

## CONNECTION BETWEEN VIBRATION AND NOISE SIGNALS IN CONDITION MONITORING SYSTEMS INVESTIGATION

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**Abstract:** This paper proposes a procedure to diagnose the technical condition of machinery and industrial equipment based on a simultaneous acquisition of vibration and noise signals. This new procedure assures the elimination of the factors that hide the defects. The aim is to acquire new knowledge in manufacturing process control, by using dynamic signal processing and interdisciplinary knowledge. Machine vibration and noise component are present in the overall spectrum at a certain frequency, and the overall level of vibration or noises are useful parameters for early detection of faults. The experimentation procedure has been validated by results based on measuring the vibration and noise signals of the milling spindle of the First MCV300 machine.

**Keywords:** noise-vibration signals, maintenance decision.

### 1. Introduction

The vibration spectrum has to be coupled with investigations based on in-situ operation noise. This idea could create a new service, especially for users of industrial equipment in the construction of machine tools, advanced equipment, automotive and related equipment [1, 13, 14].

The objective of this technique diagnose is to make one of the following decisions [3]:

- The machine continues to operate without taking any action;
- Having made some planned maintenance actions over time;
- Having made an analytical diagnosis of the causes that can provoke machine tool accidents;
- The machine tool should be stopped immediately to avoid an imminent crash [2].

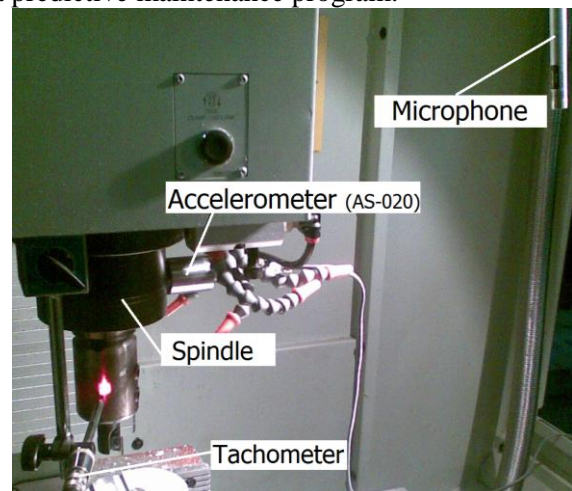
In normal operating condition assessment of a machine tool that stands out, the measurement for a single parameter is not enough. For example, in the medical field, there is not only a single variable that determines the health condition of a person, so in technical terms, only the individual signs of damage can be measured and a decision may be taken in general terms. The more obvious signs of damage are measured, the more accurate the assessment of the operating condition of the machine tool will be. Evaluation of operating conditions of a machine tool values by using the

levels of vibration and noise is the easiest and quickest way to make a diagnosis.

Requiring low cost, this method produces reliable results and generates information for an early recognition of faults and imbalances, optimal planning of maintenance and preventive action of damage or disruption of production processes [4, 5].

### 2. Experimentation on the machine tool spindle

Many companies around Europe implemented a predictive maintenance program.



**Figure 1:** Installing the sensors on vertical milling machine tool First MCV 300.

The maintenance program includes sets of experimental measurements, made by means of permanently installed sensors and periodic measurements made with ultra portable instruments.

Condition monitoring system could be put into practice using installed sensors (i.e. vibration and temperature-limited) or using periodically acquiring signals with a data logger or a combination of the two variants.

Figure 1 presents the machine tool used for experimentation. The frequencies characteristics of the sensors used for the experimentation have the useful domain 10 Hz – 10 kHz for this type of research on vibration/noise (AS-020 accelerometer and microphone unit type 4188-A-021).

The accelerometer was placed on the front of the spindle and the microphone was placed at 1 meter distance from the cutting tool.

Comparing general amplitude of vibrations recorded at regular intervals is possible using other specialized equipment (e.g. data collector 2526 of the company Brüel & Kjaer) to get another example of basic predictive monitoring program [8].

### 3. Analysis of the vibration and noise signals

The paper intends to bring new knowledge in manufacturing process control using dynamics signal processing and interdisciplinary knowledge in order to build in the future a predictive monitoring system for the machine tool [9, 10].

Predictive monitoring programs have three main objectives:

- Warning the potential defects in equipment with continuous monitoring systems;
- Monitoring the technical condition of the machine or equipment on the general level of vibration or noise;
- Early warning of defects that can remain hidden, using advanced features such as a CPB spectrum.

In order to eliminate environment noise signal during the measurements a filter was applied. Filter was conceived using mathematical average noise amplitudes for four signals acquired over time (Figure 2). This filter was applied to measure also the noise signal during the milling process of aluminum material in the following conditions:

- Cutting depth of 2 mm; milling tool with 2 inserts and diameter of 25 mm;
- Spindle speed equal with 6000 rpm.

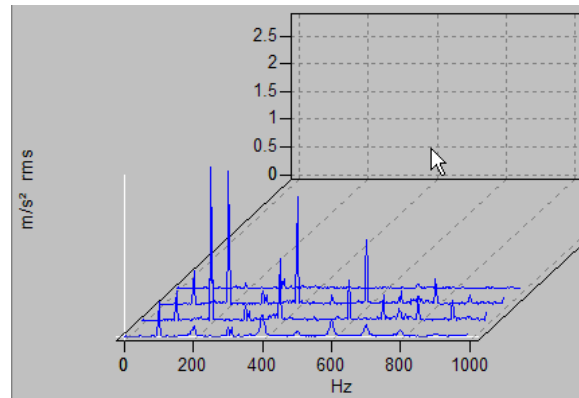


Figure 2: Frequency spectrum of vibration acceleration.

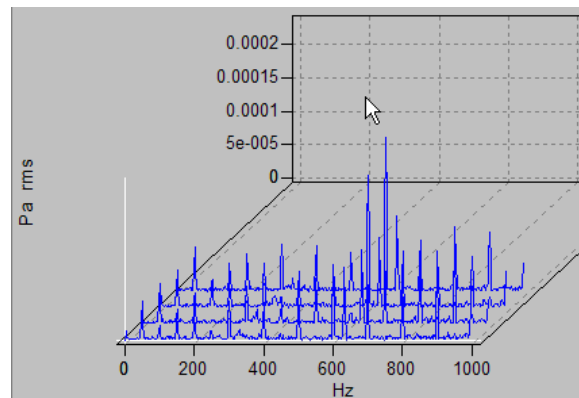


Figure 3: Frequency spectrum of noise signal.

Noise measurements were performed simultaneously with vibration measurements (Figure 3). The same number of signals (four) was acquired during time of 9 sec.

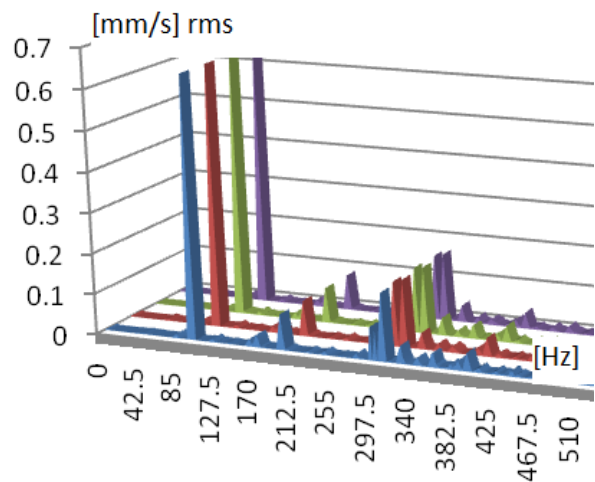


Figure 4: Samples vibration signal in frequency acquired periodically during 9 sec.

Figure 4 shows the filtered vibration signals acquired periodically at different time: 0; 3; 6 and 9 seconds respectively.

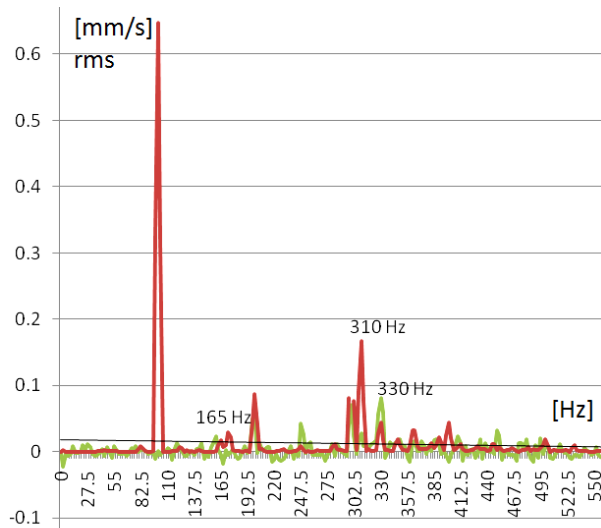


Figure 5: Overlap of the combined signals vibration-noise.

Vibration and noise signals, acquired simultaneously, were represented on the same graph in the Figure 5. By analyzing the graph the following remarks ensue:

- Frequency of 100 Hz corresponds with the spindle speed frequency that is 6000 rpm; it shows 3 peaks frequency of 165 Hz, 310 Hz and 330 Hz with both corresponding in the noise and vibration spectrum;
- The frequency of rotation of the spindle is not present in the noise output signal.

The results are based on the autocorrelation of two signals  $R(\tau)$  by using the equation (1):

$$R(\tau) = \lim_{T \rightarrow \infty} \frac{1}{T} \int_0^T y(t)y(t + \tau)dt \quad (1)$$

White noise type signals lose their correlation when  $\tau$  departs from 0. As a threshold matter, a sinusoidal signal  $y(t)=A*\sin(\omega t+\varphi)$  reaches peaks of autocorrelation for  $\tau$  values equal to the period of the sinusoidal signal  $R(\tau)=(A^2/2)\cos(\omega\tau)$ , so is no decrease of parameter  $\tau$ .

Between these limits are all other temporal signals with different attenuations of autocorrelation [6, 7]. If the time signal is a harmonic signal covered by noise, the autocorrelation function could detect harmonic signal as the autocorrelation function tends to harmonic signal at large values of the  $\tau$  parameter.

In general, most of Predictive Maintenance programs incorporate a variety of parameters to characterize accurately the technical state of the machine and to provide early warning of significant changes [11].

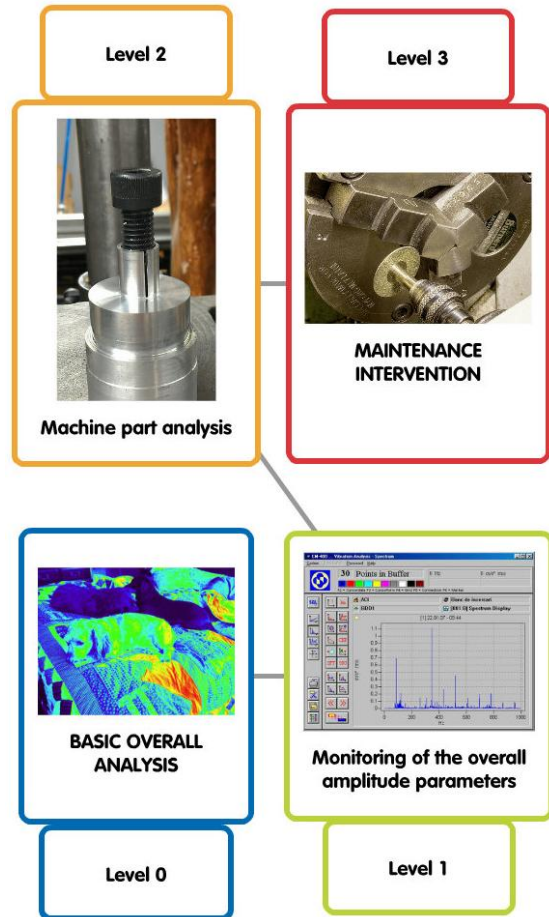


Figure 6: Levels of preventive maintenance program.

The program of maintenance proposed by this paper has several levels (Figure 6). The base level is one that checks the overall level of vibration and noise using the standard values. The last level is to obtain the causes, detection components that lead to the failure of the monitored machine.

#### 4. Conclusion

The main objective of this research and development project, in partnership between University POLITEHNICA of Bucharest and University of Bordeaux 1, is to propose a preventive maintenance system for the machinery and industrial equipment. In this context, the current issue is extremely important and allows in the future the development of a predictive maintenance service. The secondary objective of the project is finding a dynamic model of the spectrum able to eliminate those frequencies that are not due by defects.

This action has been validated so far by the very encouraging experimental results based on

measuring the vibration and noise of the spindle of the milling machine First MCV 300.

If the vibration or noise component dominates the overall spectrum at a certain frequency, the overall level of vibration or noise is a useful parameter for the early detection of faults and other operational elements in the mechanical parts of machines and equipment [12].

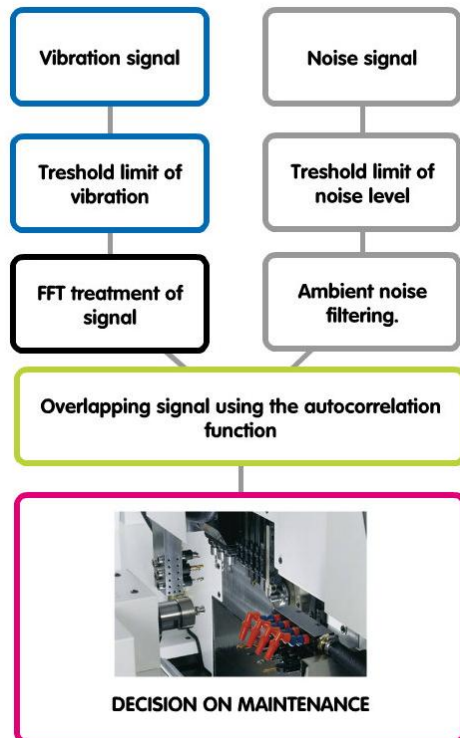


Figure 7: Steps for maintenance decision.

The decision of starting preventive maintenance program, in this context of simultaneous acquisition of vibration and noise, is illustrated in Figure 7.

Future work intends to select the proper technique for faults detection on machine tool spindles making possible to detect them before the machine breaks down, thereby reducing financial losses, such as damaged equipment and production downtime.

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