

Determination of boom vibrations of the road header during cutting based on the analysis of images from high-speed cameras

Piotr Cheluszka, Rajmund Mann
Silesian University of Technology, Poland

Date of submission to the Editor: 05/2019
Date of acceptance by the Editor: 07/2019

INTRODUCTION

Boom-type road headers are equipped with (one or two) cutting heads placed at the end of a movable boom. This boom is swung in a parallel and perpendicular plane to the floor by means of hydraulic drive mechanisms. It is possible to move the cutting heads on the heading face of the drilled roadway in accordance with the assumed cutting technology. In classic mining technology, the rock is drilled parallel to the floor (Kotwica & Klich, 2011, Driesch & Kleinert, 1993). Therefore, the construction and technical parameters of the boom swinging mechanism in the plane parallel to the floor are of significant importance from the point of view of efficiency and effectiveness of the drilling process.

In the existing solutions of boom-type road headers, two types of boom swinging mechanisms are used, this is a significant rack and pinion mechanism and an actuator mechanism. In the first case, a rack placed between the pistons of two single-acting hydraulic cylinders cooperates with a gearwheel. The reciprocating movement of the pistons is replaced here by the rotational motion of the moving part of the turntable of the road header, to which the boom is fixed (Kotwica & Klich, 2011). Different variants of this mechanism can be found in road headers. There are systems with single or two racks used, with movable or stationary gearwheel. An alternative solution is an actuator mechanism, in which two double-acting hydraulic cylinders are fixed between the stationary part of the turntable or the main frame of the road header and the moving part of the turntable (Zong et al., 2018). The advantage of the rack and pinion mechanism, compared to the actuator mechanism, is that both the angular velocity of the boom rotation and the moment of its rotation do not depend on the angle of rotation of the boom. This is the case with the actuator mechanism, because as the boom turns, the distance between the longitudinal axes of the hydraulic cylinders changes from the axis of rotation of the turntable (Tian et al., 2018).

A characteristic feature of hydraulic drives is the variability of the velocity of movement as a function of its external load (Stryczek, 2014). The large variability of the load we encounter in the case of mining rocks, causes difficulties in maintaining a stable velocity of movement at the assumed level. Hydraulic drives used in road headers are the reason for the often large fluctuation of the velocity of movement of cutting heads on the surface of the heading face. This has an impact on the process of rock excavation. The conditions of the cutting process, including mechanical properties of the rocks and their variability, values of the cutting process (angular velocity of cutting heads, web of cut and cut height), as well as the course of the cutting process resulting from the way the picks are located on the cutting head affect the size and nature of the dynamic load of the boom and the swinging drives. The swinging velocity of the boom can be expected to have a periodic character with a strongly emerging trend resulting from the variability of the average cutting resistance. The variations in the velocity of swinging of the boom as a function of time will be accompanied by the circumferential vibrations of the boom. They will be the source of pressure pulsation in the road header's hydraulic power supply system, which has an unfavourable effect on its operation.

This article deals with the analysis of the variability of the swinging velocity of the boom in the plane parallel to the floor and its circumferential vibrations during the cutting process using a road header. The measurement of the swinging velocity of the boom and the acceleration of vibrations can be carried out in various ways. Commonly used for this purpose are various types of sensors mounted directly on the tested object, enabling the measurement of displacement, velocity and acceleration at selected points. An alternative way of measuring parameters describing motion and vibration are non-contact measurements based on the analysis of images recorded by one or many cameras. Due to the often fast-changing nature of the recorded phenomena, high-speed cameras are used for this purpose, providing the possibility of image recording at a sufficiently high frequency (Stancic, et al., 2009, Garbacz & Czajka, 2013).

The article presents selected results of the measurement of the swinging velocity of the boom of a road header and its vibrations during the cutting process using high-speed cameras. Video material registrations were carried out in the laboratory of the Department of Mining Mechanization and Robotisation of the Faculty of Mining, Safety Engineering and Industrial Automation at the Silesian University of Technology during experimental investigations of the R-130 road header (produced by FAMUR S.A.). This road header cut the surface of a cement-sand block composed of layers of different compressive strength (Cheluska et al., 2018).

MEASURING SYSTEM

One of the elements of the extended measuring system, which was equipped with the tested road header was a measuring system based on two high-speed cameras Phantom Miro LC 120 (Phantom) (Fig.1 – item 1) working in a

convergent arrangement of optical axes. The control of the registration process and the acquisition of measurement data was carried out using a computer (2) with the installed tool software.

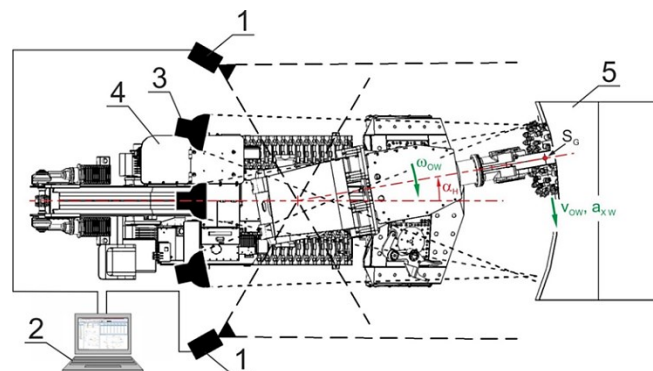


Fig. 1 Scheme of arrangement of photogrammetric measurement system elements on the test stand: 1 – high-speed cameras, 2 – camera control station, 3 – lighting, 4 – test object (R-130 road header), 5 – excavated cement-sand block

The registration of the boom movement during cutting performed simultaneously with two synchronized cameras allowed to analyse the motion of the machine in three-dimensional space. The reconstruction of the movement was based on a photogrammetric inverse space resection. For its implementation, the boom, the turntable, other road header components and stationary parts of the test stand (cement-sand block) were equipped with markers glued on their surface. The location of the traced measuring points (markers) in the space was determined on the basis of two rays running from this point and forming its image in photographs taken from two different positions (Kurczyński & Preuss, 2011). The cameras had to be set in such a way that the field of view of each of them covers the common area in which the object being examined was located (Fig. 2). The dimensions of the object being photographed (here: the front part of the road header – the turntable, the boom with its cutting heads and the cement and sand block) and the range of deflection of the boom in the plane parallel to the floor required the cameras to be spaced quite a long distance over the test object symmetrically to its longitudinal axis (Fig. 1). For this purpose, a bridge gantry was used, located in the Technological Hall, where the discussed research stand is located. Quite a considerable distance of the cameras from the examined object also allowed to protect them from dust arising during mining. The required exposure time of a single film frame, in order to avoid the smudging effect (image blur caused by their movement), must be as short as possible. During the discussed measurements it was $2 \cdot 10^{-5}$ s. With such a short exposure time, an important factor affecting the quality of the recorded film material was adequate lighting, without which it would have not been possible to obtain the required contrast necessary for the digital image analysis (Cheluska & Mann, 2019). Despite the high optical sensitivity of cameras, the ultra-short recording times of individual film frames required the use of very strong light. In addition, due to the high frequency of recording film frames, in this case 500 Hz, this light had to be characterized by a lack of pulsation, characteristic of light sources

supplied with AC power. These conditions were fulfilled by special LED lighting panels, the light of which was directed to the observed objects (Fig. 1 – item 3). To ensure illumination of the field of view of both cameras, lighting panels were placed on the gantry bridge over the test stand.

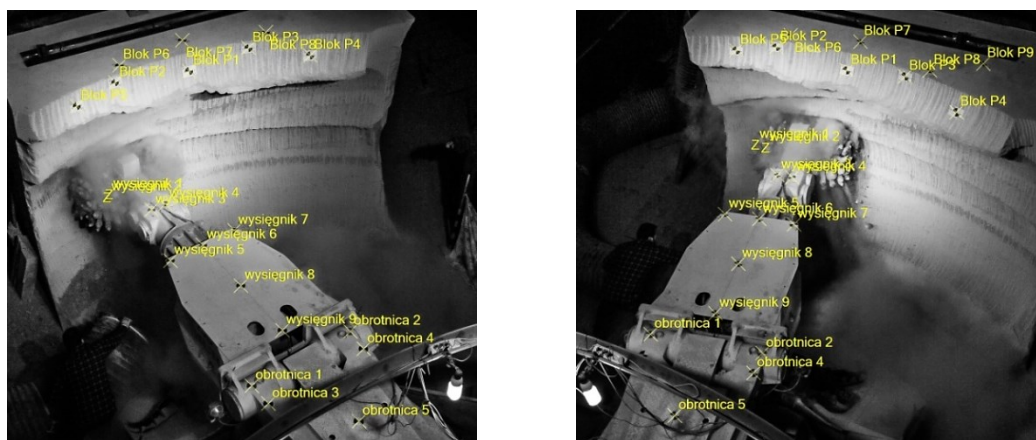


Fig. 2 View of the filmed object from the left and right high-speed cameras with visible markers

The identification of the location and orientation in 3D space of the recorded objects required filming of at least three fixed reference points along with the moving objects, which were used to determine the global XYZ coordinate system in which the motion was analysed. For this purpose, quadrant markers were placed on the upper surface of the cement-sand block. Such markers are best recognized by applications used for image analysis. The same markers were placed on the boom and the turntable of the road header. They made it possible to track the movement of selected points of the observed road header's subassemblies.

The process of cutting the cement-sand block with the cutting heads of the R-130 road header was filmed in 7.4 second time intervals. It was the maximum time allowed by the built-in memory of the used high-speed cameras with the assumed recording frequency (500 Hz) and the selected frame sizes.

The TEMA Motion 3D program – dedicated software for Phantom Miro LC 120 high-speed cameras (Fig. 3) was used to analyse the motion of the road header's boom.

After importing the films to the program, the markers were defined (Fig. 3) and the position and spatial orientation of the global coordinate system XYZ was determined basing on markers placed on the upper surface of the cement-sand block. Deformations of images caused by distortion of the lenses were corrected during film processing using correction factors obtained during calibration of the camera. The TEMA Motion 3D software enables tracking the position of the markers on subsequent frames of the recorded films. Based on the time courses of spatial coordinate values of the individual markers, the program determines the velocity and the acceleration of the boom and the turntable points.

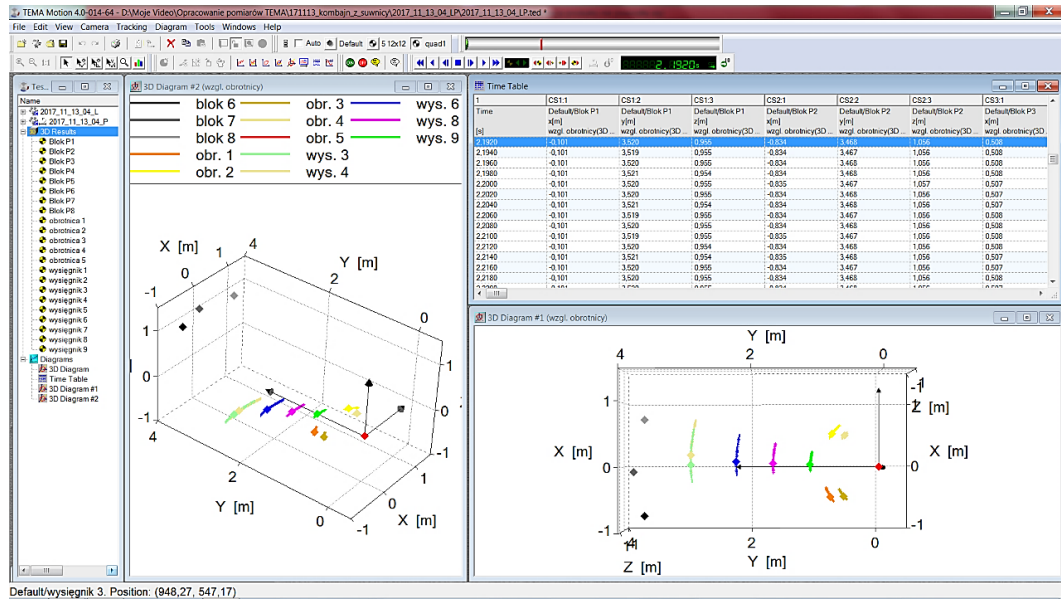


Fig. 3 Screenshot of the TEMA Motion 3D software during the analysis of movement of turntable and the boom points of the tested road header during mining

DETERMINATION OF THE VELOCITY AND CIRCUMFERENTIAL VIBRATIONS OF THE BOOM ON THE BASIS OF PICTURES ANALYSIS FROM HIGH-SPEED CAMERAS

Figures 4 to 8 show an example of the process of cutting the cement-sand block surface with the R-130 road header on the test stand.

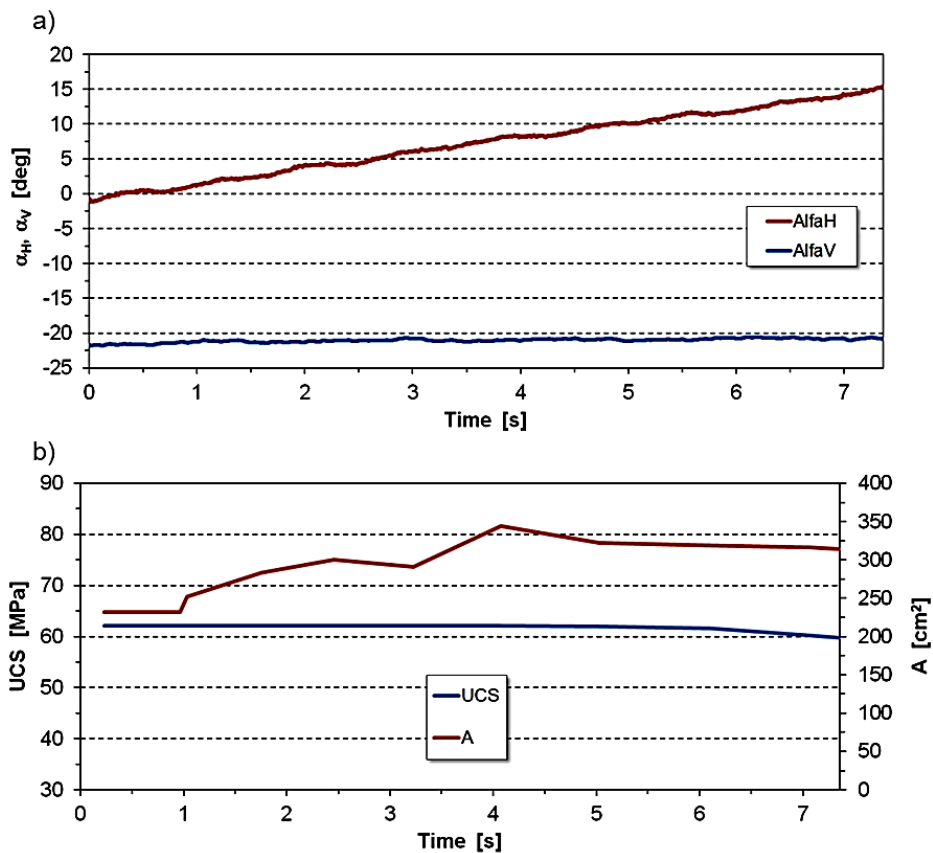


Fig. 4 Fragments of time courses: a) boom deflection angles in the plane parallel (α_H) and perpendicular (α_V) to the floor, b) uniaxial compressive strength of the cement-sand block (UCS) and cross-sectional area (A) of the sample cut

The registrations of the boom motion were made while cutting parallel to the floor in the right direction. In the time interval of 7.4 s, the boom rotated in a plane parallel to the floor in the range of angle α_H from 0 to + 15° (Fig. 4a – red line). The considered cuts were made near the floor – the angle of the boom deflection in the plane perpendicular to the floor α_V was around –21° (blue line). During cutting, the cutting heads cut rock with a UCS of about 62 MPa (Fig. 4b – blue line). As you can see, in the final phase, the UCS of the cut rock began to decrease. The mining was carried out with a web of cut of $z = 300$ mm. Due to the variable height of cut, the area of its cross-section A grew from 232 to 344 cm² in the first four seconds (Fig. 4b – red line). In the second part of the registration, the cross-sectional area of the cut was reduced to 310 cm².

The variability of the cutting process parameters and the nature of its course affect the size and the nature of the dynamic loads of picks and further – the cutting heads, their drive, drives of boom swinging mechanisms and the boom itself. The phenomena accompanying mining can be a source of high variation of the angular velocity (ω_{ow}) and the peripheral velocity (v_{ow}) of the boom (Fig. 5).

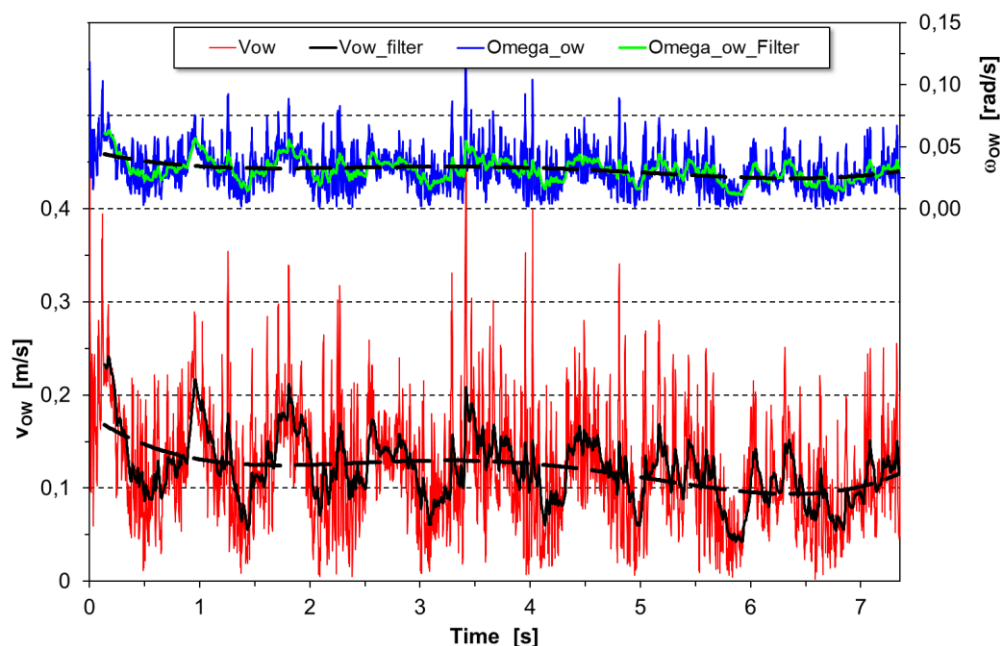


Fig. 5 Time courses of angular velocity (ω_{ow}) and peripheral speed (v_{ow}) of boom swinging in the plane parallel to the floor for example cut obtained on the basis of analysis of images recorded by high-speed cameras

The speed v_{ow} , reduced to the point of intersection of the longitudinal axis of the boom with the axis of rotation of the transverse cutting heads (point SG), is tangent to the arc with radius R being the distance of the point SG from the axis of rotation of the turntable (see Fig. 1). This pulsation is the result of variable dynamic load of the hydraulic drive mechanism of the boom swinging.

The course of the angular velocity ω_{ow} and the peripheral velocity v_{ow} of the boom swinging, determined on its basis, was obtained as a result of the numerical differentiation after the time of coordinates of the characteristic points

(markers) of the boom and turntable obtained on the basis of image analysis recorded by the high-speed cameras.

The traces obtained in this way (Fig. 5 – red and blue lines) are characterized by the occurrence of high noise. The differentiation process strengthens the contribution of measurement noise in the output signal (Paprzycki, 2015). In order to get rid of noise which distorts the real character of the examined quantities, the time courses of angular and peripheral velocities of boom swinging have been subjected to filtration. A discrete Kalman filter was used for this purpose (Grewal & Andrews, 2001) (Welch & Bishop, 2006):

$$\hat{X}_i = K \cdot x_i + (1-K) \cdot \hat{X}_{i-1} \quad \text{for } i = 1, 2, \dots, n \quad (1)$$

where:

x_i – measured value corresponding to the i -th moment of time,

\hat{X}_i, \hat{X}_{i-1} – respectively: current and previous estimated value,

K – Kalman gain factor.

The value of the K gain factor was selected experimentally as a result of comparing the spectrum of the original signal (Fig. 6a) with the spectrum obtained after filtration. Based on the assessment of the power spectral density of the original signal, significant vibration components were found in the frequency range not exceeding 10 Hz. Components with a frequency greater than this value can be considered as noise. The effect of filtration of angular velocity of the boom swinging for $K = 0.05$ is shown in Fig. 6b, and the filtered time courses of the boom's swinging velocity: ω_{OW} and v_{OW} are shown in Fig. 5 with the black and green lines.

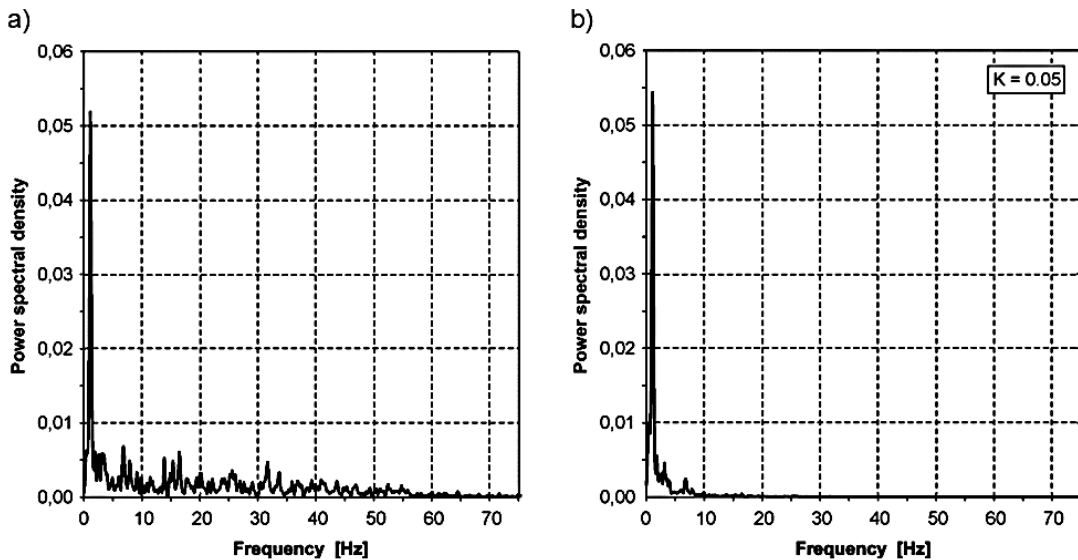


Fig. 6 Comparison of the boom swinging velocity spectrum (ω_{OW}):
a) original course, b) course after filtering with the Kalman filter (gain factor $K = 0.05$)

The analysis of time characteristics (Fig. 5) and spectral characteristics (Fig. 6) indicates a clear periodicity of the swinging velocity of the boom. The dominant component here is 1.1 Hz (6.9 rad/s). It corresponds to the angular velocity of the cutting heads at which the analysed fragment of cut was carried out. The basic

frequency of oscillation of swinging velocity overlaps with the components of frequency which are 3 times and 7 times higher. The share of these components is, however, definitely smaller. The average values of the angular velocity and the peripheral velocity of the boom are not constant (dashed lines in Fig. 5). Because the *UCS* of the cut material at the length of the examined part of the cut was essentially constant, the boom's swinging velocity adjusted to the excavation resistance proportional to the size of the cross-sectional area of the cut.

The boom motion analysis in the Tema 3D software also allowed to determine the course of circumferential boom vibrations during mining. They are a result of the variability of the external load of the boom and the dynamic properties of the hydraulic drive of the boom swinging mechanism. The temporal course of the acceleration of the boom (a_{xw}) obtained on the basis of the analysis of images recorded by the high-speed cameras (Fig. 7a) was compared with the record obtained from the accelerometer mounted at the end of the boom (in point S_G) – Fig. 7b.

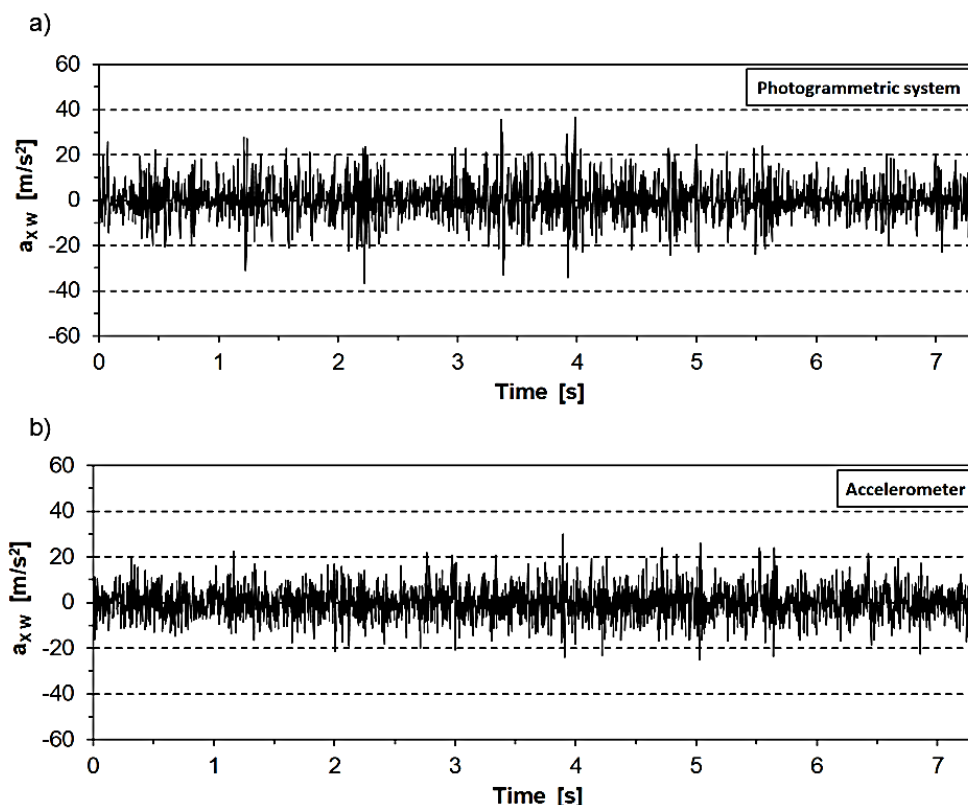


Fig. 7 Comparison of fragments of time courses of acceleration of boom circumferential vibrations (a_{xw}) obtained from: a) analysis of images from high-speed cameras, b) accelerometer

Due to the above-mentioned phenomenon of noise amplification in the process of numerical differentiation of the signal, the course of vibration acceleration obtained as a result of data processing from the vision system was filtered using the Kalman filter. Basing on the analysis of the spectrum of the vibration signal obtained with both mentioned methods, the value of the gain factor K at the level of 0.4 was chosen. These trends show a high similarity in both quantity and

quality (Fig. 8). In both cases, the vibration components with a frequency of around 35 Hz predominate. The amplitude of the oscillation of the boom's circumferential vibrations can be set at $\pm 20 \text{ m/s}^2$, and the effective value (RMS) of these curves is approximately 8 m/s^2 .

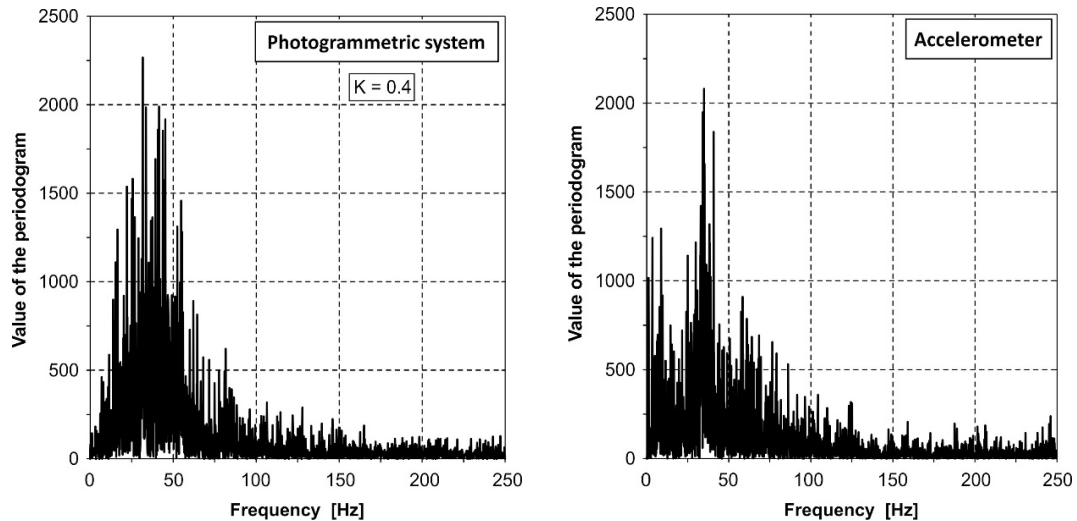


Fig. 8 Comparison of the boom circumferential vibration acceleration spectrum (a_{xw}) obtained from: a) analysis of images from a high-speed cameras after filtering the noise with the Kalman filter (gain factor $K = 0.4$), b) accelerometer

INFLUENCE OF THE CUTTING PROCESS CONDITIONS ON THE BOOM SWINGING VELOCITY AND THE INTENSITY OF ITS CIRCUMFERENTIAL VIBRATIONS

As you know, the conditions of the cutting process are changing. This is due to the variability of the rocks' workability as well as the variability of the parameters of this process, mainly the web of cuts and the cuts height. This effect also took place during the experimental investigations described in this work.

Figure 9 shows the dependence of mean values of: angular velocity (ω_{OW}^m) and peripheral velocity (v_{OW}^m) of the boom and the amplitude of these velocities ($A\omega_{OW}$ and Av_{OW}) on the efficiency of the mining process.

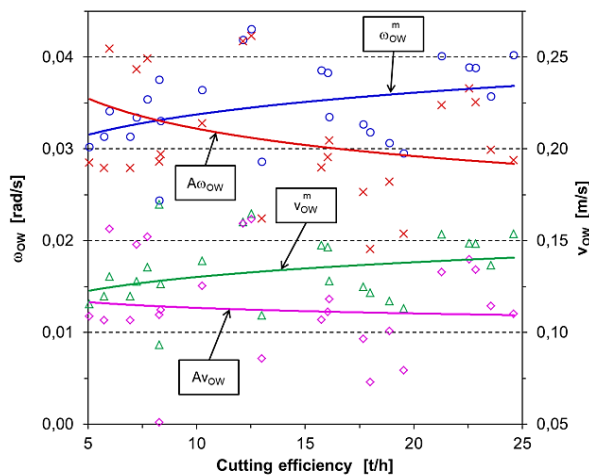


Fig. 9 Dependence of mean value (upper index "m") and amplitude (A) of angular velocity and peripheral velocity of boom swinging on cutting efficiency

The amplitude is understood here as the range of variability of the course of a given quantities, in the time interval being studied. The analysis was carried out for three cuts performed under different conditions. The increase in cutting efficiency is tantamount to the increase of the mean angular velocity (green line) and the peripheral velocity of boom swinging (blue line). The amplitude of the swinging velocity of the boom, however, is approximating decreasing with increasing cutting efficiency (lines in red and purple). This is justified because the high efficiency of cutting is not only due to the high moving velocity of cutting heads. It is also required to ensure the largest possible cross-section area of the cut. This results in an increase in the cutting zones of individual picks and an increase in the number of picks being simultaneously in contact with the cutting rock. This helps to alleviate the variability of the load of the cutting head, and, thus, reduces the extent of variability of the load of the boom swinging mechanism. This has the effect of reducing the extent of variability of the swinging velocity of the boom.

The influence of boom swinging velocity on the intensity of its circumferential vibrations is complicated (Fig. 10).

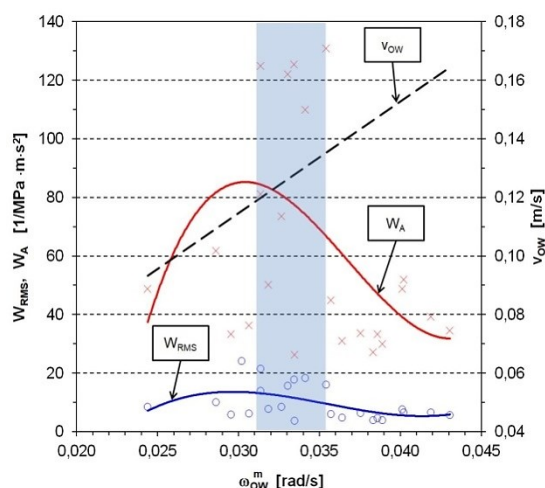


Fig. 10 Dependence of indicators of the intensity of circumferential vibrations of the boom on the average angular swinging velocity of the boom

In order to compare the intensity of circumferential vibrations of the boom during cutting in various conditions, the indicators of the intensity of vibrations of the boom were established, basing on:

- the effective value of the circumferential vibration acceleration (RMS value):

$$W_{RMS} = \frac{a_X^{RMS} \cdot W}{A \cdot R_C} \quad [1/\text{MPa} \cdot \text{m} \cdot \text{s}^2] \quad (2)$$

- the amplitude of the circumferential vibration acceleration (amplitude indicator):

$$W_A = \frac{A a_X \cdot W}{A \cdot R_C} \quad [1/\text{MPa} \cdot \text{m} \cdot \text{s}^2] \quad (3)$$

where:

a_{XW}^{RMS} , Aa_{XW} – respectively: the effective value and amplitude of acceleration of circumferential vibrations [m/s^2],
 A – the cross-sectional area of the cut [m^2],
 R_C – the uniaxial compressive strength of the excavated massif (*UCS*) [MPa].

These indicators remove the influence of the conditions of the cutting process, especially the transversal dimensions of cuts made in casing with different *UCS*. Therefore, they describe the intensity of the boom vibrations during cutting in comparable conditions, but at different velocities of movement of the cutting heads.

The waveforms of the vibration intensity indicators *WRMS* and *WA* from the angular velocity of the boom swinging are characterized by the occurrence of local maxima (Fig. 10). This means that as the boom's swinging velocity increases, the intensity of its circumferential vibrations increases initially. After reaching the maximum, in turn, it decreases. This effect is particularly visible in the case of the amplitude indicator of the boom's circumferential vibrations.

These vibrations are particularly intense in the range of the angular velocity of the boom from 0.032 to 0.035 rad/s (area in blue). It corresponds to the range of the variability of the peripheral speed of the boom v_{OW} from 0.120 to 0.135 m/s. Ensuring high velocities of movement of the cutting heads on the surface of the cut rock is therefore beneficial not only due to the efficiency of mining, but also due to the reduction of the intensity of vibrations.

CONCLUSION

The results of experimental investigations of the R-130 road header during the excavation of the cement-sand block presented in this article indicate the high usefulness of vision methods based on the use of high-speed cameras in the analysis of the behavior of machines and their components during performing of the working process. Advanced image processing algorithms that are implemented in software dedicated to this type of camera allow to track the movement of points (markers) plotted on the tested object. On this basis, it is possible to determine the time course of parameters characterizing the movement of the tested object (displacement, velocity and acceleration) and to identify the vibration intensity of selected machine construction nodes. The photogrammetry system based on two high-speed cameras enables recording and analysis of complex motion carried out in 3D space. The measurements using this method for moving objects significantly simplify the measurement system. It is not required to mount any sensors directly on the machine (with the exception of markers glued in selected places), and the measurement itself is carried out remotely. Non-contact measurements using vision techniques, however, require strict requirements regarding air transparency and lighting. In the case of testing mining machines, which work is accompanied by the release of large amounts of dust, meeting these requirements is particularly difficult. The success of such a venture therefore requires careful planning of research in

terms of proper equipment configuration (e.g. selection of lenses), its location and selection of points which location will be monitored. A large limitation here is the storage capacity for film recording, the size of which is inversely proportional to the recording frequency and the field of view of the camera. For this reason, the registration time is usually limited to a few seconds. In the case of measurements carried out for a road header during mining, it is possible to register only fragments of cuts made during the movement of the cutting heads. The conducted research indicates that at the stage of the measuring data processing, it is necessary to filter the obtained dynamic characteristics. The process of numerical differentiation introduces additional noise into these runs. The use of Kalman filter with appropriately selected gain factor allows to eliminate unnecessary components of vibrations, as a result of which it is possible to obtain waveforms consistent with those recorded using other measuring techniques (e.g. accelerometers).

Analysis of the results of measurements carried out using a photogrammetric system built on the basis of two high-speed cameras indicates that the course of mining and the conditions of its implementation strongly affect the speed of swinging of the boom and its vibrations. This impact applies not only to the average values of these quantities, but also to the extent of their variability. The behavior of the tested object results, among other things, from dynamic properties of the hydraulic drive, which is commonly used in the mechanisms of swinging the boom of road headers. The correct selection of the characteristics and the technical parameters of this drive, taking into account the drive of the cutting heads and the weight of the road header decides to a large extent on the efficiency of cutting and the dynamic condition of the road header.

ACKNOWLEDGEMENTS

This work has been implemented under the research project titled “Control of road header cutting heads movement for reduction of energy consumption of mining and dynamic loads” co-financed by the Polish National Centre for Research and Development under the Applied Research Projects (agreement no. PBS3/B2/15/2015).

REFERENCES

- Cheluszka, P., Sobota, P., Głuszek, G. (2018). Comparison of Energy characteristics of cutting using a road header with transverse cutting heads of varied construction. *Polish Mining Review*, 74(2), pp. 59-70 (in Polish).
- Cheluszka, P. and Mann, R. (2019).Vibration identification of the road header cutting head using high-speed cameras. In: *MATEC Web Conf.*, 252 (2019) 03018, DOI: <https://doi.org/10.1051/matecconf/201925203018>
- Driesch, S. Kleinert, H.W. (1993). Maßnahmen zur Verbesserung der Wirtschaftlichkeit im maschinellen Vortrieb. *Glückauf*, 129(7), pp. 519-523.
- Garbacz, P., Czajka, P. (2013). Multi-mirror system for high-speed camera monitoring applications. *Maintenance Problems*, 2, pp. 117-128.
- Grewal, M.S., A.P. and Andrews, A.P. (2001).*Kalman Filtering: Theory and Practice Using Matlab*, New York: John Wiley and Sons
- Kotwica, K. and Klich, A. (2011). *Maszyny i urządzenia do drążenia wyrobisk korytarzowych i tunelowych*. Gliwice: ITG Komag (in Polish).

- Kurczyński, Z. and Preuss, R. (2011). Podstawy fotogrametrii. Warszawa: Oficyna Wydawnicza Politechniki Warszawskiej (in Polish).
- Paprzycki, I. (2015). Zagadnienia pomiarów prędkości liniowej w spadku swobodnym. Logistyka, 3, pp. 3750-3757 (in Polish).
- Phantom Miro Lab, LC and R-Series Cameras DataSheet. [online] Available at: <https://citiusimaging.com/wp-content/uploads/2015/08/Miro-LAB-LC-R.pdf> [Accessed 1 Jul. 2019].
- Stancic, I., Borojevic, D., Zanchi, V. (2009). Human Kinematics Measuring Using a High Speed Camera and Active Markers. In: Proceedings of the 9th WSEAS International Conference on SIMULATION, MODELLING AND OPTIMIZATION, pp. 118-121. Budapest, Hungary, Sept. 03-05, Available at: <https://pdfs.semanticscholar.org/1fb1/7bdca34968ac5df1e23c127722762ca8183c.pdf> [Accessed 01 July 2019].
- Stryczek, S. (2014). Napęd hydrostatyczny. T. 2, T. 2., Warszawa: Wydawnictwo WNT (in Polish)
- Tian, J., Wang, S., Wu, M. (2018). Kinematic models and simulations for trajectory planning in the cutting of Spatially-Arbitrary cross-sections by a robotic road header. Tunnelling and Underground Space Technology, 78(8), pp. 115-123.
- Welch, G., and Bishop, G. (2006). An Introduction to the Kalman Filter. TR 95-041, Department of Computer Science, University of North Carolina, Chapel Hill, NC 27599-3175, pp.1-16.
- Zong, K., Zhang, P., Wang, P., Fu, S., Li, Y., Zhang, M., Wu, M. (2018). Multifactor Analysis of Road header's Body Pose Responses during the Horizontal Cutting Process. Shock and Vibration Volume 2018, Article ID 2387408, 18 pages, <https://doi.org/10.1155/2018/2387408>.

Abstract.

Excavation, especially of hard rocks, using boom-type road headers is a source of strong vibrations of the boom in which they are equipped. These vibrations are transferred through construction nodes further to the turntable and the body of the road header. On the one hand, they are of great importance from the point of view of the durability and the reliability of the mining machine. On the other hand, they affect the variability of the parameters at which the process of cutting the heading face surface of a drilled roadway or tunnel is carried out. For the purpose of determining the vibration intensity of the boom of the road header a photogrammetry system based on two high-speed cameras Phantom Miro LC 120 was used. During the experimental investigations of the cutting process of a cement-sand block using the R-130 road header, the boom and turntable movements were recorded. The analysis of the time-lapse pictures of the recorded footage obtained from the high-speed cameras using dedicated TEMA 3D software allowed to determine the spatial trajectory of movement of the boom and the turntable during the cutting of the massive with specified mechanical properties with set values of the parameters of this process. Basing on the time courses of the coordinates of the boom and turntable characteristic points, the courses of the actual boom swinging speed and acceleration components of its vibrations were determined. The intensity of these vibrations was related to the conditions of the cutting process.

Keywords: road header, cutting process, vibrations, measurement, high-speed cameras