한국소음진동공학회 2012년 춘계학술대회논문집, pp.208~209

VEHICLE ENGINE SOUND DESIGN

A comprehensive design cycle for car engine sound: from signal processing to software component to be integrated in the audio system of the vehicle.

François Orange [1] and Patrick Boussard [3]
GENESIS Acoustics, BP69, 13545 Aix en Provence Cedex 4 – France

ABSTRACT

This paper describes a comprehensive process and range of design tools and components for providing Improved perception of engine sound for mass production vehicles by the generation of finely tuned engine harmonics.

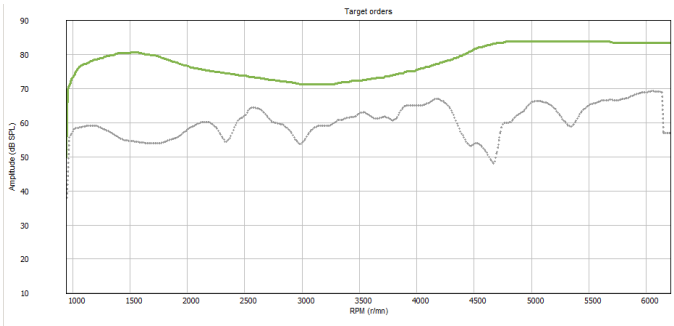

Figure 1- Example of order 2 enhancement

ANALYSIS OF ENGINE SOUND

The engine sound depends on the following parameters:

- engine architecture: 4 or 6-cylinder configurations on an inline engine, V engine, two or four-stroke engine, reciprocating or rotary engine
- engine's fuel type (gasoline, Diesel…)
- rotation speed (RPM)
- engine load or acceleration pedal position (throttle)
- gear ratio (rarely)
- torque applied on the engine by the wheels (rarely)

Preliminary work consists in recording and analyzing the natural sound of the vehicle:
1st step : time-frequency representation of a 2nd or 3rd gear - acceleration with Wide Open Throttle (WOT)
2nd step: order extraction
3rd step: throttle position influence

SYNTHESIS OF ENGINE SOUND

Genesis sound synthesis algorithm

The algorithm is based on a sum of pure tones with the following parameters:

- The frequency of each pure tone is a multiple of the engine's frequency. Example for a 4 cyl – 4 stroke engine: orders and half orders
- The level of each harmonic is given by the order analysis matrix: order rank, level, RPM. Between 2 measurement points we do a linear interpolation
- In the real-time implementation , GeneBOX, we get the engine's RPM from the CAN Bus and update the synthesis parameters every 10ms
- Only the desirable part of order is generated in order to complement the natural orders from the engine

SOUND DESIGN FOR CONSTANT SPEED

- With the harmonic sound control panel, it is possible to modify the level of each harmonic in real time for a given RPM and then to control the perception of the engine sound.

- A **sporty** car has a general higher level of harmonics than a normal car
- The amplification of consecutive harmonics (i.e. 3.5, 4, 4.5, 5) increase the **roughness** of the sound and the **sportive feeling** of the car
- The amplification of harmonics 4, 6, 8 increase the **sharpness** of the sound and sportive feeling: when RPM changes, it seems to go higher
- The amplification of **low frequency** harmonics (2, 3, 4) enhances the **feeling of a power** of the engine
- The amplification of harmonics 3, 6, 9, 12 of a 4-cylinder engine give the feeling of a 6-cylinder engine

SOUND DESIGN FOR ACCELERATION

- Much more than in constant speed, sound design of engine will be appreciated by the driver during acceleration. For this, the software allows to modify each harmonic for a range of RPM.
- The progression map of the throttle position can be edited to determine the sound according to the way the driver accelerates
- Various styles of sound design can be experimented and tested by listeners

VALIDATION AND MASS PRODUCTION SOLUTION

- The GeneBOX allows to test the sound synthesis in real cars and real driving conditions. Several setup for different cars can be uploaded on the device.
- Psychoacoustics experiments can be led in listening room to validate the final sound design selected.
- Finally the synthesis algorithm and the sound data sets are implemented as software components in the audio system of the car.

CONCLUSION

Advantages of Engine Active Sound Design

- **Cost & weight** save cost and weight on exhaust and intake design based solutions
- **Design work** reduces constraints during the design, more creativity for the sound
- **Flexibility** the sound can be easily adapted to each vehicle, and later in the design process
- **Friendliness** possibility of sounds data base to be selected by the driver
- **Adaptation** the sound can be adapted to various driver preferences and driving conditions
- **Environment** no noise impact out of the car
- **Performance** contributes to reduce the mass of the vehicle, its CO2 emission and improve its performance

Advantages of the described approach

- No hardware requirement from the vehicle: uses the standard audio system and its loudspeakers
- Ease of sound design
- Easy move to mass production by the use of standard software components
- Very good control of the development cost and time
- May improve greatly the sound perception with only a small increase of overall sound level
- Ideally suited for mid-range vehicles with 4 cylinder engines

Application for EV and HEV

- This method may be transposed for the generation of interior as well as exterior sounds for electric and hybrid vehicles