Structure borne sound from a small wind turbine: characterisation by measurement in-situ

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Introduction

Building mounted wind turbines (BMWTs) could potentially provide a useful contribution to future energy needs [1] although there is concern to ensure that structure-borne sound and vibration does not cause disturbance to residents. In order to address this issue a method is required for predicting structure borne noise from BMWT installations. This is a challenging problem for which no standard measurement procedures are available. The closest applicable standard is EN12354-5 2009 but this requires data that is not currently available. Figure 1 shows two BMWT installations to illustrate one aspect of the problem, i.e. that the same design of turbine can be installed in different ways.

Figure 1: Two building-mounted micro-wind turbines. Left: wall mounted, right: flat roof mounted.

Source characterisation

In order to predict BMWT structure-borne noise a turbine must first be characterised as a source of vibration. Having done this it should then be feasible to predict how the source vibration propagates through the mount and into the building using a series of frequency response functions, by sub-structuring. For this to be possible an independent source characterisation is required.

Three quantities exist that can be used to independently characterise a vibration source: 1) the free velocity 2) the blocked force and 3) the characteristic power [2] (as required by EN12354). Unfortunately, using conventional approaches, from a practical point of view none of these quantities are easily measured for BMWTs. For this reason the in-situ measurement of blocked forces is of interest [3].

The in-situ blocked force method

The in-situ measurement of blocked forces [3] is similar in many respects to the measurement of contact forces by inverse force synthesis [4]. For both methods one is required to measure a set of frequency response functions (FRFs) and a corresponding set of operational responses. The required operational response measurements are identical for both methods. The only practical differences are therefore in the required FRF measurements. In this respect the in-situ blocked force may be regarded as favourable because, unlike inverse force synthesis, no decoupling of the test structure is required, i.e. all measurements are performed in-situ.

Lab validation: setup

To investigate the feasibility of in-situ blocked force measurements for BMWTs a laboratory validation has been carried out. Because the behaviour of a real wind turbine is difficult to control a vibration source with a more stable operation was used. A picture of the lab validation structure is shown in figure 2. The vibration source is an electric motor with accurate speed controller. This was fixed to a plate with a mounting stub copied from a real wind turbine design. It is believed that the coupling between the motor (source) and mounting pole (receiver) reflects well the degrees of freedom involved in a real BMWT installation. The vibration activity produced by the motor will clearly be different however.

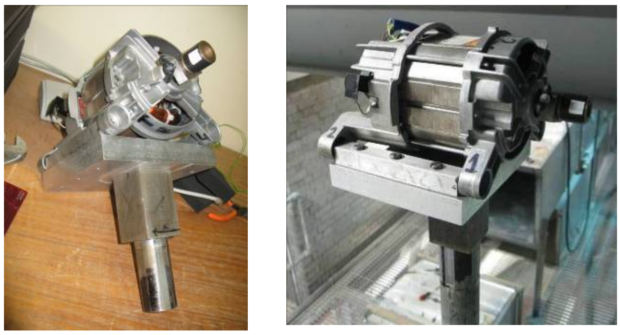

Figure 2: Electric motor used to represent a micro wind turbine for lab tests. Left: uncoupled, right: pole mounted.

A major advantage of blocked forces (making them preferable to contact forces) is that they are an independent property of the source. This means that blocked forces measured for the same source under different mounting conditions are theoretically equal. Blocked forces measured on one mount system could therefore be used to predict the operational response in a completely different system. The main aim of this laboratory investigation is to test this hypothesis. At a later date the blocked forces of several real BMWTs will be measured for a range of operating conditions. It is expected that the blocked forces obtained will be dependent upon rotational speed and/or power output. Variable wind conditions such as gusting and turbulence may also be factors. Long term monitoring will be required to capture a sufficient range of wind conditions.

It is essential therefore to have good confidence in the validity of the approach before long term monitoring begins.

Lab validation: results

In order to ensure that the blocked forces can be used to predict the behaviour of a source in different environments two installation configurations were tested. The difference between the configurations were the length of the mounting pole and the orientation of the source; the two configurations (C1 and C2) had very different resonant frequencies. Using configuration 1 the blocked forces of the source were measured at 5 points so as to include three orthogonal forces and two moments, i.e. 5 degrees of freedom. Having measured these blocked forces they were then used to predict the velocity at a remote point of the mount system again for C1. Shown in figure 3 is the predicted velocity compared with the directly measured velocity (which was not used in the determination of blocked force).

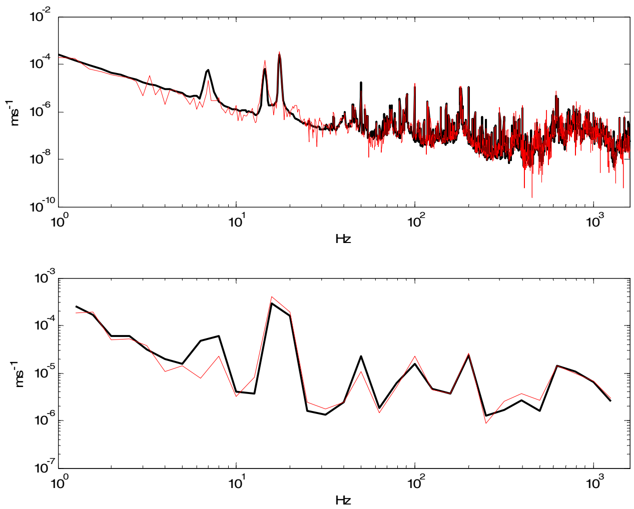

Figure 4: Blocked forces measured in configuration 1 used to predict the velocity at another point of configuration 1.

It can be seen that the velocity is predicted well particularly when we consider that good agreement is obtained over a wide frequency range (exceeding three decades). This serves as a validation of the data and indicates the quality of result that can potentially be achieved when using the blocked force method to carry out an in-situ TPA [3]. For this application however we are more concerned with obtaining a good prediction of the source's behaviour in a different environment, i.e. for C2. Thus, after measuring the blocked forces for C1 the setup was changed to C2.

In configuration C2 a velocity on the mount system was monitored and a prediction was made using the blocked forces from C1. This prediction, shown in figure 4, is of a slightly lower quality than that shown in figure 3. This aspect of the test is however considerably more challenging since the influence of the mount in C1 must be □removed□ from the characterisation to predict well the behaviour of C2. Moreover, the differences can be at least partly explained as a result of imperfect reproducibility of the motor operation. Overall, it can be seen that the method has proven successful over a frequency range exceeding 3 decades; this shows great promise for the in-situ blocked force method.

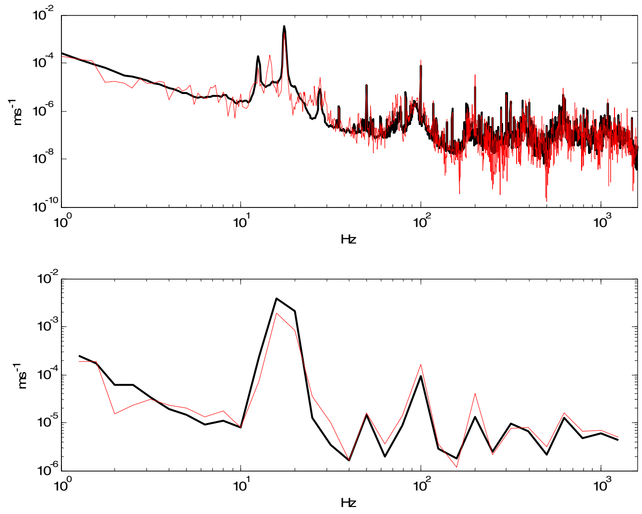

Figure 5: Blocked forces measured in configuration 1 used to predict the velocity at point on configuration 2.

Conclusions

It has been shown that the blocked force of a wind turbine type vibration source can be measured in-situ and that this blocked force can be used to predict well the response of a different system. Predictions of this type are known to be particularly difficult. This approach is to be used during a period of long term monitoring for real turbine installations. Based on the validation results shown it is believed that the method is well suited to characterising structure borne noise and vibration from small wind turbines.

Afterword

The in-situ blocked force method is also showing promise for the predition of structure borne sound from a vehicle steering system, M. Bauer [5] and other applications are soon to be investigated, Moorhouse [6].

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Literature

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