Mini-lecture Classical Flutter

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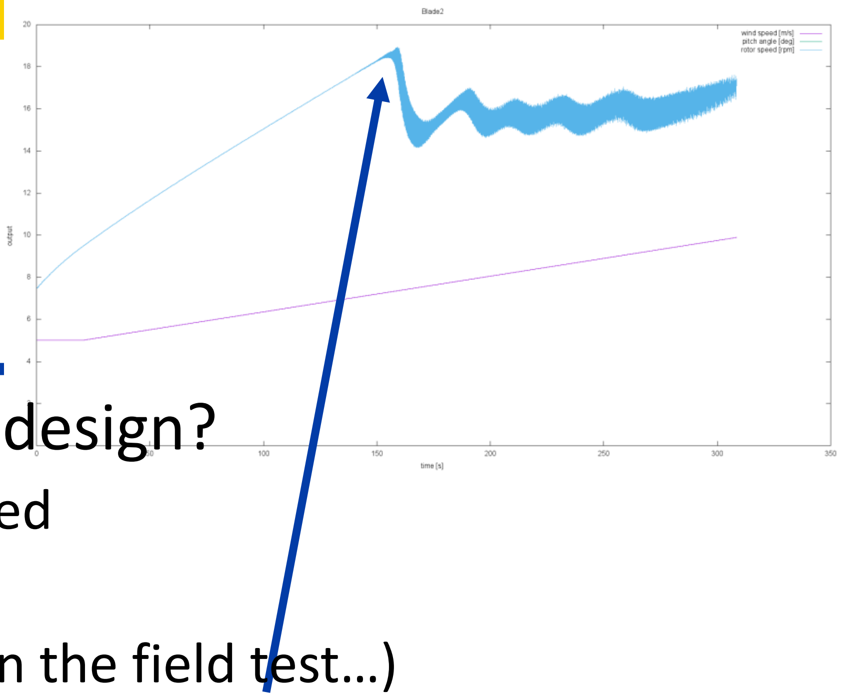
Classical Flutter

- The aeroelastic instability Classical Flutter is known from fixed wing aircraft: above a certain flying speed a wing will start to violently vibrate in a combination of torsion and flapwise.
- For wind turbines Classical Flutter will occur above a certain rotor speed.
- During the design one has to make sure that this rotor speed will not be reached during the wind turbine's life time, because the instability is destructible if not stopped very quickly.

Classical Flutter

- The increasing rotor speed changes the natural frequencies.
- When two natural frequencies coincide, in a structure the two related modes will combine to two other modes, usually one with very strong damping and one that often becomes unstable.
- A higher rotor speed will increase natural flapwise frequencies and decrease natural torsion frequencies.
- When these two combine, the classical flutter instability can occur.
- Classical flutter occurs in linear part of lift curve, so before stall.
- Vibration in flapwise and torsion direction will show a phase difference.

Classical Flutter



- How to determine the classical flutter speed of your design?
  - Set a constant wind speed or a slowly increasing wind speed
  - Set the generator torque to zero
  - The wind turbine will now speed up in the simulation (or in the field test…)
  - Above a certain rotor speed the wind turbine will show violent vibrations.
- Settings that influence the results:
  - If you use a constant rotor speed to check if the situation is unstable, this approach affects the edgewise frequency and can influence the instability
  - Dynamic stall model increases the flutter speed (so dynamic stall adds some damping such that instability occurs later, even though in linear part of lift curve)
  - Pitch angle changes the flutter speed (and also how quickly the turbine accelerates)

Classical Flutter

- When is the flutter speed high enough?
  - Depends on the turbine design, the controller, the safety measures, how quickly will the turbine shut down in an overspeed situation and how accurate is the calculation
  - As a first idea, 40% overspeed margin should at least be required
- Overspeed does not always result in classical flutter
  - Other violent instabilities are known to occur in overspeed
  - Sometimes instead of classical flutter, an edgewise mode becomes negatively damped in overspeed conditions
  - Obviously the solutions to increase the allowable rotor speed in that case is different from what works to increase the classical flutter speed
  - So check results: vibrations in torsion & flap or mainly edge? Phase angle present between flap and torsion? Operating in linear part of lift curve?

Classical Flutter

- For current size wind turbines, the classical flutter speed really needs to be determined.
- Quite small margins are sometimes found which therefore result in design changes to be necessary
- Do check if the tool you use is accurate enough for such a simulation!
  - Using mode reduction of blades will not provide accurate results!
  - Torsion obviously needs to be included as a DOF
- Increasing flutter speed can usually be achieved by:
  - Increasing torsion stiffness
  - Moving c.g. towards leading edge (in helicopters this is done using non-load carrying mass)

Classical Flutter

- Small selection of literature treating classical flutter for wind turbines & other wind turbine overspeed instabilities:
  - Classical flutter: https://onlinelibrary.wiley.com/doi/pdf/10.1002/we.242 (not open access, but beautiful paper); https://www.ecn.nl/publications/PdfFetch.aspx?nr=ECN-E--15-036 ; http://energy.sandia.gov/wp-content/gallery/uploads/EWEA-2005-pp538-SAND04-5037C.pdf
  - Overspeed instability measurements on actual multi MW size Wind turbine: http://iopscience.iop.org/article/10.1088/1742-6596/753/4/042005/pdf

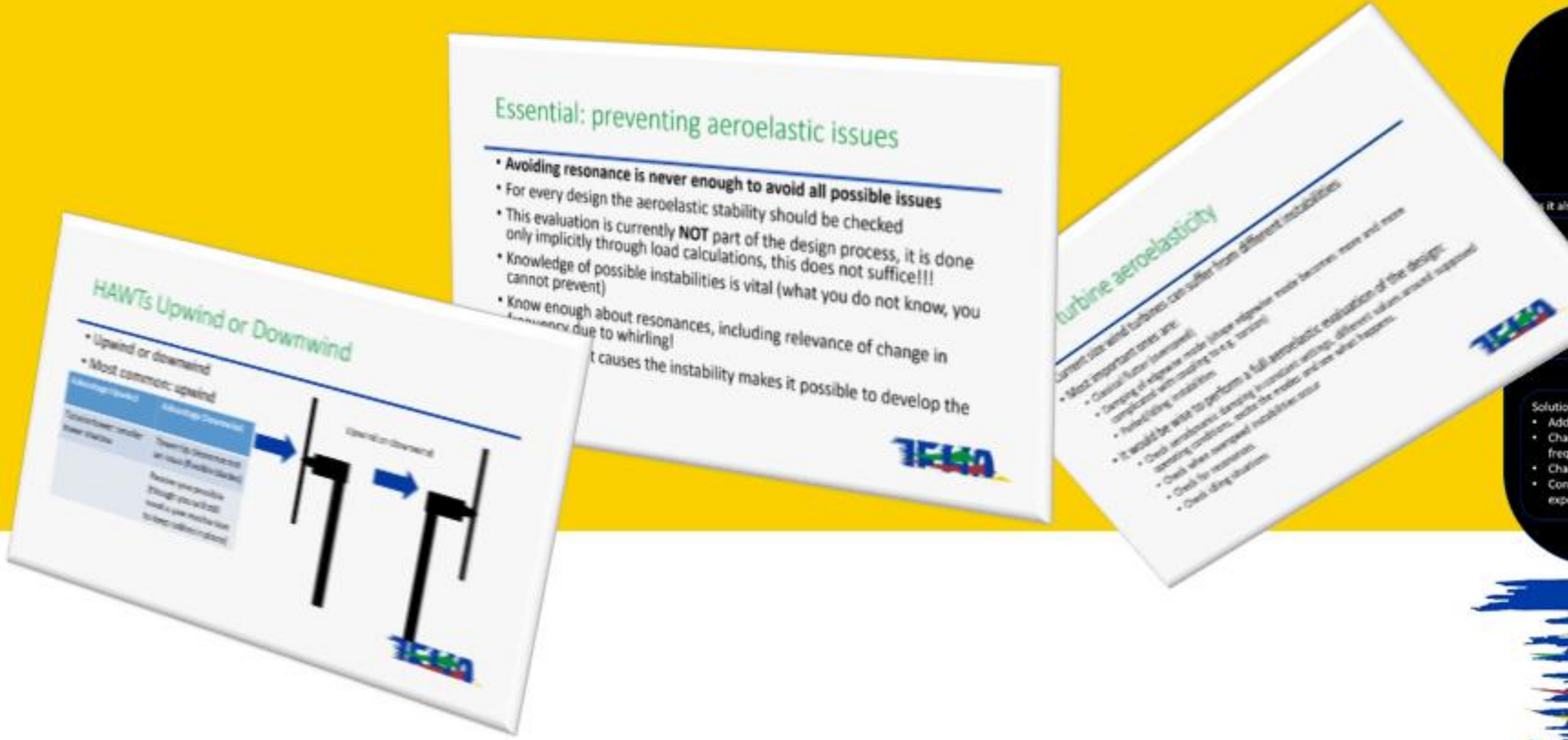
Summary

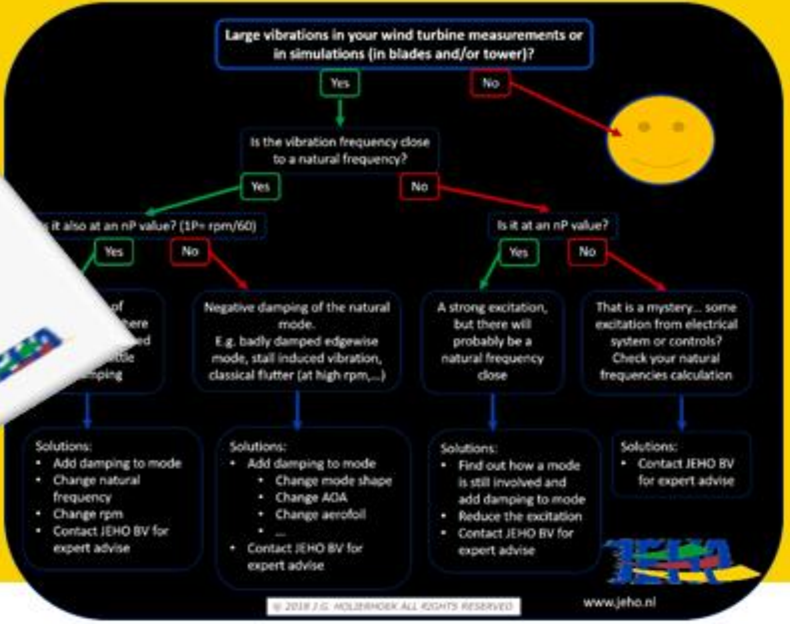
- Classical flutter speed or maximum allowable overspeed has to be determined for current size wind turbines
- Sometimes one of the edgewise modes becomes unstable in overspeed, before classical flutter can occur
- Solution depends on the phenomena that occurs (classical flutter or edgewise instability)

Interested in knowing more about this? See next slides! Interested in having an expert perform this check of your design? Contact us, we can discuss the different possibilities (info @ jeho . nl)

Wind Energy Courses Overview - 2019

Different training options provided by JEHO BV





JEHO BV

Courses we provide:

Wind energy introduction (1 day)

Basic aerodynamics for a wind turbine

Different concepts (2-3 bladed, Upwind, downwind, HAWT, VAWT, direct drive, offshore,...)

Cost of wind energy: how is it built up, where can we still improve,...

Turbine design: how, what, why,...

Wind turbine aeroelasticity (3 days)

Introduction course WT aeroelasticity

3 day of intensive training

Theory and practise are treaded

Also possible to arrange confidential course for your company

The main issues are discussed: types of instabilities, their causes, their solutions as well as resonance issues

Participants will get hands on experience to identify some of the issues presented

Workshop (2 days)

Continuation of the initial course

Analyse your own turbine design to find possible issues

Or in an open setting an adjusted public design is evaluated

Step by step it is explained how issues can be found, identified and solved

A perfect course for people that have participated in the WT aeroelasticity course and want to refresh and extend their knowledge

Evaluation training (≈ 4 weeks)

We cooperate with one or more of your engineers and perform a complete aeroelastic evaluation of the design.

The engineers will gain significant experience and the design is checked for possible resonance and stability issues

Training	days	date(s)	location
Wind turbine aeroelasticity course	3	5-6-7 March 2019	Rotterdam
Wind turbine aeroelasticity workshop	2	15-16 April 2019	Rotterdam
Wind energy introduction	1	19 April 2019	Rotterdam
Wind turbine aeroelasticity course	3	7-8-9 May 2019	Hamburg
Wind turbine aeroelasticity course	6 x ½	6 am- 10 am CET on 14-5 / 16-5 / 21-5 / 23-5 / 28-5 / 4-6	Online – live: times suitable for Iran / Russia / India / China / Australia and surroundings
Wind energy introduction	1	30 September 2019	Rotterdam
Wind turbine aeroelasticity course	3	1-2-3 October 2019	Rotterdam
Wind turbine aeroelasticity course	3	20-21-22 November 2019	Hamburg

Get to know everything about this and much much more in this course. Info: www.jeho.nl