Investigating of the effects of sampling parameters

Measurement technique of process (BMEVGAG03)

1. *Aim of the measurement*

The aim of the laboratory measurement is to determine the necessary and sufficient sampling parameters such as the sampling frequency and sampling interval by measuring pressure with a transducer (which is built in at the pressure side of a centrifugal pump).

2. *Description of the measurement*

One of the most common methods for analysing a measured signal is the spectral analysis. In order to achieve relevant results from the measured signal with using spectral analysis, the first, important step before the measurements is to determine the sampling frequency ($\mathbf{f_m} = \frac{1}{\Delta t}$), and sampling interval ($\mathbf{T} = N * \Delta t$). From the Shannon-Nyquist sampling theorem the sampling frequency is necessary two times higher than the highest frequency component (f_{max}) of the original signal. Although in the practice it is usually: $f_m = 3 - 5 * f_{max}$.

In our measurement we will see the effects of the sampling parameters on a signal recorded by a pressure sensor, which is installed at the pressure-side of the centrifugal pump. The pump delivers water by a given operating point (steady revolution number, steady flow rate). Two sets of the measurements will be performed: 1) measurement at given constant sampling frequency where the interval changes, 2) in the opposite way (constant interval, changing frequency). The pressure signal of a centrifugal pump-delivered pipe system typically contains: a frequency component resulting from the revolution number, it's harmonics, furthermore a component according to the number of the blades (blade number x revolution number). The signal also contains other flow induced components and some random noise too. At every adjusted sampling setting we take measurements repeatedly, than the evaluation program calculates the average. Afterwards the program makes a Fast-Fourier Transformation and draws the spectrum of the pressure signal.

A typical spectrum is shown on Figure 1. The first peak, which corresponds to the revolution number (1200 1/min) is properly at 20 Hz. After this can be seen the harmonics, these peaks appear at frequency values of multiplies of the 20 Hz. The measured pump has 7 blades so the next recognizable peak is at 7x20 Hz= 140 Hz. In addition there are some significant peaks at 220-240 Hz.

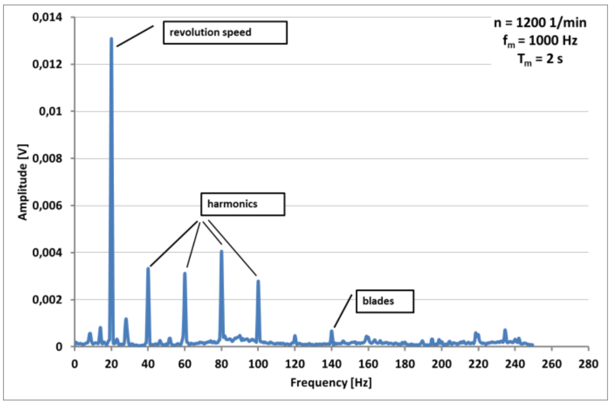

Figure 1.: the spectrum of a typical pressure signal calculated by FFT

3. The measuring system

The sketch of the system is shown on Figure 2. A BMS 25/48 type centrifugal pump (S) is integrated to the system, the suction side of the pump connects to a water tank. On the vertical pressure side there is a built-in Hottinger Baldwin Messtechnik 132.17 type pressure transmitter (P) with the measuring range of 0-10 bar. The signal of the pressure transducer goes to Hottinger KWS 3072 type signal processing system (J), from there towards to the computer. We calculate the average of the signals and do the FFT with own data acquisition program implemented in LabView software.

After starting the pump we set the revolution number to 1200 1/min. We open up fully the throttle valve (T) to get the maximum flow rate. (We keep this operating point throughout the whole measurement.)

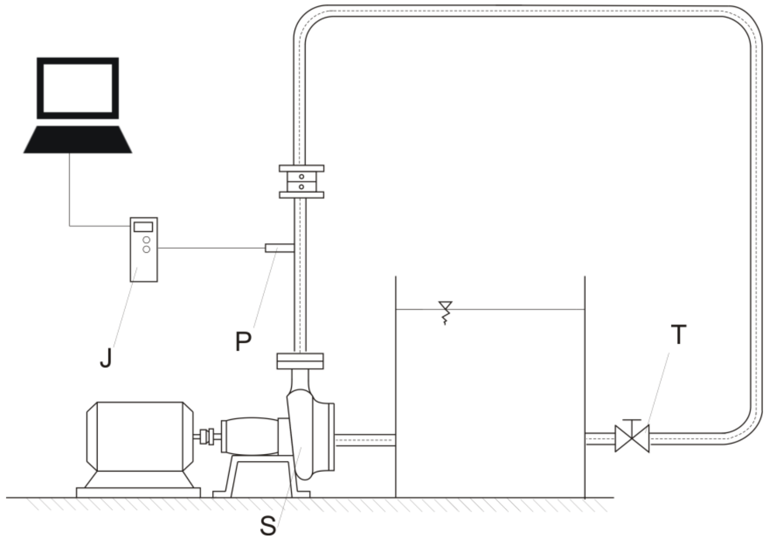

Figure 2.: The test rig
(S: pump, P: pressure transducer, J: signal processing system, T: valve)

4. Measured quantities, processing the results

A ".txt" file is the result of each measurement, which contains the spectrum (FFT results) in [frequency, amplitude] format.

The two sets of the measurements:

1) At given sampling frequency f_m = 1000 Hz we changes the measured interval (between 0,05-5s). This can be achieved by changing the number of the fixed points (N) in the data acquisition LabView software.

   Having longer intervals we will notice (Figure 3.), that the resolution of the signal spectrum becomes better; but after a limited frequency increasing towards of N will not result better resolution (Figure 4.). The task is to determine this minimal interval what is necessary to have a suitable resolution at the interesting part of the spectrum (under 300Hz) by applying this given 1000 Hz sampling frequency.

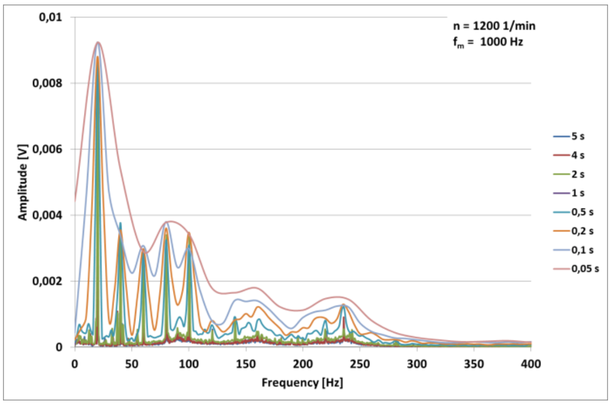

Figure 3.: The effect of changing the sampling interval on the spectrum 1.

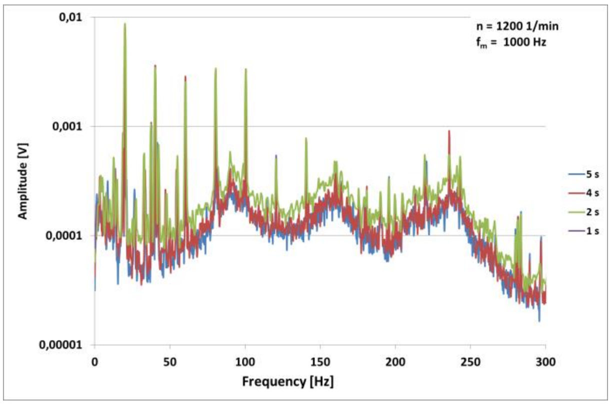

Figure 4.: The effect of changing the sampling interval on the spectrum 2.

2) This time the sampling interval will be fixed T = 2s and we change the frequency (between 250-5000 Hz).

   At lower sampling frequencies it can be observed that the spectrum still not contains the interesting frequency range fully. Increasing the frequency we can achieve the resolution which provides us a suitable spectrum. As the last time it can be recognized that we will have an upper limit, further increase will not give any more significant information about the spectrum. The task is to determine this sampling frequency that gives a spectrum with good resolution on a wide enough frequency range.

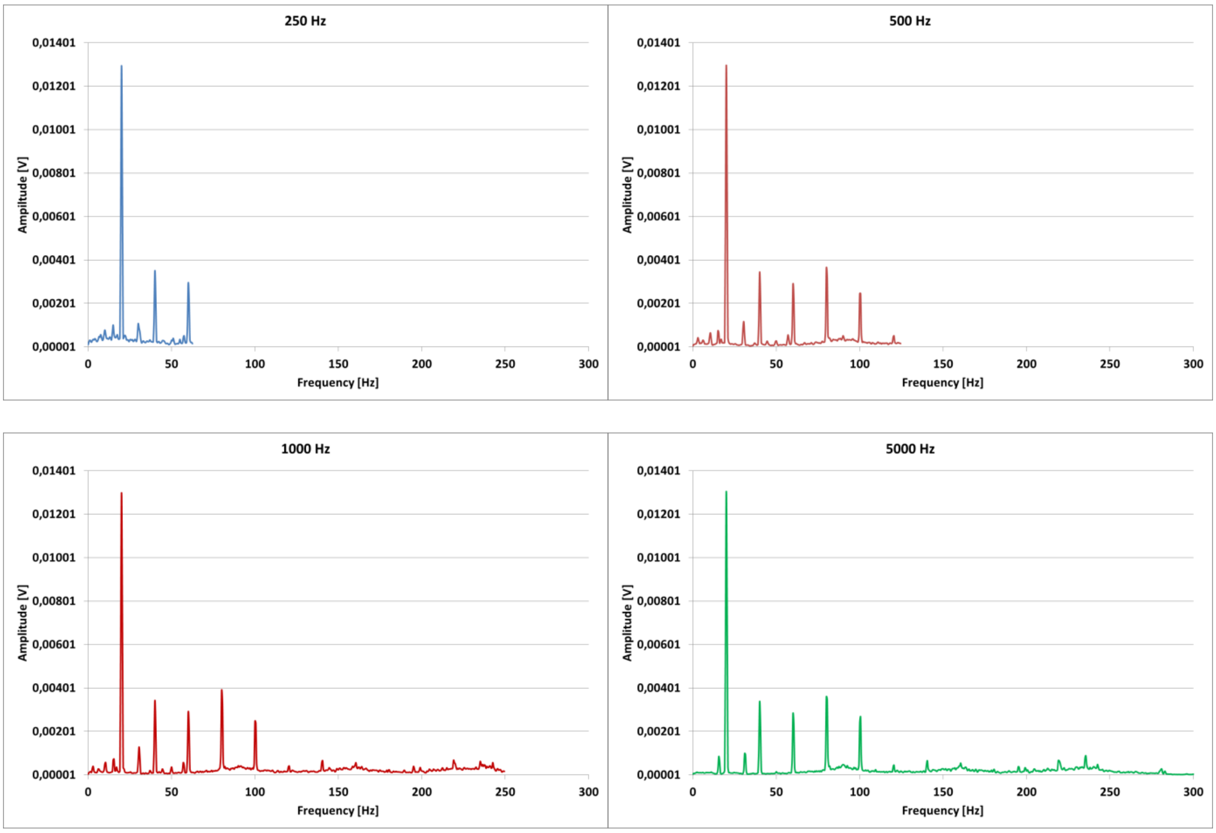

Figure 5.: The effect of increasing the sampling frequency on the spectrum

5. Questions

- Fraise briefly the essence of Shannon-Nyquist sampling theorem!
- Describe briefly the FFT (Fast Fourier Transformation) method!
- Draw a sketch about a typical spectrum a) in case of a function which is a sum of harmonic functions, b) in case of random noise!
- What kind of characteristic frequency components are presumable by measuring a centrifugal pump? Please visualize your answer with a sketch!
- Demonstrate the effect of increasing the measured time interval on the signal spectrum (at fixed sampling frequency)!