Standardization of Input Parameters for Ice-Throw / Ice-Fall Risk Assessments

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01 PROJECT MOTIVATION

02 RESULTS

03 OUTLOOK
Standardisation of input parameters for ice throw / ice fall risk assessments

Prevalent approach of ice-fall risk assessments

- Calculated Risk level: $3.4 \times 10^{-5}$
- Limit: $1 \times 10^{-6}$

BUT: Assumptions and uncertainties!

- Mathematical model
- Data basis for the location
- Risk Assessment

Wind Data

Icing Data

Dimensions | Mass | Numbers
---|---|---
3x5x10cm | 90g | 385
3x9x10cm | 243g | 69
10x13x20cm | 1.6kg | 44
16x19x20cm | 5.5kg | 2
Wind speed data

<table>
<thead>
<tr>
<th>Wind Data</th>
<th>Max. Wind speed [m]</th>
<th>Max Range [m]</th>
<th>Average hits per sqm</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Minutes averages</td>
<td>21</td>
<td>154</td>
<td>9.7 * 10^{-3}</td>
</tr>
<tr>
<td>3 Seconds maximum readings</td>
<td>27</td>
<td>180</td>
<td>8.4 * 10^{-3}</td>
</tr>
<tr>
<td>1 Hour reanalysis Data</td>
<td>17</td>
<td>118</td>
<td>1.6 * 10^{-2}</td>
</tr>
</tbody>
</table>
Size and weight distributions

<table>
<thead>
<tr>
<th></th>
<th>Dimensions</th>
<th>Mass</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 %</td>
<td>3x4x8cm</td>
<td>86g</td>
<td>250</td>
</tr>
<tr>
<td>35 %</td>
<td>5x8x10cm</td>
<td>240g</td>
<td>175</td>
</tr>
<tr>
<td>10 %</td>
<td>5x10x50cm</td>
<td>1,5kg</td>
<td>50</td>
</tr>
<tr>
<td>5 %</td>
<td>3x20x100cm</td>
<td>5,4kg</td>
<td>25</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Dimensions</th>
<th>Mass</th>
<th>Numbers</th>
</tr>
</thead>
<tbody>
<tr>
<td>77 %</td>
<td>3x5x10cm</td>
<td>90g</td>
<td>385</td>
</tr>
<tr>
<td>14 %</td>
<td>3x9x10cm</td>
<td>243g</td>
<td>69</td>
</tr>
<tr>
<td>9 %</td>
<td>10x13x20cm</td>
<td>1,6kg</td>
<td>44</td>
</tr>
<tr>
<td>0,4 %</td>
<td>16x19x20cm</td>
<td>5,5kg</td>
<td>2</td>
</tr>
</tbody>
</table>

Fig.: Scenario A; Dmax = 154m
Fig.: Scenario B; Dmax = 190m
Motivation and Project Objective

Large deviations in:

- Requirements of national / regional authorities how to assess the risk
- Stipulation of mitigation measures / regulatory requirements
- Methodologies / results of individual consultants

Project Objective:

- International guidelines/recommendations for the elaboration of ice-throw / ice-fall risk assessments
- Awareness of authorities and wind energy community about crucial parameters → Paving the way to more transparency
Project Organisation

8 international Partners (with different background):

- 4x Consultants
- 2x Certification bodies
- 1x WF operator
- 1x OEM

Under the umbrella of IEA Wind Task 19:

- [https://www.ieawind.org/task_19.html](https://www.ieawind.org/task_19.html)
- Publication of International Guidelines (not a standard)
Methodology

Unbundling in three separate sub-processes:

• Details of the mathematical model  \[ \text{Phase I} \]
• Relevant data basis (wind and icing)  \[ \text{Phase II} \]
• Risk aspects  \[ \text{(ongoing)} \]

Working approach:

• Cross-comparisons on predefined case scenarios
• Sensitivity analysis with different parameters

Identification of so-called **Highly Recommended Aspects**
(Recommendations about the ‘Must-haves’)

Mathematical Model
(i.e. statistical trajectory model)

Highly recommended aspects for the trajectory model:

- Turbine parameters:
  - Hub height, rotor diameter, operational mode.
- Consider drag! (Lift can be neglected.)
- Topography in case of complex terrain (DGM or via post-processing)
- Physical parameters:
  - Air density, vertical wind profile, radial distribution of ice on the blade, no. of relevant fragments.
Wind Data Basis

Highly recommended aspects:

- Based on 10 minutes’ averaging, covering at least one icing season:
  - Wind speed & direction
- Long term correction (if available dataset cannot be regarded as a long term)
- Representative for the turbine location (horizontal and vertical extrapolation)
  - Wind shear
- Wind statistics representative for periods when icing and melting may occur
  - Filtering shall not be done to narrow!
Icing Data Basis

Estimation of Amount of ice fragments:

1. Scaling of in situ ice fall / throw observations (e.g. Gütsch, Icethrower, R.Ice…)

\[ N_{site} = N_{obs} \times s_{ice} \times s_{rotor} \times s_{op} \]

- \( N_{site} \)…amount of ice at the site of interest
- \( N_{obs} \)…amount of ice from site measurements
- \( s_{ice} \), \( s_{rotor} \), \( s_{op} \)…scaling factors for site icing conditions, rotor dimensions and operational mode

2. Ice load distribution formula (e.g. IEC 61400-1 Ed.4): Not site-specific!

3. Ice accretion simulations: Future potential?!
PROJECT MOTIVATION

RESULTS

OUTLOOK
Aspects of Risk Assessment (Phase II)

- General approach of risk assessment
  - ALARP / MEM vs. LIRA
  - Individual risk vs. collective risk

- Thresholds and factors of uncertainty
  - Kinetic energy vs. weight of relevant ice fragments
  - Acceptable risk levels for different stakeholders

- Mitigation measures (warning signs, flashing lights…)
  - Efficiency / effectiveness of the individual measures
  - Reduction ration: Which order of magnitude?
International Guidelines for the Elaboration of Ice-fall / Ice-throw Risk Assessments
(To be published in Fall 2018)

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Thanks for your Attention.