Agenda

- Industry Context & Applications
  - Presentation of the Solution
  - Solution Portfolio Details
  - Success story
  - Why Imagine.Lab?
Industry Challenges

- **Reduce noise and improve durability**
  - Control of high frequencies (>40Hz) due to hydraulic dynamics, mechanical contacts, slip control.

- **Optimize mechanical parts and architectures**
  - Component deflection leads to the need for FEA to obtain surface velocities.
  - Simulate precisely surface, materials for given architectures.
<table>
<thead>
<tr>
<th>FEATURES</th>
<th>BENEFITS</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ ALL frequency tools to analyze precisely the oscillations (Eigen values, modal shapes, FFT…)</td>
<td></td>
</tr>
<tr>
<td>▪ Linear and non-linear model are coupled together</td>
<td></td>
</tr>
<tr>
<td>▪ FEM models with low CPU time and non linear excitations connected together with time response</td>
<td></td>
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<tr>
<td>▪ Representation of fluid and mechanical dynamics</td>
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<tr>
<td>▪ Find the contributors of natural modes and modify them to reduce vibrations</td>
<td></td>
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<tr>
<td>▪ Reduce the variations of contact forces with backlash through the optimization of the number of teeth and planets</td>
<td></td>
</tr>
</tbody>
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AMESim is able to simulate ANY vehicle powertrain architectures

- **Transmission part**
  - MT/AMT/DCT
    (Mechanical, Automated, Dual clutch)
  - AT/IVT/CVT
    (Automated, Infinitely, Continuous variable)

- **Driveline part**
  (Universal Joints, clutch dampers, DMF, chassis)

- **Engine part**
  (Crankshaft, Camshaft, valves, rocker arms)
Multi-Domain skill is required

Engine
- Crankshaft
- Camshaft Vibrations
- Torque oscillations

Clutch / DMF
- Dry/Wet, Multidisk, dampers
- Thermal aspects, slip control

Shift control
- Synchronizers, 3D animations
- Epicyclic gear trains
- Gearshift control

DCT model for Gear shift Comfort analysis (0-40Hz)

Actuation
- Switch valves
- Pressure regulation
- Hydraulic/electric Networks

Driveline
- 2D/3D Modeling
- U-joints, Tires
- ESP / ASR
- Piloted Differential

Transmission
- Robotized / Automatics
- DCT/Hybrid
- IVT/CVT

LMS®
ENGINEERING INNOVATION
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The NVH solution enables to focus on NVH sources and related corrective components efficiency:

- Winning noise (> 1 kHz)
- Idling noise (>300Hz)
- Clutches dampers
- Dual mass flywheel
- Driveline Vibratory Analysis
- Engine torsional harmonics
NVH: Engine torsional harmonics

Mode number | 1 | 2 | 3 | 4
---|---|---|---|---
Validated Software | 313 Hz | 481 Hz | 1176 Hz | 1925 Hz
AMESim (θ=0°) | 318 Hz | 482 Hz | 1165 Hz | 1744 Hz
AMESim (θ=90°) | 318 Hz | 485 Hz | 1178 Hz | 1766 Hz
Min. differences | 1.6% | 0.2% | 0.2% | 8.2%

Variable number of cylinder (1 to 18)
NVH: Driveline Vibratory Analysis

Modal shapes

Time response

1 - Observer 5 (Universal Joint) driving shaft acceleration [rad/s²/s]

Eigenvalues

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Damping ratio</th>
<th>Real part</th>
<th>Imaginary part</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.255889</td>
<td>0.037565</td>
<td>-1.942758</td>
<td>-51.728122</td>
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<tr>
<td>24.331436</td>
<td>0.051151</td>
<td>-8.337146</td>
<td>-152.404665</td>
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NVH: Dual mass flywheel

- Improving vibration comfort
- Friction due to centrifugal force
- Efficient simulation models with adequate accuracy
- Different operating conditions (start, idle, drive rattle, tip-in/tip-out,...)
NVH: Clutches dampers

- Clutch damper design
  - Hysteresis
  - 1, 2 or 3 stage springs

Driveline Analysis

- Effects of torsional dampers on Gear Shift comfort and vehicle drivability
NVH: Idling noise (>300Hz)

3D model of differential developed in order to analyze rattle noise due to gear backlash and excitation on torsional modes

Use of AMESim scene editor to help the understanding and the
NVH: Winning noise (> 1 kHz)

- Study of the balancer shafts in flexion on bearing stiffness
- Balancing produce itself an excitation of the gears backlash or whining noise
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The implementation of the method in an AMESim model leads to:

- Access to temporal analysis tools
  - Torsion of the shaft as a function of time
- Access to linear analysis tools
- Access to spectral analysis tools
  - Order tracking: torsion of the shaft as a function of the rotary velocity

- Crankshaft – Camshaft
  - 3D oscillations
    - Coupling with Non-linear bearings
    - Coupling with Non-linear dry frictions
    - Coupling with variable stiffnesses
NVH: Multi-Axle Transmission

Driveline of a 6x6 truck

- Engine
- Clutch
- Transfer box
- Front axle
- Differential
- Middle axle
- Vehicle (load)
- Rear axle

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Our Solution Benefits for design process

Increase final products quality & time to market and reduce costs

- Better physical understanding of driveline vibrations due to a coupling between linear systems with non linear ones (Dry frictions, variable stiffnesses, enstops, bearings, joints, gear backlash…)

- AMESim variable step solver is specialized in high dynamics simulation with fast stiffnesses variations like in hard non linear systems

- Reduce number of chassis dyno tests using Off-line test procedure validation

- Continuous process from simulation to test bench to improve durability

- Scaleable solutions from component to complete vehicle
Thank you