EXHAUST SOUND DESIGN
for a downsized High Performance Vehicle

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• Introduction
• Exhaust System NVH Development
  • Exhaust System Orifice Noise Approaches
  • Exhaust System Orifice Noise Simulations and Measurements
• Exhaust Sound Design Application
  • Excitation measurements
  • GT-POWER simulations
  • Active noise attenuation
• Summary
INTRODUCTION

EXHAUST SYSTEM NOISE/SOUND

Sources of exhaust noise

- Pulses (opening/closing of exhaust valves) → exhaust orifice order noise
- Exhaust gas flow noise → exhaust orifice flow noise
- Shell noise
- TC noise
- Vibration transfer to vehicle
EXHAUST SYSTEM NVH DEVELOPMENT

NVH CONTRIBUTION

- Simulation
  - Transfer function
  - Orifice noise
- Hardware
  - Prototyping
  - Transfer function measurement
  - Orifice noise measurement
EXHAUST SYSTEM NVH DEVELOPMENT

NVH CONTRIBUTION

- NVH Facilities
  - Powertrain NVH Test Beds
  - Driveline NVH Test Beds
  - 4WD Acoustic Chassis Dyno
  - Test Track (incl. pass-by capability)
GENERAL EXHAUST SYSTEM NVH APPROACHES

ORIFICE NOISE DEVELOPMENT:

OVERVIEW OF 2 MAIN APPROACHES

Excitation

Transfer Behaviour

Fine-Tuning Loop (transfer function)

Procurement

Layout

Frontloading

GT

Refinement

GT

Orifice Noise

In-Vehicle Assessment

Fine-Tuning Loop (orifice measurements)
EXHAUST SYSTEM NVH DEVELOPMENT

ORIFICE NOISE DEVELOPMENT: MUFFLER SIMULATION

COMPONENT MODEL:
Exhaust component(s) - calculation of:
- transmission loss
- transfer function
- insertion loss
EXHAUST SYSTEM NVH DEVELOPMENT

ORIFICE NOISE DEVELOPMENT: TL & TF MEASUREMENT/DEVELOPMENT

LOUDSPEAKER EXCITATION

Zero flow test rig

Acoustic flow rig at KTH Stockholm

Acoustic flow rig at KTH Stockholm

Upstream Microphones

Downstream Microphones

Graph showing Transmission Loss (dB) vs Frequency (Hz)
EXHAUST SYSTEM NVH DEVELOPMENT

ORIFICE NOISE DEVELOPMENT: HYBRID SIMULATION AND MEASUREMENT

The pressure pulses (static and dynamic pressure) are measured together with the exhaust gas temperature. These are then used for the GT-POWER excitation boundary condition.

GT-POWER exhaust system model

Mikrophone

Exhaust orifice noise results, measured & GT-POWER

Simulation

Measurement

Pressure traces for different engine conditions

Result

GT-POWER exhaust system model

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APPLICATION: EXHAUST SOUND DESIGN
3 CYLINDER HIGH PERFORMANCE ENGINE

ORIFICE NOISE APPROACH

- Development of a dominant/sporty exhaust orifice noise
  - Boundary conditions
    - Pass-by noise limit
    - Exhaust system back pressure
    - Active orifice noise attenuation

- Approach
  - Excitation from engine dyno measurement
  - Transfer function development in GT-POWER
  - Orifice noise from measured excitation & GT-POWER transfer function development
  - Additionally active noise attenuation
APPLICATION : EXHAUST SOUND DESIGN
3 CYLINDER HIGH PERFORMANCE ENGINE

EXHAUST SYSTEM MODELLED WITH GEM3D AND GT-ISE V2017
APPLICATION : EXHAUST SOUND DESIGN
3 CYLINDER HIGH PERFORMANCE ENGINE

ORIFICE ORDER NOISE SIMULATION & ACTIVE ATTENUATION

Passive exhaust system & Active exhaust system
range around 400Hz increased
3rd order increase
4.5th order increase
SUMMARY

GT-POWER is successfully used within AVL’s intake and exhaust system acoustic development processes.

GEM 3D is used both for the intake and exhaust line for the modelling of air filter boxes, resonators high frequency dampers and exhaust mufflers.

GT-POWER is used for acoustic transfer function and orifice noise development. Acoustic excitations are coming either from thermodynamic simulations or from measurements. Both give good insight to the acoustic behaviour of intake and exhaust systems in terms of acoustic damping and orifice noise.
THANK YOU

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