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Particle Emissions of 2-S scooters

**2nd Information Report for IEA Implementing Agreement AMF,
Annex XXXIII, international activities 2005/2006**

Ordered by :

ExCo Meeting AMF, Sao Paulo, Oct. 18-21, 2004
Swiss Federal Office of Energy, project nbr. 100510, Oct. 20, 2004

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Nov. 2006 B 189

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*) Abbreviations see at the end of report

1. ABSTRACT

The serious health effects of particle emissions from traffic are known from the discussions about diesel engines technology and legislation. In this context the particle emissions of small 2-S engines with lost oils lubrication cannot be neglected any more.
A particular concern is about the 2-S scooters, small motorcycles and 2-S 3-wheelers, which in several countries are used very much in congested city centers.

To promote the exchange of information and mutual collaborations and progress in this domain, the present report summarizes shortly the international technical activities and activities in the reporting institutes.

There are several possibilities to reduce emissions from 2-S engines by means of technical measures and application of the best available technology (BAT*). Nevertheless the technical efforts alone cannot solve the pollution problem in several countries. The information and involvement of the political, economical and legal authorities, as well as the awareness and education of the population (users) are very important factors.

2. INTRODUCTION

At present there is a demand for improved knowledge about particulate emissions from 2-S Scooters. Since emissions from other type of vehicles have been dramatically decreased as a result of more stringent emission regulations in many countries, the focus on 2-S Scooter emissions is becoming more obvious. Furthermore, some Third World countries suffer from extreme emissions from 2-S vehicles, due to the large number of those vehicles.

Therefore projects on measuring and evaluation of the impact of emissions have been started up in many countries. The influence of factors like: fuel, lubricant, engine and aftertreatment technology is being investigated in the different projects. These are the main factors that can be adjusted in order to develop cleaner vehicles.

In order to obtain an overview of the investigations the IEA *) AMF Annex XXXIII with following objectives was started in automn 2004 :

- an overview of the content of ongoing projects
- establishment of an information network between project leaders
- establishment of links between projects, where mutual progress can be obtained
- a summary report, describing the results from the projects

The present 2nd report gives futher overview of international activities on research of 2-S scooters in scope to promote further technical collaborations, exchange with authorities and general improvement of the critical air pollution.

3. ACTIVITIES OF THE SWISS NETWORK

Due to the large interest from different parties and also different possibilities of performing the project work it is appropriate to see different project modules, which are represented in annex A1. This network, which works on “task-sharing” basis, is always open for new interested parties to join it.

Following interconnections between Swiss working group (project A) and other working parties are to mention at present:

- exchange of samples and analytical work at EU-JRC Ispra, Italy (project B)
- exchange of information VTT Finland (project C)
- exchange of information and collaboration with the Toxicity Network France (project D)
- focusing on older engine technology and specific situation in Asian Countries (project F)
- leading of an annex of IEA AMF together with Techn. University Lyngby, DK (project G, present report).

3.1. AFHB

The extensive research activities at AFHB are reported in references of in [1]. Annex A2 represents a poster from SAE Paper, which is scheduled for publication at the Detroit SAE World Congress, Apr. 2007.

Following conclusions can be pointed out :

EC/OC

- the results of coulometric EC/OC-analysis accord well with the particle mass (PM) measurement; nevertheless coulometry indicates to high share of EC, which is due to an artefact called charring,
- charring occurs, when during the thermal extraction of SOF the heavier compounds polymerize, stay in the PM sample and offer carbon, which is recognized as EC in the second step of analysis; charring can be eliminated by a previous solvent extraction.

Buck WFC

- the WFC inline with oxidation catalyst traps and oxidizes the volatile and particulate compounds more efficiently, than the WFC alone,
- the WFC provokes some store-release effects, which are dependent on exhaust gas temperature and due to the longer time scale of changes they can overlap and falsify the instantaneous emission results,
- conditioning at full load cleans the WFC, may provoke better oxidation ability, but also damaging of the catalytic coating; durability of the investigated WFC was not sufficient.

PAH & TOXICITY

The research activities at AFHB 2006 are reported in [2]. The most important statements are:

- the amount of total PAH, as well as the toxicity equivalence TEQ correlate roughly with the total particle mass PM, so a more efficient oxidation reduces both of them.
- research with aged catalyst and with dummy (w/o coating) shows that the catalyst influences very much the emission level,
- vehicles taken randomly from the fleet have often an inactive catalyst.

3.2 EMPA

In contrast to passenger cars which have to fulfil the emission legislation for a mileage of 80'000 km, two-wheelers have no such durability requirements. So, production cost minimization may shorten the life span of the aftertreatment systems used.

Limited exhaust emissions of 8 two-wheelers (2-S and 4-S) were compared with the results of emissions from 17 gasoline-powered passenger cars, [3]. Some extracts from this publication are shown in annex A3.

The average emissions of CO and HC are much more higher, for 2-wheelers, than for passenger cars, this particularly in urban driving. Different possibilities of comparison are presented, but even the comparison of fleet emissions in [tons/year] shows an impressive contribution of 2-wheelers to the CO & HC-values in the cities.

In an EMPA-report [4] more details about the research of catalyst ageing on 6 2-S scooters are given.
About this work was already reported in [1] (p. 6, annex A3, reference [7]). Annex A4 gives more information about the used vehicles and the impression about the catalyst efficiencies over the working period.

From these works of the EMPA Laboratory for IC-Engines can be concluded, that an introduction of a periodical exhaust gas control for 2-wheelers would be a very important step to improve emission quality of this vehicle fleet.

3.3 OTHER ACTIVITIES IN THE SWISS NETWORK

According to annex A1 following activities can be mentioned :

Project B:	analytics of PAH & TEQ at JRC Laboratories, Ispra, It
Project D:	preparations for the research of toxicity 2007 with INSERM, Univ. Rouen, F; Univ. of Berne, CH; BAFU & TTM
Project C & F:	further search of funds
Project G:	present report.

4. ENEA & MUNICIPALITY OF ROME, ITALY (www.enea.it)

Due to a high level particle pollution in the big italian cities the Italian National Agency for New Technologies, Energy and Environment together with the Municipality of Rome performed research focused on particle emissions of 2-wheelers mainly with 2-S engines.

It was reported about this work in [1] (p. 6-7, annex A4, references [8], [9]). Further works concern analysis of PAH emissions from the 2-wheelers investigated before, [5].
The most important statement is, that both: particle mass emission (PM) and PAH emissions from 2-wheelers – in particularly 2-stroke – cannot be neglected in urban emission inventories. These still unregulated emission components have to be taken into consideration to enable a reduction of air pollution in the urban centres, see annex A5.

5. TECHNICAL UNIVERSITY GRAZ, A (http://fvkma.tu-graz.ac.at)

The institute for IC-engine of TU Graz (TUG) has a long tradition and experience with little 2-S engines. One of the recent projects, presented in [6] and [7], focuses on development of low emission concept of a small (50cc) 2-S engine by means of newest tools: visualization connected with 3D CFD simulation, see annex A6.
It was demonstrated, that the understanding of the internal engine processes can be considerably improved by the use of these tools.
The introduced direct injection concept, bases on cost efficient low pressure injection components, enables a reduction of the untreated HC-emissions up to 50%, compared to external mixture preparation systems.

6. EMITEC, D (www.emitec.com)

EMITEC, a supplier of metallic substrates for catalytic converters, developed several types of catalysts with turbulent structure of channels. The corrugations, or shovels in the metal foil provoke more transversal exchange of momentum and more intensified turbulence in the gas flow and consequently more intense catalytic activity. This allows to realize higher conversion rates with smaller catalysts i.e. combine the improvement of emissions with saving costs, [8] and [9], see annex A7.

7. ADEME, VALBONNE, F (http://www2.ademe.fr)

ADEME – French Agency for Environment and Energy Management performed two measuring campaigns with 2-wheelers: in 2000 with Euro 1 and in 2004 with Euro 2.

Improvements of emissions of little 2-stroke motorbikes with the newer technology were stated: in average reduction of CO 6 times and reduction of HC 3 times. These improvements are attained thanks to emission control by catalyst, which is forced by new emission norms, [10].

The study finds a strong increase emissions (CO & HC) if manipulations are done to bust the vehicle performances. Also the emissions in real world driving are higher, than in the legal driving cycles.

Concerning the unlimited emission components the ADEME study refers to the study of the European Association of Motorbike Constructors ACEM, [11].
The emissions of gaseous PAH are connected to the quantity of HC and for the complex BTX (benzene, toluene, xylene) they can be 10 to 100 times higher, than for average passenger car.

The part of this study [11] concerning particle emissions was performed by Ricardo and was reported
already in [1] (p.7, annex A5, reference [10]) and shows a particular contribution of 2-strokers to the PM-emissions.

Finally it is important to conclude, that the emission level of 2-S 2-wheelers without exhaust gas aftertreatment is much higher (approx. 2 to 15 times) than for cars. The newest technology (direct injection, catalyst, eventually secondary air system) offers more impressive reductions of emission level if faultless. Than the emissions of 2-S motorbikes are comparably to those of cars.

8. OTHERS

a) Important information about emission topics is to be found in the periodic newsletters of AECC (www.aecc.be).

In the newsletter Sept – Oct. ‘06 the recently published Euro 3 motorcycle emission limits are given, see annex A8. There are still no particle emissions in this legislation.

In the same newsletter an EU-sponsored study is mentioned; where the measures to limit the emissions of fleet are recommended:

- durability requirements for emission control,
- in-use compliance and roadworthiness procedures,
- on-board diagnostics,

- control of evaporation emissions,
- measures regarding particulate matter,
- further steps for new emission standards.

b) Engine oils for 2-S application

In [12] Yamaha presents three supplementary evaluation methods for lube oils, which are not included in the JASO standards (JASO: Japanese Automobile Standard Organization). These methods are:

- low-temperature detergency,
- low-temperature start-ability,
- exhaust port blocking.

No use of polybutene with molecular weight bigger than 1000 is recommended.

In [13] Chevron Oronite and SWRI show a screening program for oils on the DI 2-S outboard engines for boats. Field tests and an accelerated tank test procedure in laboratory were conducted. The engines in power range of 150 kW work much more at higher and highest power output, than motorcycles. With the introduction of DI-technology improvements of high temperature detergency are needed to prevent the ring groove deposits.
Several results of engine deposits tests are presented.

To increase the awareness of consumers CARB introduced environmental Star Labels for low emitting outboard engines since model 2003.

c) Chain saws – oxidation catalyst

Dolmar GmbH (D) presents in [14] a development of exhaust system with an oxidation catalyst for chain saws. This is a big challenge, since the exothermic heat flow produced in the ox-cat. is in the same range as the brake power output.

There are limits of space, of weight, of surface temperatures, restrictions due to vibration, electronic power cut-off and flame avoidance.
With lower quality of engine-out emissions (HC > 100 g / kWh) the satisfactory functioning is not feasible.

d) 2-stroke power tuning

Developments of power tuning are presented during SAE SETC ’06:

Husquarna chain saws (S): exhaust pipe tuning [15], and stratified scavenging [16].

University of Pisa (I): 2-S DI engine combined with stratified charge [17].

These works show, that the synergies between the modern methods of experimental and numerical investigations allow a better understanding of the processes and further improvements of power with no increase, or with reduction of emissions.

e) A Chinese enterprise produces 4-S motorcycles with CNG propulsion, annex A9.

f) An English enterprise developes a new concept of 2-S small engine with rotary slide valve timing, annex A10.

9. CONCLUSIONS

A lot of work is done yearly in the R&D of gasoline 2-S engines.

By connecting the efforts of newest experimental and numeric research several improvements are possible.

To reduce sustainably the emissions of 2-wheeler fleet the technical improvements of new vehicles are not sufficient.

Further legal and political steps to increase the awareness of the users and to promote control and maintenance are necessary.

10. ACKNOWLEDGEMENT

The authors want to express their gratitude to:

- Swiss Federal Office of Environment (BAFU)
  Swiss Association of Oil Manufacturers (EV)
  Swiss Association of Lubricants Industry (VSS)
  Swiss Federal Office of Energy (BfE)

  for the financial support of the Swiss Network activities.

- Mr. Andreas Mayer, TTM

  for leading and coordinating the Swiss Network activities

- Mr. Peter Finckh, EUWP Associate Chair for Transport

  for promoting the activities of Annex XXXIII and for his constant engagement for energy, environment and economic development.

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12. ABBREVIATIONS

ADEME	Agence de l'Environnement et de la Maîtrise de l'Energie, France
AECC	Association for Emission Control by Catalyst (www.aecc.be)
AFHB	Abgasprüfstelle der Fachhochschule, Biel CH, (Lab.For Exhaust Gas Control, Univ. of Appl. Sciences, Biel-Bienne, Switzerland)
AMF	Advanced Motor Fuels
ANCMA	Associazione Nazionale Ciclo Motociclo Accessori, Milano, It.
BfE	Bundesmat für Energie, CH (SFOE)
BAT	best available technology
BUWAL	Bundesamt für Umwelt, Wald und Landschaft (Swiss EPA, SAEFL)
C	Carburetor
Carb	Carburetor
CARB	Californian Air Resources Board
CPC	condensation particle counter
CVS	constant volume sampling
DC	diffusion charging sensor
DF	dilution factor
DI	direction injection
DMA	differential mobility analyser
DPF	Diesel Particle Filter
DTU	Technical University of Denmark, Lyngby DK
EC	elemental carbon
EMPA	Eidgenössische Materialprüfungs- und Forschungsanstalt
ENEA	National Agency for New Technologies, Energy and Environment, Rome, Italy (Ente Nazionale per le Nuove Technologie, l'Energia e l'Ambiente)
EPA	Environmental Protection Agency
ETHZ	Eidgenössische Technische Hochschule Zürich
EV	Erdöl Vereinigung, CH
FL	full load
G-DI	gasoline direct injection
GRPE	Groupe Rapporteur Pollution et Energie
HYC	Hybrid Concept Scooter from TUG
IEA	International Energy Agency
INSERM	Institut National de la Santé et de la Recherche Médicale, F
INSOF	insoluble fraction
JRC	EU Joint Research Center, Ispra It.
JASO	Japanese Automobile Standard Organisation
ME	Matter Engineering, CH
MPI	multipoint port injection
NanoMet	minidiluter + PAS + DC (ev. + TC, or TD)
NMOG	non methan organic gases
NP	nanoparticulates
OC	organic carbon
OP	ozon potential
PAH	polycyclic aromatic hydrocarbons
PAS	photoelectric aerosol sensor
PC	particles counts
PM	particulate matter, particulate mass
PMP	Particle Measuring Program of the UNO ECE GRPE
PN	particles number
PSD	particles size distribution
SAE	Society of Automotive Engineering
SAEFL	Swiss Agency for Environment, Forests and Landscape (Swiss EPA, BUWAL)
SAI	secondary air injection

SAS	secondary air system
SETC	Small Engines Technology Conference
SFOE	Swiss Federal Office of Energy
SMPS	scanning mobility particles sizer
SOF	soluble organic fractions
SUVA	Schw. Unfall Versicherungs Anstalt, Swiss Occupational Insurance
SWRI	South West Research Institute
T	TSDI
TC	thermoconditioner, total carbon
TD	thermodesorber
TEF	Toxicity Equivalence Factor
TEQ	Toxicity Equivalence TEQ = sum (TEF_i x $concentration_i$)
TSDI	Two Stroke Direct Injection
TP	tailpipe
TPN	total particle number
TTM	Technik Thermische Maschinen, Niederrohrdorf, CH
TUG	Technical University Graz, Austria
TWC	Three Way Cat
VOC	volatile organic compounds
VOF	volatile organic fraction
VSS	Verband der Schweizerischen Schmierstoffindustrie
VTT	Technical Research Center of Finland
WFC	wiremesh filter catalyst
WMTC	Worldwide Motorcycle Test Cycle

13. ANNEXES

A1	2-S Scooters Swiss Project Network
A2	Poster AFHB / JRC
A3	EMPA comparisons 2-wheelers -> cars [3]
A4	EMPA catalyst ageing on 6 2-S Scooters, [4]
A5	ENEA & Municipality of Rome – investigatins of PAH, [5]
A6	Low emission combustion development, TUG, [6]
A7	EMITEC turbulent catalysts, [7]
A8	AECC newsletter Sept. – Oct. 2006
A9	CNG motorcycle 4-stroke, China
A10	New concept 50cc 2-S, UK company RCV Engines