Spline based mesh generator for high fidelity simulation of flow around turbine blades

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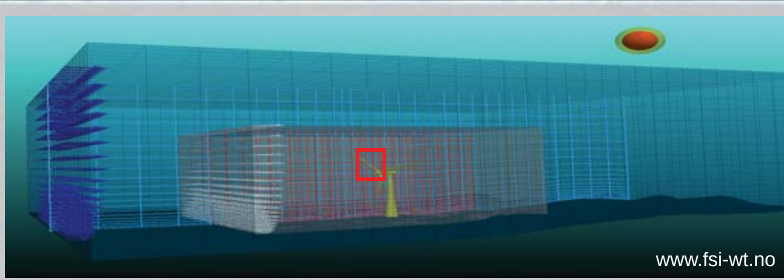
INTRODUCTION

We present a spline based mesh generator for wind turbine blades intended for isogeometric analysis (IGA). IGA unifies CAD modeling and high order analysis in a natural way, allowing us to represent the true geometry, unlike conventional tetrahedral mesh generators. Industrial CAD software, such as Rhinoceros, can easily create complex geometries, but there remains a lack of a volumentric mesh generator. The following work was developed initially for the NREL 5MW reference blade, but it has a modular approach allowing it to handle other geometries as well.



METHODOLOGY

The NREL 5MW blade is defined as a series of cross-section airfoils at various points along the blade axis. We interpolate and resample lengthwise, produce 2D meshes and loft them together. The tip is handled separately.

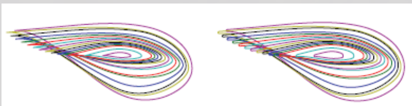
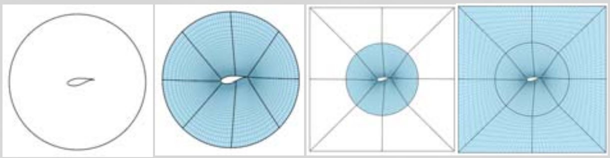


Figure 1: Artificial rounding of each airfoil allows a more efficient mesh.

Figure 2: Two-step interpolation routine with low and high order avoids a self-intersecting mesh.

TWO DIMENSIONAL MESH GENERATION

Two-dimensional mesh generation We envelop each airfoil in a circle and use transfinite interpolation (TFI) to generate the intervening "O-mesh". It is then split in eight patches and extended as necessary.

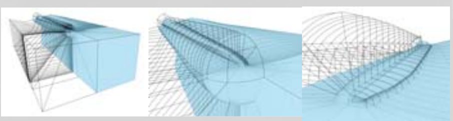


- The mesh generated is highly sensitive to parametrization (not just geometry). This is solved using a parameter-normalization technique.
- TFI cannot guarantee orthogonal meshlines close to the body, which is necessary for our applications. This is solved by "growing" the mesh layer-by-layer, using at each step a weighted average between regular TFI and orthogonal projection.
- Gridlines might intersect in rare cases (highly concave domains.) This is solved by applying a Laplacian smoothing at each layer.

Figure 3: Orthogonalization (left) and smoothing (right).

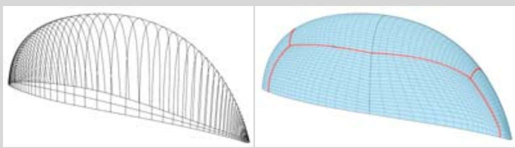
BLOCK STRUCTURE

The final block structure of the mesh consists of eight sectors (four on the tip), and an arbitrary number of decompositions in the radial and lengthwise directions.



TIP CLOSURE

To construct the tip, we raise the midline of the final airfoil some suitable distance (here, about 20 cm). Then, interpolation between the opposite sides of the airfoil and the raised midline generates a family of curves that produces a parametrization of the tip with two singularities. This surface is then sectioned into twelve patches without singularities.



The surrounding mesh can then be generated using a relatively straightforward volumetric generalization of the described TFI algorithm.

CONCLUSION

The mesh generator has been used in practice for the NREL 5MW blade in various configurations (no tip, cut-off tip, rounded tip), as well as a for other verification blades. It is easily controlled with parameters for geometry, resolution, load balancing and output format, such as OpenFOAM. It can also produce other meshes with the same topology.

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