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The effect of current signal filtering method on the value of cutting power while sawing wood

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Abstract: *The effect of current signal filtering method on the value of cutting power while sawing wood.* The goal of this work was to investigate an effect of various signal pre-processings on the outline of the electrical power curve and its influence on the measured cutting force estimation. Two signal processing methods were selected for the needs of the experiment, including digital filter and wavelet transform. The filter used was Butterworth, 3rd order band-stop with the cut-out band from 45 Hz to 55 Hz. The second approach performed was the wavelet decomposition. The carried out results analyses revealed that the properly selected digital processing method of the measured current signal affected by the electrical noise of the constant frequency of 50 Hz does not decrease of information which is carried along by the root signal. The best results were obtained if the root signal has been processed with Discrete Wavelet Transform.

Keywords: circular sawing machine, cutting power, filtering method, industrial measurements

INTRODUCTION

Monitoring of the cutting process is important for numerous technological aspects: the surface quality, state of the cutting tool, energy consumed, wear and tear of the machine and optimum time usage in respect to cutting regimes (Mandic et al. 2015). It has been also shown that monitoring of cutting process can be a valuable source of information as regarding the material properties. A signal is a physical quantity that varies with time and that can be measured. Signals may include errors due to the measuring device limitations, or environment constrains. Consequently, diverse transforms can be used for signal analysis (Weeks 2007). Transformation of the signal from the time domain to the frequency domain is very common due to the ease with which the signal can be analyzed and characterized (Brock 1983). Digital signal filtering belongs to processing methods that suppress interfering signals by removing specific frequencies. As a result, the background noise can be reduced and specific signal features highlighted. In the field of signal processing the transformation of the signal from the time domain to the frequency domain is very common due to the ease with which the signal can be analyzed and characterized (Brock 1983; Lemaster 2012).

Denaud et al. (2012) compared several signal processing techniques giving a spectral representation of sensors measurements during wood peeling process monitoring.

The goal of this work was to investigate an effect of various signal pre-processings on the outline of the electrical power curve and its influence on the measured cutting force estimation.

METHODS AND MATERIALS

Scots pine (*Pinus sylvestris* L.) samples originating from the Forest Inspectorate Lipusz in the Baltic Natural Forest Region (PL) were used as experimental samples. Samples were in the shape of rectangular blocks with dimensions of 100 mm (H) × 50 mm (W) × 2200 mm (L) with moisture content MC 35% and density ρ = 510 kg·m^{-3}. The cutting tests were carried out on the one shaft multi rip sawing machine PWR301 (TOS Svitavy, CZ) at the Complex sawmill in

Dziemiany (the Baltic Natural Forest Region, PL). The machine settings were as follows: number of saw blades n_b = 1, spindle rotational speeds: 3800 rpm (cutting speed v_c = 69.64 ms^{-1}), feed speed v_f = 40 m·min^{-1}, clearance of a circular saw blade over the workpiece 5 mm, cutting kinematics – up-sawing, electric engine power P_{EM} = 45 kW. The circular saw had the following characteristics: 350 mm (*D*) × 80 mm (*d*) × 2.5 mm (*s*), overall set S_t = 3.9 mm, number of carbide tipped teeth z = 18, and side rake angle γ_f = 25º (Aspi Sp. z o.o. Spółka komandytowa, PL) (Orlowski et al. 2014).

The measurements were performed using a measuring system consisting of a probe AC/DC current transducer DHR 100C10 (LEM USA Inc.), high-accuracy isothermal terminal block NI SCXI 1328 (National Instruments, USA), 8-channel isolation amplifier NI SCXI 1125 (National Instruments, USA), 4-Slot Chassis NISCXI 1000DC (National Instruments, USA) and computer with the acquisition board NI PCI 6281 (National Instruments, USA). The sampling rate of the probe in connection with the parameters of the measurement channel enables precise measurement of changes in electrical current consumed by the sawing machine. The measurement probe was installed on the single-phase power cable of electric engine (three-phase electric engine). The sampling frequency was 1000 Hz. The cutting power was calculated as a difference of a total electric power P_{ET} and an electric idling power P_{Eid}. Since, the measurements were carried out in one phase it was assumed that in other phases values of current have been the same (Orlowski et al. 2014b). The real electric power can be calculated as (Three phase 2015):

$$P_E = \sqrt{3} \cdot U \cdot I \cdot PF \tag{1}$$

where: U is voltage (V, U = 400 V), I is measured current (A), PF is the power factor ($PF = \cos\Phi$). It was assumed that the value of PF = 0.8 for cutting process with feed speed v_f = 40 m·min^{-1} for H_p = 100 mm, and PF = 0.3 for idling. It should be emphasised that for purely resistive load PF = 1.

The exemplary registered current signal in one phase of the electric motor of the circular sawing machine PWR301 during rip sawing of 100 mm height pine wood at feed speed v_f = 40 m·min^{-1} is presented in Figure 1a. The idling and cutting phases of the sawing are clearly distinguishable. Nevertheless, it was found that almost total course of the registered signal has been affected by a component of a cyclic nature and constant frequency of 50 Hz (Figure 1a, 2a). it was considered as an electrical noise. In fact, it was reported that noisy measurement problems are often due to improper grounding of the measurement circuit (McConnell and Jernigan, 2005). Two signal processing methods were selected for the needs of this experiment, including digital filter and wavelet transform. The filter used was Butterworth, 3rd order band-stop with the cut-out band from 45 to 55 Hz. The wavelet decomposition was performed with wavelet type db02 and the superior signal curve was assumed at the level 4.0. Both algorithms were implemented in the Signal Processing toolbox, being a part of LabView2013 (National Instruments).

RESULTS ANALYSES

In Figure 1a the course of the registered current (root signal) in one phase of the electric motor of the circular sawing machine PWR301 during rip sawing of pine wood (*Pinus sylvestris* L.) 100 mm in height, with feed speed v_f = 40 m·min^{-1}, with idling current included, is shown (Orlowski et al. 2014). Furthermore, in Figure 1b the course of the registered current signal after filtering with the Butterworth (3rd order) digital band-stop filter with the cut-out band from 45 to 55 Hz is presented. In Figure 1c the course of the registered current signal after filtering with the wavelet decomposition performed, with wavelet type db02 and the superior signal curve assumed at the level 4.0, is performed.

In Figure 2 zooms of the courses of current in one phase of the electric motor of the circular sawing machine from the rectangle of the root signal (Figure 1a), of the same ranges of the time after processing with the band stop filter (45-55 Hz) (Figure 2b) and after processing with

Discrete Wavelet Transform (Figure 2c) are shown. After filtering an electrical noise of the constant frequency of 50 Hz (Figure 1a, 2a) disappeared, and the courses in Figures 1b, c and Figures 2b, c are more smoother as a result.

For idling and for cutting parts of the course values of the real electric powers were calculated as average values, of which the mean values of the cutting powers and deviations values (significance level $\alpha = 0.05$) are presented in Figure 3. The mean values of the cutting powers are almost the same in each case, however, for the root signal (non filtered) and the signal after Discrete Wavelet Transform these values are absolutely equal. Nevertheless, the signal after wavelet processing has the lowest value of the deviation.

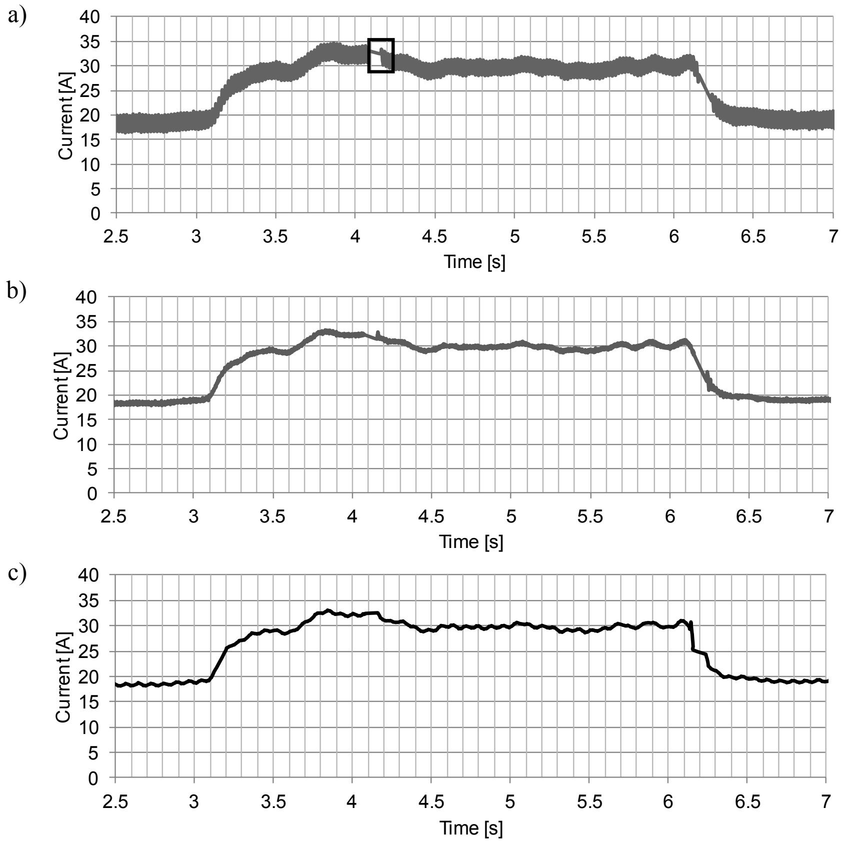

Figure 1. Registered current in one phase of the electric motor of the circular sawing machine PWR301 during rip sawing of pine wood (*Pinus sylvestris* L.) 100 mm in height, with feed speed $v_f = 40$ m·min^{-1} (root signal, a), and after processing with the band stop filter (45-55 Hz) (b) and after processing with Discrete Wavelet Transform (c)

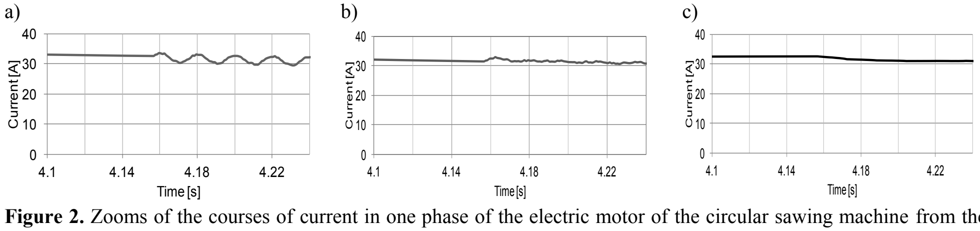

Figure 2. Zooms of the courses of current in one phase of the electric motor of the circular sawing machine from the rectangle of the root signal (Figure 1a), and zoom of the same ranges of the time after processing with the band stop filter (45-55 Hz) (b) and after processing with Discrete Wavelet Transform (c)

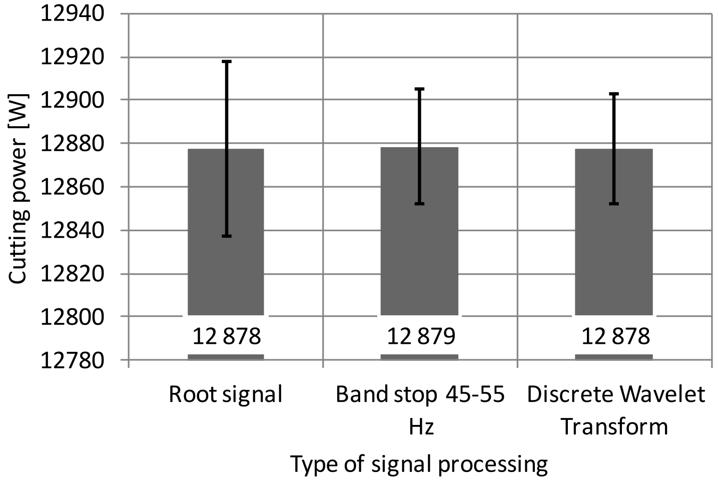

Figure 3. The effect of the type of signal processing on the mean value of the cutting power and deviations values (significance level $\alpha = 0.05$)

CONCLUSIONS

The carried out results analyses revealed that the properly selected digital processing method of the measured current signal affected by the electrical noise of the constant frequency of 50 Hz does not decrease of information which is carried along by the root signal. However, in this case the best results were obtained if the root signal was processed with the Discrete Wavelet Transform.

REFERENCES

1) Brock M., 1983: Fourier analysis of surface roughness. Bruel & Kjaer Technical Review, ISSN: 0007-2621, Marlborough, Mass., No. 3, 48 pp.
2) Denaud L., Bleron L., Eyma F., Marchal R., 2012: Wood peeling process monitoring: a comparison of signal processing methods to estimate veneer average lathe check frequency. European Journal of Wood and Wood Products. 70 (1-3): 253-261
3) Lemaster R.L., 2012: The Use of the Wavelet Transform to Extract Additional Information on Surface Quality from Optical Profilometers, Advances in Wavelet Theory and Their Applications in Engineering, Physics and Technology, Dr. Dumitru Baleanu (Ed.), ISBN: 978-953-51-0494-0, InTech, Available from: http://www.intechopen.com/books/advances-in-wavelet-theory-and-their-applications-in-engineering-physicsand-technology/the-use-of-the-wavelet-transform-to-extract-additional-information-on-surface-quality-fromoptical-p (Accessed: 25 June, 2015)
4) Mandic M., Svrzic S., Danon G.J., 2015: The comparative analysis of two methods for the power consumption measurement in circular saw cutting of laminated particle board. Wood Research 60 (1): 125-136
5) Orlowski K.A., Ochrymiuk T., Lackowski M., 2014: Empirical verification in industrial conditions of fracture mechanics models of cutting power prediction, Annals of WULS, Forestry and Wood Technology. No 85: 162-167
6) McConnell E., Jernigan D., 2005: Data Acquisition, in The Electronics Handbook (Second Edition), Whitaker J.C. (Ed.), Taylor & Francis Group: 1938–1965
7) Three-Phase power equations (2015): http://www.engineeringtoolbox.com/three-phase-electrical-d_888.html (Accessed: 30 June, 2015)

8) Weeks M., 2007: Digital Signal Processing Using MATLAB® and Wavelets. Infinity Science Press LLC, Hingham, Massachusetts.

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Streszczenie: *Wpływ metody filtrowania cyfrowego sygnału natężenia prądu na wartość mocy skrawania podczas przecinania drewna.* Celem niniejszej pracy było zbadanie wpływu sposobu filtrowania zmierzonego sygnału prądu na wartość szacowanej mocy skrawania podczas przecinania drewna sosnowego na pilarce tarczowej. Do usunięcia zakłóceń o częstotliwości 50 Hz zastosowano filtr cyfrowy typu Butterworth oraz dyskretną transformatę typu wavelet. Otrzymane wyniki wykazały, iż w ostatnim przypadku przebieg sygnału był najbardziej wygładzony, jakkolwiek, wartości średnie mocy skrawania były bardzo zbliżone bez względu na sposób obróbki sygnału.

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