SIMULIA 3DEXPERIENCE Conference Design, Modeling and Simulation

# OTraPArTe: Order Analysis and Identification of Critical Transfer Paths in Drive Trains

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## Overview

- 1. Introduction Vibration in rotating machinery
  - > What are the problems?
  - > Where do they come from?

## 2. Identification of vibrations and their sources

Order Analysis with OTraParTe

## 3. Understanding the transfer path of a vibration

Transfer Path Analysis with OTraParTe

## 4. Conclusion







## 1 Introduction – Vibrations in rotating machinery

#### **Speed-dependant excitations**

- Gears
- Motors
- Generators

#### **Transmission via all connected components**

- Shafts
- Bearings
- Support structure

#### **Dynamic loads**

Fatigue

#### Vibration of radiating surfaces

Audible noise





# 2 Identification of vibrations and their sources

- Simpack model of complete wind turbine
  - Time-Domain Simulation
     → Run-Up in complete operating range
  - Gearbox consisting of three gear stages
  - Measurement of vibration with velocity sensors at tower surface





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# 2 Identification of vibrations and their sources - OTraParTe

#### **OTraParTe: Order Analysis features**

- Simpack Time Domain Results or physical measurement data
  - Comparison of up to 3 models
  - Selection of elements from Simpack model
  - Calling Simpack measurement
  - Filtering of data
  - FFT of data
  - Visualization & Export of 2D order diagrams and 3D-Campbell plots
  - Automatic creation of Power Point slides
  - Automatic creation of ANSYS-readable .csv files with interface loads

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## 2 Identification of vibrations and their sources - OTraParTe

#### 3D – Campbell Plot

- Frequency of response peaks is proportional to frequency of rotation
  - E.g. 2nd stage order: **5.8333**
- Skewed lines are the "order slices"
- For every gear stage there are multiple order slices → Harmonics
- Vertical distributions of amplitudes are eigenfrequencies
- Hot Spots are usually resonances
   → Avoid!





# 2. Identification of vibrations and their sources - OTraParTe

#### 2D – Order slice

- Selection of gearbox stage and order, sensor type and direction
- Extraction of sloped line from 3D -Campbell plot
- Comparison of multiple sensors
- Operating range and nominal speed also shown



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At a speed of 1800rpm we find the resonance with an amplitude of 0.35mm/s

## 2 Identification of vibrations and their sources

## Source - Path - Receiver

- We found which "source" is responsible for the resonant vibration
  - But what now?
- Minimizing or shifting the excitation...
  - Changing macrogeometry of gears
  - Changing microgeometry of gears
  - ... is always preferable
- But if you want to analyze the path a vibration takes to a receiver?

## → Transfer Path Analysis







## 3 Understanding the transfer path of a vibration

- What is a transfer path?
  - Transfer path: Every possible connection
     Source → Interface → Receiver
  - Definition of interfaces between the active parts (sources) and the passive parts
- What do we need to do a Transfer Path Analysis?
  - *u*: Forces & Torques transmitted at the interfaces Here: 3 interfaces with 3 forces, 2 torques each → *u* has 15 components
  - The **FRF** (Frequency Response Functions) are obtained from Simpack Linear System Analysis



• Components of the total response





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## 3 Understanding the transfer path of a vibration



- **Spectogram:** Overview over amplitudes of one order slice
- Path 4 is a dominant component! It is a torque at the main bearing, For each path, the FRF and interface load can be analyzed separately







# 3 Understanding the transfer path of a vibration



- Information of phase is important!
  - Response terms can cancel each other out
- Impact of phasing visible with Vector plots
- Vector plot of **response** for each path
- Vector plot of **interface load** for each path
- Vector plot of **FRF** for each path

→ The response component of Path 1, is having an opposing phase to the main contributors Path 3 and Path 4





## Conclusion

## OTraPArTe – A GUI for:

- Order Analysis: Identification of vibrations and their sources
- <u>Transfer Path Analysis:</u> Understanding the transfer path of a vibration
- Usage possible in different engineering fields
- Combination of physical measurement data and Simpack results possible







# Thank you for your kind attention!

# Questions?

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