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DYNAMIC SIGNALS FILTRATION IN HIGH LEVEL NOISE CONDITION

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Abstract. To examine the opportunity of measuring bulk solids consumption the experimental setup was developed. The main problem was the presence of a non-harmonic signal at the output. Almost always there are some difficulties to build measuring circuits using non-harmonic signals. It is necessary to use one of the approximation methods to receive a wanted signal without noise. For this purpose, the local approximation method was chosen. The developed technique confirmed its positive aspects and allowed to solve the questions that were posed before the experimental setup.

Keywords: filtration, noise, local approximation method.

Introduction

A wanted signal from measuring transducers almost always requires an improvement in the signal-to-noise ratio (Oliferovich et al., 2015; L'yung, 1991). The following filtration methods are usually distinguished: backing-space method; frequency filtering; correlation method; matched filtering; nonlinear filtering (Seber & Lee, 2003; Tse & Bar-Shalom, 2003; Katkovnik et al., 2006; Hryniuk et al., 2016). All these methods are based on the use of differences in the properties of the wanted signal and interference. Sometimes, when processing trends, one has to solve the problems of detecting a useful signal (Wenk & Bar-Shalom, 2003; Getmanov & Orlov, 2011).

When conducting scientific experiments on the analysis of oscillation of rubber belt, additional difficulties were caused by the low sensitivity of the primary transducer. Smoothing of measuring trends should be carried out in such a way as to preserve the shape of the signal as much as possible and be able to determine the oscillation frequency. The shape of the periodic wanted signal was variable, representing a mixture of two or three slightly non-linear harmonic signals. The use of frequency methods subsequently did not allow preserving the waveform. Matched filtering required a significant change in the methodology of the experiment. And even after that, the chances of preserving the shape of the useful signal in this case would be minimal. For this reason, the local approximation method was chosen for the smoothing process.

1. Experiment purpose

The main purpose of the stand development was to examine the theoretical background for measuring bulk solids consumption by the analysis of a conveyor belt. Another one was to examine some theoretical uncertainties with the effect of belt tension on the self-resonant frequency.

The main constituents of the stand in the experiment:
- A conveyor belt with a width of about 620 mm has many surface defects on the front and back sides.
- Dynamometer with a limiting value of 2 tones was used to control the tension.
- Displacement sensor. It was a laser measuring sensor, measuring range 300 mm.
- Carriage. 10 mm metal plates were acquired and bolted to the channel bar to stiffen the structure.

2. Recording and processing

The sensor had a 4–20 mA output and was loaded with a resistance of 150 ohms. A digital oscilloscope was used to record measurements with the ability to record data on computer hardware. After conducting the experiments, the obtained data was converted into a Matlab mathematical processing package. Since the signal at the maximum resolution of the oscilloscope had a small number of significant digits on the scale, it was necessary to use the corresponding mathematical apparatus. In the measuring channel there were interference type "spurs", which required the use of appropriate algorithms and their settings.

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3. The experiment plan

The geared motor was connected to a frequency drive to obtain a periodic action on the belt. Disks made of 10 mm plywood were attached to the reduction shaft. Taking into account the small amplitude of the wanted signal, a single-thorn disk option was used. This made it possible to obtain the most identical strikes on the belt, which allowed averaging during subsequent processing. The frequency of exposure to the belt was slightly less than 1 Hz, which made it possible to observe several periods after hitting the belt.

The load on the belt was simulated using bags with sand. The weight of each bag was about 15 kg.

The corresponding belt tension was set with the help of the tension screw. After that, the frequency drive was turned on and the experiment began. Started with a blank belt, and then added one bag at a time. The maximum weight between the supports of 6 bags is approximately 90 kg. 40 seconds of steady-state operation were recorded at each stage.

The tension was controlled visually by a dynamometer. Differences with empty belt and filled were insignificant.

4. Approximation method

One of the effective methods of non-parametric filtering can be a local approximation method. The essence of this method is to use sliding locally parametric models. To ensure the maximum quality of smoothing, it is necessary to determine the order of locality and choose a locally parametric model.

As local models, it is proposed to use linear and quadratic approximations (Hryniuk et al., 2016):

$$y(t) = c_1 + c_2 t;$$

$$y(t) = d_1 + d_2 t + d_3 t^2,$$

where

$$\begin{pmatrix} c_1 \\ c_2 \end{pmatrix} = \begin{pmatrix} w_2 & w_1 \\ w_3 & w_2 \end{pmatrix}^{-1} \begin{pmatrix} b_1 \\ b_2 \end{pmatrix};$$

$$\begin{pmatrix} d_1 \\ d_2 \\ d_3 \end{pmatrix} = \begin{pmatrix} w_3 & w_2 & w_1 \\ w_4 & w_3 & w_2 \\ w_5 & w_4 & w_3 \end{pmatrix}^{-1} \begin{pmatrix} b_1 \\ b_2 \\ b_3 \end{pmatrix};$$

$$w_j = (t_1)^{j-1} + (t_2)^{j-1} + \ldots + (t_N)^{j-1};$$

$$b_j = (t_1 x_1)^{j-1} + (t_2 x_2)^{j-1} + \ldots + (t_N x_N)^{j-1};$$

$$t_k = [0\ \Delta t\ 2\Delta t\ \ldots\ (N-2)\Delta t\ (N-1)\Delta t\ ],$$

where Δt – quantization time.

Any value $t = t_S$ in the range of approximation $[0\ (N-1)\Delta t]$ for the formation of the output value y_i can be used. Depending on the value N and the characteristics of the noise t_k has its optimal value. Studies have shown that

$$|y_i(t_S) - y_S|$$

has a parabolic dependence, the minimum of which is in the first half of the approximation range, where y_S is the true value of the parameter.

The trend plots were approximated by a quadratic equation within the selected window. The optimal width of the window was chosen in such a way that the window did not exceed the length of the minimum decrease or rise of the change sections of the useful signal.

The group (Figures 1–6) of the graphs shows the transient processes after exposure (pink color) to the belt and the result of smoothing using a proprietary algorithm with the inclusion of the anti-interference mechanism (green) and without (black).

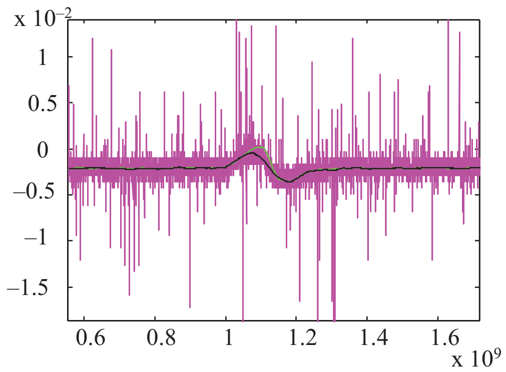

Figure 1. Transient conditions without sandbags and with belt tension 500 kgF

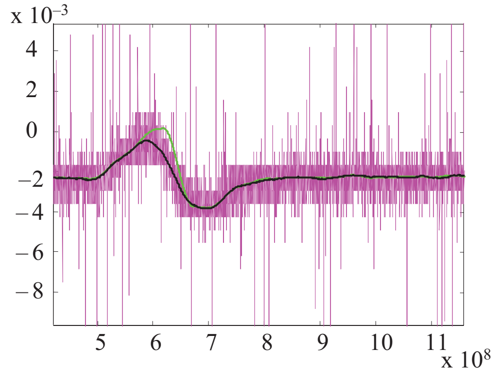

Figure 2. Transient conditions without sandbags and with belt tension 700 kgF

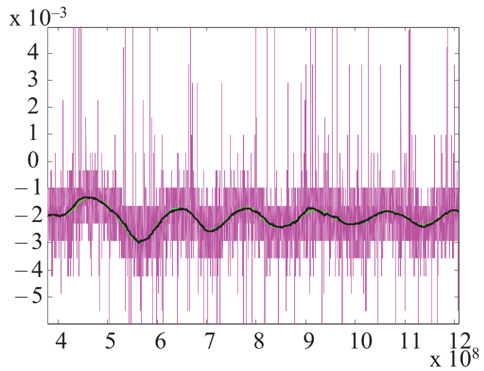

Figure 3. Transient conditions with one sandbag and with belt tension 500 kgF

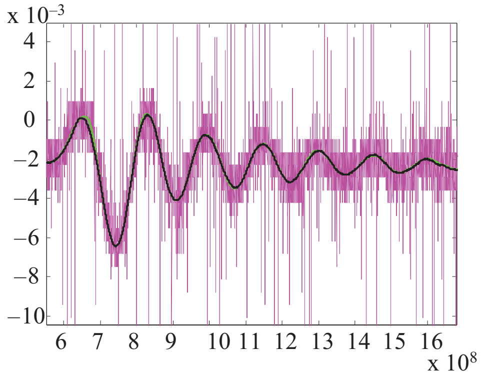

Figure 4. Transient conditions with one sandbag and with belt tension 700 kgF

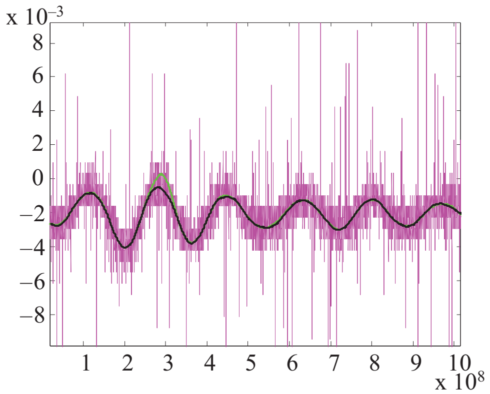

Figure 5. Transient conditions with two sandbags and with belt tension 500 kgF

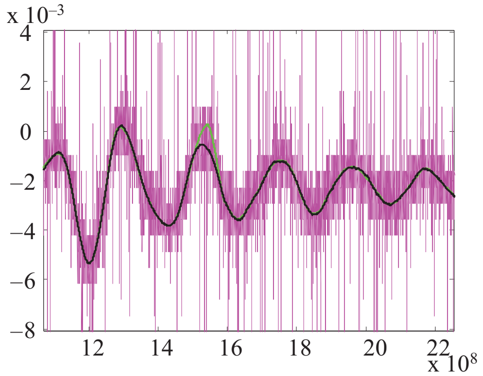

Figure 6. Transient conditions with two sandbags and with belt tension 700 kgF

Differences in transients with an empty belt and its subsequent load should be noted. Due to the low tension of the belt, long transient processes and interference of oscillation from the complex interaction of the weight, the belt and the percussion mechanism were observed. It explains the absence of a linear dependence of frequency over the entire range of loads. Frequency (period) was determined by the time interval between the maximum and the subsequent minimum.

Conclusions

Based on the results of research, several conclusions can be drawn.

1. The use of the local parabolic approximation allows us to select a useful signal against a background of a high level of interference. With this method, a high degree of conservation of the waveform is observed, which is not unimportant when constructing measuring detectors.
2. Measurement of the oscillation frequency of the conveyor belt allows you to determine the mass of material.
3. Using the sensor to control geometric dimensions on the effect of triangulation allows you to provide good sensitivity to control vibrations of industrial conveyors.

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DINAMINIŲ SIGNALŲ FILTRAVIMAS ESANT AUKŠTO LYGIO TRIUKŠMUI

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Santrauka

Biriųjų medžiagų išeigos matavimo galimybėms tirti buvo sukurta eksperimentinė įranga. Pagrindine problema buvo neharmoninis signalas matavimo įtaiso išėjime, apsunkinantis matavimo grandinių kūrimą. Naudingo signalo filtravimui nuo triukšmo būtina taikyti aproksimavimo metodus. Tyrimui pasirinktas lokalaus aproksimavimo metodas. Sukurta metodika patvirtino savo privalumus ir gebėjimus spręsti tiriamai eksperimentinei įrangai iškeltus uždavinius.

Reikšminiai žodžiai: filtravimas, trukdžiai, lokalaus aproksimavimo metodas.