PO.044

Improved Quality of Rotor Balancing Measurements through Criteria from the Guideline VDI-3834-1:2015

Michael Melsheimer, Anke Grunwald, Dr.-Ing. Christoph Heilmann (Presenter)
BerlinWind GmbH, Germany, www.berlinwind.com

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Abstract

Independent field measurement statistics presented on EWEA 2013 and 2015 reveal high shares of intolerable rotor imbalance and blade angle deviation at series wind turbines (WT), **Fig. 1**. Already for longtime, the **limit values for mass imbalance** (MI) **and blade angle deviation** (i.e. aero-dynamic imbalance, AI) are **mandatory rotor design parameters** in design fatigue load analysis according to WT design standards, e.g. [1]. However, a periodic MI and AI verification at each real individual WT is presently still not mandatory, resulting in the high shares of affected WT, **Fig. 1**. **Intolerable MI and/or AI** increase significantly the real fatigue loads and have many negative impacts on the entire WT project, **Fig. 2**. A **significant service life reduction of many WT components** is observed and confirmed by simulations, e.g. AI of 1.5° doubles the blade root damage sum and reduces its service life by one third.

Statistic evaluation of field measurements revealed that the root-mean-square based method proposed in the guideline VDI 3834-1 [2] for vibration evaluation at wind turbines is insensitive even to severe MI and AI. Hence, to prevent these issues, **exact MI diagnosis using mobile in-situ measurements is a must**.

Therefore, the guideline's revision VDI 3834-1:2015 is extended by an **annex on in-situ rotor balancing at WT**. This complements the in-situ balancing standard DIN ISO 21940-13 [3] with WT-related aspects and balancing experience. This provides **quality criteria helping to identify WT reliable rotor balancing methods** meeting the field challenges: complex WT dynamics, potential falsification by AI and non-linear aerodynamics, individuality of WT types, wind fluctuations and the manifold root causes for WT rotor imbalance.

Objectives

Limits for MI and AI (blade angle deviation) are mandatory rotor design parameters for WT design fatigue loads. Hence, one should care about them during WT operation. **Quality criteria** from VDI3834-1 **help judging the suitability and long-term benefit of balancing measurement methods** which use mobile in-situ measurements for rotor imbalance and blade angle deviation diagnostics.

Quality Criteria for In-situ WT Balancing Methods

1. **Working safety**
   Safe work procedure, e.g. prevention of unwanted excess vibration by knowledge about resonance effects, **Fig. 4**
2. **Suitable procedure**
   - Correct logical step-wise order, **Fig. 3**
   - Root cause oriented elimination /repair of issues falsifying MI measurements, e.g. erosion, blade angle deviation, temporal imbalance from blocked drainage holes, etc.
   - Defined measurement requirements to assure reproducible results, **Fig. 4**
3. **Suitable measurement system and sensors**
   - Resolution of very small WT imbalance related acceleration amplitudes (< 5 mm/s²) at the low frequencies (< 0,5 Hz) related to the rotor speed
   - Sufficient data points per revolution for correct angular imbalance location
   - Rotor speed sensor to monitor its fluctuation
4. **Suitable measurement period per test run**
   Duration long enough (mostly > 30 min) to assess/eliminate result falsification related to wind and rotor speed changes
5. **Reliable evaluation method**
   - Order analysis to remove falsification from rotor speed fluctuation
   - Several indicators for cross-checks, e.g. for AI axial and torsional vibration
6. **Correct MI limit value for evaluation**
   Individual MI limit of each WT type (e.g. from certification / type approval)
7. **Suitable imbalance amplitude calibration**
   Test mass large enough for proper in-situ calibration and counter-balancing
8. **Reliable quality control**
   - Repeated quality control during entire procedure, e.g. validation runs
   - 4-eyes principle of independent experts
9. **Well trained and experienced staff**
   - Profound knowledge of WT and its dynamics to assess unexpected behaviour on site
   - Prevention of hazard from wrong recommendations due to falsifications

Findings

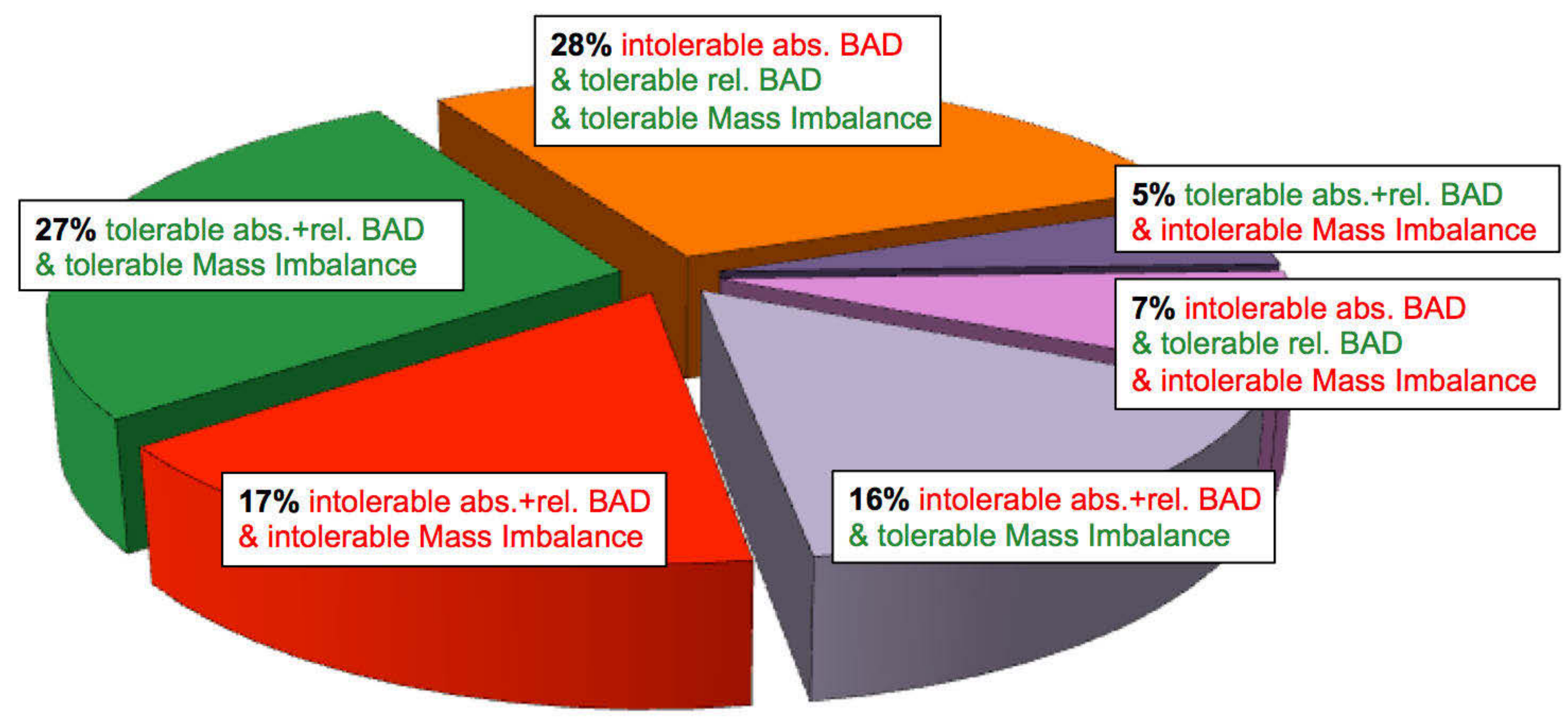

Fig. 1: Shares of turbines (without known BAD or Imbalance issues) affected by blade angle deviation and/ or mass imbalance (BerlinWind, EWEA 2015)

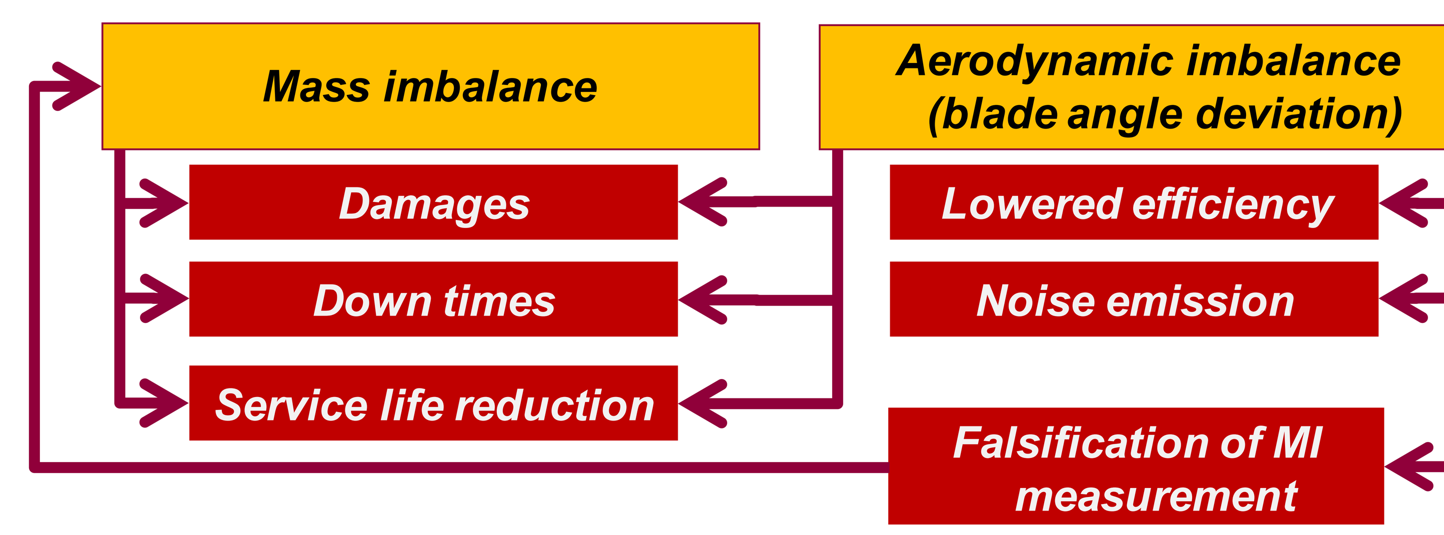

Fig. 2: Negative impacts of intolerable deviation from rotor design parameters

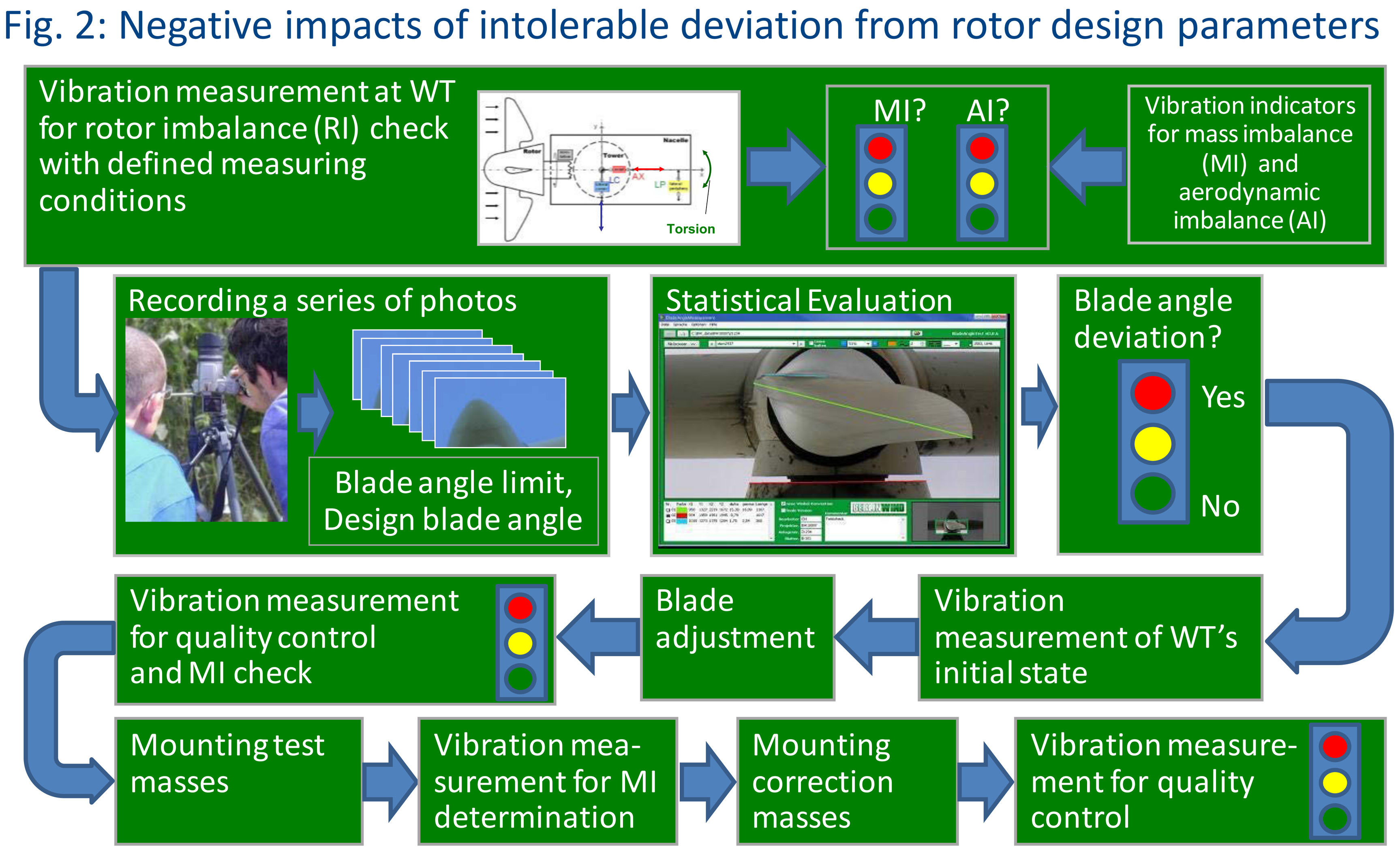

Fig. 3: Scheme of high quality balancing procedure preventing falsified results

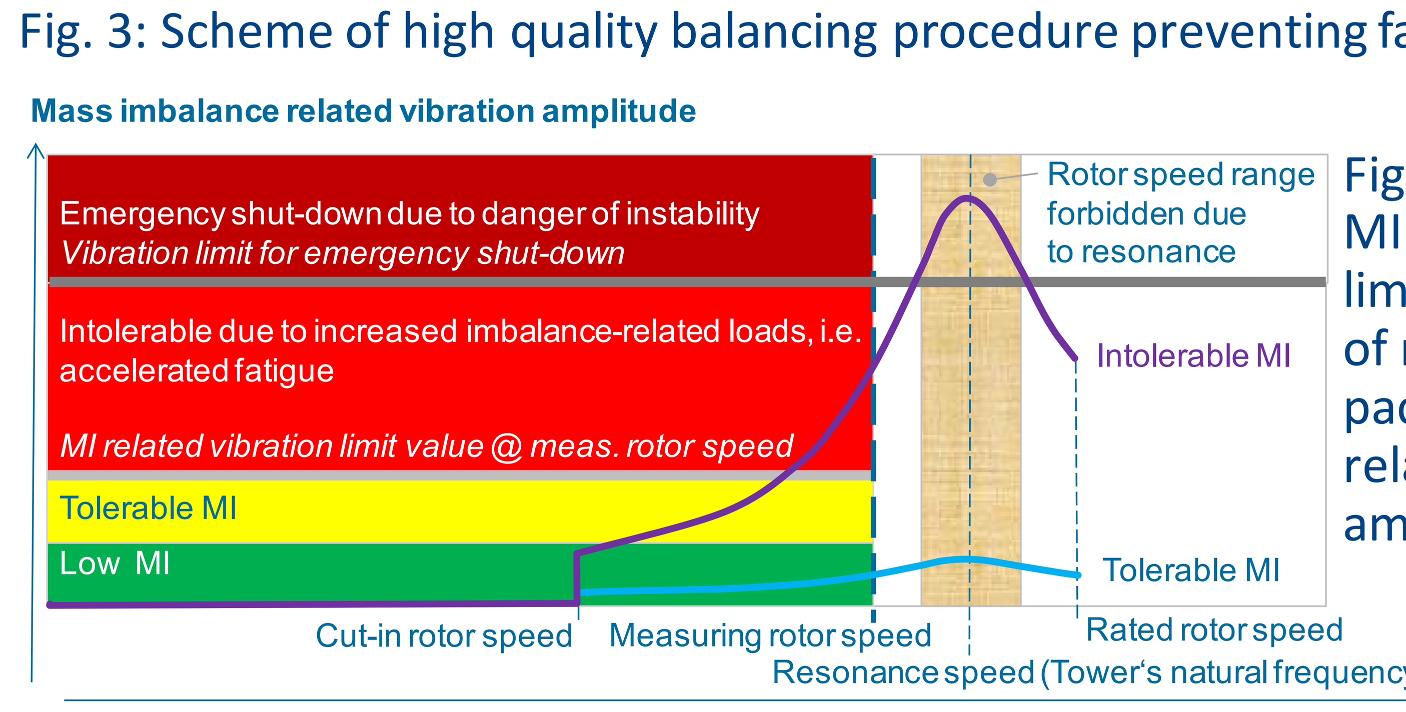

Fig. 4: Definition of MI related vibration limit value because of rotor speed impact on imbalance related measuring amplitude

Conclusions

Available WT rotor balancing methods and procedures show a different level of complexity. The quality criteria derived from VDI 3834-1:2015 help judging the **overall suitability and benefit** of a method. The criteria are as well useful to develop a **life-cycle-oriented approach for WT rotor balancing**, which reduces lifetime consumption, stand still and overall O&M costs.

References

1. DIN EN 61400-1: Wind turbines – Part 1: Design requirements
2. VDI 3834-1:2015 Measurement and evaluation of the mechanical vibration of wind turbines and their components, Part 1: WT with gearbox, incl. annex on in-situ balancing of WT rotors
3. DIN ISO 21940-13: 2012: Criteria and safeguard for in-situ balancing of medium and large rotors