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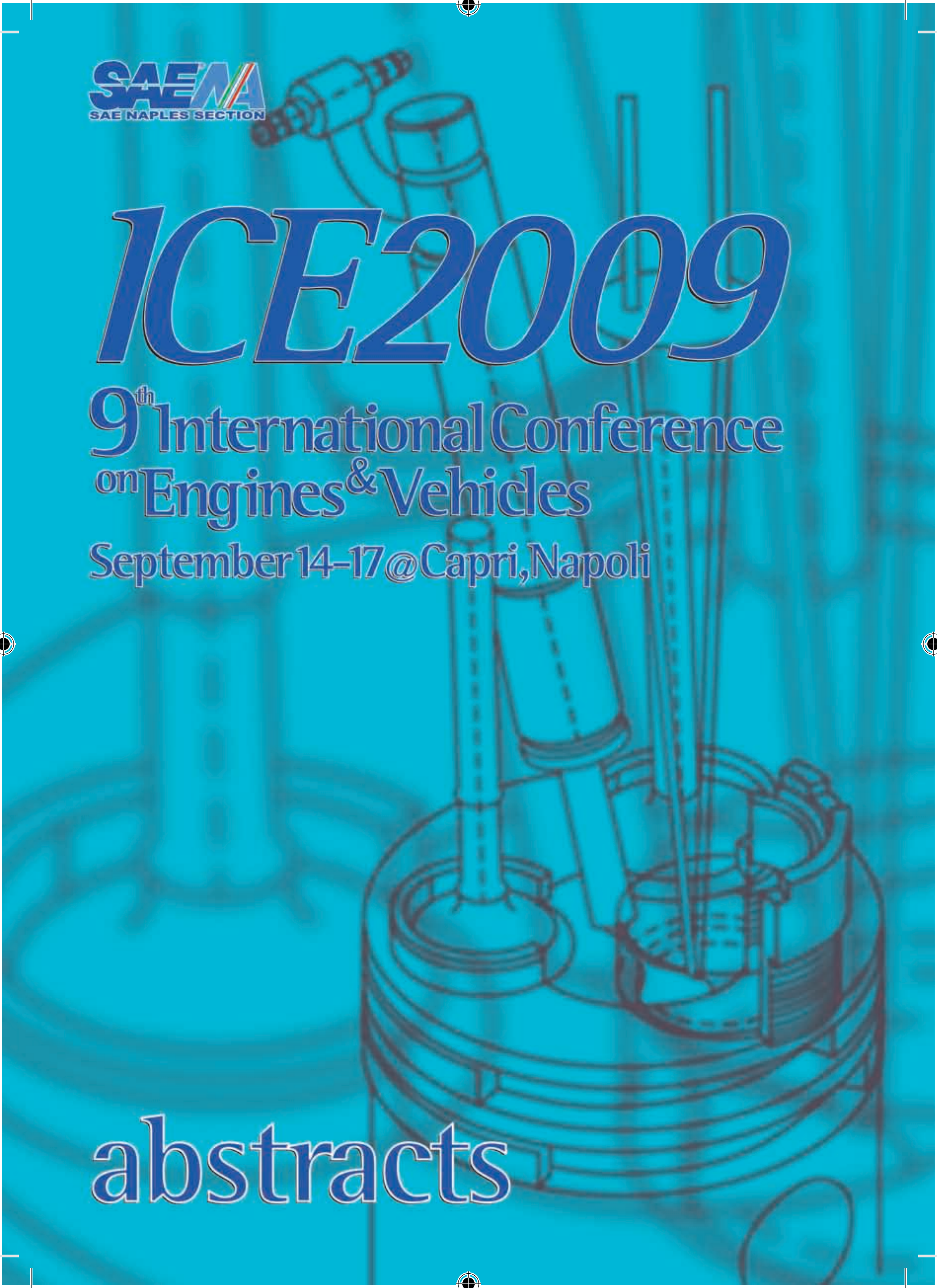

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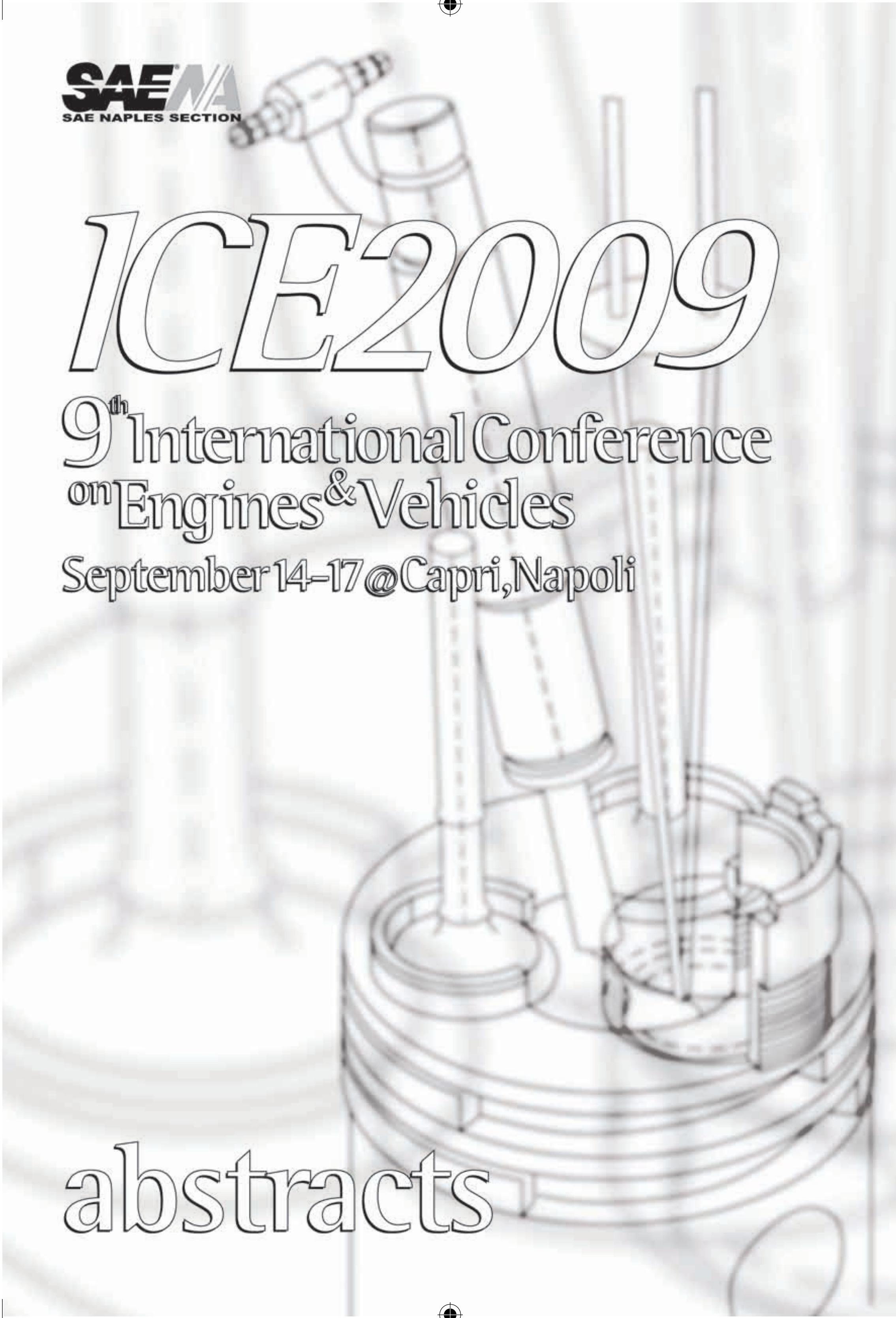

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ICE2009

9th International Conference on Engines & Vehicles

editors
Simona Silvia Merola & Bianca Maria Vaglieco

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Preface

Engine pollutant emissions and fuel consumption have become of increasing concern over the past few decades. Manufacturers of automotive vehicles, are one of the major sources of energy consumption and urban emissions, they are under significant pressure to improve efficiency and reduce exhaust emission levels. While dwindling fuel reserves and greenhouse gas emissions are motivating factors behind long-term interest in greater efficiency, ambient air quality standards and associated public health concerns have spurred the call for lower emissions. In order to achieve these objectives, new Internal Combustion Engine and Hybrid-Electric Vehicle technologies are being developed.

ICE2009, 9th International Conference on Engine and Vehicles has been organized by Istituto Motori – CNR and SAE_NA, Italian Section of SAE Int., to provide the ideal setting for the interaction among research centers, academia and industries that are involved in the engine field.

To encourage intensive discussions about new results and research approaches on engine, vehicle and propulsion device, 130 papers from around 30 countries have been selected after a review process according to SAE int. standard. These contributions cover a wide variety of aspects, from the advanced internal combustion engines to the hybrids, from the liquid and gaseous fuel to alternative ones, from the innovative experimental diagnostics to the newest numerical methodologies for modeling, simulation and control. In addition experts in these topics have been invited to deliver plenary lectures on the state of the art and future development trends for the disciplines associated with the conference.

We are very grateful to SAE Int., especially to Melissa Jena, and to Robert Kornrumpf for the precious help and kindness. We thank all the Session and Subsession Organizers for their availability and hard work; all the authors and reviewers for their contributions. A right and proper thanks is due to the sponsors for their financial support. Finally a special thanks is for all those who contributed to the organization of ICE2009 with their enthusiasm, effort and time.

Simona S. Merola and Bianca M. Vaglieco.

Fuel Injection and Combustion Process _Modeling

Fuel Injection and Combustion Process _Experiments

Alternative and Advanced Power Systems

Fuels and Lubricants

Powertrain Technology

Exhaust Aftertreatment and Emissions

Numerical simulations of Diesel engine combustion by means of OpenFOAM CFD ToolBox

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The present work is focused on multidimensional simulations of combustion in Diesel engines, using detailed kinetics reaction schemes. The selected reaction mechanism is the scheme developed by Liu et al. [1].The simulations are performed through the open source CFD Toolbox OpenFOAM (Open Field Operation and Manipulation). OpenFoam uses finite volume methods to solve systems of partial differential equations ascribed on any 3D unstructured mesh of polyhedral cells. A preliminary analysis relevant for diesel combustion studies is performed in constant volume homogeneous conditions. Here the treatment of the stiff ordinary differential equations arising from the usage of detailed kinetics reaction mechanisms and the performance of different solvers are investigated. The CVODE package has been integrated in OpenFOAM, as an alternative solver to the one provided by the original version of the code.
Then the predictive capabilities of the application available in the software for diesel engines combustion simulations are verified comparing computed pressure profiles with experimental data. The measurements are collected from a single cylinder Diesel engine with the same architecture of the real four-cylinder FIAT 1.9 litre Multi-Jet engine. The engine is fuelled with pure n-heptane, in order to allow the direct use of reaction mechanisms for a single-component fuel.

Improved Distribution of Temperature inside Semitransparent Heat-Insulating Coatings of Combustion Chamber

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H. Koegler
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The paper considers the radiative heat exchange under intensive short (radiant flux of red-hot soot particles) and long (radiation of "hot" hydrocarbonic atmosphere) IR components of total thermal flux in the combustion chamber (CC) of high-speed diesel engines. The analysis is conducted for only one spectral band in the ceramic coating and is assumed to be without any soot layer on it for this preliminary investigation. Temperature distributions are calculated for two layer coating. It consists of a top layer based on the semitransparent heat-insulating coating (SHIC) with varios thickness and a bottom one (semitransparent or opaque which could be metal substrate) with variation of reflection for transient (one complete cycle of piston movement) and steady state (cyclic heating). The improved distributions of temperature due to volumetric radiant heat losses inside semitransparent and paque heat-insulating coatings are discussed. Subsurface temperature maximum under cycle radiant-convectional heat fluxes in CC of diesel analyzed. It is shown that semitransparent coatings can accumulate penetrating radiant heat of the total thermal flux during the "hot" phase (the combustion of fuel blend) and then act as a heat source in the rest of the cycle.

Multiple injection and rate shaping Part 1: Emissions reduction in passenger car Diesel engines

F. Atzler, O. Kastner, R. Rotondi, A. Weigand
Continental Automotive GmbH, Germany

In modern passenger car diesel engines, multiple injection, MI, and rate shaping are measures, which in conjunction with others help to achieve the emissions legislation EU6 and US Tier2 Bin5. However, where hitherto mainly pollutant emissions where considered, CO2 output - i.e. fuel consumption - becomes increasingly important. Also, off cycle emissions may have to be regarded in the future. Additionally engine noise and drivability need consideration.
The complexity and effect of an applied injection strategy is defined by the overall engine concept including the after treatment system, and also by the vehicle inertia. Additionally a modern fuel injection system not only has to allow for the necessary injection strategies but at the same time needs to offer robust performance over life time.
Although a complex injection system may entail a penalty in cost, this has to be regarded in the context of the complete engine system including a possibly needed exhaust gas after-treatment, since a more expensive injection system can contribute to an overall reduction in cost. A well applied and stable injection system may allow for a simple and cheap after treatment system to be used, optimised for low engine exhaust back pressure.
In the present work, the improvements in mixture formation and combustion through multiple injection strategies, MI, and injection rate shaping were investigated. In particular, combination of ramp injection with pilot and post injections were examined. This was done, using a 500 cm3 single cylinder research engine and the Continental directly actuated piezo injector, which allows for the stable application of partial needle lifts for injection rate shaping.
The current report provides evidence that appropriate injection patterns in combination with suitable boost and injection pressures serve to achieve EU6 emissions engineering targets at the investigated operating points.
The physio-chemical effects of MI and rate shaping were also analysed by means of 3D combustion simulation, in order to improve the understanding and, hence, facilitate the appropriate application of the injection strategies. A detailed treatise on the computational investigation is provided in Part 2 of this paper (SAE 20009-24-0012).

Phenomenological Multi-Step Modeling of Diesel Injection and Combustion

G. Chiatti, O. Chiavola, F. Palmieri
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A previously developed injection system model has been enhanced including a quasi-dimensional, multi-zone, direct injection (DI) diesel combustion model, with the aim of taking into account the actual injection process, the spray formation and the droplet heating-vaporization processes. Such a goal is obtained by means of the integration of different modeling approaches. In a commercial simulation environment, a lumped parameter mechanical-hydraulic scheme is used to model the injection process, in terms of fuel flow rate and injection pressure. The spray formation processes and the droplet vaporization phenomena are then implemented in a self developed computation code, accounting for finite thermal conductibility of the liquid phase fuel. The coupling among the models allows for a detailed representation of the involved phenomena at each simulation step (e.g. fuel time pressure history, fuel properties, atomization, evaporation ambient condition); at the same time, it is possible to evaluate the operation of the injection system on the basis of atomization, vaporization and combustion behavior. The results of the numerical prediction are compared to experimental data referred to a DI diesel engine.

Improvement of a High-Performance Diesel-Engine by means of Investigation on different Injection Strategies

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K. Paule, J. Brandt v. Fackh, D. Wichelhaus
Volkswagen Motorsport GmbH, Germany

Test bench investigations on a high-performance diesel engine equipped by regulation with an airrestrictor have shown, among other things, that different injection strategies have a remarkable influence on the engine performance and exhaust emissions. A part of these investigations is reported in this paper. In particular the attention here is directed to the following two topics:

- comparison between two different injector types (solenoid vs. piezo)
- comparison among different injection timings (only main injection vs. pre-injection).

Looking for a continuous increasing of engine performance a detailed understanding of the injection and combustion processes is mandatory. For this task a fast response 3D-CFD-simulation-tool has been applied to the engine development process. This tool acts as a virtual eye inside the combustion chamber which permits to have a look beyond the test bench. So it was possible to find explanations for the occurring phenomena and then virtually test new approaches to improve the engine performance (virtual engine development). The results show, e.g., that against the expectations the piezo-injector is not overall more performing than the solenoid injector and the setting of a pre-injection under particular circumstances permits to increase the engine performance in the speed range above the choking line of the air restrictor. All the presented investigations take into account the FIA (Fédération Internationale de l'Automobile) general regulations and Volkswagen self-limitation on the smoke emissions for race engines.

Prediction and Optimization of the Performances, Noxious Emissions and Radiated Noise of a Light Duty Common-Rail Diesel Engine

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Istituto Motori – CNR – Napoli, Italy
F. Bozza
DIME – University of Naples "Federico II", Napoli, Italy

The paper illustrates the interdisciplinary matching of different numerical and experimental techniques, aimed to characterize the performances, emissions and combustion noise radiated from a small-size DI diesel engine. The main objective is the development of proper models to be included within an optimization procedure, able to define an optimal injection strategy for a common-rail engine. The injection strategy is selected to simultaneously reduce the fuel consumption, the pollutant emissions and the combustion noise.
The engine considered is a naturally aspirated, four strokes, two valves, single-cylinder engine (505 cm3 displacement), to be equipped with a prototype common-rail fuel injection system. A preliminary experimental investigation is carried out on the above engine, equipped, however, with a standard mechanical injection system (base engine). Both performance and radiated noise are measured on the base engine to provide reference experimental data in different operating conditions. Moreover, the prototype common-rail fuel injection system is characterized on a flow-meter to measure the instantaneous fuel flow rate corresponding to a pilot-plus-main injection strategy.
A deep 3D CFD analysis of the combustion period is firstly carried out on the base engine, employing realistic initial conditions derived from a 1D simulation of the whole engine. The CFD analysis is effected by accounting for the fuel spray dynamics and for the subsequent chemical reactions, leading to the prediction of the rate of heat release, pollutants formation and in-cylinder pressure cycle. 1D and 3D analyses are validated with reference to overall engine performance and experimental in-cylinder pressure data, respectively.
In addition, the 3D computed pressure cycle is post-processed to estimate the combustion related noise. The acoustic methodology is based on an innovative study performing a decomposition of the pressure signal, and allowing to quantify

the noise emission of the chosen engine operating point. The numerical results are compared to sound pressure level measurements, taken at 1m from the engine.
Once validated, both the CFD and the acoustic procedures are applied to the simulation of the common-rail prototype engine and are finally coupled to an external optimizer (ModeFRONTIER®). The experimental pilot-plus-main injection strategy is properly parameterized, for a constant overall mass of injected fuel, in terms of three degrees of freedom: the start of injection, the dwell-time and pilot injection duration. The above parameters are continuously varied by the optimizer to the aim of simultaneously minimize the fuel consumption, the pollutant emissions and the radiated noise.
The results clearly highlight a trade-off among the various objectives and the need to select a compromise solution among them. The study has the major result of proposing a technique for indicating paths towards an automatic engine optimization, characterized by the highest power output and the lowest environmental impact in terms of both pollutants and noise emitted.

Multiple injection and rate shaping
Part 2: Emissions reduction in passenger car Diesel engines
Computational investigation

F. Atzler, O. Kastner, R. Rotondi, A. Weigand
Continental Automotive GmbH, Germany

In modern passenger car diesel engines, multiple injection, MI, and rate shaping are measures, which in conjunction with others help to achieve the emissions legislation EU6 and US Tier2 Bin5. However, where hitherto mainly pollutant emissions where considered, CO2 output - i.e. fuel consumption - becomes increasingly important. Also, off cycle emissions may have to be regarded in the future. Additionally engine noise and drivability need consideration.
The complexity and effect of an applied injection strategy is defined by the overall engine concept including the after treatment system, and also by the vehicle inertia. Additionally a modern fuel injection system not only has to allow for the necessary injection strategies but at the same time needs to offer robust performance over life time.
Although a complex injection system may entail a penalty in cost, this has to be regarded in the context of the complete engine system including a possibly needed exhaust gas after-treatment, since a more expensive injection system can contribute to an overall reduction in cost. A well applied and stable injection system may allow for a simple and cheap after treatment system to be used, optimised for low engine exhaust back pressure.
In the present work, the commercial 3D CFD code “AVL Fire” was used to analyse the functioning of the so-called “ramp injection”, in particular the opening ramp. The validation data originated from a 500 cm3 single cylinder research engine, run with the directly actuated Continental piezo injector, which allows for application of variable opening velocities of the nozzle needle for injection rate shaping. The physics of mixture formation and their effects on combustion and, hence, on emissions generation was elucidated. It was established in previous work, that the quantity and the rate shaping of the pre-main injected fuel mass had a significant effect on soot emissions. Therefore the emphasis of the present analysis was on the

processes affecting soot generation and soot oxidation, in order to minimise the overall soot emission. The analysis was based on the quantification and localisation of the volumina of rich mixture above an equivalence ratio of 2. The computed results of in-cylinder pressure, heat release rate and engine out soot emission trends, were validated against test results from the same single cylinder engine, which lend its geometry and combustion system configuration for the generation of the computational grid and the initial and boundary conditions of the computation.
Agreement of the results from experiments and simulation was excellent, giving confidence in the validity of the analysis of local phenomena, which explain the differences in mixture formation and combustion of various injection strategies.
A detailed treatise on the experimental investigation is provided in Part 1 of this paper, SAE 2009-24-0004. It also includes a brief review on previous work on the subject on injection rate shaping, including the boot injection.

Modeling of Combustion and Emissions Formation in Heavy Duty Diesel Engine Fueled by RME and Diesel Oil

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A comparative study on engine performance and emissions (NOx, soot) formation has been carried out for the Volvo D12C diesel engine fueled by Rapeseed Methyl Ester, RME and conventional diesel oil. The fuel and combustion models used in this paper are the modifications of those described in [1-3].
The numerical results for different load cases illustrate that for both fuels nearly 100% combustion efficiency was predicted; in the case of RME, the cumulative heat release was compared with the RME LHV, 37.2 kJ/g. To minimize soot and NOx emissions, 25-30% EGR levels depending on the engine loads and different injection timings were analyses. To illustrate the optimal engine performance conditions, a special technique based on the time-transient parametric j-T maps [4] has been used.

Multi-dimensional modeling of the air/fuel mixture formation process in a PFI engine for motorcycle applications

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The preparation of the air-fuel mixture represents one of the most critical tasks in the definition of a clean and efficient SI engine. Therefore it becomes necessary to consolidate the numerical methods which are able to describe such a complex physical process.
Within this context, the authors developed a CFD methodology into an open-source code to investigate the air-fuel mixture formation process in PFI engines. Attention is focused on moving mesh algorithms, Lagrangian spray modeling and spray-wall interaction modeling.
Since moving grids are involved and the mesh quality during motion strongly influences the computed incylinder flow-field, a FEM-based automatic mesh motion solver combined with topological changes was adopted to preserve the grid quality in presence of high boundary deformations like the interaction between the piston bowl and the valves during the valve-overlap period.
The fuel spray was modeled by using the Lagrangian approach, and the spray sub-models (atomization and breakup) were tuned according to experimental validations carried out in previous works. Specific submodels were implemented to describe the impingement of fuel spray with the engine walls. The evolution of the resulting liquid film was also taken into account by solving the mass and momentum equations with the Finite-Area discretization method.
The proposed methodology was applied to simulate a single-cylinder SI engine for motor-scooter applications at a low load operating condition. This operating point was chosen since these engines often run very close to idle conditions when they are used in the urban areas.

Modelling and Simulation of the Combustion of Ethanol blended Fuels in a SI Engine using a 0D Coherent Flame Model

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Motor fuels are today increasingly blended with oxygenate components to reduce global CO2 emissions. Among these components, biomass-derived ethanol is very popular for spark ignition engine operation as it is not only a renewable source of energy, but it also allows to increase the engine power and thermal efficiency.
Indeed, ethanol has the advantage of a high latent heat of vaporization leading to the so-called "cooling effect" which allows to increase the air-mass flow rate in the engine while reducing the charge temperature. This last property of ethanol combined with its high octane index make the engine less sensitive to knock. Then, although ethanol is characterised by high combustion speeds, optimal values of spark advance can be maintained on a larger range of engine operating conditions and high compression ratios as well as increased levels of downsizing can be used, all these aspects contributing to improve fuel consumptions.
However, the real potential of ethanol blended fuels still has to be explored and their impact on engine control strategies has to be investigated, especially considering the possible fuel composition variability during the engine life. Both issues can nowadays be addressed at low cost using system simulations of the whole engine, provided that the models used correctly account for the effect of the fuel composition on combustion processes.
This paper deals with the extension of a 0-dimensional coherent flame model to the combustion of ethanol blended gasoline for the simulation of heat release, knock and pollutants in SI engines. This extension mainly relies on the combination of a new laminar flame speed correlation, a modified set of chemical reactions in the flame front and an adapted correlation for the knock delay. The proposed developments are validated on a wide experimental database including many engine operating conditions as well as ethanol volume fractions ranging from 0% to 30%. Parametric variations in terms of spark advance and fuel/air ratio are also performed to compare optimal engine settings obtained from the simulations and at the engine bench. A good agreement is observed, showing the interest of using system simulations to predict the influence of the fuel composition on SI engines operation.

Fluid Dynamic Study of Unthrottled Part Load SI Engine Operations with Asymmetric Valve Lifts

M. Battistoni, F. Mariani
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This paper describes how a fully three-dimensional CFD model was used to investigate the turbulence generation mechanisms of an unthrottled 4 valve SI engine operating with different intake valve lift strategies (symmetric and asymmetric). In the context of Early Intake Valve Closure (EIVC) strategies, the aim of the work is to highlight the potentialities to increase turbulence levels also at light load using asynchronous intake valve lift, thus promoting both tumble and swirl motions.
Six simulations are presented, four at low engine speed (2500 rpm) and two at high speed (6000 rpm, that serve as reference), concerning an SI engine at full and light load, with symmetric and asymmetric intake lifts. One of these simulations was executed in standard throttling conditions.
The CFD transient simulations involved three strokes of the engine: exhaust, intake and compression up to combustion TDC. 1D data are used for boundary and initial conditions. Experimental steady state flow test data are also used for a preliminary assessment of the CFD model capability.
It is shown that, at equal engine load achieved with EIVC strategies, the case with a single valve lift yields higher turbulence intensities than dual symmetric lifts.

Combination of In-Cylinder Pressure Signal Analysis and CFD Simulation for Knock Detection Purposes

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A detailed analysis of knocking events can help improving engine performance and diagnosis strategies. The paper aim is a better understanding of the phenomena involved in knocking combustions through the combination of CFD and signals analysis tools.
CFD simulations have been used in order to reproduce knock effect on the in-cylinder pressure trace. In fact, the in-cylinder pressure signal holds information about waves propagation and heat losses: for the sake of the diagnosis it is important to relate knock severity to knock indexes values. For this purpose, a CFD model has been implemented, able to predict the combustion evolution with respect to Spark Advance, from nonknocking up to heavy knocking conditions.
The CFD model validation phase is crucial for a correct representation of both regular and knocking combustions: the operation has been carried out by means of an accurate statistical analysis of experimental in-cylinder pressure data.
The simulation results allow relating the combustion characteristics to their effect on the in-cylinder pressure signal. It is then possible to highlight critical issues regarding typical knock detection methodologies, while disclosing novel approaches. One of the main results is the validation of knock detection strategies based on the low-frequency content of the pressure signal. These strategies can be used together with standard highfrequency based techniques in order to improve the detection robustness.

Cycle-by-Cycle Analysis, Knock Modeling and Spark-Advance Setting of a “Downsized” Spark-Ignition Turbocharged Engine

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E. Torella
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Recently, a tendency is consolidating to produce low displacement turbocharged spark-ignition engines. This design philosophy, known as “engine downsizing”, allows to reduce mechanical and pumping losses at low load as a consequence of the higher operating Brake Mean Effective Pressure (BMEP). The presence of the turbocharger allows to restore the maximum power output of the larger displacement engine. Additional advantages are a higher low-speed torque and hence a better drivability and fun-to-drive. Of course, at high loads, the spark-advance must be carefully controlled to avoid the knock occurrence and this determines a substantial penalization of the fuel consumption. The knowledge of the knock-limited spark timing is hence a key point in order to reduce the fuel consumption drop at high loads.
In a previous study [1], a combined procedure for the quasi-dimensional modeling of both combustion and knock phenomena was developed and applied to a 1D thermodynamic engine model in order to find the knocklimited spark-advance at wide-open-throttle (WOT) conditions, for different engine speeds. In the present paper, indeed, the previous analysis is extended to include the cycle-by-cycle variations effects. Cyclic dispersion is characterized through the introduction of a random variation on a number of parameters controlling the rate of heat release (air/fuel ratio, initial flame kernel duration and radius, EGR rate, turbulence intensity). The intensity of the random variation is specified in order to realize an Indicated Mean Effective Pressure (IMEP) coefficient of variation similar to the experimentally observed one.
A kinetic scheme is then solved within the unburned gas zone, characterized by

different thermodynamic conditions occurring cycle-by-cycle. This allows, for a given spark timing, to estimate a statistical distribution of a properly defined knock indicator.

To the aim of validating the developed methodology, a DFT analysis of consecutive experimental pressure cycles is carried out in different operating conditions. High frequency pressure oscillations, typical of knocking occurrence, can be recognized and the statistical distribution of knocking intensity is in this way identified. Numerical and experimental results are finally compared in terms of coefficient of variation, and a good agreement is found.

Numerical Study of a GDI Engine Operating in the Jet Guided Combustion Mode

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F. Bozza
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The work relates to the use of multidimensional modelling as a tool for improving the robustness of combustion of a Gasoline Direct Injection (GDI) Spark Ignition (SI) engine. A procedure is assessed for the prediction of the thermo-fluid-dynamic processes occurring in a single-cylinder, four-stroke engine, characterised by a bore-to-stroke ratio close to the unity, and a pent-roof head with four valves. The engine is at a design stage, under development for application on two wheels vehicles. A new generation six-holes Bosch injector is considered as realising a jet guided combustion mode. This last is preferred for its potential in realising effective charge stratification and great combustion stability under various operating conditions.

The three-dimensional (3D) numerical model is developed within the AVL FIRETM software environment. A sub-model for the gasoline spray spatial-temporal dynamics is first assessed on the ground of experimental data collected by injecting fuel in a constant volume vessel containing nitrogen at controlled pressure and temperature. The measured instantaneous injected mass flow rate and the mean value of the measured cone angles are used as input variables for the model. Initial droplets size at the nozzle exit section is assumed accordingly to a probabilistic log-normal distribution of given variance and expected value. Choosing the variance as linearly dependent on injection pressure, after a simple tuning of the constants entering the break-up model, furnishes well predictive results as regards spray penetration length, overall spray structure and local particle size at a given distance from the holes exit section. The simulation of the complete engine cycle is realised by using boundary conditions set on the ground of a one-dimensional (1D) simulation of the entire propulsion system, performed by means of the 1Dime code. This last exploits information derived by a preliminary evaluation of the intake and exhaust valves discharge coefficients. Representative engine operating conditions are discussed, relevant to stoichiometric full load, and lean and stoichiometric low load operations. The effects on the in-cylinder mixture formation process of parameters as the Start Of Injection (SOI) and its duration (namely injection pressure at constant injected mass) are analysed.

The work is finalised to derive preliminary guidelines towards an optimised design of the engine in the mixed mode stratified charge direct injection mode.

Modeling liquid break-up through a kinetic approach

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Liquid atomisation is an important technical field for a wide range of engineering and industrial applications, particularly in the field of internal combustion engines . In these engines, in fact, the amount of pollutants at the engine-out interface is directly related to the quality of the combustion process, which is in turn determined by the quality of the air-fuel mixture preparation in Direct Injection (DI) engines. As a consequence numerical-experimental research is crucial to their development. Despite the significant amount of research that has been carried out on DI engines simulation, breakup modelling is still a challenge.
In this paper we present a new numerical model for multiphase flows that could be particularly suited for liquid jet and droplet breakup simulation. The model is based on a Lattice Boltzmann (LB) solver coupled to a higher order finite difference treatment of the kinetic forces arising from non-ideal interactions (potential energy). Direct comparisons with literature data for Rayleigh Taylor instability on a liquid jet and single droplet breakup are presented. The analysis on the single droplet allows highlighting different regimes of secondary break-up of a liquid drop immersed in a continuous medium under the influence of a gravitational force.

Effect of Breakup Model on Diesel Spray Structure Simulated by Large Eddy Simulation

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LES of non-evaporative diesel spray have been performed to investigate the effects of breakup models of Modified TAB, WAVE and KHRT model on computational results. KIVALES that is LES version of KIVA code was used for base code. In our KIVALES, CIP scheme was incorporated in order to suppress the numerical diffusion. Results showed that the breakup model is significantly affected on the calculated spray shape, because the droplet diameter determined by breakup models affects on the transmittance of the droplet momentum into the ambient gas, the evolution of the vortex structure in the gas phase and the droplet dispersion by the vortex structure.

A CFD Study of the Effect of the Needle Movement on the Cavitation Pattern of Diesel Injectors

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The onset and development of the inner cavitating flow in Diesel injectors is analyzed in relation with the needle movement, using Computational Fluid Dynamics studies realized with moving mesh. Two real six-hole injector geometries have been considered, one with cylindrical nozzles, the other with conical nozzles. A full analysis of the flow results is presented, including a dynamic picture of the developing pattern. Results show that depending on the needle lift, the cavitation pattern varies strongly throughout the nozzle, and affects the characteristics of the flow at the nozzle exit. A kind of hysteresis in the development of the flow has also been observed between needle opening and closing.

Porous Fuel Air Mixing Enhancing Nozzle (PFAMEN)

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One of the challenges with conventional diesel engines is the emission of soot. To reduce soot emission whilst maintaining fuel efficiency, an important pathway is to improve the fuel-air mixing process. This can be achieved by creating small droplets in order to enhance evaporation. Furthermore, the distribution of the droplets in the combustion chamber should be optimized, making optimal use of in-cylinder air. To deal with these requirements a new type of injector is proposed, which has a porous nozzle tip with pore diameters between 1 and 50 µm. First, because of the small pore diameters the droplets will also be small. From literature it is known that (almost) no soot is formed when orifice diameters are smaller than 50 µm. Second, the configuration of the nozzle can be chosen such that the whole cylinder can be filled with fine droplets (i.e., spray angle nearly 180°). However, injecting through a porous nozzle is not the same as an infinite number of very small holes, due to the difference in nozzle internal flow. Therefore, the nozzle tip is modeled in COMSOL Multiphysics in order to predict the outflow direction and velocity of the fuel. The Darcy-Forchheimer equation, which follows from the Navier-Stokes equation, is used for this purpose. To validate the model, experiments have been performed in the Eindhoven High Pressure Cell (EHPC) where (for vaporizing sprays) the spray is visually analyzed and (for reacting sprays) the ignition delay has been measured.

Coupled 1D-3D Simulation of Common Rail Injector Flow Using AVL HYDSIM and FIRE

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The paper describes a 1D-3D modeling technique for the simulation of the fuel injection systems. The technique is based on the one-dimensional modeling of the fuel flow and the mechanical motion of the injection system with the AVL software HYDSIM (from e.g. the fuel rail up to the nozzle chamber) and three-dimensional modeling of the nozzle flow with AVL-FIRE (from the needle seat through the spray holes up to the combustion chamber). The nozzle mesh, including the nozzle sac region with spray holes and (optionally) the lower part of the nozzle chamber, is created with the FIRE Preprocessor. The interface between the 1D and the 3D simulation regions can be freely chosen within the nozzle chamber at any position between the needle seat and guide.

Multidimensional Modelling of Gaseous Injection in Modern Direct Injection Internal Combustion Engines: Analisys of Different Fuel Injection Strategies.

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In the short medium term natural gas has emerged as one of the most promising energy sources for internal combustion engines because its usage leads to cleaner combustion, lower CO2 emissions, and energy source diversification. However, considering that automotive DI gas engines are rather new, only limited experience exists on the optimum configuration of the injection system and the related strategy.

To facilitate the development of these applications computer models are being developed. In a previous paper, a phenomenological-3D combined approach to simulate gas injection has been presented. This model has been implemented in a modified version of the KIVA 3V code and the simulation of a gas engine is here presented.

After having validated both the injection model and the whole 3D code, an analysis of different injection strategies have been carried out in order to demonstrate that these tools are suitable for optimization of direct injection gas engines. To this aim a research engine has been simulated in under stratified charge conditions.

Multidimensional Simulation of Ethanol HCCI Engines

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This work explores the coupling of advanced combustion strategies for engines with bio-based fuels. The characteristics of ethanol combustion in HCCI mode are investigated by using a multidimensional CFD model coupled with an accurate combustion model. In such a model, the chemical source terms are computed by a detailed kinetic mechanism and are corrected in order to take into account the influence of turbulence. The predictive capability of the model is proven by comparing the results with experimental measurements. The sensitivity analysis to initial and boundary conditions gives suggestions in order to increase engine efficiency and reduce pollutant emissions.

Studying the potential efficiency of low heat rejection HCCI engines with a Stochastic Reactor Model

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The main losses in internal combustion engines are the heat losses to the cylinder walls and to the exhaust gases. Adiabatic, or low heat rejection engines, have received interest and been studied in several periods in history. Typically, however, these attempts have had to be abandoned when problems with lubrication and overheating components could not be solved satisfactorily. The latest years have seen the emerging of low temperature combustion in engines as well as computational powers that provide new options for highly efficient engines with low heat rejection.
Stochastic Reactor Models (SRM) are highly efficient in modeling the kinetics decided low temperature combustion in HCCI and PPC engines. Containing the means to define the variations within the cylinder while employing detailed chemistry, micro mixing and heat transfer modeling, the interaction between heat transfer, exhaust gas energy and the combustion process can be studied with the SRM. A multidimensional study was setup with the SRM to investigate the interaction between heat transfer, exhaust gas energy and the combustion process and its dependency from level of cylinder wall thermal insulation or heat storage, inlet pressure, inlet temperature, mixture strength, mixture and temperature stratification, compression ratio, valve timing, residual gas amount and fuel effects. The investigation reaches into combustion and engine operating regimes that so far have not been investigated experimentally before.
It is found that by using this combined approach a multidimensional span of engine and combustion characteristics can be produced, giving deeper insights in the potential for efficiency increase through combined low temperature combustion and low heat rejection.

Fuel Injection and Combustion Process _Modeling

Fuel Injection and Combustion Process _Experiments

Alternative and Advanced Power Systems

Fuels and Lubricants

Powertrain Technology

Exhaust Aftertreatment and Emissions

Two-Dimensional Temperature Measurements in Diesel Piston Bowl Using Phosphor Thermometry

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Phosphor thermometry was used during fuel injection in an optical engine with the glass piston of reentrant type. SiO2 coated phosphor particle was used for the gas-phase temperature measurements, which gave much less background signal. The measurements were performed in motored mode, in combustion mode with injection of n-heptane and in non-combustion mode with injection of iso-octane. In the beginning of injection period, the mean temperature of each injection cases was lower than that of the motored case, and temperature of iso-octane injection cases was even lower than that of n-heptane injection cases. This indicates, even if vaporization effect seemed to be the same at both injection cases, the effect of temperature decrease changed due to the chemical reaction effect for the n-heptane cases. Chemical reaction seems to be initiated outside of the fuel liquid spray and the position was moving towards the fuel rich area as the time proceeds.

High Speed Shadowgraph and Diffraction Based Imaging for Spray Characterisation and Combustion Studies

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An abridged method for high speed shadowgraph and diffraction based imaging of combusting sprays, capable to discern among spray and flame regions is presented and discussed. The measurements were done in a pressure and temperature controlled combustion chamber under conditions similar to those prevailing in a direct injected diesel engine. A set of examples are shown where the visualisation and localisation of the liquid and gas phases of reacting sprays are possible regardless of the injection sequence which is implemented. Further, the penetration of the liquid and gas phases can be measured along a single injection with the possibility of doing spray characterisation and combusting studies of a single spray spatially resolved and as function of time.

Engine Block Vibration Measures for Time Detection of Diesel Combustion Phases

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This work fits into a research program in which the multicylinder diesel engine block vibration signal is used with the purpose of developing and setting up a methodology able to monitor and optimize the combustion behavior by means of non-intrusive transducer. Previously published results have demonstrated the direct relationship existing between in-cylinder pressure and engine block vibration signals in a fixed frequency band. It was also shown sensitivity of the engine surface vibration to variation of injection parameters, when the accelerometer is placed in sensitive location of the engine block. Moreover, the accelerometer trace has revealed to be able to locate in the crank–angle domain important phenomena characterizing the combustion process. The aim of the present work is to extend the results presented in [9] with the final aim of establishing a reliable relation between the main characteristics of the in-cylinder pressure curve and the vibration trend by means of a deeper insight into the engine block signal. In this paper, the previously developed steps of the research program are briefly presented. Then, the processing technique is described and the results obtained by applying a wide variation of the engine operating conditions are presented and discussed.

Cavitation effects on spray characteristics in the near-nozzle field

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In this paper, a special technique for visualizing the first 1.5 millimetres of the spray has been applied to examine the link between cavitation phenomenon inside the nozzle and spray behaviour in the near nozzle field. For this purpose, a real Diesel axi-symmetric nozzle has been analyzed. Firstly, the nozzle has been geometrically and hydraulically characterized. Mass flow measurements at stationary conditions have allowed the detection of the pressure conditions for mass flow choking, usually related with cavitation inception in the literature. Nevertheless, with the objective to get a deeper knowledge of cavitation phenomenon, near nozzle field visualization technique has been used to detect cavitation bubbles injected in a pressurized chamber filled with Diesel fuel. Using backlight illumination, the differences in terms of density and refractive index allowed the distinction between vapour and liquid fuel phases. From these visualization results, two important conclusions can be established: on the one hand, supercavitation is detected for pressure drop conditions at which mass flow choking has not appeared yet. On the other hand, it can be seen that the spray formed by cavitation bubbles spreads as pressure drop conditions get stronger.

Finally, spray visualization in a nitrogen pressurized chamber has been developed for stationary conditions. In order to analyze cavitation influence on spray characteristics, pressure drop has been modified near the values at which cavitation bubbles had been detected out of the nozzle. Two different test strategies will be used for this purpose: fixing injection pressure, which implies changing chamber density for each test point, or fixing chamber pressure. Both kinds of measurements revealed a noticeable increment of spray cone angle when supercavitation appears. This fact can be assumed as an indicator of atomization improvement induced by the collapse of cavitation bubbles at the nozzle exit.

Modeling the Intake CO2-level during Load Transients on a 1-Cylinder Heavy Duty DI Diesel Engine

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For diesel engines the major exhaust problem is particulate matter and NOx emissions. To reduce NO_x, exhaust gas recirculation (EGR) is often used. The behavior of the EGR-level will therefore influence the emissions and it is therefore valuable to keep track of the EGR-level. Especially during transients it is difficult to predict how the EGR-level varies.
In this paper the CO_2-level in the intake is modeled on a 1-cylinder diesel engine to predict the in cylinder behavior during transients. The model is based on simple thermodynamics together with the ideal gas law. Using this, the model is validated by experimental data during transients and the correlation between model and experiment is shown to be strong. Furthermore, the total tank volume is decreased to achieve a faster mixing with the intention of simulating the behavior of the CO_2-level in a full-size engine which has a higher gas flow.

Experimental Analysis of Combustion Processes and Emissions in a 2.0L Multi-Cylinder Diesel Engine Featuring a New Generation Piezo-Driven Injector

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In this paper, the potential of new generation piezodriven indirect acting injectors on high feature diesel engine performance and emissions was assessed by combining experimental tests (carried out at both hydraulic and engine test beds) with the diagnostics of combustion and emissions. This latter was performed by means of a refined multizone combustion diagnostic tool previously developed at Politecnico di Torino. More in detail, a complete hydraulic characterization of the injection system has been carried out and injector performance, in terms of robustness and repeatability of the injection process, has been also evaluated. Injectors were then installed on 4-cylinder 2.0L Diesel engine and tests were performed in seven key-points, which were specifically selected so as to reproduce the engine operations over NEDC in terms of emissions and fuel consumption. For each key-point, different injection-train strategies were tested and the corresponding engine calibrations were optimized by Design of Experiment (DoE) methodology. In-cylinder pressure time-histories measured on the firing engine and injection rates evaluated at hydraulic test rig were then processed by the multizone diagnostic tool so as to obtain Φ-T timehistories of each zone. Finally, the injection strategy showing the best compromise in terms of pollutant emissions, fuel consumption and combustion noise was selected for each key-point and the cause-effect relationships between injection rate and combustion process were analyzed.

Numerical and Experimental Investigation of the Influence of Bio-Diesel Blends on the Mixture Formation, Combustion and Emission Behavior of a Modern HSDI Diesel Engine

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The aim of this work has been to investigate the influence of bio-diesel (FAME - fatty acid methyl ester) and reasonable blends of FAME and diesel, on the behavior of the mixture formation, the combustion process and the emission levels of a modern diesel engine. Therefore experimental investigations have been carried out on a single cylinder engine which is a modification of a four cylinder production HSDI (high speed direct injection) diesel engine. Cylinder pressure and tail-pipe emissions have been measured. Additionally the injector has been mounted on a flowmetering device to gather information about the pure flow through the injection system depending on the fuel type. In parallel with the experimental investigations CFD (computational fluid dynamics) calculations have been carried out in order to closely check local effects inside the injector and the combustion chamber. The applied chemical and physical models have been extended with the relevant property data for FAME and blends of FAME and diesel. The different methods lead to a quite uniform picture about the effects of bio-diesel, which means, that generally the hardware of modern diesel engines is capable of dealing with the investigated amounts of bio-fuel without any modification. The fuel efficiency usually decreases but emissions can be improved with raising amount of FAME.

UHC and CO Emissions Sources from a Light-Duty Diesel Engine Undergoing Dilution-Controlled Low-Temperature Combustion

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Unburned hydrocarbon (UHC) and carbon monoxide (CO) emission sources are examined in an optical, lightduty diesel engine operating under low load and engine speed, while employing a highly dilute, partially premixed low-temperature combustion (LTC) strategy. The impact of engine load and charge dilution on the UHC and CO sources is also evaluated. The progression of in-cylinder mixing and combustion processes is studied using ultraviolet planar laser-induced fluorescence (UV PLIF) to measure the spatial distributions of liquid- and vaporphase hydrocarbon. A separate, deep-UV LIF technique is used to examine the clearance volume spatial distribution and composition of late-cycle UHC and CO. Homogeneous reactor simulations, utilizing detailed chemical kinetics and constrained by the measured cylinder pressure, are used to examine the impact of charge dilution and initial stoichiometry on oxidation behavior. The measured distributions are also compared to multidimensional simulation results and with engineout emissions measurements.

Homogeneous reactor simulations show that increased dilution leads to a narrower equivalence ratio (ϕ) range that allows for acceptable UHC and CO oxidation. As dilution increases, the increased charge-fuel mass ratio for a given ϕ amplifies the impact of a reduced rich-limit ϕ for acceptable UHC oxidation, since a greater fraction of the fuel is embedded in rich mixture. In-cylinder UHC and CO imaging highlights the differences that changes in dilution and load have on the three main UHC source regions: 1) The cylinder center region contains intense near-injector fluorescence indicative of late-cycle fuel addition, while diffuse fluorescence is present from UHC and CO that is embedded in the surrounding fuel-lean bulk gases; 2) Within the bowl and central clearance volume, a rich mixture plume that exits the piston bowl is the dominant source of predicted UHC and CO, but is not observed experimentally; 3) Squish volume UHC and CO principally results from the partial oxidation of lean mixture, although UHC from piston top fuel films and crevice flows is also observed.

Effect of Injection Strategy on Cold Start Performance in an Optical Light-Duty DI Diesel Engine

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The present study investigates cold start at very low temperatures, down to -29 deg C. The experiments were conducted in an optical light duty diesel engine using a Swedish class 1 environmental diesel fuel. In-cylinder imaging of the natural luminescence using a high speed video camera was performed to get a better understanding of the combustion at very low temperature conditions. Combustion in cold starting conditions was found to be asymmetrically distributed in the combustion chamber. Combustion was initiated close to the glow plug first and then transported in the swirl direction to the adjacent jets. A full factorial study was performed on low temperature sensitivity for cold start. The effects of cooling down the engine by parts on stability and noise were studied. Furthermore, different injection strategies were investigated in order to overcome the limited fuel evaporation process at very low temperatures. A strategy with 3 pilot injections and increasing fuel quantity for each injection gave a more homogeneous combustion. The natural luminescence was symmetrically distributed in the piston bowl and all the jets contributed to the combustion. Significant improvements in combustion stability, load level and potential for load increase were observed as well.

Development of a Turbo Diesel Engine by a New Combustion Process for Heavy Duty Vehicles and Tractors

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Using a theoretical model an optimum-burning-rate process is defined for a diesel internal combustion engine. In order to perform this combustion process a new combustion chamber, named MR-1, is developed and applied to a single cylinder experimental engine. On the basis of these preliminary studies three versions of tractor engines – naturally-aspirated, turbo-charged without and turbo-charged with intercoolers – were manufactured and Stage II and Stage IIIA exhaust gas emission standard certificates were obtained for these engines. Because this combustion system uses low injection pressures, the production costs and service requirements are lower and there is no need for high quality fuels.

Enhancement of Combustion of Vegetable Oil in Diesel Engines at Low Loads with Hydrogen

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One of the fundamental problems associated with combustion of vegetable oils in diesel engines is their poor combustion at low engine speeds and loads. As a possible remedy to this problem, co-firing of small amount of gaseous hydrogen introduced into the intake air was investigated on a mechanically controlled direct injection turbodiesel tractor engine. The engine was operated at idle and several low-rpm, low-load points on fuel-grade rapeseed oil heated to 60-70°C, with up to 5.5% of hydrogen by volume (600 g/h) injected into the intake air. Emissions of HC, CO, and NOx have all markedly decreased with increasing hydrogen concentrations. At higher hydrogen concentrations the onset of the combustion became noticeably delayed and the peak combustion pressure has decreased. The results suggest that the addition of a relatively small amount of hydrogen into the intake air of an engine running on heated rapeseed oil at low rpm and low load can bring the emissions of HC and PM, normally several times higher compared to operation on diesel fuel, back to their "diesel" level. This might also aid in preventing the buildup of deposits within the engine under such operating conditions. It is expected that the effect of the hydrogen co-firing can be further enhanced by optimization of the injection timing and other parameters.

Optimization of Operating Conditions in the Early Direct Injection Premixed Charge Compression Ignition Regime

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Early Direct Injection Premixed Charge Compression Ignition (EDI PCCI) is a widely researched combustion concept, which promises soot and CO2 emission levels of a spark-ignition (SI) and compression-ignition (CI) engine, respectively. Application of this concept to a conventional CI engine using a conventional CI fuel faces a number of challenges. First, EDI has the intrinsic risk of wall-wetting, i.e. collision of fuel against the combustion chamber periphery. Second, engine operation in the EDI regime is difficult to control as auto-ignition timing is largely decoupled from fuel injection timing.

In dual-mode PCCI engines (i.e. conventional DI at high loads) wall-wetting should be prevented by selecting appropriate (most favorable) operating conditions (EGR level, intake temperature, injection timing-strategy etc.) rather than by redesign of the engine (combustion chamber shape, injector replacement etc.). This paper presents the effects of EGR concentration, intake temperature, intake pressure, injection timing, injection pressure and fuel temperature on engine performance and emission behavior in EDI PCCI mode. In addition, several minor adjustments to the conventional injector nozzle are investigated. Wall-wetting and engine performance are characterized by the measured emissions (smoke and unburned hydrocarbons) and in-cylinder pressure (CA50 and IMEP). The main contribution of this paper is to investigate the cumulative effects on engine performance and emissions, unburnt hydrocarbons (HC) in particular, of various known measures designed to address wallwetting. All experiments have been performed at low load (~ 3-4 bar IMEP) and at an engine speed of 1200 RPM, using a modified 6-cylinder 12.6 liter heavy-duty DI DAF XE 355 C engine. Experiments are conducted in one dedicated cylinder, which is equipped with a stand-alone fuel injection system, EGR circuit and air compressor, fuelled with commercial diesel fuel (EN590).

Effect of Injection Pressure with Split Injection in a V6 Diesel Engine

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Multiple fuel injections with higher injection pressure are a way to improve diesel engine performance and lower emissions of unburned HCs, smoke, particulate matter and carbon monoxide (CO). However this method leads to a higher level of NOx emissions. A combination of higher pressure split injection and exhaust gas recirculation (EGR) has potential in controlling NOx emissions and engine performance simultaneously. The focus of this study is to investigate the effect of variation in injection pressure with split (pilot and main) injection, (with and without cooled EGR) on engine performance and emissions. The engine used is a common rail direct injection V6 Diesel fitted with turbo-charged variable turbine geometry (VTG) turbochargers, fuelled with ultra low sulphur diesel (ULSD). The experiments include five different levels of injection pressure 300, 430, 500, 600, 700 bar, at two different engine speeds and various loads, 1500 rpm (35.1, 70.2 and 140 Nm) and 2000 rpm (43.3, 86.6 and 120 Nm).
Fuelled by ULSD, the experimental results show that the performance and emissions of the engine at higher pressure split injection were improved, compared to lower pressure. This applied to both EGR cases (EGR ON and EGR OFF). These results showed strong evidence that the increase of the injection pressure up to a certain value, can lower emissions of total hydrocarbons (THCs), carbon monoxide (CO) and particulate matter (PM). In addition, it has been shown that combination of higher pressure split injection with EGR has potential to lower nitrogen oxides (NOx) and fuel consumption without significant smoke penalties.

The effect of Biodiesel fuel blend rate on the Liquid-phase fuel penetration in Diesel engine conditions

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A study was conducted to investigate the evolution of liquid phase penetration of evaporating sprays under engine-like conditions, with diesel and biodiesel fuel blends. This study has been performed in a facility based on a single cylinder two-stroke direct injection Diesel engine operating at low rotational speed which provides a quiescent thermodynamic environment around TDC, when fuel is injected, realistic for current D.I. Diesel engines. Due to the absence of inlet or exhaust valves, very easy optical access to the combustion chamber can be provided through the cylinder head. Pure nitrogen is supplied to the engine as intake gas, in order to avoid combustion. The injection event is carried out by an electronically controlled common rail system. The injector is equipped with real 8-hole nozzles, with a hole diameter of 0.115 mm. Injection pressures in this study ranged between 30 and 160 MPa and different in-cylinder peak pressure and temperature values were considered.

Evaporative liquid spray evolution has been analyzed on the basis of images taken with a high speed CMOS camera at a rate of up to 30000 frames per second and purpose developed software. Thus, single injection events evolution can be tracked avoiding uncertainties associated to shot-to-shot fluctuations, and a more precise analysis of the evaporation characteristic length and time scales. From these experimental results, scaling laws based on the hypothesis of mixing limited evaporation have been evaluated for the biodiesel blends, extending the results available in the literature. Results have allowed quantifying the influence of the biodiesel content upon the liquid length.

An Experimental Study of Cluster Nozzles for DI Diesel Engine

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In a conventional Diesel engine, air is gradually drawn into the fuel spray from the surrounding area. The ignition delay period is short, so combustion starts before the fuel has thoroughly mixed with the air. Consequently, the center of the spray is overly rich, resulting in smoke, while a stoichiometric mixture is formed in the surrounding area, resulting in a high NOx concentration. Based on the Diesel concept it is practically impossible to totally avoid fuel rich and stoichiometric pockets, but the formation of soot and NOx are also time dependent. If the mixing time is sufficiently small both pollutants could be reduced simultaneously without getting into the well known soot- NOx tradeoff. In order to develop a low emission engine, research is necessary to come up with a new combustion strategy for Diesel engines, which includes the use of cluster nozzles. Conditions for low raw particulate emission are: suitable start of injection, lean air/fuel mixture, sufficiently high temperatures in the combustion chamber and a sufficient retention time with these conditions. This could be achieved by use of cluster nozzles and a careful tuning of the air/fuel mixing parameters of the engine piston geometry. Decreasing the hole-size improves mixing in the center of the spray and therefore the soot production goes down tremendously. It has been observed, that an optimum number of holes exists (6 to 8) and that a certain swirl level is necessary. Based on this experience the cluster concept was developed. The cluster nozzles can also be used for improved homogenization of in-cylinder charge so as to enable a partly homogenous mode of Diesel combustion. In this study, three cluster designs are investigated through engine measurements. They were tested in a single-cylinder engine with CRI 3.3 piezo injectors under part-load conditions for a partly homogenous mode of Diesel combustion, and also under high load conditions for conventional Diesel combustion. The experimental studies give some detailed information on how cluster nozzles could help in lowering soot formation and thereby provide more freedom to reduce other pollutants.

Renewable Biodiesel/Reference Diesel Fuel Mixtures Distribution in Non-Evaporating and Evaporating Conditions for Diesel Engines

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In spite of the recent trend, voted toward the reduction of renewable energy sources deriving from crops, the EC Commission proposes that the proportion of energy from renewable sources in the transportation sector should be at least 20 % of its final energy consumption by the year 2020. In this framework, the activities aiming to study the effects on engine performances, emissions and fuel consumption of alternative diesel fuel receive continue stimulations and supports. In this paper, results of the different behavior of biodiesel fuels in the injection process and their impact on the air-fuel mixture preparation are reported. The injection process characterization has been carried out in a non-evaporative high-density ambient in order to measure the fuel injection rate and the spatial and temporal distribution of the fuel. Moreover, the injection and combustion processes have been characterized in an optically accessible single cylinder Common Rail diesel engine that represented evaporative conditions similar to the real engine.
The studied injections have been chosen for engine working conditions of 1500 rpm at 2 bar of BMEP. A double injection strategy (pilot+main) has been adopted and a pilot energizing time has been calibrated to deliver 1.0 mm3. First generation of biodiesels like Rapeseed Methyl Ether (RME) and Soybean Methyl Ether (SME) and second generation of biodiesel like gas to liquid (GTL) have been mixed with reference diesel fuel (50% + 50%) and characterized in non-evaporating ambient while pure diesel fuel and its GTL mixture have been studied in evaporating ambient.
Images of evolving fuel in non-evaporative conditions, captured by a high resolution CCD camera at different instant from the start of injection and for different operative conditions, have been processed extracting the main parameters of the jet evolution: tip penetration, spray-cone angle, spray density distribution. These data have been also acquired in the combustion chamber of the optical diesel engine by means of a high resolution CCD camera synchronized with the injection events. Moreover the combustion processes have been studied and the pollutant emissions have been measured for several engine working conditions and biodiesel mixes.

Optical Characterization of the Combustion Process in a 4-Stroke Engine for 2-Wheel Vehicle.

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The match among the increasing performance demands and the stringent requirements of emissions and the fuel consumption reduction needs a strong evolution in the two-wheel vehicle technology. In particular, many steps forward should be taken for the optimization of modern small motorcycles and scooters at low engine speeds and high loads. To this aim, detailed understanding of thermo-fluid dynamic phenomena that occur in the combustion chamber is fundamental.
In this work, low-cost solutions are proposed to optimize ported fuel injection spark ignition (PFI SI) engines for two-wheel vehicles. The solutions are based on the change of phasing and on the splitting of the fuel injection in the intake manifold.
The experimental activities were carried out in the combustion chamber of a single-cylinder 4-stroke optical engine fuelled with European commercial gasoline. The engine was equipped with a four-valve head of a commercial scooter engine.
High spatial resolution cycle-resolved digital imaging was used to characterise the flame propagation. It was investigated the presence of diffusion-controlled flames near the valves and on the cylinder walls that induced the formation of unburned hydrocarbons and soot particles. The in-cylinder optical investigations were correlated with engine performance and exhaust emissions.

TC GDI Engines at Very High Power Density – Irregular Combustion and Thermal Risk

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Gasoline direct injection and turbocharging enable the progress of clean and fuel efficient SI engines. Accessing potential efficiency benefits requires very high power density to be achieved across a broad rpm range. This imposes risks which in conventional engines are rarely met. However, at torque levels exceeding 25 bar BMEP, the thermal in-cylinder conditions together with chemical reactivity of any ignitable matter, require major efforts in combustion system development.
The paper presents a methodology to identify and locate sporadic self ignition events and it demonstrates non contact surface temperature measurement techniques for in-cylinder and exhaust system components.

Analysis of flame kinematics and cycle variation in a Port Fuel Injection Spark Ignition Engine

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This paper reports on the analysis of flame kinematics and cycle variation in port fuel injection (PFI) spark ignition (SI) engine. The engine was equipped with a four-valve head and with an external boost device. Different operating conditions were considered. Cycleresolved digital imaging was used to investigate flame motion and the effects of an abnormal combustion due to the firing of fuel deposition near the intake valves and on the piston surface. Various algorithms are applied to the acquired images. Coefficients of Proper Orthogonal Decomposition (POD) were computed and used for a statistical analysis of cycle variability. The advantage is that the analysis can be run on a small number of scalar coefficients rather than on the full data set of pixel valued luminosity. POD modes are then discriminated by means of normality tests, to separate the mean from the coherent and the incoherent parts of the fluctuation of the luminosity field, in a non truncated representation of the data.

Performances Improvement of a S.I. Cng Bi-fuel Engine by means of Double-fuel Injection

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Natural gas represents today a promising alternative to conventional fuels for road vehicles propulsion, since it is characterized by a relatively low cost, better geopolitical distribution than oil, and lower environmental impact. This explains the current spreading of Compressed Natural Gas (CNG) fuelled S.I. engine, above all in the bi-fuel version, i.e. capable to run either with gasoline or with natural gas. This characteristic, on the one hand, permits the vehicle to go even when natural gas is not available, on the other hand requires the engine to be designed to run safely with gasoline, i.e. with compression ratio lower than what natural gas would allow. Moreover the electronic control units are programmed to adopt rich mixture and poor spark advance when running with gasoline at medium-high loads, in order to prevent the engine from dangerous knocking phenomena: this causes an increase in fuel consumption and pollutant emissions. Starting from these considerations, the authors decided to investigate on the benefit attainable by means of a double-fuel injection, i.e. the injection of a certain amount of natural gas during the gasoline operation in order to increase the knocking resistance of the mixture and to run the engine with “overall stoichiometric” mixture even at full load, thus improving both engine efficiency and its environmental impact. To this purpose, the authors carried out an experimental campaign on the engine test bed, equipped with a fully instrumented series production bi-fuel spark ignition engine; the gasoline injection was managed by means of a real-time controlled ECU, while the simultaneous injection of natural gas was performed by means of IGBT transistors properly designed for fuel injection or spark timing control connected to a counter/timing PCI board. The results obtained fuelling the engine with both fuels in stoichiometric proportion with air show, with respect to the pure gasoline operation, considerable increase in fuel economy without remarkable power losses, while, with respect to the pure natural gas operation, only power improvements have been achieved: these advantages may lead the way to the adoption of the double-fuel injection in bi-fuel-engines.

The Effect of Intake Temperature in a Turbocharged Multi Cylinder Engine operating in HCCI mode

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The operating range in HCCI mode is limited by the excessive pressure rise rate and therefore high combustion induced noise. The HCCI range can be extended with turbocharging which enables increased dilution of the charge and thus a reduction of combustion noise. When the engine is turbocharged the intake charge will have a high temperature at increased boost pressure and can then be regulated in a cooling circuit. Limitations and benefits are examed at 2250 rpm and 400 kPa indicated mean effective pressure. It is shown that combustion stability, combustion noise and engine efficiency have to be balanced since they have optimums at different intake temperatures and combustion timings. The span for combustion timings with high combustion stability is narrower at some intake temperatures and the usage of external EGR can improve the combustion stability. It is found that the standard deviation of combustion timing is a useful tool for evaluating cycle to cycle variations. One of the benefits with HCCI is the low pumping losses, but when load and boost pressure is increased there is an increase in pumping losses when using negative valve overlap. The pumping losses can then be circumvented to some extent with a low intake temperature or EGR, leading to more beneficial valve timings at high load.

Liquid Jet Deformation Induced by Cavitation in Nozzles of Various Shapes

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Cavitation in the nozzles of various shapes and liquid jets discharged from the nozzles are visualized using a high-speed camera to investigate the effects of cavitation on liquid jet deformation. Cylindrical nozzles and two-dimensional (2D) nozzles of various upstream diameters and length-to-diameter ratios (L/D) are used. For simultaneous high-speed visualizations of cavitation and a jet, a tilted acrylic plate is placed in front of the jets injected through the 2D nozzles, while three mirrors are used to capture both the front view of the jet injected through a cylindrical nozzle and the side view of cavitation. The visualizations confirm that the collapse of a cavitation cloud near the exit induces a ligament formation in 2D and cylindrical nozzles of various L/Ds. Although no vapor film is formed in short nozzles, cavitation clouds are shed near the exit and induce ligaments. It is also confirmed that the modified cavitation number, which takes into account the effects of flow contraction and frictional pressure drop, can be used to predict the development of cavitation in nozzles of various shapes.

Fuel Injection and Combustion Process _Modeling

Fuel Injection and Combustion Process _Experiments

Alternative and Advanced Power Systems

Fuels and Lubricants

Powertrain Technology

Exhaust Aftertreatment and Emissions

Hybrid Drive Systems for Industrial Applications

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Hybrid drives for automotive application are extensively discussed and have been available for several years. In contrast, hybrid drives for industrial and off highway applications are less developed. This is even though the fuel savings potential and expected other benefits are much more promising than in automotive applications.
The company HEINZMANN and the University of Karlsruhe concentrate on hybrid drives for these applications. HEINZMANN develops and produces control systems and electrical motors which can be used in hybrid drives. The Institute of Mobile Machines at the University of Karlsruhe is experienced in simulating off highway machines. In a joined project the two partners are applying an electrical mild hybrid drive to a municipal multipurpose vehicle.
In this paper the diesel-electric hybrid technology is presented as well as the different applications in construction equipment, fork lifts. A closer analysis is performed with a municipal multi-purpose vehicle equipped with the hybrid drive. Measurements of a conventional vehicle were used for the validation of a simulation model. Results of the simulation are being presented. More than 20% savings in fuel consumption have been determined.

Energy, Economical and Environmental Analysis of Plug-In Hybrids Electric Vehicles Based on Common Driving Cycles

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The objective draw by this project is to develop tools for Plug-in Hybrid Electric Vehicle (PHEV) design, energy analysis and energy management, with the aim of analyzing the effect of design, driving cycles, charging frequency and energy management on performance, fuel economy, range and battery life.
A Chevrolet Equinox fueled by bio diesel B20 has been hybridized at the Center for Automotive Research (CAR), at The Ohio State University. The vehicle model has been developed in Matlab/Simulink environment, and validated based on laboratory and test. The PHEV battery pack has been modeled starting from Li-Ion batteries experimental data and then implemented into the simulator.
In order to simulate "real world" scenarios, custom driving cycles/typical days were identified starting from average driving statistics and well-known cycles. The driving cycles are based on commonly accepted standardized cycles (FUDS, FHDS, etc) and then combined to reflect common driving habits, average commute time, thus resulting in an annual distance traveled of about 15.000 miles.
Several scenarios have been drawn considering different vehicle operation modes, i.e. EV (electric vehicle) and blended, different battery sizes, 6.97 and 8.87 kWh of stored energy and different charging availability, i.e. controlled (once a day, overnight) and uncontrolled (charging is possible whenever the vehicle is parked).
For a complete assessment of the benefits achievable by PHEVs, results are compared to two other vehicle architectures (equivalent in terms of available power): the hybrid version of the proposed model and the conventional ICE vehicle (stock vehicle converted into B20). Results show significant benefits of PHEVs in terms of petroleum reduction, overall fuel cost and CO2 emissions; it is also clear that none of the proposed configurations (i.e. different battery sizes) and vehicle operation modes (i.e. EV or blended) represents an absolute optimum, but the analysis strongly depends on the chosen objective function to minimize, vehicle components sizing and adapted strategies, fuel and electricity cost, charging availability and power grid generation mix.

Waste Energy Driven Air Conditioning System (WEDACS)

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In the port injected Spark Ignition (SI) engine, the single greatest part load efficiency reducing factor are energy losses over the throttle valve. The need for this throttle valve arises from the fact that engine power is controlled by the amount of air in the cylinders, since combustion occurs stoichiometrically in this type of engine.
In WEDACS (Waste Energy Driven Air Conditioning System), a technology patented by the Eindhoven University of Technology, the throttle valve is replaced by a turbine-generator combination. The turbine is used to control engine power. Throttling losses are recovered by the turbine and converted to electrical energy. Additionally, when air expands in the turbine, its temperature decreases and it can be used to cool air conditioning fluid. As a result, load of the alternator and air conditioning compressor on the engine is decreased or even eliminated, which increases overall engine efficiency.
A model and validating experiment both indicate throttle losses of about 1.25 kW in a modern 2 liter engine at common operating points. On the same engine in a different operating point, an automotive turbocharger is used in another experiment to recover 1.1 kW of these throttling losses. Based on these measurements, a simulated MVEG-A drive cycle predicts a fuel efficiency improvement of 15 to 19 %.

Different Hybrid Powertrain Solutions for European Diesel passenger cars

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Fuel consumption and NOx emissions of different Diesel-Electric hybrid powertrains, equipping a midsize European passenger car were evaluated in this paper through numerical simulation.
Different degrees of hybridizations, from micro to mild hybrids, and different architectures and power sources management strategies were taken into account, in order to obtain a preliminary assessment of the potentialities of a Diesel-Electric hybrid system for the European passenger car market.
Both regulated driving cycles, such as NEDC, and “real-world representative” driving cycles, such as Artemis cycles, were evaluated, in order to obtain not only an estimate of the impact of hybridization on type-approval CO2 and NOx emissions, but also an assessment of the impact of these technologies from the vehicle owner’s perspective.
Finally, the effects of internal combustion engine downsizing was also considered.

Low-Cost Pathway to Ultra Efficient City Car: Series Hydraulic Hybrid System with Optimized Supervisory Control

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A series hydraulic hybrid concept (SHHV) has been explored as a potential pathway to an ultra-efficient city vehicle. Intended markets would be congested metropolitan areas, particularly in developing countries. The target fuel economy was ~100 mpg or 2.4 l/100km in city driving. Such an ambitious target requires multiple measures, i.e. low mass, favorable aerodynamics and ultra-efficient powertrain. The series hydraulic hybrid powertrain has been designed and analyzed for the selected light and aerodynamic platform with the expectation that (i) series configuration will maximize opportunities for regeneration and optimization of engine operation, (ii) inherent high power density of hydraulic propulsion and storage components will yield small, low-cost components, and (iii) high efficiency and high power limits for accumulator charging/discharging will enable very effective regeneration. The simulation study focused on the SHHV supervisory control development, to address the challenge of the low storage capacity of the accumulator. Two approaches were pursued, i.e. the thermostatic SOC control, and Stochastic Dynamic Programming for horizon optimization. The stochastic dynamic programming was setup using a set of naturalistic driving schedules, recorded in normal traffic. The analysis included additional degree of freedom, as the engine power demand was split into two variables, namely engine torque and speed. The results represent a significant departure from the conventional wisdom of operating the engine near its "sweet spot" and indicate what is preferred from the system stand-point. Predicted fuel economy over the EPA city schedule is ~93 mpg with engine idling, and ~110 mpg with engine shut-downs.

Modelling and experimental evaluation of control management in the series hybrid vehicle Enea Urb-e

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The last years have seen an increasing need to reduce vehicle polluting emissions which has lead car producers to improve their efforts to comply with the new legislation. At the moment, hybrid electric vehicles (HEV) seems to be the most suitable solution as they match good performances in terms of both consumption and reliability. In a such dynamic market, an interest for small and light city-car is rising, especially in Europe, where urban circulation is getting worst due to huge number of vehicles. Such special characteristics, like smallness and lightness, allow these hybrid vehicles to run 40 km with a litre of fuel only.

In this scenario, the Hybrid and Electric Research Group of ENEA planned the realization of an hybrid power train suitable for small city car. The main target of the project, called "Urb-e", is to realise a power train able to achieve low fuel consumption (2.5 litre/ 100 km), low emissions (comparable to EURO 5 rules), with simple configuration and low power train cost. To fulfil this target a hybrid series power train has been chosen.

In particular, during this phase the goal of project is to realize and to calibrate a power management system able to satisfy the requested performances (power, max speed, acceleration, etc.). The difficulty is due to the use of ultracapacitors (UC) as energy storage system because of the low energy capacity. In order to achieve this goal, different control strategies are tried to manage the auxiliary power unit (APU). The principal aspects of the power management system are shown. Some driving tests results are finally reported to instance the effectiveness of the developed management.

Rule-Based Optimization of Intermittent ICE Scheduling on a Hybrid Solar Vehicle

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In the paper, a rule-based (RB) control strategy is proposed to optimize on-board energy management on a Hybrid Solar Vehicle (HSV) with series structure. Previous studies have shown the promising benefits of such vehicles in urban driving in terms of fuel economy and carbon dioxide reduction, and that economic feasibility could be achieved in a near future.
The control architecture consists of two main loops: one external, which determines final battery state of charge (SOC) as function of expected solar contribution during next parking phase, and the second internal, whose aim is to define optimal ICEEG power trajectory and SOC oscillation around the final value, as addressed by the first loop.
In order to maximize the fuel savings achievable by a series architecture, an intermittent ICE scheduling is adopted for HSV. Therefore, the second loop yields the average power at which the ICE is operated as function of the average values of traction power demand and solar power. Expected solar contribution can be estimated starting from widely available solar databases and by processing past solar energy data measured on the vehicle. Neural Networks predictors, previously stored data and/or GPS derived information are suitable to estimate average power requested for vehicle traction.
Extensive simulation analyses were carried out to test the performance of the RB algorithm, also comparing it to Genetic Algorithms-based optimization strategies previously developed by the authors. The results confirm the high potentialities offered by the proposed RB control strategy to perform real-time energy management on hybrid solar vehicles.
The proposed rule-based optimization is currently under-implementation in an NI® cRIO control unit, thus allowing to perform experimental tests on a real HSV prototype developed at University of Salerno.

Advanced Hybrid Vehicle Simulation: from "Virtual" to "HyHiL" test bench

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The present paper deals with the activities and the results achieved under a cooperative research project between IFP, D2T, LMS, G2Elab and Renault focused on Hardware-in-the-Loop (HIL) applications to hybrid power-trains conception and assessment. The main goal of this study is the evaluation of hybrid propulsion concepts and the benefits of different degrees of hybridization in a flexible architecture, by using a chain of simulation platforms: from the co-simulation to the highdynamic engine-in-the-loop test bed, through a virtual version of the last one. The activity assessed the potentialities in terms of fuel consumption reduction and the challenges in terms of pollutants emissions of micro and full-hybrid application for light-duty vehicle based on gasoline engine: over several road load cycles as NEDC, FTP72, ARTEMIS. Engine operation at the dynamic test bench reproduced the optimized hybrid schedules and the results were compared to the conventional base engine and to the other simulation platforms. Therefore, the main results show that this series of simulation environments, makes possible the evaluation of complex power-trains without the need of manufacturing a real vehicle, hence proving it's extreme usefulness as a tool.

Comparison of SC and high-power batteries for use in hybrid vehicles

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This paper reports and analyses experimental results showing the performances of two state-of-the art, com-mercially available storage systems, adequate for use onboard hybrid vehicles, i.e. a supercapacitor (SC) and a super-high power lithium battery.
The two devices were subjected to specific experimental tests adequate to ease comparisons for use onboard hy-brid vehicles.
The results are expressed mainly in terms of specific power and charge/discharge efficiency as a function of the wanted discharge time; they show that, if future cycle efficiency analyses do not reverse the result, very high power lithium batteries are a very competitive candidate for use as onboard storage within hybrid vehicles, when storage of a single technology are considered.

Comparative study of different control strategies for Plug-In Hybrid Electric Vehicles

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Plug-In Hybrid Vehicles (PHEVs) represent the middle point between Hybrid Electric Vehicles (HEVs) and Electric Vehicles (EVs), thus combining benefits of the two architectures. PHEVs can achieve very high fuel economy while preserving full functionality of hybrids - long driving range, easy refueling, lower emissions etc. These advantages come at an expense of added complexity in terms of available fuel. The PHEV battery is recharged both though regenerative braking and directly by the grid thus adding extra dimension to the control problem. Along with the minimization of the fuel consumption, the amount of electricity taken from the power grid should be also considered, therefore the electricity generation mix and price become additional parameters that should be included in the cost function.
Two control algorithms - ECMS (Equivalent Consumption Minimization Strategy) and DP (dynamic programming) - are considered in this paper to optimize the power split between electrical and mechanical energy sources. The performance obtained using dynamic programming as global optimal energy management strategy for a PHEV is used as benchmark for evaluating on-board implementable control strategy - ECMS. The ECMS is used to design two control modes - EV and Blended. The model of a PHEV version of a Chevrolet Equinox fueled by bio-diesel B20 has been developed in the Matlab/Simulink environment. A Chevrolet Equinox was hybridized at The Center of Automotive Research (CAR), at The Ohio State University as part of Challenge-X competition; the vehicle was used to validate the components of the Simulink model.

Comparison among different 2-Stage Supercharging systems for HSDI Diesel engines

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2-stage supercharging applied to HSDI Diesel engines appears a promising solution for enhancing rated power, low end torque, transient response and hence the launch characteristics of a vehicle. However, many open points still remain, in particular about the impact on emissions control and fuel economy at partial load conditions, generally requiring both high airflow and high EGR rates.
The paper analyzes and compares two types of 2-stage supercharging systems: a) two turbochargers of different size; b) one turbocharger coupled to a positive displacement compressor. The goal of the paper is to assess pro and cons of the most feasible configurations for a typical automobile Diesel engine, complying with Euro V regulations and beyond.
The base engine is the 2.8L, 4 cylinder in-line unit produced by VM Motori (Cento, Italy), equipped by a standard variable geometry turbocharger. A 1D thermo-fluid-dynamic model of the Euro V version of the engine was built and calibrated against experiments at the dynamometer bench, at both full and partial load.
Using the computational model as a starting base, a large set of alternative supercharging systems has been analyzed. The three best configurations are compared to the base engine at full load, under both steady and transient operations. Also a set of steady points, representing the operations in the NEUDC for a vehicle complying with Euro V regulations is simulated, in order to assess the influence of the supercharging system on fuel consumption and emissions.
Finally, some simplified calculations are performed to evaluate the potential of the Miller cycle in terms of NOx reduction at partial load.
The study demonstrates that the use of a supercharging system made up by a positive displacement compressor and a VGT turbocharger is able to noticeably enhance engine performance at full load, with further slight advantages, in comparison to the other analyzed systems, in terms of fuel consumption and emissions control. Finally, this system can support the application of the Miller cycle at partial load, enabling a relevant reduction of NOx, without drawbacks on the other pollutants.

Electronic Control System of a Formula SAE Gearbox Using Electric Voice Coil Actuators

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In this paper we present an electronic control system for a sequential gear of a Formula SAE racing car. The system makes the car gearbox semi-automatic, so that the driver can use flipper paddles to shift gears without operating the clutch. The gear and clutch actuation is performed by means of voice coil actuators, which represents an innovative application of these kinds of actuators. The system has been implemented and successfully validated. Test results show an outstanding performance of 40 ms for an up-shift.

Simulation of a turbocharged compression ignition engine at low loads and high rates of EGR

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In view of the incoming laws concerning the emission limits during test cycles, it is increasingly important reducing emissions at low and medium loads by using exhaust gas recirculation (EGR) techniques. The development of control strategies can be greatly improved by simulation models able to predict accurately the behaviour of the engine and its emissions in the entire field of operation, and specifically at low loads when the turbocharger is operated at low rotational speed and in the vicinity of the surge line.
Often the maps of compressor and turbine made available by the manufacturer are not extended to low rotational speeds and low pressure ratios. Methodologies have been therefore developed in order to extend the available characteristic curves to other working points, taking into account the geometry and the rotational speed of the turbocharger. For the compressor, a technique based on the fluid dynamic similitude is proposed. For the extrapolation of the turbine maps, two models based on analysis of the fluid flow at the meanline are proposed.
These methods have been applied to extend the maps of a turbocharger with variable geometry turbine (VGT) mounted on a six cylinder Diesel engine. A test series at low load and variable EGR valve opening has been simulated. Comparisons of simulation results and experiments show that the proposed methods are able to provide a good simulation of the engine points at low load and high rates of EGR where the working points of the turbocharger were found to be located in region of the maps far from the experimental points provided by the manufacturer.

Analysis of engine performances improvement by down sizing in relationship with super- and turbocharging, adapted scavenging and direct injection

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The development of future internal combustion engines with high power density in correlation with drastically reduced fuel consumption / CO2 emission and pollutant emission requires both an improvement of the thermodynamic process stages such as scavenging, mixture formation and combustion as well as new strategies regarding the engine function fields.
An advanced concept in this direction is the combination of down sizing with supercharging and turbocharging coupled in different configurations.
The paper presents the results of the comparison of four engine configurations: a 4 stroke, 4 cylinders engine family with gasoline direct injection:
1400 ccm engine, aspirated; 1400 ccm engine with turbocharging; 1400 ccm engine with super- and turbocharging; 1600 ccm engine, aspirated with a power range which is similar to the 1400 ccm engine with turbocharging
The experimentally obtained basic performances of these four engines are used in a numerical simulation program for analyzing the thermodynamic cycles and the behavior of maximum brake mean effective pressure, brake specific fuel consumption, carbon dioxide and pollutant emission, within the whole speed range when varying the intake/exhaust valve control and the direct injection modulation and timing.
This analysis allows the development of an operation strategy for a compact engine with two stages of charging for maximum efficiency at minimum pollution. Such an engine configuration appears as an advantageous alternative to some mild or full hybrid configurations which combine the mechanical with the electrical propulsion.

Application of a Fully Flexible Electro-Hydraulic Camless System to a Research SI Engine

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This paper presents the further development of an electro-hydraulic camless valve actuation system for internal combustion engines. The system (Hydraulic Valve Control - HVC) is an open loop device for engine valve fully flexible camless actuation. Valve timing and duration are controlled by a pilot stage governed by a solenoid, fast-acting, three-way valve. Valve lift is controlled by varying the oil pressure of the power stage. The system exploits an energy recovery working principle that plays a significant role in reducing the power demand of the whole valve train. In the present paper a new HVC actuator design is presented and its performances in terms of valve lift profile, repeatability and landing are discussed. Experimental data obtained by the application of the HVC system to a motored, single-cylinder research engine have been used to support the numerical evaluation of the potentialities of non-conventional valve actuation in engine part-load operation. This efficiency analysis was carried out including both thermodynamic benefits and the corresponding energy requirements of the used valve actuation system.

A Study on High Rate EGR in a Medium Size Turbo-Charged CI ICE Both in Low and High Pressure Configurations

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The most used technology able to inhibit NOx formation in combustion chamber is the Exhaust Gas Recirculation (EGR). Smoke limits, however, can be easily reached when EGR grow up to fulfill the emission limits. Further percentage increase, necessary to observe the oncoming more severe regulations, can be performed only if a control strategy is implemented on A/F ratio lower limit, based on turbo-charging level.
In this paper the authors present an analysis performed on a medium size light duty turbocharged direct injection Diesel engine aimed to the definition of the current engine layout limit in terms of smoke emission and turbocharger functionality, in case of increased EGR rates, both in short route and in long route configuration. The theoretical activity based on a mathematical model of the engine has been supported by a focused experimental campaign on test bench, with engine in original configuration and equipped with a long route EGR pipe.

Closed Loop Control of an HCCI Multi-Cylinder Engine and Corresponding Adaptation Strategies

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Homogeneous Charge Compression Ignition (HCCI) offers a significant potential to reduce CO_2 as well as NOx and particulate emissions. However ensuring stable and efficient HCCI combustion in practical use is a challenge and requires sophisticated control concepts. In the present paper a closed loop control concept is investigated for this purpose. In order to optimize the closed loop control, adaptations with neural networks are introduced. Different sensor concepts for HCCI combustion control are presented and the benefit of the analysis of crankshaft movements is analyzed.

A new mechanical variable valve actuation system for motorcycle engines

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This paper deals with the design and manufacturing of a mechanical variable valve actuation system, developed as part of the MUR financed research project concerning the realization of a high performance motorcycle engine, through a partnership of Moto Morini S.P.A. (BO), Dell'Orto S.P.A. (MI), Istituto Motori - CNR (NA), and DIME - Università di Napoli Federico II.
After a synthetic description of the main variable valve actuation methods currently employed (timing, duration and lift variation, cyclic cylinder deactivation), the paper presents the results of our mechanical variable valve actuation system, consisting of three main elements: cam, main rocker arm with fixed fulcrum and secondary rocker arm with mobile fulcrum. It enables valve lift variation through a simple translation of the intermediate element (system 1).
The study has been conducted implementing a numerical procedure specifically designed to determine cam profile and the kinematic and dynamic characteristics of the whole system, starting from the following input data: rocker arm geometry, relative positions and inertial data of elements, spring stiffness and preloading, camshaft speed and valve lift law. The model has been validated against the conventional timing system using kinematic simulations.
Results of the numerical procedure verify the validity of the variable valve actuation system, capable of a valve lift variation from 30% to 100% of the maximum lift, with a limited acceleration (lower than maximum values). Based on the numerical results, we are developing a new mechanical variable valve actuation system. The new system consists of the same three elements used previously, but they are connected in a different way (system 2). The newer system enables more general lift profile distributions with a similar geometric complexity.
A maximum closing limited to 30% does not enable cyclic deactivation of some cylinders (strategy feasible on multicylinder engines) or exclusion of one or more valves (strategy feasible on multivalve engines).
The activity was extended to research for a new solution (always a mechanical system), capable to allow inlet valves complete closing and timing and duration variation (system 3).
This paper reports results reachable with the simplest system 1. This new system gives better perspectives of use for a new two-wheel vehicle engine.

CO_2- Emission Reduction by means of Enhanced Thermal Conversion Efficiency of ICE cycles

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Most automobile manufacturers have developed hybrid vehicles that combine an internal combustion engine and an electric motor, fusing the advantages of these two power sources. For example, Toyota, in its Prius II, uses a highly efficient gasoline engine based on a modified Atkinson cycle featuring a variable valve timing management. This implementation of the Atkinson cycle is not the optimal solution because some of the air is first sucked from the intake manifold into the cylinder and subsequently returned. This oscillating air stream considerably reduces the thermal conversion efficiency of this cycle.
This paper analyzes in detail the loss of thermal conversion efficiency of an internal combustion engine - especially for modified Seiliger and Atkinson cycles - and a proposal is made for the improvement of aspirated and supercharged engines.

Modeling and Experiments on Mixture Formation in a Hydrogen Direct-Injection Research Engine

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Direct injection offers a large number of degrees of freedom, as it strongly influences the mixture stratification process. Experiments on a single cylinder research engine fuelled by H2, carried out at Argonne National Laboratory, showed the influence of injection parameters (timing and geometry) on engine efficiency and combustion stability. At low load, when a late injection strategy was performed, an unstable engine behavior was detected varying the injection direction. In order to optimize the mixture stratification process in DI H2 engines, it is important to understand the physics underlying the experimental results.
A spatially resolved representation of the in-cylinder processes is a useful tool to properly set the injection parameters. Also, the knowledge of the pre-injection flow field is of added value in optimizing the injection process. This paper describes the initial development of a 3D-CFD tool for direct-injection hydrogen engines, including numeric approach, simulation validation, and application to the mixture-formation process for a specific injection strategy.
Simulations were performed by the commercial solver Fluent and the numerical results were compared to laser-based measurements of the fuel distribution in an optically accessible engine. The calculations were found to be reasonably accurate, especially for late injection timings. The simulation results show that intake-induced tumble combines with the jet momentum when the jet is pointed away from the intake valves, which can improve engine operation for early and slightly retarded injection. For late injection timings the engine can fire stably if the injector is pointed towards the spark plug.

Experiences in Modeling and simulation of hydrogen fuel-cell based propulsion systems

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This paper presents the some issues related to modeling of hydrogen fuel-cell based propulsion systems and the main characteristics of the corresponding simulation program developed in Matlab-Simulink™ environment by the authors.
Although several hybrid vehicle simulators are available today, often researchers prefer to create programs of their own, to pursue specific pursues.
The authors have gone in this direction, and with this paper they intend to share this experience with readers wanting to do a similar job, hoping they can find useful hints to direct their activity.
The paper shows therefore the main issues to be tackled when creating hybrid vehicle simulation programs in general, and fuel-cell based in particular, and gives some details on individual component modeling.

Computer simulation of “fuel cell - electric motor” system

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The article presents results of the simulation research of “fuel cell - electric motor” system. The simulations were made for battery of alkaline fuel cells which feed a direct current disc motor with permanent magnet. An electric motor of this type is used to propel electric vehicles. The simulations were made on the basis of a voltage-current characteristics of a cell and a mathematical model of an electric motor. The cell characteristics was described by the use of a mathematical equation in the form of polynomial and the motor running by a differential equation of voltage and motion. The system was researched in a steady and unsteady state of operation. The course of voltage, current and motor rotary speed when set in motion was evaluated as well as the dependence of a motor’s rotary speed and efficiency on load torque. The simulation of motor starting up was not only made for the case of idle running but also for running with an nominal load. The article describes the characteristics, advantages and disadvantages of the applied method of simulations.

Effect of Hydrogen Fraction in Intake Mixture on Combustion and Exhaust Emission Characteristics of a Diesel Engine

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The present study experimentally investigated the performance and emission characteristics of the diesel engine with hydrogen added to the intake air at late dieselfuel injection timings. The diesel-fuel injection timing and the hydrogen fraction in the intake mixture were varied while the gross heating value per second of diesel fuel and hydrogen was kept constant at a certain value. NO showed minimum at specific hydrogen fraction. The maximum rate of incylinder pressure rise also showed minimum at 10 vol% hydrogen fraction. The indicated thermal efficiency was almost constant or slightly increased with small amount of hydrogen. A combination of hydrogen addition and late diesel-fuel injection timing contributed to low temperature combustion, in which NO decreased without the increase in unburned fuel.

Energy efficiency and potentials of electric motor types for wheel hub applications

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Nearly all OEMs worldwide try to electrify their powertrain systems. This is certainly a necessity in order to fulfill the gradually changing and challenging political requirements concerning environmental restrictions. Electric motors offer potential characteristics to overcome these challenging tasks. Today, induction and synchronous motors represent reasonable alternatives to conventional combustion engines, even due to their established assembling and their relatively low cost production. This article compares the energy consumption of induction motors (IM), synchronous motors with surface mounted magnets (SPM) and synchronous motors with interior mounted magnets (IPM) at different driving cycles. The paper intends to identify a suitable electric motor type for wheel hub applications.

Fuel Injection and Combustion Process _Modeling

Fuel Injection and Combustion Process _Experiments

Alternative and Advanced Power Systems

Fuels and Lubricants

Powertrain Technology

Exhaust Aftertreatment and Emissions

Technical and Economical Feasibility of Biofuels for Engine Applications

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Ever increasing number of vehicles in the world has led to increasing demand of fossil fuels. But the resources of fossil fuels are limited and those too are concentrated in some parts of the world. This crisis of petroleum fuels has motivated the researchers all over the world to look for alternative renewable fuels. This paper describes first generation biofuels i.e. Ethanol and Biodiesel, and their compatibility with existing internal combustion engines. This paper also reviews their economical comparison with petroleum fuels. In the next part, the paper describes second generation biofuels i.e. Lignocellulosic ethanol and Fischer-Tropsch diesel, their current status, and development needs to make them economically feasible.

Alternative Diesel Fuels Effects on Combustion and Emissions of an Euro4 Automotive Diesel Engine

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The present paper describes the first results of a cooperative research project between GM Powertrain Europe and Istituto Motori of CNR aimed at studying the impact of Fatty-Acid Methyl Esters (FAME) and gas-toliquid (GTL) fuel blends on the performance, emissions and fuel consumption of modern automotive diesel engines. The tests were performed on the architecture of GM 1.9L Euro4 diesel engine for passenger car application, both on optical single-cylinder and on production four-cylinder engines, sharing the same combustion system configuration.

Various blends of biodiesels as well as reference diesel fuel were tested. The experimental activity on the singlecylinder engine was devoted to an in-depth investigation of the combustion process and pollutant formation, by means of different optical diagnostics techniques, based on imaging multiwavelength spectroscopy. The tests on the multi-cylinder engine were done in a wide range of engine operation points for the complete characterization of the biodiesels performance in the new European driving cycle (NEDC).

The optical engine results have confirmed the good quality of spray formation of FAME fuels with engine and their capability to reduce soot formation, thanks to lack of precursors and oxygen in the fuel.

The four-cylinder engine results, besides validating single-cylinder outcomes, have also highlighted critical aspects on the interaction between the alternative fuel characteristics and the engine-management strategies of electronically-controlled diesel engines.

Simulation Study on Combustion Characteristics of a Spark Ignition Engine Fueled with Gasoline–Hydrogen Fuel Mixture

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Experiments of a pure gasoline-fueled engine and a hydrogen-enriched gasoline engine with hydrogen volume fractions in the total intake of 1%, 3% and 5% were conducted on an engine test bench at stoichiometric condition, respectively. Simulation models for gasoline and gasoline-hydrogen mixture fueled engines were built based on AVL Boost and calibrated with the measured combustion pressure, intake gas flow and brake mean effective pressure (BMEP) data from the tests. The simulation study was done at the same intake manifolds absolute pressure (MAP) with different hydrogen volume fractions in the intake and various spark timings to investigate combustion characteristics of a hydrogen-enriched gasoline engine. The simulation results showed that the effect of hydrogen addition on improving the engine combustion was more pronounced at low load conditions. The flame development and propagation durations were reduced with the increase of hydrogen enrichment level when hydrogen volume fraction in the intake was below 5%. The maximum BMEP was achieved when hydrogen volume fraction in the intake was 2%. For a specified hydrogen addition fraction, cylinder pressure first increased and then decreased with the advance of spark timing, and achieved the peak value when spark timing was set to be 13 oCA BTDC. The simulation results also showed that the cylinder pressure rise rate and combustion noise were increased, and the relevant crank angle for peak cylinder pressure was getting close to the TDC with the increase of hydrogen addition level, so the ignition timing should be delayed.

Effects of Ethanol, n-Butanol – n-Heptane Blended on Low Temperature Heat Release and HRR Phasing in Diesel-HCCI

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The study of Diesel-HCCI combustion for blended alcohols in Diesel-like fuel was performed in this experimental work to quantify their impact on the net heat release rate. Ethanol and n-butanol were two representative alcohols and were blended with n-heptane; by varying mole percentage from 0, 18, 37 and 57 and varying dilutions with simulated Exhaust Gas Recirculation (EGR) from 0, 20 and 40 percent. The engine speed, intake temperature and equivalence ratio were set at 1500 rpm, 80 °C and 0.3 respectively. The impacts of alcohols were compared with the Primary Reference Fuels by blending n-heptane with iso-octane at the same molar percentage and were tested at same conditions. The results show that blended fuels and dilution with EGR can delay the combustion in different ways. Increasing the EGR rate retards combustion by increasing contained inert species. The energy output is also decreased with reducing of energy content but does not effect on the percentage of Low Temperature Heat Release (LTHR) combustion. Increasing of ethanol, nbutanol or iso-octane fractions reduce the percentage of LTHR combustion and increase the IMEP moderately. Moreover, the addition of both alcohols in n-heptane has more impact on delaying the heat release rate than that of iso-octane when the blended RON, MON and CN are considered. The time delay between the LTHR and the main combustion are dependant on EGR fraction and mean fuel ignitability as shown in relation to blended RON, MON and CN. Moreover, a possibility to increase engine output by changing fuel ignitability is realized in this study.

Fuel Oil Emulsification Plant On Board of Diesel Engines

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The paper deals with the development of a system to feed water (or ethanol) in fuel oil emulsions into internal combustion diesel engines. Such a system can be installed on board of the engine itself, the two compounds (fuel and dispersed phase) being stored into two separate tanks.
A description of the emulsification system sections is given. The main relevant and innovative components are also described. Tests on a scaled down model are presented and results deeply analyzed.
On the basis of such results a prototype for a 382 kW, 2800 rpm, six cylinder diesel engine has been built and tested. Results show the capabilities of such an Emulsion Engine Feeding System (EEFS) to have downstream of the injector spray drops where the dispersed phase droplets are uniformly distributed with diameters less than 1μm for a wide range of operating conditions. Emulsion quality (i.e. drop diameter of the dispersed phase, diameter distribution of the water droplets, water to oil volumetric mixing ratio versus fuel flow rate) are controlled by the appropriate EEFS components dimensioning and process parameters setting.
Viscosity influence and dynamic behavior have also been analyzed and discussed.

A Study of Different Egr Routes on a Heavy Duty Stoichiometric Natural Gas Engine

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Exhaust gas recirculation (EGR) is a suitable strategy to optimize heavy duty natural gas (NG) engines. EGR could be utilized to have high specific power, with low thermal stress, but also to increase engine efficiency. NG fuelling permits a large flexibility in EGR system design, due to very clean engine exhaust. In this paper, three types of EGR routes have been studied. The best set up, which can introduce the highest EGR quantities, to provide the best reduction of the thermal load at rated power, was found to be a cooled low pressure EGR route. However high low pressure route (HLPR) could give the possibility to increase engine efficiency by modulating the power output in the widest un-throttled range operation.

Non-Esterified Plant Oils as Fuel-Engine Characteristics, Emissions and Mutagenic effects of PM

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Plant oils may be used as a sustainable, nearly CO2 neutral fuel for diesel engines. This work investigates experimentally the particulate and gaseous emissions of diesel engines fuelled with non-esterified, pure plant oils with the quality standard of DIN V 51605 (Weihenstephan RK-Qualitätsstandard 05/2000). The data are collected from three engines:

- Common rail passenger car engine from OPEL AG
- Truck engine from VOLVO
- Truck engine from MAN AG

All engines have been correctly adjusted to plant oil operation. The OPEL and VOLVO engines served for the basic investigations. The emissions of the MAN engine have been used to perform AMES tests to analyze possible health impacts of plant oil operation.

The experimental data show a reduction of particulate matter compared to traditional gasoil which may yield up to 50 % for. The particulate matter shows same primary particle sizes but the agglomerates as collected on TEM grids are different – the plant oil soot particles tend to form larger aggregates [4]. The gaseous emissions of CO and hydrocarbons HC are generally lower compared to the operation with gasoil. However, the NOX emissions are slightly higher. This may be contributed to the measured higher combustion chamber pressures and temperatures when fuelled by plant oils.

Emission samples have been extracted from ESC cycles of 13 step tests to perform the AMES test which give indication on carcinogen substances. The AMES test results gave no indication of mutagenic effects exceeding the detection limits. No significant differences could be found comparing the emissions of plant oil and gasoil operation. Thus, it can be stated that the emission from plant oil operation

does not have a health impact different to traditional gas oil. This is in contrast to some other publications – a deeper insight shows that these investigations did not properly modify the engine for plant oils. It is mandatory to make the engine modification to prewarm the plant oils to approx. 900C prior to injection. The engine´s warm-up phase needs special care to avoid any coking at the injection system and combustion chamber surfaces. The publications where a higher health risk was claimed to be found in the exhaust of plant oil fuels, did not pre-warm the plant oils – cold plant oils have been injected in the combustion chamber instead. This results in incomplete atomization and incomplete combustion with a lot of hazardous emission species (see also [4,11]. Such an operation will damage the engine after relatively short times and is, therefore, not realistic.

The investigated fuels had some influence on the engine characteristics. Higher temperatures and pressures in the cylinder have been detected for some plant oils compared to gasoil. This increase is explained by the higher oxygen content within the plant oils.

Experimental study on characteristics of diesel particulate emissions with diesel, GTL, and blended fuels

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Various alternative diesel fuels such as gas to liquid (GTL) fuels, blends of diesel and biodiesel (D + BD20), and blends of GTL and biodiesel (G + BD20) were tested in a 2.0 L four-cylinder turbocharged diesel engine. A noticeable reduction in exhaust emissions as compared to diesel fuel, except for NOx emissions, was observed by blending biodiesel with diesel and GTL fuel under selected part load conditions. There was a maximum reduction of 33% for THC emissions and 27% for CO emissions for G + BD20 fuel as compared to diesel fuel. For PM size distributions, a noticeable decrease in the PM number concentration for all particle sizes less than 300 nm was observed with the blending of biodiesel. In contrast, there was a slight increase in the number concentration of PM with diameters of less than 50 nm for the cases of EGR. In the case of particulate matter (PM) mass concentration, there were reductions of 31~59% for D + BD20 fuel and 57~71% for G + BD20 fuel. Total PM number concentrations compared to diesel were reduced by 32% for D + BD20 fuel and 43% for G + BD20 fuel under selected part load conditions.

An Experimental-Numerical Approach to Reduce Emissions of a Dual Fuel Diesel-Natural Gas Engine

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Conversion from diesel to dual fuel (diesel and natural gas) operation may represent an attractive retrofit technique to get a better PM-NOx trade-off in a diesel engine, with no major modifications of the original design. In the proposed paper, an Euro 2 heavy duty diesel engine, converted for dual fuelling, has been studied and tested to reduce pollutant emissions. Throttled stoichiometric with EGR and lean burn technologies have been selected as control strategies. A mixed experimental-numerical approach has been utilized to analyze the engine behavior by varying key operating conditions such as throttling, natural gas/diesel oil percentage and EGR. The model, based on a 3D approach, has been used mainly to understand the evolution of the distribution of the most important parameters in the combustion chamber. The use of stoichiometric mixtures, throttling and EGR, together with the adoption of a TWC, has been finally chosen as it allows to get very low gaseous and PM emissions, even if at the cost of a lower global efficiency than lean burn operation. Final emissions have been verified with respect to the ECE R49 13 mode steady state cycle. Dual fuelling allows to get a reduction in the order of 75% of NOx and PM, and higher than 30% of HC and CO.

The Impact of Natural Gas-Hydrogen Blends on Internal Combustion Engines Performance and Emissions

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The fossil fuel consumption and the related environmental impact are important issues for the world research community: hydrogen seems to be a good alternative to fossil fuels provided that it is produced from renewable energy sources.
The aim of the present work is the comparison between natural gas and a hydrogen-natural gas blend (HCNG in the following) in terms of exhaust emissions and fuel consumption. A passenger car has been tested on a chassis dynamometer according to the European emission regulations, without any change on engine calibration (i.e. spark advance). The HCNG blend used during the test has a 12% vol. of hydrogen content.
CO emissions showed a reduction of about 19% when HCNG blend is used, while HC emissions remained constant. A 70% increase was observed for NOx emissions with HCNG. A 3% reduction for CO2 emission was observed using HCNG because of the lower carbon content in the blend and the reduced fuel consumption on a mass basis. There is not significant variation of fuel consumption on energy basis, probably due to the effect of a non optimal ignition timing.

Screening Anti-Oxidant Activity at Oil Microdroplet Triple Phase Boundary Electrodes

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Highly non-polar/non-conducting media such as natural or synthetic oils cannot be analysed by conventional single phase solution voltammetry, but it is shown here that, when they are deposited onto suitable basal plane pyrolytic graphite electrode surfaces, the triple phase boundary reaction zone in liquid | liquid two-phase systems in contact to a graphite electrode can be exploited for the electrochemical determination of the content and activity of anti-oxidants such as Irganox L-135 and L-57 in fuel (methyl-laurate) and in oil (commercially available API Group III base oil) media.

The Effects of Two-Stage Fuel Injection on Dimethyl-ether (DME) Homogeneous Charge Compression Ignition Engine Combustion

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Two-stage injection strategy was studied in dimethylether homogeneous charge compression ignition engine combustion. An early direct injection, main injection, was applied to form a premixed charge followed by the second injection after the start of heat release. Experiments were carried out in a single-cylinder directinjection diesel engine equipped with a common-rail injection system, and the combustion performance and exhaust emissions were tested with the various second injection timings and quantities. Engine speed was 1200 rpm, and the load was fixed at 0.2 MPa IMEP. Main injection timing for homogeneous mixture was fixed at - 80 CAD, and the fuel quantity was adjusted to the fixed load. Second injection quantity was varied from 1 to 5 mg, and the timing was selected according to the heat release rate of the HCCI combustion without second injection.

From the results, two-stage injection strategy showed the possibility to overcome the disadvantages of HCCI such as high HC / CO emissions and difficult combustion phase control. Heat release rate and pressure rise rate were reduced with the second injection. The decreased premixed charge concentration by the second injection lowered the heat release from low temperature reaction and high temperature reaction. The second injection showed the separated heat release with the third peak in heat release rate curve as the fuel quantity exceeded 3 mg. This contributed to the power stroke enhancement, and fuel consumption reduction. Peak in-cylinder pressure was decreased as the second injection timing was retarded and the quantity was increased. The portion of the heat release after TDC was increased, and the pressure rise rate was reduced as the combustion phase was delayed and the burn duration was lengthened. However, the lowered bulk gas temperature with dropped in-cylinder pressure caused the CO emission level rise.

Fuel Injection System Simulation with Renewable Diesel Fuels

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Renewable diesel-type fuels and their compatibility with a single-cylinder medium-speed research diesel engine were studied. The report consists of a literature study on the fuels, introduction of the simulation model designed and simulations made, and of the results and summary sections. The fuels studied were traditional biodiesel (fatty acid methyl ester, FAME), hydrotreated vegetable oil (HVO), Fischer-Tropsch (FT) diesel fuels and dimethyl ether (DME).
According to the simulations, the behaviors of different renewable diesel fuels in the fuel injection system are quite similar to one another, with the greatest deviations found with DME. The main differences in the physical properties are fuel densities and viscosities and especially with DME compressibility, which have some predictable effect. The chemical properties of the fuels are more critical for a common rail fuel injection system.

Quantification of Biofuel Components in Automotive Lubricants

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Small amounts of diesel fuel can accumulate in engine oils during the normal operation of an engine. Biofuels such as fatty acid methyl esters (FAMEs), due to their higher boiling points, are rather more persistent. This leads to much higher levels of fuel dilution and is one of the main factors having an influence on the condition of used engine oil. As the use of biofuels in the automotive sector becomes more widespread, the need to assess fuel dilution levels as well as fuel and lubricant quality is of increasing importance. In this study, fuel dilution levels in lubricants have been quantified using proton nuclear magnetic resonance (1H NMR) method and correlated with the data obtained by a gas chromatography (GC) technique. Specifically, the amount of FAME has been quantified in both fresh and in selected used oil samples.

The results of this study show that fuel dilution levels can be quite reasonably quantified using the GC and 1H NMR techniques. Both techniques provide information on the type of oxidation by-product species present in the aged oils. Advantages and disadvantages of each method are detailed and a preference for one technique is expressed.

Practical automotive engineer myster of gasoline engine managment (bosch)

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BIO-DIESEL USAGE EFFECTS OF GLOBAL WORMING IS IT REALLY THAT GOOD FOR US?
A lot has been written about the benefits of the use in bio-diesel, and yet it seems to be that there wasn't a serious research about it actual contribution to the global worming process. A key assumption is in the event of massive growth in the bio-diesel the possibility to use used oil from restaurants and such will not meet the market demands, and the use of new oil will be common practice.
Since bio-diesel is manufactured mainly form vegetarian oil, it has a double effect on the atmosphere. One hand to consider is it effect on emissions, and its suitability to modern diesel engines, since most of the systems manufacturers still prohibit its use. On the other hand, while the vegetables that are required for producing the oil grow, they assist in converting CO2 into O2, thus reducing greenhouse gases, while giving the world an alternative fuel. But – is it really that good?
The key issues of the presentation will discuss the following:

- How much plants are needed to produce 1 ton of bio-diesel?
- How much energy is consumed in the process?
- How much CO2 is converted during the plants growth?
- How much CO2 is generated during 1 ton of bio-diesel burn?
- What is the cost in pollution due to the use of older injection methods?

After those issues will clear, the answer for the bio-diesel feasibility will become much more obvious.
The presentation is open for questions, and a discussion is generated on several slides. The presentation takes 90-120 minutes, and is accompanied with printed materials.

Fuel Injection and Combustion Process _Modeling
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Exhaust Aftertreatment and Emissions

Virtual Multi-Cylinder Engine Transient Test System

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Researchers at the Powertrain Control Research Laboratory (PCRL) at the University of Wisconsin- Madison have developed a transient test system for single-cylinder engines that accurately replicates the dynamics of a multi-cylinder engine. The overall system can perform very rapid transients in excess of 10,000 rpm/second, and also replicates the rotational dynamics, intake gas dynamics, and heat transfer dynamics of a multi-cylinder engine.
Testing results using this system accurately represent what would be found in the multi-cylinder engine counterpart. Therefore, engine developments can be refined to a much greater degree at lower cost, and these changes directly incorporated in the multi-cylinder engine with minimal modification. More importantly, various standardized emission tests such as the coldstart, FTP or ETC, can be run on this single-cylinder engine. These tests are currently only run using multicylinder engines, so this moves these important tests more than a year forward in the engine development cycle, and represents a significant competitive advantage. Many other advantages of this new system will be discussed in the paper.

Development of a Control-Oriented Engine Model Including Wave Action Effects

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This paper describes the development of a controloriented model that allows the simulation of the Internal Combustion Engine (ICE) thermodynamics, including pressure wave effects. One of the objectives of this work is to study the effects of a Variable Valve Timing (VVT) system on the behavior of a single-cylinder, four-stroke engine installed on a motor scooter. For a single cylinder engine running at relatively high engine speeds, the amount of air trapped into the cylinder strongly depends on intake pressure wave effects: it is essential, therefore, the development of a model that has the ability to resolve the wave-action phenomena, if successful simulation of the VVT system effects is to be performed.

The engine model has been fully implemented in the Matlab-Simulink environment: a zero-dimensional submodel is used for modeling the cylinder and exhaust manifold thermodynamics, while a one-dimensional model is used for the intake system, in order to take into account the wave action phenomena. The combustion is modeled as a single zone model, with the fuel burning rate described by Wiebe functions. The gas-wall heat transfer calculations are based on Annand heat transfer model for ICE. The gas properties are dependent on temperature and chemical composition of the gas, which are evaluated at each crank-angle. The equations of one dimensional compressible flow in pipes are solved by using the Courant, Isaacson and Rees (CIR) method, and a short description of the boundary conditions is also given. The experimental data needed for model identification are the crank-angle resolved in-cylinder pressure, intake and exhaust manifold pressure, as well as the measurements performed during typical enginedynamometer steady state tests: rotational speed, load, fuel consumption, Air Fuel Ratio (AFR), ... An automatic procedure for identifying the unknown parameters of the model by using experimental data has also been developed. The Simulink model has been identified and validated by using experimental data acquired on an engine equipped with a traditional valve timing system. It has then been used in order to examine the effects of a VVT system on the amount of air trapped inside the cylinder and on the performance of the engine. The results obtained in simulation have also been compared with the results obtained by using a 1-D commercial code (Ricardo Wave).

Use of Engine Crankshaft Speed for Determination of Cylinder Pressure Parameters

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The present study proposes the use of a MLP neural network to model the relationship between the engine crankshaft speed and parameters derived from the incylinder pressure cycle. This allows to have an indirect measure of cylinder pressure permitting a real time evaluation of combustion quality. The structure of the model and the training procedure is outlined in the paper. The application of the model is demonstrated on a single-cylinder engine with data from a wide range of speed and load. Results confirm that a good estimation of combustion pressure parameters can be obtained by means of a suitable processing of crankshaft speed signal.

Development of recurrent neural networks for virtual sensing of NOx emissions in internal combustion engines

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The paper focuses on the experimental identification and validation of recurrent neural networks (RNN) for virtual sensing of NO emissions in internal combustion engines (ICE). Suited training procedures and experimental tests are proposed to improve RNN precision and generalization in predicting NO formation dynamics. The reference Spark Ignition (SI) engine was tested by means of an integrated system of hardware and software tools for engine test automation and control strategies prototyping. A fast response analyzer was used to measure NO emissions at the exhaust valve. The accuracy of the developed RNN model is assessed by comparing simulated and experimental trajectories for a wide range of operating scenarios. The results evidence that RNN-based virtual NO sensor will offer significant opportunities for implementing on-board feedforward and feedback control strategies aimed at improving the performance of after-treatment devices.

An Experimental Evaluation of 1-D Valve Models under Dynamic Conditions

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The influence of unsteady flow in engine pipes system is a first order parameter to take into account when designing an engine. Wave motions being relatively well described by a 1-D model, these types of algorithm are very common. Logically, the boundary conditions have to use the same formulation. The importance of valve models is thus demonstrated.

The aim of this paper consists of a comparison between two valve models. In order to obtain the discharge coefficient, algorithms have been coded and tested in a stationary test bench. Different computation methods of coefficient have been used. Then, a dynamic test has been performed to determine which valve model coupled with a test analysis method gives the best result.

This work shows that each tested models give good results. As a consequence this kind of experimental setup can be used in order to study the fluid behavior under dynamic excitation and to study the temperature effect on the models.

NOx Reduction in a Medium-Speed Single-Cylinder Diesel Engine using Miller Cycle with Very Advanced Valve Timing

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The objective of this study is to achieve high reduction of NOx emissions in a medium-speed single-cylinder research engine. The main feature of this research engine is that the gas exchange valve timing is completely adjustable with electro-hydraulic actuators. The study is carried out at high engine load and using a very advanced Miller valve timing. Since the engine has no turbocharger, but a separate charge air system, 1-D simulations are carried out to find the engine setup, which would be close to the operating points of a real engine. The obtained NOx reduction is over 40% with no penalty in fuel consumption.

Optimization of the transient Diesel engine operation

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Transient emission peaks have become an important fraction of the total emissions during the standardized test cycles for passenger car Diesel engines. This paper is concerned with their reduction, in particular for nitric oxides (NOx) and particulate matter (PM) emissions, by online optimization. It is based on a former work [1] in which alternative target quantities for engine control were proposed, namely in-cylinder oxygen concentrations before (O2,BC) and after combustion (O2,AC). A generic nonlinear optimization is applied to provide a systematic determination for the optimal trajectories of these oxygen target quantities during a transient torque maneuver. The proposed method was implemented on a dynamic engine test bed using a production passenger car Diesel engine for the objective function evaluation. Torque response could be maintained unchanged while NOx as well as PM emission peaks were reduced significantly.

Control of the Diesel Combustion Process via Advanced Closed Loop Combustion Control and a Flexible Injection Rate Shaping Tool

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The presented paper deals with the set-up and performance of a newly developed control system as well as with achieved engine results. This control system is able to control the entire cylinder pressure trace by using a flexible rate shaping injector and iterative learning control (ILC). Standard thermodynamic cycles, like isobaric and Seiliger cycles, and a newly suggested class of cycles are generated and analyzed on a single cylinder engine. With this control system an extremely flexible tool for optimization of combustion processes is available to exploit the full potential of injection rateshaping on diesel engines.

The Ultra Lean Burn Partially Stratified Charge Natural Gas Engine

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It is well known that lean operation of homogeneouscharge spark-ignited engines is effective in increasing thermal efficiency and reducing exhaust emissions. In particular, the lower combustion temperatures provided by a lean air-fuel mixture result in a significant reduction in NOx emissions. Lean operation is normally restricted, however, by the “lean-limit” of combustion, as measured by the air-fuel ratio above which ignition is impossible, or combustion is incomplete. In order to extend the lean limit of operation a new “partially-stratified charge” combustion concept has been developed. This technique relies on the fact that a stronger initial flame kernel produced following the spark event should also be effective in igniting a very lean mixture which may not otherwise ignite, or which may result in incomplete combustion. An innovative spark-plug insert design, in which a small portion of “pilot fuel” is injected directly near the spark plug electrodes, provides a small pocket of relatively rich mixture that ignites more readily than the main, very lean, combustion charge. This has then been used to extend the lean-limit of operation of natural-gas fuelled spark-ignition engines, resulting in reduced brake specific fuel consumption and significantly lower levels of NOx emissions. This process has also been shown to be effective in increasing the stability of combustion, thereby reducing cyclic variations in cylinder pressure. Recent data obtained using this concept in a single-cylinder research engine are reported in this paper. In addition, some initial studies of the partially stratified-charge mixing process are also described.

Multilayered Semitransparent and Opaque Heat-Insulating Coatings for Diesel Combustion Chamber

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Heat-insulating coatings (HIC) being used in automotive industry for thermal insulation of thermally highly loaded components of combustion chamber (CC) are usually semitransparent (SHIC) for radiation of red-hot soot particles. The paper presents physical and mathematical models of radiation and conductive heat transfer and solution methods for multilayered scattering and absorbing coating. Calculations of radiation field are carried out by means of the method of moments and defined by the solution of differential equation system for moments of radiant intensity. The analysis is assumed to be without any soot layer on semitransparent one for this preliminary investigation. It allows to simulate temperature distributions for SHIC with internal radiant source above substrate with different reflection for operating conditions in CC of high-speed diesel engines (cyclic heating). The improved distributions of temperature due to absorption of volumetric radiant heat inside the top layer of semitransparent heat-insulating coatings are compared with traditional opaque HIC. The practical importance of the given research is discussed.

Influence of a Multispark Ignition System on the inflammation in a Spray-guided Combustion Process

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This study describes tests with a fast clocked multispark ignition system intended to improve the stability of inflammation during charge stratification. The advantage of this ignition system is the capability it provides to adjust the number of sparks, the duration of single sparks and the intensity of the primary current. The basic engine test parameters were first set in an optically accessible pressure chamber under conditions approximating an engine. Two strategies were examined to analyze their effect on inflammation in stratified charge mode.

On the one hand, the multispark ignition (MSI) system allows implementing an intermittent spark sequence in the spark gap between the spark plug electrodes. On the other hand, precisely timed pulsing of spark energy into the plasma channel during charge motion can generate a very large deflection of the ignition spark. Both ignition strategies were analyzed in an indicated single cylinder engine's combustion chamber at different operating points to determine the respective tolerance limits of the engine operation and inflammation process.

The results demonstrate that the multispark ignition system may be employed to extend the range of ignition without misfire by a factor of up to five in stratified charge mode. Furthermore, electrical quantities were measured to compare the ignition energy of a multispark ignition system and a conventional ignition system.

In addition, the potentials for using the ignition voltage analysis as a method of measurement to determine local air/fuel ratios at the spark plug are highlighted. Being refined in this project, this method of measurement is based on the analysis of the disruptive voltage in different modes of operation and the thermodynamic conditions derived from the ignition point.

Development of 1.2L MPI Bi-fuel LPG Engine for Indian market application

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In developing countries, the recent rise in the operating cost of gasoline passenger cars has forced vehicle / fleet owners to opt for alternative gaseous fuels like CNG and LPG. Due to non-availability of the efficient gaseous systems from OEMs, many 'retro' or after market kits are being used by the vehicle owners to take the advantage of the low kit cost. These after market systems pose major issues related to engine warranty, safety, emission compliance, performance, driveability and adverse effect on the main stream gasoline engine.

This paper describes the development of 1.2L, Bi-fuel (Gasoline – LPG) MPI engine for the Indian market. The objective of the project is to develop a bi-fuel LPG variant of the already existing gasoline engine without compromising on performance, driveability, safety and emissions with minimum cost impact. Precise control of LPG operation necessary to meet the engineering targets is achieved by use of EMS in master-slave architecture. The architecture uses two ECUs wherein the Gasoline (master) ECU and LPG (Slave) ECU works in tandem thereby eliminating sensor duplication and providing cost advantage. The system is completely diagnosable with automatic transition to gasoline in case of LPG system failure or empty tank. The vehicle meets the Bharath Stage 3 norms (equivalent to Euro 3) with sufficient margin in both gasoline and LPG mode. The max power drop in LPG is 4% which is close to the theoretical value. There is no deterioration in low end and max torque with LPG. Driveability and acceleration performance with LPG are at par with gasoline. Durability aspects specific to bi-fuel operation have been addressed by modification to the engine hardware. Compared to gasoline, the CO_2, CO and HC emissions are lower by 11%, 15% and 39% respectively. In short, this MPI LPG system, offers the best of both fuels without major cost escalation and complies with the required legal safety norms.

A thermodynamic Mean Value Model of the intake and exhaust system of a turbocharged engine for HiL/SiL applications.

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Regarding automotive applications, Internal Combustion Engines (ICE) have become very complex plants to comply with present and future requirements in reduction of fuel consumption, pollutant emissions and performance improvement. As a consequence, the development of engine control and diagnostic system is a key aspect in the powertrain design.
Mathematical models are useful tools in this direction, with applications that range from the definition of optimised management systems, to Hardware- and Software-in-the-Loop testing (HiL and SiL) and to modelbased control strategies.
To this extent an original library has been developed by the authors for the simulation of last generation automotive engines. Library blocks were used to assembly a sub-model of the typical intake and exhaust system of a turbocharged engine (with VGT, intercooler, EGR circuit with cooler and throttle). The simulation procedure, developed in Simulink® and based on a physical modelling of the gas path, was then integrated in a HiL test bench from dSpace Gmbh at Magneti Marelli Powertrain facilities. After calibration and validation –with reference to a small Common Rail Diesel engine- it was widely used in SiL/HiL testing. In the paper the model is presented and several results are reported.

Design and Validation of a Control-Oriented Model of a Diesel Engine with Two-Stage Turbocharger

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Two-stage turbochargers are a recent solution to improve engine performance. The large flexibility of these systems, able to operate in different modes, can determine a reduction of the turbo-lag phenomenon and improve the engine tuning. However, the presence of two turbochargers that can be in part operated independently requires effort in terms of analysis and optimization to maximize the benefits of this technology. In addition, the design and calibration of the control system is particularly complex. The transitioning between single stage and two-stage operations poses further control issues.

In this scenario a model-based approach could be a convenient and effective solution to investigate optimization, calibration and control issues, provided the developed models retain high accuracy, limited calibration effort and the ability to run in real time. To this extent, this work documents the development and validation of a control-oriented model of a Diesel engine equipped with two-stage turbocharger. A bottom-up modeling approach, based on the principle of modularity, is adopted to characterize the turbocharger system, as well as the engine airpath, inclusive of a high-pressure EGR loop. The approach characterizes each component as a dynamical system, applying mass and energy conservation laws to derive a set of ordinary differential equations. The reliance on physical principles limits the number of calibration parameters, which can be identified from simple steady-state engine data at few operating points.

The validated model is able to fully characterizing the flows, pressures and temperatures throughout the engine systems. In addition, prediction of engine performance (i.e., torque, BMEP, volumetric efficiency, specific fuel consumption) is provided to support further analysis, optimization and control studies.

Physics based diesel turbocharger model for control purposes

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Model-based tuning is a way followed by car manufacturers to reduce development costs. In this context, a new methodology has been developed in order to adapt a turbocharged diesel engine in the case of non-standard external conditions. Indeed, variable geometry turbine and fuel injection command laws are developed for standard conditions (20±C, altitude=0m). Turbocharger and fuel injection actuators pre-positioning maps should be adjusted regarding the inducted air mass density (influenced by the external temperature and pressure), in order to meet thermal, mechanical and pollutant emissions constraints. In order to reduce the use of climatic tests bench and extreme conditions tests in foreign countries, a model of a turbocharged diesel engine coupled to an optimization loop has been used to take into account the effect of non-standard external conditions on pre-positioning maps. This tool is based on ACHILLE, a PC-based simulation system for the internal combustion engines, developed internally at Renault.
The paper is structured in three parts:

- The mean-value model of a 2.0l turbocharged direct injection diesel engine is described, with an emphasis on the data map-based turbocharger model. The air path is modelled using mean-value restriction models (air filter, intercooler, throttle) and volumes. Incylinders physics are processed by a black box approach, in order to determine the combustion parameters and the temperature at the exit of the engine. Data relative to the compressor and turbine are read from data maps: pressure ratio and efficiency are measured as functions of mass flow rate and rotary speed on 2 distinct data maps. However, these data are usually incomplete and poorly discretized, leading to the use of extrapolation and interpolation methods to cover the entire turbocharger operating range. As standard mathematical methods give poor results, an extrapolation treatment based on mathematical methods and turbomachinery physical laws has been used in order to ensure the accuracy of the model.

- The optimization process which determines adjusted turbocharger command laws is described. Test cases for inlet air density from 0.70 to 1.20 kg/m3 are calculated and the results given by the optimisation tool analyzed. Two types of constraints are taken into account by the optimization process: thermo-mechanical limitations (turbocharger speed limit, pressure and temperature upstream turbine and after the compressor) and pollution (soot emissions). For a given altitude and outside temperature input, the tool determines the engine new full-load curve. The goal is to get the turbocharger actuator prepositioning which guarantees the good performance of the engine under these modified external conditions.
- Finally, simulation-based turbocharger and fuel injection actuator pre-positioning maps are compared to those determined experimentally. Limitations of both model and optimization process are also studied.

It is concluded that the optimization tool based on a meanvalue engine model gives very satisfying results: it requires low CPU charge, while turbocharger and fuel injection actuators pre-positioning maps given by the simulation tool are predictive. Additionally, the treatment of the turbocharger data maps allows good agreement between calculation and experimental results, while providing a good robustness level to the model.

Measurement of Instantaneous Fluid Dynamic Parameters in Automotive Turbocharging Circuit

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In the paper the difficulties related to measurement of instantaneous fluid dynamic parameters in the turbocharging circuit of automotive engines under unsteady flow conditions are highlighted, referring to pressure, mass flow rate, temperature and turbocharger rotational speed. Frequency response of transducers, sensor position, measuring procedures and filtering techniques need to be taken into account to correctly describe the unsteady behaviour of tested component. The results of an experimental campaign developed on a small turbocharger for downsized gasoline engines are presented, focusing on the evaluation of the instantaneous parameters that allowed to estimate unsteady turbine performance. Measurements were performed by using a flexible test rig, operating at the University of Genoa, particularly suitable for investigations under unsteady flow operation.

Model-based Development of Multi-Purpose Diagnostic Strategies for Gas Vehicles

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Engines using compressed natural gas or liquefied petroleum gas are commonly equipped with control systems which are not yet able to completely monitor the gas supply line status. With a particular regard to safety but paying attention even to driving comfort and finally to polluting emissions reduction, two aspects in particular have been taken into account: the first one is the need to detect as soon as possible (and to react consequently) the presence of a problem occurring inside gas supply line (leakages and blocked-valves etcetera); the second one is the ability to detect an unsafe re-fuel operation, done with inserted ignition key, in order to switch off at least as more auxiliary loads as possible. The danger from such a manoeuvre may be identified in the high probability of an eventual electrostatic discharge and/or in the risk that the vehicle may be accidentally moved during the refilling operation.
Thanks to a model-based approach, these diagnosis may be carried out by recording and analyzing several signals already available on all common production systems and may allow to give some information even about entity and location of the leakages under different environmental and engine conditions. The whole strategy may be based either on "black" or on "white-grey" box algorithms, i.e. it may be performed through a system of experimental equations or by substituting some - or all- of them through physical models. By applying all the described procedures it would be also possible to commutate towards the other fuel (in case of dual-fuel engine equipped vehicles). Several experimental tests have been carried out (some more are planned for the immediate future), first in order to identify model parameters and finally to validate and demonstrate the effectiveness of proposed strategies. Some vehicles going to be produced in the immediate future will be already equipped with some of the described algorithms.

Experimental Investigation of the Benefits of Cooled and Extra-cooled Low-Pressure EGR on a Light Duty Diesel Engine Performance

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The present paper describes an experimental study on the application of a Low Pressure EGR system, equipped with an high efficiency cooler, to a LD diesel engine operating with both conventional combustion and PCCI mode.
The research activity is aimed to carry out an analysis of the potentiality of the cooling (with engine water at 90°C) and super-cooling (with external water at 20°C) of the low pressure EGR flow gas on the simultaneous reduction of fuel consumption and pollutant emissions. The effects were evaluated running the engine with diesel conventional combustion and PCCI mode in several engine operating points.
The employed engine was a 4-cyliders LD CR diesel engine of two liters of displacement at the state of art of the current engine technology.
The overall results identified benefits on both the fuel consumption and emissions with the use of a low pressure EGR system with respect to the "classical" high pressure EGR one. The cooled EGR system showed advantage mainly at medium and high speed/load operating points.

Real Life CO_2 Emission and Consumption of Four Car Powertrain Technologies Related to Driving Behaviour and Road Type

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Four family cars are evaluated for their fuel consumption and carbon dioxide (CO_2) emission: a petrol Peugeot 1.6l 307, diesel Peugeot 1.6l 307, hybrid Toyota Prius II and LPG Seat Leon 1.6l. They are subjected to 4 driving styles: new (environment friendly), relaxed, normal and aggressive. Each driving style is tested on three road types: urban, rural and motorway.
Consumption+CO_2 is highest on urban roads for all driving styles except for the Toyota Prius where this is only valid for the aggressive style; it is lowest on rural roads except for aggressive driving that is lowest on motorway for the Peugeot 307 petrol and diesel. Aggressive driving results in a significant increase of consumption+CO_2 on urban (max. of 68% from the Peugeot petrol car) and rural roads (max. of 47% from the Peugeot diesel car). The lowest increase is for the Seat Leon LPG (9% urban and 19% rural) together with the Prius (18% rural). Aggressive driving on urban roads results in high absolute consumption and CO_2 figures of 10 to 18 l/100km and 240 to 430 g/km (Toyota Prius and Peugeot 307 petrol respectively). There is little difference between the new, relaxed and normal style; the relaxed one gives overall the lowest results with a largest difference to normal style of 20% for the Prius and Peugeot diesel on urban roads.
The Prius has the lowest consumption on urban and rural roads and the Peugeot 307 diesel is lowest on the motorway. The ascending ranges in l/100km are: Prius 5.1-7.3, Peugeot diesel 5.1-8.0, Peugeot petrol 7.7-11.7 and Seat Leon 10.1-11.9. The Otto engines consume more then the hybrid-Otto combination and the diesel engine. The hybrid technology proves less sensitive to differences in driving patterns.
Of the four cars the Prius has the lowest CO_2 emission on all road types. In the '1/1/1 road type average' the ascending ranges in g/km are: Prius 119-170, Peugeot diesel 135-210, Seat Leon 164-193 and Peugeot petrol 181-276. Note the differences and the change in order compared to the order for fuel consumption.
Analysis of the real time consumption shows the differences of petrol, diesel and hybrid powertrains.
Keys-words: CO_2, fuel consumption, driving behaviour, road type.

Investigation of the Flow Unsteadiness of Car Air-Box by Using LES

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Today, high performance race car efficiency is based on a very fine equilibrium between aerodynamic efficiency, engine performance, and chassis behaviour. In particular, from the engine point of view, one way to increase the performance is to increase its volumetric efficiency.
The aim of this paper is to present the application of the Large Eddy Simulation (LES) approach for the fluid dynamic analysis of a high performance race car airbox geometry. For a naturally aspired engine, the fluid dynamic optimisation of the airbox geometry means to optimise the energy conversion (from dynamic to static pressure) inside the airbox itself, therefore to increase the flow energy on the engine trumpet sections. The LES approach seems to be the best candidate to investigate such a flow since flow unsteadiness are expected to affect airbox efficiency in terms of pressure recovery.
The airbox simulations were performed by using the commercial CFD code Fluent v6.3. The Wall Adaptive Local Eddy-Viscosity (WALE) Sub-Grid Scale (SGS) model was adopted together with a bounded second order central differencing scheme. The LES methodology here adopted was validated by previous works.
In order to guarantee realistic fluid dynamic conditions on the airbox inlet section, a part of the car body was considered in the computational domain.
Results obtained by LES simulations were analysed in terms of mean and rms evolutions of both pressure and velocity components.
This study shows that, today, the LES technique is a very promising and proficient way to obtain detailed information about flow unsteadiness also on industrial cases.

Calibration and validation of a numerical model developed to simulate the working conditions of a scooter vehicle on a mission profile

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The purpose of the study is to develop a flexible simulation tool that allows coupling the 1-D simulation of the engine with the dynamic simulation of the whole vehicle on which the engine is installed, in order to predict vehicle operating conditions and exhaust emissions during an imposed mission profile.
In fact 1-D engine simulation can supply information on engine performance but not on vehicle performance, that strongly depends on the vehicle itself. Therefore vehicle performance simulation needs an integrated engine-vehicle approach.
The dynamic model of the vehicle (a scooter with CVT transmission) is built up in Matlab-Simulink while the engine model is realized by means of a 1-D commercial code (WAVE, Ricardo Software).
In particular, the Urban Driving Cycle (UDC) of the European Community ECE-40 homologation test (established by the EU directive 2002/51/CE) for a scooter with CVT transmission and centrifugal clutch is the aim of the simulation activity. The virtual approach allows reducing the number of experimental tests that have to be performed in order to achieve results both in terms of pollutant emissions and global performance.
The model results are then compared with the experimental results coming from the real vehicle placed on the roller test bench.

Employment of Magneto-Rheological Semi-Active Differential in a Front Wheel Drive Vehicle: Device Modelling and Software Simulations

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This paper presents a semi-active differential, denoted by MRF LSD (Magneto-Rheological Fluid Limited Slip Differential) that allows to bias torque between the driving wheels.
It is based on the Magneto-Rheological (MR) fluid employment, by which it is possible to change, in controlled manner, the internal friction torque and, consequently, the torque bias ratio.
The device is an adaptive one and allows to obtain an asymmetric torque distribution in order to improve vehicle handling.
The device modelling and the control algorithm, realized for this activity, are described. The illustrated results highlight the advantages that are attainable regarding directional behaviour, stability and traction for a front wheel drive (FWD) vehicle. A comparison with a traditional passive limited slip differential has been conducted.

Engine patent examination in the European Patent Office

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This paper aims to give a basic overview of how patents are examined in the EPO, which is not dissimilar to the process in most patent granting authorities.

Fuel Injection and Combustion Process _Modeling

Fuel Injection and Combustion Process _Experiments

Alternative and Advanced Power Systems

Fuels and Lubricants

Powertrain Technology

Exhaust Aftertreatment and Emissions

A Mean Value Model of the Exhaust System with SCR for an Automotive Diesel Engine

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Nowadays requirements towards a reduction in fuel consumption and pollutant emissions of Internal Combustion Engines (ICE) keep on pushing manufacturers to improve engines performance through the enhancement of existing subsystems (e.g.: electronic fuel injection, air systems) and the introduction of specific devices (e.g.: exhaust gas recirculation systems, SCR, ...). Modern systems require a combined design and application of different after-treatment devices. Mathematical models are useful tools to investigate the complexity of different system layouts, to design and to validate (HIL/SIL testing) control strategies for the aftertreatment management.

This study presents a mean value model of an exhaust system with SCR; it has been coupled with a common rail diesel engine combustion black box model (Neural Network based). So, dedicated models for exhaust pipes, oxidation catalyst, diesel particulate filter and selective catalytic converter are developed. With this model a simulation study on a DOC-DPF-SCR exhaust system is performed, showing a good coherence with experimental data. This model has been intended as a flexible tool to perform the simulation of exhaust system behaviour for after-treatment control and diagnostic strategies development as well as system architecture analysis. On light–duty drive cycle, the behaviour of the after-treatment system applied to an Euro 5 B-segment vehicle is evaluated. The simulations have highlighted the necessity of accurate SCR control strategies to improve the warm-up phase and optimize reactant dosing.

Sequential Identification of Engine Subsystems by Optimal Input Design

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Complexity and nonlinearity of engines makes precise first principle engine models often difficult to obtain, as for instance for emissions. System identification is a well known possible alternative, successfully used in several automotive applications. In most cases system identification is concerned with the estimation of the unknown parameters of a known set of equations. Unfortunately, for many engine subsystems, there is no sufficiently precise or real time suitable model. This paper presents a sequential algorithm which allows to derive real time suitable models on line by a combination of model structure hypothesis of increasing complexity and an associated optimal input design and selection process. This paper introduces the method and shows its use both for a rather simple and a very difficult engine identification task, a dynamical model of the airpath of a Diesel engine and a dynamical model of nitrogen oxides and particulate matter.

Modeling of silencers for internal combustion engines: 1D-3D coupling, network of 1D elements and a generic 3D cell approach

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Increasing demands on the capabilities of engine simulation and the ability to accurately predict both performance and acoustics has lead to the development of multiple approaches, ranging from fully 3D to simplified 1D models. In this work it will be described the development and application of hybrid 1D-3D approaches and an innovative one based on the 3D cell element. This is designed to model the acoustics of intake and exhaust system components used in internal combustion engines. Models of components are built using a network or grid of 3D cells based primarily on the geometry of the system. This means that these models can be built without fundamental knowledge of acoustically equivalent systems making their range of application larger as well as making them simpler to construct. Due to the 3D nature of these models it is also possible to predict higher order modes and improve the accuracy of models at high frequencies compared to conventional plane wave approaches. The solution of the 3D cell is based on a staggered grid approach. The equations of mass and energy are solved at cell centers and the momentum equation at cell connections or boundaries. The 3D acoustic cell has been validated by comparing the predicted transmission loss to measured values for a number of standard configurations found in intake and exhaust systems. These include expansion and reverse flow chambers. The transmission loss has been measured using the two load technique.

Parameter Estimation for Physical Based Air Path Models of Turbocharged Diesel Engines – An Experience Based Guidance

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Physical based air path models lead to a substructuring of the highly complex engine systems into several interacting submodels of low order. They offer detailed process information, support advanced control system design and allow to significantly reduce the calibration effort. Hence, physical approaches are predestinated to cope with the rise in system complexity and with the increasingly challenging demands concerning air system performance. Whereas the basic model equations are known a general methodology to obtain the model parameters is lacking. The purpose of this paper is to shed light on the identification procedure and to offer the automotive engineer helpful advice to gain well calibrated simulation models. Analysing the air path equations the determining factors on the parameter quality are investigated. Based on the results sensible modifications of the test bed setup and the measurement strategy are presented. In addition the need for careful data processing is discussed. The comparison of simulation results and measurement data from the engine test bed proves the potential of the developed methodology.

Hybrid 2-Zone Diesel Combustion Model for NO Formation

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This paper presents a methodology which is able to calculate emissions over crank angle (CA) using the measured cylinder pressure. The models are based on a 2-zone Diesel combustion process calculation combined with data based methods to fulfill the objective of a wide operating range, for a later possible use in transients – differently from the standard methods, which usually work accurate only in a small range. The resulting hybrid or grey box oriented model structure offers many advantages when purely physical modeling is too complicated and the combination with data based methods allow to obtain better results. The workflow of CA based emission models on the basis of a 2-zone calculation is presented. The focus of this paper is to explain the development process of a nitric oxide (NO) formation model, which is accurate over a wide operating range. For future similar data based particulate matter (PM) models the shown workflow could be used too.

Air System and Diesel Combustion Model for a 4 Cylinder Engine in Real Time Computing Conditions: Application on a EU5 Personal Car with Diesel Particulate Filter

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In an industrial context, close to the start of production and development of Engine Control Unit (ECU) systems, it is necessary to validate the complete dataset of the application and thus, to run software tests on a real ECU which is connected to a closed loop HIL Test bench. In the field of application for the simulation of dataset and the reduction of real vehicle tests, it is required to simulate an engine behaviour in terms of mixture mass and energy flow rate, temperature and pressure. The aim of this work is to reproduce this engine behaviour with a focus on combustion process and component simulation models, Oxidation Catalyst (OxiCat) and Diesel Particulate Filter (DPF).

A model has been developed with the help of experimental data extracted from an Original Equipment Manufacturer (OEM) engine project. The experimental data available from the motor test bench (injected fuel mass, air flow, temperature, pressure, air fuel ratio λ ...) and the OEM geometrical data, serve as calibration data and parameterization for the model. A physical study of each component of the air system has been performed. The discharge coefficients, the efficiencies and heat transfers are defined and modelled according to the operating conditions for the air filter box, turbocharger, charge air cooler, throttle valve, intake and exhaust manifolds, EGR valve, turbine (including torques on the shaft), OxiCat and DPF.

Additionally, combustion models have been developed to simulate the influence of the injection strategy (pre, main, post and late injections) on the exhaust temperature and the pollutants emissions, which are taken into consideration in the exothermal

reactions inside OxiCat and DPF.

The results show that the model prediction in term of pressure, and temperature are in good accuracy with the OEM project data. The after treatment temperature behaviours in the OxiCat and DPF are well reproduced by the model.

It allows the engine management department to test all ECU software strategies, including the activation of diagnostics, and validated on a closed loop HIL Test Bench with the developed engine simulation model. According to overall environmental conditions (ambient temperature, atmospheric pressure, road shape,...) non regression tests are also possible to check any deviation of engine behaviour over the simulated driving cycle in comparison with a real car behaviour.

Development of an Open Source C++ Toolkit for Full-Scale Diesel Particulate Filter Simulation

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Multi-dimensional simulation of hydrodynamics in full-scale wall-flow Diesel Particulate Filters by OpenFOAMR® , an open-source C++ object-oriented CFD code, is presented. A new fast and efficient parallel numerical solver has been developed by authors to simulate flows through porous media and it has been tested for the simulation of diesel particulate filters; errors caused by discretization of filter monoliths have been corrected by the formulation of a correction factor, that has been included in the solver. A set of experimental data, available from literature, has been used for code validation.

Experimental Study of an LP EGR System on an Automotive Diesel Engine, compared to HP EGR with respect to PM and NOx Emissions and Specific Fuel Consumption

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Previous experimental studies on Diesel engines have demonstrated the potential of high-pressure exhaust gas recirculation (HP EGR) as an in-cylinder NOx control method. With ever more stringent emissions standards, the use of a low pressure EGR loop (LP EGR) seems to be an interesting method to further reduce NOx emissions while maintaining PM emissions at a low level. Actually, contrary to HP EGR, the gas flow through the turbine is unchanged while varying the EGR rate. Thus, by closing the variable geometry turbine (VGT) vanes, higher boost pressure can be reached, allowing the use of high rates of supplemental EGR.
Some experiments are conducted on a 2.0 l HSDI common-rail DI Diesel engine equipped with HP and LP EGR loops on a test bench under low and part load conditions, as those encountered in the European emissions test cycle for light-duty vehicles. The dilution ratio, boost pressure, as well as injection pressure are modified using the LP EGR loop to study the influence of boost pressure and injection pressure on combustion (instantaneous rate of heat release) and the NOx-PM trade-off (while varying EGR rate at a given boost pressure level), thus giving optimal boost pressure and injection pressure for each operating point in terms of NOx and PM emissions. In particular, higher boost pressures and EGR rates are studied, as compared with the original HP EGR loop. Finally, the impact on LP and HP IMEP, as well as ISFC, when increasing boost pressure by closing VGT vanes with the LP EGR loop is studied.

Analysis of Behavior of Fuel Consumption and Exhaust Emissions under Onroad Driving Conditions Using Real Car Simulation Bench (RC-S)

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The investigation of vehicle performances under on-road conditions has been required for emission reduction and energy saving in the real world. In this study, Real Car Simulation Bench (RC-S) was developed as an instrument for actual vehicle bench tests under on-road driving conditions, which could not be performed by using conventional chassis dynamometer (CH-DY). The experimental results obtained by RC-S were compared with the on-road driving data on the same car as used in RC-S tests. As a result, it was confirmed that RC-S could accurately reproduce the behavior of fuel consumption and exhaust emissions under on-road driving conditions.

Influence of Ignition Timing on the Exhaust Emissions of a Ford Escort Fuelled by Various Ethanol and Petrol Mixtures

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The influence of the ignition timing on the exhaust emissions of an old technology vehicle fuelled by various ethanol/petrol mixtures was investigated. All tests were carried out on a 1300cc Ford Escort equipped with a carburettor and without a catalytic converter. The reference petrol fuel E0 and the blends E10, E20 and E50 were used, at three different constant speeds of 30, 50 and 90 km/h, under full load with wide open throttle while the vehicle was on a chassis dynamometer. All measurements were taken at three different settings of the advance angle, at 0°, 4° and 12° BTDC. With the use of an exhaust gas analyser, the concentrations of CO, CO_2, HC, O_2 and NOX in the exhaust gases at the tailpipe were recorded. For the evaluation of the results the lambda value was calculated from the available recorded data. Changing the ignition timing, while using the blends E10, E20 and E50, had the same effects on the emissions as the reference fuel E0. By advancing the ignition timing, an increase of HC and NOx emissions were measured, while no particular trends were observed in the CO and CO_2 emissions.

Lack of legislation causes large problems with evaporative emissions

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A large share of hydrocarbon emissions from vehicles comes from evaporation from vehicles fuel system. Modern vehicles with positive ignition engines have therefore for more than 15 years in Europe been equipped with systems for evaporative control. During the Swedish in service surveillance testing program evaporative emissions were measured on positive ignition vehicles already in operation on road. Results of this program imply a failure rate of more than 30 percent on evaporative emissions. These results differ from a parallel in service surveillance testing program conducted in Germany, where less than 10 percent of the tested vehicles exceeded the limit for evaporative emissions. Based on these results further investigations were started to analyze the evaporative emission of vehicles driven on Swedish roads.

One of the major differences between Sweden and Germany that could explain the results was the fuel quality. In Sweden the petrol contained 5 percent ethanol whereas in Germany the fuel did not contain any ethanol at that time. A number of references point out the effect the ethanol has on both the capacity of charcoal canister and plastic materials. This suspicion was also proved to be right by results from some of the vehicle manufactures analysis. These showed high concentrations of ethanol in the charcoal canister.

A special project is also conducted where two similar vehicles are exposed for different fuel qualities. One of the vehicles uses the Swedish market fuel with 5 percent ethanol and the other uses reference fuel without ethanol. The vehicles are driven with the fuels up to 10,000 km. Evaporative emissions are measured in the beginning and in the end and charcoal canister capacity every 500 km.

In the program charcoal canister capacity was also measured. In most cases a low capacity could be connected to high evaporative emissions in the test. In some cases the capacity could however not explain the results. Also taking into account different tank materials gave better explanation of the results. Some tank materials

show clear problems with permeation losses.

Factors influencing the charcoal canister capacity are size and geometry of canister and the quality of the carbon. The permeation through the tank and pipes are influenced by the material. Also the purge strategy is very important. Some vehicle types do hardly any purge during city driving and cold starts. This means that the system for preventing evaporative emissions do not work during conditions where it is most important for human health.

There are large global differences in the legislation on evaporative emissions. The US regulation includes durability testing, in service conformity and OBD for evaporative control. The European legislation does not contain anything of this. The only thing in the European legislation is the type approval which is done on reference fuel not containing any ethanol. The long term effects seen in this program will not be prevented by going to a reference fuel containing ethanol during type approval. To prevent this either durability or in service conformity testing is needed.

Methodology for the analysis of a 4-stroke moped emission behaviour

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Mopeds are popular means of transportation, particularly in southern Europe and in eastern and southern Asia. The relative importance of their emissions increases in urban environments which host large fleets of mopeds. In Naples, for example, mopeds make a considerable contribution to HC emissions (about 53%), although the percentage of mopeds (12.4%) in the total circulating fleet is lower than that of other vehicle categories [1].
This study presents a method for analysing the influence of kinematic parameters on the emission factors of mopeds during the "cold-start" and "hot" phases of elementary kinematic sequences (speed-time profiles between two successive stops). These elementary sequences were obtained through appropriate fragmentation of complex urban driving cycles. In a second step, we show how to estimate, for the whole cycle, the duration of the cold phase and the relevant time-dependence function.
The method was applied to analyse the regulated exhaust emissions (CO, HC, NO_X) of a 4-stroke moped (Euro 2) tested on a dynamometer bench. The experimental data were compared with ARTEMIS and COPERT emission factors, two of the emission models available in Europe to calculate road traffic emissions.

Emissions of 2-Stroke Scooters with Ethanol Blends

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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.

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.

Off-road Emission Performance of SUV with Diesel and Natural Gas Powertrain

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This study is based on a project which addresses the reduction of CO2 and pollutant emissions of off-road vehicles. For this purpose the use of CNG drive trains in high alpine areas is an interesting alternative to the standard diesel technology. The same SUV with CNG and diesel powertrain has been measured and methodically compared with regard to fuel consumption and exhaust emission performance. These real-world measurements have shown the potential when applying a CNG concept for this utilization. Subsequently, the real-world on-board measurements were compared with the results of a simulation program for SUV off-road performance.

DPF Loading Analysis by a New Experimental Modus Operandi

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The loading of a DPF entails the need of trap regeneration by particulate combustion, whose efficiency and frequency are somehow affected by the way soot is deposited along the channels.
The aim of this work is therefore the development of a new experimental methodology able to provide fundamental information about the soot loading process inside the DPF, in order to take advantage of this insight for DPF design and optimization purposes.
Small lab-scale 300 cpsi DPF samples were loaded downstream of the DOC in an ad hoc designed reactor capable of hosting 5 samples, by diverting part of the entire flow produced by an automotive diesel engine at 2500 rpm x 8 BMEP, selected as representative of the most critical operating conditions for soot production during the New European Driving Cycle (NEDC).
Soot layer thickness was then estimated by means of FESEM observations after sample sectioning at progressive locations, obtained through a procedure specifically defined in order to avoid affecting the soot distribution inside the filter and to enable estimation of the actual soot thickness along the channel length.

Estimation of deviations in NO and soot emissions between steady-state and EUDC transient operation of a common-rail diesel engine

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The study measured Mass Air Flow, (MAF), Manifold Absolute Pressure, (MAP), and emissions of NO and soot during fourteen transients of speed and load, representative of the Extra Urban Drive Cycle (EUDC). The tests were conducted on a typical passenger car/light-duty truck powertrain (a turbocharged commonrail diesel engine, of in-line 4-cylinder configuration). The objective was to compare NO and soot with corresponding steady-state emission results and propose an engine measurement methodology that will potentially quantify deviation (i.e. deterioration with respect to steady state optimum) in emissions of NO and soot during transients. Comparison between steady state, quasi-steady-states (defined later in the paper) and transients indicated that discrete quasi-steady-state engine operation, can be used for accurate prediction of transient emissions of NO and soot. Furthermore, quasisteady- state engine characterisation quantified NO and soot deterioration that may occur due to MAF and MAP deviations from their optimised (steady-state) values. Therefore, the results from quasi-steady-state can be used to estimate deterioration in emissions during transients. These results are potentially of use in modelling with a view to assess component to engine compatibility during the engine development phase and minimise emissions deterioration (due to component ageing and production variability) during the life-time of engine.

Off-cycle, Real-World Emissions of Modern Light Duty Diesel Vehicles

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This paper investigates the emissions performance of modern European light-duty passenger vehicles with turbodiesel engines during real-world driving, notably during two extreme but not uncommon operating regimes: congested urban traffic and high-speed and performance driving. Four cars and one van were tested on a chassis dynamometer and/or on the road with a portable, on-board emissions monitoring system capable of online measurements of particulate and gaseous emissions. On all cars, operation at speeds and acceleration rates in excess to those within the applicable certification NEDC cycle resulted in higher concentrations of nitrogen oxide (NO) and particulate matter (PM). High-speed driving in excess of 120 km/h resulted in a marked increase in NO and PM concentrations, with further increases past 130-140 km/h. In urban driving, highest PM concentrations occurred at the onset of and during accelerations from low rpm. Aggressive, performance driving resulted in substantial increase in NO and PM emissions per kg of fuel compared to normal driving. No marked increases outside of NEDC regimes were, however, observed on the van. The results support the arguments against increase in 130 km/h freeway speed limits and for augmenting the EU certification tests for light diesel vehicles with supplemental cycles or tests.

Portable Emission Measurement System (PEMS) For Heavy Duty Diesel Vehicle PM Measurement: The European PM PEMS Program

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Portable Emissions Measurement Systems (PEMS) represent a robust and accurate solution to study the in-use emissions of combustion engines and are becoming part of the emissions control regulations, as evidenced by the latest requirements introduced in the United States. Their application is ranging from large heavy duty engines to small light-duty vehicles and off-road mobile machinery. Currently, PEMS for gaseous exhaust measurements exhibit performances that are close to the ones of laboratory grade systems, but the development of portable PM instruments remain a complex challenge, as simultaneous progress take place in engine and after-treatment technologies.

This paper presents the PM phase of the European PEMS program, aiming at checking the feasibility of PEMS to measure accurately particle mass at low PM levels. Several PEMS, (Dekati DMM, ETaPs, Horiba OBS TRPM, Sensors SEMTECH-PPMD, AVL MSS, Control Sistem micro-PSS) are evaluated in parallel under controlled laboratory conditions (i.e. on reference test cycles) against laboratory instruments using a Euro III and a Euro V heavy-duty engine, running on low sulphur fuel. Preliminary results are presented.

A preliminary study to evaluate emissions factors by real and micro simulated driving cycle

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Transport activities contribute significantly to the air pollution and its impact on emissions is a key element in the evaluation of any transport policy or plan. Calculation of emissions has therefore gained institutional importance in the European Community. To obtain emission factors several methods make use of only vehicle mean velocity, which can be easily obtained by vehicle flow and density in the road. Recently in ARTEMIS project by Rapone et al. (2005-2007) a meso scale emission model, named KEM (Kinematic Emission Model), able to calculate emission factor has been developed. This model is based on a new statistical methodology, capable to consider more attributes than the simple mean speed to characterize driving behaviour. An interesting approach to determine the exact mix of driving cycles is represented by the use of microscopic traffic simulation models that could be used to avoid the very expensive costs of experimental campaigns needed to obtain real driving cycle. For such a reason this preliminary study aims at testing the capabilities of four well known car-following models at reproducing real life trajectories and then at checking the errors introduced by using the simulated trajectories, in the place of the real ones, for calculating traffic emissions by means of the KEM emission model.

Real-world Emission Monitoring of Natural Gas Vehicles with Higher Mileage

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This study evaluates the potential of CNG propulsion systems for long-term operation. For this purpose, light and medium duty vehicles as well as passenger cars with very different service performance were investigated under real-world conditions. The research also includes tests of a vehicle with natural gas and biomethane to assess the effects of the energy supply on the performance. The demonstration and evaluation of CNG operational fleets with higher mileage provide a sustainable monitoring of clean propulsion systems based on innovative real-world in-car measurements. A benchmarking to the same passenger car with diesel powertrain was done as well. For a consistent comparison of the different test vehicles, the results for each drive test are presented as emission rates versus the mean vehicle speed.

Ignition and Extinction Characteristics of Three Way Catalysts

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Vehicle exhaust emission control systems are most often operated under transient conditions as inlet gas species concentrations, temperature and mass flow rate vary in accordance with the driving conditions. The main objective of this article is to study the ignition and extinction phenomena associated with the reactions that occur in three way catalysts (TWC), in particular to evaluate the dependence of the ignition and extinction of the TWC reactions on the precious metal loading (PML). To this end, we report here transient experimental data for two ceramic TWC with different PML, one referred to as TWC-L (low PML) and the other as TWC-H (high PML). The present measurements were carried out on a vehicle equipped with a 2.8 liter V6 spark ignition engine that has multipoint fuel injection. During the experiments, different TWC were in turn placed in the so called underfloor position (about 1 m away from the engine) replacing the original TWC installed on the vehicle. The vehicle was tested on a chassis dynamometer (Maha LPS200). The transient operating conditions were imposed by a servo that actuates the engine throttle. A dedicated software was used to control the servo and also for data acquisition. The data obtained include inlet mass flow rates, manifold absolute pressures, engine operating temperatures, engine speeds, signals from the lambda sensors, exhaust gas species concentrations and temperatures taken both upstream and downstream of the TWC, as well as temperatures in various locations within the substrate of the TWC. The present study was executed on a vehicle only during cold start and for extended idle periods. These modes provided exhaust conditions of temperature and flow that proved very valuable in evaluating and deducing sensitivity of TWC to ignition and extinction with respect to precious metal loading, exhaust temperature and other implied factors. The experimental data revealed that: i) the ignition location depends on the PML, in particular for the TWCL the

ignition starts at the back-end and for the TWC-H the ignition starts at the front-end; ii) for the TWC-H the ignition occurs at lower inlet gas temperatures and propagates faster which reduces both the heat-up time and the ignition propagation time; iii) the extinction process starts at the front part of the substrate for both TWC; iv) the inlet temperature required for ignition was always higher than the extinction temperature owing to kinetic, heat and mass transfer effects occurring in the TWC; and v) the differences observed between the ignition and the extinction temperatures depend on the PML.

Lean NOx Trap Aftertreatment Technology Impact on Engine Oil Dilution

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Euro 6 European legislation emission limits, expected to be introduced around the 2014 timeframe, Lean NOx Trap (LNT) Aftertreatment technology is today considered one the of candidate technology to allow diesel Engine to meet the future Euro 6 limit.

The working principle of the LNT is based on its capability to store the NOx engine out during the normal lean (excess of Oxygen) phase operation condition of the Diesel engine. The NOx will be then reduced in a dedicated regeneration phase which consist in creating for relatively short time a rich exhaust gas condition inside the LNT.

The LNT regeneration strategy lead to run a Diesel engine with a rich mixture out of the combustion as a Gasoline engine. This can be obtained using advanced air and fuel management. The fuel management implicate the use of delayed injections (after and/or post injections) which can have a direct impact on oil dilution.

In this paper, an experimental assessment of the additional oil dilution phenomenon, potentially introduced by the LNT application, was proposed. The first step of the work was the characterization, in several engine operating conditions, of the NOx storage capacity of the LNT catalyst tested.

The second step was the definition of an oil dilution test procedure for a LNT system that has to take into consideration DPF and LNT regeneration events contribution. The oil dilution was measured by chemical analysis of oil sample (viscosity @ 40 °C and 100 °C).

Development of the on-board dry DeSOx filter for diesel exhaust

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NOx emitted from diesel is one of the main air pollutants for most countries. To reduce the emission of NOx could promote to diffuse diesel vehicles. A NOx storage/reduction (NSR) catalyst has been developed for the diesels. The catalyst for NSR is strongly poisoned by sulfur. We have found good reaction of $CaCO_3$ with sulfur dioxide by using a thermogravimetry. We obtained desulfurization breakthrough characteristic for the sample of the $CaCO_3$ which is washcoated on the monolith. As a result, this sample which has specific surface area, of 100 m2/g, absorbed SO_2 about 0.43 ~ 0.45 $g\text{-}_{SO2}/g\text{-}_{CaCO3}$. In this experimental condition, The conversion of the sulfate does not depend on the amount of the supported $CaCO_3$. The absorption efficiency of these samples were more than 99.4%. According to this result, it was found that the necessary amount of the absorbent was supposed to be 0.538 kg or 2.1 L for 100,000 km running.

Energy Efficiency Analysis of Monolith and Pellet Emission Control Systems in Unidirectional and Reverse-Flow Designs

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The work aims at analysing the energetic performances of monolith and pellet emission control systems using unidirectional and reverse-flow design (passive and active flow control respectively). To this purpose a onedimensional transient model has been developed and the cooling process of different system configurations has been studied. The influence of the engine operating conditions on the system performances has been analysed and the fuel saving capability of the several arrangements has been investigated. The analysis showed that the system with active reverse flow and pellet packed bed design presents higher heat retention capability. Moreover, the numerical model put in evidence the large influence of the exhaust gas temperature on the energy efficiency of the emission control systems and the significant effect of unburned hydrocarbons concentration.

Development of Cooling Characteristics of Urea-Water Solution Dosing Modules for Automotive SCR systems

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International regulations are challenging automotive industry to develop more efficient systems for reducing diesel engines NOx emissions. Selective Catalytic Reduction systems may be a concrete solution, in fact SCR systems are already on the market, firstly developed for heavy duty diesel engine applications, and now it is beginning the spreading to light automotive applications.

The urea-water solution dosing module may be subjected to strong heat transfer, so an efficient heat dissipation is crucial step to avoid injector's severe damages, as deformations of internal components or solenoid's fault. To have a system less complex and consequently less expensive, the dosing module air cooling should be preferred to liquid cooling. Obtain an efficient heat dissipation from the injector holder unit can represent a hard task: consequently dosing module design must be careful.

In this paper is presented an experimental and numerical analysis for different possible solutions to be implemented in order to ensure in all conditions an efficient heat dissipation. Particular attention is paid to thermal characteristics of materials and to peculiar heat transfer paths that can be set-up and exploited to fulfill the task. In this paper are discussed the different design solutions considered and respective performance.

A new exhaust design for reducing health risk associated with Diesel-PM

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A new vehicle exhaust concept is presented which leads to a reduced risk for the health and for the environment from submicron Particulate Matter (PM). The geometry of the exhaust induces particle grouping and coagulation leading to a shift in particle size distribution, which increases the mass/number of the larger particles at the expense of the reduction in the amount of smaller ones. Such a shift in size distribution has implications with respect to particle capturing from Diesel engines as well as from other facilities, and with respect to lower residence time, and hence exposure time, of smoke particles which are emitted to the air. The mathematical model and the supportive experiments will be described. The model presents the regimes, in terms of the operating conditions, where particle grouping and coagulation are expected and serves as a practical tool for the design of the exhaust geometry accordingly. In addition, the design is shown to be easy to apply in vehicles and lift systems. The use of this new concept will help reduce PM concentrations in main roads and in a variety of work places, and will impose less risk to the health and to the environment.

Silicon carbide based biomorphic porous ceramics as catalyst support for exhaust gas aftertreatment

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Light-weight biomorphic porous SiC based ceramics derived from paper preforms were produced by chemical vapour infiltration (CVI) for application as catalyst support for exhaust gas aftertreatment as alternative for the commercial monoliths. The composition and the structure of the ceramics as well as their porosity can be easily controlled in a wide range varying the CVI process parameter. The paper preforms were first converted into bio-template (Cb) by pyrolysis in inert gas atmosphere up to 800°C, followed by CVI with methyltrichlorosilane (MTS) in presence of hydrogen at temperatures in the range 900-1100°C. The carbon fibers of the template (Cb) were covered with thin ceramic layer which composition (SiC or Si/SiC) and microstructure (amorphous or crystalline) depends on the infiltration temperature and the MTS/hydrogen ratio. An additional thermal treatment of Cb/Si/SiC at 1300-1500°C in nitrogen containing atmosphere leads to SiC-Si3N4 composite ceramic as a result of formation of reaction bonded silicon nitride.
The effect of the composition and microstructure of the resulting biomorphic ceramics on their oxidation behavior at high temperatures - 1050 and 1450°C - under isothermal conditions during 50 hours in airflow was investigated by thermo gravimetric analysis (TGA). The morphology of crystalline SiC ceramic shows only small cracks being covered with a thin protective SiO2 layer. Introducing a second phase of Si3N4 in addition to SiC had a significant effect on the mass change after oxidation, microstructure and mechanical properties of the ceramics. In this composite, the oxidation rate decreased with increasing the Si3N4 content as well as with the degree of crystallization. Additionally, the presence of a Si3N4 phase reduces the thermal expansion mismatch between SiO2 and SiC resulting in relatively crack free and well-bonded layers. In conclusions, the oxidation resistance of crystalline SiC and SiC-Si3N4 ceramic composites is adequate for long service times under isothermal oxidation conditions in airflow at 1050°C and 1450°C.
Winding forms with variable cell density can be produced from paper and converted into ceramics with controlled composition, microstructure and porosity using CVI technique. They can be used as catalyst support for exhaust gas aftertreatment.

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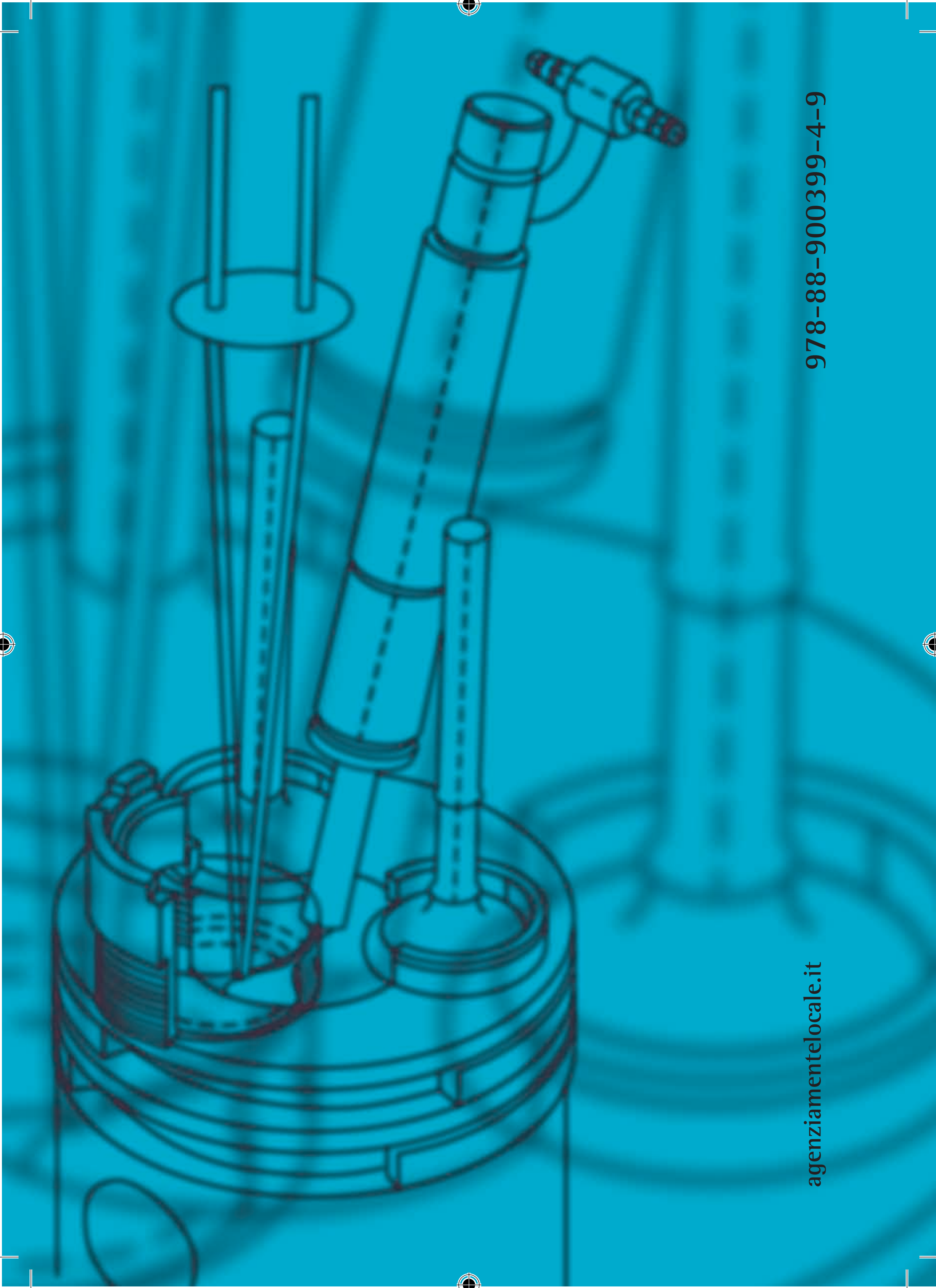

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