Chair of Applied Mechanics
Department of Mechanical Engineering
Technical University of Munich

Dynamic Substructuring in Nonlinear Finite Element Analysis

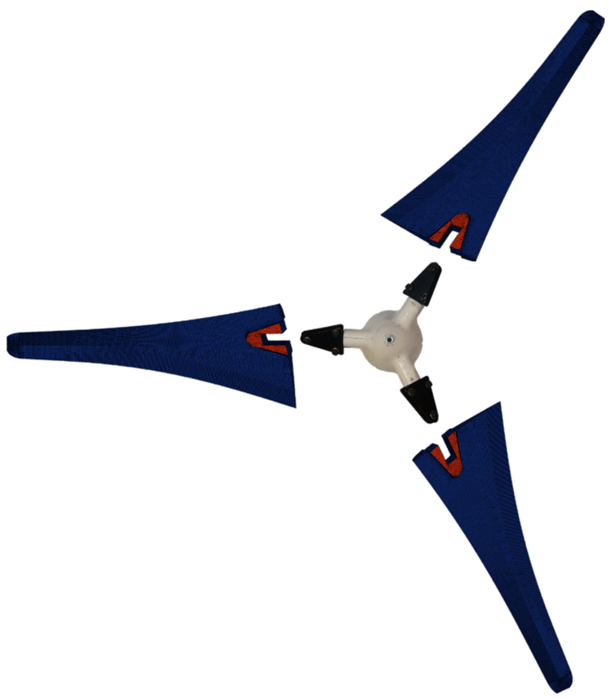
Semester-/Master Thesis

Supervision: Morteza Karamooz, M.Sc. *(MW3140, m.karamooz@tum.de, +49 (89) 289-15209)*

Problem Description

In the design procedure of dynamic structures, engineers often deal with large finite element models (FEMs) containing an enormous number of Degrees of Freedom (DOFs). Besides, they have to solve dynamic responses of the structure (such as eigenfrequency and eigenmodes, transient or harmonic response, etc.) many times (e.g. in optimization procedures), which leads to inadmissible computational time. In order to reduce these costs and simultaneously take the advantage of FEMs with very accurate and fine meshes, component model reduction methods are proposed. These methods are based on the idea that the motion of a system is written in terms of a superposition of the modes, and afterwards a truncated set of these modes are taken to approximate the response of the system. Model reduction techniques can be applied on a monolithic structure as well as on components (substructures) of a structure, which are assembled then through substructuring techniques to build the full reduced model. In the later case, one should also take the static deformation caused by connecting forces (or displacements) into account. These reduction methods are also called Component Mode Synthesis (CMS). While the linear reduction techniques are already well established in application, methods in nonlinear framework

Figure 1: Schematic of a wind turbine rotor assembly coupled with dynamic substructuring



are actively under consideration. One of the typical kinds of nonlinearities that many lightweight structures face, is geometric nonlinearity, caused by large deflections in the structures. Nonlinear model reduction techniques for monolithic structures are basically classified into direct and indirect methods. In the former one, a closed form equations of motion is required in order to construct the nonlinear reduced order model (NLROM). Whereas, in the later, the NLROM is developed without requiring to deal with the nonlinear tensors of the FEM. In other words, giving a series of input forces (displacements) to an FE Modeling package and getting the requested output displacements (forces), the NLROM is built, without knowing the details of nonlinear terms in the primary FEM. Therefore, the indirect methods (also known as non-intrusive methods) seem to be more efficient in case the structures are developed in commercial finite element (FE) packages (which is the case for most of the industrial applications), since there is no need to build the nonlinear FE tensors of the full structure.

Furthermore, it is very cumbersome to reduce a nonlinear FEM containing a fine mesh with millions of DOFs at once. Alternatively, nonlinear substructuring methods are proposed in order to deal with such models. Recently the nonlinear substructuring approach is developed, in which first each substructure is reduced by means of a non-intrusive method. They took two different linear basis in the procedure of indirect reduction of each substructure, namely, free interface modes and Craig-Bampton modes. Furthermore, the accuracy of the developed NLROMs are checked using Nonlinear Normal Modes (NNMs).

Aim of the Work

In this project, method development in non-intrusive model order reducton and dynamic substructuring of geometrically nonlinear FEMs is aimed. The already available Matlab-Abaqus code at the Chair of Applied Mechanics is further improved by implementing certain available ideas in this topic. The new implemented ideas are then tested on different nonlinear FE structures and validated. The new methods are also aimed to be compared with the already available methods to check their efficiency as well as accuracy.

Task description

- Literature Reveiw
- Modeling FE structures using Abaqus
- Performing non-intrusive model reduction of the modeled FE structures using the currently available Matlab-Abaqus code to understand it
- Implementation of certain available new ideas (and possibly, new ideas from the student) to develop the current methods in model reduction of substructures
- Coupling the reduced order substructures to built the whole reduced model
- Validation of the developed method using the modeled structure in step two
- Comparison of the developed method with the currently available methods to check the improvements
- Classification of the advantages and disadvantages of the developed method compared to other methods
- Clean documentation of the code
- Writing the thesis

Requirments

- High motivation and creativity in doing numerical simulation
- Knowledge in Finite Elemete method and Stuctural Dynamics
- Solid experience in working with MATLAB, LaTeX
- Experience in Abaqus, Paraview, Git is helpful