8th International Conference

on

Wind Turbine Noise

Lisbon – 12th to 14th June 2019

Post Conference Report

Another successful conference. Lisbon was a perfect venue with great weather, particularly if you live in Scotland like me, delicious food and the friendliest of people. Thanks to the Portuguese Acoustical Society and all the people of Lisbon for making us welcome.

First, a few statistics. 26 countries were represented, 16% of people from outside Europe, many of them old friends but also some new faces from as far afield as Uruguay and China. Germany dominated the numbers for the second conference running with 25% of the delegates with UK, Denmark, France and Belgium following behind.

There are still only 15% of women delegates (a little up from previous conferences) but encouragingly 25% of the papers were presented by women and women played a bigger part still in chairing the sessions and forums.

The central features of the conference programme were the discussion forums on specific topics. There were six of these and there is a report on each of them below.

Those topics that were not covered by forums had fewer papers this year. Tones were covered by three papers but, as we will hear later, the study of tones is not going to go away. There is increasing pressure to reduce tones as the overall noise level of turbines is reduced.

Amplitude modulation featured less this time compared with recent conferences but there is definitely a need for more work as it is perceived to be a key factor in several countries. There is still not enough work on the impact of AM on people. One to think about for 2021 perhaps.

Assessment and compliance and background noise brought us a respectable number of papers with several raising new ideas. The variability of background noise is something we still do not understand well and we started to see some thoughts on that this year.

One of the striking points that came out of this conference was the difference in research requirements between the consultants and regulators on the one hand and developers and manufacturers on the other. As regards propagation, the former were generally happy

with the quality of the models available – even models such as ISO 9613 if used with care – as they were able to provide the answer within a couple of decibels and by being conservative, that was good enough for an environmental assessment. For developers and manufacturers, however, two decibels might make the difference between a viable or non-viable wind farm, so more accurate propagation methods and, importantly, verification of them were important. In a similar way, whilst consultants and regulators found trailing edge mitigation research interesting and sometimes helpful, developers saw it as essential to drive down the cost of renewable energy.

We have had, in the past, a few presentations from wind farm neighbours who have been affected by wind farm noise. They were absent this year. If there were no people affected by wind farm noise we would not be having these conferences. We have always welcomed anyone who has a view from personal experience and without such views we cannot get the whole picture.

What follows this page are notes on each of the forums. I hope they give a flavour of the discussions. With a couple of exceptions, I've tried not to draw any conclusions, simply report what was said. It is worth mentioning that one of the great strengths of these conferences is the range of different disciplines who attend. It is not just noise consultants – in fact they probably consist of no more than 30%. There are manufacturers, business people, and lots of researchers. We also had at least two medically qualified doctors and several public health and environmental health professionals.

Finally thanks to those who helped me put together these notes. Particularly Franck and Benoit for Forum M which I did not attend, Michaela, Roger and Kaj for Forum P and Andy and David for Forum R. In the end though the buck stops here with me and I hope I have interpreted the proceedings even-handedly.

I look forward to seeing you all in 2021 in . . . . . .

Dick

FORUM E – Propagation. Moderated by David Ecotiere

Matthew Cand and Kristina Conrady on the Podium.

Most of the discussion centred round how accurate propagation modelling was and, in particular, how accurate it needed to be. Various factors affecting accuracy were discussed. For example, does turbine wake increase noise levels in some places? There was a feeling that if that were the case it might be offset by the fact that wake reduces wind speeds at downwind turbines which has the opposite effect.

The general feeling amongst consultants and others involved in modelling for permitting/planning applications was that the methods were pretty accurate. For most conditions simple engineering models are fine. Advanced models like NORD 2000 are also accurate in upwind conditions.

- Whilst it's interesting to know what's going on in more detail, it's probably not relevant to planning assessment.
- There is interaction between turbines. Great to understand how it works but practically not relevant
- Modelling is because you promised something to residents. You also take the worst case situation to make sure your promise is kept.
- We can live with propagation models for air, road and rail. Why not with turbines? We can't go to the last decibel.

There was some concern about uncertainty (UC). We don't see UC presented in modelling or measurements very often. Also, in measuring, it's hard to say whether UC is due to measurements or to propagation itself.

In Norway they had problems with different consultants producing different answers using NORD2000. So they re-introduced ISO 9613 in 2014. The view here was that we need models that are straightforward and that regulators can understand.

However, the developers and manufacturers view was different. A conservative approach has costs for developers as they are trying to maximise output. They want minimum uncertainty. They definitely need more accurate modelling and it needs to be verified by measurement. If the limit is 40dB, for example, they need that room to produce renewable energy. 2% increase due to more precise models is a lot of energy.

There was a desire, particularly amongst developers, for an international standard model. This was generally not thought to be practicable at least within a reasonable time scale. Such a model needs to be operable by someone with limited skills and be reasonably cheap. In any case many countries have their own methodology which they are going to keep. But a Good Practice Guide that could be used internationally may be the way to go.

So the meeting was split about the need for more work; with consultants being reasonably satisfied with existing models and developers and manufacturers needing more accurate models and verification by measurement.

FORUM J – Impact on People. Moderated by David Colby

The Forum started with a discussion about infrasound. The EARS project shows that Salt's theory on Infrasound is not true in practice. Infrasound just below the threshold can excite anxiety centres in the brain but EARS showed that this only extends to a couple of decibels below threshold. At 1Hz turbine noise is typically 60dB below threshold.

In more general terms, there are lots of other sources of infrasound and that from turbines is no more than some other sources. It was also felt that some of those promoting the danger of infrasound were causing unnecessary anxiety and distress to wind farm neighbours.

There is nothing in the sound of wind turbines – infrasound or audible sound - that can directly affect the pathology of your tissues and make you sick that way. The amount of energy in sound waves at the levels we are talking about here does not support any direct effect other than through the ears.

Nevertheless, there is no doubt that there are people who are ill near wind farms. Some of these people may be ill because of their reaction to the wind farm, others may be ill for other reasons or for combinations of reasons. It is important to understand that they are really ill and that they need proper individual medical treatment.

There were some differences as regards public health. One view was that it was a public health matter, because of misinformation spread on the internet, the other that it was not but rather an individual treatment issue.

Relations between developers and neighbours are important. Sometimes in the past, information given to neighbours has been misleading or incomplete. In any development there are going to be some people who will be annoyed because all development is a compromise. So it is important to be straight with people.

There have been many social surveys on attitudes to wind farm noise. They all point to the same factors – mostly non- acoustic factors such as lack of control and perceived unfairness. Industry has not been very good at taking notice of these results in the way they deal with residents. People don't trust governments or developers. More needs to be done to rectify this. Developers need to talk to people and understand the problems. If you reach out to residents you will get some residents who will understand, that is the best you can do. It is important that communication starts as soon as possible so people feel they have a say.

CANWEA has published community engagement guidance. That might be helpful.

FORUM M - SOURCE PREDICTION. Moderated by Franck Bertagnolio (DTU Wind Energy), Benoît Petitjean (GE Renewable Energy).

Summary of discussions

Around 40-50 participants attended the forum and discussions concentrated on the current state of knowledge concerning the prediction of wind turbine noise sources and what is needed in the future for the industry to control noise emissions from wind turbines at the source.

No definitive and concluding statement was made, but some sorts of consensuses were reached on a variety of topics. The following summary is not chronological and is just a probably incomplete recollection of the discussions.

The first topic addressed is the extrapolation of 2D airfoil noise data to a 3D blade in real life. This step in the design process of a wind turbine requires a certain “leap of faith” as there is no established theory to justify this extrapolation of data (although some empirical knowledge may be applied here). As a consequence, this step may compromise the final product specification, i.e. the wind turbine noise emission levels.

An important topic is the variability of the atmospheric wind which cannot be predicted accurately due to its turbulent nature. It can manifest itself as AM and other unsteady/intermittent phenomena. It results in a potentially high variability of the noise emissions which cannot be quantified accurately. Nevertheless, manufacturers provide uncertainty together with their certified noise levels, which are used subsequently by operators and developers for their immission noise predictions. However, it is difficult to take these aspects into account during the design phase.

In this respect, it is pointed out that AM is site dependent. Therefore, it is difficult - if not impossible – for the manufacturer to design wind turbines for noise and including mitigation of AM. It is difficult for the manufacturers to be pro-active on this front as long as there is no theory or sufficient information to predict this phenomenon.

In relation with the quest for better prediction accuracy levels, the manufacturers stress the fact that there is a need for the further development of higher fidelity, non-empirical methods for noise emission predictions. They have a good control of their existing engineering lower fidelity models that are finely tuned with the large amount of experimental/field data available to them. One problem of these high-fidelity methods are the high costs both in terms of computational resources and time. These methods can also be used to reduce the uncertainties mentioned above concerning the noise emission of a wind turbine in real life. These methods are also required to assess new designs that go beyond the known design space, as well as for investigating intricate physical phenomena that are difficult to study otherwise. For these purposes, a lower accuracy on absolute levels would be acceptable, if trends and deltas are captured accurately.

The aerodynamic noise levels from modern wind turbines have reached relative low levels compared to, for example a decade ago. Also, modern wind turbine rotor noise emission is more dominated by higher frequencies. Thus, for low wind speeds, in low-noise operating modes, or even during stops (i.e. periods of time characterized by low aerodynamic noise levels), it appears that mechanical noise (from gear or cooling system) can in these circumstances become predominant/emergent again. The main reason for this is the fact that aerodynamic noise scales with the (relative) wind speed impacting the rotating blades, whereas mechanical noise is relatively constant at all

operational conditions. Therefore, there should be a renewed interest in mechanical noise sources to further reduce the overall noise emissions.

As pointed out, another cause of uncertainty for noise predictions is the degradation of blade surfaces. This is a real concern for manufacturers and operators as degrading blade surfaces can result in increased noise emissions, well as the loss of energy yield.

On the modelling side, there are still some uncertainties of the impact of using a concentrated single point noise source at the hub position to represent the wind turbine noise emission, or if more advanced modelling strategies should be applied. This may become sensitive for the prediction of immission noise at shorter distances from the turbine, say below 1 km. The same goes for directivity. It is usual to assume a monopole directivity pattern when it is well known that wind turbines have a more complex directivity emission pattern.

Other topics related to wind turbine noise as a source are related to the early design phases with wind tunnel measurements. This links back to the initial topic of 2D airfoil noise. Noise measurements in wind tunnels are important for new technological developments, new concepts and design. However, it is also difficult to reach a high level of accuracy and to understand the mechanisms at play. Low-frequency trailing-edge noise peaks are often not captured in wind-tunnel measurements due to the resolution limits of focusing measurement technologies and low-frequency extraneous noise caused by the junctions between model and wind-tunnel walls or side-plates. It is stressed that measurements applying various technologies and predictions should be compared, but the analysis of their respective results should also be combined for a better understanding of the noise generation mechanisms, potentials for noise reduction and measurement artefacts. The problem is getting increasingly difficult, because modern airfoils (e.g. equipped with serrations) are getting closer to or below the threshold of wind tunnel noise detection (i.e. the background noise). In the case of insufficient signal-to-noise ratios the assessment of noise deltas becomes questionable even if focusing technologies are applied. This is a similar issue when measuring noise from a wind turbine in the field where the noise levels emitted by a wind turbine are often of the same order of the background noise.

Conclusions

To sum up, the main conclusions are that, even if much has been done to reduce wind turbine noise with some important successes and improvements, a lot remains to be understood and there is a need for further scientific advancements in the domain of wind turbine noise prediction at the source. There is still a lot of room for improvements in the prediction and reduction of wind turbine noise, although it has nowadays become a quite difficult endeavour after the important progress in this field during the last few decades.

FORUM P – Future Design of Low Noise Wind Turbines – Moderated by Michaela Herr.

Roger Drobietz and Kaj Dam Madsen on the Podium

Most work currently is on trailing edge noise because that is the dominant noise source. But there are other noise sources that need to be addressed such as mechanical/tonal noise because they become more predominant as trailing edge noise is reduced. Some had observed in the field that, as overall turbine noise got less, tonal noise became more significant. Manufacturers are certainly addressing tones.

Noise reduction has been made by: Shape of blade, passive trailing edge add-ons like serrations, and increasingly by vortex generators and control settings. Only a few years ago serrations were new, now they are commonplace, so progress is being made.

It is important to note that the developers and manufacturers view is not the same as the residents view. Any low noise technology will lead to a lower cost of energy not necessarily to lower noise levels for residents. This is not something that will happen in the future, developers have been doing it for years. There have been significant successes in cost reduction and part has been due to lower turbine noise level output.

As regards Amplitude Modulation (AM), it is a constraint in the community but not normally in the regulations. For permitting wind farms AM is not a constraint. If the developer can fix it cost neutral they will do but if there is a cost, it may not be dealt with because it is not part of the permitting process. Nevertheless, tonal noise is part of the regulatory framework and AM will be eventually so we need to keep tonality low and AM low. That's where some effort should go.

Research gaps?

- How to translate wind tunnel tests to the field?
- The trailing edge noise peak is often not detectable in wind tunnel tests due to low-frequency limitations of the measurements.
- Our understanding of noise emission with separating flow. This applies to simulation and wind tunnel testing.
- We have uncertainties predicting transition and stall in the rotational frame and under 'true' operational conditions of the turbine.

Uncertainties (UC)?

- Accuracy of predictions is an issue. Most design relies on 2D analysis and most industrially applied codes are on a semi-empirical basis. Fully 3D non-empirical methods are not available at a practical level.
- High quality validation is lacking. UC in field but also large in the lab.
- Background noise in the wind tunnel is comparable to that in the field. So have to rely on focussing technology. Also have difficulty going to low frequency. Need reliable far field data.
- UC of environmental parameters in which turbines operate.
- We need general decrease in UC.

A developer's comment was that they need more control over adaptive noise curtailment strategies and felt manufacturers don't make it easy for operators to change strategies themselves. Noise management and control has to improve. A few low noise modes may not be enough. Also is the life of a turbine going to be reduced by continual switching between modes?

Future Topics:

- Optimisation of existing technologies for add-ons and for control settings.
- Fast and reliable non-empirical simulation codes that can cope with arbitrary geometries (like serrations).
- There are many elements of research contributing to the whole picture. We need them all. We need all the good work to continue. Today we may need serrations but tomorrow we may need brushes.
- But focussing on current work should not stop people being creative – multi-rotor design; tonality free design?
- Might look into broader perspective in the future to include battery technology for example.

FORUM R – World Health Organization Environmental Noise Guidelines for the European Region (2018) – Moderated by Andy McKenzie.

Principal Speaker – David Michaud (Health Canada)

In October 2018, the World Health Organization (WHO) Regional Office for Europe released the Environmental Noise Guidelines for the European Region. The Guidelines include a conditional recommendation for wind turbine noise that is based on the annual average day evening night metric (Lden) to align with member state reporting requirements specified in the European Noise Directive (END). For the Lden recommendation, the WHO Guideline Development Group (GDG) considered the results of four original field studies published between 2004 and 2014; two from Sweden, one from the Netherlands and one from Japan. Inconsistent research on wind turbine noise was cited as the rationale for not providing an Lnight recommendation for the night time period as required by the END.

Notwithstanding the limitations discussed in the forum, the conditional recommendation of limiting wind turbine noise to a yearly Lden of no more than 45 dB is intended to restrict the prevalence of high wind turbine noise annoyance outdoors to no more than 10%. The Guidelines indicate that this marks the level, above which, there is an increased risk of adverse health effects.

In his presentation, David Michaud discussed how the conditional recommendation for a yearly Lden of 45 dB is slightly high (on average) when the location of annoyance is either indoors or unspecified in the questionnaire. Nevertheless, he showed that this value falls within uncertainty estimates observed when wind turbine noise annoyance data collected up to 2018 is considered (i.e. nine original field studies, six countries, 4751 data points). The GDG considered six studies that included a sleep component and their conclusion was that the studies were of low quality and too inconsistent to recommend an Lnight value, which would limit the prevalence of high self-reported sleep disturbance to the targeted value of 3%. Dr. Michaud noted that in the Health Canada Community Noise and Health Study, the prevalence of high self-reported sleep disturbance from wind turbine noise was observed to be just under 4% at an exposure level comparable to 45 dB Lden. Dr. Michaud emphasized that this should not however be misinterpreted to imply that 45 dB Lden provides sufficient protection against self-reported sleep disturbance, nor that there is sufficient evidence to recommend a specific night-time noise limit. The inconsistency across study designs on how sleep impacts are evaluated continues to preclude any strong conclusions in this regard.

He also noted that there was no robust scientific support to conclude from the data collected to date that there are adverse health effects associated with wind turbine noise exposure above 45 dB Lden, as stated by the GDG. The limit itself is based roughly on a dose response from four original field studies, but the strength of the recommendation is based on other parameters, that include, but are not limited to the quality of evidence, balance of benefits and harms, resource implications, the priority of the problem, and acceptability to stakeholders. Consideration for these parameters is one of the factors that distinguish the 2018 Guidelines from those published by the WHO in 1999.

A principal point of discussion amongst the forum attendees centred on the GDG's recommendation of a yearly Lden as the metric in itself irrespective of the wind turbine noise limit. There was a general consensus in the forum discussion that such a metric (considered alone) has several shortcomings.

- A yearly Lden does not account for the influence that ambient noise may have on the human response.

- Without historical SCADA data it does not readily lend itself to an acoustic audit. Where SCADA data is available, methods of mitigation where non-compliance is demonstrated, would be practically impossible to evaluate.
- A yearly Lden does not include the potential impact that tones and/or amplitude modulation may have on the human response.
- Lden assumes that an outdoor yearly average A-weighted metric is the best predictor of the human response to wind turbine noise, where the data accumulated to date would suggest that in the absence of several non-acoustic variables, it is a rather weak predictor of annoyance.
- Although an Lden metric places theoretical restrictions on night-time sound levels, the metric alone is not suitable for protecting against potential impacts on sleep.
- Although an Lden may be suitable for transportation noise, the general opinion expressed during the forum was that the metric (alone) is not ideal for setting wind turbine noise limits.

Other points raised in the forum were that:

- In making an impact assessment it is a mistake to focus only on noise. Non-acoustic factors are also important, especially for a source that is known to include several features that contribute to community annoyance.
- It may be difficult to compare the annoyance toward wind turbine noise to other sources of noise using an Lden where the source exposure patterns over the day are substantially different.
- Prediction of the proportion of people highly annoyed at any particular sound level can be made only with a high level of uncertainty.
- Lden has no intuitive appeal to residents and those who may be unfamiliar with acoustics. A yearly average metric is not easy to explain to residents. An analogy would be that people react to, and base their behaviour on, the temperature on any given day, where the average yearly temperature has no impact whatsoever on one's daily life. Regulators do not like Lden because of complexity of compliance testing and checking calculations.

There was concern that, because of the limited data base, the Guidelines have limited value to decision makers that are looking for ways to develop wind energy responsibly. Several key studies were published in the scientific literature prior to the October 2018 release of the Guidelines and a decade may pass before these publications are considered by the WHO in an updated Guideline. It is not known if the WHO considered delaying the publication of the Guidelines and/or withdrawing the chapter on wind turbines altogether. Either of these two options would have been preferable to the content published because Guidelines published by the WHO serve as a point of reference for international stakeholders and, in their current form, the reference material is incomplete, and potentially misleading.

There was also concern with the way in which the GDG reached their conclusions. There appears to have been limited consultation with parties that have practical experience in the area. Had there been an opportunity for consultation the shortcomings of Lden could have been pressed by people who were specialists in the field. It was also noted that, in spite of requests, nobody from the WHO GDG was willing to speak at the conference or join the Forum.

David Michaud suggested that there would be value in publishing a formal response to the WHO chapter on wind turbine noise. Such a response would identify the strengths and weaknesses of the current chapter with consideration for the accumulated science base in the area. Many of those at the conference are specialists in the subject and are welcome

to participate in such a response. Anyone who would like to do so, please contact Andy McKenzie (andy@hayesmckenzie.co.uk).

FORUM S – Where to Next – Moderated by Sabine von Hunerbein.

This was a final forum to look at where we are coming from as a conference series and where we need to go to.

The number of papers at each conference rose to a peak and has now fallen off. There were 45 in 2009, up to 69 in 2011, 90 in 2015 and back down to 73 in 2017 and to 50 this year. But 50 papers and over 150 delegates over the last few days is not a sign that interest in the conference is petering out. But some of the topics and evidence we've maybe seen before.

The representation of each topic measured by the number of papers has continually changed over the years and Sabine showed slides of how this had been distributed. There had been an experiment with shadow flicker in Rotterdam. This brought in the idea of non-acoustic factors and perhaps that could be investigated further, but would there be enough support?

Very little sound is ever played at these conferences which, on the one hand, is surprising as it is a conference on sound but on the other hand is not since the playing of meaningful sound that is out of context is difficult.

Format has changed over the years. In Denver the papers were 15 min and there were short breaks. Glasgow introduced parallel sessions. There is more time this year for discussion via the forums and breaks. Several people thought time for discussion was important.

There is a good mix of disciplines at the conference with consultancy, developers, manufacturers, people from research institutes and government departments.

What would you like to see in 2021? Where do we want to go? Are we getting the focus right? Right topics? Should we talk more about shadow flicker etc? Impact on people – In 2013 there were 13 papers on this subject, this year six.

Some thoughts from the floor:

- There are PhD students doing great work and reporting to conference but then they finish and go away and don't leave us with anything that we can use. How can we bridge the gap between research and everyday practice?
- Forums were very good as were moderators' introductory remarks. It would have been helpful if delegates had notice of the main points so they could formulate questions in advance.
- Workshops on specific topics with about 30 people would be good – for example measurement work.
- How we can improve site measurements accuracy. Forum might be useful but smaller workshop with people having more focussed interest would be good.
- Invite speakers for topics not directly related to what we do. For example psychoacoustics. Speakers with more general background in wind turbines.
- AM is very important. There was only one paper that looked at how to do something about it.
- Community engagement – maybe invite someone to talk about experience.
- State of the art mini lecture – on particular topics.

In summary, people liked the forums. The conference is strong at talking to other professional groups and exchanging ideas between disciplines. More neighbours of wind farms would be welcome. It's hard to take people's opinions into account if they don't come and talk to us.