The Estimation of Changes in The Noise Level Generated by Devices Equipped with Two-Stroke Internal Combustion Engines with Small Displacement Volume

Tomasz Figlus
Assistant Professor
Silesian University of Technology
Faculty of Transport
Poland

Andrzej Wilk
Professor
Silesian University of Technology
Faculty of Transport
Poland

Patryk Franke
Student of II level study
Silesian University of Technology
Faculty of Transport
Poland

Two-stroke single-cylinder internal combustion engines with small displacement volume belong to a group of driving units which are characterized by considerably noisy operation. These engines, owing to small sizes, small weight and the convenience of their use, are applied in devices such as grass trimmers, brush cutters or chainsaws for cutting wood. Their influence on the environment and labourers lowers the comfort of staying in a place where such devices are operated and poses a threat to human health. This paper presents the results of noise measurements carried out by the authors to assess a change in the noise level emitted by two-stroke single-cylinder internal combustion engines with small displacement volume, which are used as a drive in grass trimmers. In the tests and in an analysis of the results, the influence was determined of parameters such as displacement volume, power and the technical condition of the engine, on the level of the emitted noise which reaches the operator.

Keywords: *Combustion engine, noise, grass trimmers, operation.*

1. INTRODUCTION

Two-stroke single-cylinder internal combustion engines with small displacement volume are used to drive machines and devices [1-3] where a small weight and a small size, and the possibility to operated the device in different positions are required. They are single-cylinder engines cooled with air, which are characterized by a maximum displacement volume of up to 51 cm^3, power of 2.2 kW and a maximum rotational speed of up to 12,000 rpm. Since they satisfy the requirements, the engines are widely used to drive such devices as grass trimmers, brush cutters or chainsaws for cutting wood [4-5]. A typical feature of drive units of this type is, however, a high noise level, which is disadvantageous for both the environment and the operators, for it lowers the comfort of working conditions and poses a threat to human health [4-11].

The noise influence on a human being is dependent on, not only the value of the noise level, but also the time of its duration [6-11]. This creates a situation where the working conditions of an individual determine the degree of risk of health deprivation. There are standards in place which specify the permissible noise level to which a device operator can be exposed and the limit values above which ear protection should be used [8].

An example of the influence of different noise levels on the risk of health loss is presented in Figure 1.

The chosen domestic/farm devices obtain certificates of a permissible noise emission level on the basis of measurements of their acoustic power [12]. The level of acoustic power recorded in these cases does not refer directly to the evaluation of the user's exposure to a high noise level, as the noise depends on the place of carrying out the measurement [13-15].

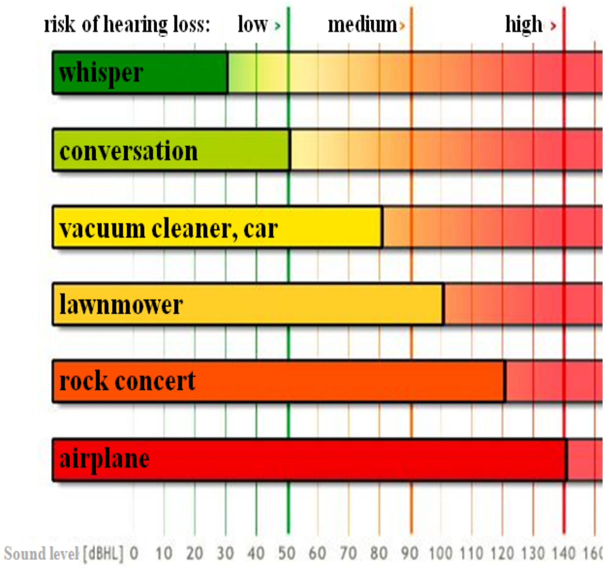

Fig. 1. The influence of sound level on the risk of losing hearing by human

In the paper there are presented the results of the authors' measurements, the aim of which was to estimate the change in the noise emitted by two-stroke single-cylinder internal combustion engines with small displacement volume. For the tests, typical

Received: May 2013, Accepted: June 2013
Correspondence to: PhD Eng Tomasz Figlus
Faculty of Transport
Silesian University of Technology
8 Krasinskiego Street, 40-019 Katowice, Poland
E-mail: tomasz.figlus@polsl.pl

grass trimmers were chosen, which use this type of drive. During the tests, the influence of displacement volume, power and the technical condition of the engine on the emitted noise reaching the operator was determined.

2. SINGLE-CYLINDER INTERNAL COMBUSTION ENGINES AS THE NOISE SOURCE

In the internal combustion engine we can distinguish many sources of noise and vibrations. The noise arising during the engine work is generated by aerodynamic and mechanical processes. The aerodynamic processes occur during intake, combustion and fumes exhaust. While the piston moves from TDC (Top Dead Center) to BDC (Bottom Dead Centre) in the cylinder, the pressure in the intake system reduces. An abrupt pressure difference occurs, as a result of which the column of gas starts vibrating. During the combustion process waves of changing pressure are formed, which are the main source of sound waves. During the exhaust there is noise because of the gas outflow through the exhaust pipe [6].

The noise caused by mechanical processes arises because of the work of systems such as the fuel pump or the crank-piston mechanism. In the case of the crank-piston mechanism, the vibrations occur because of backlash, mass unbalance, and also as a result of the piston hitting against the cylinder sliding surface. Other places that are hit include the crankshaft-connecting rod contact surface, connecting rod-piston, and piston-bolt. The hits are the direct source of noise and, in an indirect way, they influence the vibration of the cylinder sleeve and thereby, the generated noise level [16-20].

3. THE RESEARCH METHOD

The objects of the study were two-stroke internal combustion engines with small displacement volume, used to drive grass trimmers. The definition of the grass trimmer is provided in Directive 2000/14/EC of the European Parliament and the Council of 8 May 2000 [12].

For the tests, grass trimmers were used, equipped with different internal combustion engines, before and after repair, in which two different types of handles and different solutions of the cutting blade were applied.

On the basis of preliminary measurements, for the main tests of the emitted noise level, the grass trimmers presented in Table 1 were used.

The grass trimmers were grouped in the tests according to their operational wear, which depends on: the production date, the working time during one year and the time from the last repair. According to these criteria, the technical condition was determined by the repair and maintenance staff. The wear was determined on the basis of a 5-grade scale, where 0 meant a brand new grass trimmer without any signs of use, while 4 meant a device with the highest level of wear.

One of the classification criterion was to determine lack or presence of repair. Also, a state called "serviceable" was determined, which meant that the grass trimmer was fully efficient and did not need any repair.

Examples of grass trimmers used for the measurements are presented in Figures 2-3.

The measurements were carried out with the use of a Sonopan DSA meter (Figure 4) set up in the 1/3 octave analyzer mode with the nominal rotating speed of the grass trimmers.

The conducting of measurements at a nominal rotational speed of a grass trimmer corresponds to a situation of its normal operation. The values of nominal rotational speed were different for the investigated grass trimmers (depending on the model) and were contained in a range of 9,000 – 12,000 rpm.

For each grass trimmer there were 4 measurement series performed for every of microphone positions - Figures 5 and 6.

It was assumed that the measurement time would last 10 seconds.

Table 1. Grass trimmers used for noise measurement

No	Make	Model	Engine displa-cement [cm3]	Engine Power [kW]	Year	Wear	Before / After repair	Cutter	Handle
1.	Alpina Star	41D	36,3	1,6	2005	3	Serviceable	Blade	Double
2.	Budget	BMS 9038	33,0	0,9	2010	4	Before	Nylon cutter	Double
3.	Kawasaki	KBH 48	48,6	2,2	2003	2	After	Nylon cutter	Double
4.	Castorama	SL25C3	25,0	0,9	2010	1	Serviceable	Nylon cutter	Double
5.	Honda	UMT 51	51,0	1,9	1997	3	After	Nylon cutter	Double
6.	Husqvarna	232R	30,8	1,1	1998	3	After	Nylon cutter	Double
7.	McCulloch	Cabrio 310	38,0	1,3	2000	4	Before	Nylon cutter	Double
8.	MTD	600	21,0	0,7	2009	1	Serviceable	Nylon cutter	Single
9.	NAC	WLBC4 30B-2ZTU	42,7	1,3	2011	1	After	Blade	Double
10.	Partner	347B	34,0	1,2	2002	2	After	Nylon cutter	Double
11.	Stihl	FS480	48,7	2,2	2007	2	Before	Blade	Double
12.	Weed Eater	PL200	25,0	0,7	1999	3	Serviceable	Nylon cutter	Single
13.	Stihl	FS200	36,3	1,6	2002	2	After	Nylon cutter	Double

Fig. 2. Grass trimmer with single handle MTD 600 [21]

Fig. 3. Grass trimmer FS200 with double handle [22]

Fig. 4. The sound level meter DSA-50

The studies of the grass trimmers were carried out in the open air, without any objects around that would reflect the sound. The nearest obstacle was located within a distance of 7 metres.

The measuring microphone was installed on a tripod (175cm high), which corresponded to the height of the operator's ear. The microphone was placed next to the operator's ear in two positions: at the side and to the back.

The position outline is presented in Figures 5 and 6.

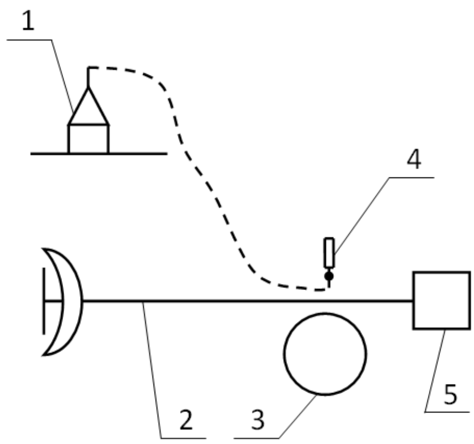

Fig. 5. A scheme of the measuring stand with the microphone "at the side", where: 1 – measuring device, 2 – grass trimmer, 3 – the operator's head, 4 – measuring microphone on a tripod – 175cm, 5 – engine

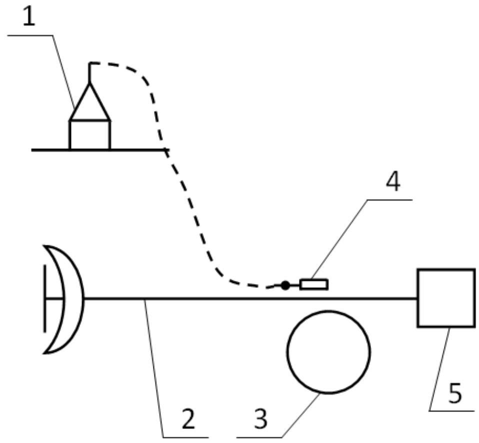

Fig. 6. A scheme of the measuring stand with the microphone "to the back", where: 1 – measuring device, 2 – grass trimmer, 3 – the operator's head, 4 – measuring microphone on a tripod – 175cm, 5 – engine

On the basis of the recorded measurement results the average values were calculated according to the dependence [6, 8]:

$$L_{Aeq} = 10 \cdot \log\left(\frac{1}{n}\sum_{k=1}^{n} 10^{0,1 \cdot L_k}\right)$$

where:

n – number of the elementary measurements in the measured set

L_k - the equivalent sound level during k of the measure period [dB(A)].

During the initial tests, measurements of the background sound were carried out. The results were between 42 and 46 dB(A), so they did not have a significant influence on the recorded noise level during the principal measurement.

4. THE RESEARCH RESULT AND THEIR ANALYSIS

In Figure 7 there is a comparison of the measurement results of noise emitted by grass trimmers which had similar power.

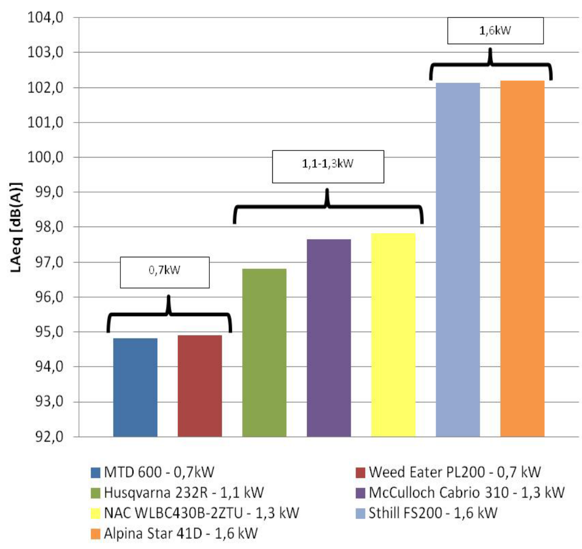

Fig. 7. The grass trimmers grouped according to power

It was noticed that an increase of power by about 0.3kW results in an increase of the noise level by about 3-5 dB(A).

In Figures 8-10 there is a comparison of noise emitted by grass trimmers with a similar engine displacement and different power.

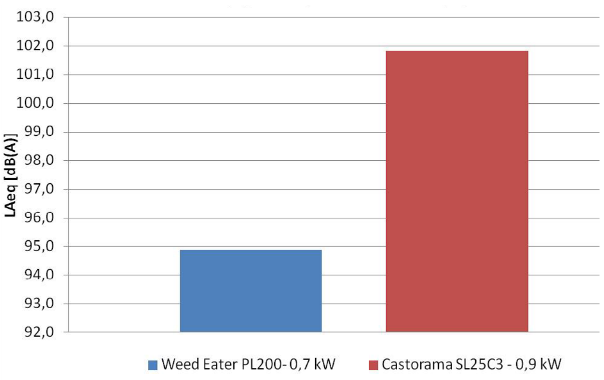

Fig. 8. The influence of the power of grass trimmers with engine displacement of 25cm^3 on the equivalent sound level

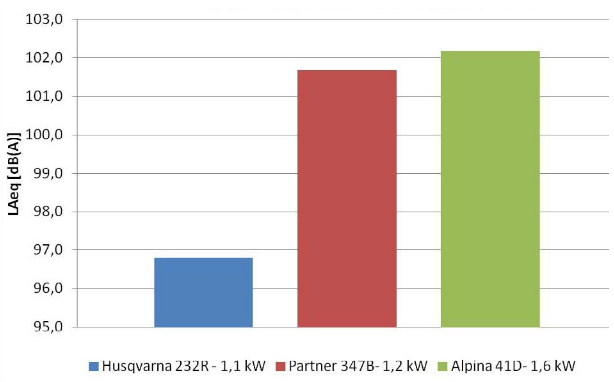

Fig. 9. The influence of the power of grass trimmers with engine displacement of 30-36 cm^3 on the equivalent sound level

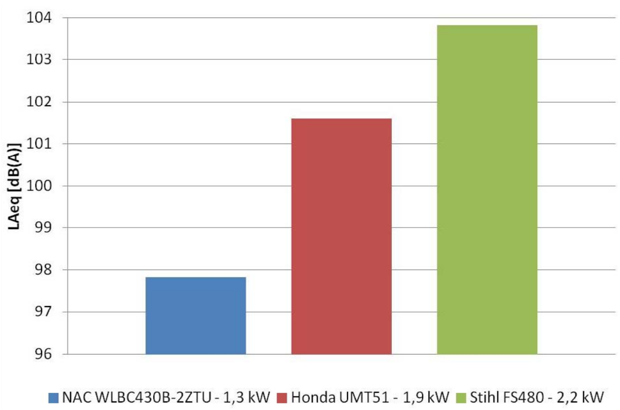

Fig. 10. The influence of the power of grass trimmers with engine displacement of 42 – 51 cm3 on the equivalent sound level

On the basis of the obtained results it can be stated that in the case of engines with comparable displacements, the higher the engine power, the higher the noise is. It results the fact that an engine with the same displacement but with higher power is more strained in comparison to an engine with smaller power. This has also an influence on the increased noise level.

Figure 11 shows an example of a dependence of the grass trimmer wear on the level of the emitted noise. For a comparison purposes, grass trimmers with similar parameters were chosen, namely with engine displacement of 48.6 – 51.0 cm^3, and power of 1.9 – 2.2 kW.

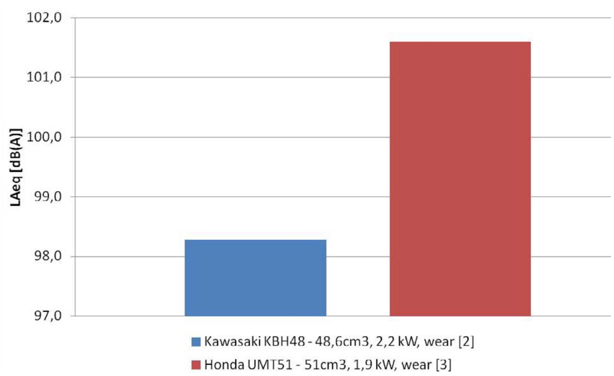

Fig. 11. The influence of wear of grass trimmers (2 and 3) with similar parameters on the equivalent sound level

An increase in the noise level was observed as the wear was increasing during operation.

Also, grass trimmers with the same technical parameters were compared, however, one of the devices was before and the other after a repair. The equivalent sound level recorded in those cases is presented in Figure 12. The difference in the level of noise emitted by the grass trimmers before and after the repair was significant and amounted to 6 dB(A).

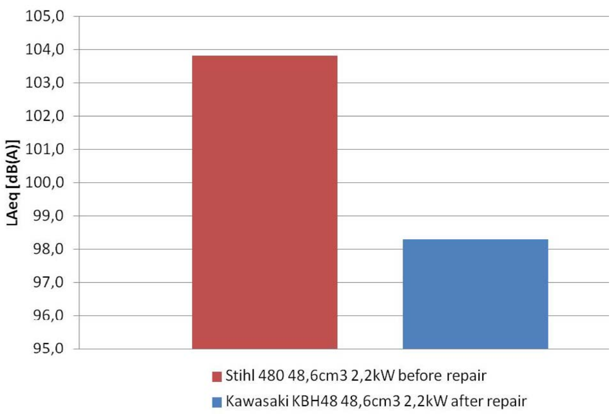

Fig. 12. The influence of repair of grass trimmers with the same engine parameters on the equivalent sound level

When carrying out the measurements, it was noticed that the type of the handle used in a grass trimmer influenced the direction of noise propagation. Grass trimmers equipped with one handle (Figure 2) and with a double handle (Figure 3) were compared. The results are presented in Figure 13.

The measurement results showed that despite the difference in the level of noise emitted by both engines, which resulted from their different power and displacement volume, the sound intensity in the case of the grass trimmer with a double handle was higher for the sound emitted to the back, while in the case of the device with one handle, to the side. This results from the fact that in grass trimmers with a double handle, the engine is installed just behind the operator's back, which makes the noise emitted at the back higher. While operating a device with one handle, the operator keeps it at an angle, so the engine, being the main source of noise, is also behind the operator's back and slightly moved to the side, which makes the noise higher towards that side.

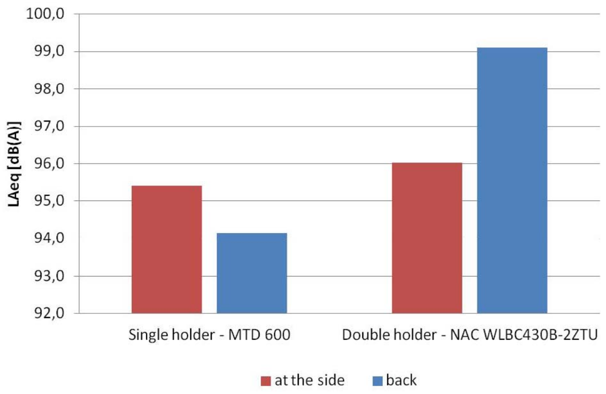

Fig. 13. The influence of the type of a grass trimmer handle on the direction of the emitted noise

5. CONCLUSION

The paper discusses an important problem of noise emission generated by two-stroke single-cylinder internal combustion engines with a small displacement volume. The engines are popular drive units used in devices operated by service companies and in households.

The measurement results of noise generated by grass trimmers with internal combustion engines showed that the sound level recorded near the operator's ear is over 90 dB(A) and is dependent on the engine power, the technical solution and condition of the grass trimmer. The conducted tests showed that a drive of this type causes a significant increase in the sound level and exposes the operator to the risk of losing hearing.

The grass trimmers with low power, of about 0.7 kW, generate noise at a level of ca. 95 dB(A), while those with power of 1.2 kW generate noise close to 98 dB(A). The models of grass trimmers with the most powerful internal combustion engines, i.e. 1.6 kW, generate noise of as much as 102 dB(A). The tests showed that an increase in the power of the grass trimmer engines with the same displacement volume causes an increase in the noise level, which in the tests amounted to 7 dB(A) and exceeded the value of 103 dB(A). The test results demonstrated that the sound level emitted by the grass trimmers grew as their wear increased. At the same time, the level of the emitted sound reduced significantly (to 6dB(A)) after repair of the grass trimmer. The measurements taken and analysis of the results with regard to the noise generated by grass trimmers with a single and a double handle showed that the former generate a higher noise level reaching the operator from the side towards the back (Figure 13), contrary to the grass trimmers with double handles.

The analysis of the results showed explicitly that there is a necessity to use individual ear protectors by operators of the currently sold and used grass trimmers equipped with two-stroke single-cylinder internal combustion engines with a small displacement volume.

The test results also indicate a need for further research in the field of noise emitted by grass trimmers equipped with two-stroke single-cylinder internal combustion engines and development of new design solutions with reduced noise emissions.

REFERENCES

[1] Trattner, A., Schmidt, S., Kirchberger, R., Eichlseder, H., Kölmel, A., Raffenberg, M. and Gegg, T.: Future engine technology in hand-held power tools. SAE Technical Papers;4, 2012.

[2] Hooper, P.R., Al-Shemmeri, T. and Goodwin, M.J.: An experimental and analytical investigation of a multi-fuel stepped piston engine. Appl Therm Eng, pp. 48:32-40,2012.

[3] Crosbie, S.C., Polanka, M.D., Litke, P.J. and Hoke, J,L.: Increasing reliability of a small 2-stroke internal combustion engine for dynamically changing altitudes. In: 50th AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition; 2012.

[4] Ko, Y.H., Ean, O.L. and Ripin, Z.M.: The design and development of suspended handles for reducing hand-arm vibration in petrol driven grass trimmer. Int J Ind Ergonomics, Vol. 41, No. 5, pp. 459-70, 2011.

[5] Mallick, Z., Badruddin, I.A., Khaleed Hussain, M.T., Salman Ahmed, N.J. and Kanesan, J.: Noise characteristics of grass-trimming machine engines and their effect on operators. Noise and Health [Internet], Vol. 11, No. 43, pp. 98-102, 2009.

[6] Engel Z.: The Environment Protection against vibration and noise, AGH, Kraków, 1980. (in Polish)

[7] Koradecka, D.: Health and worker safety, CIOP PIB, Warszawa, 2008. (in Polish)

[8] Pawlaczyk – Łuczyńska M.: Minimizing the risk of hearing loss in the workplace, Oficyna Wydawnicza Instytutu Medycyny Pracy im. Prof. J. Nofera, Łódź 2010. (in Polish)

[9] Augustyńska, D., Pośniak M.: Harmful factors in the work environment. Limits (in Polish), CIOP PIB, Warszawa 2010.

[10] Augustyńska, D. and Zawieski, W.: Protection against noise and vibration in the working environment, Centralny Instytut Ochrony Pracy, Warszawa 1999. (in Polish)

[11] Engela Z. W. and Sadowskiego J.: Environmental noise in Poland in view of European legislation Centralny Instytut Ochrony Pracy – Państwowy Instytut Badawczy, Warszawa 2005. (in Polish),

[12] Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000 on the approximation of the laws of the Member States relating to emissions into the environment by equipment for use outdoors.

[13] Burdzik, R. and Konieczny Ł.: Research into noise emissions by a car combustion engine exhaust system, Zeszyty Naukowe Akademii Marynarki Wojennej rok LII NR 1 (184), 2011.

[14] Figlus, T., Wilk, A. and Krajzel, K.: The influence of drive parameters and technical condition on the vibroactivity of devices with single cylinder internal combustion engines.Transport Problems, Vol.. 8, No. 1, pp. 79-86, 2013.

[15] Figlus, T., Wilk, A. and Krajzel, K.: Noise emmision study of lawnmowers with SI engine, Transactions of Universities of Košice, No. 3, pp. 45-50, 2012.

[16] Czech, P. and Madej, H.: Application of cepstrum and spectrum histograms of vibration engine body for setting up the clearance model of the piston-cylinder assembly for RBF neural classifier, Eksploatacja i Niezawodność – Maintenance And Reliability, Vol. 4, No. 52, pp. 15-20,2011.

[17] Komorska, I.: Diagnostic-oriented vibroacoustic model of the reciprocating engine. Diffusion and Defect Data Pt.B: Solid State Phenomena, pp. 180:214-21, 2012.

[18] Madej, H., Czech, P.: Discrete wavelet transform and probabilistic neural network in IC engine fault diagnosis, Eksploatacja i Niezawodność – Maintenance And Reliability, Vol. 4, No. 48, pp. 47-54, 2010

[19] Droździel, P., Krzywonos, L.: The estimation of the reliability of the first daily diesel engine start-up during its operation in the vehicle. Eksploatacja i Niezawodnosc, Vol. 41, No. 1, pp. 4-10, 2009.

[20] Dąbrowski, Z. and Zawisza, M.: Investigations of the vibroacoustic signals sensitivity to mechanical defects not recognised by the OBD system in diesel engines, Diffusion and Defect Data Pt.B, Solid State Phenomena, pp.194, 2012.

[21] http://www.mtdeurope.com

[22] http://www.brava.pl/STIHL/STIHL+FS+200-42.htm

ПРОЦЕНА ПРОМЕНЕ НИВОА БУКЕ КОЈУ ГЕНЕРИШУ УРЕЂАЈИ ОПРЕМЉЕНИ ДВОТАКТНИМ МОТОРИМА СА УНУТРАШЊИМ САГОРЕВАЊЕМ МАЛЕ ЗАПРЕМИНЕ

Томаж Фиглус, Анджеј Вилк, Патрик Франке

Једноцилиндрични двотактни мотори са унутрашњим сагоревањем мале запремине припадају групи погонских јединица које карактерише врло бучан рад. Ови мотори због малих димензија, мале тежине и погодности за коришћење, примењују се за погон уређаја као што су косилице за траву или моторне тестере за сечу дрва. Њихов утицај на животну средину и на удобност радника је веома неповољан и представља опасност по здравље људи. У раду су приказани резултати мерења буке која су извели аутори са намером да процене промену у нивоу буке коју емитују двотактни мотори са унутрашњим сагоревањем мале запремине, а који се користе код косилица за траву са диском. Анализом резултата ових испитивања утврђен је ефекат промене запремине, снаге и техничког стања мотора и конструкције косилице, на буку која допире до послужиоца.