

## Common Rail Mapping on Power train Test Bench

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This process contributed to adjust the mapping strategies of the particulate filter implementation for Common Rail engines. It also validates different technological solutions that solve inherent difficulties of such depollution system.

Depollution cycles mapping has also been improved by this process which optimises the ECU mapping in a reproducible way.

Complementary tests realised concern vehicles drivability mapping.

This functionality is simplified with this type of test bench by the opportunity to use different kind of measurement tools that could be difficult to integrate in a car for dimensions restrictions. This bench takes in account the gearbox clearances in the vehicles driveability mapping during programmed accelerations.

During functionary points change on vehicle, the torque variation leads to a sollicitation in the transmission natural frequency.

Torque variation is piloted by actuators (throttle, ...) and torque progressiveness by ECU's parameters modification.

The good reproducibility of actuators (throttle position, ...) and torque analysis during transient phases allows the optimisation of torque progressiveness by reproducing accelerations on a given gear by successive approximations.

A process methodology has been realised for each type of process to get quickly adjustment results. A first part is necessary to qualify the robustness of these calculators adjustments.

Keywords: Advanced automotive technology – power train systems

### INTRODUCTION

Costs decreasing necessity, engineering and production delays reduction targets enforce automotive carmakers to use new tests methodologies in association with new test benches. These new processes should allow to test and validate different ECU adjustments or even better, to optimize its functions by the definition of new strategies. The arrival of new technologies such as common rail, particle filter, gasoline direct injection intensifies this need.

SAE (D2T group) has developed a mean and methodologies simple, fast and reliant for the adjustments of injection unit allowing to validate technological solutions or power train bench settings before application on vehicles.

### TECHNICAL SOLUTIONS VALIDATION BEFORE APPLICATION ON VEHICLE

#### METHODOLOGY

The engine is set up on the frame with the same fixations and the same silent blocks as for a standard vehicle. It keeps the same gearbox and the same transmission shafts.

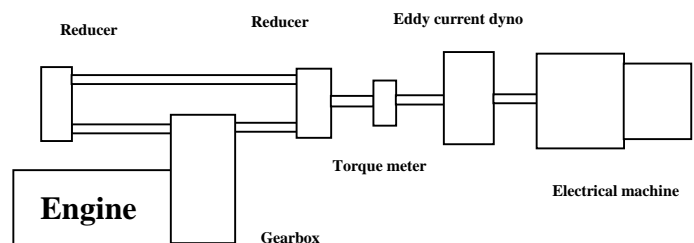
The rotary motion from the gearbox is transmitted by means of a pair of increasing speed gears, to a shaft coupled with :

- a flywheel which simulate the vehicle inertia
- a torque meter
- an eddy current dyno.
- a middle power electrical machine

This process is able to simulate the vehicle's behaviour on a flat road or on a negative or positive slope.

The engine bench is piloted by "Morphée" software and its specific road law simulation driver which controls all vehicle's parameters.

The gears shifting is piloted by a robot with pneumatic commands. The progressiveness is controlled by the emptying of the pneumatic actuated cylinder.



First of all, engine speed, selected gear and throttle position are recorded on vehicle during a specific cycle or normal running conditions.

The second step is the adjustment of gearbox shifting. The reproducibility of vehicle starting and different gear

shifting depend on the progressiveness of the clutch actuator. These stages are dissociated from the cycle and are calibrated by the technician who reproduce the starting according to the recordings on vehicle. Thus, during the get-away, the technician defines the throttle actuator position in accordance with time, then he will adjust the progressiveness of the clutch actuator to obtain the same speed engine as registered on vehicle. This process is applied to each gear changing.

For other running phases, vehicles recordings are loaded as instructions on test bench software. A first test is driven on engine speed/throttle position regulation mode. Then the cycles are simulated on engine speed/torque regulation in order to approach vehicle conditions. A refining of PID regulator will allow to optimize the cycle following. The figure 1 shows the reproducibility of the power train bench

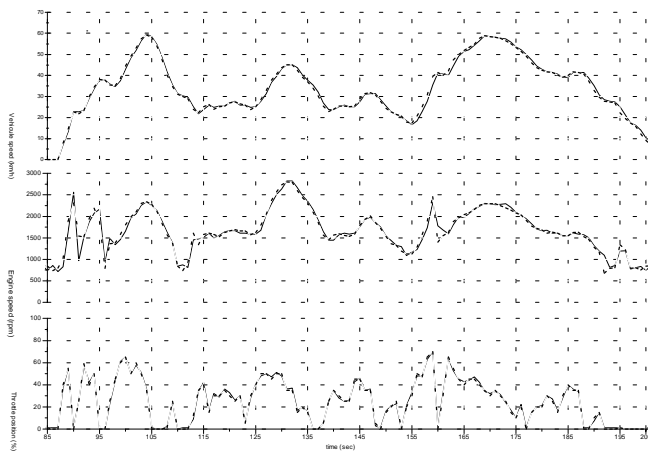


FIG. 1

that validates the process before doing test.

These operations done, the engine behavior is reproduced as set up in a car with the advantage to be immobile. So, it can be instrumented to measure any parameters as fuel consumption, oil consumption during normalized cycles, pollutants emissions or other measures needing special instruments.

## RESULTS

Tests driven on this bench allow to find technical solutions to temperature upholding in particle filters in order to ensure their regeneration. The figure 2 shows the influence of slope on exhaust temperature for example, but it is also possible to evaluate the influence of post-injection timing or to define injection strategies according to external temperatures or vehicle running conditions.

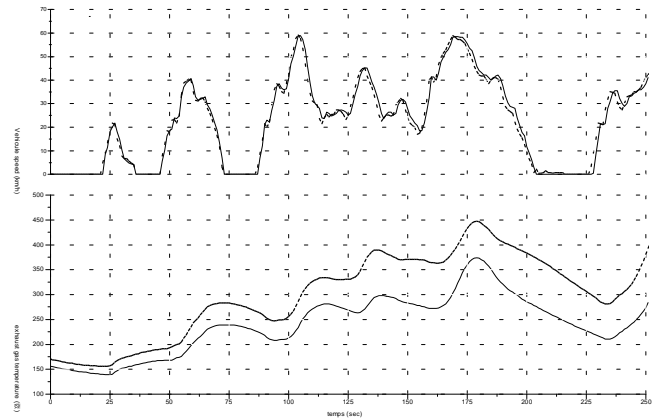


FIG.2.

## DRIVABILITY ADJUSTMENT PARAMETERS PRE-DETERMINATION

Carmakers have already developed for years processes allowing to validate and quote the vehicles drivability. Based on either subjective quotations or accelerometers measures on vehicles, these processes genuine data is the transmission natural frequency excitation and the torque circulation among transmission clearances. These phenomena are generated by too important or badly controlled torque gradients during engine working.

If these measures subjectivity part can't be evaluated on test bench, different studies have shown a direct correlation between vehicle instabilities felt by the driver and instantaneous torque measured on vehicle transmission shaft. Thus, the transmission natural frequency is felt by the driver if it is excited by a torque jerk from the engine.

To attenuate torque effects on the driver, a process is deployed on the test bench by analysis of instantaneous measured torque and applied to carmaker drivability validation scales.

During a given transient phase, torque, speed and control parameters of the engine are registered at high frequency. The repetition of the functioning point allows to calibrate the ECU in order to prevent high torque gradient which would generate natural frequency transmission excitation.

The settings choice is based on defined criteria that are permanently calculated by test bench software. Thus instantaneous torque gradient related to resulting mean torque or torque oscillations number during the transient phase are registered and saved. These criteria allow to validate an ECU mapping.

When a mapping is validated, the stability criteria are used one more time during transient and stabilized phases

which are haphazardly chosen by a specific algorithm of “Morphée”, the managing test bench software.

The engine power providing vehicle acceleration can be written :

$$P = \vec{F} \cdot \vec{V} \quad \text{or} \quad P = \left( m \frac{dV}{dt} + F_R \right) \quad (1)$$

with :

**P** the power

**F** the strength applied to the vehicle

**m** the vehicle mass

$\frac{dV}{dt} = \gamma_L$  the longitudinal acceleration

$F_R = F_0 + F_1 V + F_2 V^n$  the restrain effort

**V** the vehicle speed

From equation (1), we have :

$$\gamma_L = \frac{C \omega}{V m} - \frac{F_R}{m} = \frac{1}{m} \left( \frac{C \omega}{V} - F_R \right) \quad (2)$$

This equation shows the direct relation between torque and longitudinal vehicle acceleration. Thus we can link the drivability calculated judgment to the instantaneous torque instabilities. On the test bench, the torque meter is set up on the dyno shaft in order to measure directly the wheels applied torque. It permanently allows “Morphée”, thanks to equation (2), to calculate the vehicle longitudinal acceleration.

During stabilized engine running phases, the judgment is given according to acceleration amplitude. During transient phases, the mean longitudinal acceleration is withdrawn from the measured signal to determine the amplitude value used for the judgment.

## RESULTS

Figures 3.1 & 3.2 curves, measured on a gasoline engine, show that during the acceleration in second gear, the instantaneous torque transmitted to wheels, comes under a high gradient that excites transmission shafts and body vehicle. This instability is reduced, by reduction of fuel injected mass according to throttle position.

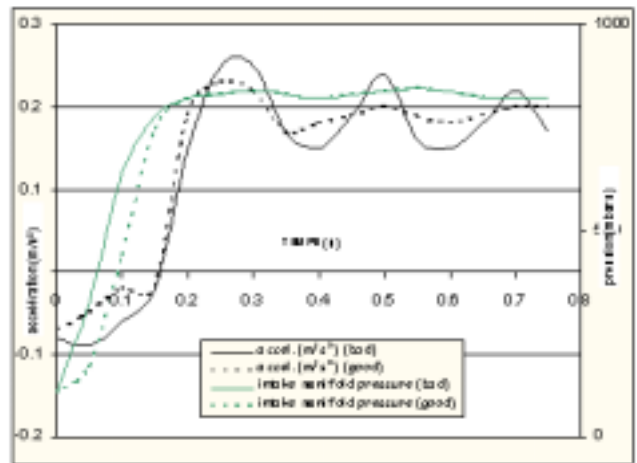


FIG. 3.1

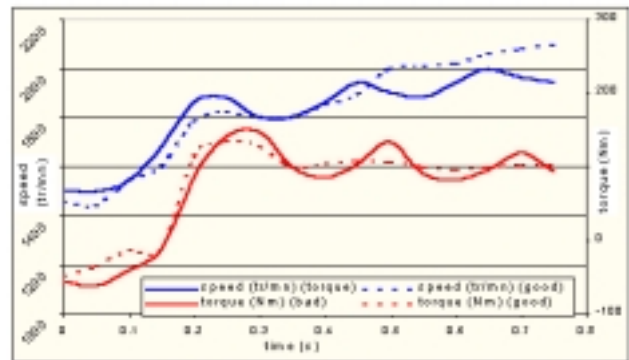


FIG. 3.2

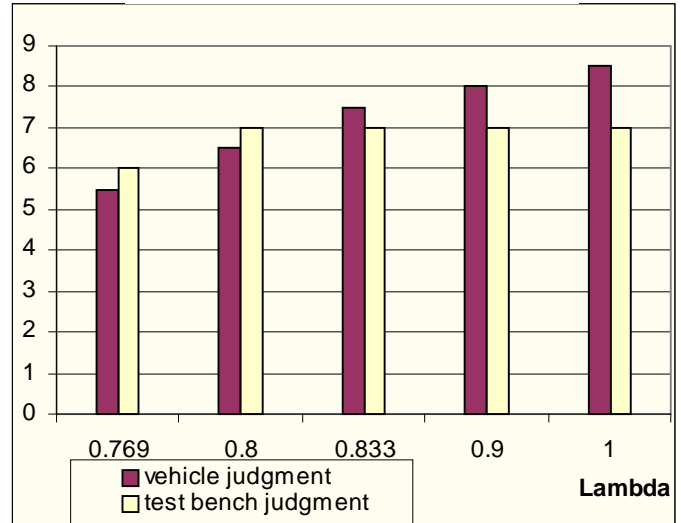


FIG. 4

## CONCLUSION

Combustion noise aspect can also be analyzed and validated by the same way on power train test bench, with

in particular the optimization of pre-injection timings during transient phases on Common rail engines which can prevent the well-known squall noise.

If it doesn't replace the vehicle, the power train test bench plays a game in costs cutting and time engineering reduction thanks to its simplicity and its capability to reproduce phenomena for which pre-validation adjustments are necessary for engine design. Tests managed on this test bench allowed a great help on development of ECU strategies for particle filter with the validation of technological solutions either realistic or exotic.

Moreover, this test bed allows to adjust ECU mapping and to validate robustness of settings defined by engineer.

## REFERENCES

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