New calibration method and tool to minimize emissions on cold-start driving cycle

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Abstract: Due to their technology complexity, Diesel engines require efficient calibration methodologies to tune engine control parameters. Several approaches are proposed based on Design of Experiments. Nevertheless most of the methodologies require several steps to optimise hot and cold settings, as well as after treatment system.

A new calibration methodology has been set up which allows to optimise simultaneously the cold and hot control maps in steady-state conditions while taking into account after treatment systems efficiency. This method combines local statistical models coming from DoE and global objectives for optimisation. A vehicle with Euro4 Diesel engine without DPF has been recalibrated with an innovative bio fuel in order to reach Euro5 emission levels with the help of this methodology.

Second part of this paper presents a calibration tool, named ICE², which allows to use this methodology. This tool is engineered in order to satisfy 4 main objectives: propose several approaches according to the user needs, optimise calibration process in terms of duration and quality, provide an easy calibration data management, and help the user to go surely through the calibration tasks without being a maths specialist. The workflow and the main characteristics of the tool are described.

Last part of this paper presents and discusses the ongoing developments of the method and of the tool.

Keywords: calibration, DoE, driving cycle, thermal effect.

1. Introduction

Customer requirements, greenhouse gas reduction and pollutant emissions regulations lead to more and more complex Diesel engine and exhaust gas after treatment technologies. One of the consequences is an increase of the number of control parameters to set up engines. Thus the development of efficient calibration methods becomes a major issue to minimize this time-consuming and costly task. Design of Experiments (DoE) is one of the solutions currently proposed to tackle these issues [1]:

Several kinds of DoE methods could be proposed
- full local, i.e. using local models and local optimisation of responses with final smoothing between local optima to obtain updated control maps;
- global, i.e. using global models (including speed and load) of engine responses from which direct optimisation of setting maps could be realized;
- mixed, i.e. using local models but direct optimisation of setting maps with constraints on a weighted sum of operating points.

Each method has advantages and drawbacks as detailed in a previous paper [2]. Local models are more accurate and easier to obtain, which made them a widespread methodology. But local optimisation requires the choice of local objectives and smoothing destroys optimality. Global models could be insufficiently accurate if the number of points is too low. They require long continuous test duration. Conversely global models could be used for several applications of the same engine and direct optimisation of maps is very powerful to obtain optimal maps when keeping regularity. Mixed method appears as an interesting compromise between both methodologies, if the set of operating points is chosen carefully to be used for several applications and if the weighting process is efficient.

Nevertheless, although regulation takes into account emissions on driving cycle as soon as engine starts at ambient temperature, thermal dimension is most of the time not directly taken into account in calibration methods. The usual calibration process consists in a sequential approach by performing the warm conditions calibration before the cold one.

Also, engine settings are most of the time optimised without taking into account their local interaction with after treatment system, which efficiency is only taken into account globally when fixing the objectives of optimisation.

The objectives of the methodological work we undertake are:
- develop calibration methods able to deal with complex calibration problems, and especially to optimise simultaneously hot and cold settings and to integrate after treatment efficiency;
- develop a calibration tool able to propose several calibration approaches, including the previous one, with a user friendly environment accessible to non maths-specialist and allowing...
to manage the great quantity of data of industrial calibration.

This work is a long-term action whose midway step is presented in this paper with illustration by application cases and perspectives.

2. Presentation of the mixed calibration methodology taking into account thermal effect and after treatment efficiency

The mixed calibration approach allows to keep the simple local models (coming for example from hyper cubic DoEs) used by the local approach, and consequently simple test bench process, but offers the ability to optimise and smooth the setting maps in a unique step with cumulated emissions target over the driving cycle.

One of the main tasks of this approach is the calculation of the OP weights in order to get some representative cumulated emissions for a given trace of the cycle.

Two methods based on barycentre principle have been developed:

- distance method: the shorter the distance between the trace and an OP, the higher will be its weight
- algebraic method: same principle but taking into account ratios of algebraic areas formed by three OPs chosen among the closest.

One other important task is the optimisation process which consists in directly optimising the cumulated engine responses over the cycle. For this purpose, distortions of the engine maps are generated instead of optimising individually the selected OP and building afterwards the engine maps by the smoothing step. The cumulated engine responses over the cycle are approximated by the weighted sums of the local models at the chosen representative OPs. The mixed map optimisation problem is then formulated as follows:

\[
\min \sum_{l=1}^{N_{op}} w_i F_i[l] \left[ m_3^p (r, c_1), m_3^{up} (r, c_1), \ldots, m_3^{op} (r, c_1) \right]
\]

subject to

\[
l(r, c) \leq An^p(r, c) \leq u(r, c)
\]

\[
\sum_{l=1}^{N_{op}} w_i F_i[l] \left[ m_3^p (r, c_1), m_3^{up} (r, c_1), \ldots, m_3^{op} (r, c_1) \right] \leq S_j
\]

where:

- \((r_i, c_i)\) are the coordinates of the OP \(l\)
- \(F_i(l)\) is the local model of the engine response \(i\) associated with the OP \(l\)
- \(m_3^{p}\) are the 2D engine maps of the control parameters in the (engine speed, load) operating domain.

The previous formulation requires an adapted parameterisation of the engine maps in order to limit the total number of unknowns in the optimisation process. This parameterisation has to be also flexible enough to model the different shapes of engine map surfaces. LoLiMoT (Local Linear Model Tree) models seem to be a good compromise between flexibility, accuracy and complexity: some very simple local models (linear or bilinear) are combined using a weighted sum. These models were more deeply explained and an example of application of this method was presented in previous references [2, 3].

In this calculation, different kinds of constraints can be introduced for the optimisation:

- global constraints on cumulated emissions;
- constraints on the parameters (limits of operating space);
- local constraints on the responses;
- smoothing constraints on the parameter maps;
- dispersion constraints (to take into account parameter dispersions and avoid that optimal setting could finally not be applied).

Introduction of the thermal dimension

The objective is to extend the mixed methodology to take into account the thermal dimension, which effect occurs on cold-start driving cycles (as for example NEDC).

For that, cold and warm parameter maps (or cold correction maps) will be simultaneously optimised and local emissions models will be obtained from DoE in cold and warm conditions.

The key step is the adaptation of the OPs weights, with a good balancing between cold and hot OPs, in order to estimate cumulated emissions over a cold start cycle.

Two methods have been used one after the other for this purpose:

- first method consist in assigning one part of the trace to cold OPs (until a given temperature) and the other to hot OPs. This method, called mixed 2D+, is simple but limited in performance.
  For example, we can consider the 2 first ECE cycles of NEDC (reaching 60°C see figure 3) as cold part of the NEDC cycle and the 2 last ECE cycles + EUDC as hot part. Figure 1 presents the distribution of cold and hot OPs on a NEDC cycle.

- second method consist in assigning to each point of the trace a weight distributed between hot and cold OPs. This method has been called mixed 2.5D
A calculation method has been developed and is illustrated in Figure 2. At each second of the cycle, a weight is attributed to three warm OPs and three cold OPs. The distribution of the assigned weight to cold or warm OPs is calculated from an evolution law depending on the coolant temperature. The main issue is to determine a relevant evolution law in order to be representative of the engine behaviour during the engine warm up.

Some preliminary tests must be performed in order to consider the impact of engine warm up on the pollutants emissions. After the engine starts, the evolutions of the pollutants emissions are observed. An example is given in Figure 3.

The tests were performed on several OPs and the engine behaviour appears similar in all cases. Thus it is possible to define a linear or quadratic dimensionless law for each engine out emission giving a good approximation of the evolution with temperature. These laws, will be implemented in the calculation of OP weights.

Note that the modelling of engine response against temperature will be still improved if we use more than 2 levels of temperatures. The weight of each point of the trace will then be spread between the 6 closest points in the (engine speed, load, temperature) 3D space.

Introduction of after treatment efficiency

In addition to this process, it is interesting to consider the evolution of after treatment efficiency during the cycle. Indeed, in the case of the presence of a Diesel Oxidation Catalyst (DOC), it is not relevant to further decrease the HC or CO emissions during the parts of the cycle where the DOC is fully activated.

Therefore, we include a factor representing the DOC efficiency during the weighting procedure in order to be representative of the pollutants emissions downstream the catalyst. It is assumed that the DOC efficiency is only a time-varying factor in this case.

3. Test case

Main specifications of the experimental apparatus

We used a 1.6-litre four-cylinder Diesel engine (DV6 ATED 4 from PSA Peugeot-Citroën). Main specifications of the engine are detailed in Table 1. The engine configuration includes a single turbocharger with a high pressure cooled exhaust gas recycling (EGR) loop. The injection system consists in Bosch CRI 2.2 injectors with injection pressure as high as 1600 bar. The exhaust line is made up of a Diesel oxidation catalyst (DOC) and a Diesel particulate filter (DPF). The engine is mounted in a Citroën C4 that satisfies Euro4 emissions standard.

<table>
<thead>
<tr>
<th>Compression ratio</th>
<th>18:1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bore mm</td>
<td>75</td>
</tr>
<tr>
<td>Stroke mm</td>
<td>88.3</td>
</tr>
<tr>
<td>Maximum power kW</td>
<td>66 @ 4000 rpm</td>
</tr>
<tr>
<td>Maximum torque Nm</td>
<td>250 @ 2000 rpm</td>
</tr>
</tbody>
</table>

Table 1: Engine specifications

Several facilities have been used for this study such as a roller test bed and a dynamic test bench driven by MORPHEE for the reproduction of the New European Driving Cycle (NEDC). The dynamic test bed provides a representative behaviour of the vehicle for example in Figure 4 concerning the thermomanagement.
Innovative Technologies for future Emissions targets
– New calibration method and tool to minimize emissions on cold-start driving cycle

Figure 4: Coolant temperatures comparison between engine test bed and vehicle

Moreover, this study is also part of a project concerning the use of bio fuels to deal with the issues of energy diversification and greenhouse gas emissions. Hence an Ethanol based Diesel fuel was chosen; the fuel formulation is deeply described in the reference [4]. The effect of this fuel on the combustion behaviour and on the pollutants emissions has been investigated in previous publications [4,5]. It has to be highlighted that the vehicle and the power train are not modified to use this innovative blend formulation. The only adaptation concerns the engine control settings calibration, in order to reduce the higher HC and CO emissions due to the new fuel which reduces conversely particulates emissions. The results presented in this part of the publication are obtained using this formulation.

As the normalized cycle starts at 20°C, it is required to present the cold conditions management whose control architecture is described in Figure 5. It consists in a correction map combined with a factor added to the warm conditions settings. This is a similar architecture for each engine parameter (rail pressure, air mass flow, etc.). This cold phase of the NEDC has a major effect on pollutant emissions and it is mandatory to assess engine and after-treatment devices behaviours during the temperature rise and therefore to update the calibration.

<table>
<thead>
<tr>
<th>Engine Speed</th>
<th>Warm Maps</th>
<th>Corrected Maps</th>
<th>Set Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coolant temp</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

Figure 5: Cold management in ECU

Results at engine test bed

For this application, a total of 25 OP (16 warm OP, 8 cold OP and idle) were chosen. Table 2 presents the comparative results between 2D+ and 2.5D methodologies obtained directly from map optimisation after optimisation on a cold start NEDC cycle. The goal was to minimize NOx emissions with global constraints on HC and CO emissions and local constraints on noise. It can be seen that slightly better reduction in NOx emissions is obtained with 2.5D methodology.

<table>
<thead>
<tr>
<th>Reference maps</th>
<th>2D+ method</th>
<th>2.5D method</th>
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<tbody>
<tr>
<td>CO2</td>
<td>100</td>
<td>101,6</td>
</tr>
<tr>
<td>CO</td>
<td>100</td>
<td>67</td>
</tr>
<tr>
<td>NOx</td>
<td>100</td>
<td>96</td>
</tr>
<tr>
<td>HC</td>
<td>100</td>
<td>58</td>
</tr>
</tbody>
</table>

Table 2: Test bench results for the 2D+ and 2.5D mixed approach

Vehicle results

The figure 6 shows a comparison between instantaneous HC emissions obtained with 2.5D + after treatment methodology (results after weighting between emissions models and including DOC efficiency) and emissions measured after DOC at roller test bench. It can be seen a quite good accordance between both results.

Figure 6: Theoretical and real instantaneous emissions of HC

The main results of the 2.5D calibration and 2.5D + after treatment calibration methods are presented in Figure 7, in comparison with results with baseline case using the original engine control maps (reference) and results of a sequential method, described in a previous paper [5] using global methodology for optimising hot part and local methodology for optimising cold settings. The emissions are measured at roller test bed downstream the after-treatment device. The aim of the calibration during the first urban cycle is to minimize CO and HC emissions while constraining CO2 emissions level.
It can be noticed that CO2 emissions are similar whatever the calibration approach. HC and CO emissions are strongly decreased with all methods. Mixed 2.5D method allows to limit NOx emissions increase on the first cold ECE1 when reducing HC and CO emissions. Including the DOC efficiency in the optimisation process allows to further enhance the HC and CO emissions reduction in cold conditions by focusing the effort on these responses on the cold operating points. It appears that 2.5D method shows that it is possible to improve still a little the initial result obtained with sequential global hot + local cold method.

![Graph showing CO2, CO, NOx, HC, PM emissions on cold start NEDC with different approaches.](image)

**Figure 7: Vehicle results on first urban cycle and on the whole NEDC with the different approaches**

Seeing the results obtained with 2.5D mixed method, we performed a new set of tests with sequential global hot + local cold method improving the NOx emissions on EUDC part of cycle when relaxing CO and HC emissions on this part and constraining them more on cold part. It can be seen on the table 3 that the final goal of this work, which consists in reaching Euro 5 emissions standard when recalibrating the Euro 4 vehicle (without DPF) with the new bio-fuel, has been finally reached.

![Graph showing CO2, CO, NOx, HC, PM emissions on whole cold start NEDC with different approaches.](image)

**Table 3: final results of recalibration of the Euro 4 vehicle to reach Euro 5**

<table>
<thead>
<tr>
<th>Test configuration</th>
<th>Fuel</th>
<th>Diesel</th>
<th>Biofuel</th>
<th>Biofuel</th>
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<th>Euro 4</th>
<th>Euro 5</th>
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<tr>
<td></td>
<td></td>
<td>Standard</td>
<td>Standard</td>
<td>New</td>
<td>SM</td>
<td>PM</td>
<td>g/km</td>
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<tr>
<td></td>
<td></td>
<td>0.136</td>
<td>0.177</td>
<td>0.143</td>
<td>0.205</td>
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<tr>
<td></td>
<td></td>
<td>0.203</td>
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<td>0.300</td>
<td>0.500</td>
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<tr>
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<td></td>
<td>0.020</td>
<td>0.131</td>
<td>0.087</td>
<td>0.230</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. **Presentation of the ICE² tool**

ICE² stands for Integrated Calibration Environment for Internal Combustion Engine. The development of this new software is continuously progressing and is currently at its third version.

The tool was designed to facilitate and speed up engine calibration work using a model based approach. Thus, it is highly oriented for that purpose and provides to the user many helpful innovative features all along the workflow: from the cycle analysis, to the design of experiments, the modelling of engine responses with control parameters and coupled-interactions, the optimisation of control settings and eventually to the delivery of final maps after a validation step.

The software, developed in a .Net framework environment is divided into three main nodes: Cycles, Engine outputs, and Maps. All of these nodes are connected together, allowing to follow a fully-integrated calibration process.

**Cycle node:**

The user imports a cycle trace (coming from cycle simulation or real test on roller test bed) that may be a regulated cycle, or any other type of cycle (from an OEM’s specific cycles, hybrid). The injection cut-off information allows specifying when the engine is producing torque or being driven (figure 8).

![Graph showing cycle trace importation.](image)

**Figure 8: importation of cycle trace**

Each time-step of the cycle is associated to an Operating Area (OA) corresponding to different engine control mode settings such as: injection pattern (w or w/o single pilot, double pilot, split main, etc), air path regulation (PWM, Pboost), or engine temperature.

In the local and mixed approaches, the cumulated engine responses over the cycle are approximated by the weighted sums of the local models at several operating points (OP), located in order to best represent the cycle.
The figure 9 presents the OP set used for the case presented in the previous section (16 hot OPs in OA1, idle in OA2, 8 cold OPs in OA3).

The following step consists in weighting these OPs according to the trace. Both distance and algebraic methods are available in ICE². The figure 10 presents the weighting between OPs corresponding to the previous case with algebraic method.

Eventually, ICE² provides a way of checking the OPs choice and weighting by using constant-speed load sweeps data as a reference. Thus, testing different combinations is easier. And this permits to find a good trade-off between a low number of OPs and a good estimation precision.

The figure 11 presents the validation of weighting with CO₂ emissions.

**Engine outputs node:**

The previous step leads us to determine a good choice of OPs that can describe the studied cycle by a steady-state local approach.

In the Engine outputs node, the engine behaviour and responses will be locally modelled for each OP. Design of experiments will be used for that purpose, with the following workflow:

Domain definition is the first and critical task as it will set the boundaries of engine’s parameters during testing. An automatic domain definition based on linear constraints has been implemented in ICE². It takes into account extreme limits defined by the user, and best fit the domain. The figure 12 presents the air path boundaries (Pboost, Air mass flow) in a 2D diagram for two injection parameters set.

The next step consists in designing the test matrix for parameter variations. The user has the choice of using optimal and space filling design, and decides the number of points he wants to generate for fitting, validation, and repeatability purposes. Those will be intelligently distributed among the domain, and then saved and sent to the test bed automation system. The figure 13 presents all pair wise projections of a 6-parameter DoE.
Test data are then imported into ICE² for response modelling. The user has the choice either to use polynomials or kriging models.

Kriging modelling is a method for spatial interpolation based on the theory of Gaussian processes. Kriging takes into account the spatial dependence of data, which means that close points will have close predicted values and the confidence intervals in-between will remain narrow. Such models are very flexible, return gradient of estimation and allow the measurement errors to be taken into account. A unique parameter has to be provided, or can be adjusted automatically. These models are used in association with space filling design of experiments for modelling responses in wide domains in which the accuracy of polynomials models is insufficient.

For polynomials models, second and third order models are available and can be independently chosen for each response. Stepwise and Box-Cox transformation can also be set up.

Statistical calculations and visualisations help judging model quality. The user can choose to ignore one or all responses of test points, and improve iteratively his models. The figure 14 presents modelling results with several statistical indicators of model quality.

If local approach is chosen, last step of workflow into the engine outputs node is local optimisation. It consists in finding one optimum set of control parameters for each OP. This is done minimizing one engine response (NOx, BSFC, etc.) under constraints on others (noise, CO, HC, etc.). Dispersions of engine’s parameters can be taken into account at that step by limiting engine’s local domain at its borders during the optimisation process. Eventually, the user can compare the optimum with the response obtained with the original setting. The figure 16 presents four responses scatter plot NOx emissions vs BSFC, smoke, noise, and soot. The “R” symbolizes the initial or reference setting, “1” the chosen optimum.
For local approach, once all optimum settings have been found on each OP, last work is to integrate those into original maps. This has to be done taking into account smoothing constraints. As a consequence, original optimum settings can not be strictly respected, and this imply a degradation of cumulated results. ICE² provides a series of tool to help solving these issues in an efficient way.

Original maps can be imported (DAMOS format is supported) and then easily visualised in ICE² with localization of OPs (figure 17).

The user has then to create a new set of maps including optimal settings. In this example, it is a cycle driven optimisation, and it will be then possible to use the OPs weighting to directly estimate cumulated emissions with the settings chosen on each OP. Also, a rough integration of the optimal settings founded during local optimisation would lead to a poor regularity of maps. It is then important on one hand to clearly state the extent of the regularization area and on the other hand to give tolerances around each parameter to increase the overall degree of liberty for maps deformation and to ensure connection to fixed surrounding area. These tolerances can be entered manually or can be proposed by the software. To do so, the user selects one cumulated engine response over the cycle (NOx, CO2, etc), and decides at which extent the maps smoothing operation will potentially modify it. Knowing this information and the weight of each OP, the algorithm uses the gradient of response at optimised sited and estimates corresponding parameters changes.

In case of mixed approach, the local optimization and smoothing steps are replaced by a unique step consisting in performing direct optimisation of maps. For this purpose the user has to choose a modelling type of engine maps (either bilinear or LoLiMoT parameterisation are proposed), the areas into which each map will be optimised and connected to the other part of map (regularisation area) and the different constraints listed in part 2 (global constraints on cumulated emissions, local constraints on the responses, limits of operating space, smoothing constraints on the parameter maps, dispersion constraints).

Eventually, the smoothing operation or direct optimisation of maps can be both analysed by comparing results of original maps, rough optimum integration maps, and final smoothed maps. The user has access to a map regularity index, to an image of the smoothness, and also to cumulated engine responses (emissions, fuel consumption, etc).

The figure 18 presents results after maps smoothing: regularity indexes of maps, initial and final cumulated emissions.

The figure 19 shows a 3D comparative view of the initial and final rail pressure maps.

The figure 20 presents time plot views of NOx and CO2 instantaneous and cumulated emissions.

Final maps can be exported easily in order to test results on an engine or roller test bed.
5. Outlook

Further work is in progress concerning calibration methodology and tool development.

Concerning calibration methodology, the work aims to go one step further than the methodology presented in this paper by taking into account the interaction between engine and after-treatment system. For that goal we will develop a global modelling of engine response including thermal behaviour, which will interact with a model of after treatment system including thermal and chemical effects. This methodology will be applied to DOC but also to SCR system.

Concerning the calibration tool ICE², whose third version already allows to use the 2D+ method, we currently work on finalizing the implementation of the 2.5D method including the after-treatment system efficiency as a function of time, and on introducing an evaluation of robustness of optimal settings. Further step will be the introduction of the global approach, whose algorithms have already been developed and used but need to be integrated in the user friendly environment of the tool.

6. Conclusions

To reduce the duration of calibration phase of Diesel engine, and then their development cost, efficient calibration methodology and tool based on DoE has become mandatory.

The mixed approach presented in this paper is a pragmatic way to optimise in a shorten time engine setting in order to satisfy emission legislation. It uses local model of engine responses against control parameters and requires then simple DoE tests. One of its main advantages consists in approximating the cumulated engine responses over the cycle by the weighted sums of the local models at several operating points. This method allows taking into account the thermal dimension of calibration problem and avoiding calibrating the engine in two steps, i.e. a first optimisation of parameter in hot conditions, then an adjustment of cold corrections. An other interesting aspect of this approach is the ability to optimise directly the control parameter maps, avoiding the local optimisation of each operating point and the tedious and optimality-destroying smoothing phase. Last advantage of this method is the ability to take into account efficiency of after treatment system against time which allows to focus the optimisation effort on each pollutant in the phase where the engine out emissions are not converted.

Good results have been obtained on a calibration project consisting in re-optimizing an Euro4 Diesel engine without DPF using a new bio-fuel in order to reach Euro5 standard. The next step of methodology development work aims to take into account interaction between engine and after treatment, with the use of global models taking into account temperature dimension.

A calibration tool, called ICE², is developed in order to facilitate and speed up the engine calibration work. The tool offers several calibration approaches that the user will select according to the specificity of his application. It guides the user into the workflow, offers many views to analyse computation results and manages the great amount of data generated by a calibration project. The present version of the tool allows to use the mixed calibration approach. Next
version will offer the ability to use the global approach.

7. Acknowledgements

The authors would like to acknowledge the other IFPEN people involved in the field of this work, especially F. Chaudoye, B. Lecointe, D. Sinoquet and F. Wahl for their active contribution.

8. References


9. Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AFR</td>
<td>Air Fuel Ratio</td>
</tr>
<tr>
<td>BMEP</td>
<td>Break Mean Effective Pressure</td>
</tr>
<tr>
<td>BSFC</td>
<td>Break Specific Fuel Consumption</td>
</tr>
<tr>
<td>CO</td>
<td>Carbon monOxide</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon diOxide</td>
</tr>
<tr>
<td>DOC</td>
<td>Diesel Oxidation Catalyst</td>
</tr>
<tr>
<td>DPF</td>
<td>Diesel Particulate Filter</td>
</tr>
<tr>
<td>DoE</td>
<td>Design of Experiments</td>
</tr>
<tr>
<td>ECE</td>
<td>European Urban Driving Cycle</td>
</tr>
<tr>
<td>EGR</td>
<td>Exhaust Gas Recirculation</td>
</tr>
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<td>EUDC</td>
<td>Extra Urban Driving Cycle</td>
</tr>
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<td>HC</td>
<td>HydroCarbon</td>
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<td>LoLiMoT</td>
<td>Local Linear Model Tree</td>
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<td>New European Driving Cycle</td>
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<td>NOx</td>
<td>Nitrogen Oxides</td>
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OA: Operating Area
OEM: Original Equipment Manufacturer
OP: Operating Point
OS: Operating Space
PM: Particulates Matter
PWM: Pulse Width Modulation
RMSE: Root Mean Squared Error
About D2T Powertrain Engineering

D2T Powertrain Engineering offers the synergy of two complementary activities: engine and powertrain engineering, and equipment and test bed engineering.

In engine and powertrain engineering: D2T offers a wide range of services from design - studies, system and control simulation - to calibration and testing. These services are provided at both its own test centers and its customer sites.

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The research programs center around:
- low-carbon IC engines,
- vehicle hybridization and electrification,
- fuels and biofuels,
- aircraft engines,
- pollutant after-treatment technologies,
- vehicle synthesis and integration.
Innovative Technologies for future Emissions targets – New calibration method and tool to minimize emissions on cold-start driving cycle

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