Review of paper wes-2022-13:

A WaveNet-Based Fully Stochastic Dynamic Stall Model

by Jan-Philipp Küppers[1] and Tamara Reinicke[1]

[1]Chair of Product Development, Universität Siegen, Paul-Bonatz-Str. 9-11, 57076 Siegen, Germany

Brief summary

The authors present a WaveNet-based Neural Network as a reduced order model for the relationship between the motion parameters of an airfoil under dynamic stall and the aerodynamic loads on it. In contrast to existing (semi-)empirical models typically tuned on phase-averaged data from oscillating blade pitch experiments, the new model is fully probabilistic and working with raw wind tunnel time series. The Neural Network is autoregressive and predicts one time step at a time by generating a probability distribution from which a sample is drawn.
The authors foresee that with the new model predictions of more realistic frequency responses and the local variance of the aoerodynamic coefficients it opens up new possibilities in the study of blade flutter and other aeroelastic problems.

Overall comments

The subject of the paper being the development of a new type of dynamic stall models based on WaveNet-based Neural Network using machine learning on raw wind tunnel data is of considerable importance for the research community. However, as also mentioned by the authors in section 7 (Discussion and outlook) its practical use, at the stage of the model presented in the paper, is still limited in so far as only one blade profile can be used within a wide but still restricted parameter range.

Therefore, a main objective with the comments from the present reviewer is to clarify what the realistic future applications of the model can be after further developments.

Can it replace (supplement) the use of the traditional dynamic stall models as e.g. the Beddoes Leishman model in aeroelastic simulations with codes as HAWC2, FAST or BLADED ?

The presented prediction time of 0.046s per time step will slow down an aeroelastic simulation. **Can the simulation time be decreased by reducing the steps of the model looking backward ?**

Another limitation at the present stage seems to be that the model is locked to a time step of 0.01s.

Page 9, line 71: *It should be noted that the time vector is not a feature used in the training data. Therefore, the model can only work with a constant time step of 0.01s.*

How difficulty is it to train in order to use different time steps ?

The following sentence is the main argumentation from the authors of the advantages of the new model:
"We argue that since all dynamic stall models use experimental data to tune their parameters, one may as well use the raw experimental data directly. The presented model extracts all relevant features from the raw data itself and can make much more accurate predictions than the commonly used models. It can not only predict unsteady forces, but also allows to derive the range of fluctuations, maximum values, and frequencies."

The use of the raw, unfiltered data has interesting potentials in modelling phenomena with stochastic response as the dynamic stall of an pitching airfoil as shown in the present paper. This also requires high quality data sets as mentioned by the authors on page 20, line 318 and could lead to a model that carries faulty data characteristics into e.g. aeroelastic simulations.
Another possibility could be to use simulated data. Its therefor surprising from the reviewers point of view that LES CFD simulations are presented as a competitive approach: page 2, line 39 *: " They state that Largy Eddy Simulation (LES) and other scale-resolving simulation methods can be a solution, but due to extreme computational requirements, they are often not well suited for the design of an entire wind turbine."*

From the reviewers point of view the use of unsteady airfoil data from high fidelity LES/DES simulations might be very interesting as input for the present model instead of/or as compliment to wind tunnel data. As an example the presented model might be able to extract post stall characteristics from 3D DES simulations[1]. In all the cases in this referenced paper the AoA was constant but the lift is fluctuating considerably due continuous vortex shedding from the separated flow. The present semi-empirical dynamic stall models are lacking the ability to generate unsteady loading for a constant AoA which might be important in aeroelastic simulations. Therefor it could be a big step forward if the described WaveNet model can do that.

Can the authors comment on the applicability of the present model for such applications ?

Finally as a general comment the experimental data and the derived stall characteristics presented in the paper are probably not directly applicable for aeroelastic wind turbine simulations due to: 1) the low Reynolds number and 2) the big amplitudes used in the experiments. Generally, the modern pitch regulated turbines do only accidently in operation enter into deep stall and with such big amplitudes. 1p AoA variations are typically well below 10 deg.

Specific comments

Line 39-41:

- **Consider to expand/modify the comments on LES simulation based on the rviewers comment above**

[1] Bertagnolio, F., Niels N. Sørensen, and Jeppe Johansen. 2006. "Profile Catalogue for Airfoil Sections Based on 3D Computations." Risø National Laboratory.

Line 130:

- Your model looks back 128 time steps which in the present case is linked to a cycle. **What guidance could otherwise be given on choosing the number of steps looking back ?**

Line 171-172:

- "*It should be noted that the time vector is not a feature used in the training data. Therefore, the model can only work with a constant time step of 0.01s. "* **Please expand on this as a fixed time step could limit the use of the model ?**

Line 271-273:

- "*Another important feature that distinguishes this model from traditional methods is that the returned frequency spectrum is close to the real spectrum as well. This opens the possibility for a more accurate analysis of blade flutter and realistic aeroelastic responses.*"

  In particular blade flutter depends strongly on the unsteady aerodynamic modelling of the linear part of the Cl curve where there is now stochastic effects. **How should the present model improve that compared e-g- with the Beddoes Leishman model ?**

Final conclusion of review

The reviewer can recommend publication of the paper but recommends to integrate response to the above review comments.