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Ordinarie medlem	550 SEK
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Gott nytt år på er alla

Nu har vibrationdagen avverkats i Oslo. En liten touch av offshore kunde ses. Jag vill passa på att tacka Reinhertsens för arrangemangen och styrelsen under ledning av Anders Olsen. Jag själv arbetade i verkligheten. Det blev en ny styrelse vald och den enda förändringen blev att Ylva Vidhög lämnade styrelsen och ersattes av Juha Plunt. Styrelsen har just avverkat sitt första möte. Juha blev ansvarig för SVIBnytt och Örjan tar hand om vår åsidosatta hemsida. Jag hoppas att vi nu kan bli lite effektivare i vårt arbete.
Det mest intressanta från årsmötet är kanske att vi har fått tillbaka några norrmän i verksamheten vilket öppnar för nya och förhoppningsvis trevliga evenemang i Norge. Nästa vibrationsdag kommer att äga rum 13-14 november 2012 i Göteborg.

För att kunna belysa de olika områden som vibrationsvetenskapen har vi idag ett antal arbetsutskott. Vi har dock konstaterat att detta arbetssätt är föråldrat. Vi har diskuterat att förnya verksamheten genom att göra dessa arbetsgrupper mer projektorienterade. Detta hoppas vi kan leda till fler intressanta symposier i framtiden och att fler kommer att kunna engagera sig under en kortare period, för ett enskilt symposium t.ex.

För övrigt har styrelsen beslutat när styrelsemötena skall äga rum. Kontakta någon av oss om du är intresserad av att deltaga eller att du vill att vi diskuterar något speciellt.

1/2-2012 i Stockholm hos Acoutronic. 10-16
21/3-2012- I Göteborg, hos Müller BBM
1/6-2012: Telefonmøde: 10:00
15/8-2012: I Linköping hos Qring Techology
24/10-2012: I Helsingør hos Vibratec

13-14/11 Årsmöte i Göteborg

Ordförande Elisabet Blom

Controlled Monte Carlo Simulation of Failure Probabilities in Wind Turbines

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ABSTRACT: Development of Variance Reduction Monte Carlo (VRMC) methods has proposed the possibility of estimation of rare events in structural dynamics. Efficiency of these methods in reducing variance of the failure estimations is a key parameter which allows efficient risk analysis, reliability assessment and rare event simulation of structural systems. Different methods have been proposed within the last ten years with the aim of estimating low failure probabilities especially for high dimensional problems. In this paper applicability of four of these methods i.e. Importance Sampling (IS), Distance Controlled Monte Carlo (DCMC), Asymptotic Sampling (AS) and Subset Simulation (SS) are compared to each other on a common problem. The aim of the study is to determine the most appropriate method for application on realistic systems, e.g. a wind turbine, which incorporate high dimensions and highly nonlinear structures.

1 INTRODUCTION

Assessment of reliability and design of highly nonlinear and high dimensional structures such as wind turbines require estimation of very low failure probabilities of the system. This task can be tackled from three different points of view. The first class of methods are the extreme value distribution fittings to the extracted data of a wind turbine (Caires & Sterl 2005, Mackay, Challenor, & Baha 2010). These data might be taken either from measured responses of a real wind turbine or from epoches of the response simulated by computer. This can be done in combination with some sampling methods such as the epochal method or the Peaks Over Threshold method (POT). It is implicitly assumed that the parent distribution belongs to the domain of attraction of one of the extreme value distributions; therefore the excess values above a given threshold follow a Generalized Pareto (GP) distribution (Naess & Clausen 2001). The required failure probability will be extrapolated from the fitted distribution.

On the other hand the so-called Variance Reduction Monte Carlo simulations (VRMC) might be used for estimating the failure probabilities (Sichani, Nielsen, & Bucher 2011a). The applicability and efficiency of the VRMC methods on wind turbines is the subject of this study in order to understand advantages and limitations of VRMC methods within the framework of wind turbines. The VRMC methods enable efficient estimation of the first excursion of the wind turbines within reasonable computation charge. However, they do not provide any means of understanding the evolution of the PDF of the process within time. This is of great interest since it gives a good insight into the statistical characteristics of the system and effect of different components, i.e. controller, on it.

Another approach for estimation of the first excursion probability of any system is based on calculating the evolution of the Probability Density Function (PDF) of the process and integrating it on the specified domain. Clearly this provides the most accurate result among the three class of the methods. The Fokker-Planck-Kolmogorov (FPK) equation is a well-known tool for realizing the evolution of a stochastic process governed by a differential equation. Although solution of the FPK for even low order structural dynamic problems require excessive numerical computations. This confines the applicability of the FPK to a very narrow range of problems. On the other hand the recently introduced Generalized Density Evolution Method (GDEM), (Li & Chen 2009, Chen & Li 2009), has opened a new way toward realization of the evolution of the PDF of a stochastic process. It is an alternative to the FPK. The considerable advantage of the introduced method over FPK is that its solution does not require high computational cost which extends its range of applicability to high order structural dynamic problems.

2 ESTIMATION OF LOW FAILURE PROBABILITIES

Estimation of failure probabilities of a wind turbine model is not a trivial task since it incorporates a highly nonlinear model for which the failure probability is to be estimated within a long time duration e.g. 600s. However on the structure part, the wind turbine consists of a simple linear model, nonlinearities in such models appear from loading. These stem from two origins namely the nonlinear aerodynamic loads and the presence of a controller. The aerodynamic loads are highly nonlinear functions of the instantaneous wind speed and the pitch angles of the blades which are calculated with different means e.g. Blade Element Momentum theory (BEM) in this study. The pitch-controller introduces additional nonlinearities to the model i.e. due to its saturation state. Next according to the design criterions the barrier level of a specified failure probability, e.g. 3.8×10^{-7}, is required to be defined. This can most efficiently be estimated if the Cumulative Density Function (CDF) of the failure probability can be derived down to low failure probabilities of the order 10^{-7}.

The focus of this paper is on the VRMC methods. Among the various available methods Importance Sampling (IS) (Bucher 2000, Au & Beck 2001, Macke & Bucher 2003) , Distance Controlled Monte Carlo (DCMC) (Pradlwarter, Schuëller, & Melnik-Melnikov 1994, Pradlwarter & Schuëller 1997, Pradlwarter & Schuëller 1999), Asymptotic Sampling (AS) (Bucher 2009, Sichani, Nielsen, & Bucher 2011a, Sichani, Nielsen, & Bucher 2011b), and Subset Simulation (SS) (Au & Beck 2001) are chosen primarily.

All of the methods aim at the same subject, i.e. estimation of the low failure probability events. However they tackle the problem from very different points of view. IS moves the so-called sampling density of the problem to the boundaries of the failure region hence generates more samples in this area. DCMC works more on a logical basis where the idea is to run all the simulation samples simultaneously and find those processes which are closer to the boundaries of the safe domain and increase the outcrossing events by putting more emphasis on these important events. The AS development is based on the asymptotic estimation of failure probabilities (Breitung 1989). Here the advantage of the linear relationship of the safety index for multi-normal probability integrals is considered to estimate low failure probabilities by proper scaling of the probability integral. AS forces more outcrossing by increasing the excitation power. SS takes its basis on the conditional probability estimation. It breaks the problem of a low failure probability estimation into estimation of a multiplication of some higher probabilities. Next a conditional sampler i.e. Modified Metropolis-Hastings algorithm is used to estimate the conditional probabilities.

Primarily introduced methods are used for failure probability estimation of a Single Degree of Freedom (SDOF) oscillator. Comparison is made on the results of the methods in terms of their accuracy, requirements and computational load. Standard Monte Carlo (SMC) simulation for the same system is performed for global comparison of accuracy of the methods.

This study prevails advantages and disadvantages of each of the methods in application on dynamic systems. Next, the method with highest merit is chosen and applied on a wind turbine model developed in previous study c.f. figure 7.

3 IMPORTANCE SAMPLING

3.1 *Introduction*

To apply IS (Macke & Bucher 2003) it is necessary to have estimation of the system responses at the failure time instance, i.e. displacements, when it is excited by the increments of the Wiener process. This estimation is the basis for constructing the so-called control functions which their characteristics are that they bring the system response to the failure state at failure time instance, i.e. $t_k = k\Delta t$, if the system is excited with them. Next, these deterministic drifts are added to the Wiener increments and the result is used as the final system excitation. Starting by designing control functions, if excitations are not Wiener increments themselves, they should be represented in terms of them. Suppose the system is described by the Itô SDE (1)

$$\left.\begin{aligned} d\mathbf{Z}(t) &= \boldsymbol{\mu}(t,\mathbf{Z})dt + \boldsymbol{\sigma}(t,\mathbf{Z})d\mathbf{W}(t) \\ \mathbf{Z}(s) &= \mathbf{z} \end{aligned}\right\} \tag{1}$$

where $\mathbf{Z}(t)$ is p-dimensional system response subjected to the initial conditions $\mathbf{Z}(s) = \mathbf{z}$ for any $0 \le s \le T$ and $\mathbf{W}(t)$ is the vector of q-dimensional unit Wiener processes. Given that the failure domain boundary is specified by the failure surface $g\big(\mathbf{Z}(t,\mathbf{W})\big) = 0$ such that

$$\mathcal{F} = \Big\{\mathbf{Z} \,|\, g(\mathbf{Z}) > 0\Big\} \tag{2}$$

using (1), (2) can be written in the terms of the Wiener excitation i.e. $\mathcal{F} = \Big\{\mathbf{W} \,|\, g(\mathbf{W}) > 0\Big\}$ the failure probability can be defined as

$$\begin{aligned} P_f &= \int_{\mathcal{F}} dP_{\mathbf{W}}(\mathbf{w}) \\ &= \int_{\mathbf{R}^q} I\Big[g\big(\mathbf{Z}(t,\mathbf{W})\big)\Big] dP_{\mathbf{W}}(\mathbf{w}) \\ &= E_{\mathbf{w}}\Big[I\big[g(\mathbf{Z})\big]\Big] \end{aligned} \tag{3}$$

where $I[.]$ is an indicator function which is equal to 1 if the process has outcrossed to the failure domain and else is zero. The probability measure $P_{\mathbf{w}}(\mathcal{B})$ relates a probability to any sub-domain $\mathcal{B} \in \mathbf{R}^q$, i.e. a differential volume around a sample point $\mathbf{w}$, and can be written as $dP(\mathbf{W}) = f_{\mathbf{W}}(\mathbf{w})d\mathbf{w}$. $E_{\mathbf{w}}$ signifies the expectation operator under the probability measure $f_{\mathbf{W}}(\mathbf{w})$. Based on (3) SMC estimates the failure probability of the system by (4); where N_{sim} is the number of Monte Carlo samples.

$$\hat{P}_f = \frac{1}{N_{sim}} \sum_{j=1}^{N_{sim}} I\left[g(\mathbf{Z}^{(j)})\right] \tag{4}$$

3.2 *The Girsanov Transformation*

The idea of the IS based on the Girsanov theorem is to introduce a square integrable drift $\mathbf{u}(t)$ - i.e. $\sum_j^p \int_0^T \mathbf{u}_j^2(\tau)d\tau < \infty$ - into the excitation, which brings the systems response to the failure region at the desired time.

$$d\tilde{\mathbf{W}}(t) = \mathbf{u}(t)dt + d\mathbf{W}(t) \tag{5}$$

The Itô SDE (1) can then be written as

$$\left.\begin{aligned} d\mathbf{Z}(t) =& \boldsymbol{\mu}(t, \mathbf{Z})dt - \boldsymbol{\sigma}(t, \mathbf{Z})\mathbf{u}(t)dt \\ &+ \boldsymbol{\sigma}(t, \mathbf{Z})d\tilde{\mathbf{W}}(t) \\ \mathbf{Z}(s) =& \mathbf{z} \end{aligned}\right\} \tag{6}$$

The Girsanov theorem then states that the process $\tilde{\mathbf{W}}$ is a Wiener process under the probability measure $P_{\tilde{\mathbf{W}}}$. Therefore generating samples of $\tilde{\mathbf{W}}$ under the probability measure $P_{\mathbf{W}}$ corresponds to generating samples of $\mathbf{W}$ under the probability measure $P_{\tilde{\mathbf{W}}}$. This means that the drift of the excitation might be designed in any sense that brings the system to the failure at the desired time instance. Next, the probability measure should be changed properly to take into account the effect of this transformation which is done in the following way

$$\left.\begin{aligned} P_f &= \int_{\mathbf{R}^q} I\left[g(\mathbf{Z}(t, \mathbf{W}))\right] \frac{f_{\mathbf{W}}(\mathbf{w})}{f_{\tilde{\mathbf{W}}}(\mathbf{w})} f_{\tilde{\mathbf{W}}}(\mathbf{w})d\mathbf{w} \\ &= \int_{\mathbf{R}^q} I\left[g(\mathbf{Z}(t, \mathbf{W}))\right] \frac{dP_{\mathbf{W}}(\mathbf{w})}{dP_{\tilde{\mathbf{W}}}(\mathbf{w})} f_{\tilde{\mathbf{W}}}(\mathbf{w})d\mathbf{w} \\ &= E_{\tilde{\mathbf{w}}}\left[I\left[g(\mathbf{Z})\right] \frac{dP_{\mathbf{W}}(\mathbf{w})}{dP_{\tilde{\mathbf{W}}}(\mathbf{w})}\right] \end{aligned}\right\} \tag{7}$$

where $g(\mathbf{Z}) = g(\mathbf{Z}(t, \mathbf{W}))$ and the ratio $dP_{\mathbf{W}}(\mathbf{w})/dP_{\tilde{\mathbf{W}}}(\mathbf{w})$ is the well-known Radon-Nikodym derivative of the probability measure $dP_{\mathbf{W}}(\mathbf{w})$ with respect to the measure $dP_{\tilde{\mathbf{W}}}(\mathbf{w})$. $E_{\tilde{\mathbf{w}}}$ signifies the expectation operator under the probability measure $f_{\tilde{\mathbf{W}}}(\mathbf{w})$. Upon the Girsanov theorem the probability measure of (7) can be changed to $f_{\tilde{\mathbf{W}}}(\mathbf{w})$ hence (8)

$$P_f = E_{\mathbf{w}}\left[I\left[g(\tilde{\mathbf{X}})\right] \frac{dP_{\mathbf{W}}(\tilde{\mathbf{w}})}{dP_{\tilde{\mathbf{W}}}(\tilde{\mathbf{w}})}\right] \tag{8}$$

where $g(\tilde{\mathbf{Z}}) = g(\mathbf{Z}(t, \tilde{\mathbf{W}}))$. The significance of equation (7) is that the probability measure can be changed so that the process $\tilde{\mathbf{W}}$ can be used instead of the original process $\mathbf{W}$ to estimate the failure probability of a system provided that the Radon-Nikodym derivative is taken into account. Based on (7), the failure probability of the system can be estimated using (9)

$$\hat{P}_f = \frac{1}{N_{sim}} \sum_{j=1}^{N_{sim}} I\left[g(\tilde{\mathbf{Z}}^{(j)})\right] \left(\frac{dP_{\mathbf{W}}(\tilde{\mathbf{w}}^{(j)})}{dP_{\tilde{\mathbf{W}}}(\tilde{\mathbf{w}}^{(j)})}\right) \tag{9}$$

4 RUSSIAN ROULETTE & SPLITTING WITH DISTANCE CONTROL

The method encompassed two components "Russian Roulette and Splitting" (RRS), which replaces "unimportant" realizations with the "important" ones, and "Distance Control" (DC), which takes care of determining the importance of the realizations. The method substitutes the processes with low probability of causing failure, called the unimportant processes, by the so-called important processes i.e. processes with higher probability of failure. This substitution might be readily done by splitting(duplicating) some of the important processes with control over their statistical weights such that the statistics of the simulation is not changed after splitting. The distance measure is used to distribute the samples in the state space. Pradlwarter and Schuëller (Pradlwarter, Schuëller, & Melnik-Melnikov 1994) define this in the following way. A given realization $\mathbf{z}(t)$ of the p-dimensional state vector $\mathbf{Z}(t)$ is associated with a vector $\mathbf{l}(\mathbf{z}(t))$ with non-dimensional components $l_i(\mathbf{z}(t))$.

$$l_i(\mathbf{z}(t)) = \frac{z_i(t) - \mu_{Z_i}(t)}{\sigma_{Z_i}(t)} \quad , \quad i = 1, \cdots, p \tag{10}$$

where $\mu_{Z_i}(t)$ and $\sigma_{Z_i}(t)$ denotes the mean value and the standard deviation of the possible non-stationary process $\mathbf{Z}(t)$. In case these cannot be determined analytically a preliminary SMC is performed. The components $l_i(\mathbf{z}(t))$ may otherwise be specified with arbitrarily selected relative weight. The distance measure $d(\mathbf{z}(t))$ related to the realization is then defined as

$$\left.\begin{aligned} d(\mathbf{z}_j(t)) =& \sum_{k=1}^{K} a_j ||\mathbf{l}(\mathbf{z}_{j_k|j}(t)) - \mathbf{l}(\mathbf{z}_j(t))|| \\ & a_1 > a_2 > \cdots > a_K \end{aligned}\right\} \tag{11}$$

where $\mathbf{z}_{j_k|j}(t)$ denote the k[th] closest realization to $\mathbf{z}_j(t)$ and $||.||$ is the Euclidian norm. The closest realization with the weight a_1 is weighted highest. The weights were chosen as

$$a_j = 2^{1-j} \tag{12}$$

For a SDOF oscillator subjected to Gaussian white noise $||\mathbf{l}(\mathbf{z})||$ with $\mathbf{l}(\mathbf{z}(t))$ defined by (10) is proportional to the mechanical energy of the oscillator. However, (10) does not represent the mechanical energy in any other case than the indicated. Instead, (11) can be replaced with

$$d\big(\mathbf{z}_j(t)\big) = \sum_{j=1}^{K} a_j E_m\big(\mathbf{z}_{j_k|j}(t) - \mathbf{z}_j(t)\big) \tag{13}$$

where E_m is the mechanical energy of the system. The mechanical energy, itself could alternatively be used as a distance measure. This possibility is also examined by the authors though no improvement of the results compared to the weighting proposed by (11) is observed; which has already been reported in the literature (Pradlwarter, Schuëller, & Melnik-Melnikov 1994, Pradlwarter & Schuëller 1997).

5 SUBSET SIMULATION

The subset simulation strategy starts from the reachable barrier level(s) by a predefined low number of samples and increase the level gradually until the highest barrier level required. This can be done by defining intermediate probability levels $p_f = p_f^{(m)} < p_f^{(m-1)} < \cdots < p_f^{(1)}$ corresponding to the intermediate barrier levels $b = b_m > b_{m-1} > \cdots > b_1$. Using this property taken from the fact that failure probability can not increase as the barrier level increases, the required failure probability p_f is written as

$$p_f(b_2|b_1) = \frac{p_f(b_2 \bigcap b_1)}{p_f(b_1)} = \frac{p_f(b_2)}{p_f(b_1)} \tag{14}$$

using (14) the final failure probability, i.e. the lowest failure probability required, is written as the following product

$$p_f(b) = p_f(b_1) \prod_{i=1}^{m-1} p_f(b_{i+1}|b_i) \tag{15}$$

The method then follows with estimation of each of the m terms on the right hand side of (15) using some type of Monte Carlo simulation. Therefore it is beneficial to let the barrier level be chosen in an adaptive manner and fix the intermediate failure probabilities associated to them. All of the terms in the product are chosen large enough so that they can be estimated with low number of samples, i.e. $p_0 = 0.1$ in conjunction with (16).

$$\left.\begin{aligned} p_f(b_1) &= p_0 \\ p_f(b_{i+1}|b_i) &= p_0 \quad , \quad i = 1, \cdots m-1 \end{aligned}\right\} \tag{16}$$

$p_f(b_1)$ can then be estimated efficiently by SMC with low number of samples i.e. $N_{sim} = 100$. However the conditional probability terms in (14) can not be estimated by SMC and need a technique which is capable of generating samples conditioned on the previous samples. Au and Beck (Au & Beck 2001) proposed using a Modified Metropolis-Hastings (MMH) algorithm for this purpose and called it the *subset simulation*. The method starts with a SMC with N_{sim} number of samples which allows accurate estimation for the first term on the right hand side of (15). The realizations of the excitations in the i^{th} level of the simulation, i.e. $\dot{\mathbf{W}}^{(i)} = \{\dot{\mathbf{w}}_1^{(i)}, \cdots, \dot{\mathbf{w}}_{N_{sim}}^{(i)}\}$ where $\dot{\mathbf{W}}^{(i)}$ denotes increments of the Wiener process, which their response corresponds to the barrier levels higher than the barrier level b_1. These realizations provide a set of the so-called seeds for generating the next generation of excitations. Candidates for next generation of excitations are generated using a conditional sampler , e.g. MMH, using these seeds. This step provides the estimation for the conditional terms in (15) and will be repeated m times , c.f. (15), to reach the required failure probability i.e. p_0^m provided (16).

$$p_f^i = \frac{p_f^{i-1}}{N_{sim}} \sum_{j=1}^{N_{sim}} I_{\mathfrak{F}^{(i)}}(\dot{\mathbf{w}}_j^{(i)}) \quad , \quad i = 1, \cdots, m \tag{17}$$

where $p_f^0 = 1$; p_f^i represents the minimum failure probability calculated in the i^{th} step of the simulation. $\mathfrak{F}$ denotes the failure domain and $I_{\mathfrak{F}^{(i)}}(\dot{\mathbf{w}}_j^{(i)})$ is the indicator function which will be one if the response to $\dot{\mathbf{w}}_j^{(i)}$ lies in the i^{th} intermediate failure domain and is zero otherwise.

6 ASYMPTOTIC SAMPLING

The method is developed based on the asymptotic estimation of multi-normal integrals. The problem of approximating a multi-normal probability integral (18) on the scaled LSF which can be represented after proper transformation of random variables as

$$p(\beta; \boldsymbol{\xi}) = \int_{g(\beta^{-1}\boldsymbol{\xi})<0} \prod_{i=1}^{N} \varphi\Big(-\frac{1}{2}\xi_i^2\Big) d\boldsymbol{\xi} \tag{18}$$

where $\boldsymbol{\xi} = \{\xi_1, \cdots, \xi_N\}$ denotes the vector of standardized independent multi-normal random variables; LSF is defined as $g(\beta^{-1}\boldsymbol{\xi}) < 0$. The first parameter in the parentheses on the left hand side denotes scaling of the variables in the LSF. $\varphi(.)$ denotes the standard

normal density function. The boundaries of the integral in (18) can be changed to unscaled LSF which reads

$$p(\beta;\boldsymbol{\xi}) = \beta^N \int_{g(\boldsymbol{\xi})<0} \prod_{i=1}^{N} \varphi\Big(-\frac{\beta^2}{2}\xi_i^2\Big) d\boldsymbol{\xi} \qquad (19)$$

which is shown to be asymptotically equal to $\Phi(-\beta)|J|^{-1/2}$ as $\beta \to \infty$; where $|J|^{-1/2}$ is a parameter related to the first and second order derivatives of the LSF at the design point. (18) and (19) mean that the desired low probabilities can be approximated on a scaled failure domain and then transformed back into the unscaled domain. This idea forms the procedure of AS (Bucher 2009) which starts with a SMC on the scaled variables i.e. excitations with *artificially* increased standard deviation. The reliability index is primarily estimated based on the scaled failure probability, e.g. $\beta(f) = \Phi(1 - p^{scaled})$, and is then scaled back to the unscaled space, e.g. $\beta(1) = f^{-1}\beta(f)$. The desired probability is estimated as $\Phi^{-1}\big(\beta(1)\big)$ then. More details of the method and some practical aspects for improving its efficiency on dynamic problems are presented in (Sichani, Nielsen, & Bucher 2011a, Sichani, Nielsen, & Bucher 2011b).

7 NUMERICAL SIMULATION

7.1 *SDOF oscillator*

The first simulation is based on a single DOF linear oscillator (20), characterized by $\omega_n = 1s^{-1}$ and $\zeta_n = 0.01$

$$\ddot{x}(t) + 2\zeta_n\omega_n\dot{x}(t) + \omega_n^2 x(t) = w(t) \qquad (20)$$

$w(t)$ is zero-mean Gaussian white noise with unit intensity. The barrier level is normalized with respect to the standard deviation of the response $\sigma_X = (4\zeta\omega^3)^{-1/2}$.

$$b_N = \frac{b}{\sigma_X} \qquad (21)$$

The failure event is defined as the maximum of the absolute value of the response of the oscillator exceeds a certain threshold "b", i.e. $\Pr(|y(t)| > b)$ for $t \in [0, 600]$. The normalized barrier level is assumed to be $b_N = 5$ in simulations. Simulations are carried out with $\Delta t = 0.0614s$ and $t \in [0, 600]s$ which involves 9772 samples to examine the performance of the method in high dimensions. Exact failure probability and reliability index for the problem, calculated with standard Monte Carlo simulation with 2×10^6 samples, are $P_f(600) = 2.07 \times 10^{-4}$ and $\beta = 3.5310$ respectively.

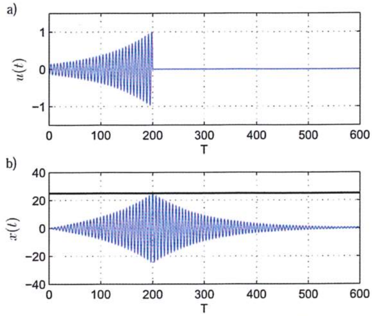

Figure 1: Control function and response of the SDOF oscillator; a) Control function, b) response.

7.1.1 *Importance sampling*

Figure 1.a shows one of the control functions of the SDOF oscillator. The response of the system to this excitation, i.e. deterministic drift, is shown in 1.b. Estimation of the failure probability for different time instances are shown in figure 2. As seen from this figure IS is very attractive in the first sight due to its high accuracy for failure levels. However its shortcomings in application to more complicated problems are also considerable. Since failure may occure at any time instance within a distinguished time period $t \in [0, T]s$, IS requires that all of the control functions that cause failure during this time interval should be available to allow considering the interaction between different design point control functions. This requires heavy dynamic analysis in order to compute these control functions primarily and also high memory is required to save them. Unfortunately this requirement specifically for Multi Degree Of Freedom (MDOF) nonlinear systems poses severe difficulties as in such cases there exist no analytical solution for the design point excitations. In such cases a high dimensional optimization algorithm should be used to find the design points excitations, alternatively called control functions, which is very expensive, (Koo, Der Kiureghian, & Fujimura 2005).

These problems have also been noticed by other researchers however to the best knowledge of authors IS applications are very limited i.e. nonlinear SDOF systems, (Naess & Gaidai 2008), or linear MDOF systems with only one stochastic excitation process (Jensen & Valdebenito 2007). The above reasons conclude that using IS with presented scheme may not be considered a proper candidate for for application to wind turbine models.

7.1.2 *Russian roulette & splitting with distance control*

The DCMC with the distance measure considered as a weighted summation of six closest neighbor processes i.e. $K = 6$. The parameters of the DCMC are

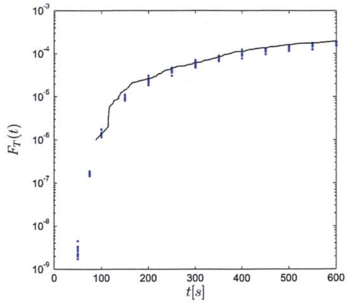

Figure 2: Estimations of the failure probability with IS; Solid line: SMC, dots : IS

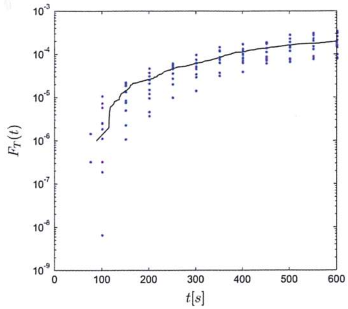

Figure 3: Estimations of the failure probability with DCMC; Solid line: SMC, dots: DCMC

chosen $\beta = 0.8, p_0 = 0.5, w_{min} = 5 \times 10^{-5}$, (Pradlwarter & Schuëller 1999), and the results are shown in the figure 3. A unique feature of DCMC compared to the other algorithms implemented in this study is that it works directly on the responses and does not make any changes in the excitations. Advantages of DCMC are generality of application and low memory requirements and its capability in handling high dimensional problems. The method's shortcomings are the implementation of it which requires all of the samples to run in parallel i.e. all 500 simulations should evolve simultaneously to allow statistical weighting adjustment. This requires to change the states during the time integration of the governing equations. This may cause some practical issues during implementation of the algorithm on practical codes. Next, DCMC like IS is capable of estimating failure probability of a predefined threshold level. This is less motivating in wind turbine problems where the opposite is required i.e. the threshold for a given failure probability.

7.1.3 *Asymptotic sampling*

For each barrier level $N_{sim} = 500$ number of samples with 5 support points are used with different Δf and

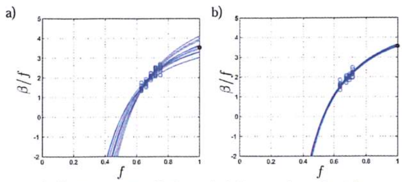

Figure 4: Estimations of the reliability index β with asymptotic sampling for 600[s]; single DOF oscillator. a) Uniform distributed support points , CoV$(P_f(600))$=1.2 b) Non-uniform distributed support points, CoV$(P_f(600))$=0.2

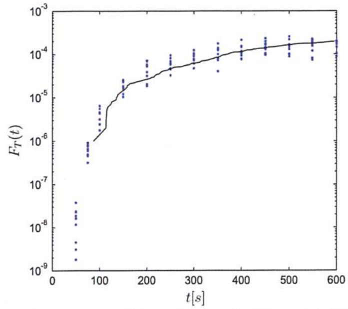

Figure 5: Estimations of the failure probability with AS; Solid line: SMC, dots: AS

range of *f*. Figure 4 illustrates the effect of distribution of support points. Clearly too low values for f will cause all of the processes to cross out which does not give any information while choosing too large f will cause few out crossings which increases the uncertainty of the estimation. It is seen that the maximum accuracy of the method, i.e. the least standard deviation of the estimate, is achieved when the support points are distributed in the region where 2 to 98 percent of the realizations crosses out c.f. figure 4.b compared to figure 4.a in which 2 to 50 percent of the realizations have crossed out. The black dots on the right hand side of the figures show the exact value of the beta. Figure 5 shows estimations of the failure probability for the same barrier level in different time instants where solid line shows the SMC results.

7.1.4 *Subset simulation*

Results of SS applied on the oscillator for failure for different time instants within the time interval $t \in [0, 600]s$ are shown in figure 6 as counterpart of figures 2, 5 and 3. For estimation of failure probability in this figure 4 levels of MCMC is used only for $T = 400s, 450s, 600s$; for $T = 150s, 200s, 250, 300, 350s$ 5 MCMC levels are used and for $T = 100s, 75s, 50s$ respectively 6,7 and 8 MCMC levels with $p_0 = 0.1$ with $N_{sim} = 500$ samples in each step. The proposal distribution is assumed uniform with half spread

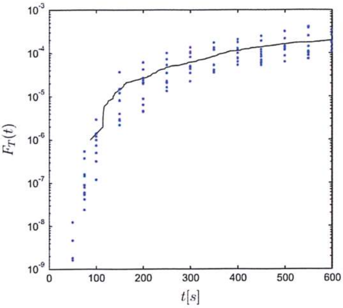

Figure 6: Estimations of the failure probability with SS; Solid line: SMC, dots: SS

equal to the standard deviation of the excitation seeds (Au, Cao, & Wang 2010).

The SS approach is based on changing the excitation realizations like IS and AS. The method is based on designing new excitations within a fixed time duration based on previous excitation realizations which have reached the highest barrier levels in previous simulations e.g. seeds. In this way it may be interpreted as a stochastic optimization procedure. The method has several interesting features which is in line with requirements of the wind turbine design criteria. An advantage of SS is that it estimates the thresholds related to a given failure probability. This is what is required in wind turbine design codes, (IEC 2005), while the other three methods provide the failure probability given for a predefined threshold level. SS is a very accurate method for low failure probability estimation of high dimensional nonlinear systems (Au, Ching, & Beck 2007). However some practical procedures should be taken into account for very high number of basic variables which should be kept in memory during simulations e.g. random numbers required to generate the turbulent wind field. Nevertheless the method seems to propose a good candidate for application on the wind turbine model. Most favorably the method is a so-called acts as a black-box which means it does not require any a-priori knowledge of system which adds to its advantages.

7.2 *Wind turbine*

Design codes for wind turbines are based on a return period (expected first-passage time) of $T_r = 50$year, which itself requires design values related to the failure probability of the wind turbine models down to the order 10^{-7}. According to the IEC61400-1 standard (IEC 2005), the design value r of a stochastic response $\{R(t), t \in [0, \infty[\}$ (deformation, bending moment, stress, etc.) is obtained by extrapolation of the failure probability under normal operation of the design value r in a referential epoche T to T_r. Presuming independent failure events in adjacent referential epoches the exceedance probability of the design value is given as

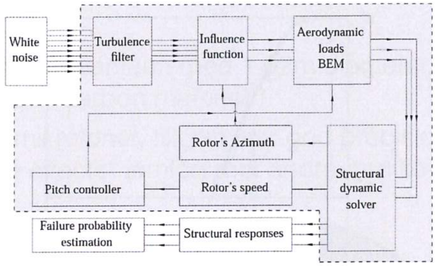

Figure 7: Flowchart of the wind turbine model.

$$P\Big(R_{max}(T_r) > r\Big) \simeq \frac{T_r}{T} P\Big(R_{max}(T) > r\Big) \quad (22)$$

$R_{max}(T)$ and $R_{max}(T_r)$ denote the maxima value in intervals T and T_r. With $T_r = 50$ year and $T = 600s$, (22) provides the relation

$$P\Big(R_{max}(T) > r\Big) \lesssim \frac{T}{T_r} = 3.8 \times 10^{-7} \quad (23)$$

The design value r is obtained as the solution of (23). It is out of question to determine this by SMC simulation due to the indicated low failure probability. The suggested approach in the IEC61400-1 standard is to use a Weibull or a Gumbel distribution as the distribution function $F_{R_{max}(T)} = 1 - P\Big(R_{max}(T) > r\Big)$. The locations, scale and shape parameters, which are estimated from the available sample. Applicability of the selected method on a reduced order model of a 5MW reference wind turbine developed in previous study c.f. figure 7, (Sichani, Nielsen, & Bucher 2011b), is tested. Specifications of the wind turbine model are adopted from the NREL reference wind turbine (Jonkman, Butterfield, Musial, & Scott 2009). It is attempted to cover the principal behavior of a wind turbine.

The model consists of structural and aerodynamic loads but no controller, i.e. fixed rotational speed is assumed. The details of the model specifications are explained in (Sichani, Nielsen, & Bucher 2011b). The wind field is simulated in 31 nodes on 50m distance from nacelle of the rotor with 63m blades using a state space model. Failure probabilities of the model are estimated with the AS as the primary candidate method. Figure 8 shows failure probability of the wind turbine model estimated with SMC with 4×10^5 samples, AS with 32×500 samples (Sichani, Nielsen, & Bucher 2011b), Weibull and Gumbel fits with 500 simulations each. The results of AS estimations show good consistency with the SMC results. The AS method has the advantages of very low memory requirement and simplicity of application even for very high dimensional problems.

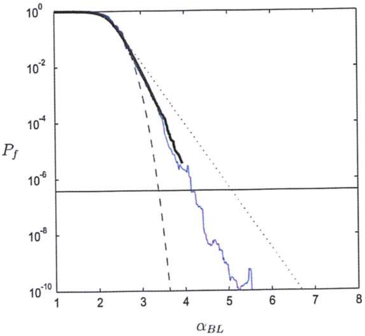

Figure 8: Estimated failure probability of the wind turbine for fixed speed wind turbine. —: 50 year recurrence period, bold black: SMC, – –: 3-parameter Weibull distribution, · · · : Gumbel distribution, blue: AS.

8 CONCLUSIONS

Among the methods considered in this paper IS shows the highest accuracy however faces serious difficulties in application on wind turbine models due to excessively high number of dynamic analysis it requires for nonlinear systems. The DCMC method is applicable on such models however certain features, i.e. parallel running and communication of samples during solution, are required which may limit its applications on practical codes. The AS and SS methods seem the most suitable methods since they have similar characteristics regarding no a-priori knowledge about model as well as low memory requirements. The AS method is already applied on a wind turbine model and results show good agreement with the SMC with much higher efficiency.

It worth mentioning that total number of dynamic analysis required by all of the methods mentioned in the paper for accurate results may be considerably larger than the nominal number of samples, e.g. 500 in this paper, except the DCMC method.

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- Ställbart frekvensomfång 20Hz- 20 KHz, även möjlighet till analys av singel frequency
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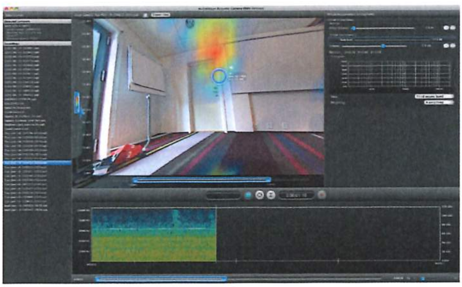
- RPM funktion
- Konkurrenskraftigt pris!



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SYSTEM IDENTIFICATION AND DAMAGE DETECTION OF A WIND TURBINE BLADE

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Introduction

Wind industry is developing very fast towards the installation of off-shore wind turbines in order to exploit continuously and unobstructed wind energy. Because off-shore wind turbines are exposed to strong wind currents and are installed to a corrosive and unfriendly marine environment, there is a necessity for their condition to be monitored constantly. Due to their remote location, monitoring, maintaining and repairing is extremely difficult to be made and early damage detection can prevent failure of wind turbine's crucial components and the structure itself.

The importance of Structural Health Monitoring (SHM) system in Wind Turbines is significant, considering that a robust, reliable and efficient condition monitoring system is able to detect minor damages in the initial stage and avoid or diminish any repair or maintenance work, minimizing service cost and downtime of the wind turbine. The disadvantages of the existing monitoring systems can be confronted by the development of sufficient vibration based methods on new generation wind turbines based on totally random excitation by unpredicted wind loads.

In the past, there have been applied Wavelet Pattern Recognition, Variance Analysis and Resonant Comparison damage detection techniques on a wind turbine blade, based on fatigue test and analyzing the produced stress waves, [Sundaresan et al.]. Resonant Comparison was implemented on a wind turbine blade segment in a previous analysis as well, in comparison with Transmittance Function (TF), Operaional Deflection Shapes (ODS) and Wave Propagation fault diagnosis methods, [Ghosal et al.]. Additionally, a two meters wind turbine blade was subject to vibration testing, detecting and localizing defects by using the Continuous Wavelet Transformation (CWT), [Dolinsky and Krawcuk]. More recently Claytor et al. (2010) devi-

sed a time series model was built in order to detect defects on a wind turbine blade section. Time series methods based on vibration testing do not require physics based models or complete structural models and make effective use of natural random vibration data records, [Fassois and Sakellariou].

The existing health monitoring systems are very expensive, unreliable and inadequate. Additionally, current damage detection techniques are keen to uncertainties and minor damages may be extremely difficult to be detected. Vibration based techniques help to develop novel models for robust and effective fault detection and localization in complex structures like wind turbines under 'noisy' conditions. Vibration based methods of condition monitoring, more reliable and cost efficient, are able to detect minor and major defects of the structure, reduce the service and repair cost, identify damage in the initial stage and prevent and minimize unnecessary replacement or repair of a component, as well as reducing the downtime of the wind turbine. Preliminary tests and results on a wind turbine blade are presented and discussed below.

Measuring Procedure

In order to test and apply the techniques, a small scale wind turbine blade was examined.

Figure 1: Examined Blade

The tested blade (figure 1) was attached to a clamp, to represent the attachment of a blade to a rotor. The blade was excited by a piezoceramic patch, located on the back of the blade, by random excitation. Additionally, on the blade there were placed three accelerometers to acquire the response of the vibrated blade. The blade was tested under lab conditions, with a sampling frequency of 1280 Hz and 51200 samples.

The following graph (graph 2) illustrates the experimental procedure which was followed in order to acquire the response signals from the vibration test of the blade. After installing siglab's (Data Acquisition device or DAQ) software, in a laptop, the excitation signal with all the specifications was determined. Afterwards, the excitation signal was driven to the piezoceramic patch passing through a piezo-amplifier in order for the input signal to be amplified. The blade was vibrated for a measurement of 40 seconds and the response signals were acquired by the three accelerometers which were attached on it. Then, the acquired signals were lead to a signal conditioner to be amplified and finally they were driven to the data acquisition device. The rest of the signal processing and data analysis was made in MATLAB software. Figure 2:

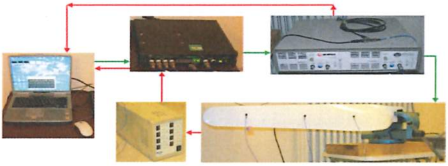


Figure 2: Experimental Procedure (Green Arrows: Signals Driven to the Structure, Red Arrows: Signals Driven to DAQ

System Identification

System identification deals with the problem of building mathematical models of dynamical systems based on observed data from the systems [L. Liung]. After all the signals were acquired, the acquired data were sed to build a mathematical model. The mathematical models which were built were AR (Auto-Regressive),
ARMA (AR with Moving Average), ARX (AR with eXogenous input) and ARMAX models. For each model there are a number of parameters (model order) which are determined and define the examined structure.
Hence the next step after acquiring the signals is to find the proper model order. In order to do this we some implement statistical criteria. The following graphs illustrate two of the criteria, the AIC (Akaike Information Criterion) and BIC (Bayesian Information Criterion) criteria for the ARX model. The optimum
model order is designated by the minimum value of model order in the below graphs. Usually, the BIC is a
more trusted criterion, because the AIC has a tendency to overestimate the model order.

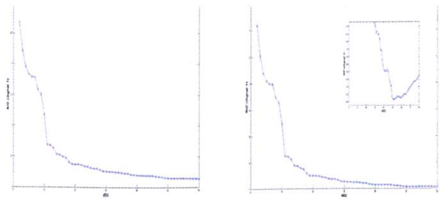
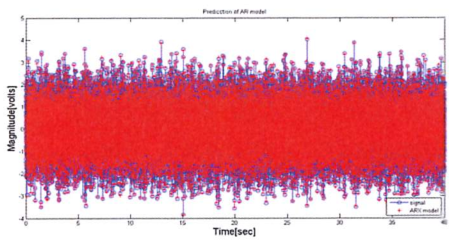


Figure 3: AIC (Left) and BIC (Right) Criteria, (BIC zoomed in order for the minimum to be clear)

For the examined blade the model order which was selected was ARX (51,51). After the model order is chosen, the model should be validated in order to verify whether the chosen order was right or wrong and to check if our system is represented by the mathematical model properly.

One of the most important criteria for model validation is the one step ahead prediction. It indicates the difference between the acquired data and the model which was developed. The smallest the deviation is from the real data, the better the model which was built is.



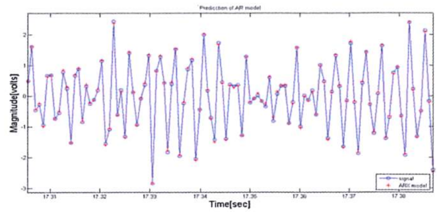


Figure 5: One Step Ahead Prediction of ARX (51, 51) [zoomed]

As it is clear from the above graph, the ARX model (51,51) which was selected and developed was validated by the above criterion, hence the chosen ARX model can be selected and will be used to the damage detection process.

Damage Detection

Following the model order selection and after all the parameters of the model were defined, the Frequency Response Function (FRF) diagram was plotted. The FRF plot illustrates the magnitude of each frequency of the structure within the examined frequency range. The frequencies with higher amplitudes which form a peak on the FRF chart designate the natural frequencies of the blade, a characteristic property of the structure. The following figure (figure 6) depicts the FRF of ARX (51,51). When damage applies the dynamic properties of the structure change, hence the FRF of the examined system changes detecting the occurred

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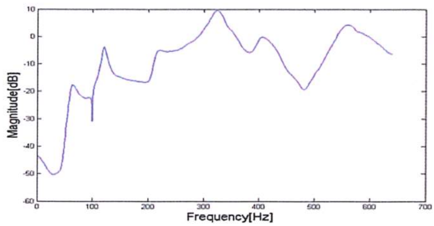

Figure 6: FRF of ARX (51,51)

damage. The damage which was applied on the tested blade was a slight loosening on the clamped edge of the blade, representing the change in the stiffness of the mounted edge of a blade on the wind turbine rotor. After the damage was occurred on the blade, an ARX (51,51) model was built for the new state and the produced FRF was compared to the "healthy" state FRF of the blade (figure 7). It is clear that the FRF of

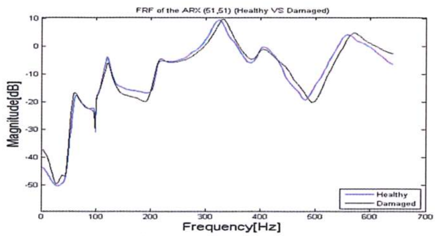

Figure 7: FRF of the ARX (51,51) (Healthy VS Damaged)

the damaged state of the blade shows a shift in the peak, meaning a change in the properties of the structure, detecting the damage successfully.

Conclusions

Novel parametric models based on vibration techniques are promising and efficient in detecting minor damages on a structure. More improved methods which will be applied in the future can help, not just detecting the damage, but locating the exact position of it, making these techniques an important tool for health monitoring of wind turbine structures. In the future, different types of damages will be implemented, such as inner delamination of the blade verified by ultrasonic detection. The next, after all the types of damages will be tested, the blades will be examined on a rotating configuration with the same damages. For all the above, in order for damage to be diagnosed, except the PSD and FRF plots, model residual-based and functional model-based methods will be used and will be compared regarding their efficiency and reliability.

Acknowledgements

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Protokol
Årsmöte i Skandinaviska Vibrationsföreningen, SVIB

Tisdagen den 22 november 2011 på Reinholtsen i Oslo.

a) Fastställande av dagordning
Dagsorden belv godkendt af de fremmødte.

b) Val av mötesordförande och mötessekreterare
Torbjörn Kloow blev valgt til mødeleder, og der var indledningsvis 1 minut stilhed til ære for Alf Olsson. Anders Olsen blev valgt til mødesekretær.

c) Val av justeringsmän för dagens protokoll
Claes Fredö og Per-Olof Ekenberg er valgt som justeringsmän

d) Fråga om stämman blivit behörigen kallad
Enighed om at der er indkaldt senest 10 dage før på hjemmesiden. Godkendt af de fremmødte.

e) Avgående styrelsens redogörelse för verksamheten under det föregående Torbjörn Kloow beretter om redegørelsen. SVIB har haft problemer med hjemmesiden og det var været svært at få SVIB Nyt ud i 2011. Derudover er SVIB nu en ideel forening.
f) Revisionsberättelse
örjan Johansson oplæste revisionsberetning. Redovisning er i orden iht, alle regler.

g) Fastställande av resultat- och balansräkningar
Torbjörn Kloow gennemgår balance og resultat rapport, som begge godkendes.

h) Beslut rörande ansvarsfrihet för den avgående styrelsen
Forsamlingen godkender ansvarsfrihed for den afgående bestyrelse.

i) Fastställande av budget för kommande verksamhetsår
Torbjörn Kloow gennemgår forslag til nyt budget for 2012. Der afsættes SEK 50.000 til ny hjemmeside(laves evt. Af Stefan fra PCB). Invited speakers budgetteres til SEK 30.000. Guld acc. Sponseres i 2012 af PCB. SEK 5.000 udgår af 2012 budgettet.

j) Fastställande av föreningens årsavgift för medlemmar och pensionärer
Årsafgift på SEK 550 fastholdes. For pensionærer fastholdes SEK 280.
k) Val av ordförande för tiden t o m nästkommande årsmöte
Elisabet Blom modtager genvalg

l) Val av vice ordförande för tiden t o m nästkommande årsmöte
Ylva Vidhög modtager ikke genvalg og træder ud af styret
Juha Plunt modtager valg til vice ordførende.

m) Val av sekreterare
Anders Olsen modtager valg som SVIB sekretær

n) Val av skattmästare
Torbjörn Kloow modtager genvalg som skattemester

o) Val av övriga styrelsemedlemmar
Örjan Johansson modtager genvalg. Søren R K Nielsen modtager genvalg.

p) Val av två revisorer och revisorssuppleant
Ralf Collin och Leif Norman utsågs till revisorer.Revisorsuppleant er vacant

q) Tillsättande av en valberedning
Anders Åhlström(PCB) og Kristian Meisingset(Reinertsen) modtager valg. Desuden skal Anders Brandt, SDU spørges vedr. Dette

r) Övriga ärenden
Torbjörn Kloow foreslår en ændring i vedtægterne, således at regnskabsåret følger kalenderåret.
Det foreslåes at der sammen med SVIB nyt udsendes et følgebrev om status for SVIB samt fremtiden og endvidere omkring opdatering af medlemsdatabase.
Styret skal desuden arbejde på et oplæg omkring fakturering af omkostning for styrets medlemmer. Nogle styremedlemmer har haft et væsentligt tidsforbrug samt rejseomkostninger som bør kunne bekostes af SVIB.

Mötessekreterare:
Anders Olsen

Justeringsmän:
Claes Fredö Per-Olof Ekenberg

Middagen efter årsmötet

BALANSRAPPORT BAS96 BFL

Skandinaviska Vibrationföreningen

Utskriftsdatum: 11-11-11 15:00 /carolina
Räkenskapsår: 1009 - 1108
Period: 10-09 - 11-08
Balansrapp BAS96 BFL

Konto	**Namn**	**IB År**	**Ing saldo 10-09**	**Förändring**	**UB 11-08**
TILLGÅNGAR					
Omsättningstillgångar					
1020	Plusgiro Nordea	64 260,07	64 260,07	27 242,17	91 502,24
1040	Checkkonto SEB	100,00	100,00	13 752,70	13 852,70
1210	Kundfordringar	47 165,00	47 165,00	6 205,00	53 370,00
1300	Interrimsfodringar	0,00	0,00	1 975,00	1 975,00
Summa omsättningstillgångar		111 525,07	111 525,07	49 174,87	160 699,94
SUMMA TILLGÅNGAR		111 525,07	111 525,07	49 174,87	160 699,94
SKULDER OCH EGET KAPITAL					
Kortfristiga skulder					
2110	Leverantörskulder	-10 695,00	-10 695,00	4 445,00	-6 250,00
2210	Företagsskatt	6 098,00	6 098,00	-2 266,00	3 832,00
2220	Skattekonto	71,00	71,00	4 019,00	4 090,00
2481	Moms 2009/2010	-850,50	-850,50	0,00	-850,50
2482	Moms 2008/2009	-3 881,00	-3 881,00	3 881,00	0,00
Summa kortfristiga skulder		-9 257,50	-9 257,50	10 079,00	821,50
Långfristiga skulder					
2790	Avräkning utlägg	0,00	0,00	-99,00	-99,00
Summa långfristiga skulder		0,00	0,00	-99,00	-99,00
SUMMA SKULDER		-9 257,50	-9 257,50	9 980,00	722,50
Eget kapital					
2990	Eget Kapital	-84 073,94	-84 073,94	0,00	-84 073,94
2999	Redovisat resultat	-11 873,01	-11 873,01	0,00	-11 873,01
Summa eget kapital		-95 946,95	-95 946,95	0,00	-95 946,95
BERÄKNAT RESULTAT		-6 320,62	-6 320,62	-59 154,87	-65 475,49
SUMMA SKULDER O EGET KAPITAL		-111 525,07	-111 525,07	-49 174,87	-160 699,94

RESULTATRAPPORT BAS96 BFL

Skandinaviska Vibrationföreningen

Utskriftsdatum: 11-11-11 15:01 /carolina
Räkenskapsår: 1009 - 1108
Period: 10-09 - 11-08
Resultatrapp BAS96 BFL

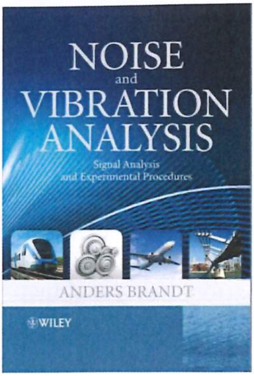
Konto	Namn	Per 11-08	%	Period fg år	Uppn	Ack År	%
RÖRELSENS INTÄKTER							
Försäljning							
3010	Medlemsavgift Sverige	92 950,00	78	18 000,00	516	92 950,00	78
3011	Medlemsavgift EU	14 300,00	12	24 665,00	58	14 300,00	12
3012	Medlemsavgift Export	8 800,00	7	0,00	0	8 800,00	7
3020	Medlemsavgift Pensionär Sverige	2 520,00	2	0,00	0	2 520,00	2
Summa försäljning		118 570,00	100	42 665,00	278	118 570,00	100
SUMMA RÖRELSEINTÄKTER		118 570,00	100	42 665,00	278	118 570,00	100
Material och varor							
4012	Hed o Pens 2005 ideell	0,00	0	-10 695,00	0	0,00	0
Summa material och varor		0,00	0	-10 695,00	0	0,00	0
BRUTTOVINST		118 570,00	100	31 970,00	371	118 570,00	100
Arbetskraft							
5329	Mat o logi	0,00	0	1 650,00	0	0,00	0
5330	Mat o Logi ideell	-2 205,60	-2	1 650,00	-134	-2 205,60	-2
5510	Resekostnader	0,00	0	1 699,00	0	0,00	0
5511	Resekostnader ideell	0,00	0	1 699,00	0	0,00	0
Summa arbetskraft		-2 205,60	-2	6 698,00	-33	-2 205,60	-2
Övriga kostnader							
6700	Bokföringskostnad	0,00	0	-4 200,00	0	0,00	0
6701	Bokföringskostnad ideell	-18 750,00	-16	-7 250,00	259	-18 750,00	-16
6750	Främmande tjänster	0,00	0	-5 040,00	0	0,00	0
6751	Främ tjänster ideell	-33 128,00	-28	-8 627,50	384	-33 128,00	-28
6850	Porto	0,00	0	-567,00	0	0,00	0
6851	Porto ideell	0,00	0	-978,75	0	0,00	0
7171	Representation	-900,00	-1	0,00	0	-900,00	-1
7172	Representation ej avdragsgill	-2 100,00	-2	0,00	0	-2 100,00	-2
7690	Övriga kostnader	-475,50	-0	-200,21	238	-475,50	-0
7691	Övriga kostnader ideell	-2 375,00	-2	-275,79	861	-2 375,00	-2
Summa övriga kostnader		-57 728,50	-49	-27 139,25	213	-57 728,50	-49
RÖRELSENS KOSTNADER		-59 934,10	-51	-31 136,25	192	-59 934,10	-51
RESULTAT FÖRE AVSKR		58 635,90	49	11 528,75	509	58 635,90	49
Finansiella intäkter/kostn							
8050	Ränteintäkter kundfordringar	9,00	0	0,00	0	9,00	0
8180	Valutakursförluster	-84,73	-0	0,00	0	-84,73	-0
8190	Övriga finansiella kostnader	2,70	0	0,00	0	2,70	0
Summa finans intäkter/kostn		-73,03	-0	0,00	0	-73,03	-0
RESULTAT FÖRE SKATT		58 562,87	49	11 528,75	508	58 562,87	49
Skatter							
8910	Skatteskuld 2009/2010	0,00	0	-3 176,00	0	0,00	0
8912	Skatteskuld 2008	592,00	0	1 717,00	34	592,00	0

Under 2011 har vi delat ut den Guldaccelerometer som tilldelades H P Wallin och Kent Lindgren för deras insatser med att bygga upp MarcusWallenberglaboratoriet, KTH. Med vid ceremonin på Marcus Wallenberglaboratoriet var, förutom pristagarna, donatorn Anders Åhlström PCB, Elisabet Blom SVIB och Torbjörn Kloow SVIB. Efter en trevlig pratstund med HP och Kent fick vi en trevlig rundtur på laboratoriet.

SVIB vill tacka PCB bidraget till utmärkelsen.

Noise and Vibration Analysis: Signal Analysis and Experimental Procedures

Review of a new textbook, Brant A, 1st edition 2011, J Wiley and Sons (ISBN 978-0-470-74644-8)



First, it is a true pleasure to review a good textbook on noise and vibration technology written by a Scandinavian author with a strong reputation as an excellent teacher. Anders Brant is renowned for teaching hard digested subjects, as practical measurements of random data or frequency response functions, digital signal processing and analysis, modal analysis and other advanced experimental methods, in a readily accessible manner. The book is well bound with 400+ pages of relevant content. It is accompanied by a downloadable toolbox and examples, which were however not present at the announced website at the time of this review. I got a sample of the software from the author and it is really ambitious with script variants for Matlab as well as the free Octave.

In addition to student needs, it seems also to be quite valuable for practicing engineers who e.g. may want to experiment with the influence of different signal processing parameters. Do we need another book that covers test-based noise and vibration analysis and procedures, and what is then missing in existing textbooks? As the author points out, the book is aimed as compre-hen¬sive literature for university graduate courses on the subject and he hopes that it also will be a useful handbook for engineers and researchers measuring and analyzing noise and vibration signals. The first five chapters (115 pages) are introductory content necessary for a course book and probably well known to practicing experimentalists: 1) Introduction, 2) Dynamic signals and systems, 3) Time data analysis, 4) Statistics and random processes and 5) Fundamental mechanics.

Although this is basic content, Anders Brant makes some usually rather difficult theory easily understandable like the discussion on convolution in Chapter 2 or the thorough discussion in Chapter 3 on the fundamental properties of digital time data analysis. Although well known and subjects learnt decades ago, I actually found those chapters very entertaining to read.

A large part of the book treats measurement of frequency response functions and modal analysis. Theory of modal analysis is presented in Chapter 6, which is a well written and explained summary of the most important basics of modal analysis. It is a good introduction to experimental as well as computational modal analysis of dynamical systems with references to some classic textbooks. More advanced aspects of experimental modal analysis are saved to the last chapter of the book.

Transducers are introduced in Chapter 7 including accelerometers, force transducers, the impedance head, the instrumented impact hammer and shakers. Principles as well as calibration and mounting of accelerometers are commented. It is when I read this chapter that I start to suspect that the book will cover more of vibration than acoustic (noise) analysis. Measurement microphones are treated in less than one page and I found the first minor detail where I disagree with the author which is the short note on calibration of microphones. Latest accredited calibration values should be used and the procedure presented in the book shall be used only to check the microphone calibration. The same applies to the use of portable, handheld accelerometer calibrators.

Chapters 8-10 are a "must read" even if you think you know everything you need to know about the frequency analysis of signals. It starts ground up with the theory for periodic, random and transient signals and proceeds with a very thorough treatise on experimental, digital frequency analysis including DFT, FFT, leakage, the picket fence effect, time windows, corrections for applied windows, oversampling, circular convolution, aliasing and estimation of spectra and correlation functions in great detail. Again, the presentation is a good mix of practical consequences and theoretical details.

Chapter 11 is a short, neutral discussion about commercial measurement and analysis systems and general specifications for good test systems.

Chapter 12 treats rotating machinery analysis, and introduces the use of tachometers, order analysis and tracking including synchronous sampling, again easily understood.

The Vold-Kalman filter method is shortly commented but the reader has to get more details from the references.

Frequency response measurements are treated in Chapter 13 and 14, single-input and multiple-input respectively. This is one of the very strong and detailed parts of this book and fills 65 pages. The theory and practical measurement issues are comprehensively discussed and well illustrated both using impact hammer and shaker excitation.

Chapter 15 introduces Principal Component Analysis as a technique to orthogonalize signals from different sources as well as their use for data reduction with a very nice and illustrative example of image compression by using only the largest principal components. Virtual signals and virtual coherence functions are introduced and typical use for noise source identification with an automotive example is given.

The final Chapter 16, "Advanced Analysis Methods" includes short introductions to various subjects not treated previously, like shock response spectra, the Hilbert transform, Cepstrum analysis, the envelope spectrum, operating deflection shapes and a very short introduction to experimental modal analysis methods for the identification of modal parameters.

So what are my main impressions? I think it is a very good and up to date course book for advanced signal analysis and vibration measurement classes on graduate level. Maybe it is a bit heavy for undergraduate courses. It is of course also well suited as a textbook for advanced, comprehensive courses for practicing engineers. It is also good reading for everyone that makes this type of measurements professionally.

Do I miss anything essential? Well, I think it is the special analysis techniques and procedures that need be used in acoustics. An acoustic cavity (e.g. a room) is typically a dynamic system with many overlapping modes already at relatively low frequencies. The high generic variability of detailed system properties like e.g. frequency response functions was realized by acousticians already in the 1950's and has to be understood also today especially when properties of ensembles of "identical" objects are needed. This inherent uncertainty seems not to be well known among practicing engineers, especially those who entered the field with a structural dynamics background. This large uncertainty is the main reason why vibro-acoustic systems are preferably analyzed and tested at higher frequencies with methods different than the ones covered by this book. The book may eventually be disappointing for a reader who is more interested in noise issues than vibration analysis. Hopefully this void can be filled in a future edition of this book.

Göteborg 2011-07-07

Juha Plunt PhD, Principal Specialist, Müller-BBM Scandinavia AB

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M+P–consulting engineers bv is an internationally active company, based in the Netherlands. Its services cover the fields of noise, vibration and air quality aspects of industry, building and road, rail and air transport. Their competences are research, development and project based consultancy.

MÜLLER-BBM
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Müller-BBM VibroAkustik Systeme GmbH develops multi-channel measurement technology and provides solutions for any application involving measurement of vibration and acoustic signals. The main product, PAK, is an all-modular platform consisting of a front end series and the corresponding software. Vehicle manufacturers and suppliers as well as the aeronautics and space industry have been using the system to collect, analyze, and evaluate dynamic data.

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Is a consulting and engineering company specialized in acoustics and vibration in the fields of buildings, environment and technology. Deep consulting expertise in the automotive industry and other industrial sectors distinguish the company. The consulting engineers will also be happy to answer any questions regarding Müller-BBM VibroAkustik Systeme's PAK system and its uses.

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