International Journal of Scientific & Engineering Research, Volume 6, Issue 10, October-2015 627
ISSN 2229-5518

Methodology of vibroacoustic isolation selection for utilization in checkweighting systems

Paweł Nowak, Marcin Kamiński, Roman Szewczyk

Abstract— Paper presents methodology of vibroisolation selection on the example checkweighter system. Analyzed system was simplified - main modules are represented by the concentrated masses, connected by universal models of bonds. In paper two ways of determination of bonds parameters are presented. First way requires physical presence of analyzed system and can be utilized for applying vibroisolation on developed system in order to minimize vibration transmission to the system. Second way can be applied during system development. Utilization of Finite Element Method analyses allows to design proper shape of bonds between modules. Presented method utilizes numerical simulations for different parameters of vibroisolation. Multiparameter optimization provides significant reduction of vibration transmission to the crucial elements of checkweighter system. Due to that mass measurement accuracy can be significantly improved.

Index Terms— Checkweighter, mechanic modeling, spectral analyse, vibes, vibration suppression, vibroisolation, vibroisolation efficiency

1 Introduction

VIBROISOLATIONS are utilized to minimize transfer of vibrations from environment to device ("displacement vibroisolation") or inversely – to lower the amplitude of vibes transferred from working device to its surroundings ("force vibroisolation")[2],[3]. Considering checkweighter, which is sensitive mass measurement system which does not generate significant vibes itself, vibroisolation has to be selected in order to minimize influence of external vibrations. Properly selected parameters of isolators - coefficients of dumping (c_{izol}) and stiffness (k_{izol}) should result with significant attenuation of dynamic impact transmitted to checkweighter.

2 Simplified checkweighter model

Analyzed checkweighter [6] is, from the mechanics viewpoint, a system with many degrees of freedom. In order to simplify the analyses during vibroisolation selection this system was reduced to model with decreased number of degrees of freedom. Considering checkweighting process most important interactions occur between weighting module and conveyor belt utilized to transport weighted objects. This is caused by direct transmission of all dynamic interactions between those objects to measurement signal. Transporter and weighting module are connected with wishbone, which can be represented as parallel elastic-dissipation system with stiffness k_{p2} and dumping c_{p2}. Due to the fact, that transmitter stiffness is significantly bigger than wishbones (which principle of operation is based on deflection), conveyor can be simplified as a concentrated mass m_{p2}. Weighting module is placed on thick aluminum board connected with supporting structure of checkweighting system. During analysis those elements were simplified by one concentrated mass m_w. Two transporters (which are delivering and receiving weighted elements) are connected to the aluminum board with square shaped brackets. Those objects were replaced in model, as well as main transporter connected with weighting module, with concentrated mass m_{p1} placed on ideal spring with stiffness k_{p1} parallel with suppressor with dumping c_{p1}.

Whole checkweighter system is placed on vibroisolators, which parameters – stiffness k_{izol} and dumping c_{izol} [4],[5] are to determine. Figure 1 presents simplified model of checkweighter.

2.1 Analytical description

Based on created checkweighter model, kinematic equations (1), (2) and (3) were derived.

$$m_{p1}\ddot{x}_{p1}+c_{p1}\left(\dot{x}_{p1}-\dot{x}_{w}\right)+k_{p1}\left(x_{p1}-x_{w}\right)=0 \quad (1)$$

$$m_{p2}\ddot{x}_{p2}+c_{p2}\left(\dot{x}_{p2}-\dot{x}_{w}\right)+k_{p2}\left(x_{p2}-x_{w}\right)=0 \quad (2)$$

$$\begin{aligned}&m_{w}\ddot{x}_{w}+2c_{p1}\left(\dot{x}_{w}-\dot{x}_{p1}\right)+2k_{p1}\left(x_{w}-x_{p1}\right)+c_{p2}\left(\dot{x}_{w}-\dot{x}_{p2}\right)+\\&+k_{p2}\left(x_{w}-x_{p2}\right)+c_{izol}\left(\dot{x}_{w}-\dot{z}\right)+k_{izol}\left(x_{w}-z\right)=0\end{aligned} \quad (3)$$

Without vibroisolation between checkweighter and ground, (3) would be formed as (4). Equations (1) and (2) would remain analytically the same. On the other hand both consists displacement x_w, so transmitter movement would be different.

$$\begin{aligned}&m_{w}\ddot{x}_{w}+2c_{p1}\left(\dot{x}_{w}-\dot{x}_{p1}\right)+2k_{p1}\left(x_{w}-x_{p1}\right)+\\&+c_{p2}\left(\dot{x}_{w}-\dot{x}_{p2}\right)+k_{p2}\left(x_{w}-x_{p2}\right)=0\end{aligned} \quad (4)$$

- *Paweł Nowak is with Industrial Research Institute for Automation and Measurements PIAP, Jerozolimskie 202, 02-486 Warsaw, Poland pnowak@piap.pl,*
- *Marcin Kamiński is with Industrial Research Institute for Automation and Measurements PIAP, Jerozolimskie 202, 02-486 Warsaw, Poland*
- *Roman Szewczyk is with Institute of Metrology and Biomedical Engineering, Warsaw University of Technology, Boboli 8, 02-525 Warsaw, Poland*

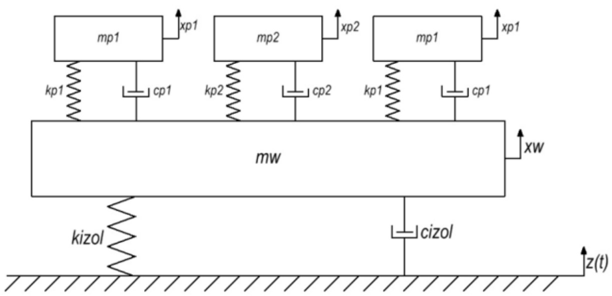

Fig. 1. Simplified mechanic scheme of checkweighter system.

2.2 Initial parameters determination

Values of coefficients of stiffens k_{p1} and dumping c_{p1} occurring in (1), (3) and (4) were determined. To determine those parameters (5), (6) and (7) were utilized.

$$k_{p1} = \omega_{p1}^2 m_{p1} \quad (5)$$

$$c_{p1} = 2\xi_{p1}\sqrt{k_{p1}m_{p1}} \quad (6)$$

$$\xi_{p1} = \ln\left(A_i / A_{i+1}\right) / 2\pi \quad (7)$$

In order to obtain parameters ω_{p1}, m_{p1} and A_i/A_{i+1} for those calculations, transient characteristic of system had to be determined. Thus impulse response of vibration on block under weighting module was measured. Results are presented in Figure 2.

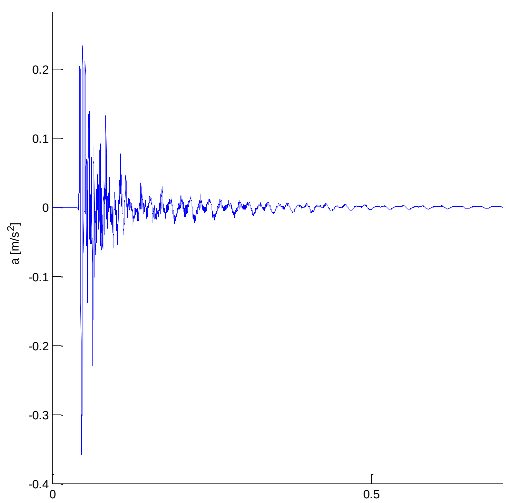

Fig. 2. Impulse response of vibrations on block under weighting module

During analyses FFT was applied on measured response. Results are presented in Figure 3 and clearly indicate that initial resonance frequency of checkweighter setup equals 33 Hz. Also impulse extortion generates large amount of signal harmonics. Those frequencies are not caused by resonance of block itself. Their source are resonances of elements connected to the block.

Basing on systems characteristics presented on figures 2 and 3 required parameters results were obtained as follows:

$$\omega_{p1} = 2\pi f_{p1}\Big|_{f_{p1}=33Hz} \approx 207 rad/s$$

$$m_{p1} = 8kg$$

$$\frac{A_i}{A_{i+1}} \approx 1,1$$

Then, basing on (5), (6) and (7) values k_{p1} and c_{p1} were calculated. Their values are k_{p1}=343936 N/m and c_{p1}=5.2·10^{-6}.

Similar determination of analogous coefficients k_{p2} and c_{p2} for transmitter placed over the weighing module is impossible due to the fact that this module works with electromagnet, which prevents its free movement. Theoretically those coefficients can be extract from the measurement data but due to the complexity of the signal it was proved impossible as well.

Thus stiffness coefficient k_{p2} was determined with utilization of finite element method on transmitter model. Obtained value is k_{p2}=26455 N/m, where mass of conveyor over weighting module is m_{p2}=5.5 kg. Values of vibroisolation parameters (c_{izol}, k_{izol}) are object of analysis.

3 Numeric Modeling

Equations (1), (2), (3) and (4) as well as values of coefficients were implemented in Matlab-Simulink software. Group of simulations was conducted [1], in order to obtain spectral characteristics of vibration transmission from the base (*z*) to

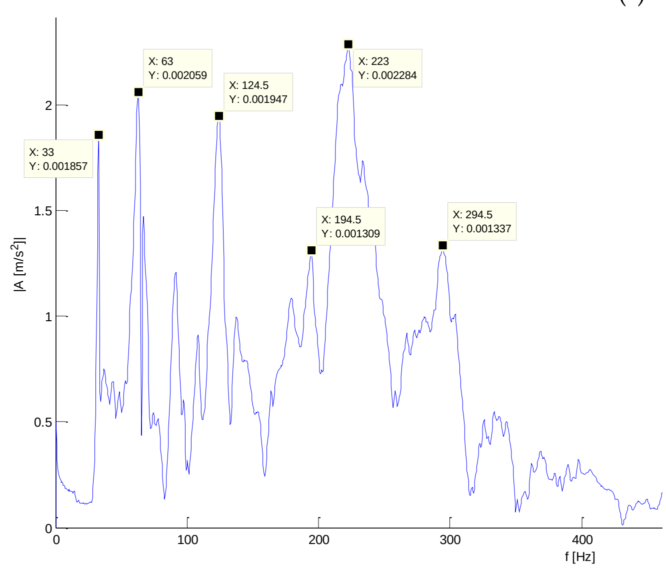

Fig. 3 Frequency analysis of impulse response

the block under the weighting module (x_w), auxiliary transmitters (xp1) and weighting transmitter (xp2). Those simulations were conducted for different values of vibroisolation parameters. Obtained characteristics are presented in Figures 4-9.

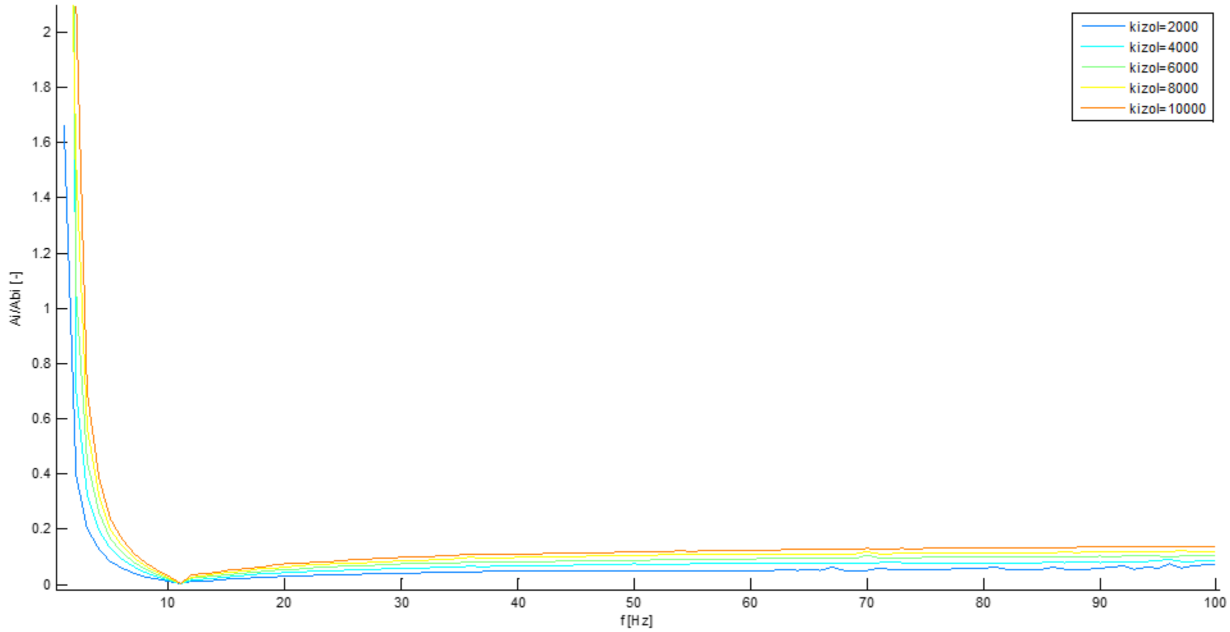

Fig. 4. Efficiency of vibroisolation on weighting transmitter *x_{p2} for different values of vibroisolation stiffness k_{izol}, for dumping coefficient c_{izol}=0.2*

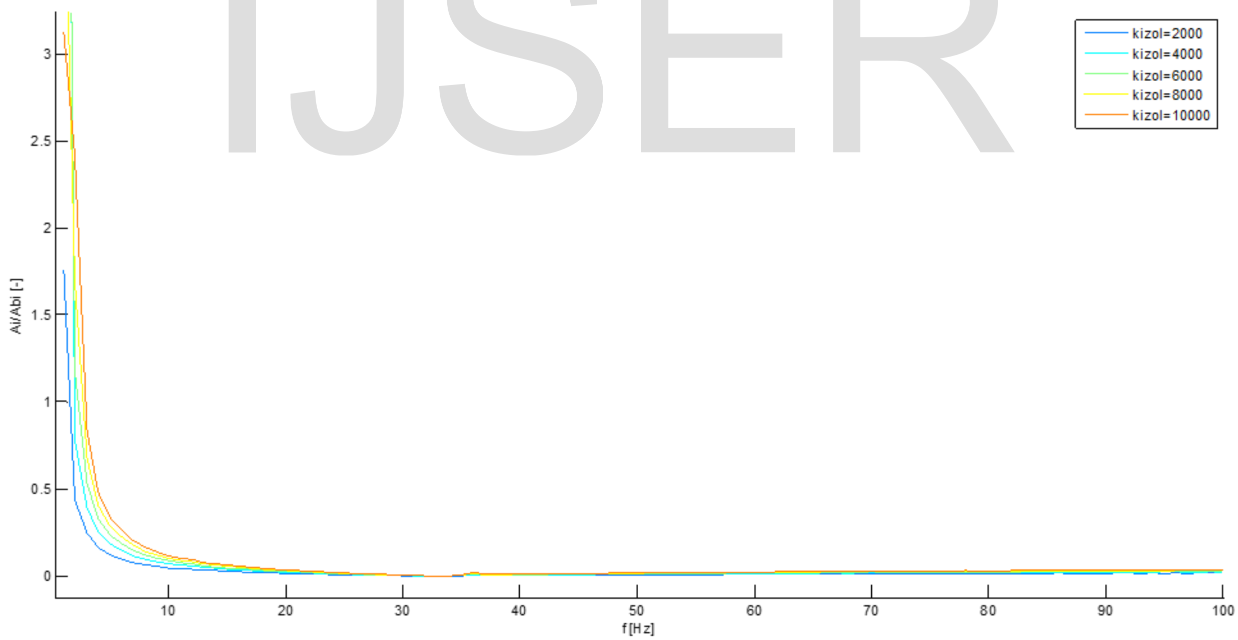

Fig. 5. Efficiency of vibroisolation on auxiliary transmitters x_{p1} for different values of vibroisolation stiffness k_{izol}, for dumping coefficient c_{izol}=0.2

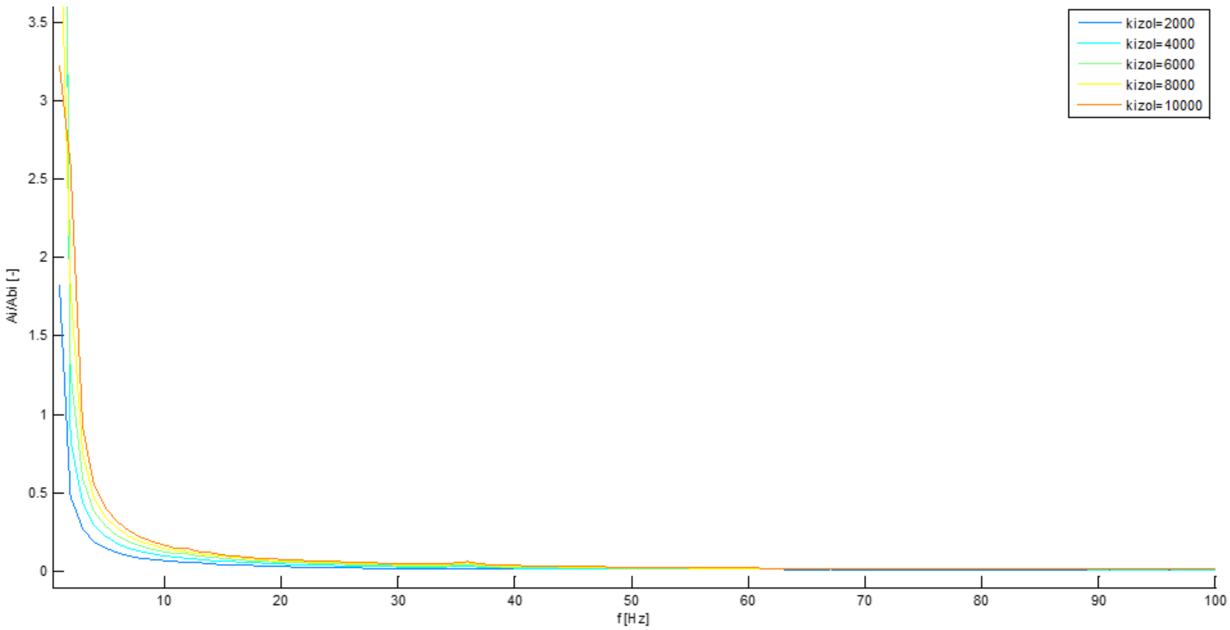

Fig. 6. Efficiency of vibroisolation on block under the weighting module x_w for different values of vibroisolation stiffness k_{izol}, for dumping coefficient c_{izol}=0.2

Fig. 7. Efficiency of vibroisolation on weighting transmitter x_{p2} *for different values of vibroisolation dumping c_{izol}, for stiffness coefficient k_{izol} =2000N/m*

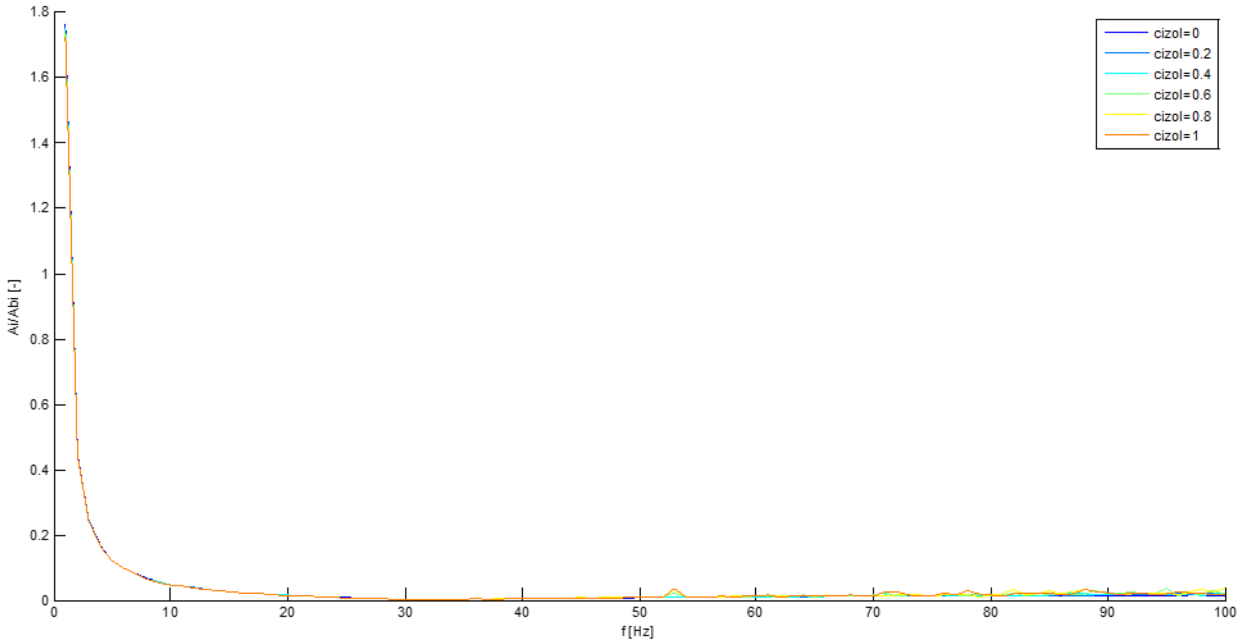

Fig. 8 Efficiency of vibroisolation on auxiliary transmitters x_{p1} for different values of vibroisolation dumping c_{izol}, for stiffness coefficient k_{izol} =2000N/m

Fig. 9. Efficiency of vibroisolation on block under the weighting module x_w for different values of vibroisolation dumping c_{izol}, for stiffness coefficient k_{izol} =2000N/m

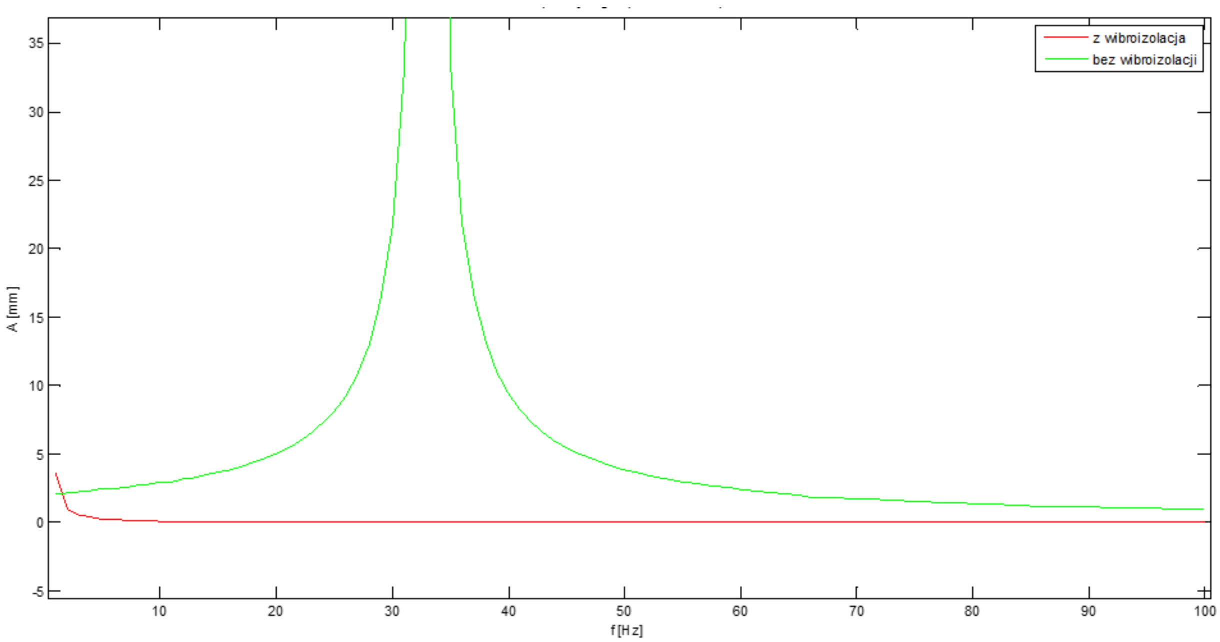

Fig. 10. Vibration spectrum of auxiliary transmitters without (green) and with vibroisolation (red) with coefficients c_{izol}=0,2, k_{izol}=2000 N/m

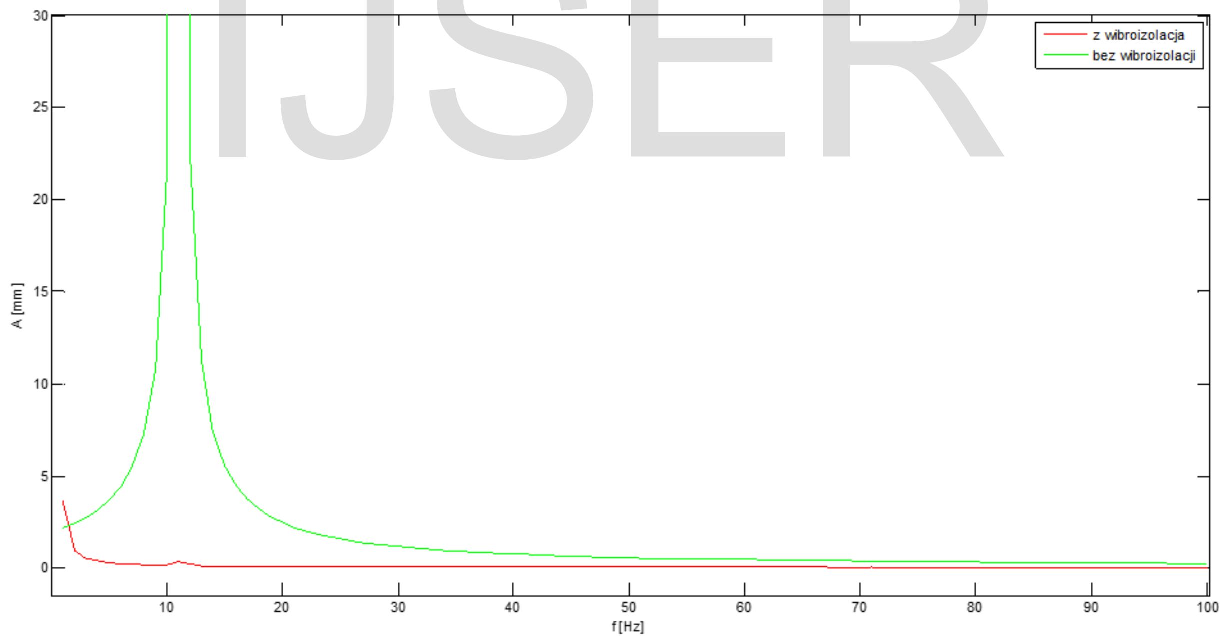

Fig. 11. Vibration spectrum of weighting transmitter *without (green) and with vibroisolation (red) with coefficients c_{izol}=0,2, k_{izol}=2000 N/m*

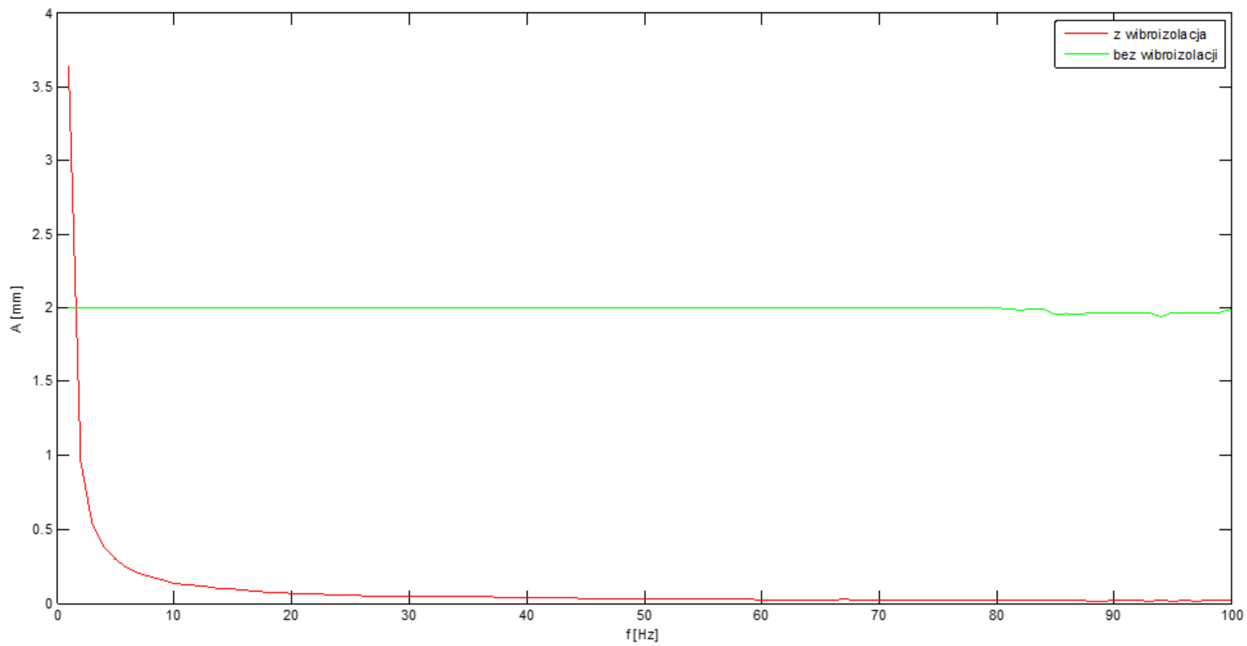

Fig. 12. Vibration spectrum of block under the weighting module without (green) and with vibroisolation (red) with coefficients c_{izol}=0,2, k_{izol}=2000 N/m

After analysis of results of simulation presented on Figures 4-9 optimal parameters of the vibroisolation coefficients were selected. Optimal attenuation of vibrations was obtained for coefficients c_{izol}=0.2 and k_{izol}=2000 N/m. Figures 10-12 present spectrum of vibrations on the models of analyzed checkweighter elements. Green characteristics present spectrum of vibes transition on analyzed object without vibroisolation between. Red characteristics present analogous spectrum with utilization of optimized vibroisolations.

As presented in Figure 10 vibration transition from base to the auxiliary transmitters. It is clearly visible that utilization of optimized vibroisolations significantly decreases amplitudes of transmitted vibrations. The most important is suppression of checkweighter resonance frequency (33 Hz).

Figure 11 presents vibration suppression on weighting module. Due to crucial role of this module in checkweighter operation, efficient isolation of vibration propagation is crucial during improvement of measurement accuracy. Significant suppression of main harmonics frequency (10 Hz) is visible.

Figure 12 presents vibration transition on block under conveyor belts, which in simplified model represents supporting structure of checkweighter. Due to significant mass, resonance frequency of this element is not visible in analyzed spectrum. On the other hand significant attenuation of vibrations amplitude in whole analyzed spectrum is visible.

4 Conclusion

In paper exemplary method of vibroisolation selection was described. Due to considerable complexity of analyzed system, development of simplified model was required. Reduced model contained four concentrated masses, connected by universal models of bonds.

Most universal bond model contains parallel connection of ideal spring and ideal suppressor. Coefficients of those models determine their behavior. Thus determination of those parameters is crucial during system modelling. Two ways of parameters determination was presented in paper. First was based on spectral analyses of impulse response of initial model. This method is more reliable but requires physical presence of analyzed object, thus cannot be utilized during system design. Second method of determination of bonds coefficients utilized Finite Element Method analysis conducted on model of the element. Results obtained with this method may be utilized during system design, in order to optimize its resonance frequency.

Based on created model numerical simulations of vibration transition were conducted. Influence of vibroisolation parameters was tested, and based on that optimal stiffness and dumping coefficients were selected.

Conducted simulations for optimized vibroisolations confirmed significant attenuation of vibrations transmission. Resonance frequency of all modules of checkweighter system were suppressed. The most important, for the system purpose, is suppression of vibrations on weighting module. Due to efficient vibroisolation improvement of mass measurement accuracy can be achieved.

Basing on numerical procedure vibroisolators can be selected from commercial elements, without conducting expensive and time-consuming tests or real object.

Acknowledgment

INNOVATIVE ECONOMY NATIONAL COHESION STRATEGY
EUROPEAN UNION EUROPEAN REGIONAL DEVELOPMENT FUND

This research is result of the project co-financed from the European Regional Development Fund under the Operational Programme Innovative Economy 2007-2013 (contract number POIG.01.03.01-14-086/12)„Grants for innovation".

References

[1] M.R. Hath, *Vibration simulation using MATLAB and ANSYS*, CRC Press, 2000

[2] R. Lewandowski and B. Chorążyczewski, „Identyfikacja parametrów lepkosprężystego tłumika drgań". *Zeszyty Naukowe Politechniki Rzeszowskiej. Mechanika*, pp. 203-214, 2008

[3] M.W. Dobry, "Efficiency of the constant interaction force vibroisolation (WOSSO)", *Journal of Theoretical and Applied Mechanics*, pp. 1083-1091, 2014

[4] H. Jaworowski, S. Kasprzyk and J. Wapiennik „Vibroisolation Parameter Selection Method and Stability Determination of a Discrete-Continuous System of the (∞,t)-Type", *ZAMM-Journal of Applied Mathematics and Mechanics* pp. 212-215, 1980

[5] J. Goliński, *Vibroisolation of Machines and Devices*. WNT, 1979

[6] R. Ugodziński, Ł. Gosiewski and R. Szewczyk. „FPGA based processing unit for a checkweighter". In *Recent Advances in Automation, Robotics and Measuring Techniques*, pp. 713-719, 2014.