Akustik für Motor und Fahrzeug

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- Lecture by Dr. Franz Diwoky
- Mixed audience (Mechanical Engineers and Audio Engineers)
- Overview of all topics for vehicle acoustics
- Topic: Renew and edit existing material, new shape, new order, updates
- Main challenges:
  - Coordination: Parallel working in same file (Latex) with same syntax (graphic, wording, style)
  - Mechanical and acoustic knowledge for both groups of students
  - English (vocabulary, mechanical engineering) -> Glossary
- Lecture half theoretical and half practical with one excurse to AVL
- Very few lectures for NVH on TUG

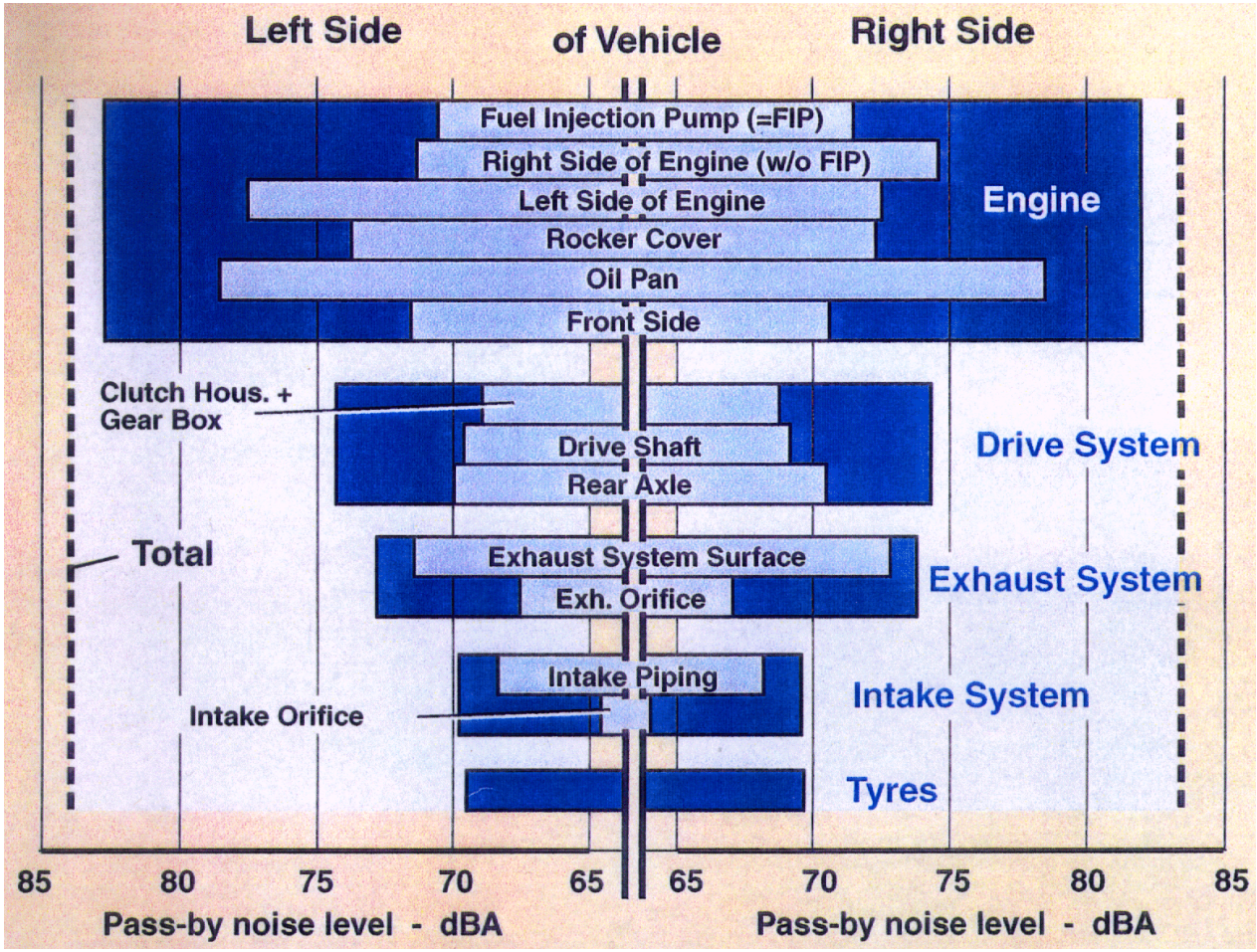
Akustik für Motor und Fahrzeug

- Introduction
- Physical fundamentals
- Internal Combustion Engine
- Radial Solution – Near and Far Field
- Intake and Exhaust
- Duct Acoustics
- Transmission
- Structural Dynamics
- Vehicle
- Wheels
- Simulation
- Measurement

Introduction

- Noise Vibration Harshness (NVH)
- Motivation:
  - Politics, traffic noise (EU guidelines)
  - Customer
- Internal noise (passenger compartment)
- External noise (emission/noise pollution)
- Significant contributions:
  - Power unit (engine and transmission)
  - Intake and exhaust systems
  - Aerodynamic noise (caused by car body)
  - Tyres (rolling noise, contact with street)

Introduction



[1] Overview of vehicle noise sources

Physical Fundamentals

- Principles of sound propagation
- Helmholtz equation
- Wave equation
- Acoustic sound measurement variables
  - Sound pressure, velocity, power, intensity…
- Transmission in liquids, gases, solids
- Sound fields (free field, diffuse, active, reactive)

Internal Combustion Engine

- Power unit (engine and transmission) is the main acoustical and vibrational excitation
- Main sources:
  - Engine noise
  - Oil pan
  - Combustion
  - Mechanical noise
    - Piston-liner, valves, shaft bearing
- Noise transmission of engine structure

Radial Solutions Near and Far Field

- Spherical solution of the Helmholtz equation
- Harmonic Helmholtz equation
- Near and far field approximation
- Overview of wave forms
  - Plain wave, standing wave, radial propagating wave

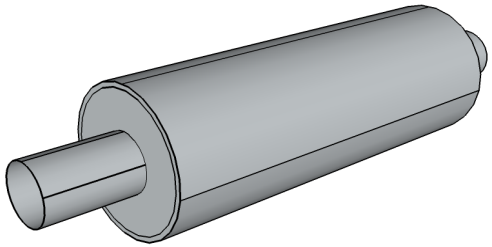
Intake & Exhaust

- Requirements:
  - Cheap
  - Heat & weather resistant
  - Easy to maintain

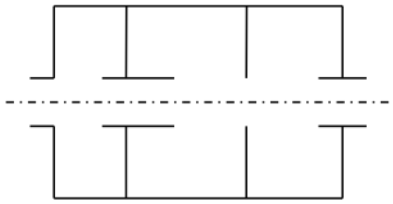
- Consists of:
  - Exhaust manifold (Krümmer)
  - Turbocharger
  - Catalytic converter
  - Mufflers

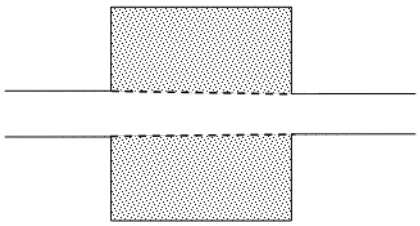
- Sources of Noise:
  - Gas flow
  - Exhaust orifice
  - Pulses due to valve opening/closing
  - Structure born noise through suspensions

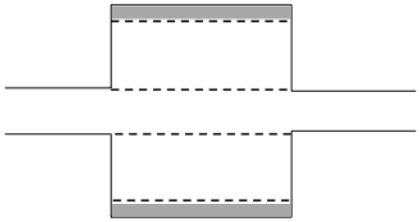
Intake & Exhaust



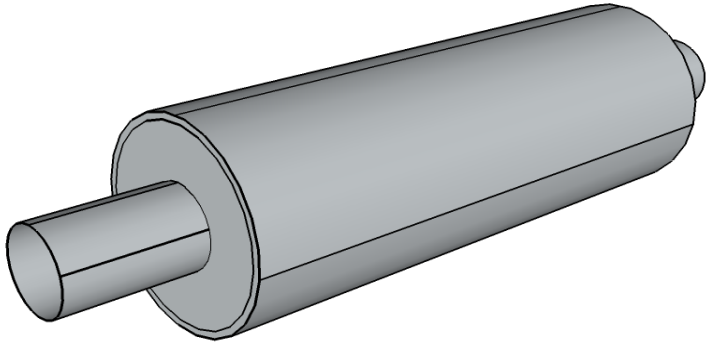
- Common muffler types:
  - Reactive
  - Dissipative
  - Hybrid

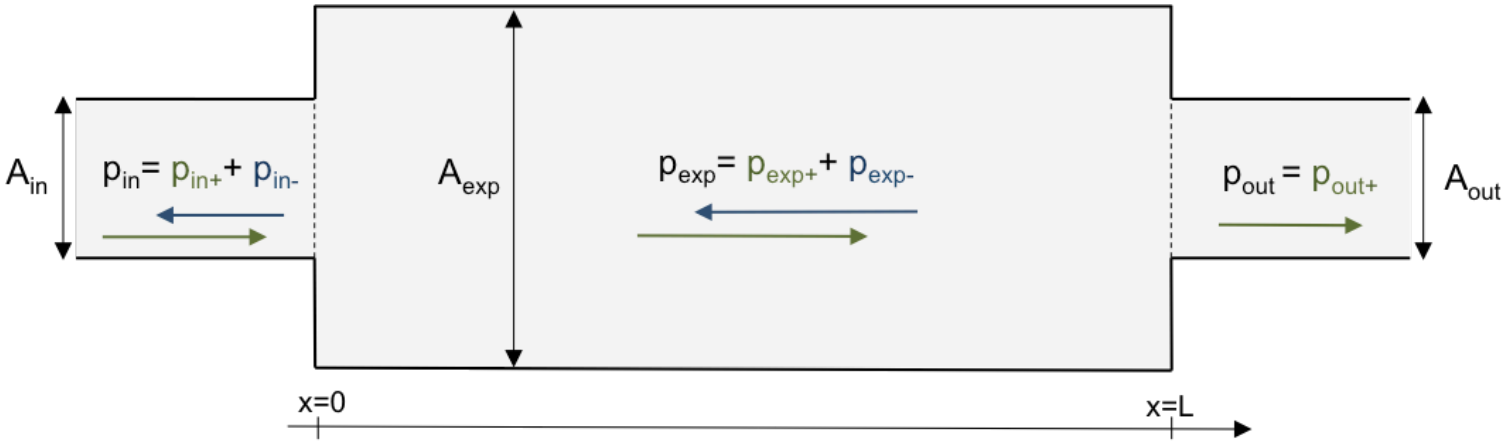




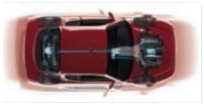


Duct Acoustics





Transmission



Shuffle (Ruckeln)

Boom (Dröhnen)

Clonk
(Lastwechselschlag)

Rattle
(Getrieberasseln)

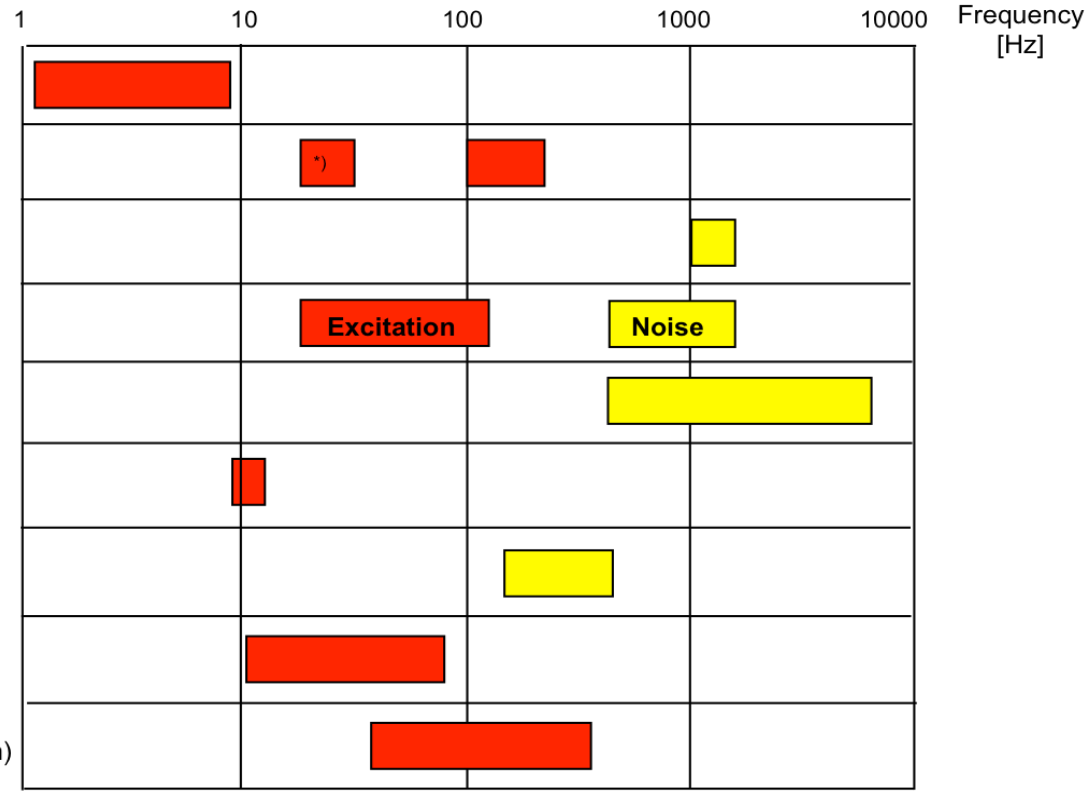
Whine (Heulen)

Chatter
(Kupplungsrupfen)

Whoop

Shudder (Schütteln)

Humming (Brummen)



Transmission noise sources [1]

Structural Dynamics

- Overview of wave (forms in structure)
  - Longitudinal, transversal, expansion wave, bending wave, torsional wave, Rayleigh wave
- Conditions for propagation (critical frequency)
- Bending waves
- Plate acoustics
- Sound propagation in solids

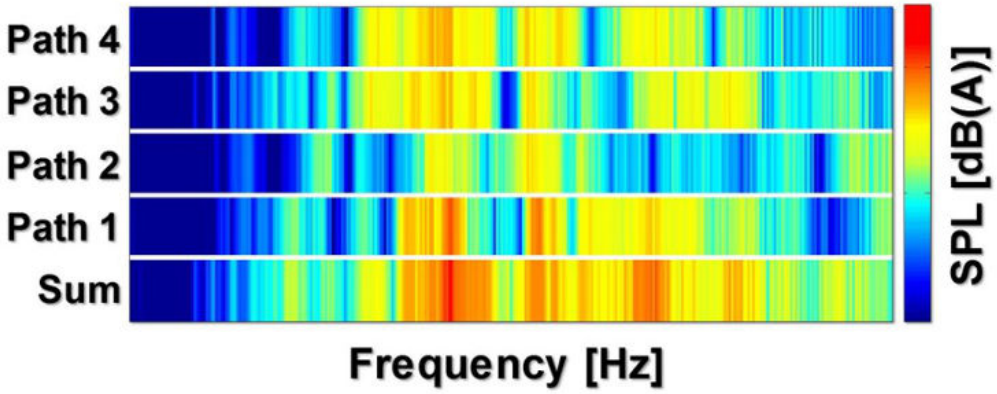
Vehicle

- Engine noise
- Rolling noise
- Drivetrain
- Wind noise
- Noise reduction methods
  - Damping – insulation and attenuation
  - Fundamentals and practical examples
- Influence of holes
- Transferpath Analysis example (TPA)

Transferpath Analysis

Transferpath Analysis: Method for detection of the dominant excitation and transmission via air borne and structure borne noise over defined paths

Random Example:
Path 1: Engine - Clutch - Gearing - Cardan shaft (front) - Central bearing - Cardan shaft (back) – Main axis gear – Main axis gear bearing (middle) – Main axis support bearing (middle) - Car body



[2] Transferpath Analysis

Vehicle

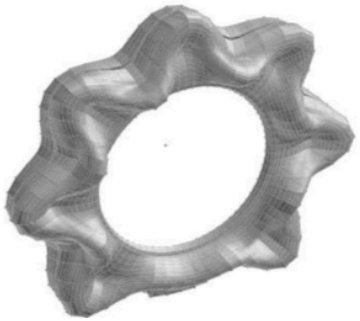
- Aerodynamic sound source detection (stall and turbulences)
  - Theoretical models of radiators (monopole, dipole, quadrupole)
  - Pass-By-Test, aeroacoustic wind tunnel
  - Influence of side-mirrors, antennas, windows, sunroof
- Structure borne and air borne noise and transmission
- Railway, motorcycles, noise immission barriers
- Brief overview of vehicle simulation and measurement methods

Wheels

- Tyre noise – mostly relevant > 50km/h (highway vs. city noise)

- Tyre-Road interaction:
  - Local slip
  - Block impact / release
  - Vibrating sidewall

- Tyre modeling (FEM)

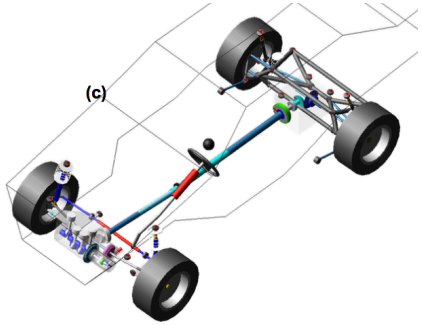


Natural Oscillation at 203Hz [1]

FEM model of a tyre [1]

Simulation

- MBS (Multi Body Simulation)
  - System of rigid bodies
  - Simulation up to 50Hz
  - Application e.g. char chassis



MBS model [3]

- FEM (Finite Element Method)
  - Body discretized into several elements
  - Net fineness limited due to limited computing power

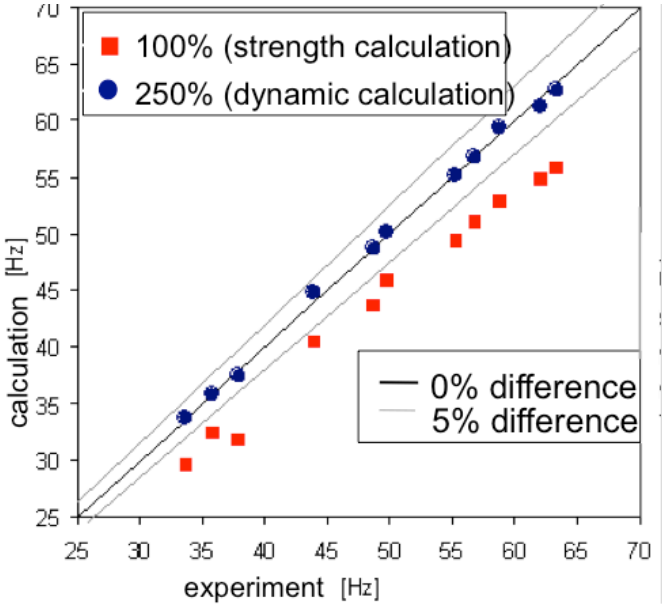
FEM model of a tyre [1]

- SEA (Statistical Energy Analysis)
  - Higher frequency range, application e.g. inside compartment
  - Comparable to statistical room acoustics

Measurement

- Vibration Measurement
  - Piezoelectric acceleration sensor
  - Voltage prop. to acceleration
  - Mounting: Beeswax
  - For higher temp.: welded nut
  - Weight of sensor is important

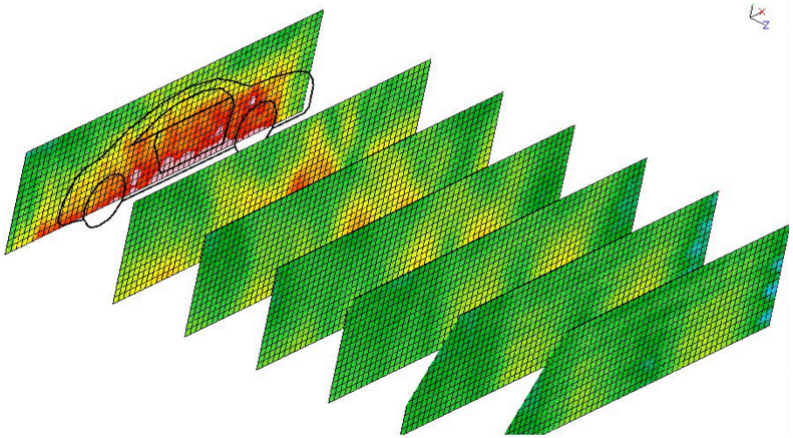
- Comparison of measurement and simulation



Measurement-simulation comparison [3]

Measurement

- Sound source localisation



Sound source localisation [3]

Quellenverzeichnis

- [1]: Quelle AVL
- [2]: https://www.fka.de/de/kompetenzen/akustik/highlights/17-gesamtfahrzeug-nvh.html [Download 10.02.2021]
- [3]: Quelle ViF

Thank you!