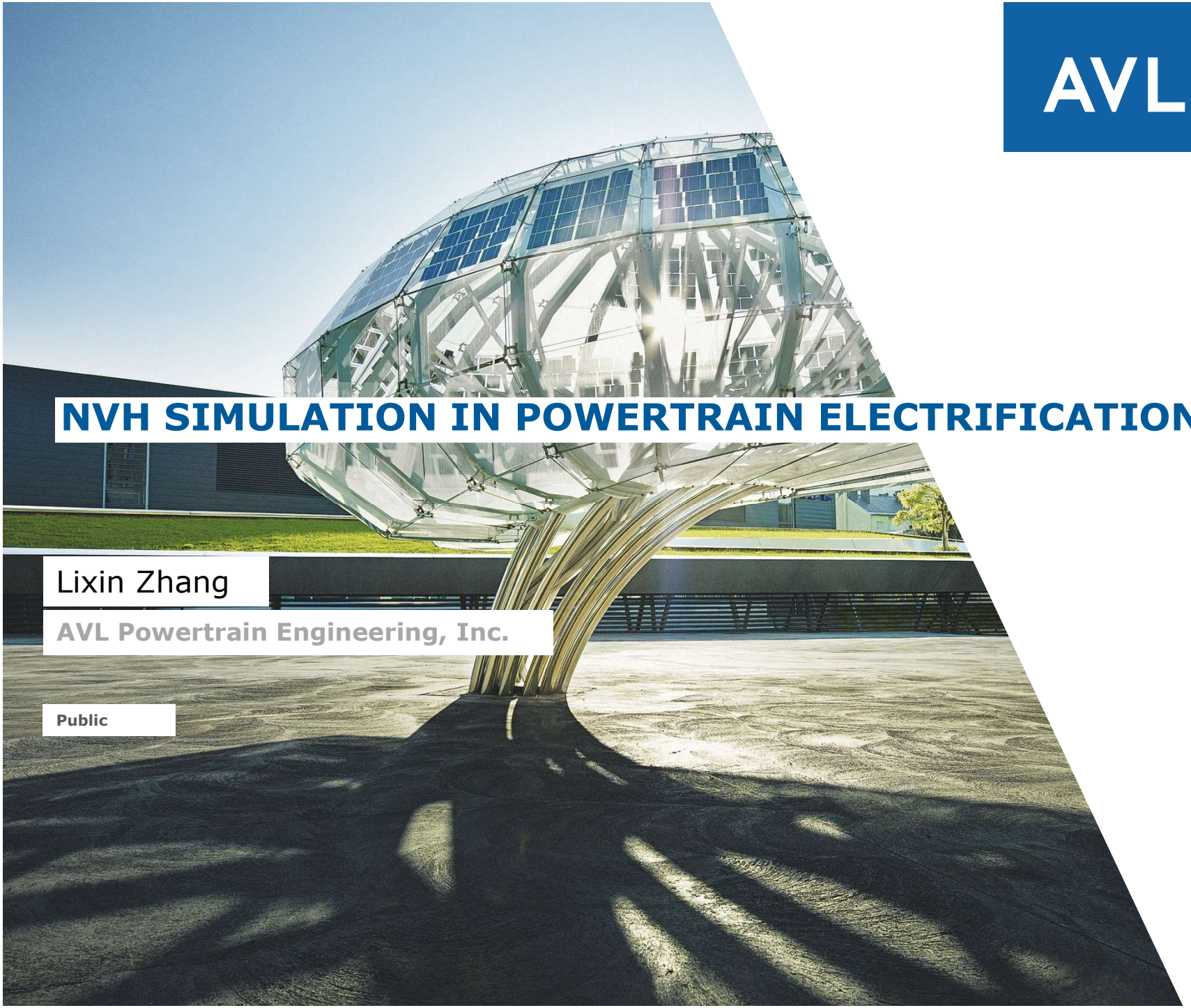


NVH SIMULATION IN POWERTRAIN ELECTRIFICATION

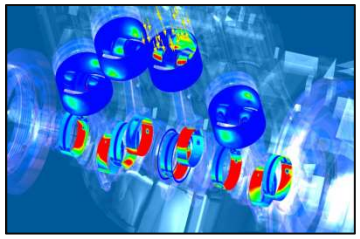
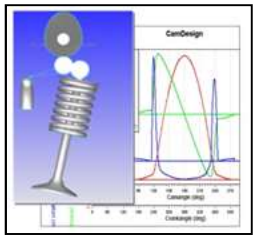
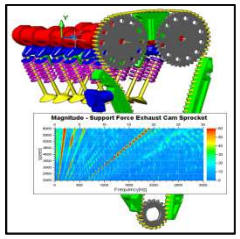
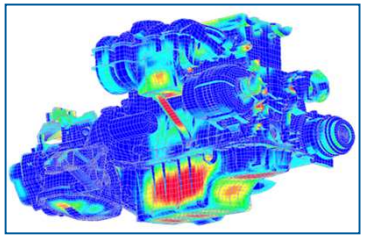
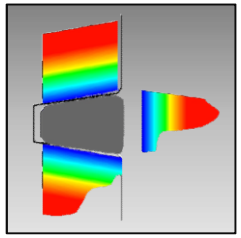
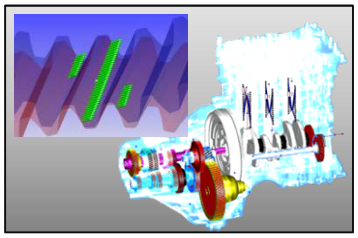
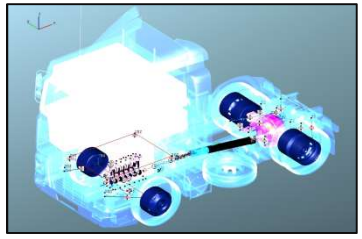
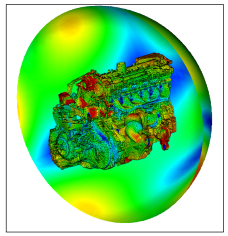
Lixin Zhang

AVL Powertrain Engineering, Inc.

Public

INTRODUCTION
AVL POWERTRAIN ENGINEERING

INTRODUCTION
AVL EXCITE – PRODUCT FAMILY

EXCITE Designer

Analytical methods for fast dimensioning of cranktrains and drivelines in the concept phase

EXCITE Power Unit

Dynamics, durability and NVH of engines, transmissions and powertrains

EXCITE Acoustics

Efficient sound radiation calculation

EXCITE Timing Drive

Reliable dynamic analysis of all kinds of valve trains and timing drives

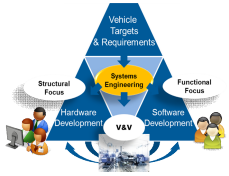
EXCITE Piston&Rings

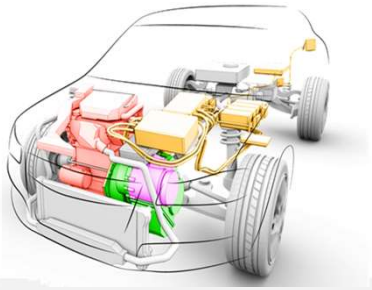
Efficient tool for piston ring design analysis and optimization

INTRODUCTION
AVL'S ELECTRIFICATION COMPETENCIES

Electrified Engine Components | Micro & Mild Hybrid | Full Hybrid | Plug-In Hybrid | Range Extended | Pure Battery | Fuel Cell

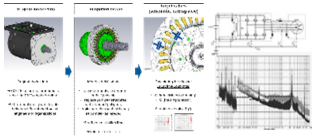
System Design &Simulation



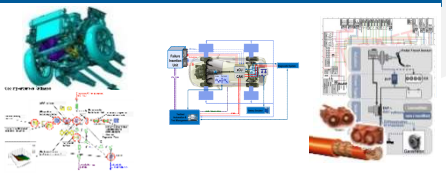


System Validation & Calibration

EMC



System Integration

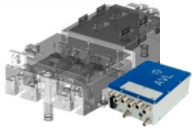


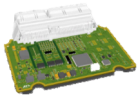
Controls & Safety


Engine


Fuel Cell


Machine

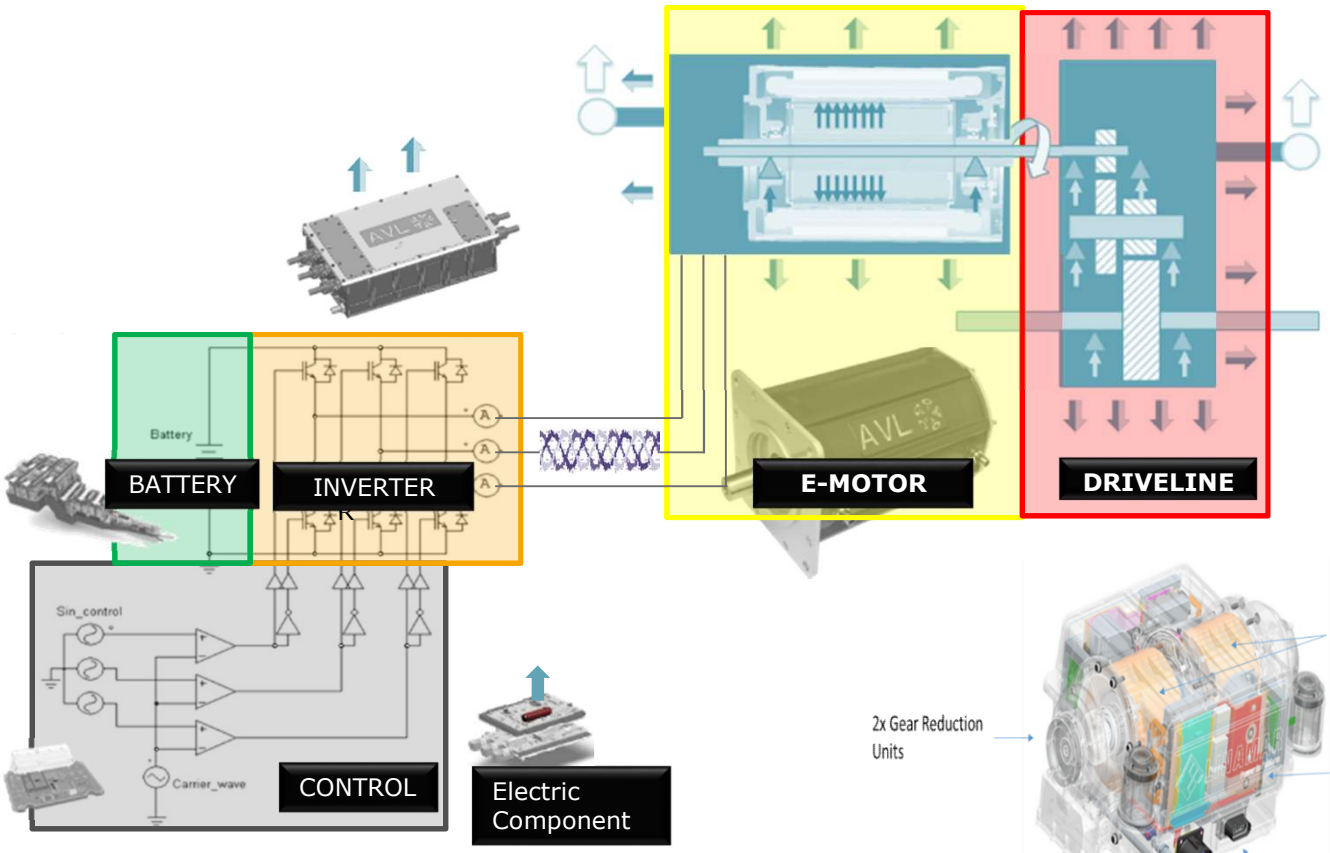

Power Electronics


VCU


Battery

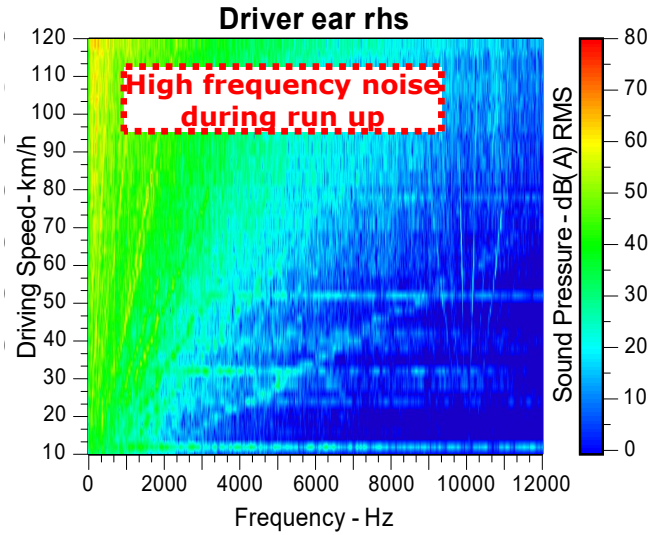

Transmission

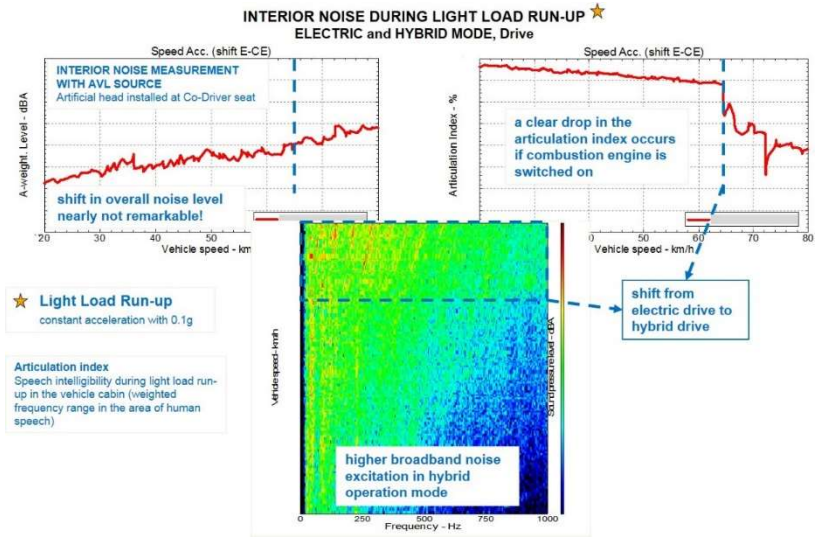
INTRODUCTION
LAYOUT OF ELECTRIFIED POWERTRAIN



INTRODUCTION
NVH CHALLENGES - ELECTRIFIED POWERTRAIN

- Increased system complexity
  - more components ➔ more potential noise sources
- Completely new noise sources
  - E-machine
  - Inverter
  - Relay noise
- No masking by IC-engine (in full electric mode)
- More complex control strategy leads to more NVH critical operating conditions
- Non-stationary operating conditions
  - Start/Stop
  - ICE Engagement
  - High influence of control strategy (H)EV

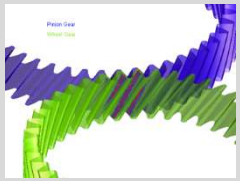


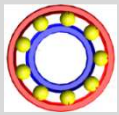


TOTAL NOISE BY MECHANICAL AND ELECTROMAGNETIC EXCITATION

Mechanical noise

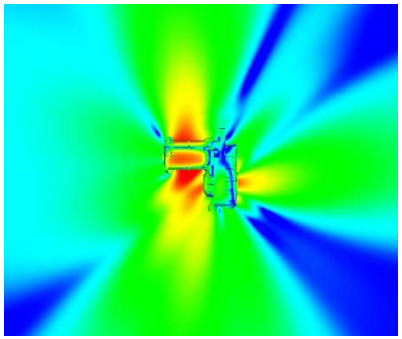
MBS





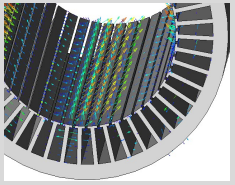
Driveline excitations

Total Noise



Electromagnetic forces

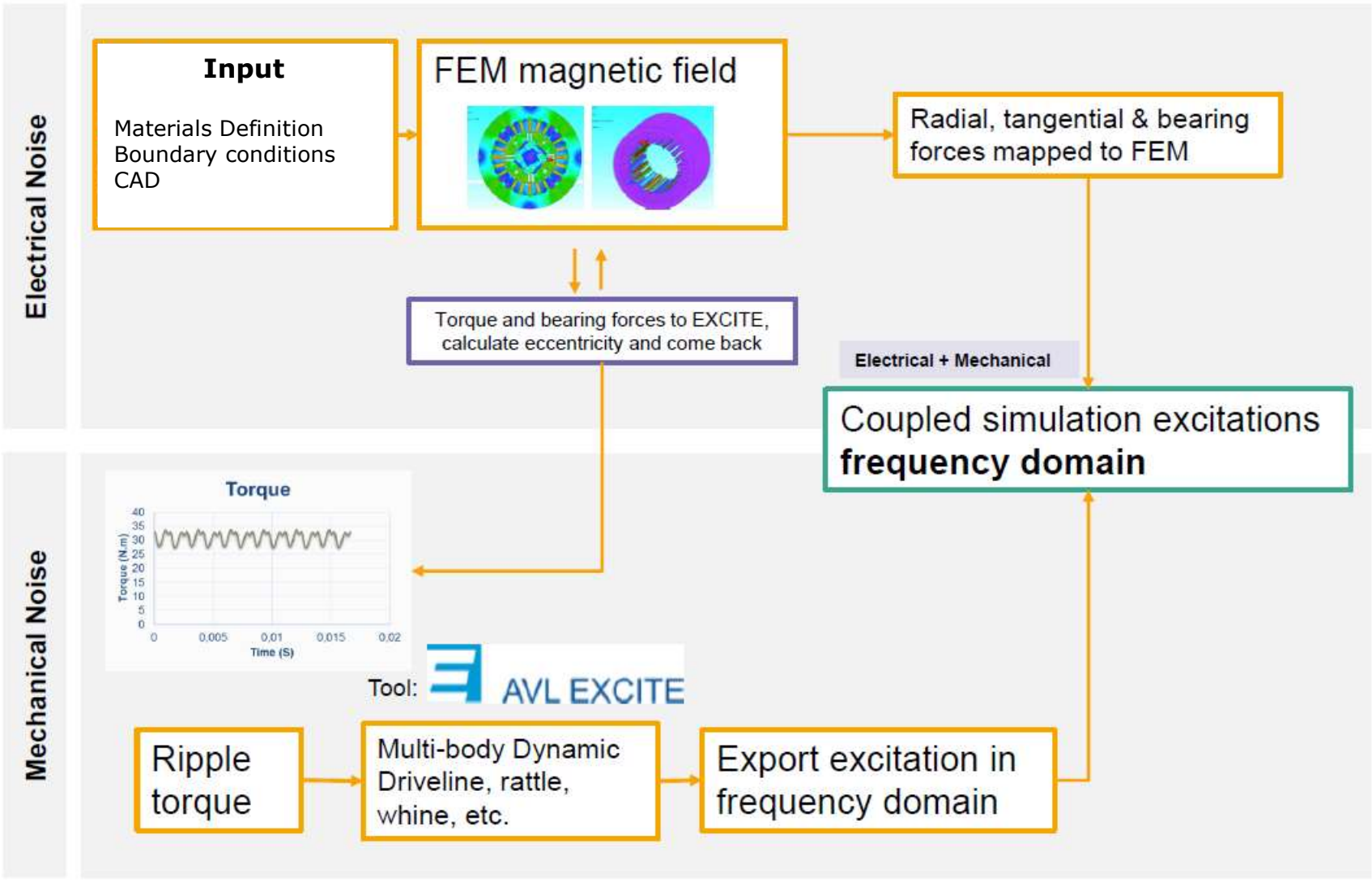
FEM



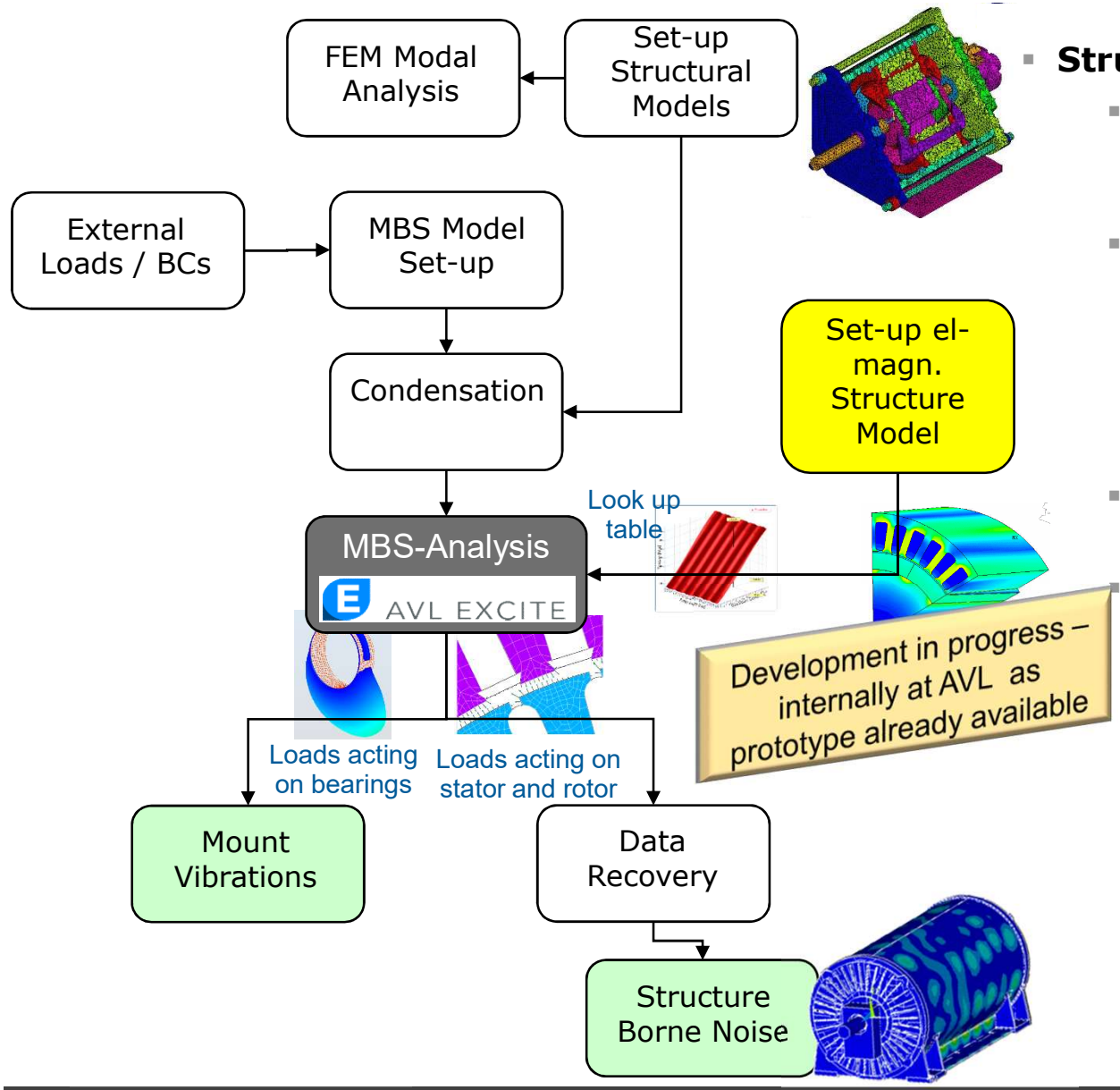
E-Machine excitations

Coupled excitations can add up and amplify structural/airborne noise problems

CURRENT WORK FLOW
NVH OF ELECTRIFIED POWERTRAIN



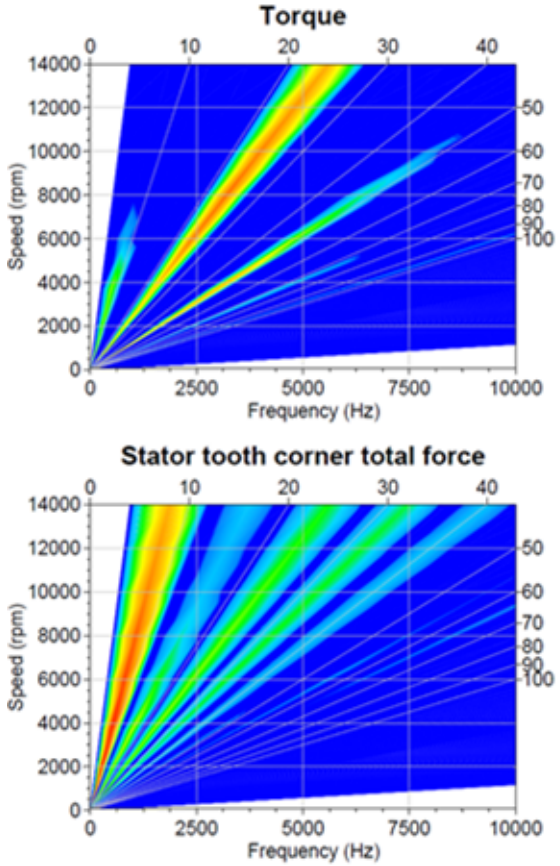
WORK FLOW IN DEVELOPMENT NVH OF ELECTRIFIED POWERTRAIN



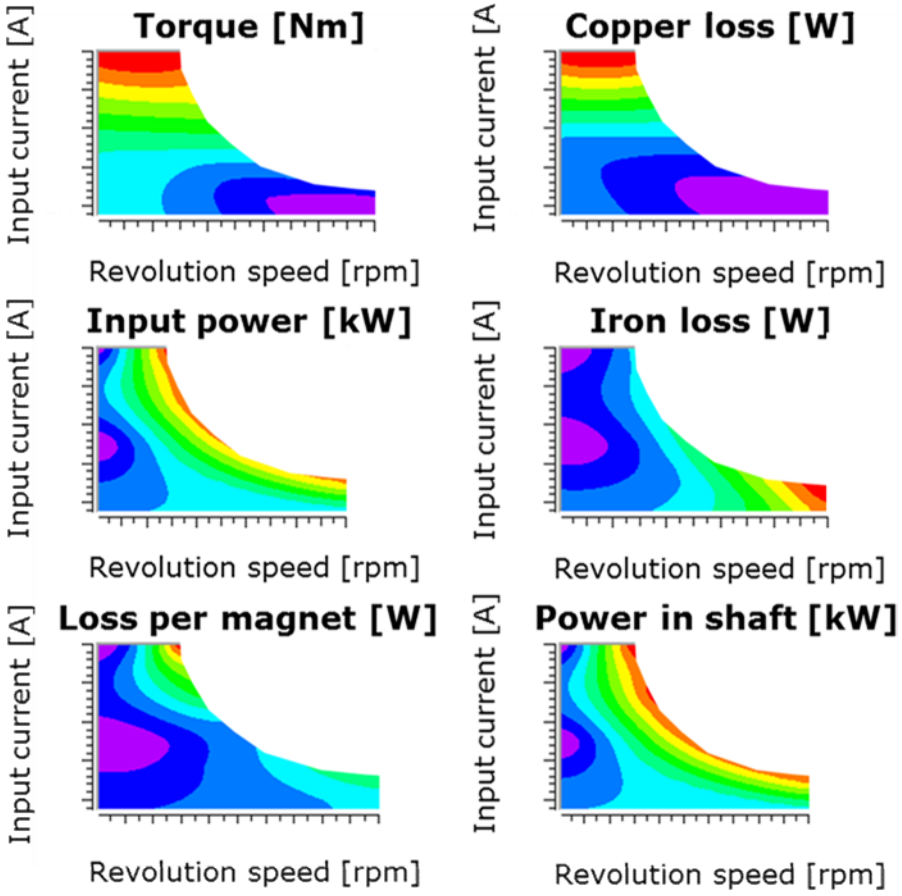
- **Structure Borne Noise**
  - Electro-magnetic field excitation on housing is considered within the MBD analysis
  - Radial and circumferential forces are extracted during iteration process from the e-machine coupling model (EMC1-joint) and applied onto the condensed FEM housing
  - No separate FEM forced response calculation required
  - Structure borne noise is direct result from MBD analysis (data recovery, modal data recovery)

CASE STUDY
E-MACHINE ELECTROMAGNETIC EVALUATION

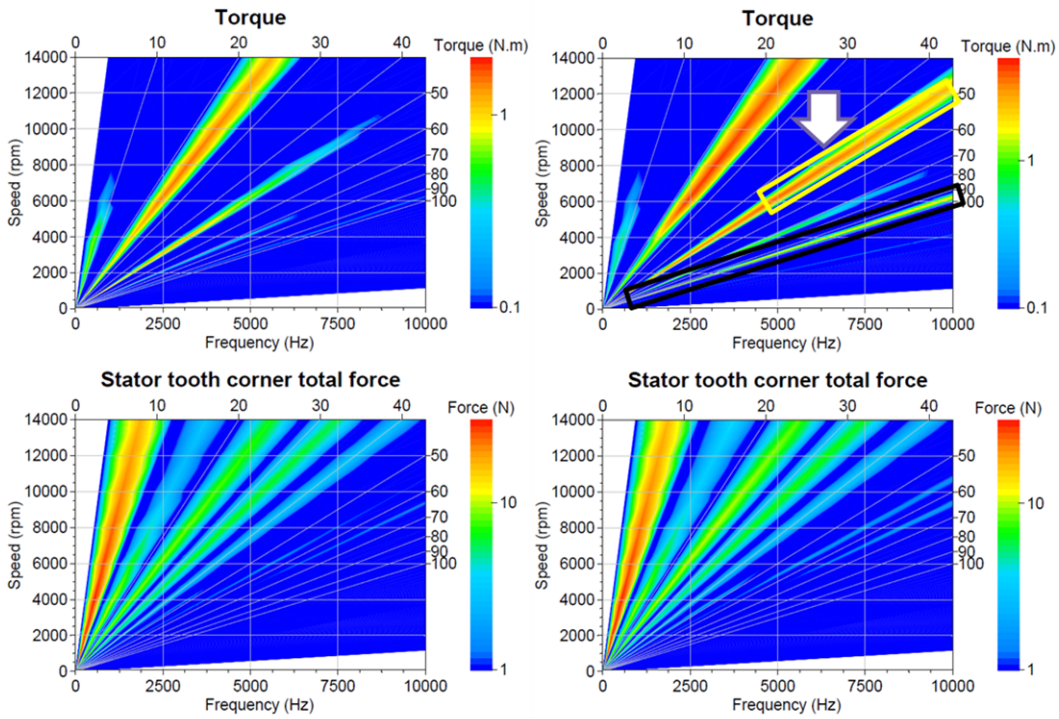
Campbell diagram



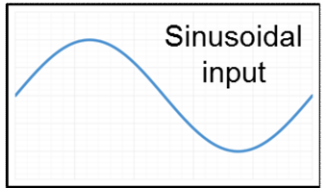
Operation map

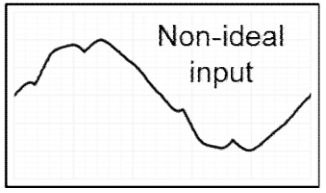


CASE STUDY
EFFECT OF INVERTER ON NVH



Perfect input signal is **not good enough**

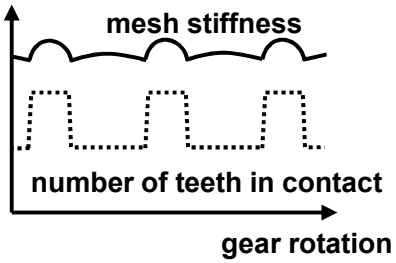




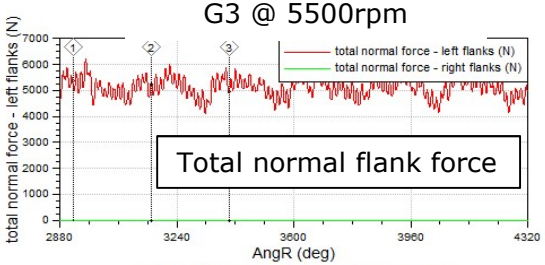
Actual inverter harmonics included to evaluate realistic excitations

Effect on NVH:
24th , 48th, and 96th torque order increase

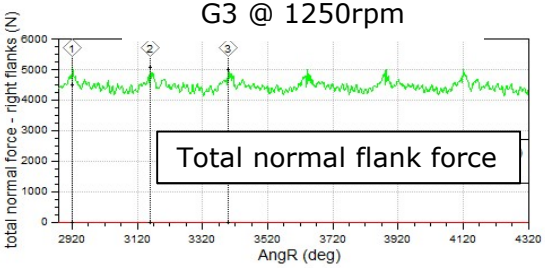
CASE STUDY
MECHANICAL NOISE: GEAR WHINE

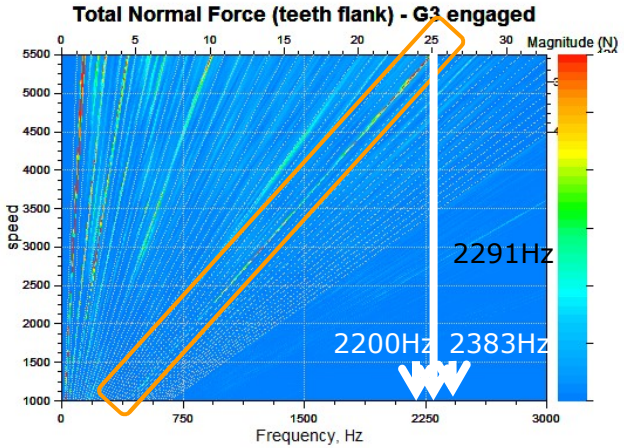


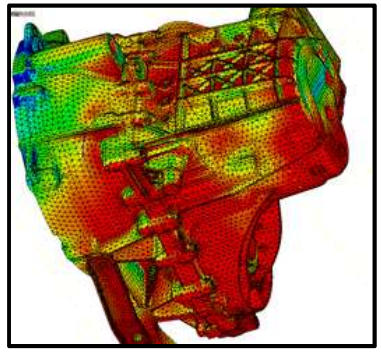
G3 @ 5500rpm



G3 @ 1250rpm





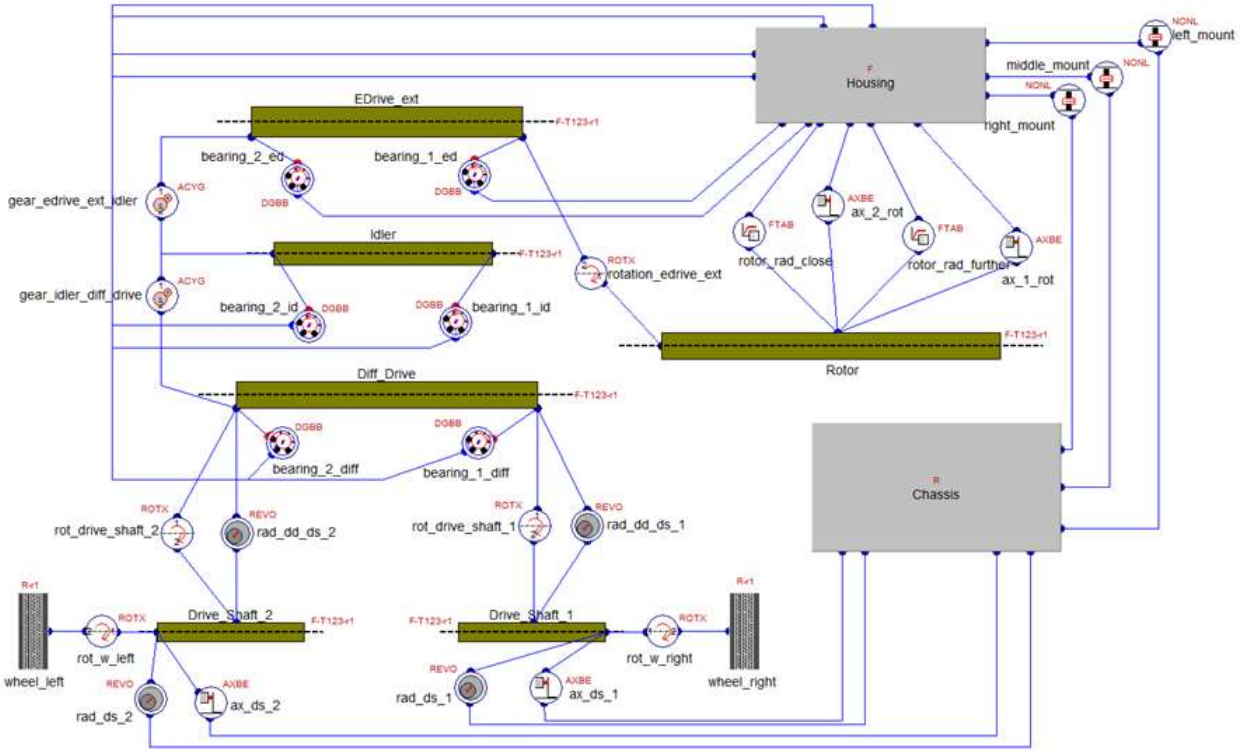


Surface normal velocity levels

	Z1	z2
Third Gear	25	37
Final Drive	15	63

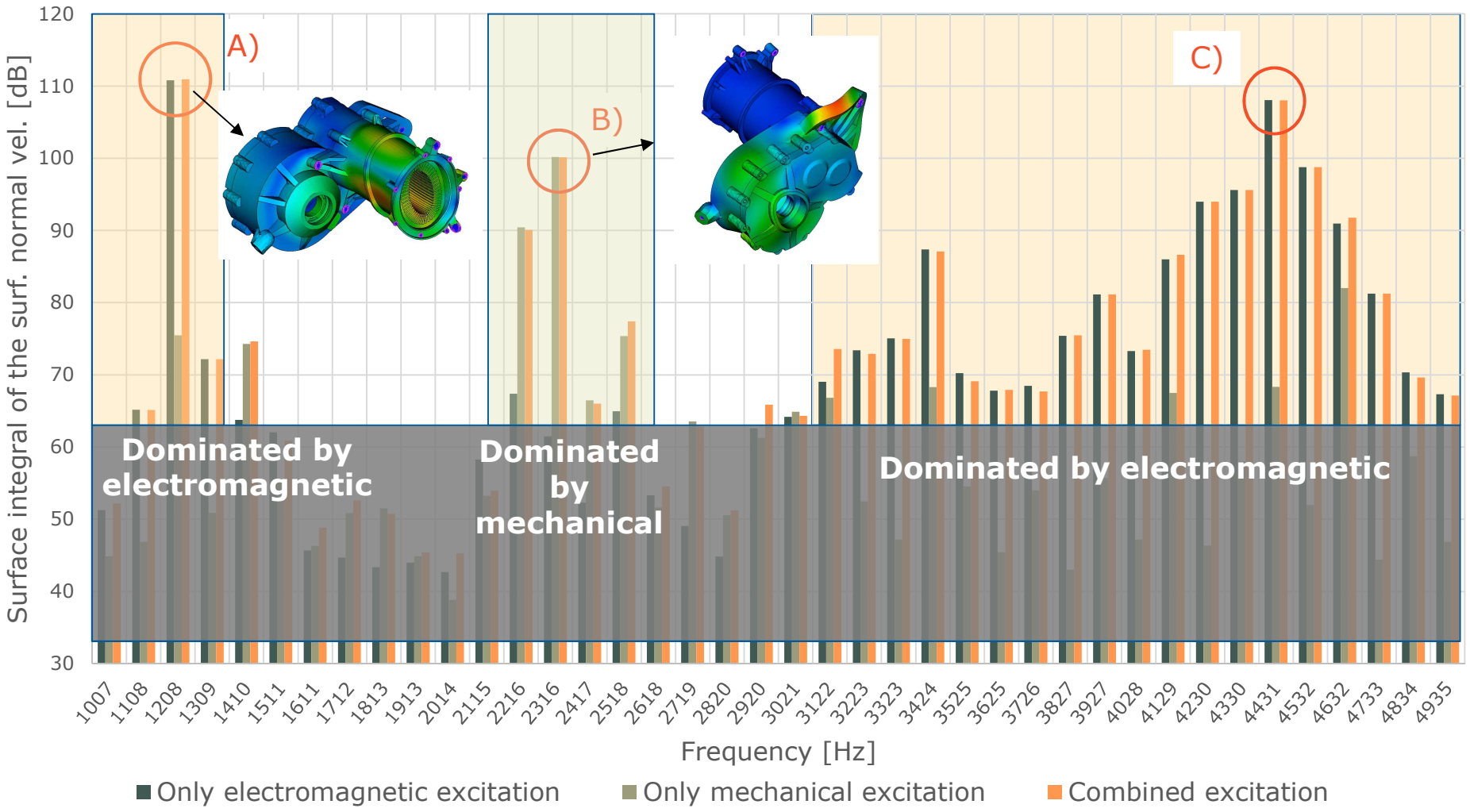
1st harmonic,
25.Ord @5500rpm → **2291Hz**

CASE STUDY
EXCITE POWERUNIT MODEL FOR NVH



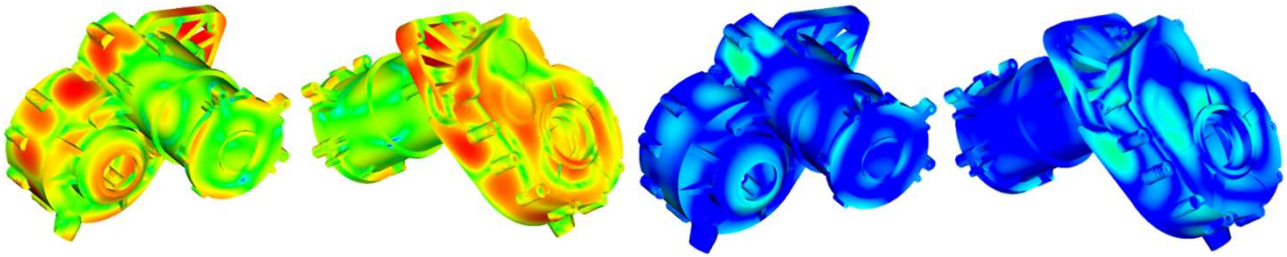
- Mechanical Torque provided by classic Multi-body dynamics simulation
- Electromagnetic loads applied as external load to structure

CASE STUDY
TOTAL NOISE RADIATION



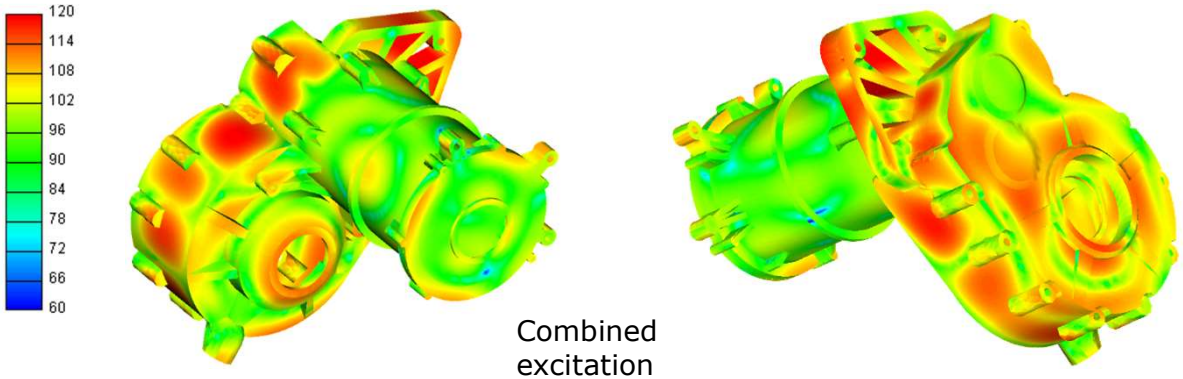
Peak "A": stator forces Peak "B": Gear Mesh Frequency (GMF) Peak "C": stator forces

CASE STUDY
SURFACE VELOCITY



Only electromagnetic excitation

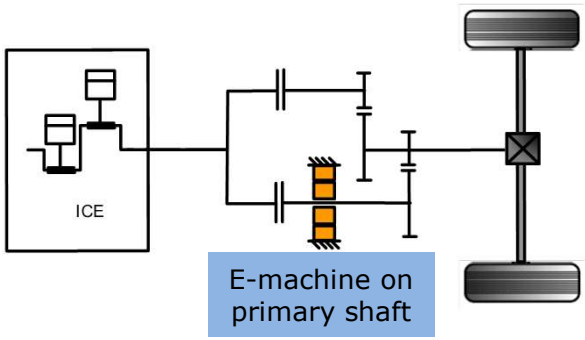
Only mechanical excitation

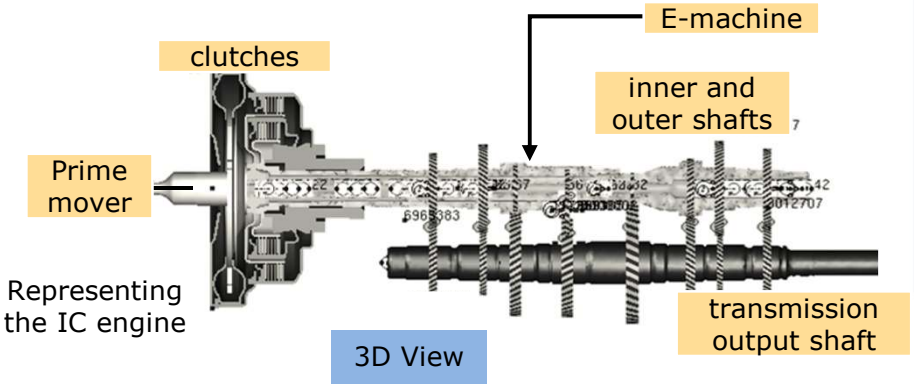


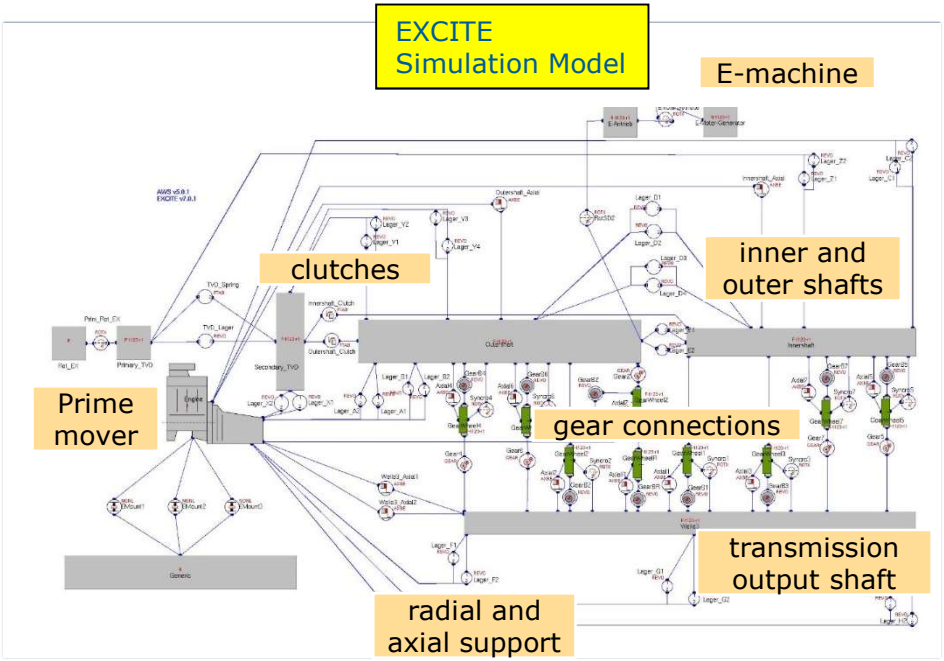
Combined excitation

Electromagnetic excitation is dominant at this speed

CASE STUDY:
NVH SIMULATION OF A PARALLEL HYBRID



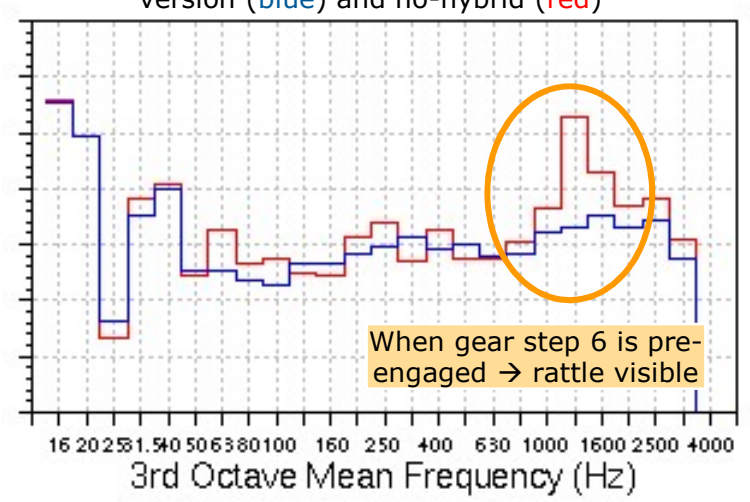


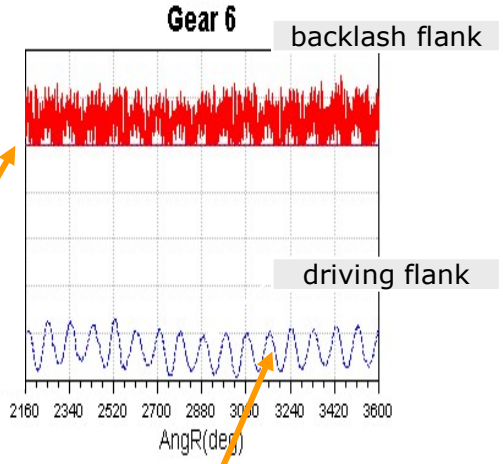


AVL EXCITE

CASE STUDY:
NVH SIMULATION OF A PARALLEL HYBRID

Structural response on transmission housing for hybrid version (blue) and no-hybrid (red)





w/o hybrid high frequent force visible (=rattle) due to friction torque in second clutch

No impacts and only low frequent force fluctuation due to additional output torque w/ hybrid


AVL
AVL
THANK YOU
AVL
www.avl.com