PORTABLE COMPUTER DIAGNOSTICS SYSTEM PSD – THE MEASUREMENT POTENTIALITY AND APPLICATION EXAMPLES

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Abstract

In this paper a diagnostics system for static and dynamic measurements of any machine tool in the wood industry is presented. The assessment of the state of the examined machine tool is feasible on the base of such measured mechanical quantities as axial run-out, radial run-out, rotational speed, a spindle or tool relative vibrations, bearing housing absolute vibrations, static and dynamic axial or radial displacements. The use of the computer programmes, of which the system is equipped with, allows the user to conduct analyses in detail. The latter can improve the controlled cutting process. Some actual experimental results are performed.

Key words: *Computer diagnostics, static and dynamic measurements, tools, machine tools*

INTRODUCTION

The natural character of the cutting force always includes a larger or smaller accidentally changeable component. As a result of it the stable system of the machine tool answers with vibrations, which are generally damped. Cutting of wood is mainly accompanied with forced and free vibrations. Nevertheless, sometimes in the unstable systems self-excited vibrations develop (*chatter* – the name commonly used in metal cutting, *washboarding* – the concept applied in the case of sawing on band saws and circular saws, and *regenerative quasi-washboard* for the case of sawing on sash gang saws) [1, 3, 4, 5, 8]. Not only deviations originating from the cutting zone affect the tool (i.e. a circular saw or band saw) position, dimensional accuracy of a workpiece, and its surface roughness but also dynamic and static properties of the machine tool. The latter depends on the design and the machine tool service conditions [3].

The cutting process may be investigated on laboratory stands, i.e. in the case of wood milling [2], continuously controlled with the use of the expert system [9, 10] or examined periodically with a portable computer measurement diagnostics system of machine tools PSD [6]. The latter was especially designed by authors for wood industry needs.

CHARACTERISTIC FEATURES OF THE SYSTEM

The presented diagnosis system may be applied for the assessment of any machine tool on the base of such mechanical measured quantities as rotational speed, a spindle or a tool relative vibrations, bearing housing absolute vibrations, static and dynamic axial or radial displacements. It may be used not only in the laboratory conditions but also in the operating regime. Some chosen examples of the diagnosis system applications in determination of different serviceable parameters are as follows:

- axial run-out of the fixed clamping flange (still in relation to the spindle) in the case of circular sawing machines in static and dynamic conditions;
- axial circular saw run-out (transverse displacements) in static and dynamic conditions;
- radial run-out of the circular sawing machine spindle;
- lateral run-out of the band saw;
- axial and radial run-out of band saw wheels;
- level of vibrations of the machine tool on the base of accelerations measured in the ranges of 2g ($2\times9.81 m/s^2$), 10g and 50g with the designed integrated piezoelectric accelerometer;
- static natural frequencies of the circular saw and basing on the critical speed theory determination of the real optimal rotational speed [11] as a result of them.

The block diagram of the portable computer measurement diagnosis system PSD is performed in Fig. 1.

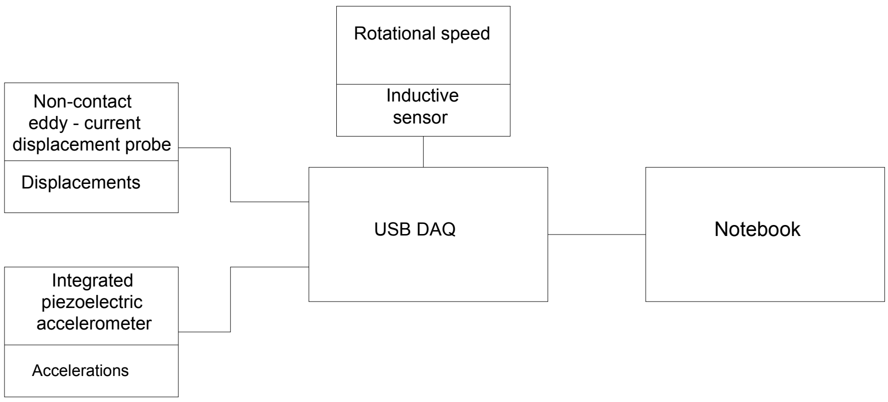

Fig. 1. Block diagram of the portable computer measurement diagnosis system PSD

The presented diagnosis system PSD consists of:

- a notebook, in which measured data are stored and computed;
- the USB Data Acquisition Hardware (DAQ, 250 kHz 14Bit A/D);
- a non-contact eddy-current displacement probe for measuring of run-out and displacements;
- an integrated piezoelectric accelerometer, which signals may be also applied for determination of speeds and displacements (after double integration of the obtained signal);
- an inductive sensor for evaluation of rotational speeds.

Furthermore, the system is provided with two computer programmes for measurements (*PomiarDAQ.exe*: designing of the test parameters, measurement control, visualisation of signals and FFT analysis) and additionally a software for numerical data handling (*Opzb.exe*, i.e. integration, digital filtering, constant component removal).

MEASUREMENT POTENTIALITY EXAMPLES

In this chapter some chosen results obtained during investigation of a brand-new circular sawing machine and additionally determination of critical rotational speeds of the circular saw blade are presented.

Position of the eddy-current displacement probe on the circular sawing machine during examination of the spindle radial run-out and the spindle axial run-out are shown in Fig. 1a. If behaviour of the circular saw in axial direction is investigated, the sensor should be placed below the bottom of the gullet as it is performed in Fig. 1b.

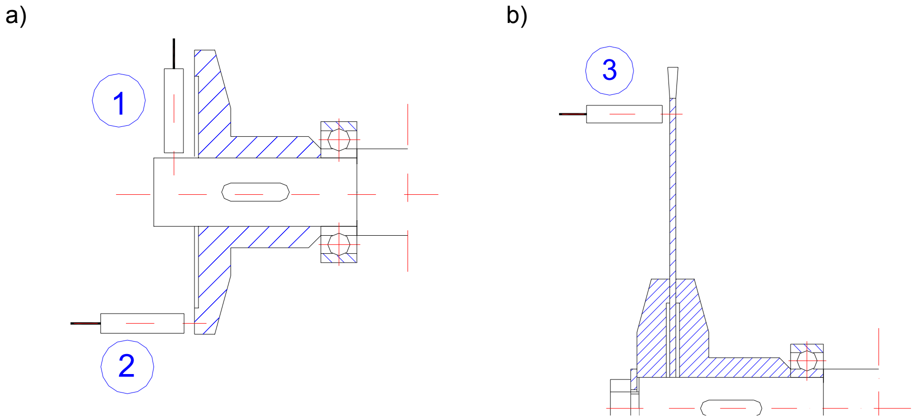

Fig. 2. Positions of the eddy – current displacement probe on a circular sawing machine during examination of: a) 1 – spindle radial run-out, 2 – collar axial run-out, b) saw blade axial run-out

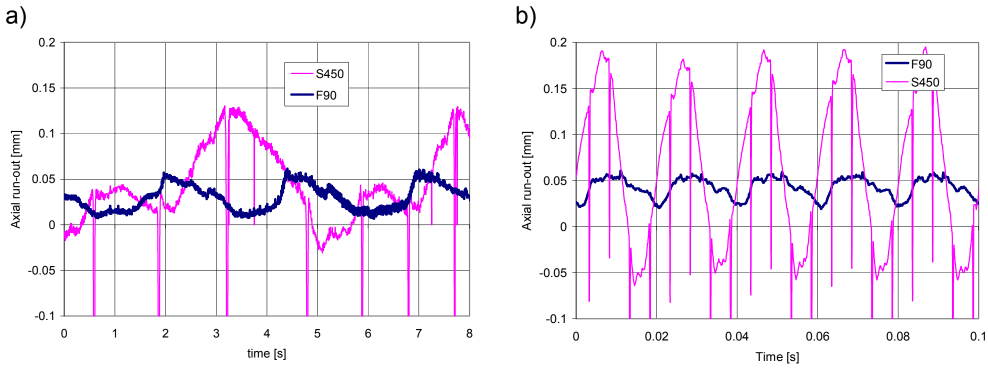

Fig. 3. Axial run-out of the collar (F90) and the circular saw blade (S450) of a brand-new circular sawing machine, where: a) static conditions, b) dynamic conditions

In Fig. 3 axial run-outs of the collar and the circular saw blade time data in both static and dynamic condition are shown. Additionally, these axial run-outs are compared in a bar chart (Fig. 4). It is noticeable that in static conditions a ratio of the axial circular saw blade run-out and the axial collar values is roughly equal to the ratio of the circular saw diameter

(diameter of gullets) and the collar diameter (4.34 ≅ 4.7). A small difference between these ratios may also be caused by the circular saw axial run-out. However, the large value of the circular saw axial run-out is a simultaneous effect of a lack of the collar perpendicularity to the spindle axis. In dynamic conditions values of the axial circular saw run-out are larger in relation to the static conditions due to a low value of the saw blade stiffness.

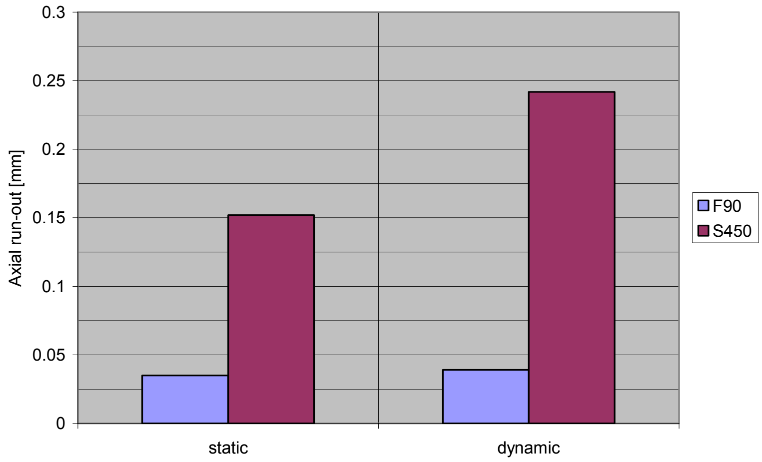

Fig. 4. Comparison of axial run-out values of the collar and the circular saw blade in static and dynamic conditions of a brand-new circular sawing machine (time data in Fig. 3)

The amplitude power spectrum (FFT) of the circular saw displacement signal (Fig. 3b) is shown in Fig. 5. In this spectrum there is visible only one basic frequency f_b = 48.82 Hz, which is equal to the spindle revolution frequency.

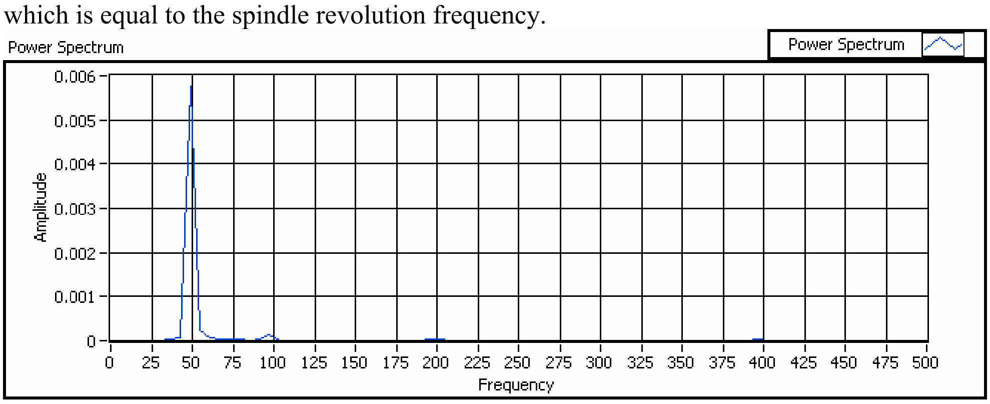

Fig. 5. Amplitude power spectrum of the circular saw blade axial displacement signal (Fig. 3b), where basic frequency f_b = 48.82 Hz

Determination of natural frequencies of the still circular saw blade, which are useful to evaluation of critical rotational speeds of circular saw blade, is yet another domain of applications of the presented portable computer diagnostics system PSD [7]. Natural frequencies of the still circular saw blade (data: saw diameter D = 350 mm, hole diameter d = 30 mm, saw blade thickness s = 2.6 mm, collar diameter and saw blade diameter ratio

A/D = 0.36) obtained after the FFT of the time circular saw blade displacement signal from the impulse test are performed in Fig. 6. The static natural frequencies are as follow: $f_{n=1}(0)$ = 114 Hz, $f_{n=2}(0)$ = 163 Hz and $f_{n=3}(0)$ = 276 Hz.

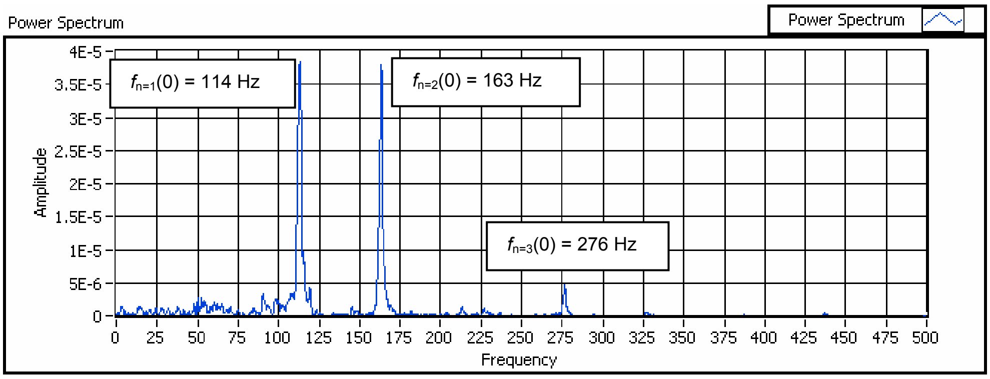

Fig. 6. Natural frequencies of the still circular saw blade obtained in the impulse test (Fast Fourier Transform of the time data, saw diameter D = 350 mm, hole diameter d = 30 mm, saw blade thickness s = 2.6 mm, A/D = 0.36)

SUMMARY

The presented diagnosis system may be applied for the assessment of any machine tool in the wood industry on the base of such mechanical measured quantities as rotational speed, a spindle or a tool relative vibrations, bearing housing absolute vibrations, static and dynamic axial or radial displacements. It may be used not only in the laboratory conditions but also in the operating regime. The system consists of a notebook, the USB Data Acquisition Hardware (DAQ), a non-contact eddy-current displacement probe, an integrated piezoelectric accelerometer and an inductive sensor. Moreover, the use of the computer programmes of the system is equipped with allows the user to conduct analyses in detail, which can improve the controlled cutting process.

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REFERENCES

1. HUTTON S.G., ZHAN J.L. (1989): The Causes of Washboarding in Bandsaws. Proc. Of SawTech'89, October 2-3, Oakland, CA, USA: 12-1÷12-10.
2. JAVOREK L., OSWALD J. (2001): Silové charakteristiky pri obrábaní dreva I. Frezovanié. (Force characteristics of wood machining. I. Milling, *In Slovak*). Vedecké štúdie 4/2001/B, Technická univerzita vo Zvolene, Zvolen.

3. MARCHELEK K. (1991): Dynamika obrabiarek. (Machine tools dynamics, *In Polish*) WNT, Warszawa.
4. OKAI R., TANAKA C., IWASAKI Y. et al. (2005): Application of a novel technique for band sawing using a tip-inserted saw regarding surface profiles. Holz als Roh- und Werkstoff 63(4): 256-265.
5. ORŁOWSKI K. (2003): Materiałooszczędne i dokładne przecinanie drewna piłami. (Narrow-kerf and accurate sawing of wood, *In Polish*) Sera Monografie Nr 40. Wydawnictwo Politechniki Gdańskiej, Gdańsk.
6. ORŁOWSKI K., KAPCIA J., WASIELEWSKI R.: Portable computer measurement system of machine tools in wood industry. Annals of Warsaw Agricultural University: Forestry and Wood Technology Nr. 57: 111-113.
7. ORŁOWSKI K., SANDAK J. (2005): Measurement of the critical rotational speed of circular saw. // In: COST Action E35 /European Cooperation in the Field of Scientific and Technical Research/: Fracture mechanics and micromechanics of wood and wood composites with regard to wood machining : workshop proceedings: Rosenheim, 29-30 September 2005./Eds. Prof. S. Tschegg, G. Sinn. - Vienna, Austria : BOKU - University of Natural and Applied Life Sciences, Institute of Physics and Materials Science, CD-ROM, Working Group 3: Wood machining: p. 1-9.
8. ORLOWSKI K., WASIELEWSKI R. (2006): Study washboarding phenomenon in fame sawing machines. Holz als Roh- und Werkstoff. - Vol. 64, Nr. 1 (2006): 37 – 44.
9. SANDAK J. (2006): Wood Machining Process Control and Monitoring: Potential and Limitations. In: Proc. of the 1st Jubilee Scientific Conference "Manufacturing Engineering in Time of Information Society". Gdańsk, 1st – 2nd June 2006. Eds. W. Przybylski, J. Wojciechowski. Gdansk University of Technology, Faculty of Mechanical Engineering, Department of Manufacturing Engineering and Automation, Gdańsk: 353-360.
10. SANDAK J., TANAKA C. (2001): Expert Systems in Bandsawing. Proc. of the 15th International Wood Machining Seminar. IWMS 15, Los Angeles, Loyola Marymount University, July 30 – August 1, CA. Wood Machining Institute, p. 281 – 292.
11. SVOREŇ J., DANKO P. (2004): Vplyv dražok tela na kritické otáčky pílových kotúčov. (The effect of saw blade slots on critical rotational speeds of circular saw blades, *In Slovak*). Acta Facultatis Technicae, Zvolen – Slovakia, VIII, 2004(1): 13-19.