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ANALYSIS OF INFLUENCE OF TECHNICAL CONDITION PARAMETERS OF THE PETROL CHAIN SAW AND WOOD CUTTING ON THE MAGNITUDE OF EMITTED VIBRATIONS

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Abstract. The authors attempt to find functional relations between changing parameters of technical condition of the petrol chain saw engine and the magnitude of vibrations measured on the body and the handles. The presented investigations can contribute to learning the factors intensifying vibrations and will facilitate the development of the method for making a diagnosis on the chain saw technical condition with the use of vibroacoustic signals. In addition, the authors also try to show the influence of wood cutting, apart from the engine, on the magnitude of vibrations measured on the chain saw handles.

Key words: petrol chain saw, technical condition, clearance, bearing, vibrations

INTRODUCTION

Vibrations are a commonplace phenomenon in the surrounding world. Machines, especially those with rotary elements, are the source of vibrations of various origins and effects. All the machines are divided into quiet and noisy, and piston engines and petrol chain saws belong to the latter group. Vibrations generated by machines are predominantly connected with the technical condition of sets and systems of an investigated object, therefore they are most often used as diagnosing signals. The observation of machines' vibroacoustic processes provides direct information about the level of their wear and degradation, which is their technical condition [Cempel 1989].

Petrol chain saws equipped with gouge saws started to be used in Polish forests in the 1950s. Multiple increase in wood cutting effectiveness as compared to hand saws and relevant gratification system caused that in the 1960s they were used in every forest inspectorate. The introduction of these chain saws was not restrained either by initially high prices and huge exploitation costs, or by later revealed occupational diseases. During work with a chain saw, an operator is subjected to the hazards of noise, vibrations and

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exhaust gases. Modern chain saws, significantly improved, are used in all the wood working processes and the cultivation of young tree stands.

Before the privatization of forest work execution internal combustion chain saws belonged to forest inspectorates. This caused that they were systematically subjected to periodic services and necessary repairs, therefore their technical condition was generally good. Nowadays, when they are a private possession of an operator who often lacks the appropriate education and training as for the correct diagnosing of its technical condition, they are improperly exploited, which imposes a real danger to the operator's health. In the majority of cases a chain saw is used as long as it is possible to start it. Only lack of such a possibility determines its service and necessary repair. That is why in contemporary circumstances of the chain saw usage finding simple and quick methods of diagnosing its technical condition, without the necessity of its dismantling, can encourage its users to visit service departments regularly.

The undertaken investigations covering various models of chain saws are an attempt at determination of their technical condition by measuring vibrations on steering handles. The way to such an aim is to find connections between the technical condition of a chain saw engine (body vibrations) and the magnitude of vibrations occurring on steering handles during wood cutting as well as the maximum worktime of an operator within one shift.

MATERIAL AND METHODS OF INVESTIGATIONS

The undertaken investigations of various models of chain saws (Table 1) aimed at measuring vibrations on the steering handles and the body. The results of these investigations can be used in diagnosing the technical condition of a chain saw. The way to such an aim is to find connections between the technical condition of the chain saw engine and the magnitude of vibrations emitted by this engine.

Table 1. Basic technical parameters of investigated chain saws
Tabela 1. Podstawowe parametry techniczne pilarek użytych do badań

Model Model	Cylinder volume Pojemność skokowa cm^3	Power Moc kW	Vibration acceleration: front/back handle Przyspieszenie drgań: uchwyt przedni/tylny $m \cdot s^{-2}$	Chain saw weight without saw and guide Masa pilarki bez piły i prowadnicy kg	Recommended scale of chain saw inches Zalecana podziałka piły łańcuchowej cale	Recommended length of guide Zalecana długość prowadnicy cm
H 444	44	2.2	–	5.2	0.325	33
H 242	42	2.3	3.6/5.4	4.7	0.325	33-46
H 246	46	2.3	3.6/5.4	4.7	0.325	33-46
H 51	51	2.3	4.7/5.6	5.2	0.325	33-46
H 257	57	2.7	4.0/8.2	5.6	0.325/ 3/8	33-51
H 254XP	54	3.0	4.0/8.2	5.4	0.325/ 3/8	33-51
H 262XP	62	3.4	4.0/8.2	5.8	0.325/ 3/8	33-51

Twelve internal combustion chain saws of Husqvarna firm were investigated. During these investigations their serial numbers and production year were registered. The oldest chain saws were Husqvarna model 444 from the year 1983, while the newest were from 1994.

Prior to vibration measurements the technical condition of the chain saws was checked (Table 2). As the main parameters for evaluation of the technical condition of a chain saw engine, the following were taken:

– clearance in crankshaft bearing (from the side of clutch) – L,
– run-out of crankshaft neck (from the side of clutch) – B,
– compression pressure in cylinder – P.

Table 2. Values of technical condition parameters of investigated chain saws
Tabela 2. Wartości parametrów stanu technicznego pilarek użytych do badań

Model Model	Trade number Nr fabryczny	Production year Rok produkcji	Bearing clearance Luz łożyska mm	Crankshaft neck run-out Bicie czopa wału mm	Compression pressure Ciśnienie sprężania MPa
H 246	without number bez numeru	1993	0.01	0.01	1.02
H 257	4470330	1994	0.01	0.02	0.80
H 242	4380262	1994	0.01	0.05	0.83
H 242	4380256	1994	0.02	0.02	0.82
H 51	4450243	1994	0.02	0.03	0.88
H 51	4450088	1994	0.02	0.03	0.86
H 254 XP	3120277	1993	0.03	0.05	0.85
H 444	8965	1983	0.04	0.04	0.96
H 262 XP	190283	1991	0.05	0.04	0.78
H 444	8958	1983	0.06	0.05	0.93
H 51	4450211	1994	0.06	0.08	0.85
H 262 XP	2510323	1992	0.07	0.06	0.83

The bearing clearance and the crankshaft neck run-out were measured only from the side of clutch since, during work, the shaft neck and the bearing are under the load of cutting resistance significantly bigger than the opposite, and consequently the changes of these parameters are here more visible. The bearing clearance and the crankshaft run-out were measured with a dial indicator with accuracy of 0.01 mm. The indicator was fixed to the guide with the use of universal holder with magnetic base. The sensor lever was pressed against the shaft neck in the point of the neck cooperation with the needle bearing of the clutch drum (after clutch dismantling), close to the inner bearing race, and then the shaft was manually pressed according to the assumed measurement direction. The measurements of bearing clearance were executed in the plane parallel to the guide plane in two mutually perpendicular directions: parallel Z and perpendicular to the cylinder axis X (Fig. 1).

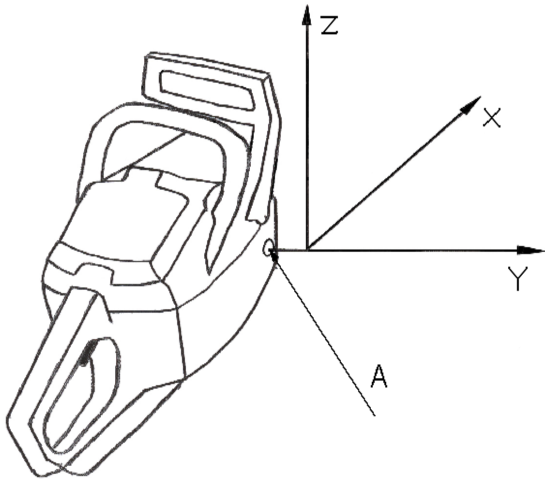

Fig. 1. Measurement directions of bearing clearance and vibrations on engine body: X – parallel to the guide axis, Y – parallel to the engine crankshaft axis, Z – parallel to the cylinder axis, A – the point of sensor fixing during vibration measurements on the body
Rys. 1. Kierunki pomiarów luzu łożyska oraz drgań na korpusie silnika: X – równoległy do osi prowadnicy, Y – równoległy do osi wału korbowego, Z – równoległy do osi cylindra, A – miejsce montażu czujnika podczas pomiarów drgań na korpusie

The compression pressure was measured with a pressure gauge (type SPCS 15) of measuring range up to 1.5 MPa equipped with a pen recorder allowing for automatic recording of results with accuracy of 10 kPa. The compression pressure was measured on the warm engine with the chain saw throttle open, while the engine was cranked manually with the starter cable. These measurements were repeated five times and on their basis the mean value was calculated.

The measurements of vibrations on the chain saw handles (front and back) were executed with the maintenance of measurement directions according to the ISO 7505 norm and with use of Brüel & Kjaer meter type 2231 with the unit and module type 2522 for the evaluation of the influence of vibrations on humans over the frequency range from 8 to 1000 Hz. The equipment allowed for multiple measurements over a specified time period and for recording the obtained results in meter memory. For measurement execution a special attachment was fabricated enabling to fix the sensors (accelerometers) directly on engine body, connected with the body with the use of a bolt fastening the guide and the clutch cover. The attachment mounted rigidly to driving unit body ensured the unequivocal sensor setting to determine vibrations in three mutually perpendicular directions (Fig. 1):

– parallel to the guide axis (X),
– parallel to the axis of the engine crankshaft (Y),
– parallel to the cylinder axis (Z).

During the measurements on the handles and the body of the chain saw, the measuring equipment allowed for simultaneous registration of the following vibration parameters:

– maximal peak value (Max P),
– maximal root mean square value (Max L),
– minimal root mean square value (Min L),
– equivalent vibration acceleration (Aeq),
– summary value of three directions X, Y and Z (Aeq_{SUM}).

The vibration measurements were executed for two different states of the chain saw engine work: during log sawing and without sawing. For sawing, each time a new chain saw was used to exclude the necessity of measuring its bluntness. The wood used for the investigations was fresh pine. The diameter of sawn logs ranged from 15 to 27 cm. During vibration measurements on the handles the chain saw was held in hands, while for vibration measurements on the body, without sawing, it was freely mounted with the use of rubber V-belt on a horizontal beam, about 50 cm above the ground. This way the influence of accidental changes of the conditions of the chain saw hold by an operator was eliminated together with vibration value changes caused by them. The rotational engine crankshaft speed during the vibration measurement without cutting was set with the use of throttle shock absorber bolt (to ensure relatively steady rotations of the engine crankshaft) and amounted to 8000 ± 100 rev/min. These rotations were similar to those during wood cutting. Five repetitions were made for each chain saw, and then the results were averaged.

INVESTIGATION RESULTS AND THEIR ANALYSIS

Bearing in mind the fact that various models of chain saws were subjected to the investigations, it was necessary to evaluate the homogeneity of the sets. In such a situation it was crucial to check whether the chain saws of various models, of various technical condition subjected to the investigations are significantly different, or whether it is still possible to treat them as one set. The analysis of the results of changes in Aeq_{SUM} under the influence of technical condition parameters showed that all the chain saws taken for the investigations can be discussed together since it is impossible to reject the hypothesis that their variances and mean values of vibrations on the body belong to the same set.

The majority of the investigated chain saws was characterised by generally good technical condition, only the chain saws of 444 model showed also the external signs of a long usage period.

The results of bearing clearance, crankshaft neck run-out and compression pressure measurements of subsequent models are presented in Table 2, while the results of vibration acceleration measurements on the chain saw handles and the body during wood cutting and without cutting are illustrated in Figures 2 and 3.

The lower the values of bearing clearance and crankshaft neck run-out and the higher the value of compression pressure in the engine cylinder, the better the technical condition of a chain saw. The preliminary analysis of the measured values showed that equivalent vibration acceleration Aeq and summary vibration of three directions Aeq_{SUM} measured on the body were, to the highest extent, correlated with the chain saw technical condition.

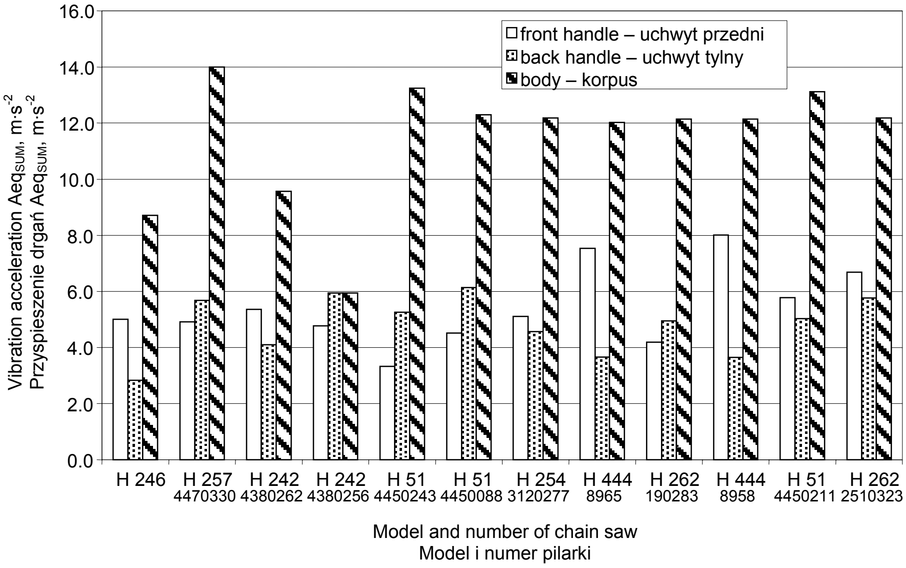

Fig. 2. Results of vibration acceleration measurements Aeq$_{sum}$ on handles and body without wood sawing

Rys. 2. Wyniki pomiarów przyspieszenia drgań Aeq$_{sum}$ na uchwytach oraz korpusie bez przerzynki

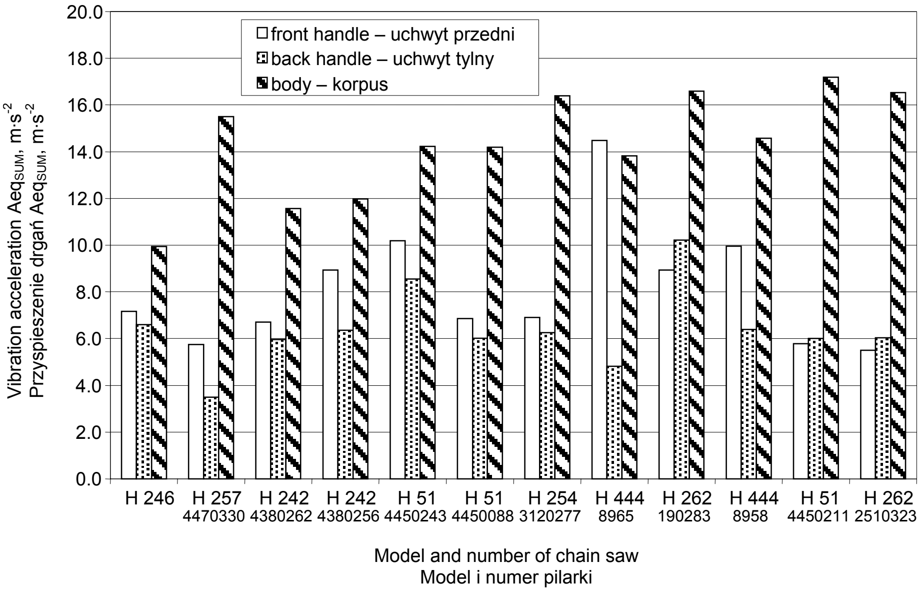

Fig. 3. Results of vibration acceleration measurements Aeq$_{sum}$ on handles and body during wood sawing

Rys. 3. Wyniki pomiarów przyspieszenia drgań Aeq$_{sum}$ na uchwytach oraz korpusie podczas przerzynki

DISCUSSION

Table 3 presents the exemplary multiple regression equation as well as the values of linear correlation coefficients for vibration acceleration Aeq_{SUM} on the engine body for the investigated set of chain saws. The variance analysis for independent variables: x_1 – bearing clearance, x_2 – crankshaft neck run-out, x_3 – compression pressure showed, in the investigated case, that the level of influence of the investigated parameters of the chain saw technical condition on the magnitude of vibrations is different, which confirms the earlier observations by other authors [Ciesielczuk et al. 1998, Kosno 2004].

Table 3. Multiple regression equation and test values of vibration acceleration Aeq_{sum} measured on engine body during wood sawing and values of linear correlation coefficients
Tabela 3. Równanie regresji wielokrotnej i wielkości testowe przyspieszenia drgań Aeq_{sum} pomierzone na korpusie silnika podczas przerzynki oraz wartości współczynników korelacji liniowej prostej

Multiple regression equation Równanie regresji wielokrotnej	Test values – Wielkości testowe						r_{tab}	r_L	r_B	r_P
	R_{tab}	R_{obl}	t_{tab}	t_L	t_B	t_P				
Y = 24.72 + 5.05x1 + 15.28x2 – 14.74x3	0.726	**0.8261**	2.306	1.761	0.425	2.188	0.576	**0.6695**	**0.6386**	0.5342

The initial evaluation of investigation results proves the occurrence of significant dependence between the vibration values and the parameters of chain saw technical condition. For the investigated set of chain saws multiple and linear correlations of the investigated values were determined and distinct connection between the vibration magnitude and bearing clearance was found (Fig. 4), for which the calculated value of correlation coefficient amounts to 0.6695, at critical value 0.576, which points out at significant dependence between these investigated values. It is similar in the case of shaft neck run-out (Fig. 5), here the linear correlation coefficient amounted to 0.6386, which is also a significant dependence. As for the compression pressure no distinct connection was found, but the value of linear correlation coefficient is very close to the critical value and amounts to 0.5342. Yet, the analysis of multiple regression equation shows that compression pressure has a bigger influence on the magnitude of vibrations Aeq_{SUM} on the body than the clearance or the run-out ($t_P = 2.188 > t_L = 1.761 > t_B = 0.425$).

The comparison of minimal and maximal values of vibration acceleration shows that clearance in crankshaft bearing, as proved by the earlier investigations [Ciesielczuk et al. 1998], is an important, yet not the only determinant of vibrations on the chain saw handles. Both crankshaft run-out and compression pressure are equally important here.

Even modern chain saws, which are commonly sold, do not comply with the standards of an 8-hour workday [Ordinance of Minister of Labour and Social Policy 2002]. Any chain saw during its usage is subjected to wear, therefore its technical condition deteriorates.

The undertaken investigations showed that the level of vibrations increases along with deteriorating technical condition of chain saw. It is especially visible and useful in diagnostics of a chain saw if the vibrations on engine body are taken into account. During sawing a chain saw is also the source of vibrations and noise, which can cause

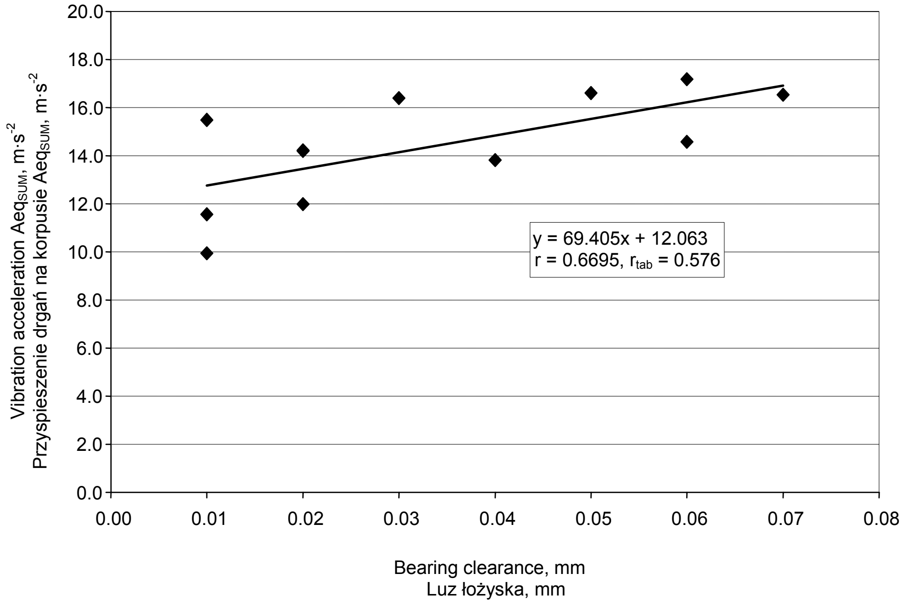

Fig. 4. Influence of bearing clearance on vibration level Aeq_{sum} on chain saw body
Rys. 4. Wpływ luzu łożyska na poziom drgań Aeq_{sum} na korpusie pilarki

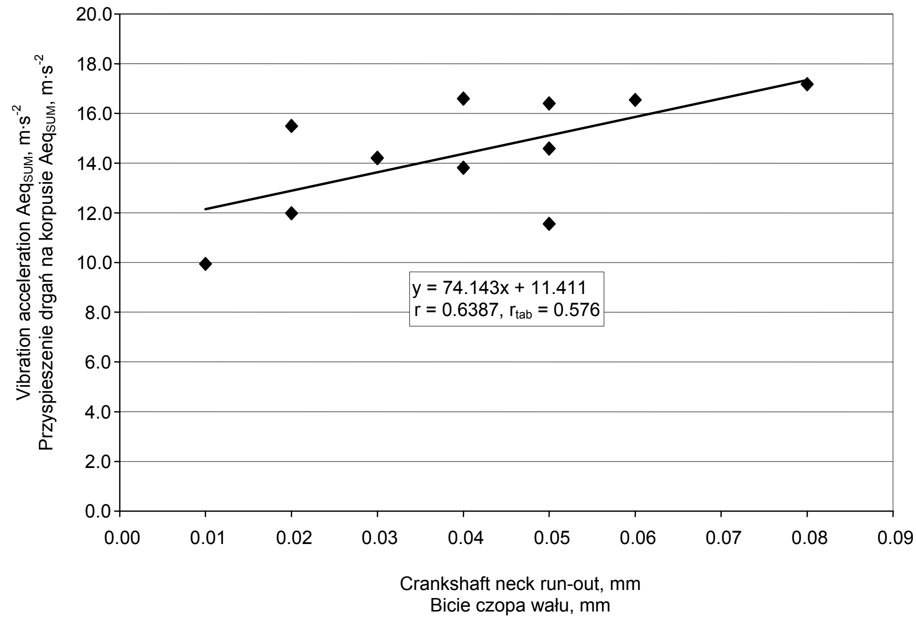

Fig. 5. Influence of crankshaft neck run-out on vibration level Aeq_{sum} on chain saw body
Rys. 5. Wpływ bicia czopa wału na poziom drgań Aeq_{sum} na korpusie pilarki

an increase in the level of body vibrations of 15% [Obliwin and Sokołow 1988]. One can also claim that in the case of cutting with the use of a chain saw the vibrations occurring on both the body and the handles are higher. Only in some single cases the results were different, which might have been caused by the timber structure (knots, anisotropic structure).

New chain saws, currently available on the market, generate vibrations of the values exceeding the Polish norms [Ordinance of Minister of Labour and Social Policy 2002]. The investigations undertaken previously by many authors [Ciesielczuk et al. 1998, Kosno 2004] prove the dependence between the vibrations emitted by a chain saw and its technical condition. The ivestigations undertaken by Ciesielczuk et al. [1998] and by Kosno [2004] proved that the magnitude of vibrations is, to the largest extent, influenced by an increasing clearance in crankshaft bearings; significant is also crankshaft neck run-out while compression pressure in cylinder has a considerably lower effect on vibrations [Obliwin and Sokołow 1988]. Presented by them connections between the values of vibrations and clearances in crankshaft bearings, crankshaft neck run-out as well as compression pressure are a good reason to claim that the increasing clearance and run-out together with the decreasing compression pressure have a distinct influence on the magnitude of vibrations emitted by a chain saw. Excessive values of these parameters (clearance and run-out) can cause multiplication of a chain saw body vibrations.

CONCLUSIONS

1. The undertaken investigations showed that parameters of a chain saw technical condition (bearing clearance, crankshaft neck run-out, compression pressure) cause a linear increase of a chain saw vibroacoustic signals. The change of bearing clearance has the biggest effect on the magnitude of vibrations occurring on the chain saw body.
2. The executed measurements showed that wood sawing causes an increase of vibration level on the chain saw body of about 28%, on the front handle of about 63% and on the back handle of about 52%.
3. Thanks to quick and non-invasive method one can encourage users to more frequent services, which would consequently improve the safety of an operator work and decrease the risk of diseases.

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ANALIZA WIELOCZYNNIKOWA WPŁYWU PARAMETRÓW STANU TECHNICZNEGO PILARKI SPALINOWEJ ORAZ PRZERZYNKI DREWNA NA WIELKOŚĆ EMITOWANYCH PRZEZ NIĄ DRGAŃ

Streszczenie. Autorzy próbują znaleźć zależności funkcyjne pomiędzy zmieniającymi się parametrami stanu technicznego silnika pilarki spalinowej a wielkością drgań mierzonych na korpusie i uchwytach. Przedstawione badania mogą przyczynić się do poznania czynników intensyfikujących drgania oraz ułatwią opracowanie metody diagnozowania stanu technicznego pilarki za pomocą sygnałów wibroakustycznych. Autorzy starają się również wykazać, jaki wpływ na poziom drgań rejestrowanych na uchwytach pilarki ma oprócz silnika przerzynka drewna.

Słowa kluczowe: pilarka spalinowa, stan techniczny, luz, łożysko, drgania

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