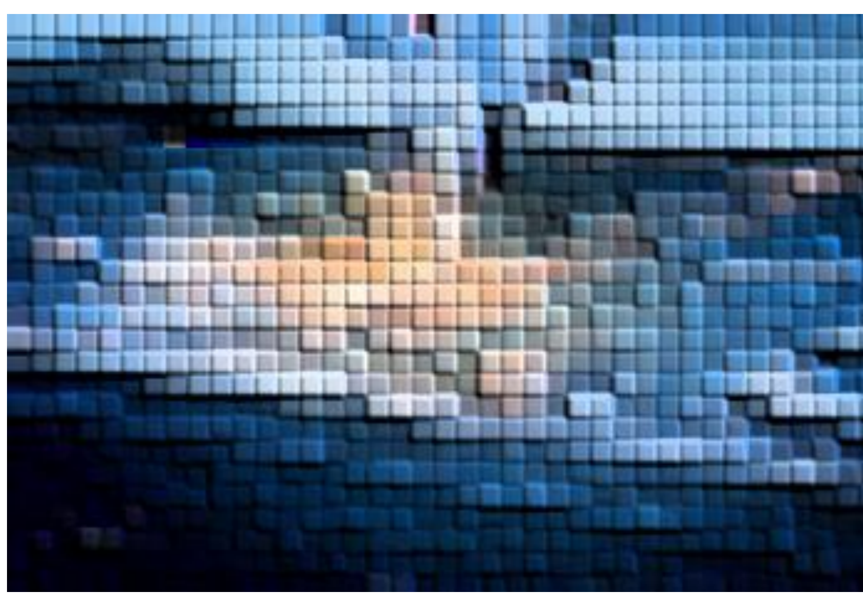
SEQUOIA
Smart Solutions for Vibration Monitoring

OMA on Machine Tool

Output-Only Modal Analysis to
a Machine Tool



The Power of Knowledge Engineering

ABSTRACT

This Report present the application of classical FEM modal analysis and output-only Modal Analysis techniques (Stochastic Subspace Identification SSI,Frequency Domain Identification FDD and Enhanced Frequency Domain Decomposition EFDD) to a Machine Tool. It will be shown that the numerical analysis is only the first project approach in designed process. This is because, in FEM model, is impossible recreated the real situation the machine and FEM analysis has fundamental simplification for solve equation.

While the output-only modal analysis from operational vibration data provide the real dynamic behavior of the machine that directly influencing the results.

From operational data an additional mode of vibration was identified that could not be extracted by the utilized classical modal analysis techniques. It was revealed that this mode of vibration was nonstructural and that it was caused by the drives and the control system of the Machine Tool. Furthermore, this nonstructural mode could directly be linked to imperfections of the production results for specific machine movements. **The results that we will show in this document will normalization to reference frequency and photo will pixelated for protecting customer data.**

THEORY OVERVIEW

In the following the theory of the applied output-only modal analysis techniques will be summarized. The FEM analysis techniques are well known and will not be presented.

Frequency Domain Decomposition - FDD

The Frequency Domain Decomposition technique is an extension of the classical frequency domain approach referred to as the Basic Frequency Domain or Peak Picking technique. For the classical technique modes of vibration are directly extracted from the power spectral density matrix of the measured responses at the resonance peaks, while it is required that the modes of vibration are well separated. Of course, this is not always the case.

The power spectral density matrix, that can be estimated easily for instance via Fast Fourier Transformation, is also utilized by the Frequency Domain Decomposition technique. However, in contrast to the classical technique, it is not directly processed, but decomposed by applying the Singular Value Decomposition at each spectral line. Proceding this way decomposes the power spectral density matrix into auto spectral density functions of single degree of freedom systems.

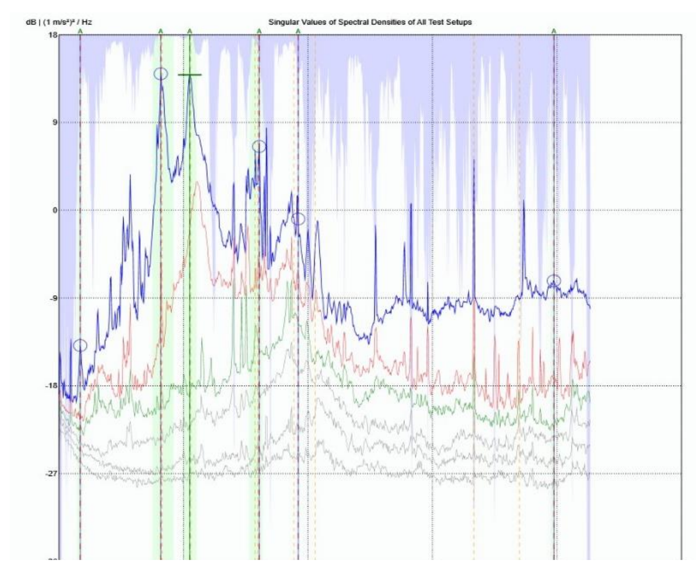


Figura 1 Example of FFD

Enhanced Frequency Domain Decomposition - EFDD

The Enhanced Frequency Domain Decomposition (EFDD) technique is an extension to the Frequency Domain Decomposition (FDD) technique. FDD is a basic technique that is extremely easy to use. You simply pick the modes by locating the picks in SVD plots calculated from the spectral density spectra of the responses. Animation is performed immediately. As the FDD technique is based on using a single frequency line from the FFT analysis, the accuracy of the estimated natural frequency depends on the FFT resolution and no modal damping is calculated. Compared to FDD, the EFDD gives an improved estimate of both the natural frequencies and the mode shapes and also includes damping.

Stochastic Subspace Identification - SSI

In the Stochastic Subspace Identification (SSI) techniques a parametric model is fitted directly to the raw times series data. A parametric model is a mathematical model with some parameters that can be adjusted to change the way the model fits to the data. In general, we are looking for a set of parameters that will minimize the deviation between the predicted system response of the model and measured system response (measurements). This process is often called model calibration. See the following picture 2. All known linear and time-invariant time domain modal identification techniques can be formulated in a generalized form as an innovation state space formulation

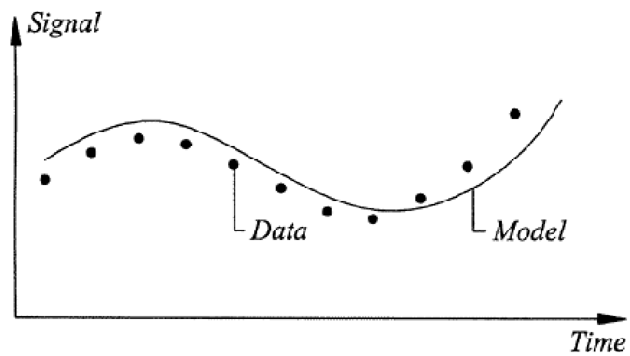


Figura 2 SSI

$$\hat{\boldsymbol{x}}_{t+1} = \boldsymbol{A}\hat{\boldsymbol{x}}_t + \boldsymbol{K}\boldsymbol{e}_t$$
$$\boldsymbol{y}_t = \boldsymbol{C}\hat{\boldsymbol{x}}_t + \boldsymbol{e}_t$$

where the A-matrix contains the physical information, the C-matrix extracts the information that can be observed in the system response and the K-matrix contains the statistical information. The statistical information allows for a covariance equivalent modeling, so that the model can have the correct correlation function and thus also the correct spectral density function.

APPLICATION

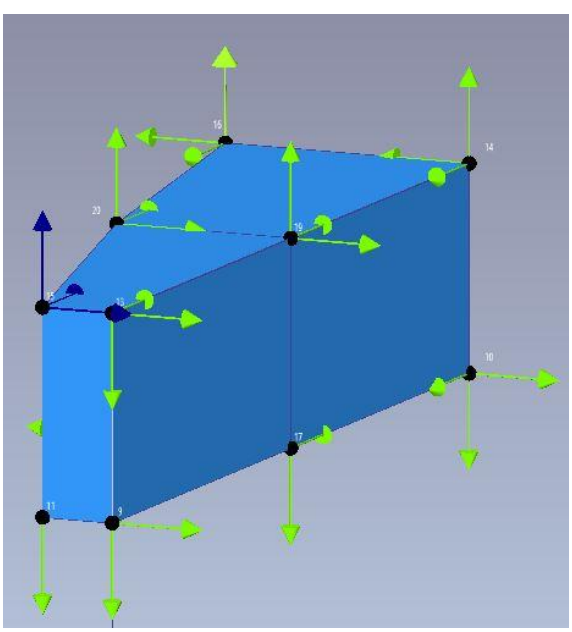


Figura 3 OMA Model

For investigate behavior of the machine under vibration view is was conduce 4 set of measure. In which two triaxial points is was define how reference for other set up measures.

Three types of analysis were carried out on the measures:

- FFD;
- EFFD;
- SSI.

This is to make the model validation process possible by comparing the three types of analysis.

The model for OMA is was does using Artemis Modal SW in which we have use 14 point for modeling the structure and 60 measure of vibration. Let you show model in figure nearly.

FEM Model

The data obtained by mathematic modelling of the element under investigation are reported as reference. The modeling was performed with SW Ansys in which the main elements of the structure were modeled.
I report later the first 3 modes of vibrating structure in the configuration "Y+".
Let's see how the first modes are very close and it is difficult to say which is the prevailing one without having data on the mobilized mass. So we will take as benchmark the mode with the lowest frequency.

N°	[Hz]
1	0.234
2	0.24
3	0.288

Figura 5 FEM Vibration Modes

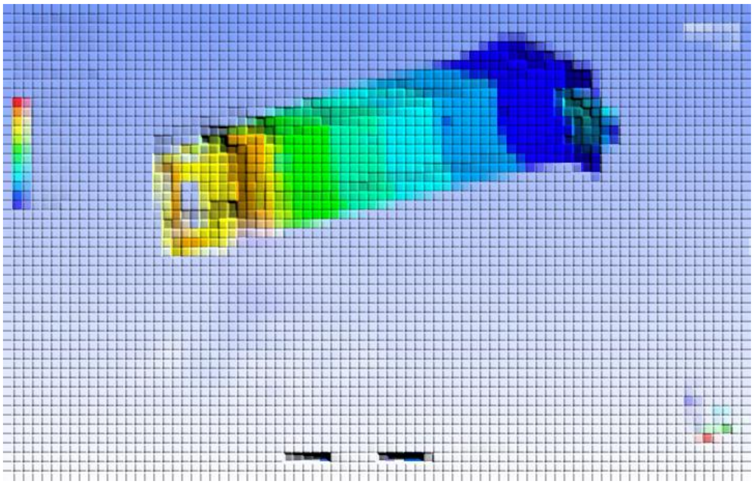


Figura 4 FEM Model

RESULTS

We briefly report in Figure 6 show the results obtained through the 3 techniques reported above. We observe how a modes of vibrating with a lower frequency (0.164 Hz) is identified respect that identified through the FEM analysis. Around 0.234 Hz, on the other hand, we find similarities with the FEM model both in terms of frequency and in terms of modal form.

SSI			EFFD			FFD	
Frequency [Hz]	Damping [%]	Complexity [%]	Frequency [Hz]	Damping [%]	Complexity [%]	Frequency [Hz]	Complexity [%]
0.164	2.399	0.54	0.164	2.356	0.77	0.034	82.999
0.211	2.219	4.553	0.211	2.095	9.741	0.163	0.436
0.315	2.087	30.191	0.319	0.967	29.549	0.210	8.226
0.333	2.931	33.356	0.377	0.939	40.955	0.321	33.18
0.565	0.382	56.92	0.795	0	62.148	0.384	68.32
0.666	0.174	95.88				0.795	61.793
0.739	1.735	82.947					

Figura 6 OMA Results

CONCLUSION

With this brief analysis it was possible to show that at a frequency of about 0.164 Hz is the first frequency proper to the investigated structure. The mode of vibrating mainly affects the Z axis of the machine, causing a slight torsion of the element supporting the arm on which the spindle is installed.
In the light of this, we therefore recommend an in-depth study among the interested parties to investigate what the real behavior of the machine under real operating conditions. Evaluate how experimentally identified modes can influence the quality of the process.

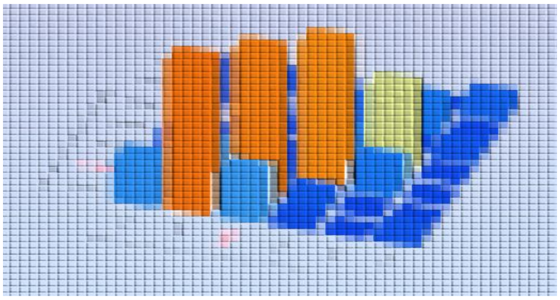


Figura 7 MAC FFD-SSI

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