

# DECADE Newsletter

Issued for the workshop  
***'Modelling emissions and fuel consumption of vehicles operating in dynamic conditions'***  
Brussels, 18 September 2003

DECADE is a project funded under the 5<sup>th</sup> Framework Programme of the European Commission in the programme Energy, Environment and Sustainable Development. The full title of the project is 'Development and Validation of a highly accurate emissions simulation tool capable of comparatively assessing vehicles operating under dynamic conditions'.

The DECADE consortium exists of the four principal partners

- *MIRA, United Kingdom, project coordinator*
- *IDIADA Automotive Technology, Spain*
- *CLE (Centre of Logistics and Expert Systems), Germany*
- *Vito (Flemish Institute for Technological Research), Belgium*

and the associated partners

- *Transports de Barcelona, Spain*
- *City of Salzgitter, Germany*
- *Kraftverkehrsgesellschaft mbH Braunschweig (KVG), Germany*
- *De Post / La Poste, Belgium*
- *University of Lund, Sweden*

The project lasts from April 2000 until September 2003.

The aim of the project is to produce a microscopic (i.e. at vehicle level) simulation tool for the simulation of fuel consumption and emissions (CO<sub>2</sub>, CO, THC, NO<sub>x</sub> and PM) for real traffic transient vehicle operation. The specific task was to include a method for calculating dynamic emissions, and thereby reaching higher accuracy than traditional emission simulation modelling. The final simulation tool calculates emissions and fuel consumption on a second-by-second basis for a specific vehicle on a given speed profile.

The emission simulation tool developed within the project is called **VeTESS**, which stands for **V**ehicle **T**ransient **E**missions **S**imulation **S**oftware. It is based on a detailed calculation of the engine power required to drive a given vehicle over any particular route. This includes the rapidly changing (transient) demands placed on the engine, an area that has proved an obstacle to accurate simulation in the past.



The project has focused initially on three vehicles (with different engine technologies), representing typical European light vehicles. The selected vehicles were:

- a EURO IV gasoline passenger car (VW Polo 1.4 16V, same platform as Skoda Fabia and Seat Ibiza),
- a EURO III family-size diesel car (Skoda Octavia TDI 90 HP, same platform as VW Golf, Audi A3 and Seat Toledo)

- and a EURO II light commercial vehicle (Citroen Jumper 2.5D, also marketed as Citroen Relay in the UK, same platform as Peugeot Boxer and Fiat Ducato).



Figure 1: DECADE control vehicle models

### ENGINE TESTS

The engines have been tested outside the vehicles to yield a set of data that fully describes the emissions they produce under steady and transient conditions. This implies that dynamic ‘engine-with-aftertreatment’ maps are developed from dynamic engine dynamometer tests. The engine tests are performed on Vito's E<sup>2</sup>Trac engine dynamometer with VOEMLow as emission measurement equipment for simultaneous pre- and post-catalyst emission measurements. These data sets have been incorporated into the simulation tool to provide models for these three vehicles.

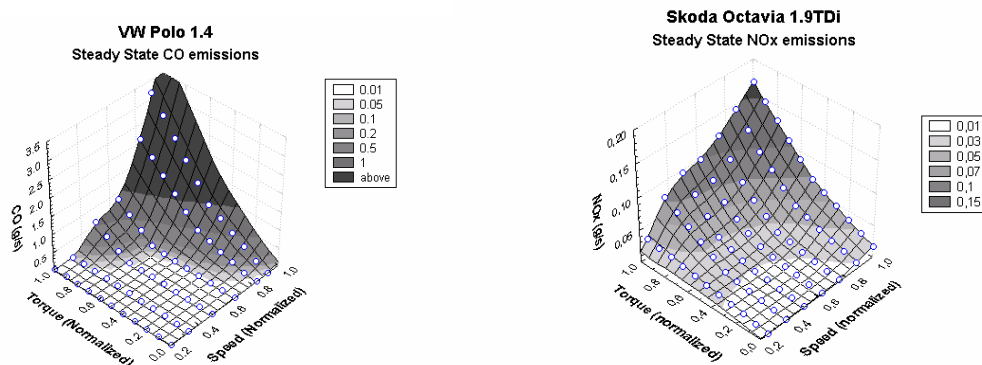


Figure 2: Steady state engine maps for VW Polo (CO) and Skoda Octavia (NO<sub>x</sub>)

### VEHICLE TESTS

In order to potentially refine the modelling algorithms used within VeTESS, several parameters which were thought to have influence on emissions and fuel consumption, were investigated more in depth. This was achieved using Design of Experiment (DoE) statistical analysis techniques. This way the data set required for the simulation tool was reduced by identifying which vehicle operating parameters or combination of vehicle operating parameters have significant effects on tailpipe emission production. Data collection was achieved by running an ordered series of chassis dynamometer experiments.

Three sets of chassis dynamometer emission tests were carried out. Each set of tests would look at the effect on vehicle exhaust emissions of three different parameters. Therefore nine parameters would be investigated in total. Each of the nine parameters would be tested at two conditions or levels. These levels were selected to be at opposite extremes of what a vehicle would face under real world driving conditions. Table 1 shows the sets of DoE tests and the test conditions for each parameter.

<b>DoE SET 1 (chassis dyno, CLE, Germany)</b>			
<b>Drive cycle type:</b>	ECE15 + EUDC	↔	US-FTP
<b>Vehicle mass:</b>	Empty weight	↔	+50% of max load
<b>Tyre pressure:</b>	-30%	↔	+30%
<b>DoE SET 2 (chassis dyno, IDIADA, Spain)</b>			
<b>Fuel type:</b>	Reference fuel	↔	Commercial fuel
<b>Gear matching:</b>	Low rpm gearing	↔	High rpm gearing
<b>Engine airflow:</b>	Nominal airflow	↔	Restricted air filter
<b>DoE SET 3 (chassis dyno with climatic wind tunnel, MIRA, United Kingdom)</b>			
<b>Temperature:</b>	-20°C	↔	+30°C
<b>Humidity:</b>	20%RH	↔	80%RH
<b>Air conditioning:</b>	Off	↔	On

Table 1 : overall DoE test matrix for influencing parameters (3 vehicles per set)

All tests were performed with a minimum mileage of 5000km to avoid running in effects of engines and catalysts. The engines were also tested in hot conditions, so the influence of start-up or engine warming-up was not included in the tests. The emission measurements were performed at chassis dynamometer at three sites: CLE in Germany, IDIADA in Spain and MIRA in the United Kingdom.

To quantify the accuracy of the simulation tool, an extensive set of measurements was carried out on the control vehicles. This included real traffic measurements in and around Mol (Belgium) and Barcelona (Spain) for city, rural and motorway traffic, measurements on proving ground at IDIADA, and measurements on chassis dyno at CLE, IDIADA and MIRA according to the EU cycle and a real traffic based cycle (called MOL cycle). One of the findings was that the emission levels measured during the official EU cycle, can be very different from the emissions produced in real traffic based cycles (see figure).

In all tests a common emission measurement system was used, Vito's VOEMLow mobile emissions measuring equipment. Where regular CVS-systems were available, emission measurements on chassis dynamometers were performed with both systems to establish the correlation between VOEMLow and regular CVS-systems.

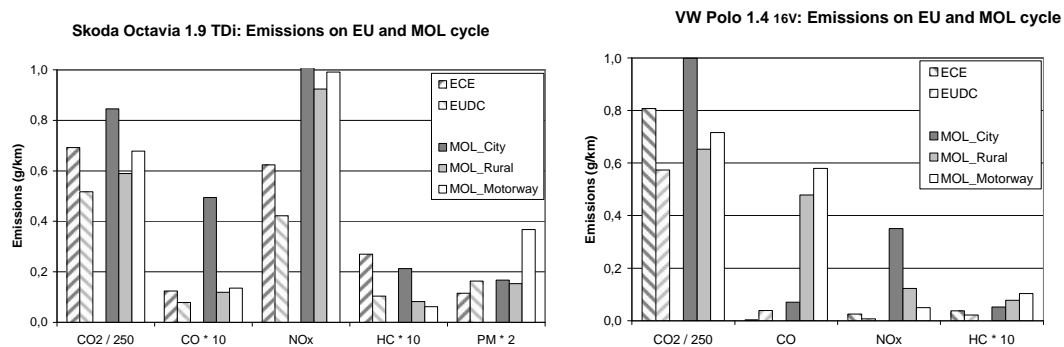


Figure 3: Emissions of Skoda Octavia and VW Polo on EU and MOL cycle

Apart from the three control vehicles, measurements on other 'un-controlled vehicles' were carried out to indicate if the emissions simulation tool can also be used for other vehicles (of which at the most standard engine maps are available). The un-controlled vehicles were mainly different vehicles supplied by three associate partners. These vehicles were used for on-the-road measurements in real traffic. The public transport companies of Barcelona and Braunschweig provide MAN city buses. The Belgian Post provided a Renault Kangoo and a Citroen Jumper. Test results were also shared with the consortium of an other EC funded project, ARTEMIS. This allowed to conclude the applicability of the simulation tool for vehicles of which a transient engine map was not available.



Figure 4: MAN bus measured in the city of Barcelona.

### **ACCURACY OF THE MODEL**

A great number of measurements have been used to validate the latest VeTESS version 1.18b and to quantify the accuracy of the simulation tool both for control vehicles (of which transient engine data were measured in depth) and for uncontrolled vehicles (of which no transient engine data were available).

#### **Control vehicles**

VeTESS simulations for fuel consumption and CO<sub>2</sub> emissions have high accuracy (generally within 5%) for the three control vehicle technologies. It is however very important to match the gear shifting strategy. Wind speed and gradients are parameters which are not always known, but which have a clear effect on local fuel consumption and emissions.

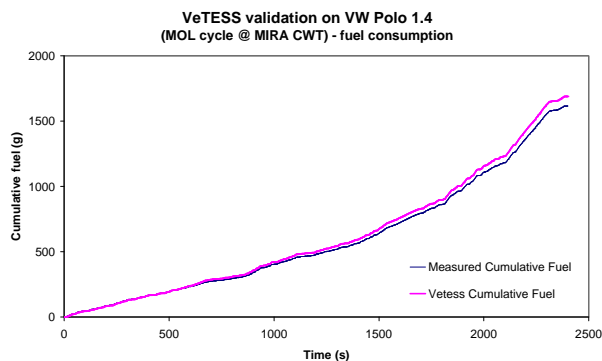


Figure 5: Simulated vs measured fuel consumption for VW Polo

For emissions the results differ between technologies. The simulation of NO<sub>x</sub> and PM emissions of the diesel technologies generally has an acceptable accuracy (accuracy within 10 to 20%). However specific engine control strategies or single events may have a serious impact on the actual emissions produced on the road.

Catalyst behaviour may vary depending on engine operation in the past minutes (memory effect), on external circumstances and on the catalyst condition itself. All these make it difficult to estimate emissions, especially for modern gasoline engines equipped with a three-way catalyst. Some of these specific effects may be included in the simulation, but these effects are difficult to generalize for engine families.

#### **Uncontrolled vehicles**

As no engine maps were available for other light duty vehicles, the engine data of the control vehicles were used to simulate uncontrolled light duty vehicles. The engine specificity however

turned out to be very important. The use of these engine data gave fairly acceptable results for fuel consumption and CO<sub>2</sub> emissions, but the estimations for other emissions were generally too far off.

For heavy duty diesel technology without exhaust gas aftertreatment, simulations based on steady state engine data gave very acceptable results, especially for fuel consumption, CO<sub>2</sub> and NO<sub>x</sub> emissions, which are known to be less sensitive for transient effects. The results vary for CO and HC emissions, partly because of the low accuracy of the some available engine maps, partly because of the lack of transient data. Highest accuracy was achieved if the engine data were derived from the vehicle engine itself.

### ***APPLICABILITY OF THE SIMULATION TOOL***

There are various possible applications of the simulation tool. The main application is to quantify what emissions are created when a certain vehicle drives a certain route (with a given speed profile). So speed recordings can be linked to local emissions and fuel consumption.

In other possible applications the impact on fuel consumption and emissions can be quantified for:

- change of driving behaviour,
- traffic measures,
- introduction of intelligent speed adaptation (ISA),
- optimisation of logistics,
- increased vehicle mass,
- engine scaling,
- number of gears,
- ...

Effects can also be linked with air dispersion to see the effect on air quality.

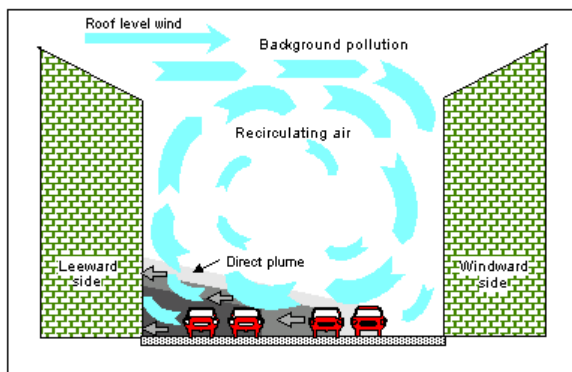


Figure 6: principle of air dispersion calculations

### ***HOMEPAGE***

A homepage is created for the DECADE project. A brief description is available for a wide public. Progresses and results of the project are updated in this homepage. The web site can be found on <http://www.cle.de/umwelt/decade/index.html>.

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