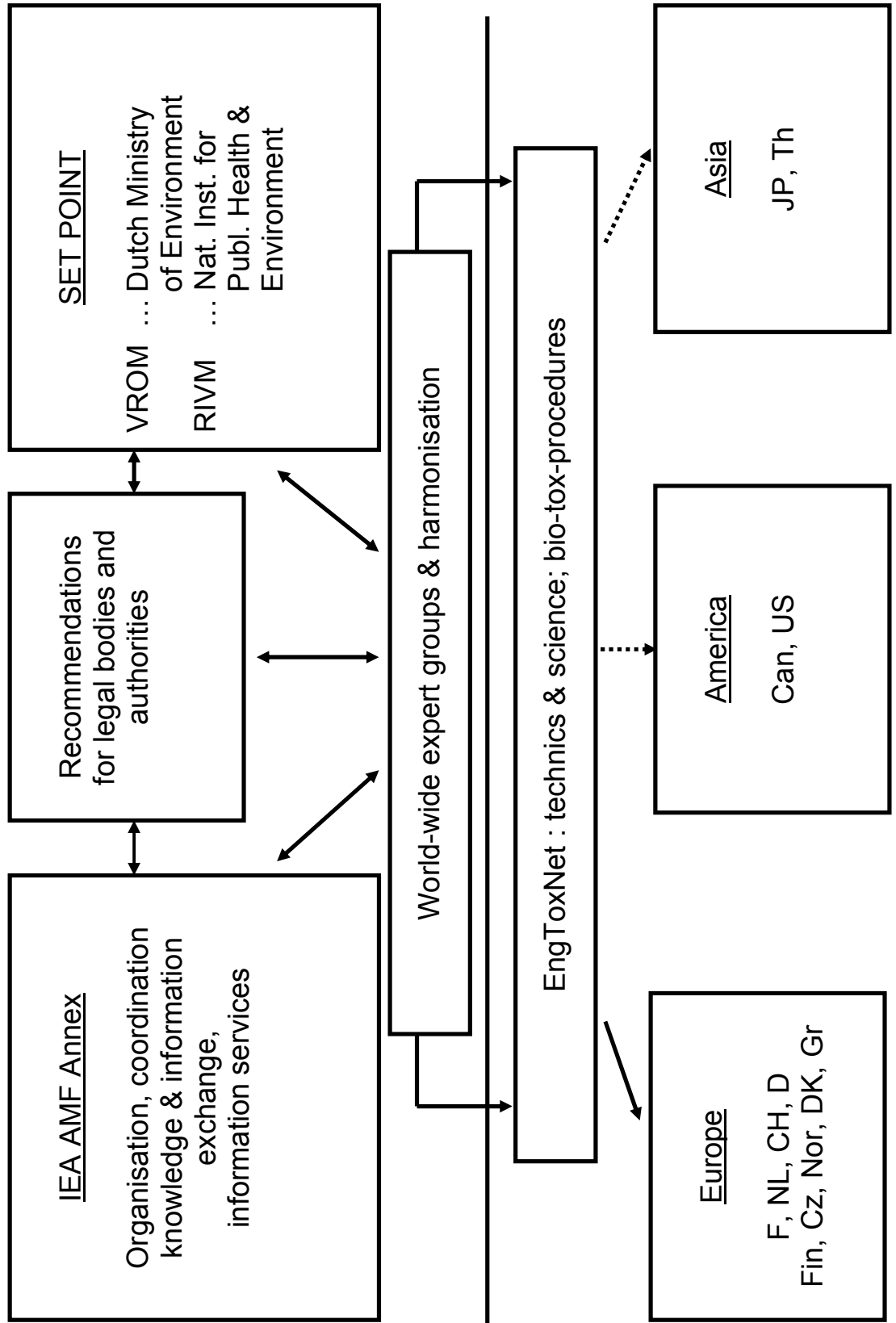
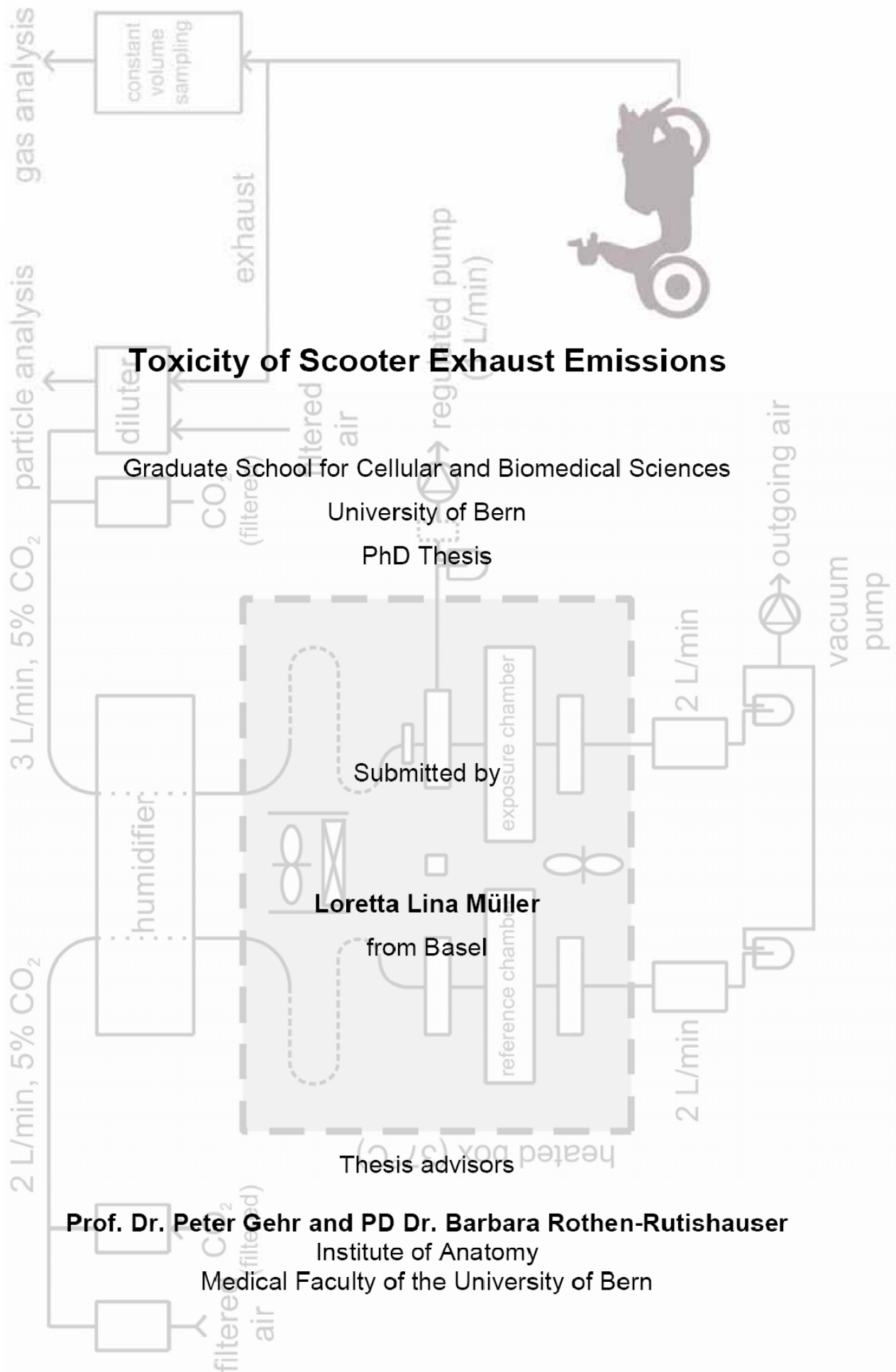




Worldwide Activities on Toxicity of Exhaust Gases from Engines





Toxicity of Scooter Exhaust Emissions

Graduate School for Cellular and Biomedical Sciences
University of Bern
PhD Thesis

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Summary

The number of registered scooters, the small two-wheeled vehicles with a maximal speed of 45 km/h and an engine capacity lower than 50 cm³, is increasing year by year. Depending on the technology, two-stroke scooters can emit high amounts of carbon monoxide (CO), nitrogen oxides (NO_x), hydrocarbons (HCs), polycyclic aromatic HCs (PAHs) and particulate matter (PM) mainly in the nano-scaled size range. Compared to normal passenger cars, the emissions can be so high that scooters have to be treated as so-called superpolluters.

In a first project the toxicity of different engineered nanoparticles and diesel exhaust particles (DEP) in different cell cultures and especially the differences between mono- and co-cultures was evaluated. It could be shown that the interplay of different lung cell types modulate substantially the oxidative stress and (pro-) inflammatory responses upon DEP exposure (Project 1).

In order to develop a method to evaluate the toxic potential of scooter exhaust emissions, a new exposure system was constructed and established (Project 2). After the removal and the dilution (1:100) of the exhaust sample, the exhaust emissions were CO₂ enriched (5%), humidified (85% relative humidity) and heated (37.5°C). The diluted exhaust emissions passed the exposure chamber where the cell cultures were placed. Mono-cultures of human alveolar epithelial A549 or of human bronchial epithelial 16HBE14o⁻ cells, as well as a co-culture model of the human epithelial airways consisting of an epithelial cell layer, human monocyte-derived dendritic cells at the basal side and human monocyte-derived macrophages at the apical side were used. The cell cultures were pre-exposed to the air-liquid interface for 24h and then exposed to the exhaust emissions by diffusion processes. In parallel to the exposure to exhaust emissions, cell cultures were exposed to reference air (filtered ambient air, treated similar to the exhaust emissions). In addition a negative control (cells left in the incubator) was included. For the establishment of the exposure system, cell cultures were exposed to the exhaust emissions for one or two hour time periods followed by a post-incubation for zero, four, eight, twelve or twenty-four hours. A two-stroke direct injection Peugeot scooter with "worst case" conditions (normal fuel, army oil, normal oil ratio, dummy muffler) was used. For the cell analysis, the cell morphology and the tight junction arrangement, the cytotoxicity and the (pro-) inflammatory response were measured.

The analysis of the establishment and optimization of the exposure system showed that the triple cell co-cultures with 16HBE14o⁻ cells exposed to the exhaust emissions during two hours and post-incubated for eight and twenty-four hours presented the highest differences between reference and exposed cells. For all further comparisons of the toxic potential of different vehicles, the previously mentioned settings were used.

In the third project various settings of two different two-stroke scooters (carburetor and direct injection), a four-stroke scooter and a passenger diesel car with and without a diesel particle filter were tested. The applied settings were worst case (same as in the establishment experiments of the exposure system), worst case – filtered (filtering out of the particles after the removal of the exhaust), best case (Aspen fuel, Motorex oil, only 50% oil ratio, oxidative catalyst, wire mesh filter catalyst) and absolute best case (Aspen fuel, Motorex oil, only 50% oil ratio, coated particle filter). The overall toxic potential was highest for carburetor worst case conditions, followed by direct injection worst case, the four-stroke scooter and the passenger diesel car. The technical optimizations for the two-stroke scooters, especially the coated particle filter, reduced the toxic potential to a lower level than for diesel cars. For the passenger diesel car, the particle filter did not reduce the toxic potential. The particle number concentration was found to be the most relevant parameter for the toxic potential.

The newly developed exposure system can be used for standardized testing of different exhaust emissions and for the evaluation of the effects on the toxic potential of single technical optimizations. The toxic potential of two-stroke scooters was higher than of four-stroke scooters and diesel cars and can be reduced with technical optimizations, which should be introduced.

3 Discussion of the Findings

This PhD study mainly aimed to develop a new exposure system to directly expose lung cell cultures to total exhaust emissions at the air-liquid interface and the evaluation of the toxic potential of different vehicle emissions. In addition we investigated the differences in reactions of cell mono-cultures and triple cell co-cultures upon NP exposure.

This new exposure system allows the direct exposure of cell cultures to total exhaust emissions. The direct exposure of cell cultures *in vitro* mimics the situation in the lung as realistically as possible. The flow pattern of diffusion processes especially reflects the *in vivo* situation (Ochs and Weibel, 2008). Additionally the use of the triple cell co-culture model of the airway epithelial barrier offers a more realistic model than mono-cultures of one cell type alone (Alfaro-Moreno et al, 2008; Muller et al, 2010b; Rothen-Rutishauser et al, 2008). Compared to the *in vivo* situation in the lung even the use of three different cell types (epithelial cells, macrophages and dendritic cells) combined in the co-culture model only represents part of the complexity. However, the co-culture model can not consider all of the different cell types (over 40) in the lung (Ochs and Weibel, 2008), the blood circulation, the lymph circulation or the interplay of various organs. The whole complexity of the human lung could only be included by using *in vivo* testing of animals or humans. With the application of *in vivo* exposure of animals at least the complexity of a whole organism can be considered, but the problem of the extrapolation from animals to humans still exists. The actual experimental design and the cell culture model used need to be adapted to investigate chronic exposure as it occurs in the reality. This is a general disadvantage of *in vitro* cell cultures exposed at the air-liquid interface. Further experiments will use cell cultures to co-expose them to exhaust emissions and to other stressors, such as the influenza virus. Furthermore, it allows the testing of single technical optimizations, which would be not possible with epidemiological tools. This testing can be carried out even before the technical optimization is on the market and can be treated as a pre-test and evaluation of the effects on the toxic potential. Industrial players may use such testing as a sales argument and for their marketing.

Comparing the new exposure system with other exposure systems described in the literature (Table 2 in Muller et al, 2010a), the probably most important conclusion is

the need for more standardization. As the systems use not the same conditions, different biological samples and also variable technical settings of the vehicles, it is just not possible to compare the results of different publications.

Only very few and quite old studies about the toxicity of scooter exhaust emissions are published. Zhou and colleagues showed the mutagenicity of scooter exhaust PM (Zhou and Ye, 1997) and an activation of oncogenes in human diploid cells strain cells (Zhou and Ye, 1998b). Further they could show the effects of lubricant on the mutagenicity (Zhou and Ye, 1998a). Studies using cell cultures or *in vivo* studies about the toxic effects of scooter exhaust emissions do not exist and therefore the results can not be compared to the current research literature.

The presented PhD thesis showed adverse effects of exhaust emissions in a model of the human airway epithelial barrier and a reduction of the toxic potential when technical optimizations, such as better fuel, better oil or particle filters, were introduced. Following the precautionary principle with this knowledge and the knowledge of adverse health effects due to the single components of the exhaust (e.g. CO, HC, NO_x, particles) (Ackermann-Liebrich et al, 1997; Becker et al, 2005; Braun-Fahrlander et al, 1997; Brauner et al, 2007; Donaldson et al, 2005; Ghosh et al, 2010; Pan et al, 2004; Xiao et al, 2003), there is a high importance of a (further) reduction of the exhaust emissions. For a more precise analysis about which of the exhaust emission compounds should be focused on, further studies are necessary. Out of the here presented results it can only be concluded that the particle number concentration is the most relevant parameter and should be reduced as much as possible.

Effects of particles can be induced by two different ways: Either particles enter the cells and interact with cell-internal structures or particles attach to the cell surface and activate receptors inducing cell signaling. Further it has to be differentiated if the effect is induced by the particle itself or by substances adsorbed to the particle surface and released either in the cell or close to the cell surface (Limbach et al, 2007; Oberdorster et al, 2005). In order to distinguish between the two ways, the number of particles localized intracellular should have to be determined. However, for exhaust particles it is very difficult and refers to a real challenge. Their sizes are in the nanoscaled size range and therefore need to be visualized by TEM. Only bigger agglomerates could be detected inside cells, however, since this occurs only in suspension experiments in the here presented experimental setup, i.e. air-liquid

exposed cells, no such agglomerates could be detected. It has to be assumed that smaller agglomerates or single particles entered the cells, but as they are not very electron dense and have no well defined shapes, they could only be identified clearly including the methods of elemental analysis (Brandenberger et al, 2010a). Elemental analysis by the mean of electron spectroscopic imaging (ESI) is applicable when the elemental composition of the particles is known. This requirement is not fulfilled for exhaust particles. They have no constant chemical composition and a previous chemical element analysis of the particles would be needed. With this information ESI could be performed and theoretically particles could be identified intracellular. As an elemental analysis of exhaust particles is a time-consuming and expensive issue, this was not possible to do within this study and would be an additional interesting topic for an ongoing study.

Finally, it can be concluded that the newly developed exposure system is a tool for testing the toxic potential of different vehicle's exhaust emissions in a human epithelial airway model, as well as testing the effects of single technical optimizations (e.g. particle filter, better fuel and oil). Further, statistically significant differences between cell cultures exposed to exhaust emission and such exposed to reference air were found. Between the toxic potential of different vehicles or set-ups only few statistically significant differences could be shown. Probable reasons for that fact can be the short exposure time (2 h), the high dilution of the exhaust emissions (1:100) and the low number of experimental repetitions (n=3). The most relevant exhaust parameter which might mainly be responsible for the toxic potential is the particle number concentration, which should be reduced as much as possible.

In summary, it can be concluded that a new exposure system to investigate the effects of (scooter) exhaust emissions in cell cultures *in vitro* could be developed and established. Furthermore, it was applied to compare the effects of exhaust emissions of different vehicles and set-ups. The implementation of modern particle filters in two-stroke scooters was shown to reduce the toxic potential. Overall, the particle number concentration was found to have a statistically significant effect on the toxic potential and should be reduced as much as possible. Concerning the cell cultures, it was shown that the interplay of different co-cultured cell types (epithelial cells, MDM and MDCC) alters the oxidative stress and (pro-) inflammatory responses upon NP exposure and can mimic the reality in the airways better than mono-cultures.

Chemical Characterization of Emissions from Modern Two-Stroke Mopeds Complying with Legislative Regulation in Europe (EURO-2)

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In view of a new amendment to the European legislative regulation on emissions from two-stroke mopeds a study was carried out to comprehensively characterize exhaust gases of mopeds complying current EURO-2 emission standards. Three mopeds with different engine types (carburetor, direct injection, and electronic carburetion system ECS) were investigated by applying two different driving cycles, the legislative cycle ECE47 and the worldwide motorcycle test cycle WMTC. Thereby, particulate matter (PM), regulated compounds, carbonyls, volatile hydrocarbons (VOC), and particle-associated polyaromatic hydrocarbons (PAH) were analyzed and ozone formation potentials (OFP) as well as toxicity equivalents (TEQ) determined. The ECE47 emission factors for almost all species and moped types were much higher in the nonregulated, prior cold phase than in the hot phase, which is considered for legislation. Great differences for the mopeds could be observed for NO_x, VOC, and PM, whereas discrepancies between the driving cycles ECE47 and WMTC were smaller. In addition, a positive influence on exhaust composition caused by technical modifications of the ECS engine was determined. Results indicate that regulation of total hydrocarbons (THC) alone might not be sufficient to regulate PM, especially for direct injection engines. Moreover, recommendations for a revised future test protocol are demonstrated and discussed, whereby the cold phase and the hot phase are taken into account.

Introduction

Powered two-wheelers (PTW) play an important role in the transport sector. In some countries mopeds with two-stroke engines and displacements of not more than 50 cm³ represent a large fraction of PTW particularly in southern Europe and Asia. Across the 27 European Union (EU) countries 18.4 million registered motorcycles compared to 12.9 million mopeds in 2006 (1). In Asia, PTW account for up to 75% of the whole vehicle fleet, and approximately 85% of these are powered by two-stroke engines (2). It is known that for many exhaust constituents yields from two-stroke engines are higher than those of four-stroke engines because of the

required mixture of gasoline and lubricant oil, which results in a substantial fraction of unburned or incompletely combusted oil e.g. ref 3.

Consequently, contributions of PTW to overall road transport emissions and therefore to air pollution must be taken into account. In the past decade, exhaust pollutants from light and heavy duty vehicles have been reduced significantly in the EU by continuously implementing stricter emission regulations. However, a similar gradual reduction for pollutants in moped exhaust has been delayed since first legislation came into force in 1999 (4) with one amendment being passed in 2002 (5). Supporting Information (SI) Table S1 illustrates all legislative regulations for PTW emissions and for comparison the three most recent permitted emission levels for diesel and gasoline passenger cars in the EU.

While there is a lot of literature on exhaust emissions of passenger cars and heavy duty vehicles available, comprehensive surveys on PTW, particularly on mopeds are rare. A few research groups have investigated the particle fraction of moped emissions e.g. refs 6–8. Recently, some work on polycyclic aromatic hydrocarbons (PAH) e.g. ref 3, 9, 10., selected volatile organic hydrocarbons (VOC) as well as carbonyl species (3) have been published.

In view of the preparation of a new amendment to the European directive 97/24/EC (4) the European Commission - Joint Research Centre (EC-JRC) Ispra carried out a comprehensive study in order to evaluate emissions of mopeds complying with the present legislation EURO-2. Thereby, main goal was that a wide range of exhaust constituents in gas and particulate phase were investigated together. Chemical analysis performed included the regulated species total hydrocarbon (THC), nitrogen dioxide (NO_x), carbon monoxide (CO) as well as carbon dioxide (CO₂), and particulate matter (PM) mass. In addition, particle-associated polyaromatic hydrocarbons (PAH), carbonyl compounds, and volatile organic hydrocarbons (VOC) were studied. PAH are known to strongly contribute to human health effects (11). Carbonyls and VOC cause photochemical smog and ozone formation (12). Some of them are known to be carcinogenic (13).

Moreover, tests were carried out by applying two different driving cycles, the European legislative driving cycle for mopeds, ECE47, and a new proposed driving cycle for motorbikes, WMTC.

Experimental Section

All experimental work was carried out at the Vehicle Emissions Laboratory (VELA) of the Institute for Environment and Sustainability (IES) at the EC-JRC Ispra, Italy.

Test Fleet. The test fleet consisted of three new mopeds of different manufacturers with two-stroke engines, displacements of 50 cm³, and oxidation catalysts. All three complied with the latest European emission legislative standard for mopeds, EURO-2, but had three different engine technologies. In particular, one moped (moped-CA) was equipped with an ordinary carburetor, one moped (moped-DI) had direct injection technology, and the third moped (moped-CAec) was equipped with an electronic carburetion system (ECS). Latter one consists of an engine control unit (ECU) and an electro-actuated carburetor, whereby the air/fuel (A/F) ratio and the oil dosing are electronically controlled according to several engine operating conditions.

For all tests semisynthetic oil (API TC, Jaso FC, ISO-L-EGD) and a certified reference fuel (CEC RF-02–99 oxy 0.8–1.2; SI Table S6) were used.

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EUROPE

Report on New EU Measures for Motorcycle Emissions

The European Commission's Directorate-General for Enterprise and Industry has published the final version of a report on possible new measures for motorcycles emissions. The report was produced by the Laboratory of Applied Thermodynamics (LAT) at Aristotle University of Thessaloniki, Greece.

As well as the potential for new emissions limits for motorcycles, tricycles, quadricycles and mopeds and for measurement of CO₂/fuel consumption, the report addresses durability, in-use conformity, on-board diagnostics and evaporative emissions control. Five scenarios have been modelled, ranging from continuation of current emissions limits to the introduction of the same emissions limits as Euro 5 cars for all powered two-wheelers.

The report says that by 2020, without changes to current legislation, Powered Two-Wheelers (PTWs) will emit more total HC emissions than all other vehicle categories and will also become much more important relevant contributors of CO emissions. Their contribution to NO_x and PM emissions also increases after 2013, as the introduction of DeNO_x and DPF aftertreatment systems in passenger cars and heavy-duty vehicles will reduce emissions of those classes of vehicle. The contribution of PTWs to urban emissions increases to ~10% and 20% of total road transport NO_x and PM emissions respectively by 2020.

The report also says that the contribution of tricycles and quadricycles to total road transport emissions cannot be considered negligible. In particular, quadricycles will be responsible for more than 35% of total PM from the sector in 2020. The report also comments that "it is absolutely critical that a durability regulation is introduced for PTWs, otherwise significant departures from the emission standard may occur at rather short distances (i.e. less than 5000 km)." The report (No. 08.RE.0019.V4) is at http://ec.europa.eu/enterprise/sectors/automotive/files/projects/report_measures_motorcycle_emissions_en.pdf.

Commission announces Workshop on Heavy-duty GHG Emissions

The European Commission's Directorate-General for Environment has announced that it is organising an international workshop on Greenhouse Gas certification methods for heavy-duty vehicles. It will be held at the Commission's Joint Research Centre in Ispra, Italy on 19-20 April 2010.

DG-Environment says that a reliable and realistic method is needed to certify the fuel consumption and

CO₂ emissions of complete heavy-duty vehicles. The Commission has started the development of a method and is aware of similar activities in other parts of the world. It is organising the workshop because there is a common interest in ensuring mutual awareness, consistency and synergy of these activities.

New European Commission creates Climate Change Directorate

Following the formal endorsement of the new European Commission by the European Parliament, the new Commission has created a Directorate-General on Climate Action (DG-CLIM).

The new Directorate brings together climate-related units from existing Commission departments on the environment, external relations and industry. The Environment Directorate will remain responsible for air quality legislation and other environmental issues, including industrial emissions and the integrated pollution prevention and control (IPPC) Directive, but protection of the ozone layer will move to DG-CLIM.

At the same time, DG Transport and Energy was split into two Directorates - DG Energy and DG Mobility and Transport (DG-MOVE).

Commission rejects Italian PM₁₀ Air Quality Derogations

The European Commission has rejected 11 out of 12 of Italy's second request for more time to meet air quality targets for particulate matter (PM₁₀) in the regions of Campania, Puglia and Sicilia. Most of Italy's earlier requests were rejected last year.

On 1 February 2010, the Commission approved a time extension for one zone in the region of Campania. The other 11 zones did not qualify for various reasons. The Commission said that four of them have already met EU air quality standards.

Possible Commission Actions to reduce Transport CO₂ Emissions

The European Commission is considering CO₂ emissions standards for lorries and road pricing to help further reduce transport's greenhouse gas emissions, according to a statement by a Commission official at a European Parliament briefing on the Copenhagen Climate Summit on 12 January 2010.

DG-JRC Report shows Benefits of Infrastructure Charging

The overall benefit of charging trucks for the pollution they cause outweighs the limited negative price impact on consumers, according to a new report from the EU's Joint Research Centre (DG-JRC).



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In addition total emissions of toxic air pollutants such as benzene, 1,3-butadiene, and toluene, decreased by approximately 40% between 1990 and 2005. Despite the progress, though, approximately 127 million people live in areas that exceeded any national ambient air quality standard in 2008. Ground-level ozone and particulate pollution still present challenges in many areas of the country, EPA says.

The report (www.epa.gov/airtrends/2010/index.html) also discusses the effects of international transport on climate change. It notes that Black Carbon has warming effects, while aerosols containing sulfates and organic carbon tend to have cooling effects.

California proposals on Evaporative Emissions from Recreational Vehicles

The California Air Resources Board (CARB) has issued draft proposals to regulate evaporative emissions from Off-Highway Recreational Vehicles (OHRVs) and On-road Motorcycles.

The proposed regulation would set evaporative emissions standards over a 'tip test' (equipment tilted 35 ± 5 degrees in each direction), running loss test, hot soak test and diurnal test. Limits for the sum of these 4 tests would be 1.75 g/test for model years 2014 to 2018 and 1.25 g/test for 2019 and subsequent model years. There would be an on-board refuelling vapour recovery standard of 0.25 g per gallon filled. Gas and electric units with diurnal emissions $\leq 50\%$ of the standard would earn credits, to be used in the same model year. For small volume Sand Car manufacturers there would be design requirements on fuel hose and fuel tank permeation and carbon canister working capacity.

California to ease Requirements on Existing Diesel Emissions

On 22 April 2010, the California Air Resources Board (CARB) decided to ease their regulations designed to reduce diesel emissions from existing trucks and construction equipment. However, full details will not be known until a detailed proposal is released later this year.

With construction activity only half the level it was when CARB adopted the regulations, the expected emissions from these on- and off-road sources of diesel particulates and nitrogen oxides are below targets set in the regulations. Also, CARB's discovery that it overestimated emissions from the off-road category creates an emissions 'cushion' that allows the agency to make the rules less onerous in the early years. The regulations as originally enacted require owners to install diesel exhaust filters and replace engines and/or purchase newer equipment and vehicles on prescribed schedules over several years.

California introduces Ferries with SCR and looks for Demonstration Projects

Two diesel-engined ferries using Selective Catalytic Reduction (SCR) to control NOx emissions have entered service in California's San Francisco Bay.

The two MTU Series 2000 engines used in each ferry are able to operate on a biodiesel/ultra-low-sulfur diesel fuel blend. The specification for the ferries required emissions to be 85% below the US Environmental Protection Agency's Tier 2 marine emissions requirements at 25 knots and 85% load. Testing results by the ferry operator showed that emissions approximate to EPA's Tier 4 marine requirements, due to go into effect in 2016.

The California Air Resources Board (CARB) has also announced the availability of grants for an Advanced Technology Demonstration Project for demonstration of the hybridisation of an existing marine vessel. In another project, CARB is offering grants for an \$800 000 (€595 000) Advanced Technology Demonstration Project for aftertreatment devices on existing locomotive engines operating in California.

Port of New York/New Jersey launches Clean Truck Programme

The Port Authority of New York and New Jersey and US Environmental Protection Agency have launched a \$28 million (€21 million) programme to replace pre-1994 trucks serving the ports with newer models that generate less pollution and greenhouse gases.

There will also be a truck phase-out plan in which pre-1994 model trucks will be excluded from Port Authority marine terminals from 1 January 2011. From 1 January 2017, trucks not equipped with engines that meet or exceed 2007 federal emissions standards will no longer be able to call on the terminals.

The Port Authority has also begun three other initiatives. The Ocean-Going Vessels Low Sulfur Fuel Program will offer financial incentives to encourage the use of low-sulfur fuel by operators of ocean vessels. The Cargo Handling Equipment Fleet Modernization Program will reimburse port tenants for 20% of the cost of replacing existing cargo handling equipment with new equipment that meets federal on-road emissions standards or the most recent federal off-road emissions standards. In addition two switcher (shunting) locomotives serving the ports will be retrofitted with ultra low-emitting GenSet technology.

New York State developing Clean Construction Equipment Database

The New York State Energy Research and Development Authority has issued a request for proposals to create an internet database intended to



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The proposals will set limits on CO and NOx for most such equipment. Depending on the calorific output and fuel used, there would also be limits for organic gaseous carbon (OGV), non-methane hydrocarbons (NMHC), SO₂, dust (particulate) emissions and/or smoke. The regulation can be downloaded from <http://ec.europa.eu/enterprise/tris/pisa/app/search/index.cfm?fuseaction=getdraft&inum=1587177>.

NORTH AMERICA

EPA withdraws Emissions Approval for 200 000 Small Off-Road Vehicles

The US Environmental Protection Agency has found that the sale and import of up to 200 000 small off-road vehicles relied on false or incomplete tailpipe emissions data. EPA has withdrawn its emissions approval of the import and sale of the affected gasoline-powered off-road motorcycles and all terrain vehicles. The California Air Resources Board has also voided its executive orders covering the same vehicles that were sold in California.

The action to void emissions certificates affects the companies that manufactured and imported these vehicles. EPA says that consumers who own models covered by the voided certificates are not responsible for the wrongdoing and can continue to use their vehicles. EPA issued the certificates in 2006 and 2007 to the US counterparts of four of China's largest manufacturers of these types of vehicles: Hensim USA, Loncin USA, Peace Industry Group, and Seaseng. The certificates were issued based on applications compiled by their consultant, MotorScience Enterprise. EPA says it believes MotorScience Enterprise intentionally submitted false or incomplete emissions information. The Chinese manufacturers are Chongqing Hensim Group Co., Chongqing Longting Power Equipment Co., Zhejiang Peace Industry and Trade Co., and Zhejiang Chisheng Industry and Trading Co.

US proposes Caribbean Marine Emissions Control Area

EPA, the US Environmental Protection Agency, has submitted to the International Maritime Organization (IMO) a proposal to designate portions of the coastal waters around the US Virgin Islands and Puerto Rico as an Emission Control Area (ECA). This would result in the control of NOx, SOx, and PM emissions from all ships operating in the area. The proposal follows IMO's agreement in March this year to the designation of North American coasts as an ECA.

From 2015, the fuel used by all vessels operating in ECAs must not exceed 0.1% (1000 ppm) sulfur. Starting in 2016, new engines on vessels operating in

these areas must use emissions controls that achieve an 80% reduction in NOx emissions.

IMO members are expected to consider the latest proposal at the Marine Environmental Protection Committee meeting starting on 27 September 2010.

US-EPA issues Final Rule on Air Toxics from Stationary SI Engines

Complementing its final rule on Hazardous Air Pollutants (HAPs) from existing compression-ignition stationary engines, published in March this year, the US Environmental Protection Agency has now issued its 'final rule' on the reduction of HAPs from existing stationary spark-ignition (SI) engines.

The rule covers emissions from existing engines where the total power of the engines on a site located at what EPA designates as a 'major source' is less than or equal to 500 horsepower. (A 'major source' of HAP emissions is generally a stationary source that emits or has the potential to emit 10 tons per year or more of any single HAP or 25 tons per year or more of any combination of HAP). It also applies to existing engines on any site that is located at an 'area source' (a stationary source that is not a 'major source'). EPA estimates that more than 330 000 stationary SI engines are used in the US to generate electricity or to power equipment used in oil and gas production, industrial, agricultural or other facilities.

The regulations are formulated in terms of CO or formaldehyde emissions as surrogates for a range of hazardous air pollutants.

Further details are at www.epa.gov/ttn/oarpg/new.html.

Environmental Organisations want EPA to Regulate Non-road GHG Emissions

One day after the US Senate upheld the Environmental Protection Agency's authority to regulate greenhouse gas (GHG) emissions, a coalition of environmental groups filed a lawsuit challenging the EPA's failure to address GHG emissions from ocean-going ships, aircraft and non-road vehicles and engines used in industrial operations.

The lawsuit was filed by Earthjustice and the Western Environmental Law Center on behalf of Oceana, Friends of the Earth, the Center for Biological Diversity, the Center for Food Safety, and the International Center for Technology Assessment. Together, aircraft, ships and non-road vehicles and engines emit approximately 290 000 tons of soot every year. They are responsible for 24% of US mobile source GHG emissions, and emissions from these sources are projected to grow over coming decades, said Earthjustice.



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Australian Prime Minister proposes Scrapping Scheme

Australia may soon follow in the footsteps of other international markets with a "cash for clunkers" programme.

As part of her government's climate change policy for the forthcoming Australian elections, Prime Minister Julia Gillard has announced a 'Cleaner Car Rebate', offering a A\$2000 (€1360) subsidy to new car buyers who trade-in pre-1995 cars.

Gillard said the rebate is part of a plan to cut vehicle emissions by one million tons, with mandatory emissions regulations to be introduced for new cars from 2015. If the Labour government is re-elected, the programme will start on 1 January 2011.

Motorbikes over 10 Years Old in Vietnam to undergo Exhaust Inspection

Vietnam's new regulations on vehicle emissions will focus first on motorbikes more than 10 years old, then on new motorbikes and remaining vehicles, the Registration Administration chief has told reporters.

The agency is elaborating a scheme to control exhaust from motorbikes to submit to the government for approval. Its objective is to ensure that 80 to 90% of motorbikes in Hanoi and Ho Chi Minh City meet exhaust standards by 2015. At present, less than half the bikes in circulation in these cities meet the emissions standards. From 2010-2013, the scheme will concentrate on media activities, developing an exhaust testing system, technical facilities and staff. During this stage, only 20% of motorbikes will be checked. In the second phase (2013 to 2015), the scheme will be scaled up to control most motorbikes in Hanoi and HCM City and spread this programme to other big cities. Vehicles that meet exhaust standards will be granted a one-year certificate. Exhaust verification stamps will also be stuck on checked vehicles. Vehicles that fail to meet exhaust standards will have to be repaired to meet the standards.

Singapore consulting on Euro 4

Platts reports that Singapore's National Environment Agency (NEA) has said that the government is in consultation with the oil industry on the adoption of Euro 4-equivalent emissions standards for gasoline-fuelled vehicles.

The agency said that they are consulting the oil industry on the lead time needed to supply 50 ppm sulfur gasoline, possibly by 2012. The current standard in Singapore is 500 ppm. No time frame has been set at this moment on the adoption of a higher emissions standard or the Euro 4 emissions standard for petrol vehicles, the NEA said.

"For diesel vehicles, we have, in the Singapore Sustainable Development Blueprint which was launched in April 2009, indicated that we are targeting to move to Euro V vehicle emissions standards by 2014/5," NEA spokesman said. Since October 2006, all new diesel vehicles have had to meet Euro IV standards. The government "expects all taxis to achieve Euro IV emissions standards by 2014, and the Land Transport Authority will work with public bus operators to attain this standard for all their buses by 2020."

Fuel Cell Bus for Singapore

Singapore's Nanyang Technological University (NTU) has unveiled GreenLite, a hydrogen-electric bus that is the result of a joint research project between NTU and Beijing's Tsinghua University.

The research project was developed in partnership with Singapore's Land Transport Authority (LTA), Singapore bus company SBS Transit and Chinese bus manufacturer Higer. Launched by Mr Teo Ser Luck, who is a Senior Parliamentary Secretary and Mayor of the Youth Olympic Village on NTU's Yunnan Garden campus, the bus will transport athletes and officials within the village during the games Youth Olympic Games.

GreenLite uses a hydrogen fuel cell system that powers the bus and charges the lithium-ion batteries when necessary. NTU says that unlike other hydrogen fuel cell buses which typically have capacities of between 80 and 150kW, the dual design combining a proton exchange membrane (PEM) fuel cell stack with lithium-ion batteries enables the bus to run on a fuel cell power capacity of only 40kW.

Tokyo Buses to test Synthetic Fuel

Buses running on a mixed synthetic fuel comprising 20% biodiesel with Fischer-Tropsch diesel derived from natural gas (GTL) are being tested on routes in Tokyo, Japan between July and December 2010. The government-funded field trials are to be conducted by a team from Toyota, Hino and Showa Shell Sekiyu KK. The partners say the fuel has no sulfur and emits less particulate matter and carbon monoxide when combusted than regular diesel fuel.

Guam to move to Ultra-low Sulfur Diesel

The Governor of Guam has signed into law a bill that will, from January 2011, make ultra-low sulfur (<15 ppm) the legal standard for diesel fuel on Guam. Fuel companies will, however, be given time to deplete their on-island inventories of diesel fuel that does not meet the new standard before tanks are replenished with ultra-low sulfur diesel.

Emissions of Fine Particles and Organic Compounds from Mopeds

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Abstract

In 2004 worldwide sales of powered two-wheelers (PTWs) were about 34 million units and are predicted to rise to over 40 million by 2009. Only in the last 10 years has the environmental impact of mopeds (scooters included) and motorcycles been seriously considered. Particular concern has been raised over two-stroke (2-S) scooters which in several countries such as Italy are widely used in congested city centers.

In this study, the emissions of fine particles and some organic compounds (benzene, formaldehyde, 1,3-butadiene, and benzo(a)pyrene) the exhausts of nine mopeds (2-S and 4-S), responding to different European emission legislative standards (pre-Euro, Euro 1, and Euro 2), were evaluated during the type approval driving cycle. Particulate was characterized as total mass collected on filters and as the total number of particles and size distribution in the range 7 nm–10 μm measured by the ELPI (Electrical Low Pressure Impactor). Introduction of the 4-S working cycle and oxidation catalyst on small engine two-wheeler vehicles, resulting from Euro 1 and Euro 2 limits coming into force, has appreciably reduced emissions of total hydrocarbons (including benzene, 1,3-butadiene, formaldehyde, and benzo(a)pyrene) and particulate matter. When considering engine technology, 2-S emit about three times more quantified organic compounds compared to 4-S. Total particle number emissions, occurring mainly during the acceleration phase, which corresponds to a rich combustion mixture, range from $7 \times 10^{12}/\text{km}$ to $6 \times 10^{13}/\text{km}$, with higher values for 2-S engines. Size distribution of solid particles peaks at about 0.1 μm .

Key words: unregulated emissions; particle size distribution; two-wheeler emissions; particle number emissions; emission factors

Introduction

IN 2004 global powered two-wheeler (PTWs) sales were about 34 million units, a figure which is predicted to rise to over 40 million by 2009 (Pinch and Reimer, 2007). The most frequently sold (especially in Asia and in some Mediterranean countries) are small size, low-power, and low-cost PTWs. There is a parallel select market of high-value and large-engine motorcycles (chiefly in North America, Europe, and Japan). Depending on the proportion of PTWs in the circulating fleet, urban air pollution can be strongly influenced by two-wheeler emissions, which are not negligible when compared with those of modern passenger cars. Indeed, CO and HC emissions of motorcycles are much higher than those of modern passenger cars, which are low emitters of such incomplete combustion products. Recently,

it was further demonstrated that the motorcycle fleet contributes considerably to total vehicular NO_x emissions (almost 20% that of cars) (Vasic and Weilenmann, 2006); this is due to the leaner and closer to stoichiometric operative conditions of new technology two-wheelers (Ntziachristos *et al.*, 2006). According to 2005 data, there are over 5 million mopeds circulating in Italy, which represent over 55% of all two-wheeler vehicles (ANCMA, 2004). The term “moped” describes any low-powered motor-driven vehicle with an engine capacity of less than 50 cm^3 and a maximum design speed of 45 km/h. Although in recent years Italian sales of two wheelers with an engine capacity higher than 50 cm^3 have exceeded those of mopeds, there has been increased attention in moped emissions due to the high pollution levels of two-stroke (2-S) engines which constitute almost 80% of all mopeds in use. For most regulated and unregulated pollutants 2-S vehicle emissions are much higher than those of four-stroke (4-S) engines because the combustion process involves a mixture of gasoline and lubricant with a substantial emission of unburned oil. Owing to the introduction of European legislative emission limits for mopeds (Directive

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10SETC-0107

Real-time Particle Emissions from 2-stroke Motorbikes with and without PMP Sampling System

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ABSTRACT

This paper describes various aspects of the particle emissions from a 2-stroke motorbike. It gives an indication of issues which may face emissions engineers if (or when) such vehicles become subject to particulate legislation similar to that for light duty vehicles.

A DMS500 fast particulate spectrometer was used to examine transient particle emissions from the CVS tunnel for two 2-stroke motorbikes over the European ECE R47 and urban New European Drive Cycle (NEDC) drive cycles. One was direct injected and the other was carburetted.

Transient size spectra and number data from the output of a two stage, Particulate Measurement Program (PMP) compliant heated dilution system are presented for the carburetted 2-stroke motorbike running the urban phase of the NEDC. Estimates of the particle number emissions relative to the Euro 5b light-duty diesel vehicle legislation are presented.

INTRODUCTION

The majority of light-duty on-road vehicles have 4-stroke engines, either gasoline or diesel fuelled. Emissions legislation has encouraged a steady reduction of PM mass emissions, and the new European limit for solid particle number (measured by the PMP methodology) will have a significant further reduction of particle number emissions [5,6,7]. For small motorbikes, 2-stroke engines have significant advantages. Their power-to-weight ratio generally exceeds that of 4-stroke engines, while their relative mechanical simplicity can result in lower manufacturing costs.

Crankcase-scavenged 2-stroke engines suffer from two main emissions problems. “Short circuiting” occurs when un-burnt fuel passes straight from the transfer port and out of the exhaust, while high oil consumption is due to the use of intake air directly from the crankcase. The use of Gasoline Direct Injection (GDI) technology resolves the short circuiting problem, but careful engine calibration is required to avoid high particle emissions due to local variations in air-to-fuel ratio (AFR). Additionally, the 2-stroke engine may introduce engine oil into the fuel, together with oil droplets carried through from the sump. This oil may be involved in combustion and leads to the possibility of significant ‘large’ particle emissions.

Traditional techniques such as SMPS instruments [8] have been used to study engine emissions, and are generally highly sensitive. However, their scanning nature makes them unsuited to transient measurements. Transient emissions may be disproportionately significant, since accurate control of the engine during these

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Real-time Particle Emissions from Two-Stroke Scooters

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• CAMBUSTION •

Introduction

The majority of light vehicles used on road have four stroke engines, either gasoline or Diesel fuelled.

Emissions legislation has encouraged a steady reduction of on-road PM mass emissions, and the future European limit for solid particle number (measured by the PMP methodology) will see a significant further reduction of Diesel particle number emissions (Diesel Particulate Filters being widely adopted as a means of compliance).

For small motor scooters, two stroke engines have significant advantages. Their power to weight ratio generally exceeds that of four strokes, while their relative mechanical simplicity can result in lower manufacturing costs.

Crankcase-scavenged two strokes have suffered from two main emissions problems- "short circuiting" (in which un-burnt fuel passes straight from the transfer port and out of the exhaust) and high oil consumption due to the use of intake air directly from the crankcase. The use of Gasoline Direct Injection technology removes the short circuiting problem, but careful engine calibration is required to avoid producing high particle emissions due to local variations in air fuel ratio. In addition, combustion of oil droplets carried through from the sump can produce very large particles with a significant contribution to the total mass.

Traditional techniques such as SMPS instruments have been used to study engine emissions for many years, and have the advantage of high sensitivity. However their scanning nature makes them unsuited to transient measurements. Transient emissions may be disproportionately significant, since accurate control of the engine during these conditions is more difficult.

This poster describes the use of a DMS500 type fast particulate spectrometer (Reavell 2002, Reavell et al. 2002, Symonds et al. 2007) to examine transient particle emissions from two different two stroke scooters.

Cambustion DMS500

Instrumentation and sampling system

- Fastest engine exhaust particle size spectral measurement available (~200 ms $T_{10-90\%}$ at 10 Hz data rate)
- Measurement ranges of 5 nm – 1000 nm, or 5 nm – 2500 nm
- Outputs of particle size, mass and PMP correlated solid particle number
- Built in 2-stage dilution and heated sampling line for sampling direct from engine exhaust.
- Primary compressed air dilution 5:1 inhibits agglomeration and condensation (not used during CVS tunnel sampling). A variable secondary diluter (capable of up to 500:1) of the rotating disc type extends the dynamic range of the instrument. Output data are automatically corrected for the total dilution factor.
- Particles enter a charger and are strongly electrically charged (Reavell et al. 2004).
- Charged particles pass into a classification column in which a radial electric field and an axial sheath flow are present (below).
- Particles are carried down the column by the sheath air, and are deflected outwards by the electric field depending upon their electrical mobility.
- Particles land upon any of 22 circumferential metal rings, each is connected to a sensitive electrometer. The charged particle flux produces a current (electrical mobility) spectrum.
- Real-time data processing converts this into both spectral data, and calculated solid particle mass / solid particle number data (Symonds et al. 2007)

Sampling system (integrated with DMS500)

Part A: Idle and Drive-by: 100 cc carburettored

The exhaust was sampled directly with the DMS500 using its heated line. For the idle test, the sample probe was placed ~1m from the exhaust:

The spectrum is bimodal in nature, with a low concentration mode at around 20 nm and a high concentration mode at around 150 nm. Compared with Diesel or Gasoline Direct Injection accumulation mode particles this second mode is larger in size (c.f. 70-100 nm) and narrower in width (GSD ~1.4, c.f. ~1.6). This would be more typical of a condensation aerosol, for example lubrication oil. The instability is partially due to variations in ambient dilution.

By contrast, the 'drive-by' test shows on average much smaller particles (around 40 nm) The difference in size may be due to dilution conditions if the aerosol is volatile, or more likely differing engine conditions whilst under load.

Part B: Dynamometer: 49 cc, direct injection

A 49 cc direct injection 2-stroke motor scooter was mounted on a motor-cycle dynamometer. The exhaust was fed into a constant volume sampling dilution tunnel, and the DMS500 sampled from this dilution tunnel, along with a gas analyser. The DMS500's internal rotating disc diluter was used (at a factor of 50) to bring the concentration within the dynamic range of the instrument. All real-time particle concentration data here has been corrected for the internal dilution, but not for the dilution tunnel as this is dependent upon exhaust flow. Two ECE-R47 moped drive cycles were performed, the first with an oxidation catalyst fitted to the exhaust, and the second with the catalyst replaced with a blank substrate (to avoid changing engine performance). Contour plots of the particle size spectrum over each drive cycle are shown below:

Catalyst

No Catalyst

For most of each cycle, the spectrum is bimodal in nature, with one mode around 20 nm, and the other varying from ~40 nm to ~90 nm. This compares well with 4 stroke direct injection data. However, upon hard acceleration, a ~120 nm mode is seen briefly. Just prior to the 45 kph cruise section, there is evidence of a ~500 nm mode, some four orders of magnitude lower concentration than the other modes. However, when mass weighted, this mode accounts for over 10% of the mass concentration due to the large size of particles (below). To the right can be seen detail of the acceleration in the catalysed test:

Catalyst - 340s accel

Catalyst - 340s accel, expanded

The DMS500's lognormal parameterisation is used to fit two modes to the spectrum, termed loosely "Nucleation" and "Accumulation" to fit parlance applicable to Diesel emissions (Symonds et al. 2007), without necessarily passing judgement upon their physical nature. Note the fit does not pick out the weak mode at 500 nm.

The plot below shows an estimate of cumulative solid particle number taken from the accumulation mode fitted by the DMS software. Also shown is the cumulative mass (unit density). The proposed Diesel Euro stage 5&6 limits for particle number and mass are 6×10^{11} #/km and 4.5 mg/km respectively; note that this bike would fall this number standard (5.6×10^{11} #/km) yet pass this mass standard (2.2 mg/km). Note that this assumes that the particles in the second mode are solid.

Shown below are the total particle number and mass rates (the latter assuming unit density), along with CO and CO₂ rates from the gas analyser

Catalyst

No Catalyst

Conclusions

An initial investigation of 2 stroke particle emissions shows that: The concentration of particles varies with load as is expected, but cold start behaviour is similar to behaviour at the end of the cycle. With the DI engine a 500nm mode is present during accelerations. This mode is not seen on 4 stroke engines, and it is surmised that it is due to oil droplets. The same may be true for the 150 nm mode seen at idle on the carburetted engine. The authors consider that the differences in particle mass and number rate with and without the catalyst are due to variability in the testing, and not an effect of the catalyst.

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Entwicklung eines Viertakt Ottomotors mit Kurbelgehäuseaufladung

Kurzfassung

Derzeit werden für kleinvolumige Motoren bei Zweiradfahrzeugen, bei Anwendungen in Elektroaggregaten, welche beispielweise auch für Range Extender verwendet werden können, sowie bei tragbaren Arbeitsgeräten, zwei unterschiedliche Technologien eingesetzt. Einerseits sind das Einzylinderzweitaktmotoren und andererseits Einzylinderviertaktmotoren. Die Zweitakttechnologie leidet unter den hohen Kohlenwasserstoffemissionen, verursacht durch die Spülverluste beim Ladungswechsel, womit ein unangenehmer Geruch und Rauch sowie schlechter Verbrauch verbunden sind. Zweitaktmotoren haben jedoch den Vorteil eines geringeren Gewichtes und einer hohen spezifischen Leistung, was in einem hubraumbeschränkten Marktsegment deutliche Vorteile bringt. Die Viertaktmotoren bringen den Vorzug gut kontrollierbarer Emissionen mit sich. Diese gut etablierte Technologie in Verbindung mit katalytischer Abgasnachbehandlung hat jedoch den Nachteil geringer spezifischer Leistung. In dieser Veröffentlichung wird eine Kombination beider Technologien vorgestellt, welche die jeweiligen Nachteile verhindern soll. Ein Viertaktmotor, aufgeladen über das Kurbelgehäuse, nutzt ein zweitaktähnliches Kurbelgehäuse zur Vorverdichtung der Ansaugluft, verwendet jedoch einen Viertaktzylinderkopf für exakt kontrollierbaren Ladungswechsel. Das Öl zur Schmierung des Kurbeltriebs wird dabei mit der Ladeluft vermischt. Um den hohen Ölverbrauch und die damit verbundenen Emissionen zu vermeiden, wird zwischen Kurbelgehäusepumpe und Zylinderkopf ein Ölabscheidesystem implementiert.

Nach einem historischen Rückblick auf die Kurbelgehäuseaufladung werden eine detaillierte Beschreibung des Arbeitsprinzips sowie ein Einblick in die Forschungs- und Entwicklungsarbeiten gezeigt. Zur ersten Absicherung des Konzeptes wurde eine 0D-1D Ladungswechselrechnung durchgeführt. Nach der ersten Konstruktions- und Berechnungsphase wurde ein Prototyp dargestellt und am Motorenprüfstand und in einem Fahrzeug untersucht. Die daraus gewonnenen Erkenntnisse führten in weiterer Folge zu einer Neukonstruktion eines kurbelgehäuseaufgeladenen Motors, der als seriennaher Prototyp dargestellt, und am Motorprüfstand und im Fahrzeug betrieben wurde. Eine Zusammenfassung und ein Ausblick über die Verwendbarkeit dieser erarbeiteten Technologie schließen diesen Vortrag ab.

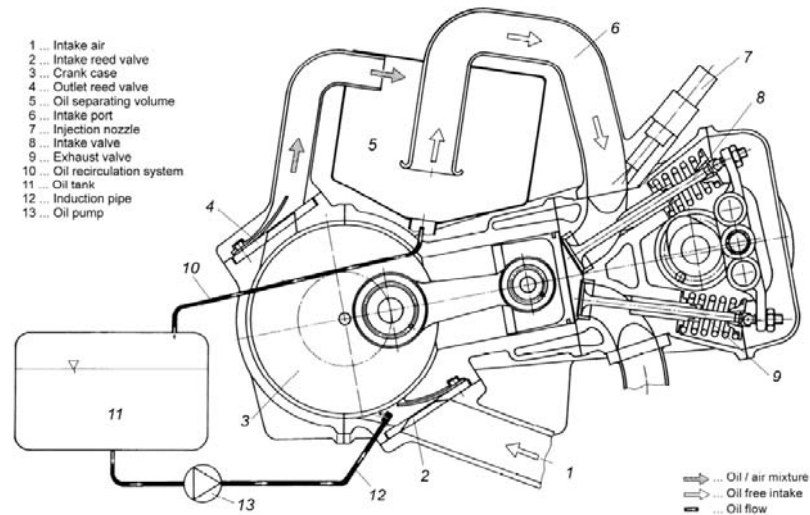


Abb. 2: Funktionsbeschreibung des kurbelgehäuseaufgeladenen Viertaktmotors mit Ölrückgewinnung /4/, /5/
 Fig. 2: Functional description of a crankcase supercharged four-stroke engine with oil separating system /4/, /5/

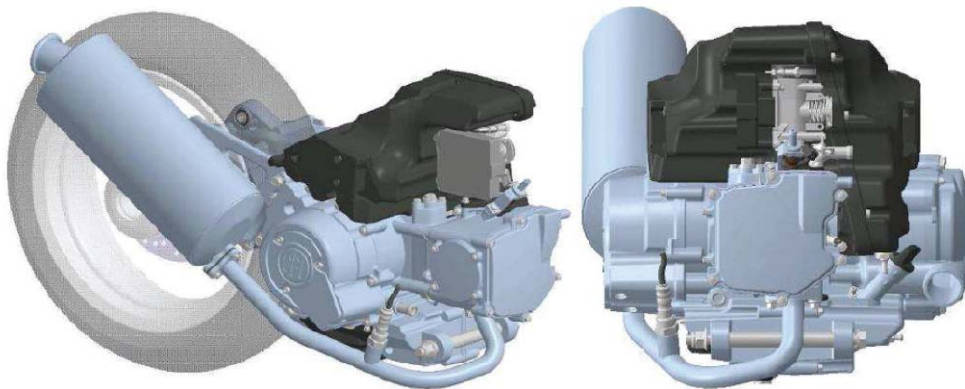


Abb. 23: 3D Ansicht der zweiten Generation des kurbelgehäuseaufgeladenen Motors, einschließlich aller Komponenten für eine Fahrzeugimplementierung.
 Fig. 23: 3D view on the second generation of crankcase super charged engine, including all components for vehicle implementation.

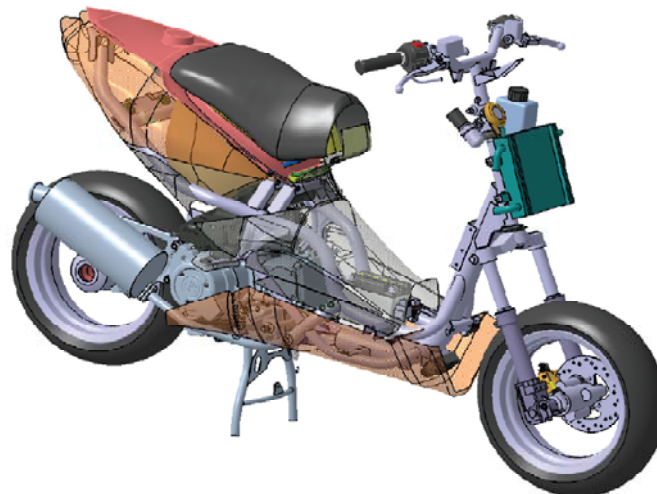


Abb. 25: 3D Fahrzeugeinbau der zweiten Generation des kurbelgehäuseaufgeladenen Motors
 Fig. 25: 3D vehicle integration of the second generation of crankcase supercharged engine

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Are loop scavenged 2-stroke engines for recreational purposes able to fulfil future emission limits?

Abstract

The present technology applied in two-wheeler two-stroke engines is realized by external mixture formation with carburettor. This engine concept – used in displacements between 50cm³ and 500cm³ per cylinder – has to put up with heavy drawbacks concerning torque characteristics and maximum achievable power in order to cope with emission limitations. Due to high scavenging losses, the applied exhaust gas after treatment concepts, often realized via an oxidation catalyst, reach their endurance limit. More severe future emission limits, discussed for 2012 (EURO IV), as well as the planned evidence of endurance, strive for the inevitable change of the system to four-stroke or two-stroke engines with internal mixture formation to achieve a reduction of scavenging losses.

High system costs, complexity and space prevent the application of known automotive high pressure direct injection systems in small capacity engines. Due to these circumstances, different systems and technologies have been developed to cope with the specific requirements for these engine types. A system comparison gives a survey on the mode of operation, the field of application, and the achievable emission limits.

Extensive test bench investigations with an optical analysis of the mixture preparation and scavenging process, supported by 3D CFD simulations, lead to new findings concerning mixture formation in loop scavenged two-stroke engines. Different novel mixture formation variations were scrutinized. The most promising variation was realized in a 50cm³ and a 250cm³ two-stroke engine respectively. The detailed documentation of the development on the engine test bench proves that the targeted use of charge movement during the scavenging process, even with low pressure injectors, is able to realize a sufficient internal mixture formation in the two-stroke engine. The separation of air and fuel trapping efficiency enables a significant reduction of fuel scavenging losses as well as an optimization of the oxidation process in the exhaust gas after treatment system. The application in prototype vehicles could further confirm a decrease of emissions and a reduction of fuel consumption. The new low pressure direct injection concept shows the high potential to fulfil future emission regulations.

The working principle of the innovative low pressure injection system

The consolidated findings of the above described scavenge process analysis can arrestingly be implemented in the new Low Pressure Direct Injection System (LPDI), that was worked out at the Institute for Internal Combustion Engines and Thermodynamics at Graz University of Technology. As described in Fig. 14, the new system is capable of creating two different mixture formation methods. In the first mode, the fuel is applied directly into the cylinder during the scavenge process. For this direct injection mode (Fig. 14a) the injection direction is orientated towards the piston surface, opposite to the exhaust port. This injection direction causes a strong interaction with the scavenge flow, that is orientated in the opposite way. The strong flow from the transfer ports inhibits excessive spray contact with the piston. Due to the droplet breakup in the collision zone of the spray, a satisfying mixture preparation, even with a low pressure injector of 4bar, can be achieved. A visualisation of the DI mode, in hardware and in simulation, can be found in Fig. 17.

The second possible mixture formation is the stratified injection mode. Here the benefit of the rear transfer port, having the lowest of all scavenge losses, comes into force. In Fig. 14b, c and d, the course of mixture preparation can be seen. First, when the piston is in the area of top dead centre (TDC) the fuel is introduced in the volume below the piston. This is possible due to a piston window that is located at the rear transfer port. In the pre compression phase of the crankcase, when the piston is in the down stroke, the fuel has time to vaporise, supported by the radiated heat of the piston (Fig. 14c). The special design of the rear transfer port enables the scavenging of the rich mixture below the piston. The rich mixture is mainly scavenged through the rear transfer port, and not through the main and the side transfer ports, as the inlets of these ports are positioned lower in the crankcase and not in the cylinder wall (Fig. 14d). This method of mixture preparation takes into account the short cut scavenging of the main transfer port, in the early scavenging phase of the two-stroke engine, as described in Fig. 12. The main transfer port is scavenged by lean mixture from the crankcase.

Due to the geometrical behaviour of this new engine concept, certain restrictions concerning injection phasing are prevalent. In Fig. 13 the possible injection timing can be seen. The direct injection is of course only possible, when the piston is below the injection duct of the cylinder. A further restriction is the cylinder pressure. The direct injection pressure of 4-7bar must be higher than the cylinder pressure. This is the reason why the exhaust port opening must occur at least some degree of crank angle before the injection can begin. The injection duct in the cylinder must be located below the exhaust port, in order not to damage the valve plate of the low pressure injector which would be caused by compressive deformation coming from the combustion pressure.

The stratified mixture preparation mode can be achieved by injection when the piston is in the upper part of the cylinder. Start of injection is possible when the piston window is opening the injection duct in the cylinder, and it must be finished before the duct is closed again in the combustion stroke. An injection, when the piston is closing the injection duct, must be avoided because the fuel would wash away the lubrication oil film covering the piston skirt. Further the fuel deposits in the piston ring area would cause high HC-emissions. To ensure the system robustness for industrialisation, the injection during this phase is inhibited by the engine management system software.

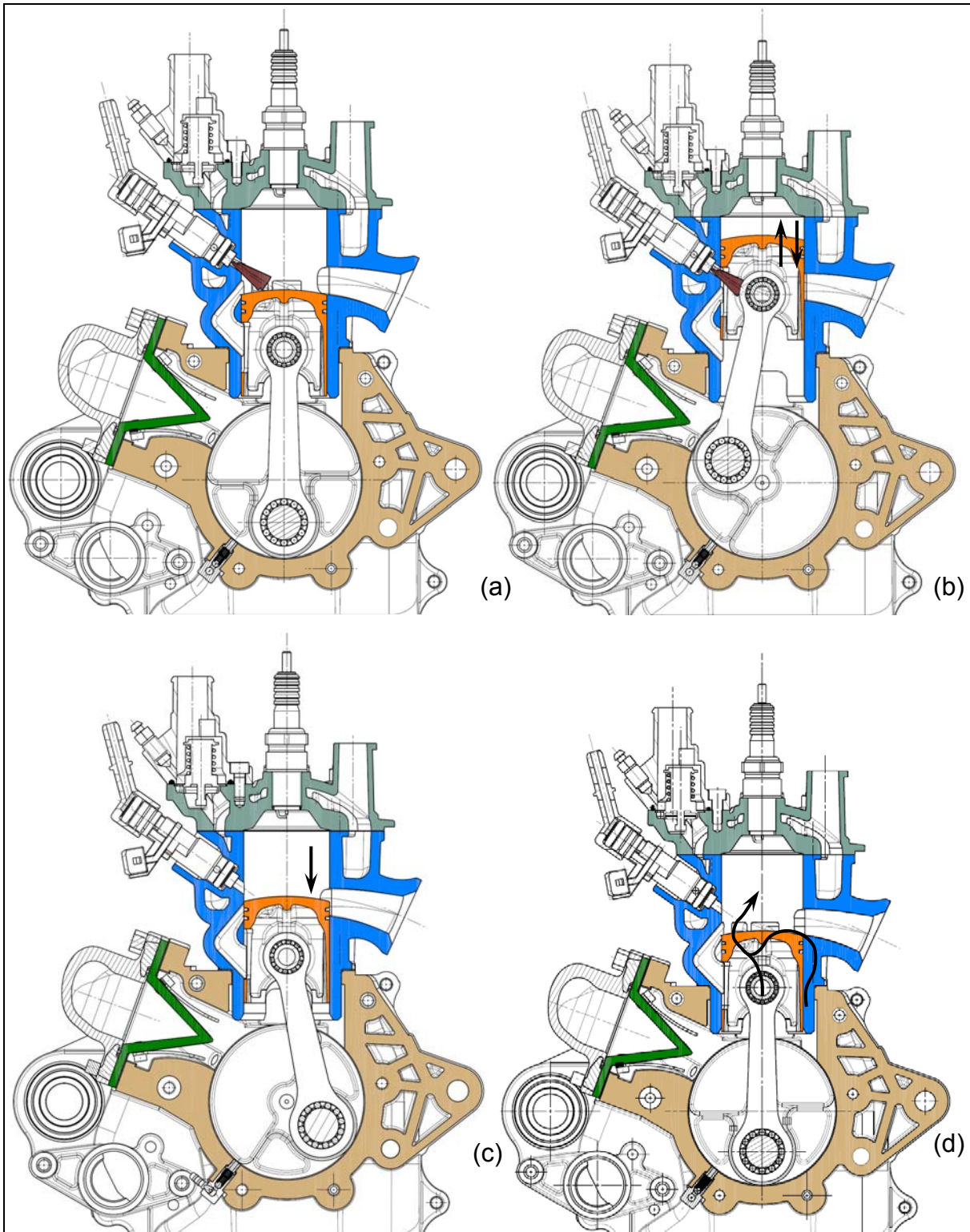


Fig. 14: Functional description of the new low pressure direct injection strategy

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Suitable on different condition road: In urban city flat road, electric motor is running smoothly. The user can recharge the battery from home power supply on 220 volts. On country side or mountain road, we can use gas motor or dual hybrid power. 35 degrees climbing capacity on dual power driving. It is very easy.

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Climbing capacity: 30 degree

Electric Motor

3. Motor: 350Watts Brushless motor, with self-charging
Max speed: 35km/h; 21.74mile/h
Climbing capacity: 10 degree

4. Product size: 1880x670x1080 mm
5. Brake: automatic front & rear drum brake
6. Standard loading capacity: 150kgs/330lbs
7. Charging time: auto-charging while running

FOB Ningbo Price: USD545.60/PC (Based on 20ft container order. 30pcs)

Sample Order Price: USD596.65/PC

Thank you!



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E-Bike Quotation

	2nd Generation Product (STVZO)		2nd Generation Product (Standard)	
Photo				
	STVZO Unit Price		Standard Unit Price	
Unit Price	FOB NINGBO 198.4USD	Motor power:500W	FOB NINGBO 180.3USD	Motor power:500W
	FOB NINGBO 202.4USD	Motor power:800W	FOB NINGBO 184.3USD	Motor power:800W
	FOB NINGBO 216.6USD	Motor power:1000W	FOB NINGBO 198.5USD	Motor power:1000W
Item No.:	500/800/1000			
Motor power:	500W/800W/1000W			
Dimension :	Length 44" x Height 49"			
Driving system:	Chain			
Max load :	120kg/266.7lbs			
Battery:	12AH / 36V (12V X 3pcs)			
Life of Battery:	over 250Cycles			
Charger:	110V-240V			
Top speed:	15.6mph		terrain)	
Max range:	21mile			
Tires :	10" Aluminum Mag Wheels (Oversize Tires)			
Brake:	Front/Rear Disc			
Net weight:	40..5kg/89.3lbs			
Gross weight:	43kg/94.8lbs			
Carton size:	45.2"X 13" X18.1"			
Qty/20'GP	160pcs			
Qty/40'GP	320pcs			
Qty/40'HQ	360pcs			

Sales Example Linkage:

http://www.amazon.com/Super-Turbo-800watt-Electric-Scooter/dp/B001T8E6KM/ref=pd_sbs_sg_1

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http://www.x-tremescooters.com/electric_scooters/x600/x600.html

http://www.amazon.com/Evo-800w-Electric-Scooter-Powered/dp/B002YEPAPK/ref=sr_1_1?ie=UTF8&s=miscellaneous&qid=1277194812&sr=8-1-catcorr