In-situ characterisation of structure borne noise from a building mounted wind turbine

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Abstract

Building mounted micro wind turbines (BMWTs) could potentially provide a useful contribution to renewable energy production but a means of predicting structure-borne sound and vibration is required. A particular difficulty is that BMWTs can only be operated when properly installed, therefore any source characterization measurements must be conducted in situ. Methods such as inverse force synthesis are possible but would only give a description of the source activity for a specific case. This paper describes the application of a new source characterization procedure whereby a source (BMWT) is characterized in terms of blocked forces measured in-situ. The main advantages of the approach are that (1) all required measurements can be performed in-situ and (2) the blocked forces obtained are an independent property of the source and can therefore be transferred to predict levels in different installations. Examples of measurements on idealized structures and on a mock-up wind turbine installation are given. The validity of the approach is confirmed by comparing measured and predicted velocity at different points on the same receiver structure and in a different receiver structure.

1 Introduction

Micro wind turbines attached to buildings have the potential to generate structure-borne sound and vibration which could potentially be disturbing to occupants. In order to assess the scale of the problem a method is required to characterize building mounted wind turbines (BMWTs) as sources of structure borne sound.

It might be thought that the simplest way to characterize a BMWT would be to measure the level of structure-borne sound in an affected room. However, the structure-borne sound measured would be dependent upon the room size and reverberation time, the building construction type (i.e. solid or cavity wall), the mounting system and the turbine itself. As a result, little can be inferred from such measurements regarding the BMWTs ability to produce structure borne sound in other installations.

Currently in the UK there are three manufacturers supplying BMWTs to the domestic market and each of these turbine manufacturers has at least two mounting options available. UK building stock is primarily solid and cavity brick construction but there are also many stone, wood and steel frame structures in existence as well as other bespoke buildings. It is therefore clear that there are many possible turbine, mount and building combinations and that this would make a survey of sound pressures in buildings impractical. This is especially true because BMWTs are an emerging technology with relatively few operational installations. A further difficulty is that wind conditions vary from day to day and from one site to another.

It is now widely agreed that the ‘activity’ of structure borne sound sources should be described independently by the free velocity or blocked force [1]. The blocked force is generally considered to be the more difficult of these quantities to measure and as such relatively few blocked force measurement approaches are to be found in literature. The free velocity on the other hand has been widely accepted as a useable approach and has even been standardized [2]. Unfortunately, it is impossible to measure the free velocity of a BMWT in operation since it requires the source to be resiliently mounted using a bespoke test rig.

However, there are particular difficulties in the case of BMWTs. First, in order to achieve realistic loading the BMWT must be installed in a representative way, i.e. mounted to a pole and exposed to real wind conditions. It must also be connected to an appropriate system which draws power from (and therefore loads) the turbine. In addition to this it must be allowed to rotate freely to face the wind as designed. To measure the free velocity requires the source to be mounted on resilient mounts which cannot be reconciled with the above requirements. Therefore, whilst the free velocity method could potentially provide trasnferrable data it cannot be applied in practice. This is opposite to the building survey method mentioned above which can be applied in practice but does not provide transferrable data. In this paper we investigate a method which is both practical and provides transferrable data.

For reasons discussed above it would be desirable to characterize structure borne sound sources using in-situ measurements, the main benefit being that representative source operation can be ensured. In-situ measurements are those which are performed whilst the vibration source is installed and allowed to operate properly under load. One such group of methods, known as Inverse force synthesis (or force identification), has become fairly well developed, in part, due to its use in the automotive industry for transfer path analysis (TPA) [3].

The purpose of this paper is to describe an alternative to the well known inverse force synthesis approach and its application to the problem of characterizing BMWTs as structure borne sound sources. This alternate method, known as the 'in situ blocked force approach', allows the blocked force of a vibration source to be measured in-situ but without the need to remove the source as is required for inverse force synthesis. The dual benefits are therefore that the required measurements are less time consuming and that the source is characterized independently.

2 Background

2.1 Inverse force synthesis and TPA

Inverse force synthesis is achieved by measuring the acceleration(s) caused by an operational vibration source and then, through knowledge of the structural dynamic properties of the receiver, working backwards to calculate the forces which caused them. Measuring these forces (which the source applies to a receiver structure) indirectly is often preferable to measuring them directly because it avoids modifying the source-receiver interface and is therefore non invasive. Partly for this reason the inverse force synthesis approach has become popular and it has been shown that it can be used to good effect. In this section we discuss the application of these techniques to the BMWT problem.

Shown in figure 1 is a representation of BMWT installation. The wind turbine is the vibration source, the mount system and building are considered as transmission paths and the dwelling is the problem area where annoyance may be caused. Other systems could be broken down in a similar way, for example one could consider a car wheel as a vibration source, the suspension as a transmission path and the cabin sound pressure to be the required target quantity. The illustration is useful in breaking down the components of a wind turbine installation and helps to identify key points and components. For example point **c** is the interface between the wind turbine (W) and the mounting system (M).

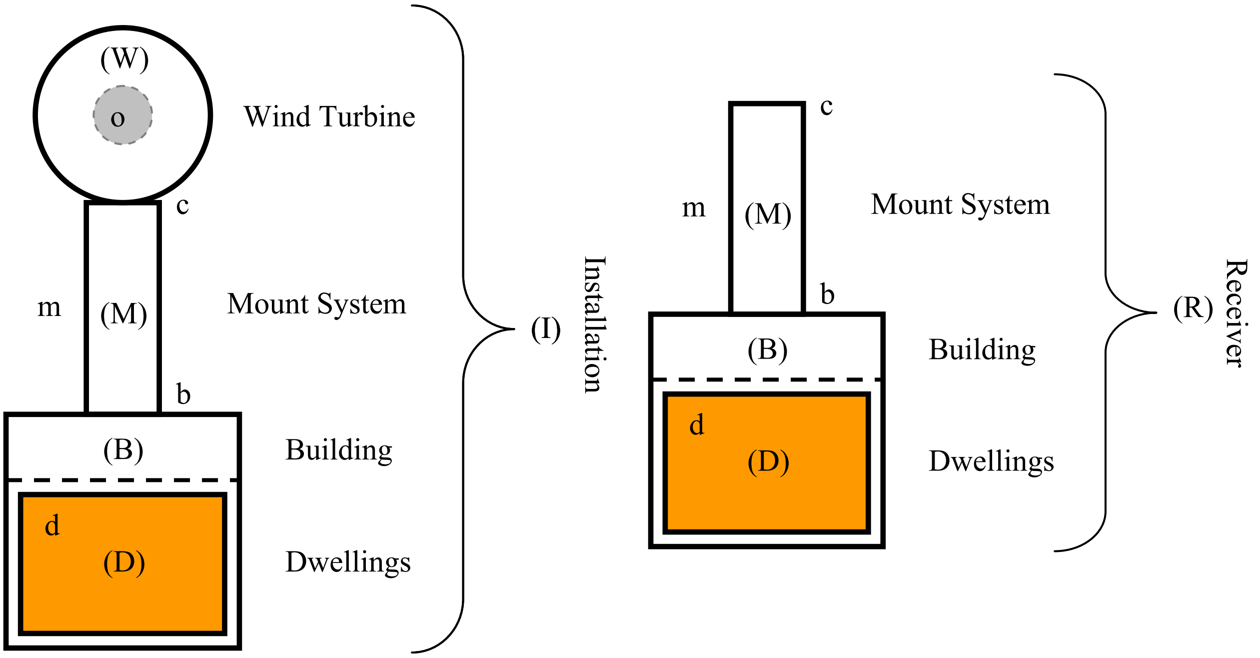

Figure 1: Left - representation of a BMWT installation and right - a building with attached mounting system, the receiver without the source.

Inverse force synthesis is the first step in determining the sound pressure at points **d** in the dwelling (D) when performing a transfer path analysis (TPA). The first measurement needed for inverse force synthesis, in our case, would require the removal of the turbine as shown in on the RHS of figure 1.

By exciting points **m** on the mounting system whilst simultaneously monitoring the accelerations at **c** it is possible to build a matrix of accelerances, each component in the matrix being an acceleration at **c** divided by a force applied at **m**.

The next step requires measurements on the installation (I), LHS of figure 1, this means refitting the wind turbine having previously removed it. The wind turbine would then be allowed to operate whilst accelerations were measured at the same points as were excited in the previous test, e.g. the points **m** on the mounting system. The forces at **c**, applied by the wind turbine to the mounting system, could then be found by solving the inverse problem,

$$\mathbf{a}_{\mathbf{Im}} = \mathbf{A}_{\mathbf{Rcm}}{}^{\mathbf{T}}\mathbf{f}_{\mathbf{Ic}} \tag{1}$$

where $\mathbf{a}_{\mathbf{Im}}$ is a vector of accelerations on the mount, $\mathbf{A}_{\mathbf{Icm}}{}^{\mathbf{T}}$ is a transposed matrix of accelerances measured by exciting points **m** on the mount whilst measuring the responses at the interface **c**. The result, a vector of operational forces $\mathbf{f}_{\mathbf{Ic}}$ then describes the operational forces applied to the mount system at **c**. A similar procedure could be used to determine the forces at **b** where the mount system couples to the building. This is inverse force synthesis.

Having determined the forces at the interface **c** it should then be possible to relate these forces to the target quantity, the sound pressures in the dwelling at points **d**. This requires a further step with the turbine removed which could be carried out during the measurements of $\mathbf{A}_{\mathbf{Rcm}}{}^{\mathbf{T}}$. To measure the relationship between the forces $\mathbf{f}_{\mathbf{Ic}}$ and sound pressures in the dwelling $\mathbf{p}_{\mathbf{Id}}$ two approaches can be used. The direct approach would be to excite points **c** at the interface with a force whilst measuring sound pressures at points **d**. The reciprocal approach is to acoustically excite points **d** using a monopole source with a known volume velocity whilst measuring the accelerations at the interface **c**. In either case one obtains a matrix of vibro-acoustic frequency response functions **H** relating the contact forces to the sound pressure in the room, by

$$\mathbf{p}_{\mathbf{Id}} = \mathbf{H}_{\mathbf{Rmd}}\mathbf{f}_{\mathbf{Ic}} \tag{2}$$

Thus the sound pressure in the room at points **d** can be determined from the operational forces computed from operational acceleration measurements using equation (1) and the vibro-acoustic frequency response function $\mathbf{H}_{\mathbf{Rmd}}$. For all measurements except the operational acceleration measurements the turbine should be removed for the tests. Beside the slight inconvenience of having to remove the vibration source for some of the measurements there is also another drawback which is of particular significance to wind turbine characterization.

The main problem with inverse force synthesis is that the quantity obtained, $\mathbf{f}_{\mathbf{Ic}}$, can be heavily influenced by the mounting system. This is a problem because not always will the same mount system be used for a given turbine. For example, just changing the length of a BMWT mounting pole will change the resonant frequencies of the system meaning the wind turbine would experience a whole new set of reaction forces during operation. It is feasible that even very slight changes to the mount system could lead to dramatically different forces at the interface.

In order to avoid this issue one can use an independent source characterization quantity such as the free velocity or blocked force. We have already discounted the free velocity approach as being impractical. However, we will now investigate an inverse, in situ approach for measurement of blocked forces which has some similarities with inverse force synthesis.

2.2 In-situ blocked force approach and in-situ TPA

Compared to the measurement of contact forces or free velocities there are relatively few studies describing the characterization of structure borne sound sources by blocked forces. One reason for this is the practical difficulty in trying to fully block the motion of a vibration source whilst measuring accurately the reaction force. A recent paper describes such a measurement for an automotive suspension system and although relatively successful a complicated test rig was required [4]. Such a measurement would not be possible for a BMWT however if it were to operate properly in real wind conditions. A less conventional approach has however been described and validated in [5,6] for beam like structures and in [7] for a vehicle steering system. Unlike the inverse force synthesis approach all measurements are performed in-situ. This allows one to measure the blocked forces in-situ using an existing installation. Its suitability for characterization of BMWTs will be discussed in the following.

Using the above example of a BMWT installation shown in figure 1, the blocked force of the wind turbine can be found as follows,

1. with the turbine installed measure accelerations at **c** due to force excitations at **m** and build an in-situ measured accelerance matrix $\mathbf{A}_{\mathbf{Icm}}^{\mathbf{T}}$
2. measure the operational accelerations at points **m** while the wind turbine operates $\mathbf{a}_{\mathbf{Im}}$

The blocked force of the wind turbine $\mathbf{f}_{\mathbf{Wc(bl)}}$ can then be found by solving,

$$\mathbf{a}_{\mathbf{Im}} = \mathbf{A}_{\mathbf{Icm}}^{\mathbf{T}}\mathbf{f}_{\mathbf{Wc(bl)}} \tag{3}$$

where the subscript **(bl)** indicates that this is the blocked force of the wind turbine **W** at the interface **c**.

In a further useful step this blocked force can also be used to perform a transfer path analysis, again without removing the vibration source. Using blocked forces instead of contact forces to predict the sound pressures in the room at points **d**, equation (2) becomes,

$$\mathbf{p}_{\mathbf{Id}} = \mathbf{H}_{\mathbf{Imd}}\mathbf{f}_{\mathbf{Wc(bl)}} \tag{4}$$

The difference from Eq (2) is that $\mathbf{H}_{\mathbf{Imd}}$ is a set of vibro-acoustic FRFs measured whilst the turbine is installed.

In summary the in-situ blocked force approach is potentially favorable to inverse force synthesis because it allows a source to be characterized independently and entirely in-situ saving measurement time and effort. Furthermore, based on equations (3) and (4) it should also be possible to perform an "in-situ TPA" where the source characterization data remains valid regardless of the installation. This is particularly important to a BMWT installation where the receiver structure varies or may be completely unknown.

3 Preliminary tests on idealized structures

Based on the above discussions it is clear that there may be significant benefits in characterizing vibration sources in terms of blocked forces rather than contact forces. At the current time however there are only a few cases available to illustrate the actual benefits [5-8]. The purpose of this section is therefore to demonstrate that the aforementioned benefits are valid and in particular to show that the blocked force is an independent property of the source which can be used to predict source behavior in a different extreme situation.

The first example below is the result of a simple course of study using laboratory structures. The purpose of the experiment was to illustrate that the blocked force is an independent property of the source not influenced by the connected receiver structure. Whilst the structures are idealized the experiment is relevant to the current problem because, ultimately, a wind turbine is a vibration source attached to a beam which has multiple contacts to a receiver structure.

More detailed information can be found in [5,6] but it should suffice to say that the vibration source was a beam with two steel feet that could be coupled rigidly to two different receiver beams. Both receiver beams were cut from the same bar and therefore had the same material properties, the only difference with regards to the experiment being their length. What can be seen is that the contact forces measured by inverse means for the two receivers differ significantly and that the blocked forces measured in-situ under the same conditions were invariant.

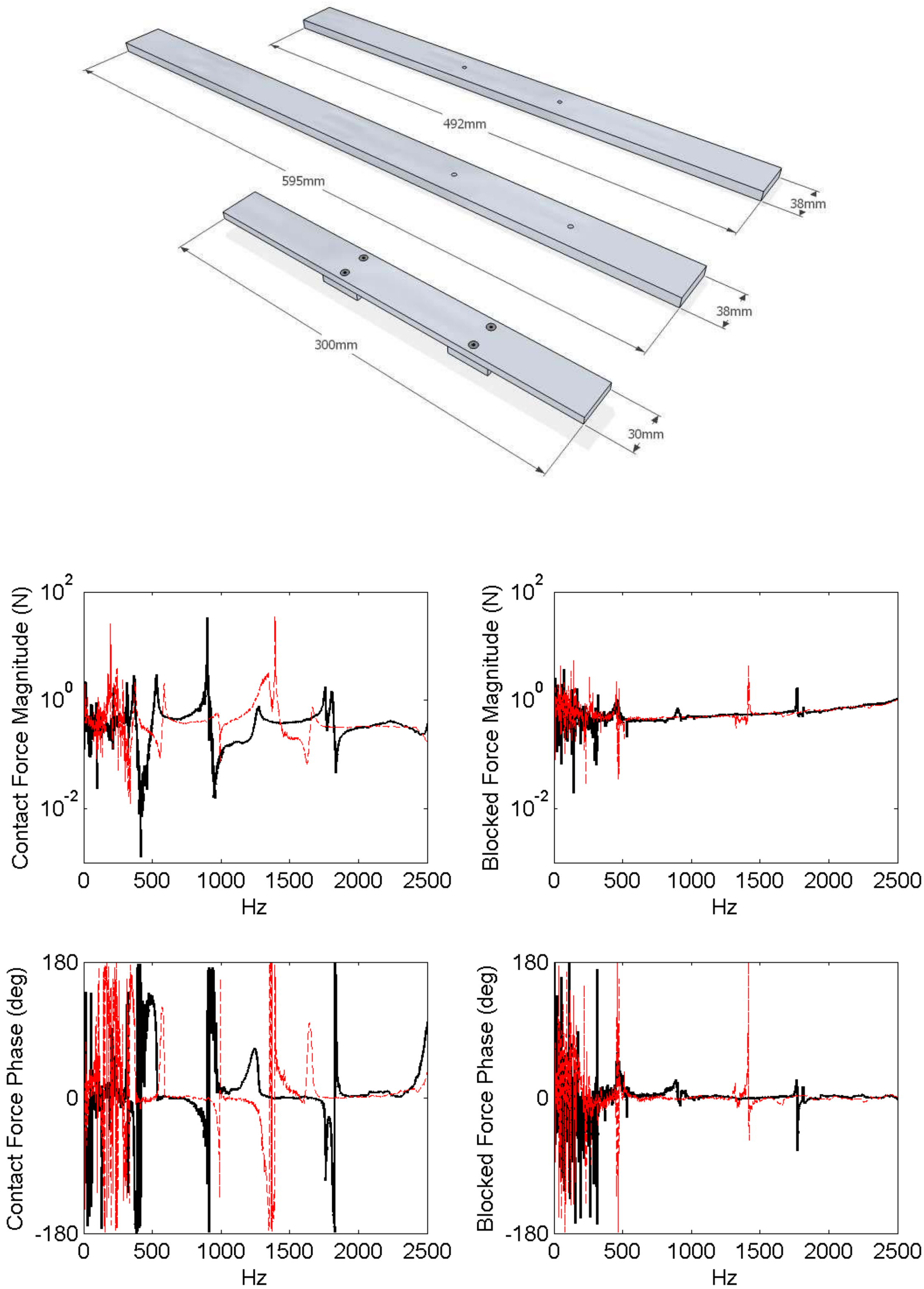

Figure 2: Upper diagram shows the source structure (left) and the two receiver beams beside. The plots below show, Left – measured contact force and force phase between the source beam and to two receiver beams shown above, right – blocked force and blocked force phase for the same situation. Black line is receiver one and red line receiver two.

The same data as displayed in figure (2) was also used to test the validity of the measured blocked forces in relation to conventional theory. It is well known that,

$$v_{sf} = Y_s f_{bl} \tag{5}$$

i.e. a vibration source's free velocity v_{sf} is equal to its mobility Y_s multiplied by its blocked force f_{bl} . Using the previous notation, equation (5) can also be written in terms of accelerance,

$$v_{sf} = \frac{A_s}{j\omega} f_{bl} \tag{6}$$

Where $j=\sqrt{-1}$ and ω is radian frequency. The important point is that, in theory, the free velocity is related to the blocked force by a sources' mobility or accelerance. Thus, as a further test of the in-situ measured blocked force it is possible to validate further by comparing a measured free velocity to one which is predicted.

Figure (3) compares the directly measured free velocity to that predicted from blocked forces (Eq. 5 or 6) The result is significant because the blocked forces used to make this prediction were measured in-situ, i.e. whilst the source was coupled to another object. Thus, measurements performed for an installed condition can be used to determine the source's behavior in a blocked condition (figure 2) and from this a free condition (figure 3).

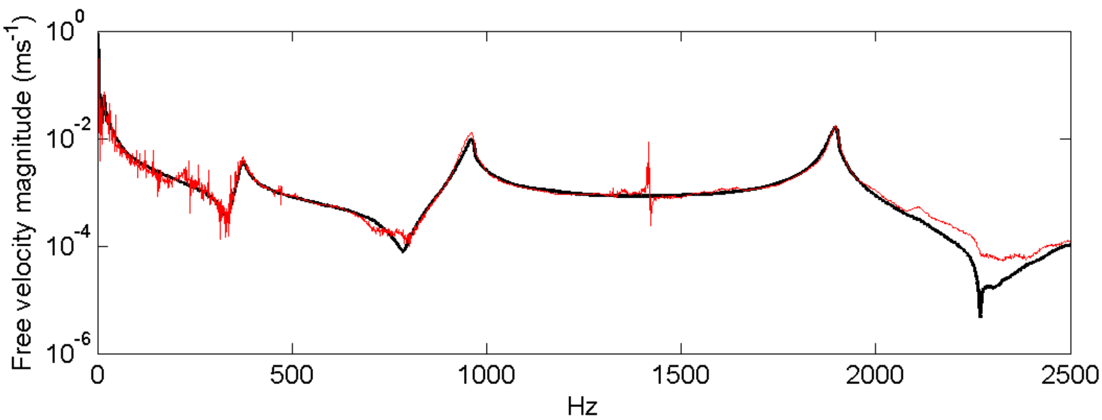

Figure 3: prediction of free velocity from in-situ measured blocked force, black line is directly measured free velocity and the red line is predicted.

It is also shown in [5,6] that this same in-situ measured blocked force data could be used to predict the behavior of the source whilst installed to different receivers. Interestingly, it was necessary to include forces and moments in the calculations in order to obtain the agreement shown in figures 2 and 3; without these degrees of freedom the blocked force obtained was not the same for both receivers and the predicted free velocity was significantly in error.

4 Application to wind turbines

At the current time it is not possible to publish real wind turbine data.. The measurement of blocked forces for a wind turbine type source can however be clearly illustrated using preliminary measurements that were carried out in the lab prior to testing the real thing. The measurements were made to validate the approach and to ensure that all the appropriate degrees of freedom were being accounted for.

A wind turbine and mounting are usually coupled by inserting the pivot shaft at the bottom of the turbine into the open end at the top of the mounting pole. To prevent vibration caused by a non perfect fitting the pivot shaft is then held in place by two or more grub screws, this prevents the turbine rattling in the top of the pole. It is not known in advance which degrees of freedom will be of importance at the interface between the pole and mount in terms of vibration transmission or structural coupling. In order to investigate this problem a laboratory test was set up which comprised an electric motor attached to a cylindrical shaft to represent the turbine and a wall mounted scaffold pole to represent the mounting.

Figure 4 gives an illustration of the type of connection between wind turbine and mounting system. Also included are the axes used to describe orientation in the paper. The z direction is always parallel with the pole so that the x and y axes are perpendicular. Figure 4 also shows a photograph of the experimental setup, it can be seen that a steel scaffold pole was connected to the wall of the laboratory reverberation chamber by TV aerial brackets. Into the top of the pole the electric motor, described above, was mounted.

To begin with it was assumed that up to 5 degrees of freedom may have to be included to describe the interface between turbine and mount, these were the orthogonal x, y and z directions as well as rotations about the x and y axes. Rotations around the vertical z direction were not considered as the pivot shaft at the bottom of a turbine is coupled to the turbine through a bearing which should prevent coupling in this degree of freedom.

Figure 4: Left – illustration of the interface between turbine pivot shaft and mounting pole with axes for orientation. Right – a photograph of the laboratory test used to validate the method.

To gain as much insight as possible from the test two different source activities were used. First the motor was artificially excited with a hammer and secondly it was run normally so as to provide a more realistic and challenging test. The first result, shown in figure 5, is for the motor under artificial excitation. The purpose of this test was to show clearly the effect of neglecting degrees of freedom in the blocked force characterization. Unfortunately it is not possible to measure blocked forces directly to validate the in-situ measured blocked forces so the only way to easily check the quality of the characterization is by using the blocked forces to predict a response velocity, acceleration or sound pressure.

Thus, the blocked forces of the motor were found by solving equation (3) and they were then checked by using,

$$\mathbf{v}'_{\mathbf{Im}} = \mathbf{Y}_{\mathbf{Imc}}\mathbf{f}_{\mathbf{Wc(bl)}} \tag{5}$$

where $\mathbf{v}'_{\mathbf{Im}}$ is the velocity at a point on the mounting system, $\mathbf{Y}_{\mathbf{Imc}}$ is a set of transfer mobilities relating the blocked forces $\mathbf{f}_{\mathbf{Wc(bl)}}$ of the wind turbine to $\mathbf{v}'_{\mathbf{Im}}$. Shown in figure 5 is the directly measured velocity $\mathbf{v}'_{\mathbf{Im}}$ and a velocity predicted using blocked forces from equation (3). In this instance an artificial broadband excitation of the source was used for the source activity.

The experimental procedure was to measure $\mathbf{A}_{\mathbf{Icm}}$ relating several points on the mount to 5 degrees of freedom at the interface **c**. Accelerometers were then mounted at points **m** on the mount to monitor the operational accelerations on the mount $\mathbf{a}_{\mathbf{Im}}$. To obtain a good clean result more operational response points were used than there were degrees of freedom at the interface, in fact 25 points were used to determine 5 generalized blocked forces corresponding to translations in the x, y and z axes and blocked moments about the x and y axes. As mentioned above, rather than run the motor for this first test an artificial excitation was applied using an instrumented hammer, this measured force was then used to normalize the measured accelerations. This is equivalent to exciting the motor with one Newton at one point. The benefit of this approach is that clean data is obtained which can be more easily interpreted than results from operational measurements.

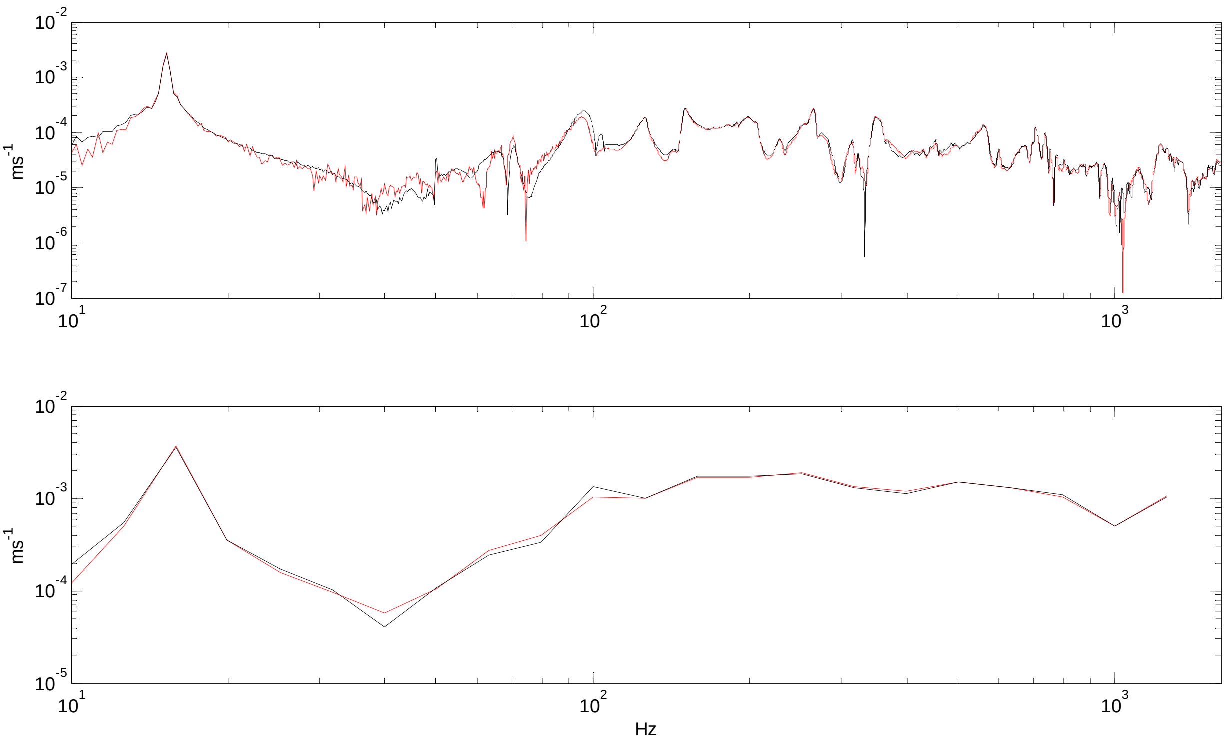

Figure 5: Prediction of operational velocity from blocked forces in 5DOF. Top – 1/4Hz narrow band plot of directly measured (black) and predicted velocity (red). Bottom – Third octave band plot of the same.

Figure 5 shows that for this ideal experiment taking into account 5 degrees of freedom (3 translation and two rotation) at the interface allows for an excellent prediction of the reference velocity $\mathbf{v'_{Im}}$. The noise in the prediction below 100Hz is a result of using a hard hammer tip to perform the measurements. This could be improved by using a softer tip but this would likely also degrade the prediction at higher frequencies (when making such measurements it is generally necessary to make some such compromise). Since the purpose of this test is only to identify the important degrees of freedom no attempt was made to optimize the measurements for a specific frequency range.

After obtaining this result it was then possible to try to simplify the problem by removing degrees of freedom from the measured FRF matrices and the operational data vectors. Removing one degree of freedom at a time the impact of such simplifications was investigated. Figure (6) shows the same predicted velocity but neglecting blocked moments at the interface. If moments are of importance one would expect to see a poorer prediction of the reference velocity and this is shown to be the case.

Although the reference velocity prediction shown in figure (6) is fairly good, in comparison to figure (5) the prediction is still considerably worse. If we pay particular attention to the frequency range to which the measurements were best suited (100-1600Hz) it is particularly clear that excluding moments would result in reduced accuracy of the representation. In fact it was found that for the best results all 5 degrees of freedom initially accounted for should be included.

Shown in figure (7) is the accelerometer arrangement used for subsequent tests which is based on the above discussion.

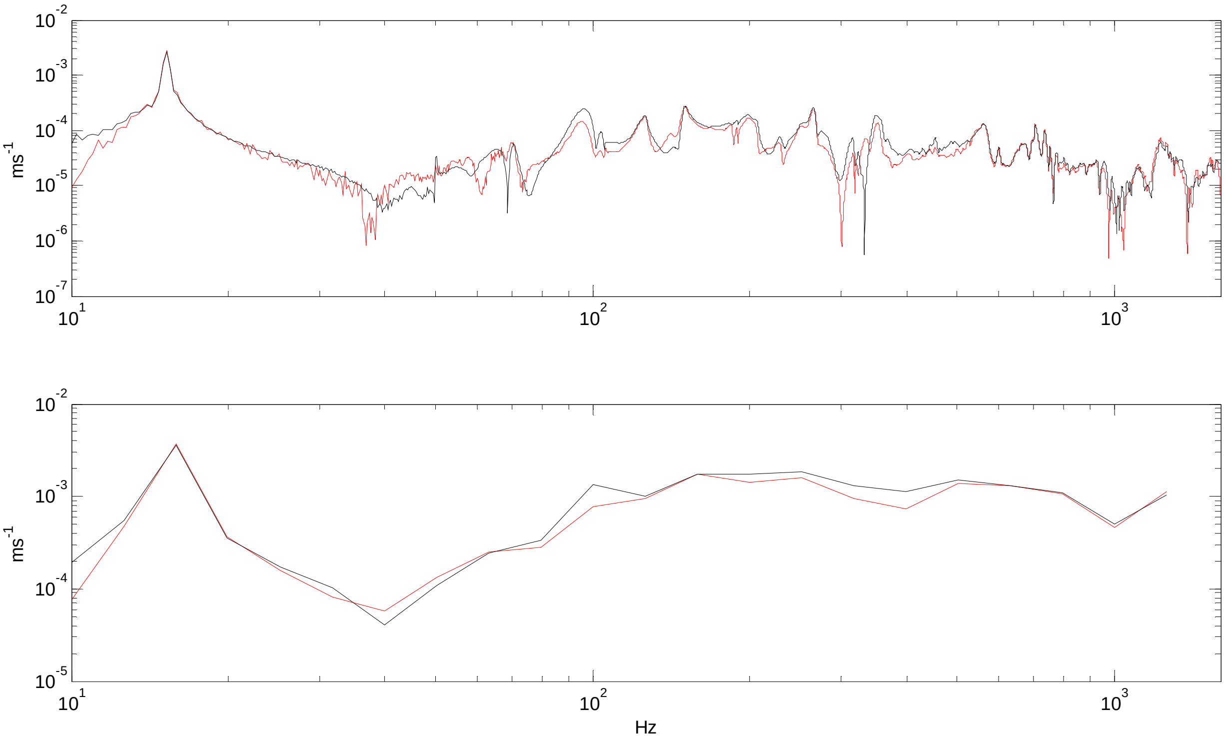

Figure 6: Prediction of operational velocity from blocked forces in 3DOF. Top – 1/4Hz narrow band plot of directly measured (black) and predicted velocity (red). Bottom – Third octave band plot of the same

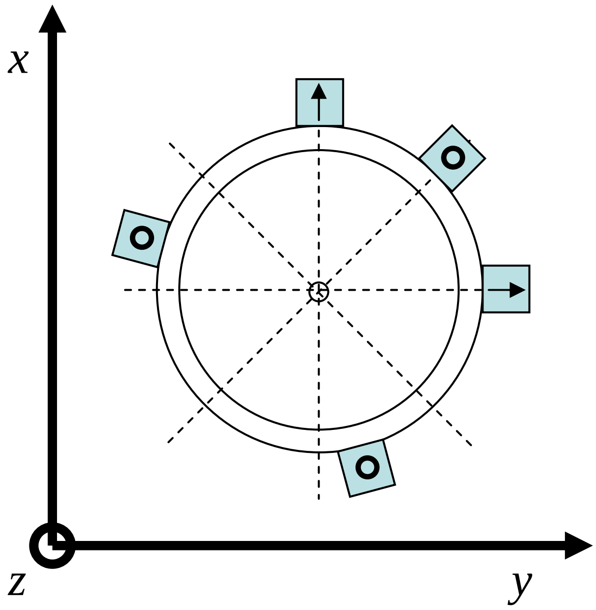

Figure 7: Optimum arrangement of accelerometers around the interface **c** during the measurement of $\mathbf{A}_{\mathbf{Icm}}$. Three accelerometers are mounted oriented in the vertical z-dir at 120 intervals to take into account motions in the z-dir and rotations about x and y. A single accelerometer each for the x and y directions proved sufficient.

It could be argued that the artificial excitation used to generate the excellent velocity prediction shown in figure (5) flatters the method somewhat because it avoids the complexities of real vibration source operation. It was therefore necessary to test the method using a more realistic case. The motor source representing the wind turbine was therefore fitted with a rotational speed controller device so it could be operated at a steady speed. A slight imbalance was also added to the motor's output shaft to produce a reasonable vibration level from the otherwise unloaded motor. The measurements were then repeated for the new setup.

In practice, monitoring 25 accelerations (as in the previous example) on a real wind turbine installation over a long period of time would be impractical. For this reason the number of remote monitoring positions was reduced to 10 which should be more manageable and therefore realistic. Thus, $\mathbf{A}_{\mathbf{Icm}}$ was measured by exciting 10 positions on the mount system whilst the accelerometers were mounted at the interface as shown in figure (7). Then with the motor operational (running at 1000rpm) the acceleration $\mathbf{a}_{\mathbf{Im}}$ was monitored at the points previously excited. Equation (3) was then used to calculate the blocked force vector for the motor. Whilst measuring $\mathbf{A}_{\mathbf{Icm}}$ an additional point was also excited to determine the mobility $\mathbf{Y}_{\mathbf{Imc}}$ to be used as an input to equation (5) for a reference velocity $\mathbf{v'}_{\mathbf{Im}}$ prediction and validation. Shown in figure 8 is the prediction of this reference velocity.

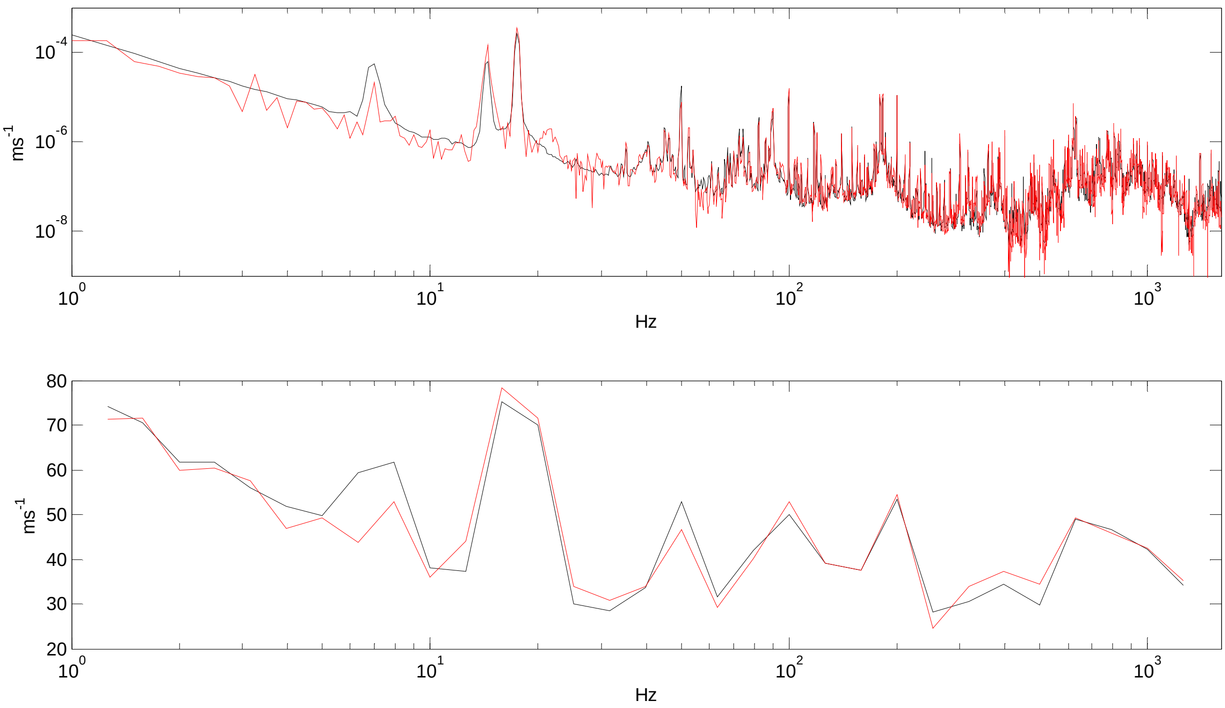

Figure 8: Prediction of operational velocity from blocked forces measured while the motor was running at 1000rpm. Top – 1/4Hz narrow band plot of directly measured (black) and predicted velocity (red). Bottom – Third octave band plot of the same

Although not quite as good as the reference velocity prediction shown in figure (5) the result shown in figure (8) is still respectable. To some extent the discrepancies below 100Hz can again be attributed to the hammer tip used during FRF measurements. Also with the added complexity of a tonal excitation which was not perfectly stable it could be argued that such differences between measurement and prediction are to be expected especially at frequencies not excited by the vibration sources operation. In view of this it appears sensible that between 100 and 1600Hz where the measurements were most accurate the two major peaks are predicted with little error. This result gives an indication of the quality of the result likely to be obtainable when performing an in-situ TPA.

As described earlier, a major advantage of blocked forces over contact forces is that they can be used to make predictions like the above for different installations to the one in which the source characterization is performed. This is important for vibration sources such as wind turbines where the properties of the mounting system may vary from one installation to another.

Having already measured the blocked forces of the motor, as described above, it was then a simple method to test whether this is actually the case. This was done by first changing the length of free mounting pole above the top mounting bracket and changing the orientation of the motor by rotating the pole. In order to provide a challenging test a dramatic change in free pole length of approximately 60% was used. After changing the configuration of the installation the mobility $\mathbf{Y}_{\mathbf{Imc}}$ was re-measured to facilitate a prediction of the new reference velocity $\mathbf{v'}_{\mathbf{Im}}$ using equation (5) and the blocked forces measured in the earlier configuration. Shown in figure (9) is the reference velocity prediction obtained from this approach

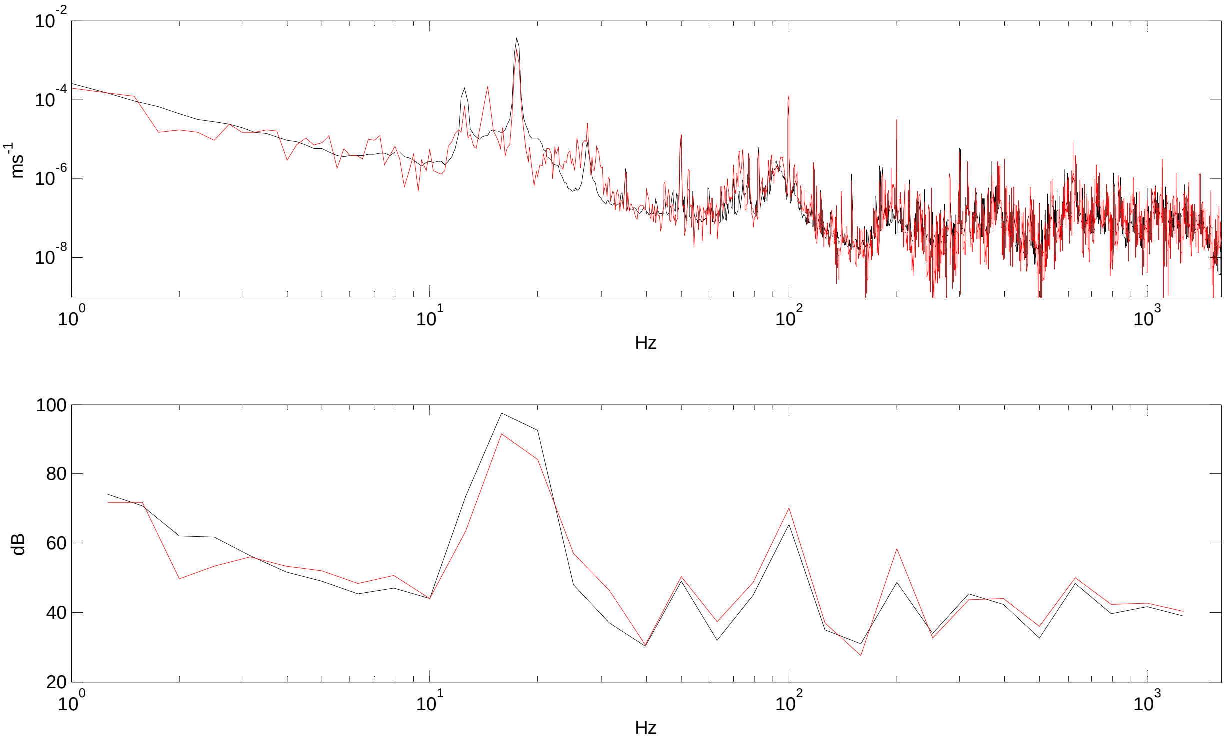

Figure 9: Prediction of operational velocity from blocked forces transferred to a different installation. Top – 1/4Hz narrow band plot of directly measured (black) and predicted velocity (red). Bottom – Third octave band plot of the same

Referring to figure (9) it can be seen that the blocked forces measured in one configuration can be used to predict reasonably well a response in a completely different configuration. If contact forces had been used to characterize the motor such a prediction would not have been possible. Although the velocity prediction shown in figure (9) is considerably poorer than that shown in figure (8) the result may still be considered a success given that the blocked forces were obtained on a receiver with a strongly resonant response and that the prediction was achieved on a receiver with resonances at completely different frequencies.

At the current time it is common to consider a vibration source as a “black box” so it is assumed that the source operates in the same way regardless of how it is constrained. In reality this is probably not completely the case. Further investigation would be required to investigate this point but it seems likely that when such a drastic change is made to an installation the forces occurring inside the differently constrained vibration source could be changed significantly and that this in turn could alter source behavior internally. In fact this provides a further argument for performing source characterization measurements in-situ using a representative installation.

5 Conclusions

It has been shown that blocked forces can be measured in-situ even for complicated vibration sources such as wind turbines. It was also shown that blocked forces are an independent property of the source even when measured in-situ; the same cannot be said for contact forces which were shown to vary significantly from one installation to another. It was therefore concluded that blocked forces are a more appropriate source characterization quantity for vibration sources such as wind turbines which can be attached to one or more different receiver structures. Using a mock up wind turbine installation in the laboratory it was found that the interface between turbine and mounting system should be characterized taking into account 5 degrees of freedom to achieve the best results. Finally it was shown that, even for a source whose operation is not perfectly repeatable, the in-situ measured blocked forces can be used to predict the vibration response in different installations. The purpose of these preliminary investigations was to investigate how best to measure blocked forces for real wind turbines exposed to real wind conditions in the field. Measurements on real wind turbine installation are currently underway and it is hoped to be able to present some of these at the conference.

Acknowledgements

The contribution from the EPSRC to this work is gratefully acknowledged. Grant ref EPSRC EP/G066582/1

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