# Modelling of an eAxle with planetary and cylindrical gear stages for structural dynamic investigation

AVL International Simulation Conference 2019

# Modelling of an eAxle with planetary and cylindrical gear stages for structural dynamic investigation

## Introduction to dynamic simulation of eAxle with EXCITE™ Power Unit

### Goals of analysis:

- dynamic evaluation of the system
- gear mesh assessment
- bearings assessment
- mounts vibrations
- NVH analysis
- detecting possible dangerous phenomena in new design or finding a root of existing problems

### Possible solutions/approaches

- Basic/simplified simulation (GGEA, center nodes)
- Advanced simulation (ACYG, center nodes, DGBB)
- Extended simulation (microgeometry, tooth nodes, stator forces)

### Tools

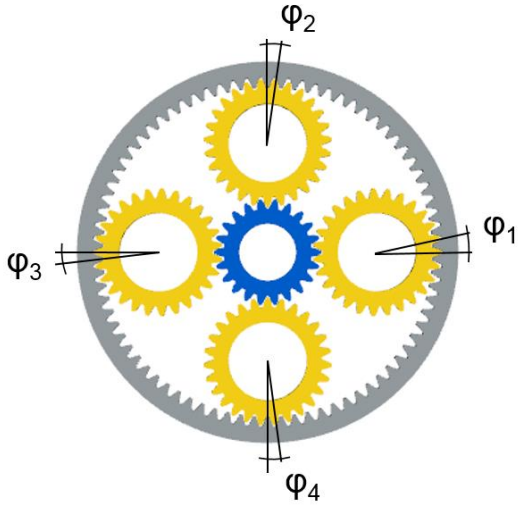
- Condensation/Data recovery
- Node Set, Surface selection
- 2D results (Impress Chart)
- 3D results (Impress 3D, Impress M)
- Animated results
- Modal analysis
- COMPOSE Apps
- EXCITE™ Acoustics

Gears evaluation tools

- Advanced Gear Animation
- Contact Pattern Plots

PGS/e-Motor

- Retained nodes selection
- Phasing tool



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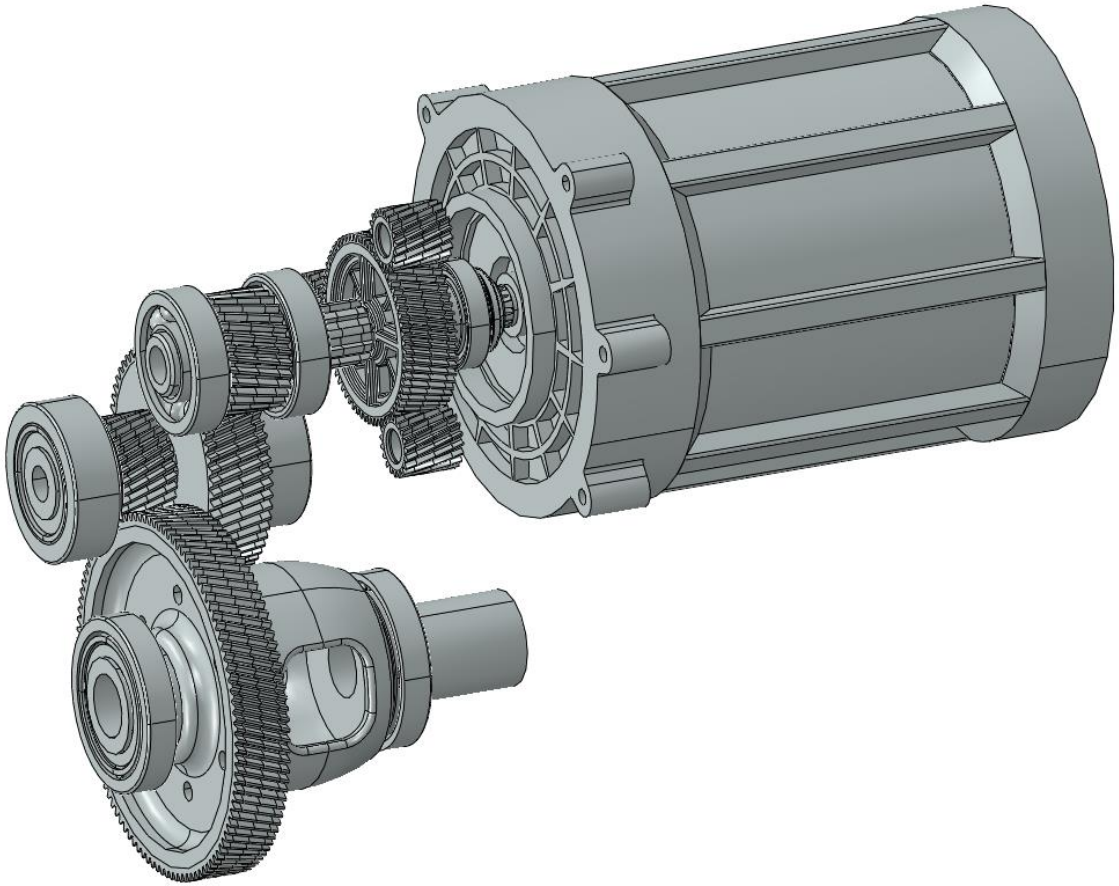
## Model description



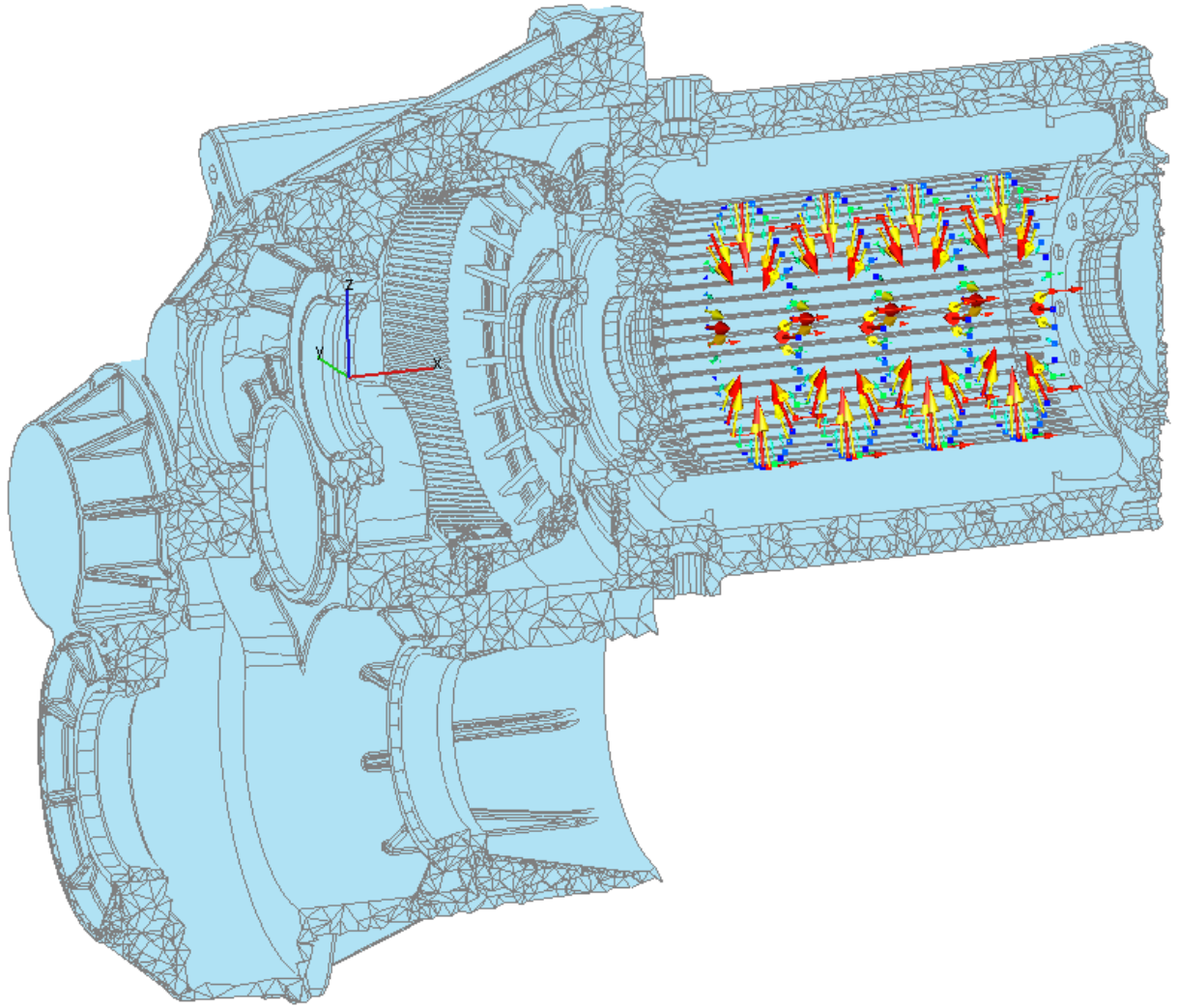
Passenger car eAxle – main data:

| | | |
|---|---|---|
| Maximum vehicle speed | 180 | km/h |
| Maximum angular velocity (e-Motor) | 21000 | rpm |
| Maximum angular velocity (differential) | 1170 | rpm |
| Transmission ratio | 18 | - |
| Transmission ratio (PGS) | 2.585 | - |
| Transmission ratio (CGS) | 7 | - |
| Total mass | 80 | kg |

# Modelling of an eAxle with planetary and cylindrical gear stages for structural dynamic investigation

## FE modelling workflow

- Identifying bodies and joints
- Defining retained nodes positions (bearings, gears, spline gears)
- Creating FE models with retained nodes
- Condensation (sub-recovery matrix)
- Validation of FE model (TP, MA, Hammer / Shaker test)
- Extensions for e-Motor/PGS



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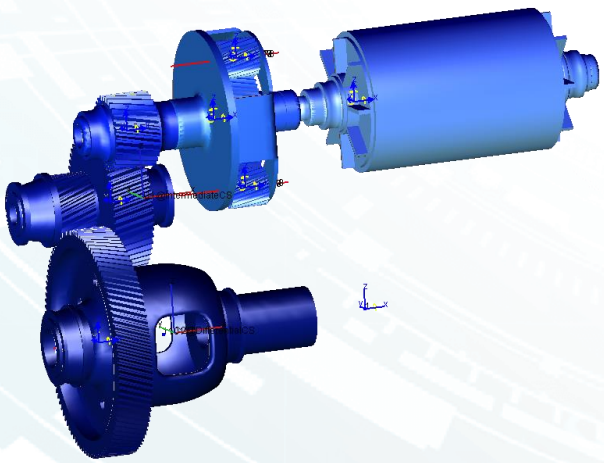
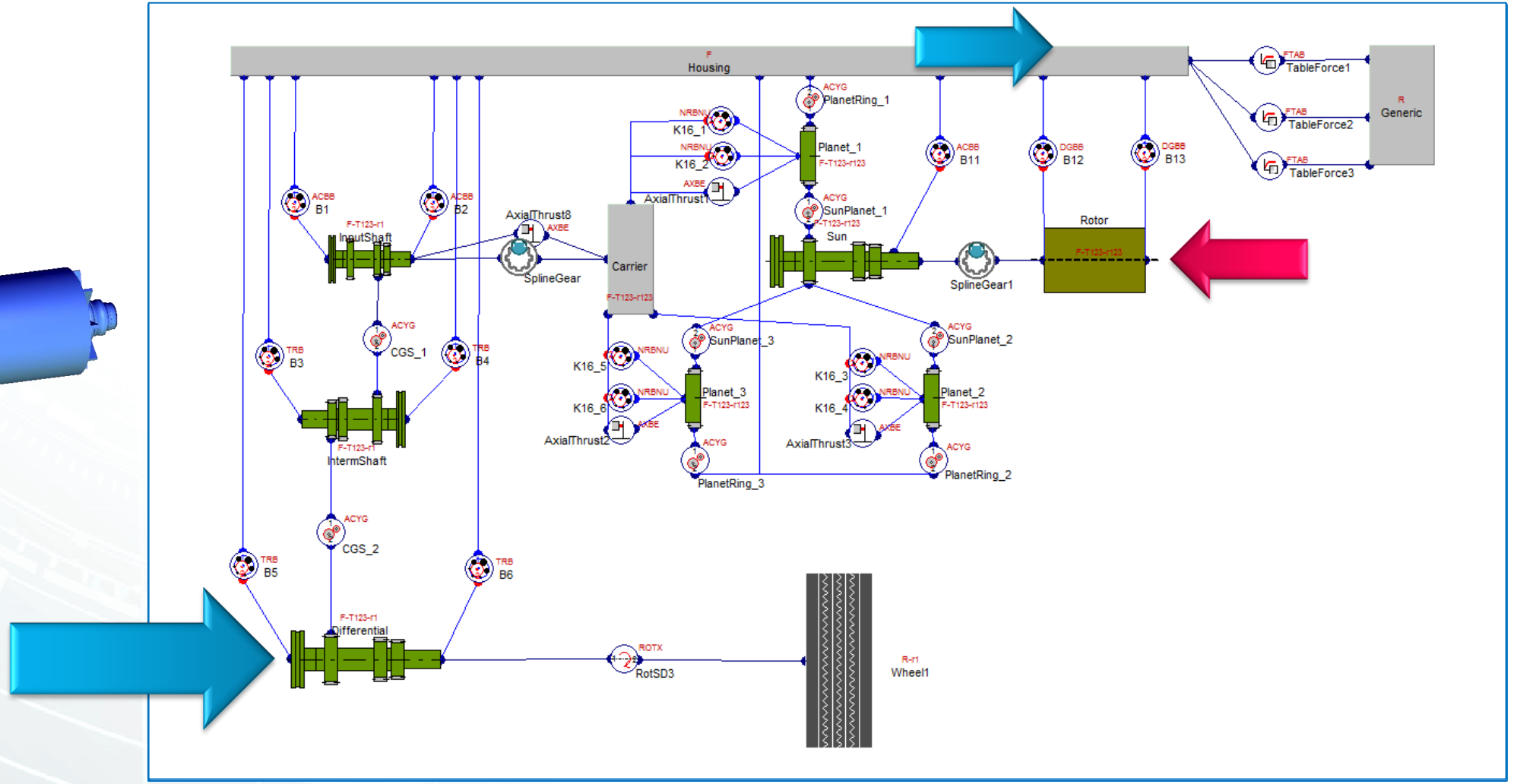
## EXCITE™ Power Unit model





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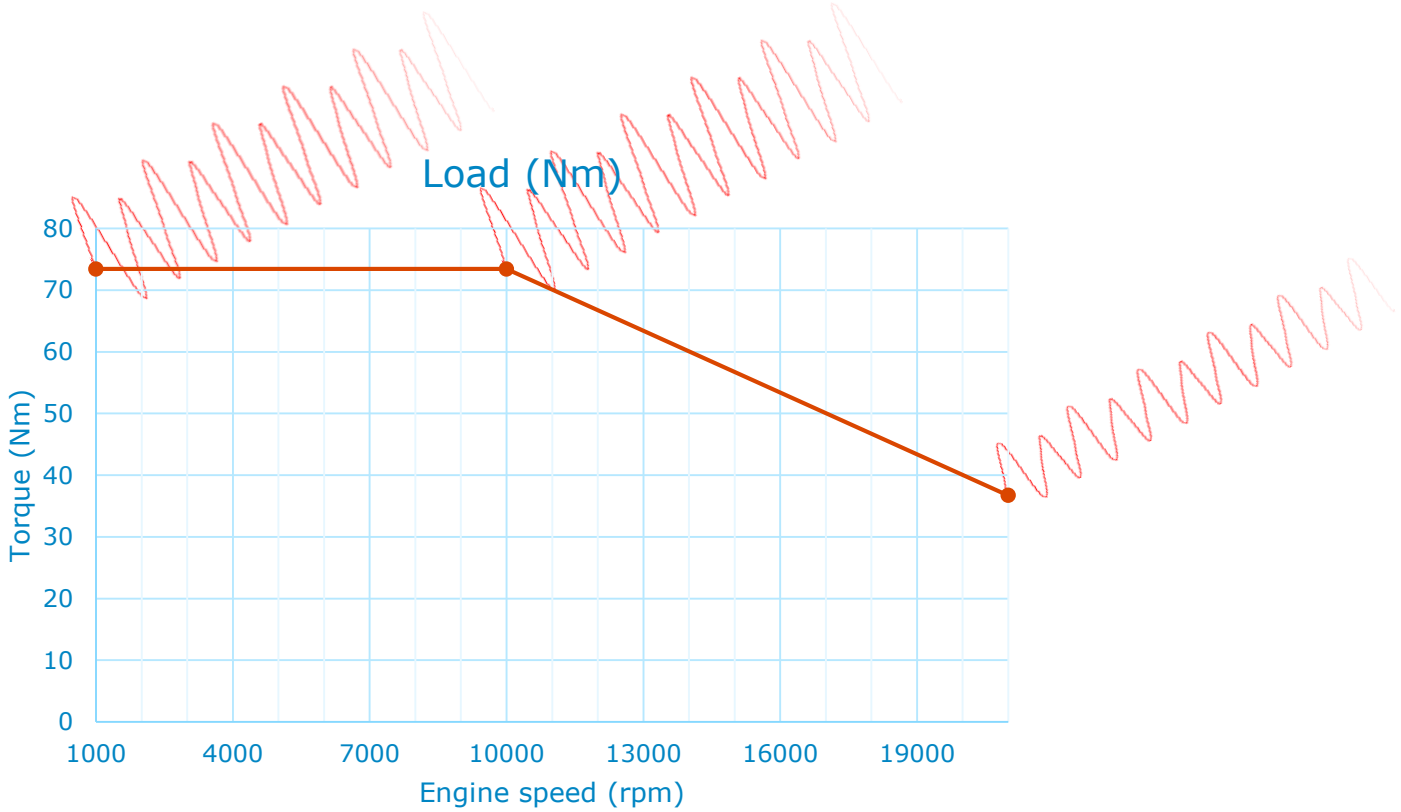
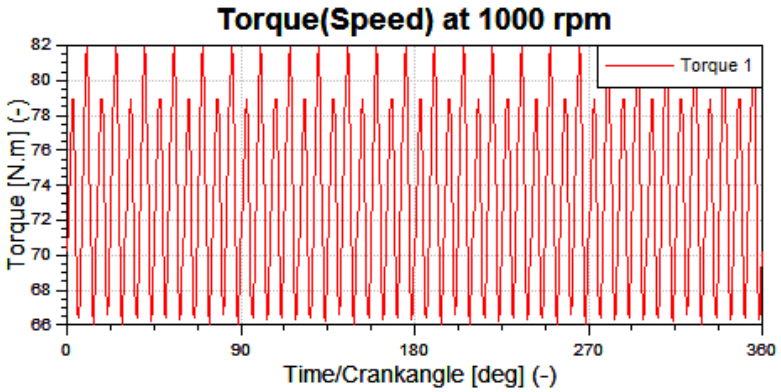
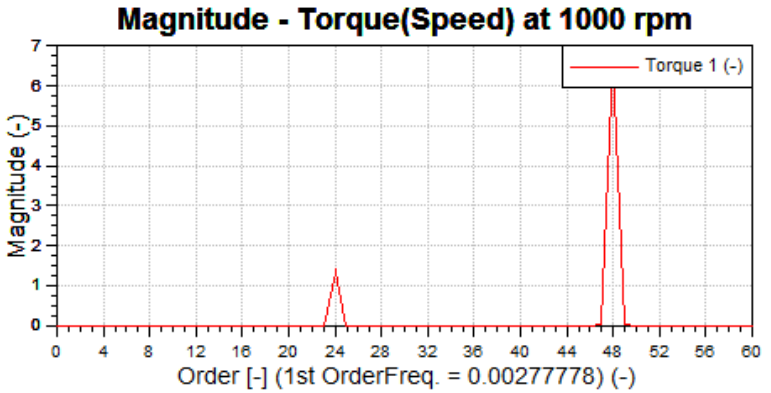
## EXCITE™ Power Unit model - loads



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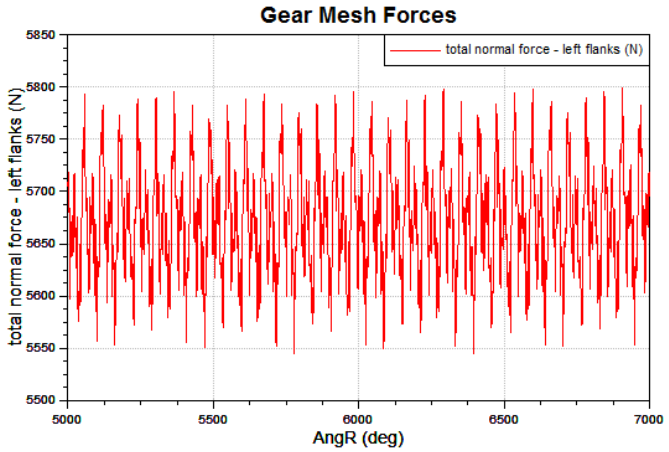
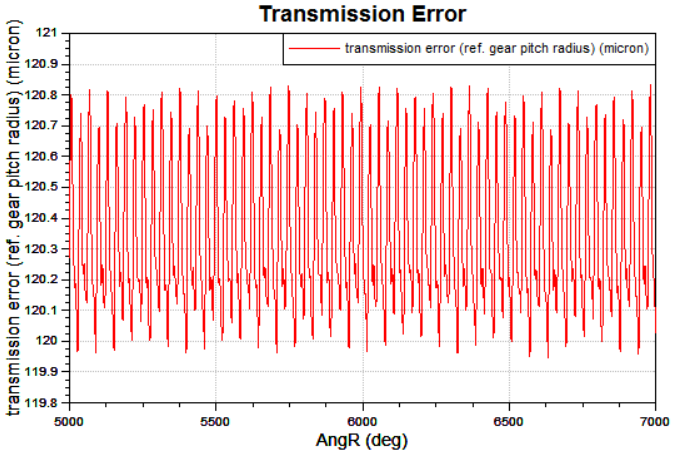
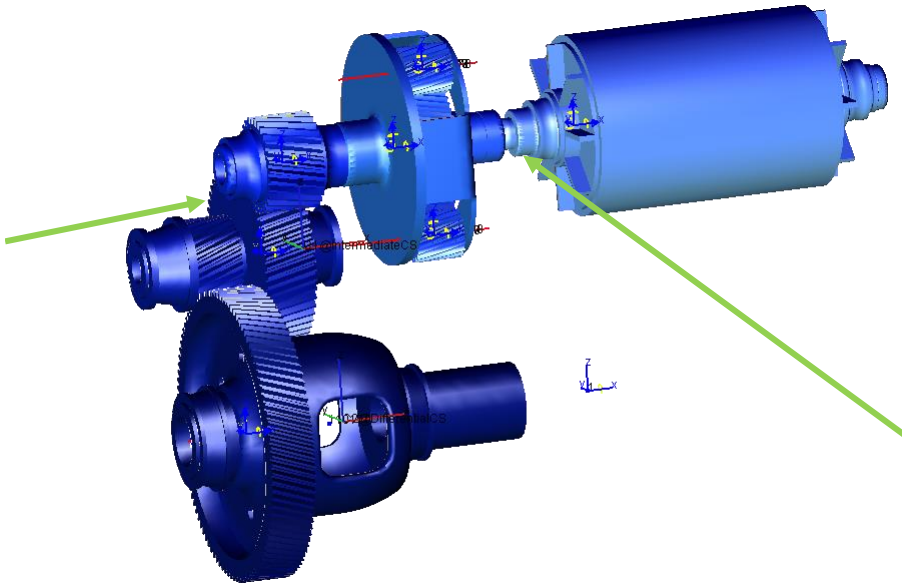
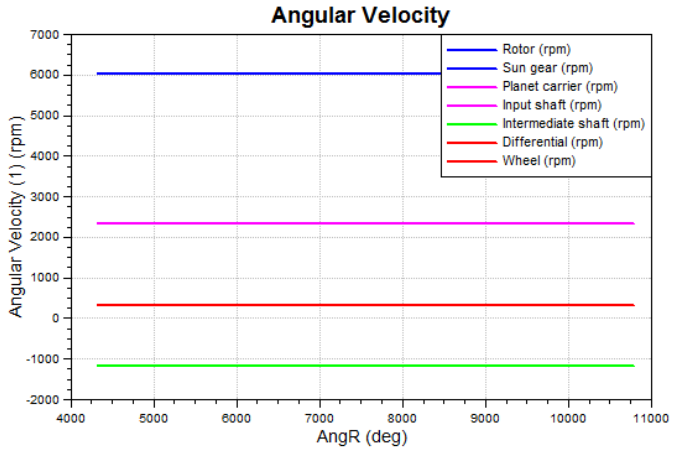
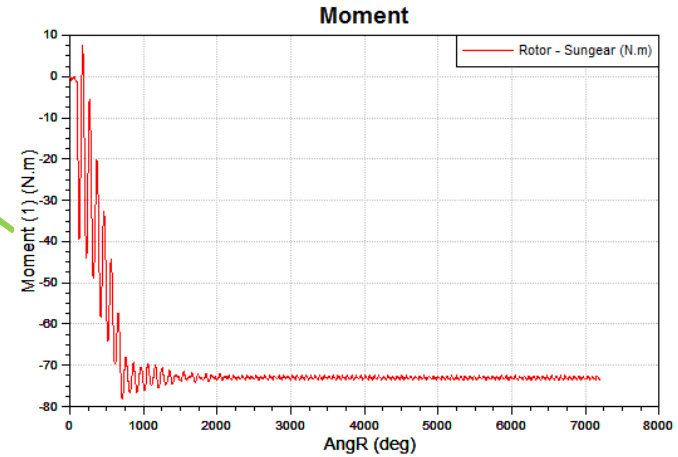
## EXCITE™ Power Unit – 2D results





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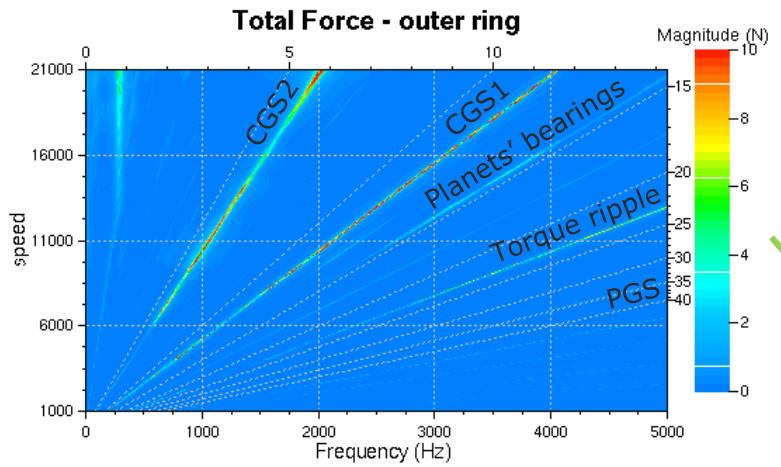
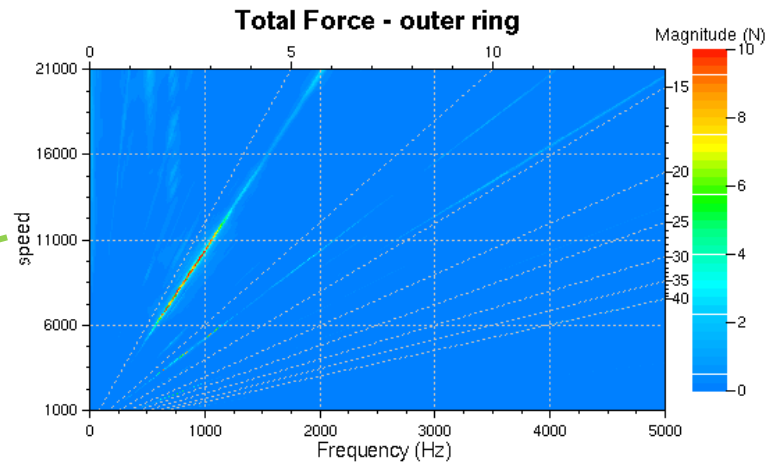
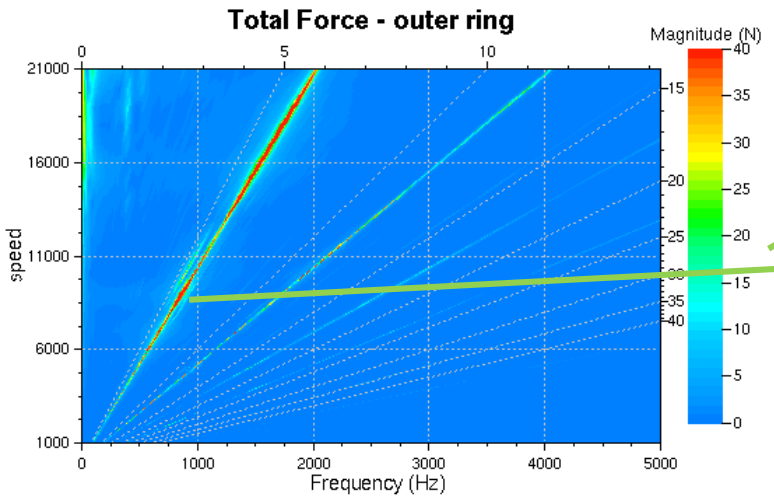
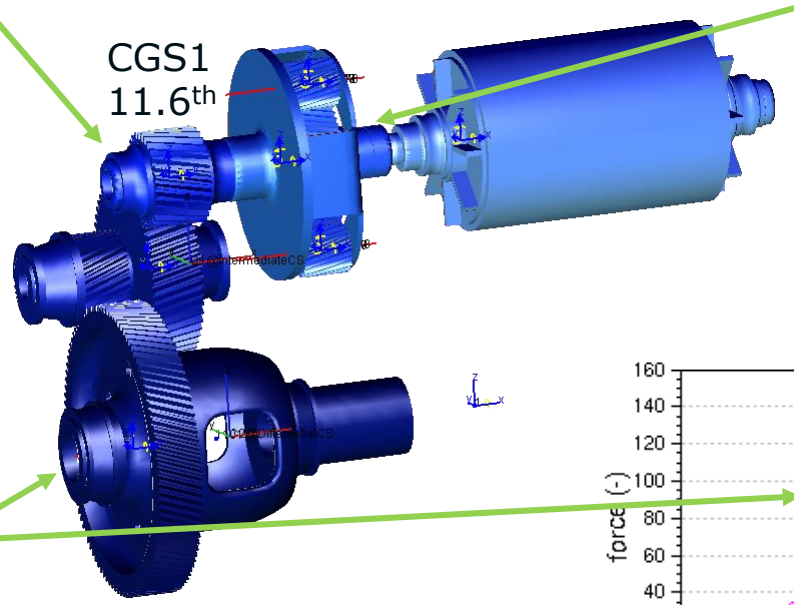
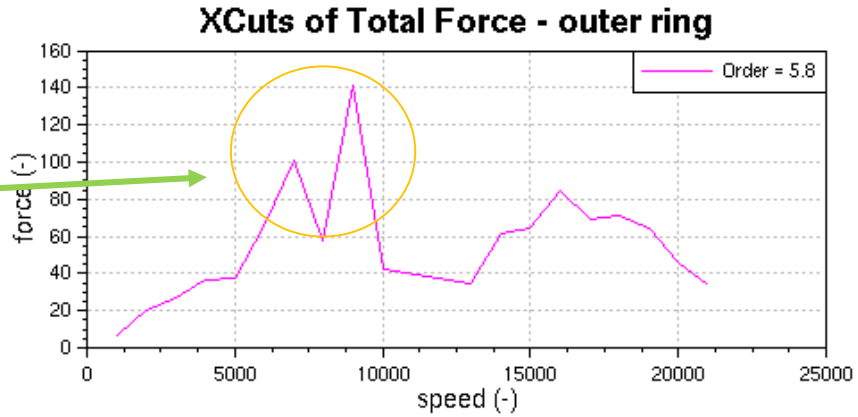
## EXCITE™ Power Unit – 2D results



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## EXCITE™ Power Unit – Modal Analysis

Modal Analysis (Beta Version)

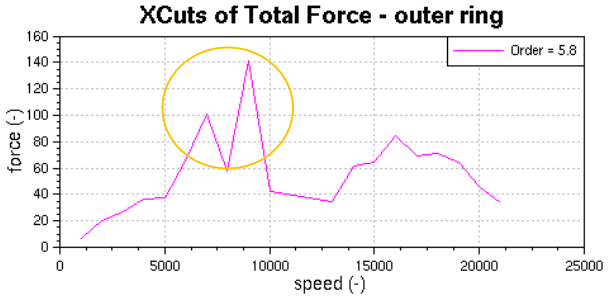
Select Case Set to browse: PGS

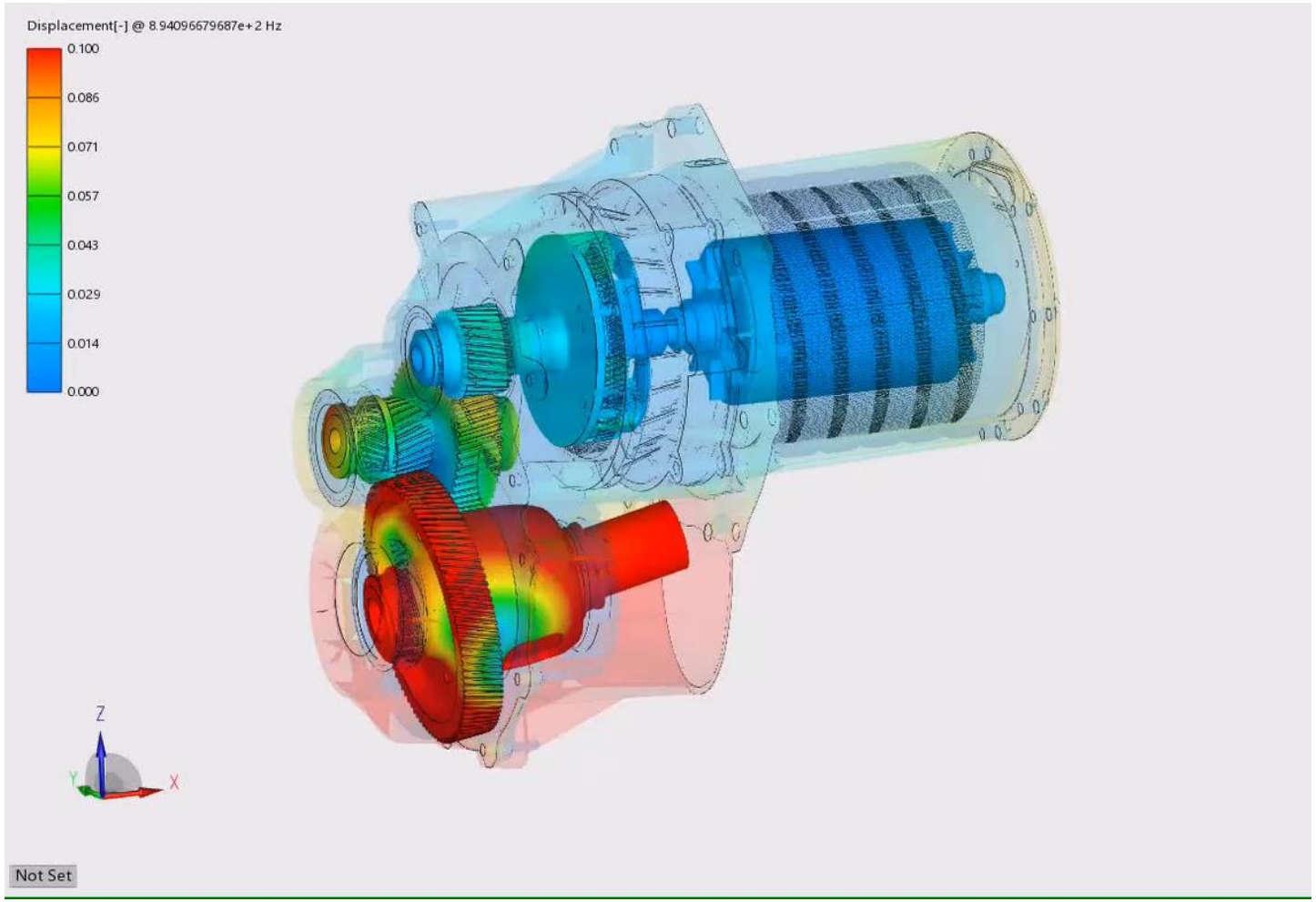
Select Case to browse: 06000

Modal Analysis of Model E_axle_v5_20191_housing_bear_flex at Evaluation Step Last

Show Mode Shapes

| Mode | Frequency (... | Dominant DOF | Kinetic En... | Dominant B... | Kinetic Ener... |
|---|---|---|---|---|---|
| 16 | 575.2416 | Retained modal DOFs | 30.51 | Rotor | 34.71 |
| 17 | 640.4139 | Rotation X | 49.62 | Differential | 53.96 |
| 18 | 743.5801 | Translation X | 32.02 | Sun | 38.13 |
| 19 | 744.7056 | Retained modal DOFs | 26.39 | Sun | 37.75 |
| 20 | 744.7056 | Retained modal DOFs | 26.39 | Sun | 37.75 |
| 21 | 812.918 | Translation X | 56.46 | Planet_2 | 27.97 |
| 22 | 812.918 | Translation X | 56.46 | Planet_2 | 27.97 |
| 23 | 845.6646 | Rotation Y | 34.03 | Housing | 45.08 |
| 24 | 894.0967 | Rotation Y | 32.91 | Differential | 52.44 |
| 25 | 928.6282 | Rotation X | 33.6 | IntermShaft | 62.63 |
| 26 | 978.224 | Retained modal DOFs | 27.9 | Housing | 41.65 |
| 27 | 1200.5426 | Rotation Y | 35.19 | Differential | 51.51 |
| 28 | 1341.3176 | Retained modal DOFs | 27.18 | Housing | 60.84 |
| 29 | 1427.0023 | Retained modal DOFs | 37.41 | Housing | 29.85 |
| 30 | 1448.2884 | Retained modal DOFs | 37.26 | Carrier | 38.33 |
| 31 | 1448.2884 | Retained modal DOFs | 37.26 | Carrier | 38.33 |



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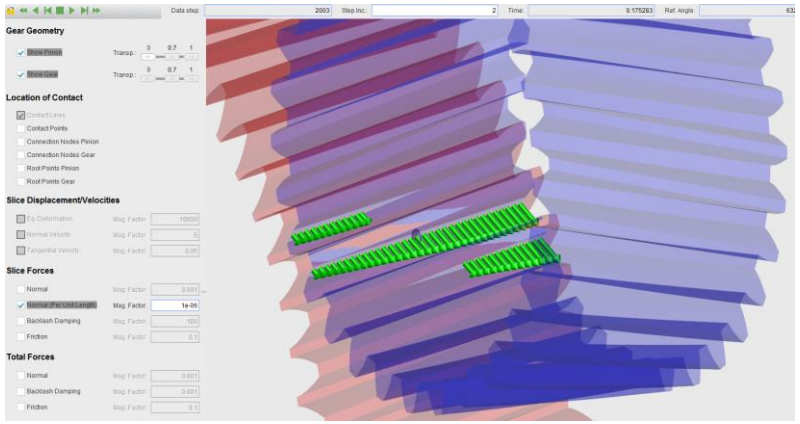
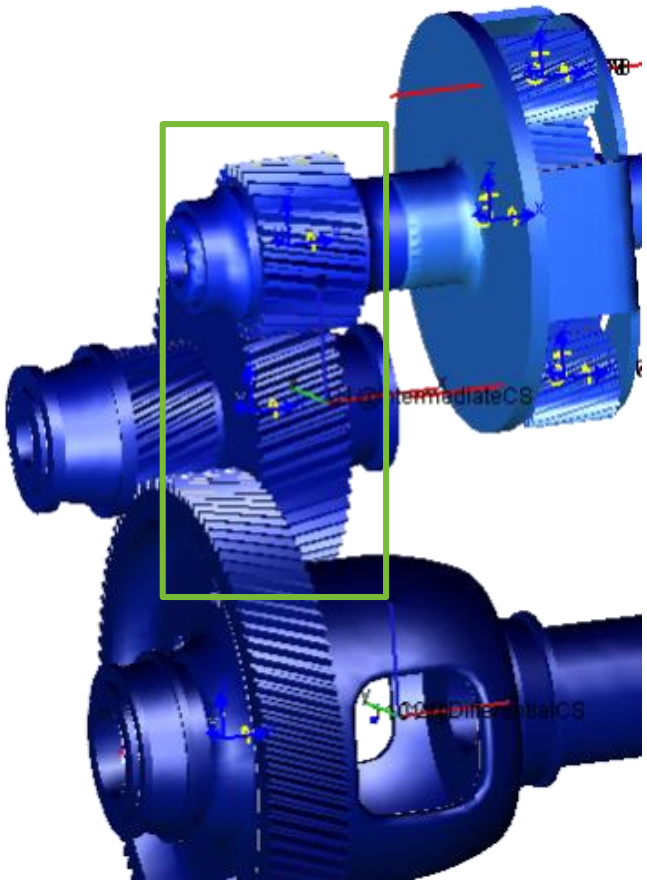
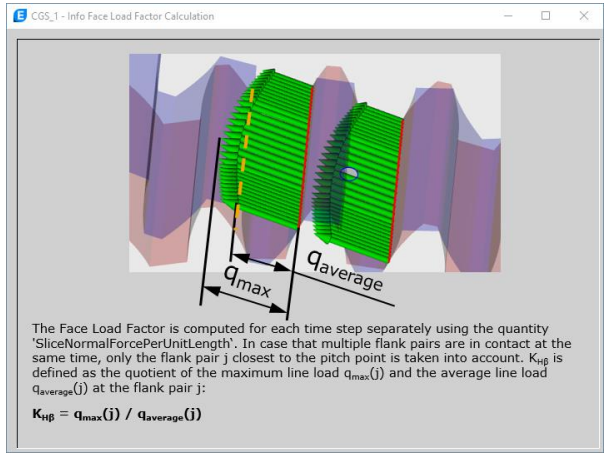
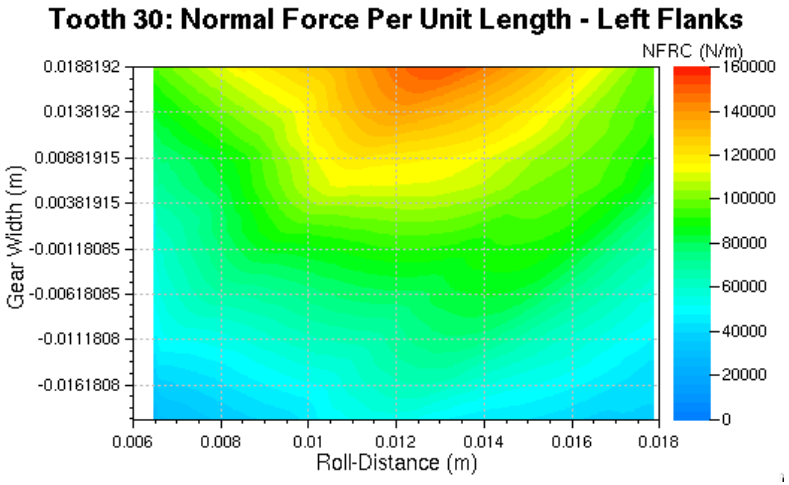
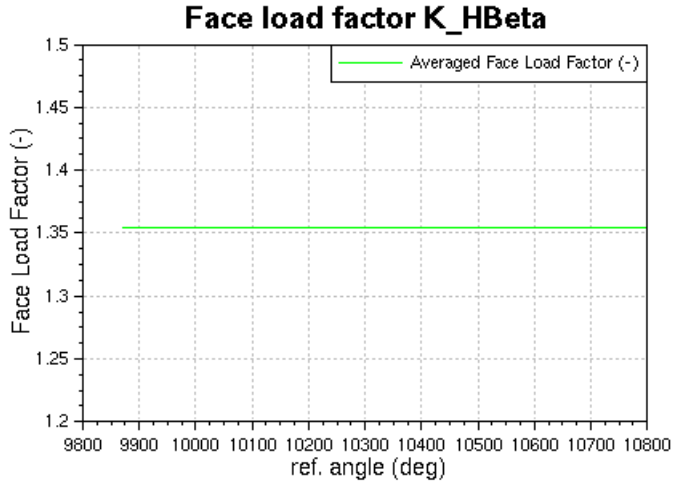
## EXCITE™ Power Unit – 2D results





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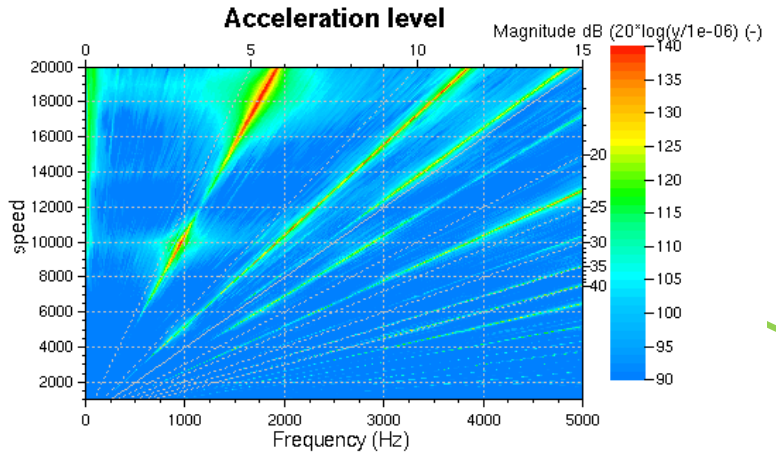


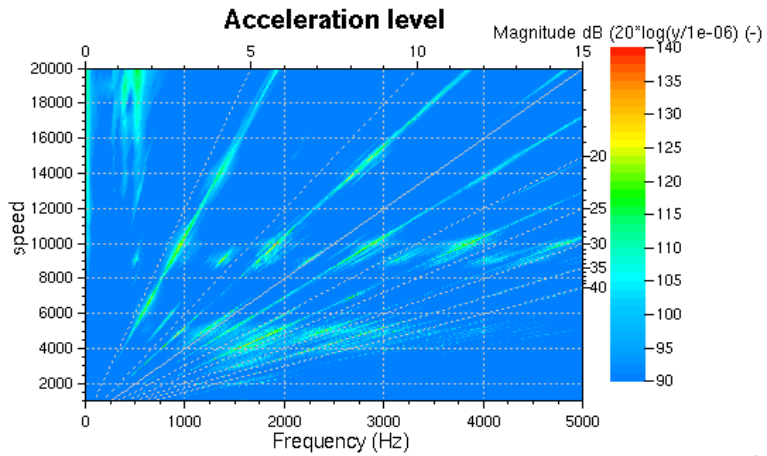


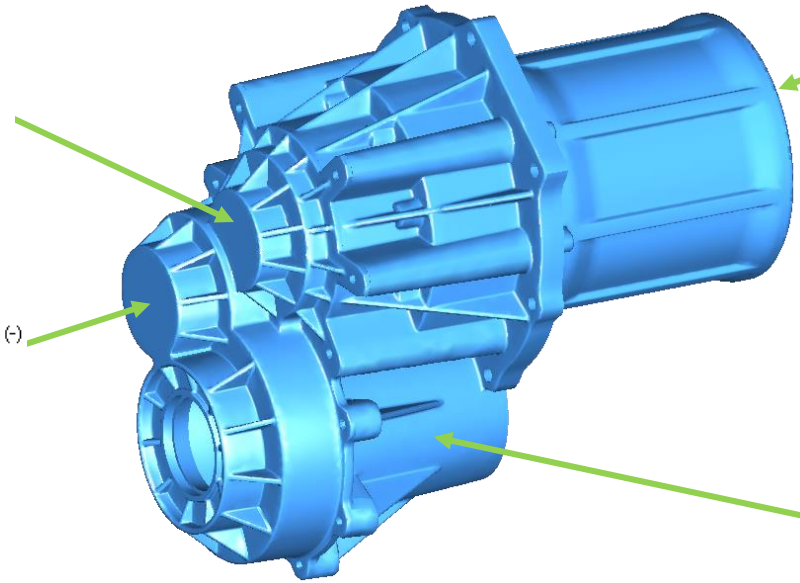

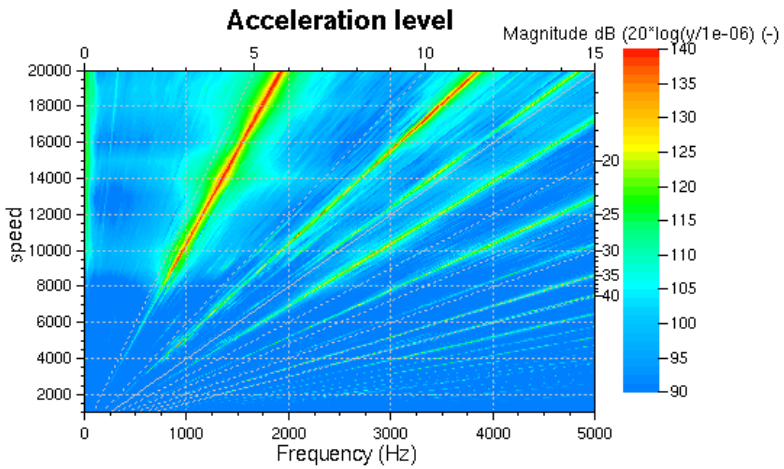


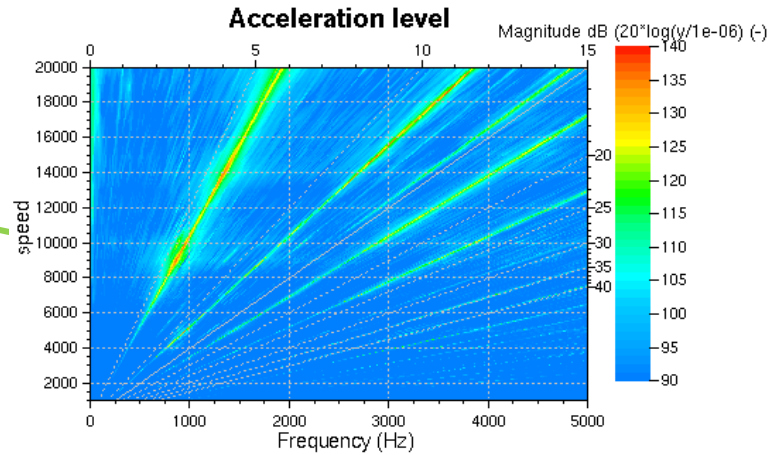

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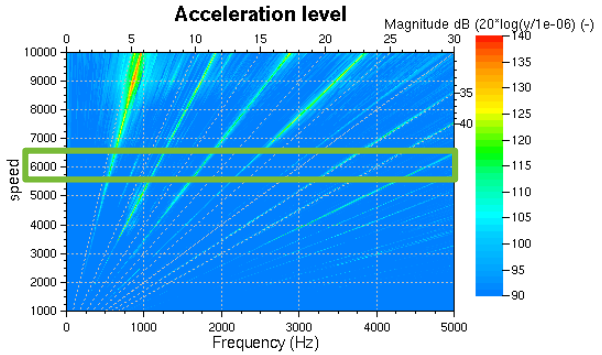
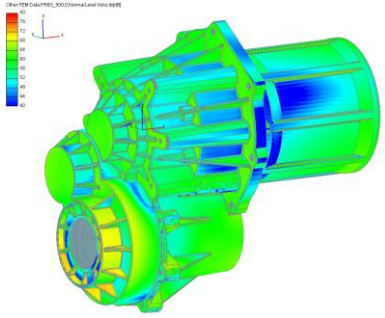
## EXCITE™ Power Unit – 3D results

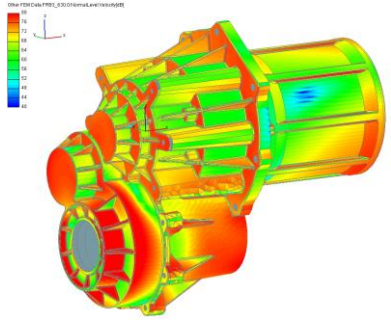
## Normal Level: Velocity (dB)



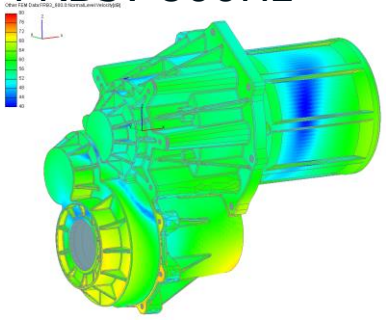

FRB3: 500Hz



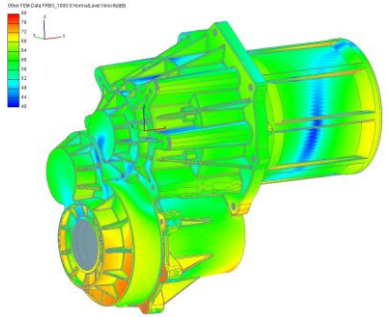
FRB3: 630Hz



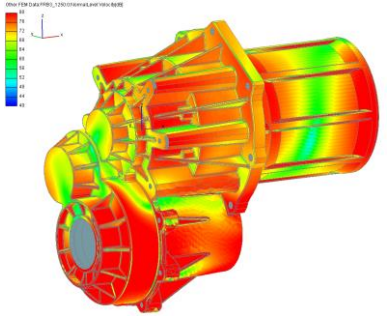
FRB3: 800Hz



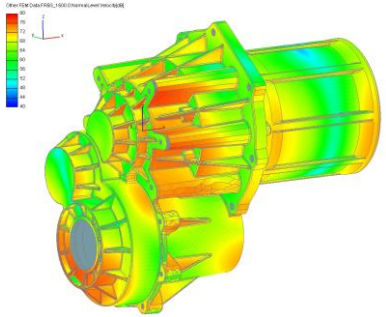
FRB3: 1000Hz



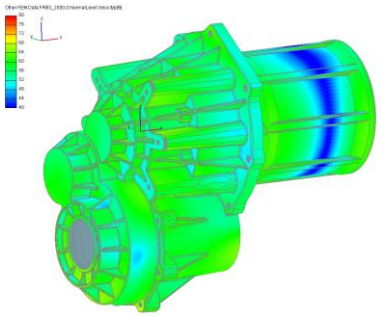
FRB3: 1250Hz



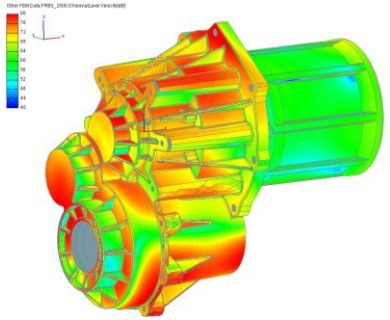
FRB3: 1600Hz



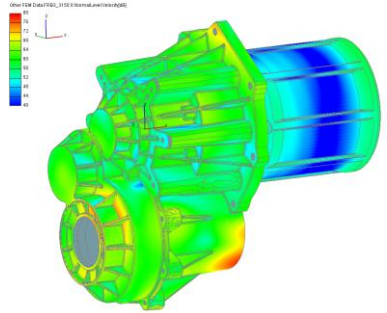
FRB3: 2000Hz



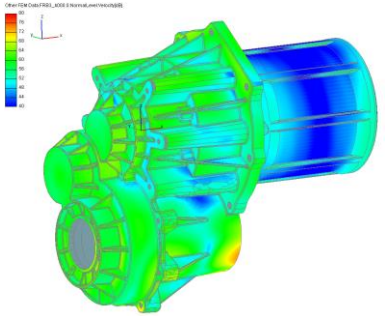
FRB3: 2500Hz



FRB3: 3150Hz



FRB3: 4000Hz



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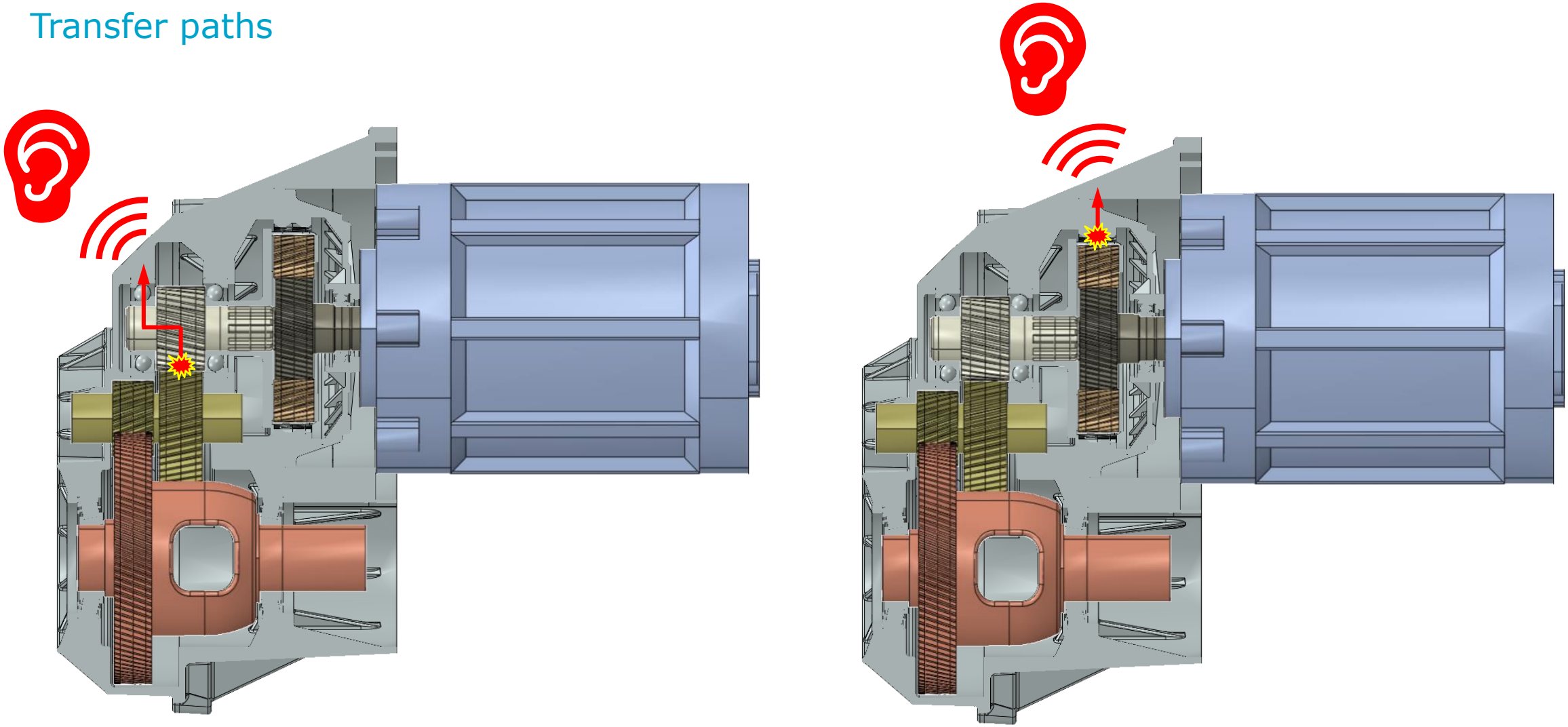
## Transfer paths



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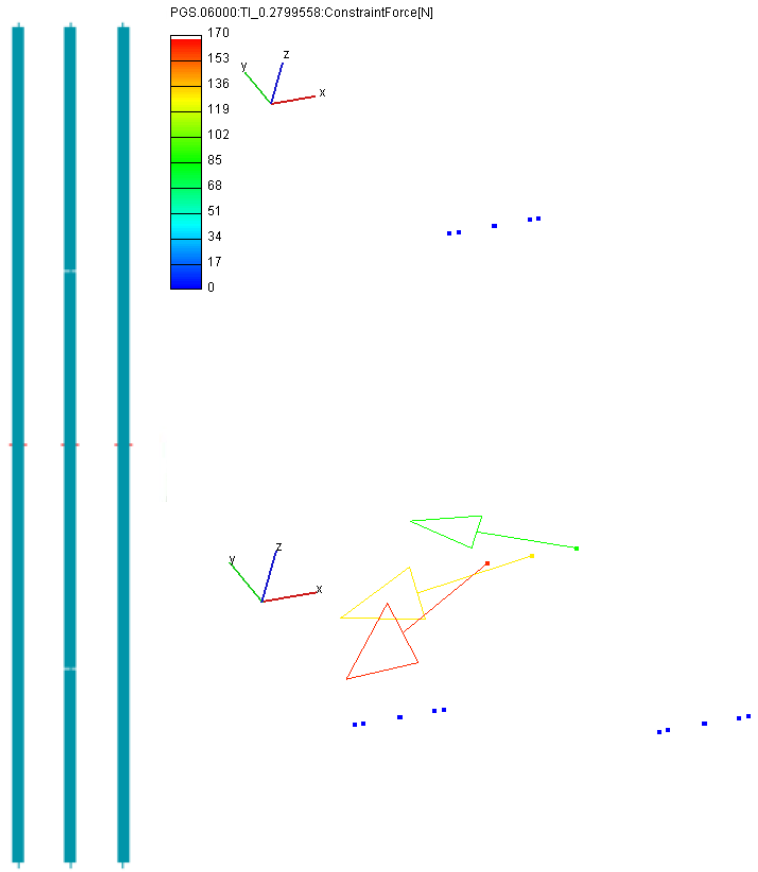
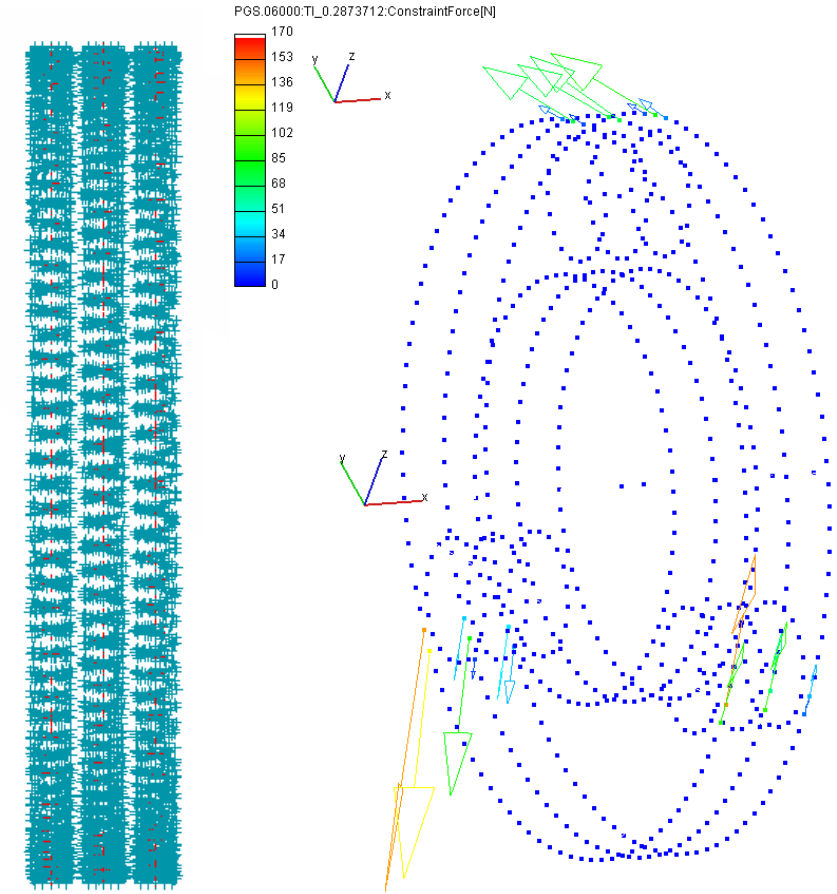
## EXCITE™ Power Unit – 3D results

### ACYG flexible body



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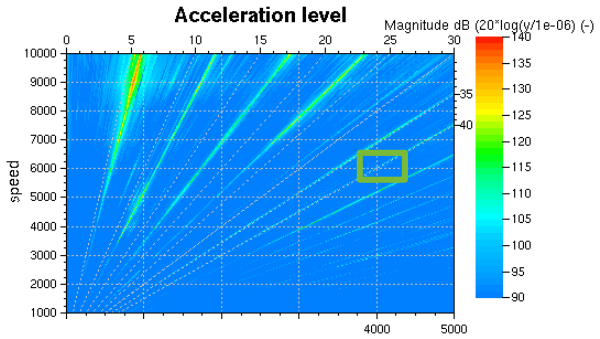
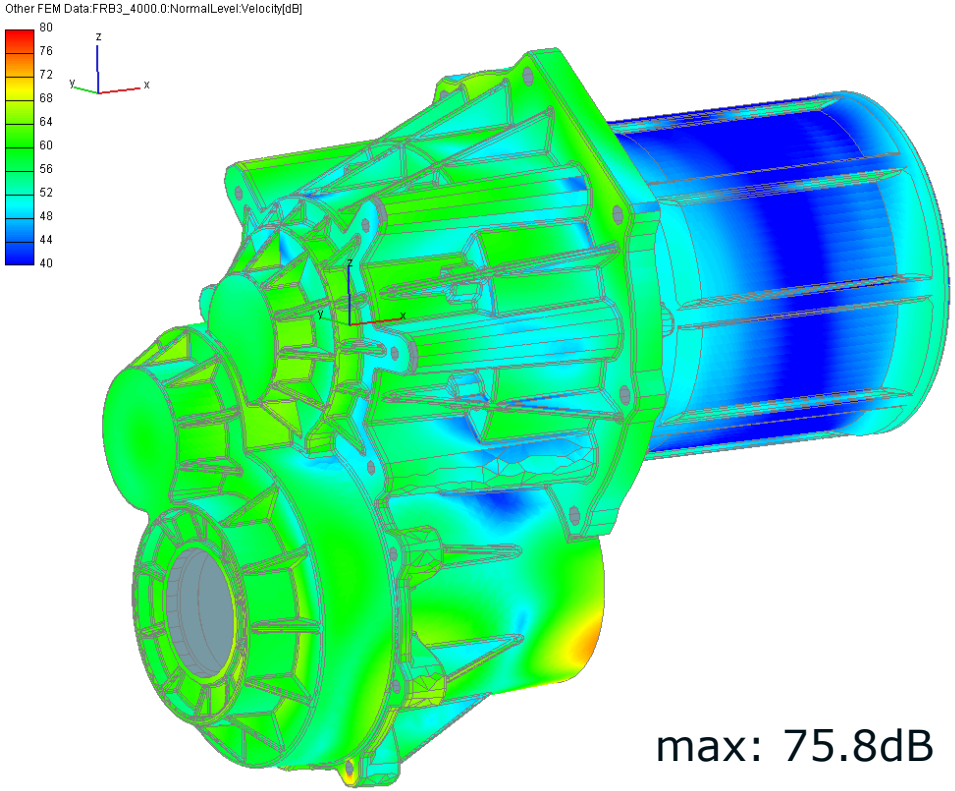
## EXCITE™ Power Unit – 3D results

## ACYG flexible body

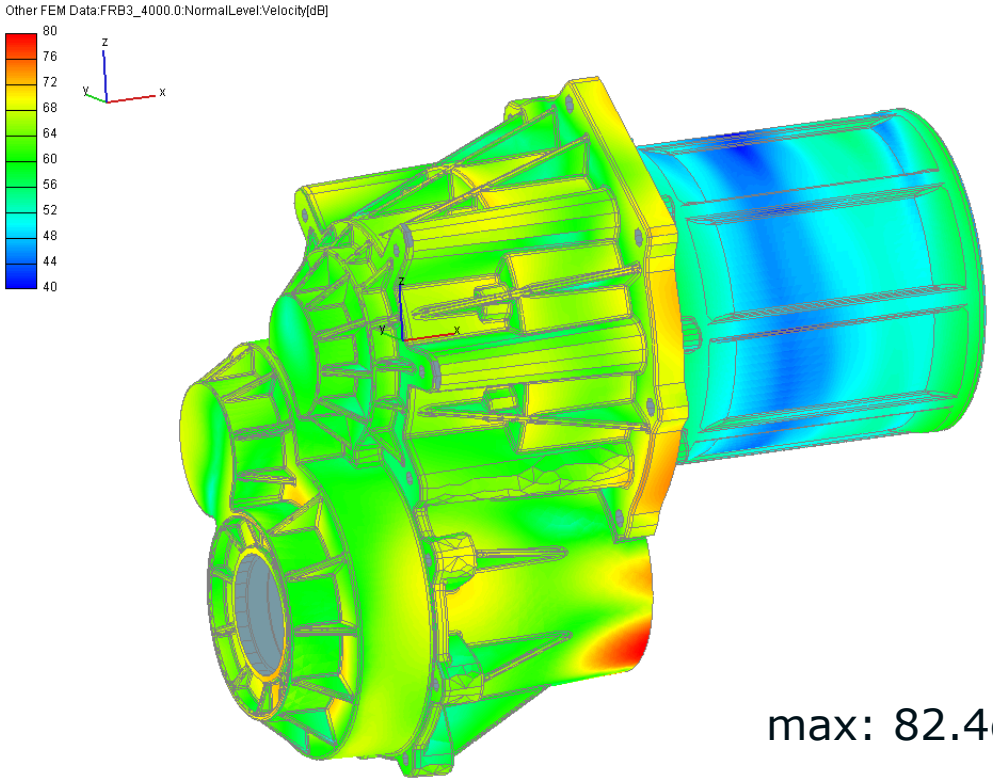



FRB3: 4000Hz




max: 75.8dB

FRB3: 4000Hz




max: 82.4dB

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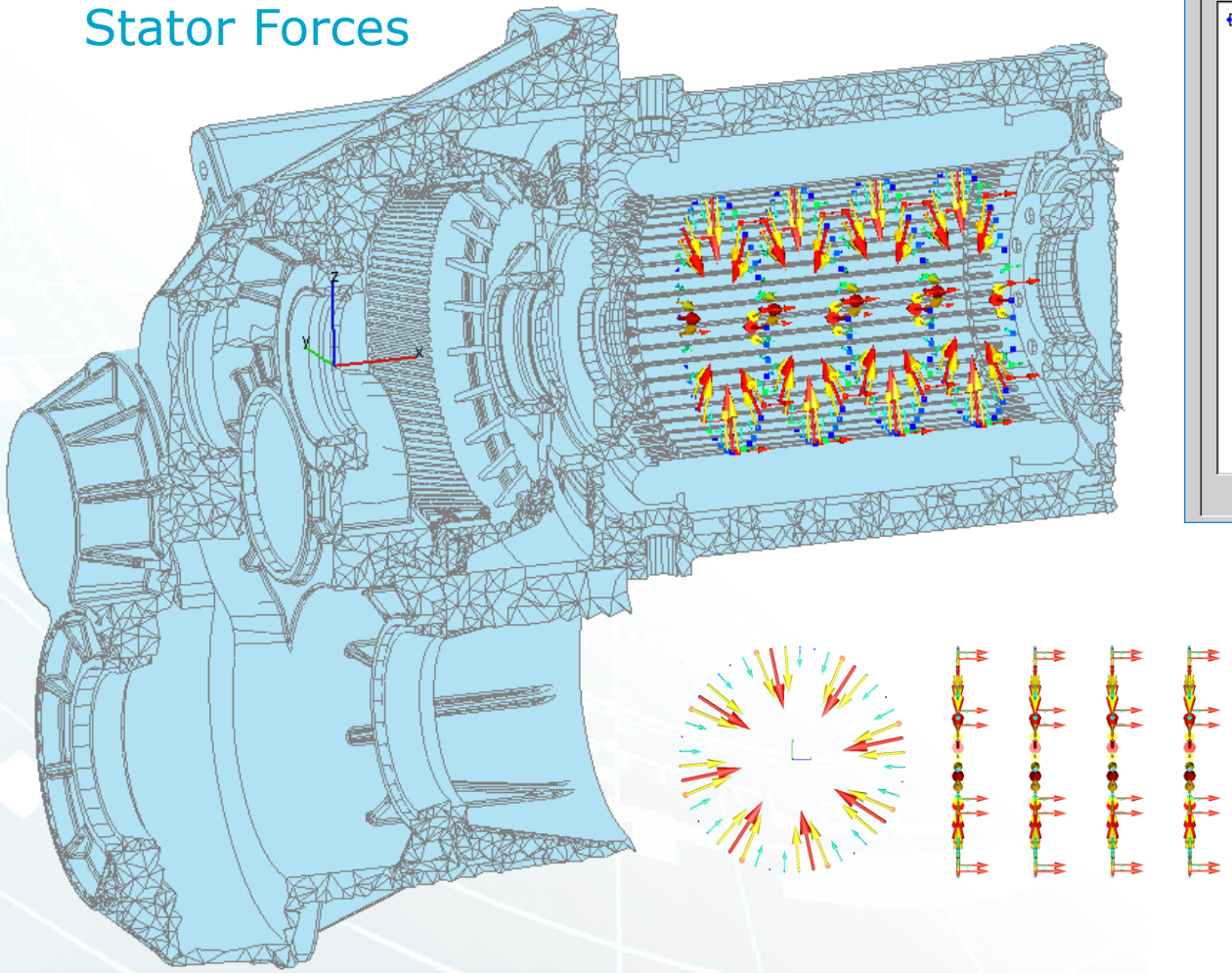
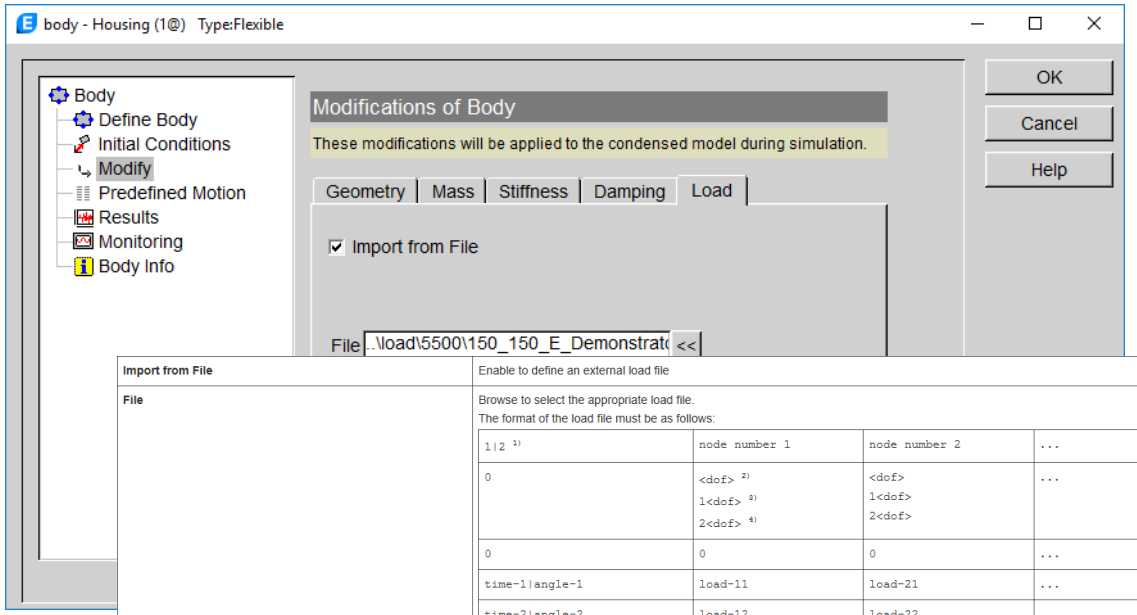
## EXCITE™ Power Unit – 3D results

### Stator Forces










| Import from File | Enable to define an external load file |
|---|---|

**File**

Browse to select the appropriate load file.
The format of the load file must be as follows:

| 1\|2 [1] | node number 1 | node number 2 | ... |
|---|---|---|---|
| 0 | <dof> [2]<br>1<dof> [3]<br>2<dof> [4] | <dof><br>1<dof><br>2<dof> | ... |
| 0 | 0 | 0 | ... |
| time-1\|angle-1 | load-11 | load-21 | ... |
| time-2\|angle-2 | load-12 | load-22 | ... |
| time-3\|angle-3 | load-13 | load-23 | ... |
| ... | ... | ... | ... |

with:

| | |
|---|---|
| [1] | 1 ... load versus time<br>2 ... load versus angle |
| [2] | <dof> ... degree-of freedom 1 to 6<br>load defined in absolute coordinate system |
| [3] | 1<dof> ... degree-of freedom 1 to 6<br>load defined in reference coordinate system |
| [4] | 2<dof> ... degree-of freedom 1 to 6<br>load defined in body coordinate system |

Example:

```
1 10001 10001 10001
0 11 12 13
0 0 0 0
0 0 0 16227.5
3.33333333333e-005 0 0 16949.8
6.66666666667e-005 0 0 17729.8
0.0001 0 0 18567.5
...
```

# Modelling of an eAxle with planetary and cylindrical gear stages for structural dynamic investigation

## EXCITE™ Power Unit – 3D results

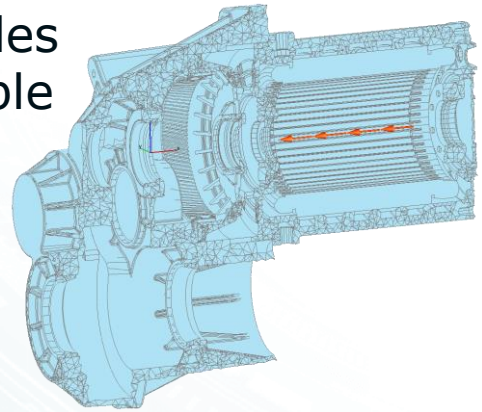
### Stator Forces

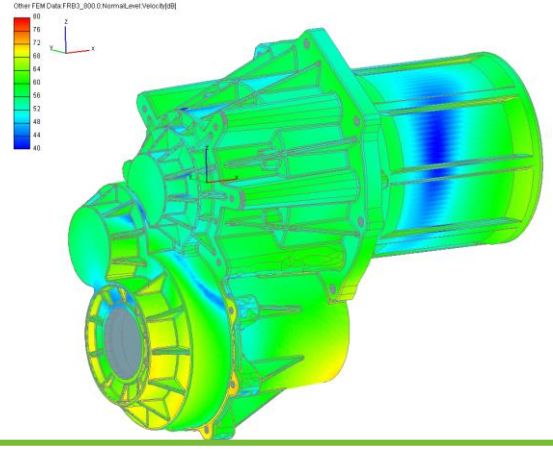
FRB3: 800Hz

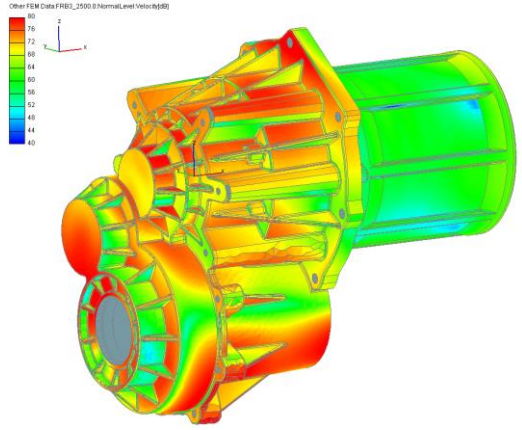
FRB3: 2500Hz

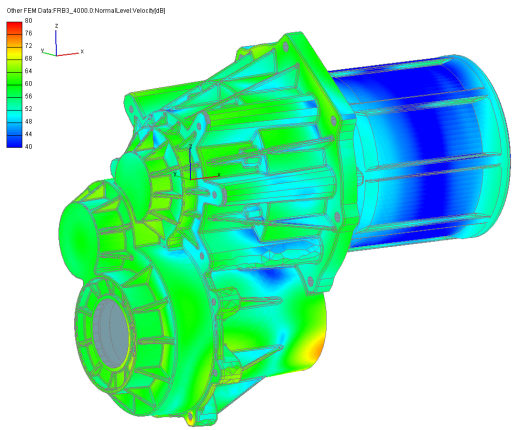
FRB3: 4000Hz

Center nodes
Torque ripple

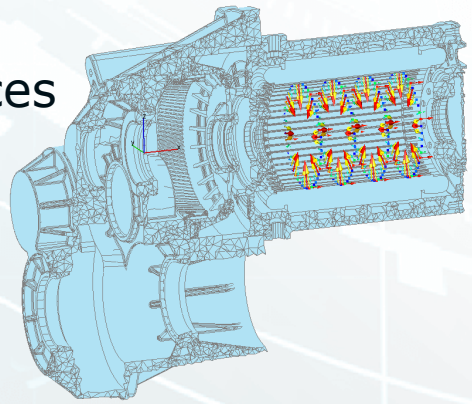


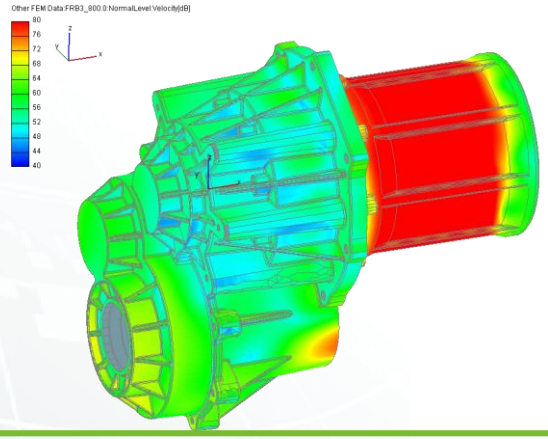


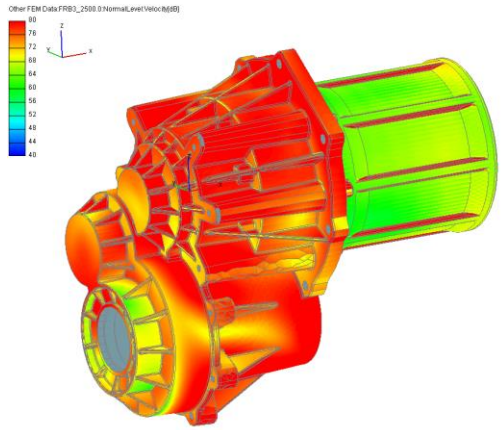


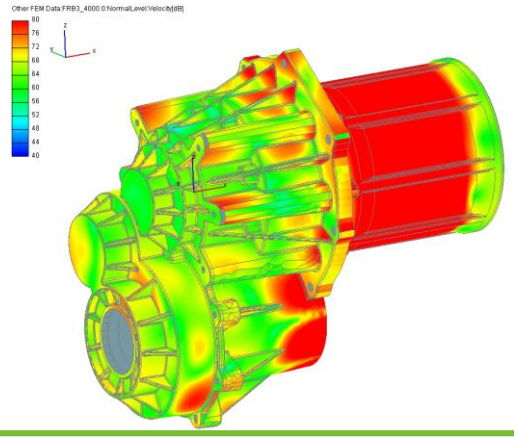


Stator forces



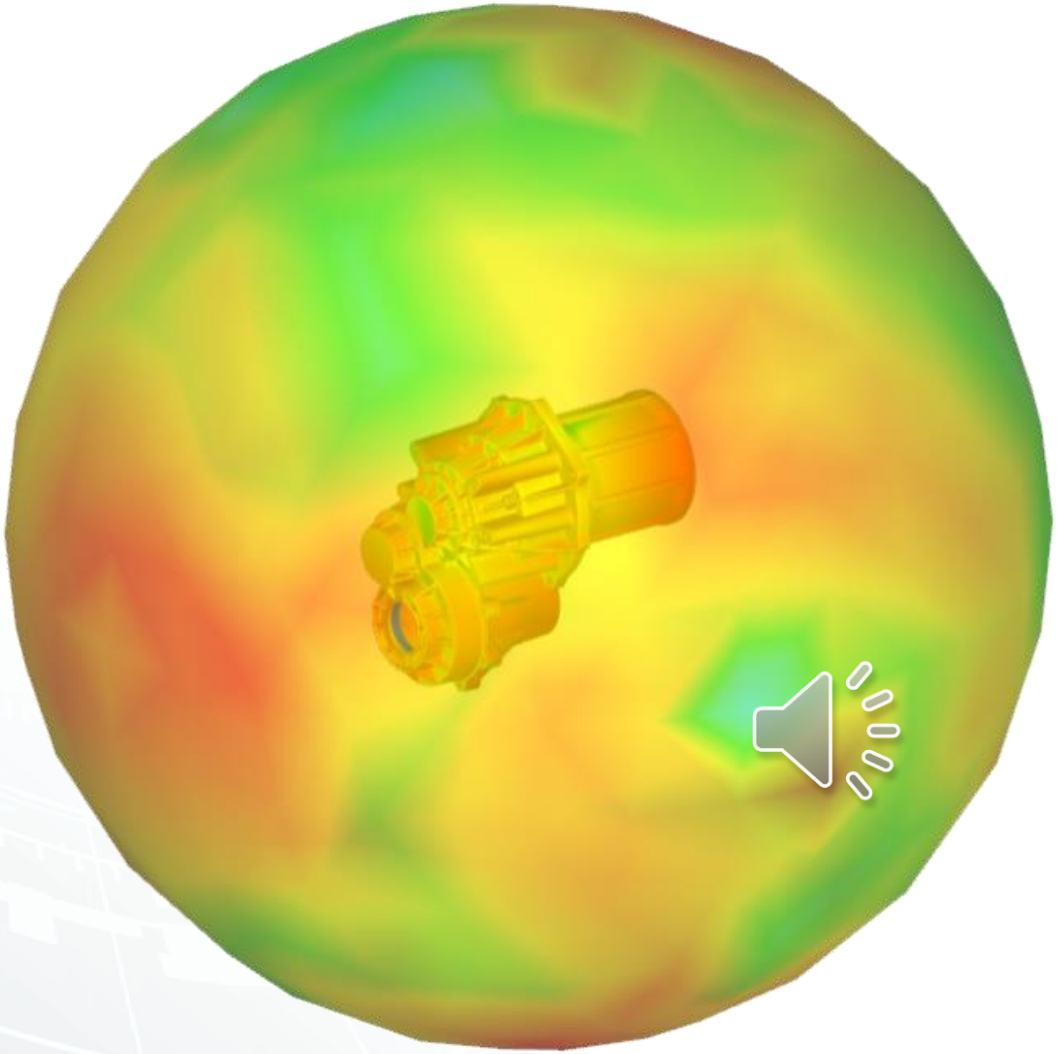






# Modelling of an eAxle with planetary and cylindrical gear stages for structural dynamic investigation

## EXCITE™ Acoustics



# AVL International Simulation Conference 2019