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Title: Synchronization of Engine Test-Bench Data

In the engine development process, the ability to judge NVH comfort as early as possible is a great benefit. The prediction of engine noise on the basis of a prototype engine without the need to install it in a real car significantly speeds up the development process and leads to a cost reduction, as prototype modifications can be evaluated faster.

Meaningful predictions of the perceived NVH comfort cannot be achieved just by comparing order levels, but require listening to an auralization of the engine noise at the driver's position. With the methods of Transfer Path Analysis and Synthesis (TPA/TPS) a prototype engine can be virtually installed in a car using test-bench data. The interior noise can be estimated by combining source signals containing near-field airborne radiation and mount forces together with transfer functions describing the transmission to the target position in the cabin. Even the transfer functions of a predecessor car could be used if the new car body is not yet available.

For several reasons, the source signals for TPA/TPS cannot always be measured simultaneously, in which case they are not synchronous: For example, if they are measured on different test benches, if partial measurements at modified components are performed subsequently, or if the number of sensors and measurement channels is limited. Especially the rpm signal of the measurements may differ. The sound shares calculated using such unsynchronized measurements would not superimpose correctly because the engine cycles do not correspond. Even for small deviations in the engine speed, the frequency and phase of the engine orders differ, which could lead to auralization artifacts like cancellation, exaggeration, and beat tones. Thus, synchronized input signals are strictly necessary for a correct Transfer Path Synthesis in the time domain.

In this paper, a synchronization approach is presented that is based on analysis and resynthesis techniques: The basic principle is a high-quality order analysis using a high-resolution rpm signal and a non-linear resampling algorithm resulting in a signal that is equidistantly sampled with respect to crankshaft angle. In a second step, synchronized signals are calculated by order synthesis according to the reference rpm signal. For an even more authentic synthesis, a noise analysis and synthesis is carried out, which adds filtered white noise depending on the synchronized engine rpm. Beyond synchronization, the algorithm can also be used to slow down, speed up, or reverse an engine run-up and to modify order level and phase values for sound design applications.

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