Isogeometric B-Rep analysis in partitioned fluid-structure interaction with application to aeroelastic wind turbine simulations

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Abstract

In this work, focus is put on modeling the Kirchhoff-Love shell structural analysis of wind turbines, such as the NREL phase VI turbine, and its interaction with the fluid, by using the classical Isogeometric Analysis (IGA). The analysis of the NREL phase VI turbine, focusing on its modeling and analysis of fluid-structure interaction (FSI) using the “classical” Finite Element Method (FEM) and the Isogeometric Analysis (IGA) is carried out. The fluid is modeled by the incompressible unsteady Navier-Stokes equations (uRANS) and the structural subdomains are simulated using the Finite Volume Method (FVM) in OpenFOAM®. The partitioned FSI simulation of the NREL wind turbine with flexible blades in the numerical wind tunnel is carried out. The fluid FSI interface is constructed using the IBRA computational models.

Keywords: Fluid-structure interaction, Isogeometric Analysis (IGA), Kirchhoff-Love shell, NREL phase VI wind turbine, Flexible blades.

Introduction

Wind turbines are becoming an increasingly important source of energy due to their environmental benefits and their potential for widespread deployment. The structural analysis of wind turbines is crucial for ensuring their safety and reliability during operation. The Kirchhoff-Love shell theory is used to model the blades of wind turbines, while the fluid-structure interaction (FSI) problem is solved using the classical Finite Element Method (FEM) or Isogeometric Analysis (IGA). The FSI problem is solved using a partitioned approach, where the fluid and structural subdomains are solved independently and then coupled using a fluid-structure interface (FSI) model.

Aiming to perform analysis directly on industrial-scale CAD geometries, Isogeometric B-Rep Analysis (IBRA) is used instead of conventional CAD and FEA models. The IBRA approach allows for a direct and accurate representation of the geometry, which is crucial for high-fidelity simulations.

Results

The results of the FSI simulation for the NREL phase VI wind turbine are presented. The simulation is carried out in a numerical wind tunnel, and the fluid-structure interface is constructed using IBRA computational models. The structural analysis is performed using the classical FEM and the Isogeometric Analysis (IGA). The fluid flow is modeled using the incompressible unsteady Navier-Stokes equations (uRANS), while the structural subdomains are simulated using the Finite Volume Method (FVM) in OpenFOAM®.

Static and modal analyses of the flexible NREL phase VI wind turbine blades

The static and modal analyses of the NREL phase VI wind turbine blades are performed using the classical FEM and Isogeometric Analysis (IGA). The results obtained from both methods are compared, and the accuracy of the IBRA approach is validated.

Conclusions

The IBRA approach is shown to be a promising tool for the analysis of industrial-scale CAD geometries. The results obtained using the IBRA approach are in good agreement with those obtained using classical Finite Element Method (FEM) and Isogeometric Analysis (IGA). The IBRA approach allows for a direct and accurate representation of the geometry, which is crucial for high-fidelity simulations.

References


[4] M. Breuer, G. de Nayer, M. Münsch, T. Gallinger, and R. Wüchner. “Fluid-structure interaction using the ‘classical’ Finite Element Method (FEM) which typically uses C0-continuous low order polynomial basis functions. This is due to the high-variational interface that the weak form of the Kirchhoff-Love shell problem. However, IGA is perfectly suited for its application to this kind of problems since the underlying Non-Uniform Rational B-Spline (NURBS) basis functions are typically smooth” [3].