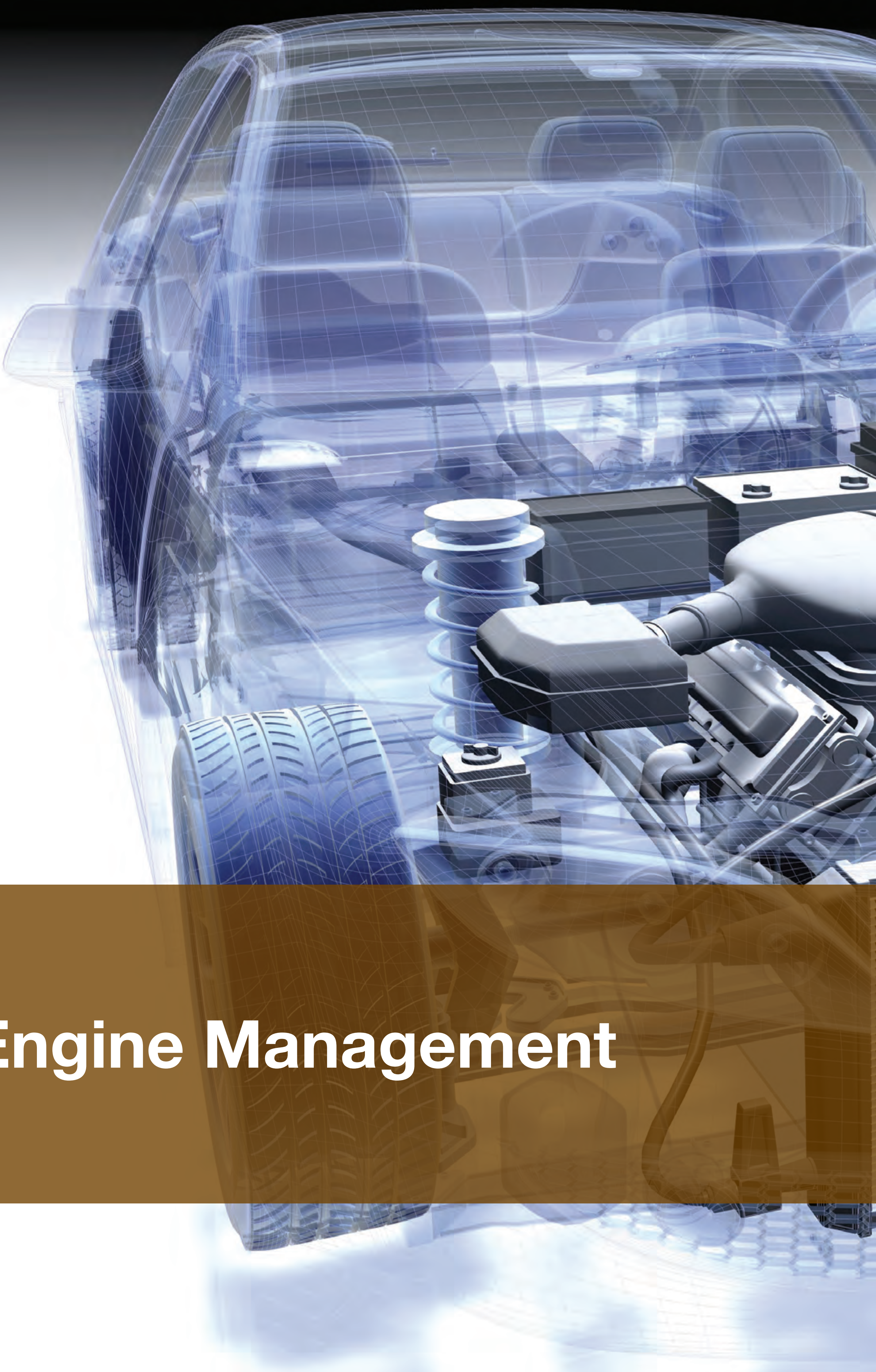

Engine Management

p. 71 to 77

Reciprocating Engines: Fuels, Ignition, Pollution

Module 4: Introduction to Engine Management

3 Days

Level: **Foundation**

PURPOSE

To inform participants about the strategies used to manage the engine operation in order to improve performances. This training requires a basic knowledge related to the components of engine control, as offered in modules 2 and 3 (sheets 28 and 29).

AUDIENCE

Engineers and technical staff from design and testing departments wishing to discover the engine management. It is recommended to initially follow modules 1, 2 & 3.

LEARNING OBJECTIVES

- To know engine control basics.
- To be able to determine and to carry out SI and Diesel engines set torque, by air, timing and fuel management.
- To know depollution and OBD strategies necessary to meet the standards.

PREREQUISITE

It is recommended to previously follow MOT/MOT1-E, MOT/MOT2-E and MOT/MOT3-E.

WAYS AND MEANS

Conventional talk with applied examples and describing the limits to physics.

Coordinator: Guillermo Ballesteros

AGENDA

Engine management bases — 1 d

Stakes, definitions, architectures.

Automatisms: PID regulators (principle, tuning, gasoline idle speed and Diesel EGR control), new tuning methods and prospects.

Diesel and gasoline engines physics applied to the management problem, by the following parameters: air, fuel, torque, engine speed, depollution.

Determining and carrying out set torque — 1.25 d

Interpreting of the driver's intentions and taking external requirements into account.

Taking driving pleasure into account, idle speed.

How to meet the set torque in SI and Diesel engines.

Air management: translating the instruction into an air quantity and throttle driving, airflow measurements with the pressure/velocity strategy, exhaust gas recirculation EGR.

Fuel management: fuel supply, starting, evaporative emission system (canister).

In Diesel engines, managing the injection pressure and the injected quantity, injector driving, injection modes.

Timing management: torque variations driving by the ignition/knocking advance (ignition computing sequence).

Depollution and OBD (Diesel and SI engines) — 0.75 d

Standards: presentation of objectives.

Optimization strategies of the parameters that affect depollution (starting, air-fuel ratio control).

Diesel particulates filter regeneration, NOx trap, SCR.

On Board Diagnostics (OBD): engine control related strategies to meet standards.

Can be tailored to your specific needs and made available at the location of your choice

Engine Management: Control Software and Calibration

5 Days

Level: **Advanced**

PURPOSE

To know the different steps of the development process of an engine control strategy.

AUDIENCE

Engineers and technical staff from design and testing departments or in connection with these departments wishing to understand how power train management is defined, developed and validated. This training is based on an experimental approach by designing a real engine control system.

LEARNING OBJECTIVES

- To be able to transform a strategy, based on physical phenomena in the engine, into a control law that will be programmed in the computer.
- To define, design, simulate, integrate and validate a control strategy in a V cycle development process.
- To code and understand the constraints of coding in a real time environment.
- To understand and apply the design of experiments.
- To know the process to optimize parameters in order to meet the different customers' needs: cold engine starting, performances, consumption, driving pleasure, noise.

WAYS AND MEANS

This training is based on knowledge acquisition through practice. An engine control project is the basis for the learning. The learner is active during this training: he designs, realizes, tests, analyzes and validates himself the engine management system he has developed.
Stages of active learning are:
- **fully applied training with real world examples on Matlab work station**
- **design and calibration of control strategies with Matlab-Simulink**
- **engine model and torque structure design with Matlab-Simulink**
- **engine management validation with an engine model: MIL**
- **manual and automatic coding with Simulink (RTW) and C language**
- **software integration in a computer**
- **software validation with HIL test**
- **validation and calibration on engine test bench.**

At the end of the training, participants will own the models, calibration tools, control strategies and a digital computer they have developed.

Coordinator: Guillermo Ballesteros

AGENDA

Functions and structure of an engine management system — 0.25 d

Introduction: why are there electronics in the engines.

General structure of gasoline and Diesel engine management systems.

Components: actuators, sensors, logic controllers.

Electronic system: power supply, webs, optical cables, multiplexing.

Software: structure, input/output processing, strategies, calibrations, evolutions.

Development methods: contributors, key-steps, V cycle, tools.

Developing a control law — 1.5 d

Automatics basic knowledge: tuning the IPD (integral plus derivative) regulator.

Modeling a gasoline engine: system input and output, assessment of the inlet air volume, modeling the intake manifold, assessment of the manifold pressure, throttle gas flow calculation using Barré de Saint-Venant law, ignition advance efficiency, engine dynamics equation and speed calculation.

Control law development practical on Matlab workstation: designing an idle speed tuning on a gasoline engine. Design a torque structure.

Block diagram representation. Establishing the different sub-models: calculation of airflow, of the torque shown, of the speed. Introducing air/fuel ratio and speed measurement noises. Speed IPD regulation.

Exercises to use the created law: actions on the influences and tuning of the IPD regulation parameters. Observation of the speed signal obtained.

Validation of a control law — 1.5 d

Validation steps are performed with Matlab-Simulink, on computer and engine test bench.

Validation steps: What are the reasons? What are the objectives? What kind of technologies and tools are used?

MIL - SIL validation: strategy functional validation with an engine modeling.

SIL validation: presentation of the approach, interests of this step, automatic code generation.

HIL validation: presentation of the approach, interests of this step, computer strategy integration after encoding, hardware test on a bench.

Functional validation with an engine, strategy test on engine bench. Comparison between simulation and measurements. Calibration methodology.

Implementing a control law in a control unit — 0.75 d

Transcription of a control law into a code that can be integrated into the Electronic Control Unit (ECU).

ECU programming and calibration. Automatic coding and manual coding.

Development tools: mock-up and fast prototyping of the engine control strategies.

Fixed point and floating point.

Development and calibration — 1 d

The development and calibration work will be illustrated by real examples.

Different performances to be taken into account: basic tuning, performances, driving pleasure, cold engine operability, depollution/standards to meet, DPF regeneration, OBD and diagnostic.

Consideration of dispersions, the surrounding conditions, ageing. Choosing the operating points that represent the cycle. Impact of the different engine tuning parameters.

Example of the advance and EGR calibrations optimization on a constant low load point. Impact of water temperature on the development parameters.

Specific calibrations methodologies. Calibration tools development by the control strategy designer. Calibration scheduling in order to reduce the cost of tuning.

Definition of DoE. Representative operating points. Optimization of calibration. Use of numerical models.

Can be tailored to your specific needs and made available at the location of your choice

NEW

Engine Calibration and Tuning

5 Days

Level: **Advanced**

PURPOSE

To better understand engine tuning and calibration. To provide an overview of the tuning process to specialists (project, architecture, system design, software development, component development, software integration, functional validation, calibration, ...).

AUDIENCE

Engineers and technical staff working on engine control functions, systems or components or closely associated with these activities, in order to improve their knowledge of engine tuning and calibration.

LEARNING OBJECTIVES

- To understand the relationship between engines physical functionalities and customer requirements.
- To manage the requirements compromise.
- To understand how EMS affects engine performances.
- To understand the relationship between design and customer requirements.
- To understand EMS tuning process and development.
- To know tuning procedures and calibration tools.
- To understand the theory and the interest of DoE.
- To practice develop and DoE.
- To understand numerical optimization tools.
- To understand the use of numerical models for tuning.
- To practice calibration tools and synthesize engine control tuning.

WAYS AND MEANS

This course is an overview of engine tuning knowledge presented by industry professionals with concrete and real life examples. The last two days are based on concrete and practical exercises:

- **teaching design of experiment is enhanced by the use of computer tools (Matlab)**
- **teaching optimization settings is facilitated by the use of industrial computer tools.**

Coordinator: Guillermo Ballesteros

AGENDA

Introduction — 0.25 d

Engine management system fundamentals. Tuning process and calibration in a V development cycle. Customer requirements, relationships between engine technical definition and customer requirements.

Fundamentals of engine performance tuning — 0.75 d

Torque and power concepts. Vehicle acceleration and speed concepts, gear impact.

Engine constraints and components constraints.

Engine performance related to injection and fuel control strategies, to air loading, supercharging and air control strategies. Tuning tests and calibrations to ensure engine development performance.

Measurements, benches, tools and test analysis. Calibration compromises. Inter-compromise performance. Validation plan.

Fundamentals of engine pollution and OBD tuning — 0.75 d

Emissions regulations, nature of pollutants, cycles and global levels. Engine out emissions fundamentals. Fuel properties impact on emissions. Engine and components constraints.

Engine emissions related to injection and fuel control strategies. Engine emissions related to air loading and air control strategies. Diagnostics and OBD calibration and development.

Tuning tests and calibrations to ensure engine emissions development. Measurements, benches, tools and test analysis. Calibration compromises. Inter-compromise performance. Validation plan.

Fundamentals of engine consumption tuning — 0.75 d

CO_2 regulation, CO_2 emissions and tax incentives.

Engine consumption fundamentals: performance.

Engine and components constraints.

Engine consumption calibration related to injection and fuel control strategies, air system and air control strategies, combustion control (phasing injections and ignition).

Measurements, benches, tools and test analysis. Calibration compromises. Inter-compromise performance. Validation plan.

Fundamentals of engine drivability — 0.5 d

Definition of the driving pleasure. Drivability objectification.

Physics fundamentals of powertrain drivability.

Engine and components constraints.

Torque structure fundamentals: target, set point and raw torque.

Drivability strategies: pedal progressivity, anti jerk, dynamic engine speed control, vehicle dynamic control.

Power train phases of life and related calibration: engine off, on-road driving, highway driving, docking, acceleration, idle speed.

Measurements, benches, tools and test analysis. Calibration compromises. Inter-compromise performance. Validation plan.

Design of experiments — 1 d

Customer and cycle driving operating points.

Design of experiments (DoE) theory.

Impact of engine operating parameters on tuning.

Practice of the design of experiments with Matlab.

Numerical models and optimized operating variables. Model quality and predictability validation. Impact on the DoE nature.

Local or global DoE. Calibration methodologies associated with the DoE.

Synthesis and optimization of the engines calibration — 1 d

Digital calibration tools suitable for control strategies.

Commercial generic digital tools for calibration (type AVL CAMEO).

Industrialization and integration of calibration methodologies in a development process.

Minimizing the total number of trials. Creating databases of test data.

Taking into account the drift and dispersion, environmental measurement conditions in tuning numerical models.

Exploitation of DoE. Numerical optimization methodologies.

Autopilot benches. Bench measurements with low dynamics (BFD).

Optimization of multi calibrations. Synthesis and management of the inter-compromise requirements. Smoothing calibrations.

Practice of a computer optimization and calibration tool.

Can be tailored to your specific needs and made available at the location of your choice

Gasoline Engine Management

3 Days

Level: **Advanced**

PURPOSE

To know in the case of spark ignition engines:
- the different functions related to air supply, fuel supply and combustion
- the sensors and the actuators related to each of these functions and how to use them
- the strategies used.

AUDIENCE

Engineers and technical staff from design and testing departments wishing to know the main components and functions of the SI engine management.

LEARNING OBJECTIVES

- To have an overview of the gasoline engine control system.
- To have the necessary elements to diagnose some simple failure modes.
- To be able to talk to specialists to understand and make control strategies evolve.

WAYS AND MEANS

Interactive training with real life examples.

Coordinator: Guillermo Ballesteros

AGENDA

Engine management system architecture and torque structure — 0.5 d

Logic controller, hardware and Software structures, application engine control architecture.
Interpretation of the driver's intentions.
Transients and drivability.
Torque supervision, intersystem management.
Estimation of FMEP losses (frictions), IMEP LP (pumping): example of data analysis dyno test bench.
Basic knowledge on idle speed monitoring.

Air supply function — 1 d

Standard air circuit
- Sensors and actuators: air flow meter, pressure sensor, motor throttle and its control.
- Air supply chain, torque model (or inverted model): combustion equation, Barre de Saint-Venant equation.
- Air supply chain, direct model: loading equation, transients management.
- Dispersions control: closed loop by lambda probe, adaptatives.

Deriving air circuit
- Turbocharger supercharging, variable timing: sensors and actuators, impact on the control structure.

Basic knowledge on the operating safety.

Fuel injection and ignition functions — 1 d

Components and related strategies for the following sub-systems:
- Top dead center and camshaft sensors, acquisition circuits of angular position of crankshaft and camshaft.
- Indirect gasoline injection (MPI) and direct one (GDI), gas injection.
- Canister.
- Upstream and downstream oxygen sensors.
- Ignition: technologies evolutions.
- Knocking: acquisition circuit of the accelerometer signal.

Diagnostic, depollution and ageing of catalyst — 0.5 d

Regulatory aspects, ageing of catalyst, OSC (Oxygen Storage Capacity).
Catalyst diagnostic.
Lambda probe diagnostic.
Misfire diagnostic.

Can be tailored to your specific needs and made available at the location of your choice

Diesel Engine Management

3 Days

Level: **Advanced**

PURPOSE

To know each of the different functions used in the Diesel engines control, the components used (sensors and actuators), the strategies adopted that take these components and the engine operating physics into account.

AUDIENCE

Engineers and technical staff from design and testing departments wishing to know the main components and functions of the Diesel engine management.

LEARNING OBJECTIVES

- To know the actions performed by the system to realize the set torque (torque structure).
- To know how the different sensors and actuators work and when they are used.
- To set the control strategies for the turbocharger, the exhaust gas recirculation rate (EGR), the variable swirl system for engines that include it, the injection pressure, the phasing and the injected quantity for each injection performed during an engine cycle.
- To use the failures detection modes (diagnostic).

WAYS AND MEANS

Interactive training with real life examples.

Coordinator: Guillermo Ballesteros

AGENDA

Torque structure — 0.5 d

Transmission of the driver's wished set torque to the wheels by action of the engine control on the air (turbocharger) and fuel (injection system) supply. Pedal mapping. Working with a driven engine or with a cruise control. Interaction of the other systems of vehicle stability (AESP, ASR).

Full load limits. Anti-surge strategy. Torque structure advantages.

Air supply function — 1 d

Airflow regulation by the EGR valve and of the intake collector pressure by the turbocharger actuator position.

Interaction between the EGR regulation and the turbocharger regulation.

Advantage of an oxygen probe in the EGR regulation.

Cycle adjustment in dynamics to optimize pollutant emissions.

Operating the variable swirl shutters, the EGR cooler by-pass.

Fuel injection function — 1 d

Pressure oscillations created during injection, influence on the injected flow rates during multi-injections. Correction by a hydraulic behavior simulation model.

Choosing the drive ratio of the high pressure pump, influence of the rail volume and of the HP pipe lengths on the injected flow rate.

Rail pressure regulation on high or low pressure.

Engine speed regulation, regulation by function, idle speed regulation, anti-surges.

Failures diagnostics — 0.5 d

Diagnostics of rail pressure loop differences, of minimum pressure monitoring, sensor signal plausibility.

Supercharging pressure diagnostic.

Depollution system diagnostics (OBD).

Can be tailored to your specific needs and made available at the location of your choice

NEW

Introduction to Engine Management Practical Approach by Modeling and Simulation

9 Days

Level: **Advanced**

PURPOSE

To inform participants about the strategies used to manage the engine operation in order to improve performances. This training requires a basic knowledge related to the components of engine control, offered in modules 2 and 3 (sheets 29 and 31).

AUDIENCE

Engineers and technical staff from design and testing departments wishing to discover the engine management with a practical way and desiring a comprehensive and practical understanding of engine control.

LEARNING OBJECTIVES

- To be able to determine and to carry out SI and Diesel engines set torque, by air, timing and fuel management.
- To know depollution and OBD strategies necessary to meet the standards.
- To understand the relationship between engine physics and control.
- To know engine control basics.
- To understand the relationship between EMS design and customer requirements.
- To understand engine management system process development.
- To identify the components necessary to control the engine and its requirements, to describe their operation.
- To design and develop engine control strategies.
- To validate and calibrate engine control strategies.

PREREQUISITE

It is of interest to initially follow MOT/MOT1-E, MOT/MOT2-E and MOT/MOT3-E.

WAYS AND MEANS

This training provides an overview of engine management systems. It is based on concrete examples and a pragmatic approach by modeling and simulation. A control project underlies learning. The student is active throughout the training: he develops, realizes, tests and validates himself the control software he has developed.
The steps in this active learning are:
- **Design, build and calibration of control strategies in Matlab-Simulink**
- **Engine model development for torque structure design with Matlab-Simulink**
- **Strategies validation with an engine model (MIL) with Matlab-Simulink.**

Coordinator: Guillermo Ballesteros

AGENDA

Engine management introduction and discovery by practice — 3.5 d

Stakes, definitions, architectures, sensors, actuators, ECU, control strategies.

Automatisms: PID regulators (principle, tuning, gasoline idle speed and Diesel EGR control), new tuning methods and prospects.

Diesel and gasoline engines physics applied to the management problem, by the following parameters: air, fuel, torque, speed, depollution.

Control law “hands design”. All introductory concepts are reworked with the example of a spark ignition engine: design and implementation of a torque structure, design and implementation of an idle speed control strategy.

Spark ignition engine torque and emissions control — 1.75 d

Interpreting of the driver’s intentions and taking external requirements into account.

Taking driving pleasure into account, idle speed.

How to meet the set torque.

Air management: translating the instruction into an air quantity and in throttle driving, airflow measurements with the pressure/velocity strategy, exhaust gas recirculation EGR.

Fuel management: fuel supply, starting, evaporative emission system (canister).

Managing the injection pressure and the injected quantity, injector driving, injection modes.

Timing management: torque variations driving by the ignition/knocking advance (ignition computing sequence).

Operation of pollutant strategies to control engine out and after-treatment.

Diesel engine torque and emissions control — 1.75 d

How to meet the set torque. Diesel torque structure. Torque control by injection control.

Air management: translating the torque instruction into an air quantity, supercharging control.

Fuel management: fuel supply, starting, managing the injection pressure and the injected quantity, injector driving, injection modes, control of the injection patterns. Injections corrections strategies.

Operation of pollutant strategies to control engine out and after-treatment. Pollutants and air diesel chain: controlling the amount of air, amount of fresh air and EGR rate.

After-treatment control systems: oxidation catalyst, DPF, SCR and NOx trap.

Engine cross control — 2 d

Engine synchronization: crankshaft and cam timing. Strategies, operating technologies and components.

Powertrain supervision: Interpreting the driver will, choice of the powertrain operating point, intersystem arbitration.

OBD: issue of OBD in a Euro 6 context: impact on the architecture of motor control. Globalized approach to diagnosis.

Intersystem: functional issues of CAN, VAN, digital links sensors-ECU intersystem networks.

Can be tailored to your specific needs and made available at the location of your choice

Engine Management Training

30 Days

Level: **Advanced**

PURPOSE

To give engineers all the necessary knowledge on the engine operating physics and on the engine electronic control so that they can take part in the development of control and calibration strategies on a Dyno test bench and on a vehicle.

AUDIENCE

Engineers and technical staff from automotive industry who want to improve their knowledge of powertrain electronic management.

LEARNING OBJECTIVES

- To know the parameters used to characterize and control performances, efficiency, combustion, emissions.
- To know the combustion mechanisms and how the exhaust gas after-treatment systems work.
- To know the architecture and the functions of the engine control systems, the sensors and the actuators.
- To have some basic practical knowledge on applied automatics to engine control.
- To be able to describe the advantages and the make-up of a torque structure.
- To be able to tune up the control strategies of gasoline and Diesel engines, possibly associated to an automatic transmission.
- To be able to implement of the diagnostic functions, both from regulatory and operating safety standpoints.
- To know how to build a control law.
- To be able to do the tuning and calibration process on an engine.

WAYS AND MEANS

- **Fully detailed training with applied exercises.**
- **Basic simulation may be used.**

Coordinator: Marc Bonnin

AGENDA

Engine operating and technology — 13 d

Thermodynamic cycles, engine general architecture, technology of the different components.

Geometric parameters, effective and shown performances parameters, efficiency, emissions, air loading parameters.

Engine mechanics: stress transmission, rotating and alternative masses balancing, acyclisms, vibrations.

Combustion in spark ignition engines and in compression ignition engines: pollutants formation, normal and abnormal combustion.

Control parameters: airflow, fuel flow, intake temperature and pressure, residual burnt gas, ignition or injection advance. How changing these parameters (motorized throttle intake exhaust gas recirculation, gasoline and Diesel fuel injection systems, variable timing, turbocharging).

Fuels: characteristics, influence on engine operation.

Exhaust gas after-treatment systems: catalysts, filters, traps; trap bleeding and filter regeneration systems; control strategies of these systems.

Engine management — 17 d

Hardware

Electronic control system architecture, data exchanges, development process.

Technical definition, properties and use of sensors (flow rate, speed, position, pressure, temperature, oxygen probe) and of actuators (injectors, motorized throttle, EGR valves, ignition).

Software

Applied automatics to engine control. IPD regulation. Bode and Nyquist plots.

Torque structure. Slow and fast control. Development of a control law on the example of idle speed regulation on a gasoline engine.

Gasoline engines control strategy: architecture, synchronization, air loop, fuel injection, air/fuel ratio regulation, ignition advance, anti-knock correction, canister bleeding, catalyst actuation.

Diesel engines control strategy: rail pressure, injected flow, multi-injections, correction of dispersions, unbalances between injectors, drifts, supercharging, EGR, after-treatment.

Control in the case of automatic transmission: shift laws, interference with torque structure.

Diagnostic: EOBD regulation, operation safety; loop difference.

Statistical analysis, failures, torque structure monitoring, degraded modes. Roles and development process.

Can be tailored to your specific needs and made available at the location of your choice