

Emissions of 2-Stroke Scooters with Ethanol Blends

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ABSTRACT

A well balanced use of alternative fuels is an important objective for a sustainable development of individual transportation worldwide.

Several countries have objectives to substitute a part of the energy of traffic by ethanol as the renewable energy source.

Investigations of limited and unregulated emissions of two 2-S scooters with gasoline-ethanol blend fuels have been performed in the present work according to the measuring procedures, which were established in the previous research in the Swiss Scooter Network (since 2000).

The investigated fuels contained ethanol (E), in the portion of 5, 10, 15 and 20% by volume.

The investigated 2-S scooters represented a newer and an older 2-stroke technology with carburettor. The newer one was investigated with and without catalyst and the older one only in the original state without catalyst.

Since there is a special concern about the particle emissions of the small engines, the particle mass and nanoparticle measurements were systematically performed.

The nanoparticulate emissions were measured by means of SMPS (CPC) and NanoMet *).

The most important results for application of ethanol blends on 2-S scooters are:

- addition of ethanol to the gasoline provokes a leaner tuning of the engine operation,
- influence of the leaning effect by means of ethanol depends very much on the basic original tuning,
- for the investigated newer 2-S scooter the irregularities of combustion and loss of power were remarkable, with higher ethanol content,
- the richer basic tuning of the newer 2-S scooter enabled a satisfactory driveability with E10,
- the older 2-S scooter with richer basic tuning was little influenced by ethanol blends: good performances and reduction of CO and of fuel consumption up to E20, no impact on (nano)particles emissions,
- at the beginning of operation with ethanol blends some release of particles (residues) from the engine and exhaust system was observed (wash out effect),
- with catalyst there is an efficient reduction of CO, HC, PM and NP, the higher share of ethanol can lower the exhaust temperature and due to that lower the catalytic converter efficiency.

*Abbreviations see at the end of paper

The present investigations with ethanol did not concern the durability of parts exposed to the chemical influences of ethanol. Also the cold startability, particularly in extreme conditions was not addressed.

INTRODUCTION

Laboratories for IC-Engines and Exhaust Emission Control (AFHB) of the University of Applied Sciences, Biel, Switzerland are involved since 2000 in several research projects about emission factors and possibilities of reduction of (nano)particle emissions of 2-wheelers. A special attention was paid to the 2-stroke scooters, which have much higher particle emission, than the 4-strokers.

In an international network project several topics were investigated, [1, 2, 3, 4, 5, 6] and the combinations of technical measures to lower the particle emissions of scooters confirmed the expected effects and showed considerable reduction potentials.

These technical measures were:

- Higher tier lube oils
- Lower oil dosing
- Active oxidation catalyst
- Supplementary filtration & oxidation device (WFC).
- Special fuel.

The special fuel used in those tests was Alkylat Aspen gasoline with a uniform HC-matrix (mostly isooctane) and no aromatics.

The idea of using ethanol blends was known, but not applied before in the research of scooters.

Ethanol is used for passenger cars since a long date (Brazil). In the last years, due to the increasing prices of crude oil, there is a growing interest for ethanol. Several countries have objectives to substitute a part of the energy of traffic by the renewable energy. On the other hand there are interferences with the prices of food in certain regions.

Some manufacturers offer FFV (flex fuel vehicles), which is particularly challenging for high ethanol content (E85) in countries, like Sweden with colder climatic conditions.

There are several technical problems to resolve to guarantee the long live operation of the engine with E85, [7, 8, 9, 10, 11]:

- adaptation of engine construction in regard to a changed thermal stress of combustion chamber parts,
- adaptation of spark plugs and injectors,
- fuel injection system,
- wear of valves, pistons, rings and liners,
- polymer materials and sealings,
- crankcase ventilation and oil dilution,
- software of engine ECU, new or flexible parameter settings.

Small portions of ethanol E5 are generally accepted for the vehicle fleets without any adaptations.

Very useful information about handling of gasoline-ethanol blends up to 10% v/v is given in the CONCAWE report No. 3/08, [12].

The objectives of the present work are to investigate the limited and the unregulated emissions of two typical 2-stroke scooters 50 cc with different ethanol blend fuels. The vehicles are with carburettor and without catalyst, which represents the most frequent technology in Eastern Asia and offers the information of engine-out emissions.

The newer type vehicle, which is originally equipped with oxidation catalyst was also investigated with ethanol and with ox.cat.

During the test a systematical analysis of particle mass (PM) and nanoparticles counts (NP) was performed.

INVESTIGATED SCOOTERS

The research of emissions with alcohol was performed on the Piaggio Typhoon 2-stroke and with an older type 2-stroke scooter Piaggio Vespa (lube oil directly mixed with the fuel).

Fig. 1 shows both vehicles in the laboratory and Table 1 represents the most important data.



Piaggio Typhoon 2-S 50 cc



Piaggio Vespa

Fig. 1: Investigated 2-S scooters



	Piaggio	Piaggio
vehicle identification	Typhoon	Vespa
model year	2004	1974
transmission no. of gears	variomat	m4
km at beginning	670 km	19992 km
engine:		
type	2 stroke	2 stroke
displacement cm ³	50	50
number of cylinders	1	1
cooling	Air cooled	Air cooled
rated power kW	3.2	2.4
rated speed rpm	6500	5700
idling speed rpm	1800	1800
max vehicle speed km/h	45	45
weight empty kg	84	88
mixture preparation	carburettor with automatic oil pump	carburettor blend 2% lube oil in gasoline
SAS (secondary air system)	yes	no
catalyst	dummy	no

Table 1: Data of the investigated scooters.

Both vehicles use simple conventional carburetors with a cable-controlled throttle body and needle.

Fuels

As a basic fuel a standard gasoline, lead-free, RON 95, Swiss market quality was used.

At the beginning of network projects about the particle emissions of 2-S scooters a big charge of this gasoline was purchased to perform all research with the same fuel.

The sulphur content of this gasoline was analysed and no sulphur was found (detection limit < 2 ppm).

The investigated fuel blends contained ethanol (E), in the portions of 5, 10, 15 and 20% by volume.

The most important parameters of the used fuels are summarized in the Table 2.

It can be seen, that with increasing the ethanol ratio the stoichiometric air requirement of the blendfuel decreases. That means by an approximately equal air flow rate the air-fuel-mixture will be leaner. Furthermore there is less heat value in ethanol. The fix boiling point and the high latent heat of evaporation of ethanol may cause serious problems of cold starting.

		Gasoline	Ethanol C ₂ H ₅ OH	E10	E15	E20
density	[g/cm ³]	0.737	0.789	0.742	0.745	0.747
stoichiometric air / fuel ratio	[-]	14.6	9.0	14.00	13.71	13.42
lower calorific value	[MJ/kg]	43.0	26.8	41.3	40.4	39.6
^{*)} boiling point	[°C]	30 - 200	78.5			
^{*)} Research Octane Nbr.	[-]	95	111			
^{*)} latent heat of evaporation	[kJ/kg]	420	845			

Table 2: Parameters of used fuels.

^{*)} according to [9]

Lube oils

The used lube oils were according to the requirements of vehicle manufacturers:

- for Piaggio Typhoon – fully synthetic Selenia HI-Scooter 2 TECH oil, product code: 1050, Piaggio 2966, API TC ++
- for Piaggio Vespa – fully synthetic oil Motorex Nbr. 4, [13].

MEASURING APPARATUS & PROCEDURES

CHASSIS DYNAMOMETER

- roller dynamometer: Schenk 500 G5 60
- driver conductor system: Zöllner FLG, 2Typ. RP 0927-3d, Progr., Version 1.4
- CVS dilution system: Horiba CVS 9500T with Roots blower
- air conditioning in the hall (intake and dilution air) automatic, temperature: 20 - 30 °C, humidity: 5.5 – 12.2. g/kg

The measuring set-up on a chassis dynamometer is represented in Fig. 2.

TEST EQUIPMENT FOR REGULATED EXHAUST GAS EMISSIONS

This equipment fulfills the requirements of the Swiss and European exhaust gas legislation – 70/220/EWG; 98/69/EG/2003/76; 97/24/EG - chap. 5 - 2002/51/EG.

- gaseous components:
 - exhaust gas measuring system Horiba MEXA-9400H
 - CO, CO₂ infrared analyzers (IR)
 - HC_{IR}... only for idling
 - HC_{FID}... flame ionization detector for total hydrocarbons
 - NO/NO_x... chemoluminescence analyzer (CLA)
 - O₂... Magnos (paramagnetic analyzer)

The dilution ratio DF in the CVS-dilution tunnel is variable and can be controlled by means of the CO₂-analysis.

- measurement of the particulate mass (PM): sampling from the full-flow dilution tunnel filter temperature $\leq 52^{\circ}\text{C}$ conditioning of filter: 8 - 24 h (20°C , rel. humidity 50%) scale: Mettler, accuracy $\pm 1 \mu\text{g}$

PARTICLE SIZE ANALYSIS

In addition to the gravimetric measurement of particulate mass, the particle size and counts distributions were analyzed with following apparatus:

- SMPS – Scanning Mobility Particle Sizer, TSI (DMA TSI 3071, CPC TSI 3025 A)
- NanoMet – System consisting of:
 - PAS – Photoelectric Aerosol Sensor (Eco Chem PAS 2000)
 - DC – Diffusion Charging Sensor (Matter Eng. LQ1-DC)
 - MD19 tunable minidiluter (Matter Eng. MD19-2E, see Fig. 2).

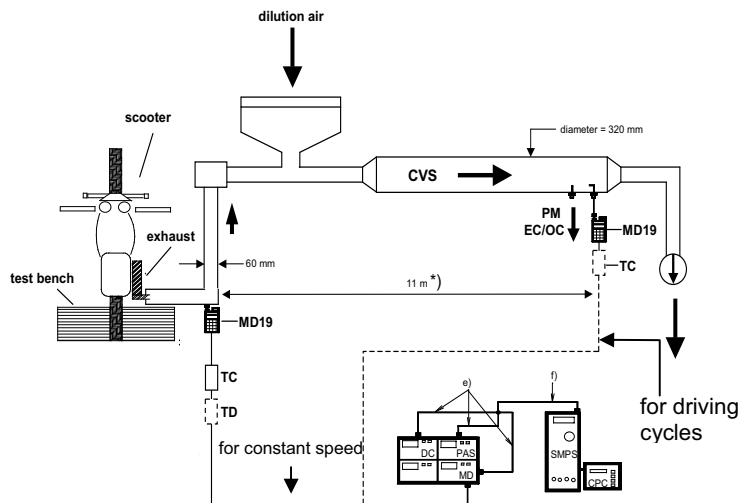


Fig. 2: Sampling and measuring set-up for nanoparticulate analysis of scooters.

SMPS enables to count nanoparticles according to their size distribution (10-500nm).

PAS (photoelectric aerosol sensor) is sensitive to the surface of particulates and to the chemical properties of the surface. It indicates the solid particles.

DC (diffusion charging sensor) measures the total particle surface independent of the chemical properties. It indicates the solids and the condensates.

The sampling and measuring set-up during the tests is shown in [Fig. 2](#).

The sampling position for NP-measurements is at tailpipe (TP) for basic investigations at constant speed and for driving cycles the sampling position from CVS (according to PMP) is used. The minidiluter MD19 is heated to 120°C .

Except of one investigation all NP-measurements in this work were performed without the thermoconditioner (TC).

The stationary warm operation was prolonged until 20 min to get enough mass on the measuring filters for the analysis of PM.

The driving resistances of the test bench were set according to the Swiss exhaust gas legislation for motorcycles.

RESEARCH PROCEDURES

The basic investigations with ethanol-based fuels were performed with each variant of fuel according to the same procedure:

- 5 min conditioning at full load
- legal test cycle
 - for Piaggio Typhoon limited to 45 km/h ECE 47, ¹⁾
 - for Piaggio Vespa unlimited speed ECE 40, ²⁾
- constant speed 40 km/h
 - first 5 min conditioning
 - further 10 min measurements of PSD's with SMPS
 - last 3 min → last scan SMPS.

The legal driving cycles are represented in [Fig. 3](#).

¹⁾ according to 97/24/CE chap. 5 annex 1

²⁾ according to 97/24/CE chap. 5 annex 2