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Powertrain NVH Development

Diesel Transient Noise Optimization

Diesel Truck NVH Development

Aside from "classical" requirements concerning further reduction in fuel consumption and exhaust emissions of heavy-duty diesel trucks, NVH aspects have become more and more the focus of attention. In 1989, the night driving ban in Austria for trucks exceeding the 80 dBA limit required by the ISO Standard R362 drive-by test gave an additional impetus to NVH improvement of heavy-duty diesel trucks.

Current engine noise optimization is typically based on steady-state engine measurements, as high-dynamic acoustic test cells are rare. Yet, according to current noise legislation, the vehicle drive-by test requires transient engine operation, since transient noise of DI diesel engines exceeds steady-state noise significantly (see Figure 1). Therefore, the knowledge of NVH relevant differences between both engine operating conditions is a prerequisite for effective noise improvement.

Simulation of Drive-by Test in Acoustic Test Cell

At FEV the transient NVH tests according to the accelerated vehicle drive-by test are performed with the complete powertrain using appropriate transmission gear ratio (Figure 2) and eddy-current brake inertia.

The transient speed/load increase is controlled by a special device actuating the load control system of the engine. This device guarantees reproducible and reliable transient test procedure.

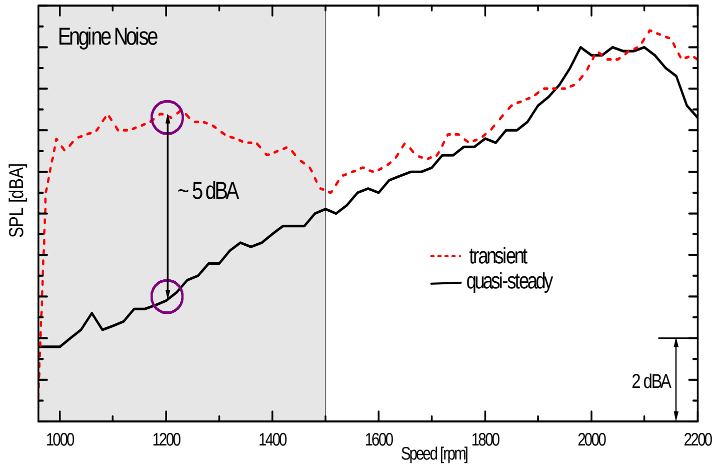

Figure 1: Engine Noise - Comparison Transient / Quasi-steady Speed Increase

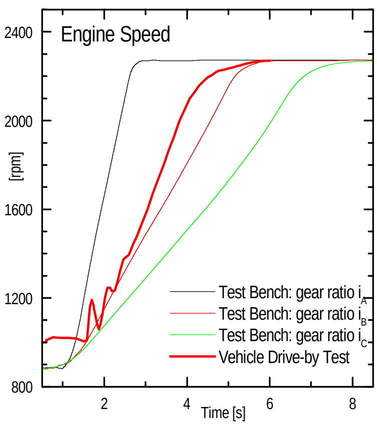

Figure 2: Drive-By-Test Simulation

Multi-channel data acquisition includes simultaneous recording of all transient condition relevant engine and NVH parameters. A sampling rate of 40 kHz per channel in combination with a crank position sensor (data oversampling of 12 MHz for 1°CA resolution) allows for crank angle related time event analysis, cycle by cycle, during transient speed increase.

Transient Noise Excitation

Transient noise of diesel engines can exceed steady-state full load noise by up to 6 dBA. The significant combustion noise increase due to enlarged ignition delay is considered to be the main cause for transient diesel engine noise. The excitation analysis in respect to combustion and gear train excitation (injection pump drive shaft), when comparing transient/quasi-steady speed condition, is subject of Figure 3. Transient noise results from combustion excitation increase in the direct noise characterized frequency range 0.8-2kHz.

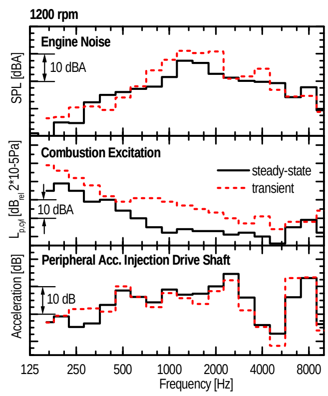

Figure 3: Excitation Analysis

In this context, not only the amount of pre-mixed fuel at start of combustion, but especially the difference between steady-state and transient condition temperatures of intake air and combustion chamber walls has a considerable in-

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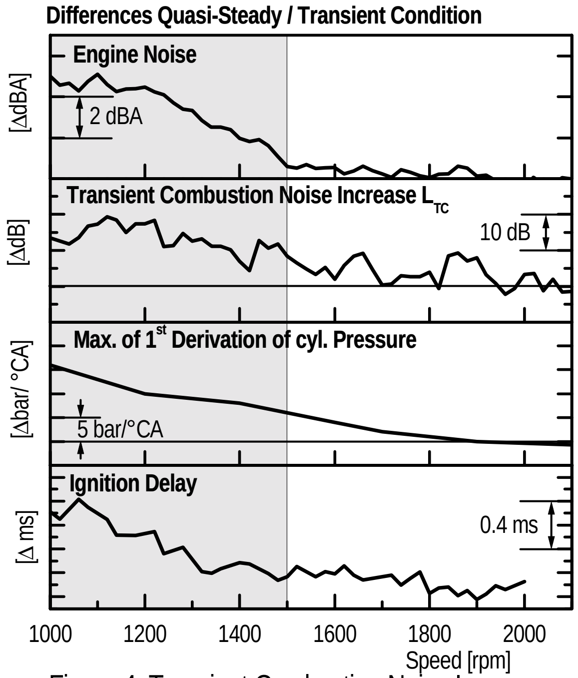


Figure 4: Transient Combustion Noise Increase

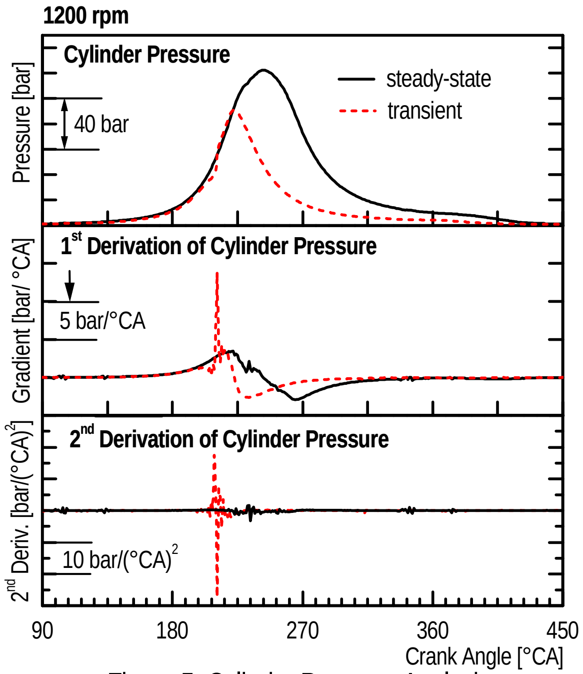


Figure 5: Cylinder Pressure Analysis

fluence on ignition delay and combustion noise intensity respectively. These effects occur in combination with the dynamic advance of injection timing (driveability) and significantly lower boost pressure

The basic relationship between transient engine noise and combustion excitation is subject of Figure 4. Besides the engine noise level differences between transient and steady-state condition, the transient combustion excitation relevant parameter differences (1st derivation of cylinder pressure, L_{TC} and ignition delay) are represented, too.

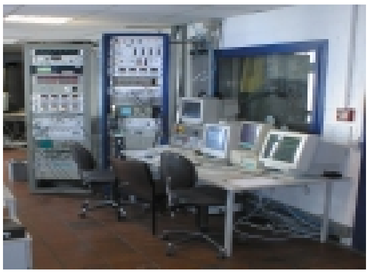
The 1000-1500rpm speed range, characterized by the significant transient engine noise increase, reveals a clear correlation between ignition delay, combustion excitation and noise. The iginition delay results in a "harsh" combustion indicated by a significant increase in 1st and 2nd derivation of cylinder pressure (see Figure 5).

Transient Noise Optimization

Transient noise improvement measures, besides structure optimization and encapsulation, must aim at reducing the ignition delay by:

- optimization/reduction of transient shift of begin of injection,
- injection rate optimization controlling the amount of premixed fuel present at the begin of combustion, e.g. pilot injection, rate shaping etc.;
- increase in boost pressure at start of transient operation, e.g. variable turbine geometry, electrically driven/ supported turbo charger or two-stage turbo-charging;
- temperature rise in the combustion chamber, e.g. load dependent exhaust gas re-circulation .

Transient tests have to be implemented in the powertrain NVH development process as prerequisite for excellent product quality during all driving conditions. The simultaneous development in a combined NVH/Thermodynamic powertrain test cell is prerequisite to find the most favorable compromise between excellent vehicle acceleration performance and acceptable transient noise and emission behavior.



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