_{reg}}\right)[\text{g/s}] \tag{3}$$

For the definition of the these parameters, information on cold-start additional emission and on the transient phase has to be known. By processing the experimental online results, measured on the Type Approval driving cycle (UDC+EUDC) with cold start for the tested motorcycle using commercial unleaded gasoline, the cumulative curves of emissions are obtained as a function of time: CO and HC experimental cumulative emission are shown in Figure 2. As suggested by EMPA [13,14] to calculate the absolute cold extra-emission, the hot contribution can be fitted with a line (with very high correlation coefficients) whose intercept can be considered equal to cold-start additional emission E_C. The duration "T_{reg}" of the thermal regime reaching is calculated as the instant in which the profile of the cumulative emission deviates from the linear regression, and cuts two lines parallel to the linear regression but which have the constants equal to the constant of linear regression ± 2*standard deviation of emissions [15,16]

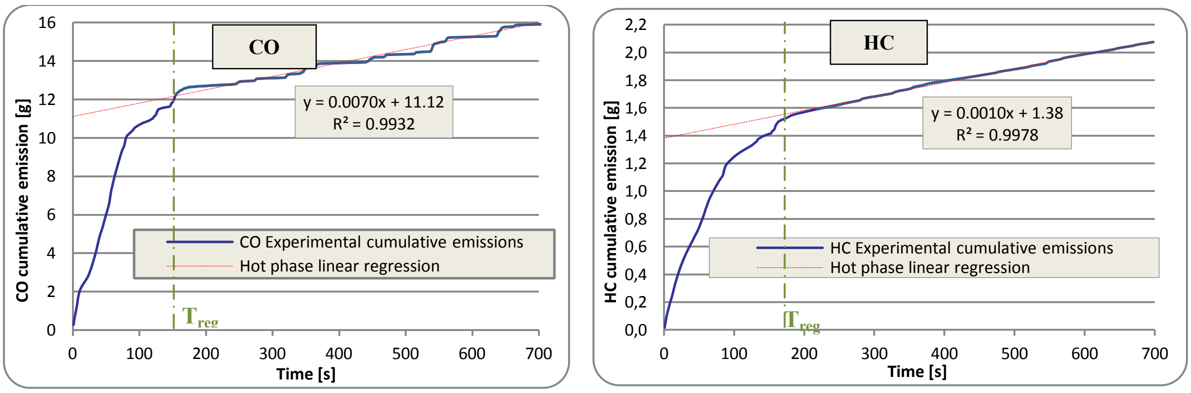

Fig. 2. CO and HC experimental cumulative emission for tested motorcycle during UDC driving cycle

The next step, necessary for fixing the "f_0" parameter, consists in defining experimental and analytical curves for the cold cumulative extra emission. The experimental curve can be derived through the total cumulative emission by subtracting, in the transient time, the values of the hot phase linear regression. The analytical function, instead, is computed by integration of the function $f_{cold}(t)$ (Equation (3)), so obtaining the functional expression of Equation (4). In Figure 3, parameter "f_0" can be tuned in order to fit the analytical function to the experimental curve [5]. From the values obtained with this method the cold cumulative emission, the parameter "f_0" and the duration of the cold-start transient "T_{reg}" clearly depends on the pollutant.

In order to evaluate the influence of different driving patterns on the cold start extra emission and transient duration, the experimental test procedure measured exhaust emissions also at constant speed and for UDC, WMTC and Urban Cold driving cycles. Tab. 2 and Tab. 3 show all cold transient data obtained by employing the calculation procedure already described, thus completing the assessment of cold emissive behaviour.

$$E_{\substack{cold\\cum}}(t) = \int_0^t f_{cold}(t)dt = f_0\left(T_{reg} \cdot e^{\frac{t}{T_{reg}}} - \frac{e \cdot t^2}{2T_{reg}} - T_{reg}\right)[g] \quad (4)$$

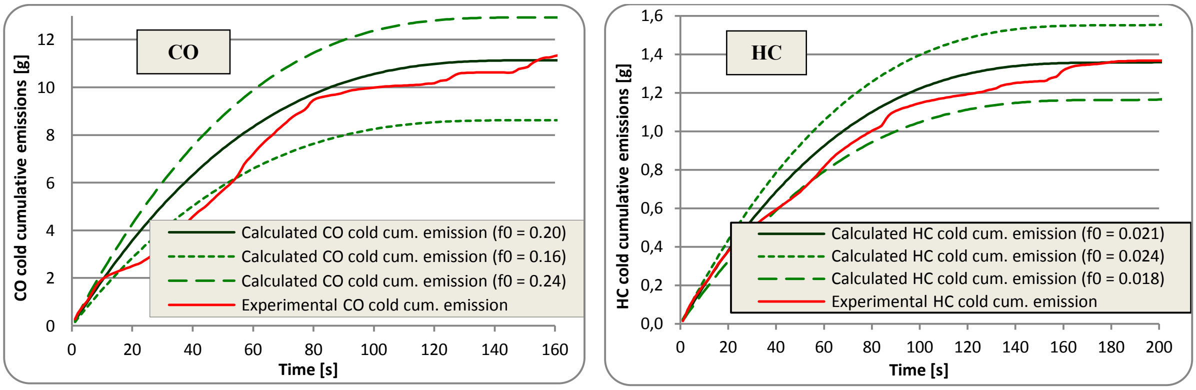

Fig. 3. Experimental and calculated CO and HC cold cumulative extra emissions during UDC driving cycle

Table 2. Motorcycle cold transient data of carbon monoxide for different driving cycles

Driving cycle	*Average speed* [km/h]	*Transient duration* T_{reg} [s]	*Cold-start emission* E_C [g]	f_0 [g/s]	$e_{cold}=E_C/T_{reg}$ [g/s]	$e_{cold}^*=f_0(e/2-1)$ [g/s]	*Cold emission factor* [g/km]	e_{hot} [g/s]	*Hot emission factor* [g/km]	e_{cold}/e_{hot}
Idle	0	190	12.99	0.190	0.068	0.068	-	0.0015	-	45.58
20 km/h	20	205	14.13	0.190	0.069	0.068	12.41	0.0011	0.20	62.66
40 km/h	40	115	6.84	0.165	0.059	0.059	5.35	0.0009	0.08	66.09
60 km/h	60	95	5.56	0.160	0.059	0.057	3.51	0.0018	0.11	32.51
80 km/h	80	95	6.53	0.185	0.069	0.066	3.09	0.0027	0.12	25.46
UDC	16.69	155	11.12	0.200	0.072	0.072	15.47	0.0070	1.35	10.25
WMTC	22.44	150	10.66	0.200	0.071	0.072	11.40	0.012	1.62	5.92
Urban Cold	20.39	175	12.45	0.200	0.071	0.072	12.56	0.0202	3.80	3.52
Medium values		*148*	*10.04*	*0.186*	*0.067*	*0.067*	*9.11*	*0.0059*	*1.04*	*31.50*

Table 3. Motorcycle cold transient data of unburned hydrocarbon for different driving cycles

Driving cycle	*Average speed* [km/h]	*Transient duration* T_{reg} [s]	*Cold-start emission* E_C [g]	f_0 [g/s]	$e_{cold}=E_C/T_{reg}$ [g/s]	$e_{cold}^* = f_0(e/2-1)$ [g/s]	*Cold emission factor* [g/km]	e_{hot} [g/s]	*Hot emission factor* [g/km]	e_{cold}/e_{hot}
Idle	0	200	1.12	0.015	0.0056	0.0054	-	0.00068	-	8.24
20 km/h	20	225	1.52	0.0185	0.0068	0.0066	1.22	0.00068	0.12	9.93
40 km/h	40	135	0.83	0.017	0.0061	0.0061	0.55	0.00073	0.07	8.42
60 km/h	60	150	1.18	0.0215	0.0079	0.0077	0.47	0.00059	0.04	13.33
80 km/h	80	135	1.11	0.023	0.0082	0.0083	0.37	0.0006	0.03	13.70
UDC	19.53	180	1.38	0.021	0.0077	0.0075	1.41	0.00101	0.22	7.59
WMTC	24.29	225	1.76	0.021	0.0078	0.0075	1.16	0.00204	0.26	3.83
Urban Cold	19.41	235	1.82	0.021	0.0077	0.0075	1.44	0.00224	0.41	3.46
Medium values		*186*	*1.34*	*0.020*	*0.0072*	*0.0071*	*0.946*	*0.0011*	*0.16*	*8.54*

It is apparent that "f_0" is the value of function (3) corresponding to t=0 (that is: $f_0=f_{cold}(t=0)$), but it would be difficult a comparison with the measured cold emission factor at initial time, because of a unclear continuous sampling at the start engine. The usefulness of this value rather derives from the observation that it can be considered constant with the change in driving cycles, since it represents the level emission level at the initial instant, and then it is a function only of the vehicle, pollutant and ambient temperature. In fact, it is found in Tab. 2 and Tab. 3 that the values of "f_0" estimated with this procedure vary not significantly with the different test cycles.

To validate the whole procedure, the cold-star emissions were subsequently estimated through the use of the cold cumulative emission function (4) corresponding to t=T_{reg}, so obtaining E_C^* (5), and the cold emission factors deduced as $e_{cold}^* = E_C^* / T_{reg}$ (6).

$$E_C^* = E_{\substack{cold\\cum}}(t = T_{reg}) = f_0 \cdot T_{reg}\left(\frac{e}{2} - 1\right) \text{ [g]} \tag{5}$$

$$e_{cold}^* = \frac{E_C^*}{T_{reg}} = f_0 \cdot \left(\frac{e}{2} - 1\right) \text{ [g/s]} \tag{6}$$

As appreciable proof of validation, in Tab. 2 and Tab. 3 it's evident the equivalence between these cold emission factors (e_{cold}^*) and those calculated initially through the analysis of the cumulative curves of emissions shown in Fig. 1 ($e_{cold}=E_C/T_{reg}$). Besides, it is clear that the cold emission factors e_{cold}^*, as estimated in (6), is a function only of "f_0" and then it is independent from particular driving cycle; this observations leads to the further conclusion that, for a certain vehicle and for a certain pollutant, the experimental results of a single driving cycle are sufficient for the estimate of the cold emission factor e_{cold}^*. In this regard, the value pairs (E_C; T_{reg}), derivable for all driving cycles in Table 2 and Table 3, and now reported in Fig. 4, are characterized by a linear interpolation with a very good degree of approximation, whose slope is precisely the cold-start emission factor relating to this vehicle and the particular pollutant in question. The Tab. 2 and Tab. 3 also show the hot emission factors e_{hot} for each driving cycle, that are derived by slope of the linear regression of the experimental cumulative curves of emissions reported in Fig. 2

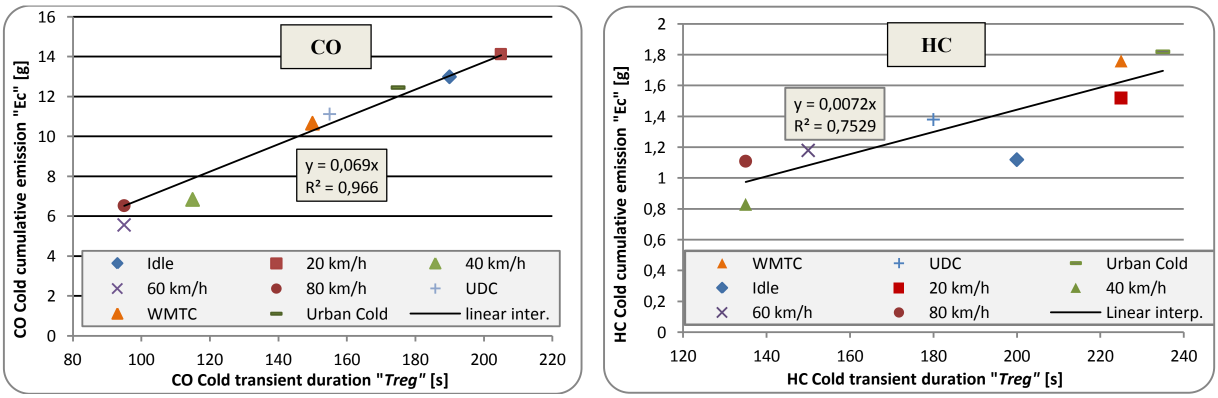

Fig. 4. Cold-start emissions of CO and HC estimated against the cold transient duration for each driving cycle

3.3. Results of all test fuels: comparisons and discussion

From the literature review previously shown, it's evident that alcohol–gasoline blended fuels can really lower the regulated pollutant emission of motorcycles without change to the engine design, but information related to the cold-start emissions are rather limited; for this reason an expansion of the relevant cold emissive behavior is deemed necessary.

In the successive step of the study, then, in order to evaluate the influence of different ethanol-gasoline mixtures on the relevant cold extra emissions and transient duration, the experimental test procedure measured exhaust emissions during UDC driving cycle for all the testing fuels. One fuel (E0) is commercial unleaded gasoline with a research octane number (RON) of 95 with oxygenated additive (8.1 %v/v), the results of which have already been presented in the previous section. Second fuel (G0) is unleaded gasoline without any oxygenated additive, which is also used as a reference fuel and as base fuel for the preparation of ethanol-gasoline blended fuels: the other three fuels are ethanol-gasoline blends containing 10% (G10), 20% (G20), and 30% ethanol (G30), v/v. The properties of all test fuels are listed in Table 4.

Table 4. Properties of tested fuels

Test fuels	*E0*	*G0*	*G10*	*G20*	*G30*
Hi [MJ/kg]	44.30	44.30	42.30	40.47	38.50
Density [kg/m^3]	730	745	750	755	760
RON	95.5	94.7	96.7	98.8	100.8
Carbon (wt %)	86.56	86.56	81.20	76.47	71.97
Oxygen (wt %)	1.8	0.0	5.4	10.2	14.4
Benzene (vol.%)	0.67	0.83	0.75	0.66	0.58
Aromatic (vol.%)	33.3	33.7	30.3	27.0	23.6

The tested motorcycle is fitted with a very efficient electronic fuel injection systems, allowing the control of fuel feeding and enhancing catalyst efficiency also in cold transient; the on-board central unit controls the fuel injection strategy with feedback signal from the oxygen sensor placed in the exhaust pipe. In this conditions we can investigate the effect of ethanol addition on the pollutant emission under the original fuel injection strategy.

Information on the cold start transient for different tested fuels are deduced by using the analytical procedure above presented and are summarised in Table 5, while in Fig. 5 the cold-start emission factors of CO and HC are plotted against the oxygen content of all testing fuels. The most evident effect of the use of improved engines, in combination with catalytic technology can be observed in the tested Euro-3 motorcycle, for all the testing fuels, in the differences between emissions during the cold-start and the hot phases. During the cold start, the engine and catalytic converter are not at their optimal operating conditions: given the rich gasoline content in the air–fuel mixture, with the catalytic converter failing to reach the light-off temperature, the motorcycle emits higher concentrations of CO and unburned fuel.

CO formation in engine depends mainly on air/fuel mixture equivalence ratio. As regards all the tested fuels, mixture enrichment during cold start increase CO emission in comparison with the levels recorded for steady engine operation. It's evident in Tab. 5 that the decrease of CO cold emissions during the transient time is associated with the increase of ethanol content in the blended fuels: lower CO cold emission levels are observed for ethanol-gasoline blended fuels in comparison with unleaded gasoline E0 and G0, as the amount of oxygen in ethanol molecule eases the oxidation of carbon monoxide.

Table 5. Motorcycle cold transient data for different tested fuels during the UDC driving cycle

	CO					HC				
Test fuels	*Cold transient duration* T_{reg} [s]	*Cold cumulative emission* E_C [g]	f_0 [g/s]	*Cold emission factor* E_C/T_{reg} [g/s]	*Cold emission factor* [g/km]	*Cold transient duration* T_{reg} [s]	*Cold cumulative emission* E_C [g]	f_0 [g/s]	*Cold emission factor* E_C/T_{reg}[g/s]	*Cold emission factor* [g/km]
E0	155	11.12	0.200	0.072	15.47	180	1.38	0.021	0.0077	1.41
G0	165	10.66	0.170	0.065	14.24	180	2.50	0.037	0.0139	2.54
G10	165	9.21	0.150	0.056	11.33	180	1.89	0.028	0.0105	1.93
G20	150	7.41	0.135	0.049	10.03	175	1.30	0.021	0.0074	1.38
G30	165	10.91	0.175	0.066	12.91	180	2.00	0.030	0.0111	2.02

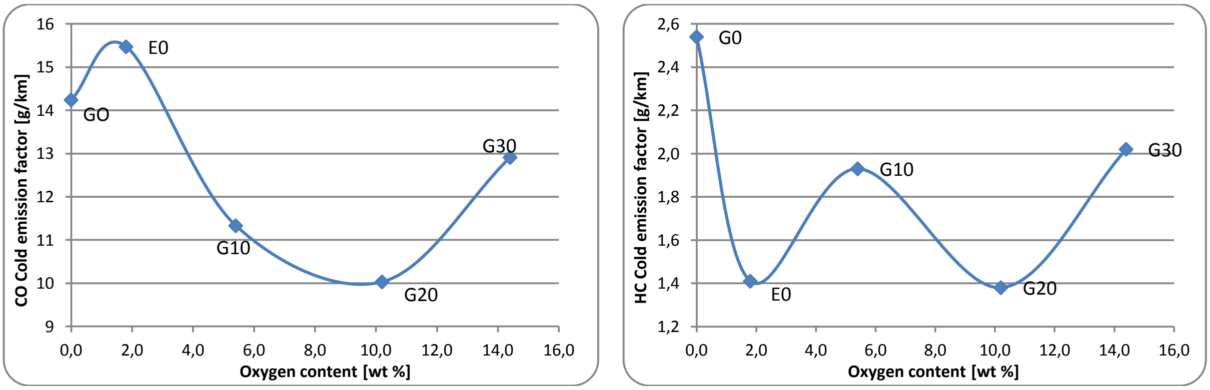

Fig. 5. CO and HC cold-start emission factors plotted against the oxygen content of testing fuels

The reduction of CO cold emission factor compared to unleaded gasoline E0 and G0 is significant in the case of G10 and G20 tested fuels (11.33 g/km and 10.03 g/km respectively), due to improving the combustion process under the fuel-lean conditions in these ethanol-gasoline mixtures: ethanol-blended gasoline can supply more oxygen in the cold start transient for more complete and efficiency combustion in cylinder and therefore reduces CO formation.

From Table 5 it's observed that HC cold emission factors if motorcycle is fuelled with unleaded gasoline E0 (1.41 g/km) appears much lower as compared to the GO reference fuel (2.54 g/km) due to the known positive effect of oxygenated additive in the commercial gasoline. About the blended fuels (G10, G20, G30), it's important to stress that when alcohols are used as blending components in gasoline, all "hydrocarbons" emissions (thus also including alcohols which are not, per definition, a hydrocarbon) are measured with the FID; there is consequently a hazard that the FID reading is overestimated, leading to estimates of HC emissions higher than they really are. However, in the European regulation, no special adjustments are performed regarding this.

In general, the HC cold emission factors decrease with increasing of ethanol percentage in the blended fuels, for two reasons. First, this is the result of sufficient oxygen during combustion process: the oxygenated characteristic of ethanol in blend fuels is more effective in enhancing oxidation of hydrocarbons than that in air. Second, with rising of ethanol content, the RVP of the blend fuels increases to reach a maximum at about 15% v/v of ethanol addition, and then decreases at higher percentages [17]; high volatility of G20 blend fuel improves fuel vaporization during the transient time, thus reducing the formation of unburned fuel in the first engine cycles. As a consequence, HC formation from post-flame oxidation of the unburned ethanol-gasoline mixture is also reduced [18].

G30 exhibits higher HC cold emission levels then the G10 and G20 blend fuels due to the lower volatility of G30 blend fuel that decreases at higher ethanol percentage (>20% v/v). Besides, incomplete combustion occurs in the combustion chamber when an engine operates over a definite lean limit: misfires can become more frequent, with the unburned fuel leading to increased HC emissions [19,20]. Probably, in spite of the fact that the tested vehicle is characterized by an accurate mixture control of fuel injection system, the amount of the fuel supply could not be adjusted immediately according to the combustion condition; this also results in an partial combustion and then in higher HC emissions in the G30 blend fuel [21].

4. Conclusions

The use of biofuels in the transport sector can save significant amounts of fossil fuels and greenhouse gas emissions. Ethanol-blended gasoline is one of the broadly employed renewable alternative fuels used for vehicles; as little is known concerning the cold-start emissions of motorcycles fuelled with ethanol-gasoline mixtures, an expansion of the relevant cold emission factors was deemed necessary.

This paper investigated the influence of ethanol–gasoline blends on cold emissive behavior of a catalyst four-stroke motorcycle. In the experimental activity CO and HC emissions were evaluated in the exhaust of a motorcycle belonging to the Euro-3 legislative category, and a calculation procedure for the cold-start transient behavior was applied to analyze the cold extra emissions. CO and HC cold-start emission factors were analysed in connection with the oxygen content of all testing fuels; these results indicate that using ethanol–gasoline blended fuels, cold start emissions decrease for the leaning effect caused by the ethanol addition that enhances combustion and the higher volatility of blended fuels that (in certain ethanol concentrations) improves fuel vaporization during the transient time. The G20 blend fuel (20% v/v ethanol content) reveals a significant reduction of cold emissions compared to the use of gasoline without any oxygenated additive. The high-ethanol content blend G30 results in higher emissions than those of low content blends; this may be attributed both to incomplete combustion that occurs in the combustion chamber during the transient time when the engine operates over a definite lean limit, and to the lower volatility of G30 blend fuel that decreases at higher ethanol percentage (>20% v/v).

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