Title: An Automated Simulation Approach of Drive Trains towards Tonality Free Wind Turbines

Author: Ben Marrant, ZF Wind Power Antwerpen NV

Abstract:

Worldwide there is a tendency to locate wind turbines closer to urbanized areas. When wind turbines include geared drivetrains, mechanical noise is produced at the gear mesh frequencies. In case this mechanical noise exceeds the aero-acoustic masking level of the wind turbine rotor this is being perceived as annoying tones to observers close to onshore wind parks. In order to mitigate this tonality risk in an early development stage, when the designer has most impact on the gearbox design, ZF has developed an overall automated simulation approach. The approach is amongst others based on discretized wind turbine drivetrain models in SIMPACK and allows quick scanning of the design variables of the wind turbine drivetrain in terms of stiffnesses and inertias and their impact on the tonality risk. This is then used as a tool to optimize the gearbox design for an optimal performance in the wind turbine with respect to NVH.

Title: Digital Twin for Wind turbines - Simulation meets machine learning

Authors: Andrei Degtiarev and Matthias Kohlhepp, Schaeffler Technologies AG & Co. KG

Abstract:

The main bearing is one of the central mechanical components of a wind turbine. All external dynamic forces of the turbine act on the main bearing. Through new technical achievements, its Digital Twin can provide insights into the entire system main bearing. As a virtual image of the bearing, the digital twin helps to study it in detail and understand it even better.

A simulation model was built up by using structural parts imported from ABAQUS as components of BEARINX Simulation Model. It is also possible to convert this model with the help of SIMPLA into a SIMPACK dynamic model. BEARINX and SIMPLA are part of the simulation tool chain developed by Schaeffler.

This method creates a digital twin of the bearing that can provide information about the load and behavior of the individual wind turbine during operation. With the data from a sensor called load sense pin, new information can be drawn from the model. This information or results can also be monitored in real time with an online application in order to draw conclusions for development. At the same time, it is possible to store the information in the Schaeffler Cloud (Data Platform) for later analysis and conversion.

Title: REXS – The Standardized Interface for the Simple Exchange of Gearbox Data

Author: Norber Haefke, FVA GmbH

Abstract:

A variety of CAE tools are available for the design and analysis of a gear unit and its components, each with its own strengths. Practical efforts are being made to combine these strengths as much as possible, so that most companies can use not just one CAE tool for gearbox development, but several. To date, however, no industry-wide standard has been established for exchanging gearbox calculation data between these tools. This leads to many cost- and maintenance-intensive custom solutions, as well as duplication of work that could be avoided.

An important milestone for Industry 4.0 is the establishment of industry-wide standards. FVA e.V., the Research Association for Drive Technology, is developing an industry-wide standard for the simple exchange of data in gearbox development, in close collaboration with research and industry, under the name REXS (Reusable Engineering EXchange Standard). Version 1.2 of the REXS interface was recently published. REXS is published under Creative Commons license, and detailed documentation of the specification is freely available to all in German and English at www.rexs.info.

The aim of the REXS initiative is to provide a "digital twin" in gearbox development and calculation. REXS defines a uniform modeling and nomenclature for the gearbox and its components across standards and industries, based on detailed terminology from 25 FVA Project Committees and 50 years of joint industrial research.

We will introduce the REXS interface and discuss the reasons for its development. We will then describe why the FVA-Workbench is the perfect vehicle to develop this standard and to force this to global market. Next, we will explain the basic principles of the REXS model and present the extensive information that is available online, including a database with detailed information about the available parameters as well as the public ticket system that guides the development process. We will provide an overview of the current status of REXS and the planned next steps. Finally, we will demonstrate the simple exchange of data between the FVA-Workbench and Simpack.

Title: Load Calculations with Simpack and Integration into Company Specific Workflows

Author: Jochen Harms, elb|sim|engineering

Abstract:

The development processes for wind turbines are subject to continual optimization and improvement, especially in view of the increasing market pressures.

Many manufacturers are now replacing their conventional simulation tools with more powerful and sophisticated simulation tools for load calculations. This enables further cost reductions through optimization and detailed component analysis. For this reason, the multi-body simulation code Simpack is increasingly important for OEMs and suppliers.

This presentation describes how a load calculation process with Simpack can be set-up and easily integrated into an already existing company specific workflows.

Title: Cracking Problems in Wind Turbines

Author: Javier Rodríguez, Principia, Madrid, Spain

Abstract:

By their very nature, wind turbines are subjected to many variable and cyclic loads and, consequently, they are prone to experiencing fatigue cracking problems in various parts of the turbine. Examples include the aluminium rings (alurings) of the blades of several commercial wind turbines, the gears of the yaw control mechanism and even the main rack supporting all the equipment.

Principia has used numerical simulation with Abaqus and fe-safe to study the origin of many of those cracks, determine their ability to propagate, and analyse the merits of various strategies proposed to solve existing problems or prevent their future occurrence. Among the technologies involved, besides local stress and strain fatigue initiation criteria, are critical distance methods and crack representations based on the extended finite element method (XFEM) to assess the growth behaviour.

The paper concentrates on two of the cases studied, that of the alurings and that of the yaw drive gears. It describes the methodology used for

Title: Wind Turbine Load Calculations with Nonlinear Flexible Rotor Blades

Author: Martin Cardaun, CWD RWTH Aachen University

Abstract:

The trend towards increasing power output of modern wind turbines leads to higher towers and longer rotor blades, resulting in more flexibles structures. As these components increase in size, nonlinear structural behaviour becomes more important. Therefore, accurate multi body simulation models that consider nonlinear effects are needed. The calculation of global deformations of the respective bodies as well as of the resulting aerodynamic loads suffer from accuracy due to the conventional linear model order reduction. In this presentation, the workflow and usage of a new functionality for nonlinear model order reduction is presented. With an exemplary rotor blade model several tests will be done for both static and dynamic load cases. It will be shown that nonlinear flexible bodies in Simpack come to good agreement with comparative calculations in finite elements software. It can be obtained that the bend twist coupling due to a deflection of the blade influences the aerodynamic loads in a stronger way than linear flexible bodies describe. Due to this deviation in combination with blade element momentum theory the rotor torque can be overestimated because the angle of the incoming wind determines the lift and drag forces acting on the blade. Non torque loads and turbine power output are directly linked to these effects. Therefore load calculations of several design load cases are carried out to quantify their influence on system level. In the context of these explanations, further aspects of nonlinear model order reduction, such as modal damping and computing time, are discussed.

Title: Simulation of Loads in the Drivetrain of Wind Turbines using Simpack

Authors:
Berthold Schlecht, Thomas Rosenlöcher
Technische Universität Dresden, Chair of Machine Elements

Abstract:
The extensive requirements for the reliable operation of wind turbines make the design and the dimensioning of wind turbine gearboxes to an interdisciplinary challenge. In the meantime, the possibilities of the dynamic simulation already used in an early stage of the development process. By means of simulation models, the natural frequencies can be determined and compared to possible excitations. The simulation of the operation of the wind turbine under different wind speeds allows the calculation of component loads as basis for the further design process. The presentation concentrates on the challenges of the dimensioning and the design of gearboxes for wind turbines and the associated dynamic properties of the complete system on the example of the 5 MW reference wind turbine of NREL. The available simulation model is used to determine the influence of the level of detail of the model on the resulting loads for the bearings and the occurring load distribution in the gearing of the first planetary gear stage. The available results offer improved possibilities to design drivetrain components and to understand dynamic effects during the operation.

Title: Multibody Simulation Methodology for the Assessment of Drivetrain NVH-Behavior, Electric and Off-Road Vehicles

Author: Joerg Berroth, MSE RWTH Aachen University

Abstract:

This contribution presents a hybrid model for the auralization and evaluation of the drive related interior noise in electric vehicles and off-highway machines, combining the aspects of electromagnetic force excitation, structural-dynamic and subsequent acoustic response in the case of electric vehicles on the one hand as well as the aspects of excitations arising from hydrostatic gearboxes, structural dynamics and the acoustic response for a tractor on the other hand. The presented methodology was first developed and implemented in the course of a joint project between three RWTH institutes and is currently extended and refined for different types of drive trains. The basic function of the methodology will be explained and its application is illustrated for given combinations of drive trains and transfer path structures, see figure 1 and figure 2. The strength of the methodology is illustrated based on simulation results as well as validation cases that are discussed based on measurement results for the given drive train configurations.

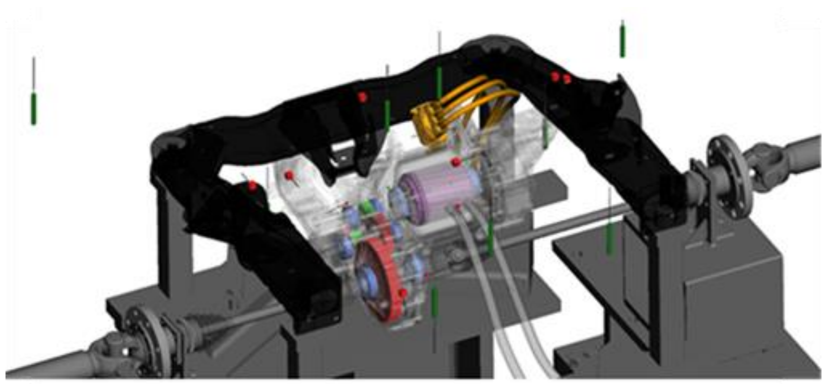

Figure 1: Vehicle Drive train

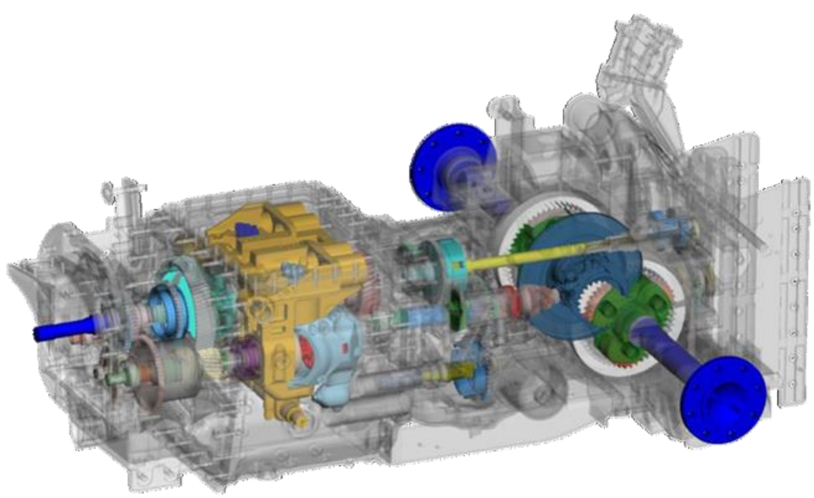

Figure 2: Tractor Drive train

Title: Aerodynamics and Aeroacoustics of Duct Wind Turbines for Urban Environments

Author: Francesco Avallone, Delft University of Technology

Abstract:

Ducted Wind Turbines are a potential technological solution for wind energy harvesting in urban environment. During the talk, the effect of wind turbine geometry and yaw angle on the aerodynamic performances and far-field noise are discussed.

Title: On the application of an Equivalent Fluid for Simulating Porous Materials for Trailing Edge Noise Reduction

Author: Daniele Ragni, Delft University of Technology

Abstract:

Porous materials can be used to mitigate wind turbine noise. This talk will focus on the application of the equivalent fluid approach to simulate a porous trailing edge. The approach is assessed by comparing numerical and experimental results; high fidelity numerical results are further used to explain the relevant flow physics behind noise reduction.

Title: INFRASOUND, GRID CONNECTION AND DIGITAL TWINS: RESEARCH FOR THE WIND INDUSTRY

Author:
Stefan Hauptmann, MesH Engineering GmbH

Keywords: Multibody Systems, NVH, Acoustics, Wind turbines, Drive trains, Digital twins, IIOT

Abstract

This presentation provides a conclusion about our current research activities in the field of wind turbines and their drivetrains. The focus is to highlight the benefits of those projects for the wind energy industry. Besides, the evolution of the application of the software tools Simpack and Wave6 throughout the projects will be shown.

From 2016 to 2019 the collaborative research project „Objective criteria for vibration and noise emissions from onshore wind turbines (TremAc)" was carried out by Karlsruhe Institute of Technology (KIT), Stuttgart University, Technical University of Munich (TUM), Universität Bielefeld, Universität Halle-Wittenberg, and the MesH Engineering GmbH (MesH). This project evaluated wind turbine emissions of low-frequency vibrating ground motions and low frequency noise and assessed their effects on the local residents. As part of this collaboration, MesH focused on the development of a detailed wind turbine drivetrain model as multibody system model in Simpack to analyse the generation and transfer of vibrations within the wind turbine and the vibroacoustic emissions of the wind turbine applying the Wave6 software code. The project results and new founds are currently available to the industry. A software tool for "Order and Transfer Path Analysis (OTraPArTe)", as developed during the research project is available as well as a frequent- and amplitude-dependant modelling strategy for elastomeric bushings. The generated simulation results will guide manufacturers of elastomeric vibration isolating elements for the drive train to account for low-frequency vibrations.

Since 2017, "New requirements for drive train and structural components of wind turbines due to grid-supporting control procedures" have been identified in the project called "Gridloads", conducted by Fraunhofer IEE and MesH. The aim of this project was to examine the effects that are expected due to the application of new grid-supporting control procedures, e.g. the provision of momentary reserve, as demanded in grids with high penetration of renewable energies. Our focus was on the investigation of the effects of grid-supporting control concepts on the structural dynamical loads and the stability of wind turbine. Hence, a Simpack model which represents the structural dynamics of a generic wind turbine, was coupled to a Simulink model which represents the electrical grid and the control systems to analyse and evaluate the system dynamic and loads. The exploitation of the project results for the benefit of our industrial customers includes a new developed process to linearize multi-physical models considering aerodynamics, structural dynamics and grid connection in a coupled Simpack and Simulink environment. This enables the visualization of thus calculated coupled eigenmodes, as well as the stability analysis applying Floquet theory and multiblade coordinate transformation, available within the "Mesh Aero-Elastic Stability Tool for Rotating Systems (MAEStRoS)". The analysis process also includes the load simulations as defined by certification bodies using modified Simpack Load Scripts. Also, the "Order and Transfer path analysis Tool (OTraPArTe)" and noise emission calculation tool Wave6 are used in the overall analysis process.

Starting in 2020, the e-TWINS project as a cooperation between Technical University of Munich (TUM), Zentrum für Sonnenenergie- und Wasserstoffforschung Baden-Württemberg (ZSW), Hochschule München (HM) and MesH will analyse how digitalisation might assist the turnaround in energy policy. For 3 years, the objective of this project is to advance and promote the application of Industrial Internet-of-Things and Big Data in future smart energy systems. MesH shall focus on the development of digital twins of drivetrains using state-of-art machine learning techniques and on the development of middleware infrastructure that will establish and support the holistic nature of the future energy systems with focus on renewable energy sources. MesH intends to reveal new business models in Industry 4.0 with the goals of offering cloud-based holistic software services for digitalization of energy systems of grid operators and deployment of digital twins of drivetrains for OEMs. A special focus will be the application of Simpack models as part of these digital twins in grey-box modelling perspective.

All Projects are partially funded by BMWI.

Title: Code to Code Comparison for the IEA 15 MW – Offshore Wind Turbine

Author: M. Y. Mahfouz, Po Wen Cheng

Stuttgart Wind Energy (SWE)

Keywords: Floating offshore wind turbine (FOWT), Spar, Hydrodynamics, Second order forces, QTF, Multibody model, OpenFAST, Simpack, Design load cases (DLC).

1. Introduction

In this study, we investigate for the first time the response of a 15 MW Offshore Wind Turbine (OWT) using two different numerical tools (OpenFAST and Simpack). This work is part of the COREWIND project, which is a European Horizon 2020 project.

2. Objectives

The main goal of this study is to investigate the responses of a very large OWT model; using two different numerical tools (OpenFAST and Simpack) in a code-to-code comparison. The turbine's response to Design Load Cases (DLC) for power production (DLC 1.2) according to IEC 61400-3 standard will be calculated. These results demonstrate the feasibility of a turbine as large as 15 MW on a floating foundation.

3. Methodology

DLC 1.2 is simulated for the OWT in both OpenFAST and Simpack. The meteorological conditions used in these simulations are for a location defined in the COREWIND project. The location is at the Southeast Coast of Gran Canaria Island with sea depth 200m.

Acknowledgment

The research leading to these results has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No. 815083 (COREWIND+).

Potentials of wind turbine test sites for numerical modelling and wind energy research

The German project WINSENT aims to establish a wind turbine test site in complex terrain on the Swabian Alb. The project is a joint project of several Universities and research institutions in Southern Germany, being part of the research cluster WindForS. Within the project different steps to prepare the test site are performed. One part of the project is to compare numerical models of the research turbine of different levels of detail code to code, including standard BEM-code as FAST as well as high fidelity FEM- and CFD-models. In the future, the simulations of all models will be compared against measurements from the two test turbines. The University of Stuttgart is developing the SIMPACK model of the test turbine. So far we have achieved qualitatively good agreement between SIMPACK and other established software. The results will be presented at the conference together with some ideas about how we will use the SIMPACK model on the operational test site.

Authors: Fiona Lüdecke[1], Helena Canet[2], Philipp Bucher[2], Giorgia Guma[1], Po Wen Cheng[1]
1: University of Stuttgart
2: Technical University Munich

Title: Wind and Drivetrain Simulation, Overview and Update

Author: Steve Mulski, Dassault Systemes

Abstract:

With current market pressures and changing climate, simulation is now more essential than ever in quickly realizing new designs and minimizing the levelized cost of energy. This presentation will give an overview and update of the latest simulation technology and functionality available for designing and optimizing wind turbines and drivetrains. In addition to covering specific functionality (for example: fluid coupling, bearings, gearwheels, multi-domain interfaces), an overview of simulation workflows and a glimpse at the future of the entire product life cycle will be shown.

Title: R&D Update on Multibody System Simulation

Authors: Fabian Miczek, Dassault Systemes

Abstract:

Highlights from the Multibody System Simulation development are presented. This covers new features in recent and upcoming SIMULIA Simpack releases as well as new possibilities for multi-physics couplings.

Title: Multibody System Simulation on 3DEXPERIENCE

Author: Axel Dewes, Dassault Systemes

Abstract:

The **3D**EXPERIENCE platform enables the user to leverage the full power of Dassault Systemes software portfolio. With Simpack Power'By **3D**EXPERIENCE, the Simpack MBS user is offered to take advantage of the platform features to save, share and re-use simulation results as well as saving 3D product structures as Simpack models. The presentation will provide an overview of current capabilities of Simpack Power'By. Furthermore a preview and outlook on integrating Simpack technology on **3D**EXPERIENCE through a native motion analysis app is given.

Title: Abaqus for Wind-Turbine Foundations

Author: Deepak Datye, Dassault Systemes

Abstract:

The stability of offshore wind turbines depends to a significant extent on the support provided by their foundations. These foundations need to provide support against vertical, lateral, as well as overturning forces experienced by the turbine. Their strength is derived from the structure-soil configuration within the ground, and hence the prediction of the foundation behavior for design purposes requires consistent representation of the soil, structure, and the interactions between them.

As a general-purpose code, Abaqus provides tools for representing the behavior of individual components of soil-structure systems. A range of features are available that can be helpful for analyzing and simulating the behavior of such systems, including foundations for wind turbines. An overview of some of these features is presented, along with examples that show how these features can be used for modeling and analyzing wind turbine foundations.

Title: Structural Models for Rotorblade Design

Author: Stefan Dietz, Dassault Systemes

Abstract:

Realistic simulation of rotor blades requires both, advanced structural- and sophisticated multibody system models. Structural models need to take into consideration the composite material and the large deformations of today's turbine blades. This is necessary to accurately capture the twist-bend coupling behavior, for example. General purpose multibody system simulation is also required to simulate the overall system behavior to the necessary level of fidelity, with all of it's fluid-structural couplings. Simpack is therefore the right tool to determine realistic loading conditions for wind turbine in all conditions and with any design. Detailed blade modes need to be accurately reduced for efficient simulations of entire holistic system models, and retain all necessary physical effects. This presentation covers an overview of recently implemented technologies for rotor blade simulation, including composite beam technology and nonlinear model order reduction.

Title: Towards Digital Wind Turbine Noise Certification

Author: Wouter van der Velden, Dassault Systemes

Abstract:

Flow and acoustic simulations are performed on the NM80 full-scale 3-bladed wind-turbine, tested during the DanAero campaign. SIMULIA PowerFLOW's Lattice Boltzmann Method is used to predict the turbulent-resolved unsteady flow around the full wind-turbine, yielding good results with reference data. The noise at certification position for several rotor revolutions is computed using an auralization technique from simulated flow data stored along a portion of the rotor revolution. The auralization process is based on a frequency-domain Ffowcs-Williams and Hawking noise spectrum computation from blade wall-pressure pressure fluctuations, taking into account ground reflection. Noise spectra at several azimuthal copies of the microphones are finally corrected to take into account blade-motion Doppler effects end atmospheric absorption and smoothly appended to recover the full rotor revolution. Significant cost reduction in simulation time is found with the new post-processing process, making the entire process suitable for industrial turn-around-times.

Title: Scope of Electromagnetic simulation in the design of Wind Turbines

Author: Arnab Bhattacharya, Dassault Systemes

Abstract:

In this presentation, we will focus on three main areas of Electromagnetic (EM) simulation relevant to wind turbine designers: impact of a lightning strike on the turbine; generator design and optimization; and radar return estimation from wind turbines. Using the full suite of low and high frequency EM solvers available in CST Studio Suite, we are able to address all these applications to help the engineers consider the impact of the material choice and construction of the blades on lightning protection and radar returns. With our electrical machine design tools, we can assist designers in optimizing the design of the permanent magnet synchronous or asynchronous induction machines to achieve the best performance. With the move towards composite non-metallic materials for the nacelles, such as GFRP, the susceptibility of the electronic equipment in the nacelle to lightning (LEMP) has increased. Simulation can be very useful in predicting the coupling effect between the LEMP and cables along with designing protective measures by way of applying metallic shield on the nacelle. The case for the need of EM simulation to address all these topics will be made with several examples during the presentation.