23rd International Conference
ENGINEERING MECHANICS 2017
Svratka, Czech Republic, 15 – 18 May 2017

ACOUSTIC CLIMATE IN THE CABINS AS A FACTOR OF REBUILDING EFFECTIVENESS OF LONG TERM OPERATED BUCKET WHEEL EXCAVATORS – A CASE STUDY

M. Sokolski*, P. Sokolski**

Abstract: *The unprecedented case of two old bucket wheel excavators type SRs–1800 which were relocated from Spain to Poland is treated. Both machines were submitted to total reconstruction in Poland and then they were put into operation. Then, the complex investigations during continuous removal process of overburden was carried out. One of the goals was to evaluate the acoustic climate in the cabins - as a factor which determines the comfort and safety of the operators of these machines. In the paper the research results of one of this excavators are presented. It has been shown that the acoustic climate in the cabin after modernization of this excavator meets the relevant requirements.*

Keywords: Bucket Wheel Excavator, Operators' Cabin, Noise Hazards, Acoustic Climate.

1. Introduction

More than 35 % of the total electric energy production in Poland is based on brown coal. This is largely due to considerable domestic resources and lower costs of this kind of energy by about 20 % then that from black coal. To maintain this cost advantage many mining companies tend to extend the useful service life of their most expensive basic machinery beyond that specified in the original design.

The basic machines for open pit lignite mines are very expensive. For example a new bucket wheel excavator with annual capacity of 7 million bank cubic meters may cost up to 4.5 million US dollars. For this reason its purchase is in generally justified if the expected pit life is over of 10 - 15 years (Dudek and Sokolski, 2000; Sokolski, 2007).

However, during long time of operation these machines are subjected to several degradation processes which are in detail analyzed in the works (Dudek and Nowakowski, 1995; Nowakowski, 1999; Smolnicki et al., 2010). These degradation processes contribute to the reduction of safety level and can cause dangerous events: serious damages or even catastrophes (Mlynczak, 2014). One of their symptoms are increased noise and vibrations level which, beside thermal and weather conditions, are the most important factors creating a microclimate of work environment for operators (Sokolski, 2007).

That is why since the 1990s the complex program of modernization of all the old basic machines has been consistently put into practice in Polish brown coal companies. This revitalization strategy is of particularly importance for improving the energy security of Poland.

2. Problem formulation

An alternative solution to buying new basic machines for open pit mining is acquiring used objects. Spectacular results were achieved when two old bucket wheel excavators SRs 1800 (years of construction 1985 and 1986) have been purchased and transported to Poland from a lignite mine which was decided to be closed (As Pontes de Garcia Rodrigues in Spain).

* Marek Sokolski, PhD. Assistant Professor: Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, Lukasiewicza Street 4; 50-371 Wroclaw; PL, marek.sokolski@pwr.edu.pl

** Piotr Sokolski, PhD.: Faculty of Mechanical Engineering, Wroclaw University of Science and Technology, Lukasiewicza Street 4; 50-371 Wroclaw; PL, piotr.sokolski@pwr.edu.pl

Both excavators were upgraded in Poland. In particular, the electrical equipment of driving units was rebuilt, moreover many elements of the steel structures were replaced or regenerated. The first of these excavators was put into operation in 2010 and the second one (Fig. 1) started working in 2011. Then both bucket wheel excavators were subjected to attestation tests carried out by the team from the Faculty of Mechanical Engineering of Wroclaw University of Science and Technology.

One of the main targets of these approval tests was to assess the comfort and safety of the operators. The research program included, among other things measurement and analysis of noise level and noise spectrum in the operators' cabins of each of these excavators. The research was carried out in summer time during the continuous removal process of overburden. Due to the limited length of this paper, the research results of one of these bucket wheel excavators (shown in Fig. 1) are presented.

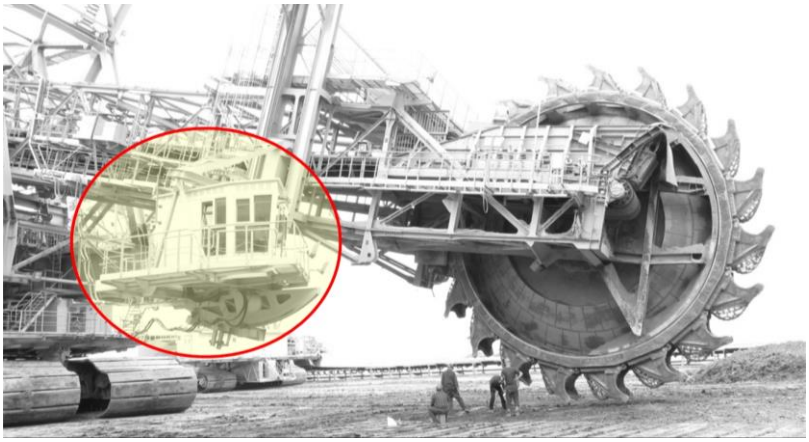

Fig. 1: Research object - bucket wheel excavator. Operator's cabin is marked (authors' own archive).

3. Method of assessment of acoustic climate in cabin

Evaluation of acoustic climate is nowadays an important issue. It can be done for both a small area like an operator's cabin and surrounding of an open pit mine. In the second case it can be performed through different techniques. An example of such a procedure is presented in (Pinzari et al., 2015). Assessment of the noise hazards and acoustic microclimate in the workplace is generally performed under the assumption that the noise level is deterministic.

In this approach, the acoustic microclimate in the cabin of bucket wheel excavator is evaluated by the A-weighted equivalent sound pressure level LAeq (determined for a nominal eight hour exposure period). The recommended occupational exposure limits of noise level are defined in proper international standards (e.g. ISO R 1996) and in the Ordinance of the Polish Minister of Labor and Social Policy ("Ordinance on maximum permissible concentration and intensity of harmful factors in the work environment in accordance with national limit values"). In accordance with these guidelines, the noise level should not exceed the following values:

- in the cabins and control rooms without telephone communications LAeq(perm) = 75 dB(A),
- in the cabins and control rooms with telephone communications LAeq(perm) = 65 dB(A).

In the more detailed assessment of acoustic microclimate, according to the recommendation of ISO R 1996, the sound spectrum and so-called Noise Rating curves NR are used. According to this idea, the octave noise spectrum is compared with the values of the relevant curve *NRx*, recommended for places where the assessment of noise hazard is made (e.g, in cabs, engine rooms, etc.). Index *x* of noise curve *NRx* is assumed from the formula:

$$x \cong L_{\mathrm{Aeq(perm)}} - 5\,;\ \mathrm{dB(A)} \tag{1}$$

However in real conditions, especially in cases of basic machines for open pit mining which are continuously operated in varying weather conditions, the noise level is a random variable. The main causes of noise in these machines are changeable in time force excitations generated particularly in driving units of bucket wheels, belt conveyors, slewing units and crawler movement units.

For these reasons, the noise in these machines should be treated in a probabilistic approach, wherein the *p*-Quantile Q_p of noise level (where *p* – confidence level) is a measure of acoustic microclimate.

According to this idea, if the Quantile Q_p is not greater than the permissible value of noise $L_{Aeq(perm)}$ i.e. when:

$$Q_p \leq L_{Aeq(perm)} \tag{2}$$

then the acoustic microclimate in the cabin meets the requirements determined in relevant standards.

4. Results

In accordance with the deterministic approach, the acoustic microclimate in the cabin should be analyzed on the basis of the octave noise spectrum and the relevant curves *NR60* (for cabins with telephone communication) and *NR70* (for cabins without telephone communication).

However the noise spectrum is by nature a temporary image (specific "screen-shot") of acoustic climate and therefore is not representative for several hours working cycle of excavators. This was confirmed by results of the research. Exemplary results are shown in Fig. 2. In some points the noise spectrum in the cabin exceeded the permissible values in the bands f ≥ 1 kHz.

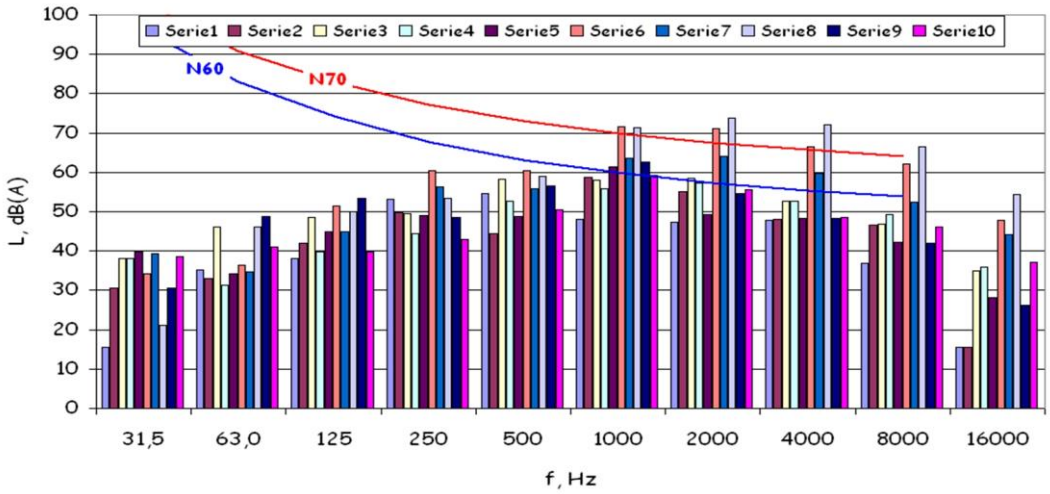

Fig. 2: Noise spectrum in the closed cabin.

In accordance with the probabilistic approach, the noise level in the cabin was analyzed in order to estimate its statistical distribution. The relevant histograms are shown in Fig. 3.

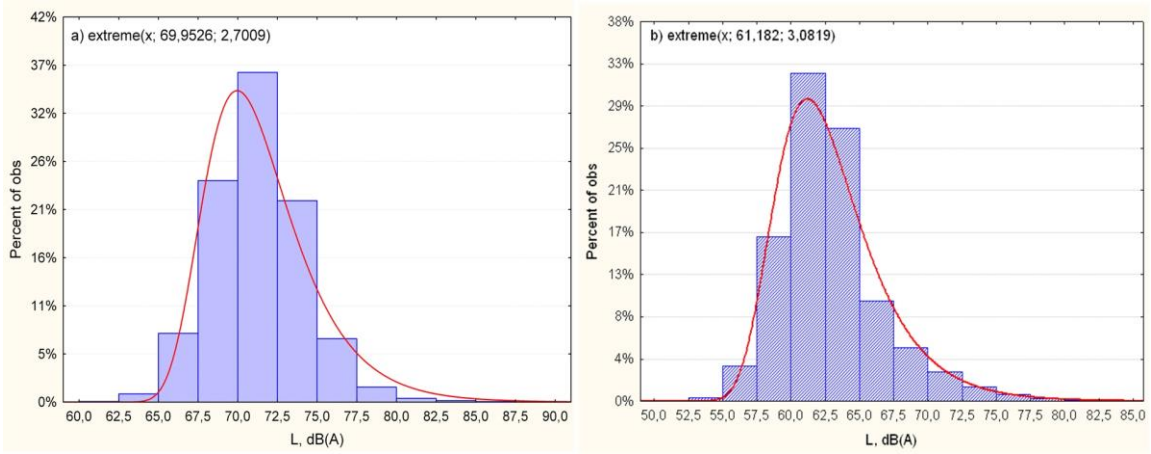

Fig. 3: Histograms of noise level: a) in the open cabin, b) in the closed cabin.

Then the Kolmogorov–Smirnov test was applied and the parameters of statistical distributions of noise level were estimated by using the method of maximum likelihood (with Statistica package).

The best accordance with experimental data was obtained for the Gumbel Extreme Value Distribution (Type I) which can be expressed as:

$$f_G\left(L_{\mathrm{Aeq}}\right)=\frac{1}{b}\exp\left\{-\frac{L_{\mathrm{Aeq}}-a}{b}-\exp\left(-\frac{L_{\mathrm{Aeq}}-a}{b}\right)\right\} \tag{3}$$

where: b – the scale parameter, a – the threshold (location) parameter.

On this basis the following values of Quantiles $Q_{0.95}$ were estimated:

- in the open cabin $Q_{0.95(\mathrm{open})}$ = 78.0 dB(A).

- in the closed cabin $Q_{0.95(\mathrm{closed})}$ = 70.3 dB(A).

Therefore the results show that the closed cabin of the tested bucket wheel excavators meets the requirements for cabins and control rooms without telephone communication.

This is quite a significant achievement, when considering that the cabin is located near the bucket wheel, which is a source of noise level of the order of L_{Aeq} = 90 – 95 dB(A).

5. Conclusions

Significant increase in noise hazards and deterioration of acoustic climate is an attribute of degradation processes of long time operated basic machines for open pit mining. This effect is especially important in the areas of continuous human presence, in particular in operators' cabins as long exposure to excessive noise can have a critical influence on human health. Virtually all of systems can be damaged, including respiratory, digestive, visual, cardiovascular and nervous ones (Cannistraro et al., 2016).

One way to solve these problems is to rebuild driving units of these machines in the context of reducing their acoustic activity. Such a procedure has been applied to two old bucket wheel excavators (built in 1980s) which were brought from Spain and subjected to a thorough reconstruction in Poland.

Total approval investigations have shown that the renewed excavators meet the stringent requirements for acoustic microclimate. Some relevant results of research of microclimate in the operator's cabin are presented in this paper.

However because the noise level in the basic machines for open pit mining is a random variable, the assessment of noise hazards should be done in a probabilistic approach. As a measure of the microclimate the *p*-Quantile of noise level (where *p* – assumed confidence level) determined on the basis of relevant model of statistical distribution can be assumed. This model should be estimated on the basis of consecutive long time research of basic machines for open pit mining.

References

Cannistraro, G., Cannistraro, A., Cannistraro, M. and Engineer, F. (2016) Evaluation of the sound emissions and climate acoustic in proximity of one railway station. International Journal of Heat and Technology, Vol. 34/2, pp. 589-596.

Dudek, D. and Nowakowski, T. (1995) Problems of degradation and maintenance of surface mine engineering machines. In. Proc. of Int. Symposium on Materials Ageing and Component Life Extension, Milan, Italy, Vol. 2. Eds. V. Bicego, A. Nitta, R. Viswanathan Warley: Engineering Materials Advisory Services, pp. 1285-1294.

Dudek, K. and Sokolski, M. (2000) Improved vibroacoustic characteristics - A goal to be pursued in the open pit mining machinery of the XXI century, in Proc. of Mining Symp. Mining in the new millennium. Challenges and opportunities, Las Vegas, Nevada, USA, (ed. Golosinski). Rotterdam; Brookfield, A. A. Balkema, pp. 193-199.

Mlynczak, M. (2014) Bucket wheel excavators : past to present experiences in safety operation, in: Probabilistic Safety Assessment and Management, PSAM 12, Honolulu, Hawaii, USA, International Association for Probabilistic Safety Assessment and Management (IAPSAM), pp. 1-8.

Nowakowski, T. (1999) Comparative analysis of degradation degree of bucket wheel excavators. Proceedings of ESREL '99 - The Tenth European Conference on Safety and Reliability, Munich-Garching, Germany, Vol. 1, Eds. G. I. Schueller, P. Kafka Rotterdam: A. A. Balkema, 1999, pp. 223-227.

Pinzari, M., Alfaro Degan, G. and Lippiello, D. (2015) Environmental noise impact from opencast quarries: A comparison between stochastic and deterministic approaches. In 15th International Multidisciplinary Scientific Geoconference and EXPO, SGEM 2015, Vol. 3, No. 1, pp. 263-270.

Smolnicki, T., Harnatkiewicz, P. and Stanco, M. (2010) Degradation of a geared bearing of a stacker. Archives of Civil and Mechanical Engineering, vol. 10, No. 2, pp. 131-139.

Sokolski, M. (2007) High vibroacoustic hazards level – attribute of the degradation of the open pit mining machinery. Surface Mining, R. 49, nr 3/4, pp. 148-152 (in Polish).