Torsional Vibration Analysis in ArtemiS

Irregular rotations or "torsional vibration" of rotating systems, can lead to a significant impairment of the subjective quality impression of a product, or even indicate a possible defect. In addition to the usual airborne and structure-borne sound analysis, ArtemiS can be used to evaluate torsional vibration in the time and frequency domains.

Introduction

The precondition for making such an analysis is an RPM recording in a separate analog channel with a sufficient number of pulses per revolution, which means a sufficiently high sampling rate. Such a signal can be measured, for example, with a magnetic sensor mounted radially to a gear wheel (see figure 1). The number of teeth of the gear wheel chosen for the measurement should be more than twice the maximum order to be measured. For example, if the signal needs to be analyzed up to the 60th order, the gear wheel must have more than 120 teeth. The sampling rate should be chosen so that at least 5 or 6 sample values are measured for each tooth. For proper analysis, the signal must be approximately sine- or triangle-shaped and must not have a constant or DC component.

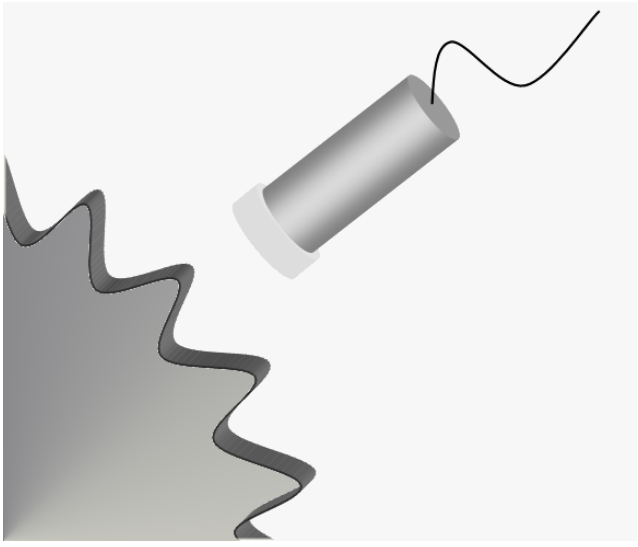


Figure 1: Schematic of the measurement setup for measuring rotary irregularities

In order to apply the analysis functions available in ArtemiS to the RPM signal, the signal must be pre-processed. This is done using the *Speed vs. time* function in the Filter Pool. It is possible to pre-process and analyze in one step.
A measurement setup as shown in figure 1 delivers a sine-shaped signal, which is digitized and saved. Figure 2 shows an example of such a signal.

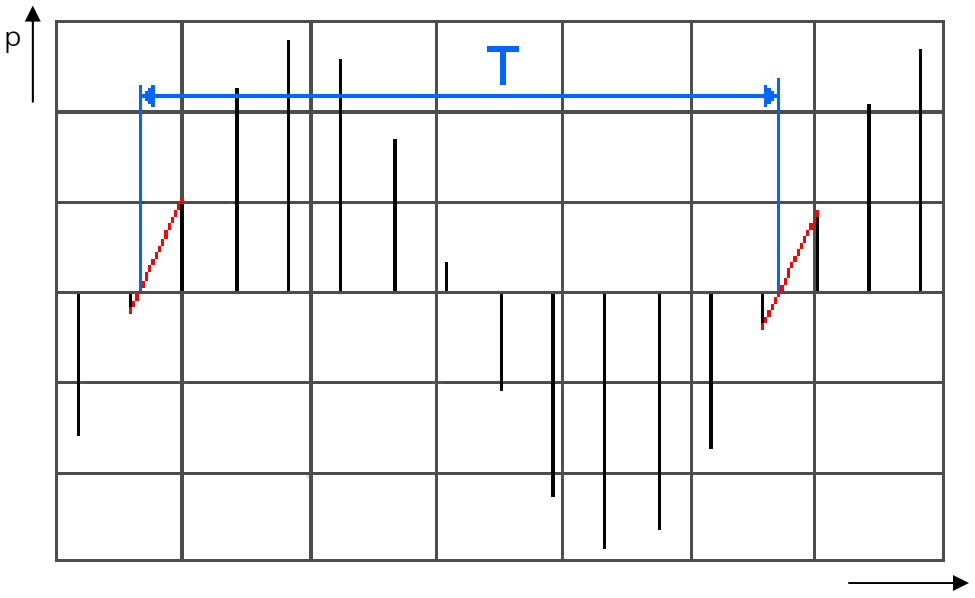


Figure 2: Schematic of an RPM signal for torsional vibration analysis

One period length corresponds to one tooth on the gear wheel. The *Speed vs. time* function scans the signal for zero crossings with a positive slope. Afterwards, the exact position of the zero crossing is determined by interpolating between the sample values (see figure 2). From the period length T between two zero crossings and the number of teeth on the gear wheel used in the measurement, the current RPM value can be calculated:

$$\text{current RPM} = \frac{1\,\text{min}}{\text{T[in minutes]} \cdot \text{number of cogs on the gear wheel}}.$$

The number of teeth is entered in the *Edit Pulse Factor* menu in the field "*Impulses per Revolution*" (see figure 3).

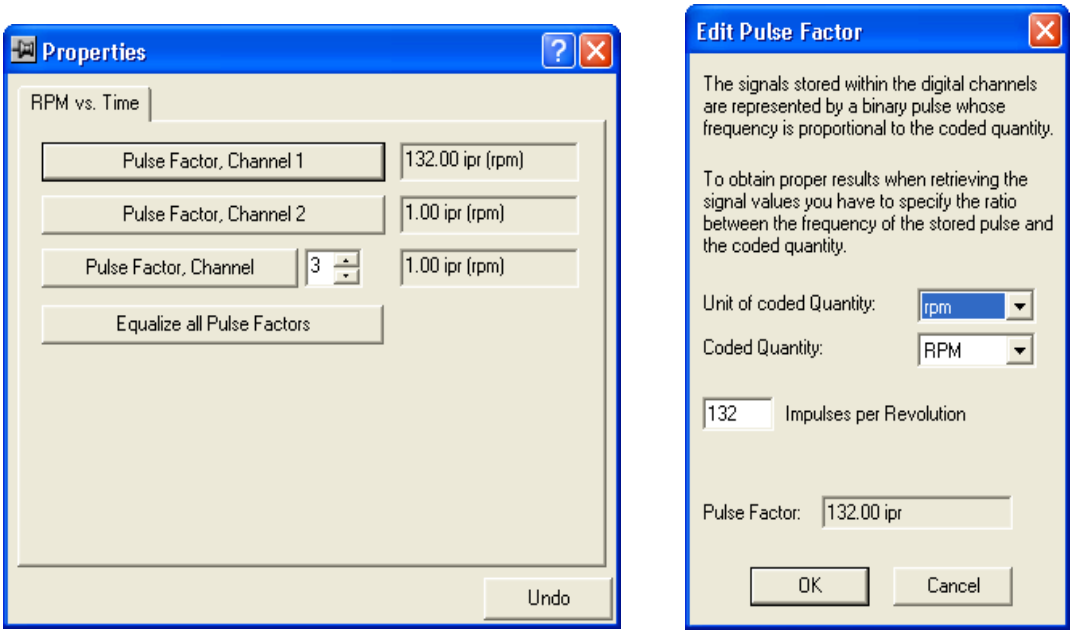


Figure 3: Properties dialog of the *Speed vs. time* function (left) and *Edit Pulse Factor* menu (right)

The *Edit Pulse Factor* menu is opened by clicking on the *Pulse Factor* button in the *Properties* dialog of the *Speed vs. time* function. In this menu, the pulse factor and the desired output units for the signal can be specified. In addition to [rpm], other units such as [°/s] for angular speed are available as well.

Application Example

In ArtemiS, first the signal to be analyzed, containing the high-resolution RPM data, is inserted into the Source Pool, and the *Speed vs. time* element is inserted into the Filter Pool of a project. Depending on the selected unit, the corresponding title of the *Speed vs. time* element in the project appears; in the example below, it is *RPM vs. time*.

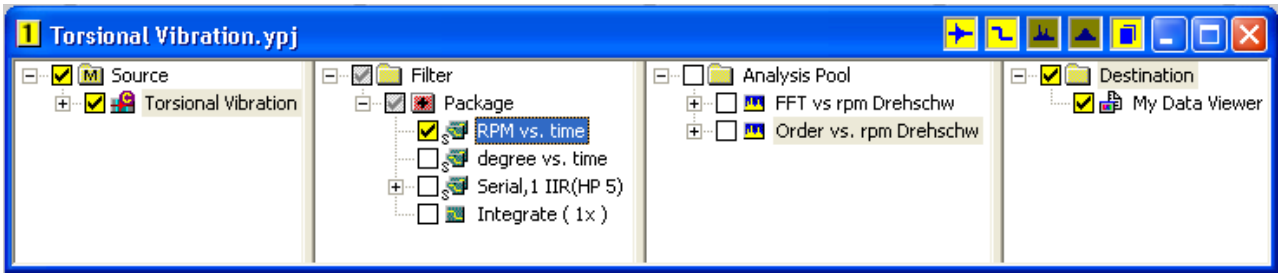


Figure 4: ArtemiS project for torsional vibration analysis

If no analysis is selected in the project, clicking on the *Calculate* button will display the RPM curve in the *Data Viewer* as shown in figure 5.

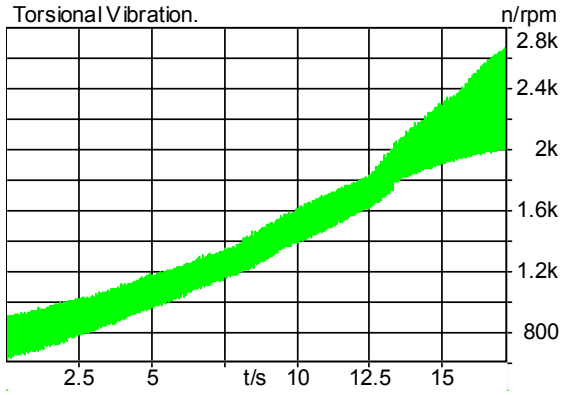


Figure 5: RPM vs. time

In order to calculate the angular speed rather than the revolution speed, the unit [°/s] must be selected instead of [rpm] in the *Speed vs. time* element in the Filter Pool. In that case the title of the element in the project will be "*degree vs. time*". For figure 6, the RPM curve from figure 5 was converted into the time-dependent angular speed.

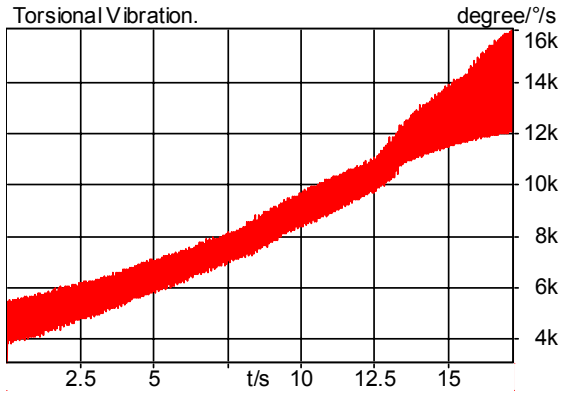


Figure 6: Angular speed vs. time

In many cases, the user is only interested in the variable component of the revolution speed or angular speed. Using a simple high-pass filter (e.g. at 5 Hz), the constant component can be filtered out. Figure 7 shows the angular speed from figure 6 without the constant component. For this result, the *Speed vs. time* function with the unit [°/s] and the 5 Hz high-pass filter were used together as a *package* in the Filter Pool.

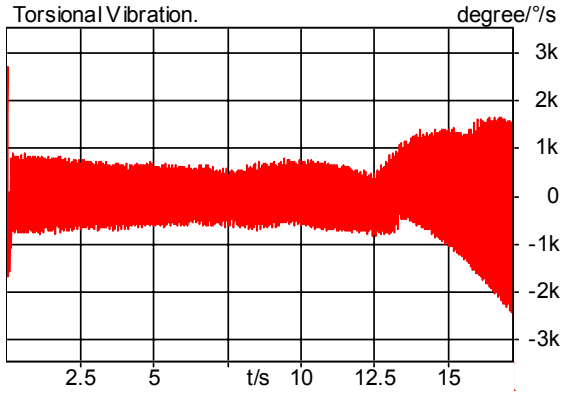


Figure 7: Angular speed vs. time without constant component

More importantly, each of the signals shown in figures 5 to 7 can also be subjected to the desired analyses. Frequently used analysis functions in this context are the *FFT vs. rpm* and the *Order vs. rpm* analysis. In order to perform such an RPM-dependent analysis, it makes sense to record not only the high-resolution RPM signal, but also a simple RPM signal via the pulse input. (If necessary, a frequency divider can be used to reduce the high-resolution signal to the maximum allowed pulse frequency of the pulse input).
The figures 8 and 9 show the results of the *FFT vs. RPM* analysis and the *Order vs. RPM* analysis of the angular speed shown in figure 7. The results show the variations of the angular speed over time, i.e. the torsional vibration. In this example with 132 pulses per revolution, aliasing effects occur above the 61st order (see figure 8, above approx. 2 kHz).

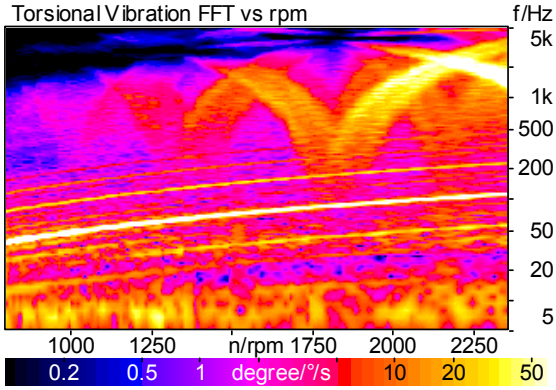


Figure 8: *FFT vs. RPM* analysis of the angular speed from figure 6

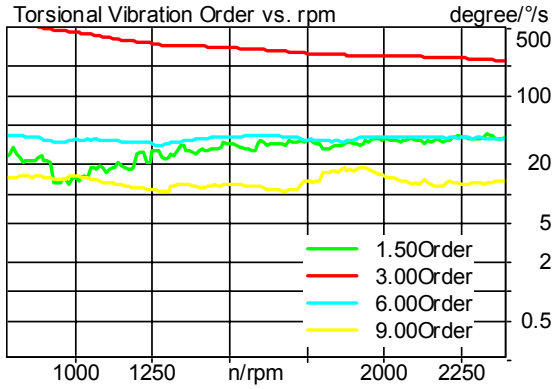


Figure 9: *Order vs. RPM* analysis of the angular speed from figure 6

In the *package* in the Filter Pool, an additional function called "*Integrate*" can be selected. When activated, this function integrates the angular speed before the analysis, thus determining the rotation angle φ. Figure 11 shows the rotation angle.

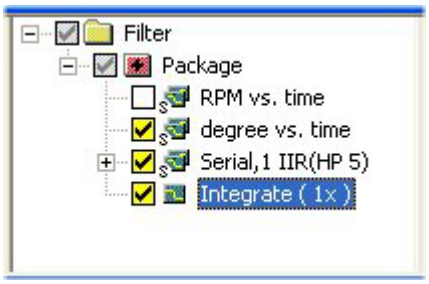


Figure 10: Filter Pool with a *package* containing a *Speed vs. time* element with the unit [°/s], a 5 Hz high-pass filter, and an integration element

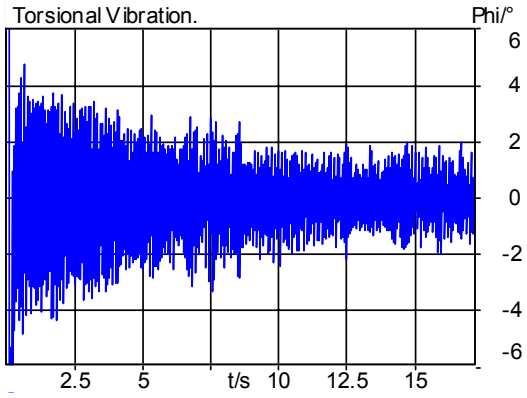


Figure 11: Rotation angle vs. time without constant component

A comparison between the results of torsional vibration analysis made with ArtemiS and those from more costly specialized systems has shown that the analysis results match very well.

Note

In order to use the features presented in this application note you will need the ArtemiS Basic version (Code 4600) and the ArtemiS Signature Analysis Module, ATP 03 (Code 4603).

Do you have any questions or remarks? Please write to: Application-Notes@HEAD-acoustics.de.
We look forward to receiving your response!