

The influence of the cutting attachment on vibrations emitted by brush cutters and grass trimmers

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Abstract. Generally, the choice of cutting attachment used in brush cutters for brushwoods and grasses depends on the type of work, on one hand, and the size of the engine, on the other. However, at the same time, the use of individually chosen cutting elements entails a certain risk of vibration resulting from their varying design and size, which has a big impact on comfort and working time, but most importantly on operator health.

The aim of the study is a preliminary analysis of the dangers due to vibration of brush cutters and to determine how the choice of the cutting attachment affects the intensity of the vibrations emitted by the machine. Furthermore, one aim was to determine the daily vibration exposure, relative to an equivalent value of vibration, experienced by the device operator.

This study involved four models of brush cutters with three machines of each model, differing in size (displacement and engine power) and equipped with six different cutting elements. A vibration acceleration test was carried out in accordance with the applicable PN-EN ISO 5349-1 and 2: 2004 and Directive 2002/44 / EC.

An analysis of the obtained results leads to the conclusion that the examined professional brush cutters emit vibrations of such intensity that the daily exposure limit (5 m s^{-2}) is exceeded more than two-fold. One cannot directly determine the influence on vibration intensity by the type of cutting attachment or the exhaust, but it should be noted that use of a cutting unit as recommended by the manufacturer creates less harmful vibrations, especially when the engine runs at the nominal rotational speed. In order to minimise the risk due to vibrations from brush cutters, engines with a cylinder capacity below 45 cm^3 are recommended to be equipped with trimmer heads and disk knives, while engines with over 50 cm^3 should run with circular saws.

Keywords: brush cutter, grass trimmer, clearing saw, hand-arm vibration, vibration acceleration, daily vibration exposure, ergonomics

1. Introduction

A brush cutter is a portable machine with a cutting attachment mounted on a shaft, usually more than 1 m long (thus occasionally, it is called ‘boom saw’) (Więsik et al. 2005; Wójcik 2008a).

The group of brush cutters consists of two sub-groups: brushwood cutters and grass cutters (grass trimmers). These are different with regard to the type of the cutting attachment most often used: a saw blade (circular or chain) in a brushwood cutter, and a nylon line cutting head or a grass

cutting blade in a grass trimmer. The use of line heads as well as grass cutting blades in brushwood cutters is feasible, and the option to use saw blades in grass trimmers is in no way taken into consideration (Wójcik 2008a).

Brushwood cutters and grass trimmers have analogous construction. In professional designs (meant for long-lasting work), a set of handles is fixed on the backbone boom (13, Fig. 2), hence, it is fully separated from the engine as well as the transmission shaft and the cutting attachment – the parts that emit vibrations. In the tools designated for short-term activities, only the engine is isolated, and the handles are

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fixed directly to a shaft protective casing. One of the handles is D-shaped (loop handle) and the other has a grip form, and the transmission works through a flexible shaft. In some cases, both handles are fixed to a steering wheel (track rod) that helps operating the tools of this kind (Wójcik 2008a).

Although regulatory recommendations (Directive 2002/44/EC – Vibrations) stipulate standard duration of daily work with grass trimmers (4 h) and brush cutters (3.5 h), yet, work with the use of these machines is laborious and hazardous (Okada et al. 2009; Kashima, Uemura 2010). Various stressors play a key role: unfavourable microclimate, dust, physical and mental load, and especially operator exposure to noise and vibration (Kozikowski 1994; Skarżyński 1994; Bovenzi et al. 1995, 2012; Ishikawa et al. 2013).

The issue of vibration emitted by brush cutters has become the subject of interest to numerous research teams. Their works mainly focus on decreasing low-frequency vibrations, since these are responsible for vascular disorders (Okada et al. 2009; Rajbhandary et al. 2011), which gradually lead to an industrial injury called vibration white finger (VWF) or hand-arm vibration syndrome (HAVS), a secondary form of Raynaud's syndrome.

The reduction of low-frequency vibration can be achieved by using various methods. One of them is the optimisation of shaft construction. The vibration can be decreased by 20–30% by bending downwardly the shaft part in between the engine and the steering wheel, along with increasing the thickness of the shaft pipe wall (but not its weight) in the area for mounting drive shaft bearing and the handles (Yoshida et al. 2013).

Another way is the construction of steering wheel handles from the materials with the anti-vibration characteristics (most often various elastomers), resulting from either inner structure (Yoshida et al. 2013) or outer structure (Rajbhandary et al. 2011) of the material used. This method brings

about 25% reduction of vibration, regardless of the aforesaid type of material.

Studies have been also carried out on the pairs of vibration absorbers with accurately synchronised resonance frequencies that are fixed directly to the brush cutter shaft, as close as possible to the handles. The method allows for reduction of the effective vibration value even by 50% (Hao, Ripin 2013).

However, even though vibration reduction to some extent can be achieved using the methods described, vibrations emitted by brushwood cutters and grass trimmers have yet remained above the threshold levels fully acceptable by humans. At the same time, vibration changes, depending on the status of engine operation, the type of cutting head and work technology applied. All at once, vibration values presented by the producers of brush cutters are different than those obtained in test studies (Kashima, Uemura 2010).

2. Study objective

The aim of the present study was a preliminary analysis of vibration hazards due to the use of brush cutters, with the intention of evaluating the effects of different cutting attachments on vibrations emitted by the machines of this kind at the point the handles held with hand-arms by the operator and to determine daily exposure to vibration A(8) based on the equivalent vibration value.

3. Materials and Methods

Four professional STIHL manufactured models of brush cutters (for brushwood and grasses), which were of diffe-

Table 1. Basic technical parameters of machines used for testing (materials Stihl)

Parameter	Model	FS 400	FS 450	FS 500	FS 550
Displacement [cm ³]		40.2	44.3	51.7	56.5
Power [kW]		1.9	2.1	2.4	2.8
Weight [kg]*		8.0	8.0	10.0	10.0
Sound pressure level [dB (A)]		98	99	99	102
Sound power level [dB(A)]		108	109	112	112
Vibration handle left / right handle [m/s ²]		2.0/1.6	2.0/1.6	2.5/2.1	3.2/2.3
Overall length without tools [m]		1.77	1.77	1.69	1.69
Fuel tank capacity [dm ³]		0.67	0.67	0.76	0.76

* without fuel, cutting element and guards working unit

rent sizes, i.e. with different capacity of cylinders (displacement) and engine power output, were tested. Three machines of each model were tested. The technical parameters of the models are presented in Table 1. The machines were equipped with the producer that had two types of cutting heads: four-line AutoCut Mowing Head (Fig. 1a) used in the models FS 400 and 450 and Chisel-tooth circular saw blade (Fig. 1b) used in the models FS 500 and 550. Due to the differences in cutting head structure, two different types of head covers (Fig. 1c, d) were used in the trials. The brush cutters were used 3–8 months before the tests, mainly for thinning young forest stands and grass trimming on small areas. Technical condition of the machines tested was satisfactory, i.e. there were observed: no damage to head covers, mechanisms, joints and shock absorbers; no fuel or lubricant leaking; no angular transmission overheating; no excessive noise as well as proper operation of all levers and stable engine idling.

In all the models of tested machines, the cutting head was driven by a rigid shaft (string shaft), which transmitted engine power to the cutting attachment indirectly through the angle gear. Additionally, the machines included the 4 point anti-vibration system (Fig. 2).

Next to the standard cutting heads recommended for particular models, other cutting attachments authorised by

the producer, such as double line AutoCut head (Fig. 3a), PolyCut cutting attachment with three pivoting thermo-plastic blades (Fig. 3b), TriCut brush knife/shredder blade (Fig. 3c) and grass cutting blade with eight cutters (Fig. 3d), were tested.

All the cutting attachments tested were brand new. Their basic technical parameters were assessed before mounting to the machines tested (Table. 2).

During the trials, the covers of the cutting attachments were exchanged according to the type used. Consequently, for the nylon line head, the plastic cover (Fig. 1c) was used, with a blade to cut down the line length (device weight: 0.45 kg). When other cutting attachments were tested, the blade for line cutting was dismantled, and then the cover weight was 0.1 kg. The cover (Fig. 1d) made of light alloy cast (0.1 kg) was used only when working with the circular blade.

Vibration measurements were carried out in accordance with the norms: PN-EN ISO 11806-1:2012E – Machinery for agriculture and forestry – Agricultural and forestry machinery – Part 1. Safety requirements and testing for portable, hand-held, powered brush-cutters and grass-trimmers (e.g. PN-EN ISO 5349-1 and 2: 2004): Mechanical vibration — Measurement and evaluation of human exposure to hand-transmitted vibration (Part 1:

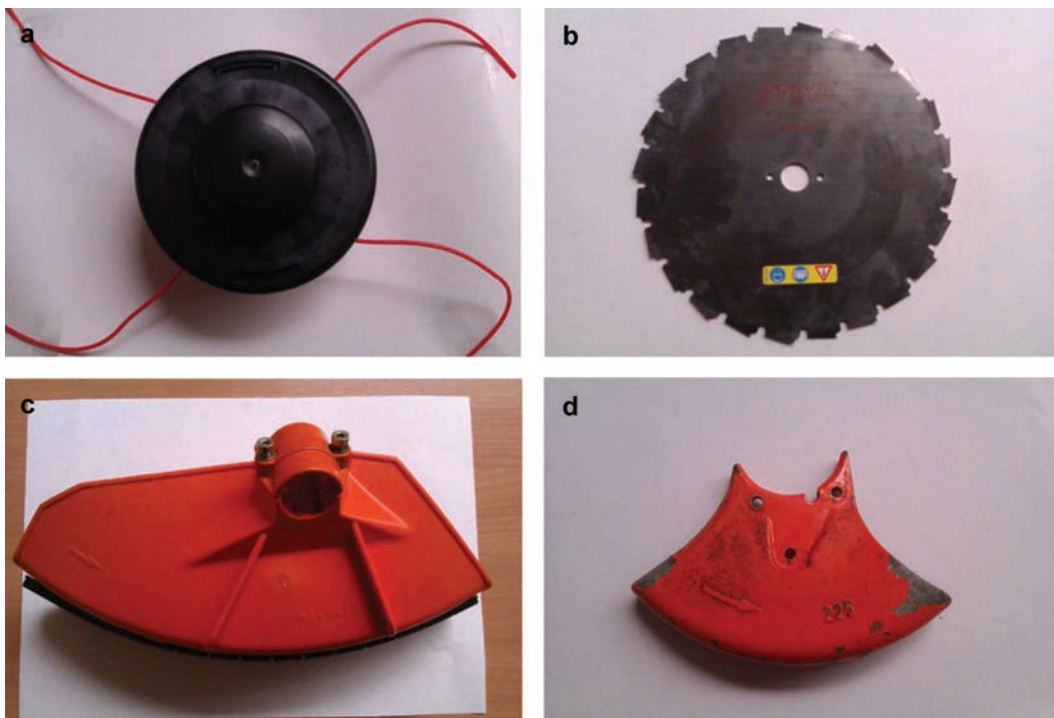


Figure 1. The cutting elements and the cover of the cutting unit of respondents machines: a – four-trimmer automatic cutting head, b – a circular saw, c – trimmer head cover, d – cover blade (photo: K. Wójcik)

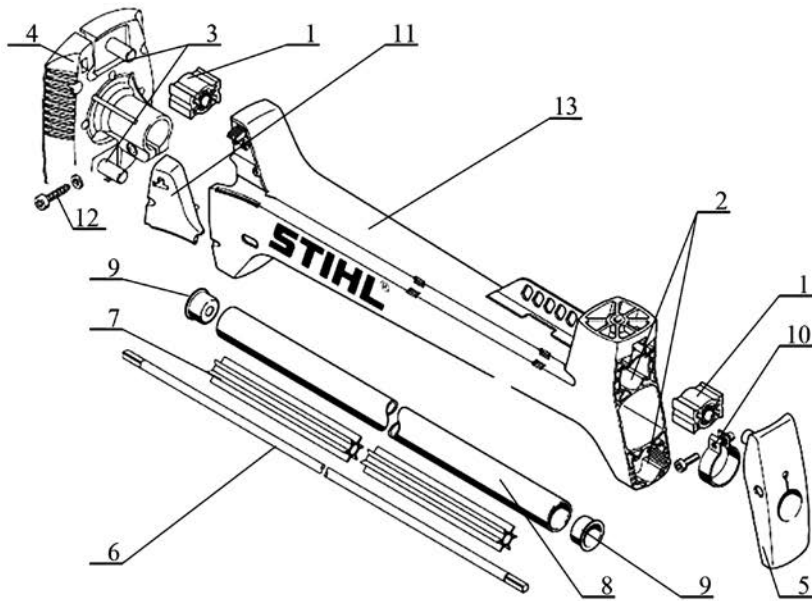


Figure 2. Four-vibration system Stihl used in brush cutters to brushwoods: 1 – shock absorbers (rubber or spring), 2 – seatings shock absorbers, 3 – retaining rods shock absorbers, 4 – cover the front drivetrain (clutch cover), 5 – cover column mounting crossmembers with handles, 6 – shaft string, 7 – elastic insert, 8 – cover string shaft, 9 – cap roll cover with a hole, 10 – terminal shaft guard with bolt, 11 – cover, 12 – screw, 13 – the backbone boom (Stihl materials)

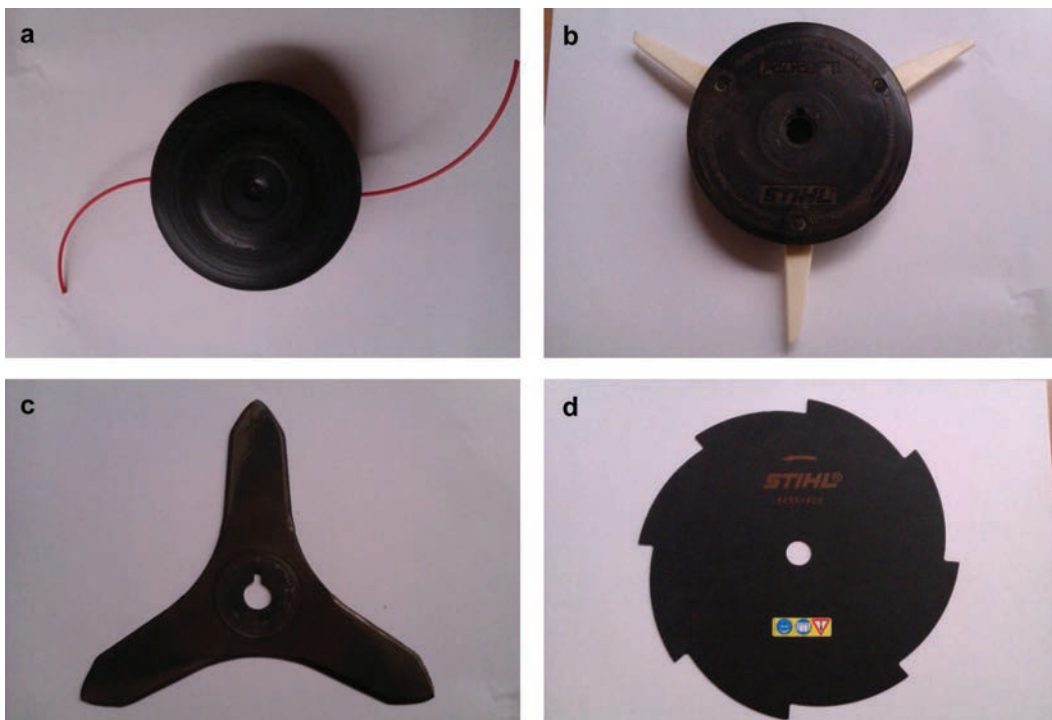


Figure 3. Additional cutting elements used in the study: a – two-trimmers self-acting cutting head, b – three-knife cutting head with hinged blades type Polycut, c – the three-knife head type double-sided disc TriCut, d – eight-knife saw blade (photo. K. Wójcik)

General requirements, Part 2: Practical guidance for measurement at the workplace).

In accordance with the aforesaid norms, the sum of the weighted root mean square acceleration values should be

Table 2. Basic technical parameters of cutting elements used in the study (author. K. Wójcik)

Parameter \ Name and type	Trimmer head SuperCut 40-2	Trimmer head AutoCut 40-4	Cutterhead Polycut 1	Shield knife TriCut	Shield knife	Circular Saw
Weight [kg]	0.55	0.60	0.45	0.55	0.65	0.50
Diameter [mm]	330	330	280	300	255	225
The number of cutting elements	2 cutting lines a diameter of 2,4 mm	4 cutting lines a diameter of 2,7 mm	3 knives	3 double blade	8 blades	24 teeth Chisel

estimated for all the cutting attachments recommended by the producer for certain conditions of engine operation. For a brushwood cutter, these are: idling and nominal rotation speed, i.e. 133% of rotation speed at the maximum power, and for a grass trimmer with the nylon line head and head cover mounted, the maximum nylon line length is also taken into consideration. If vibration measurements taken at the point of each handle show values not higher than those presented in Table 3, it can be assumed that vibration stays at an appropriate level (bearing in mind that the values obtained represent permissible vibration for a given machine, and not the levels fully acceptable for humans; therefore, vibration reduction is still something to work towards).

Figure 4 presents the mode of measuring vibration at the brush cutter handles (both for brushwood and grass), where the support with three piezoelectric vibration sensors is marked with 1. This allowed for simultaneous measurement of vibration acceleration towards three perpendicular directions.

Table 3. Acceptable value vibration acceleration in $m \cdot s^{-2}$ PN-EN ISO 11806-1: 2012

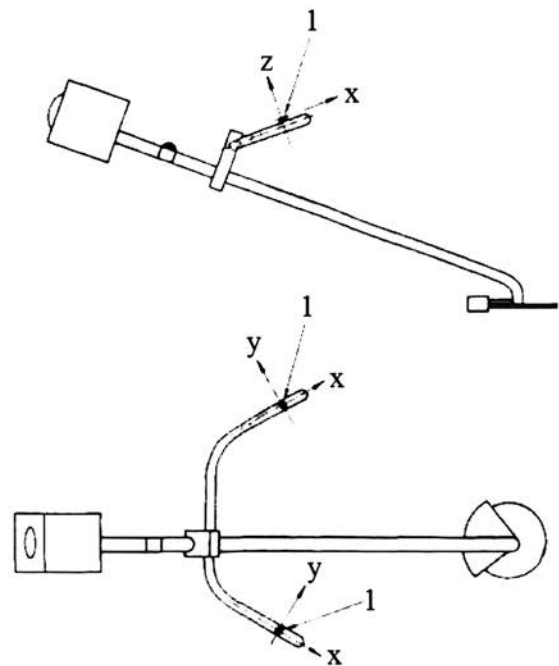
Engine capacity brush cutters to brushwoods and grass	
$\leq 35 \text{ cm}^3$	$> 35 \text{ cm}^3$
$15 \text{ m} \cdot \text{s}^{-2}$	$7.5 \text{ m} \cdot \text{s}^{-2}$

The measurements were conducted in the machine hall (Dept. of Forestry Mechanization, Warsaw University of Life Sciences- SGGW). Two modular precision sound level meters, Type 2231 (Brüel & Kjær, Denmark) for measuring the effect of vibration passed on through hand-arms were used in trials, which included piezoelectric sensors (accelerometers) on three-axis support that allowed to measure vibration at the points of the so-called actual contact of the operator's hands with brush cutter handles. Using two complete sets of sound level meters made it possible to

simultaneously measure vibrations on both brush cutter handles under the same experimental conditions in all the trials conducted.

The measurements were carried out on the experimental panel securing appropriate conditions for the experiments of this kind, i.e. leveled surface, 15°C – 20°C temperature (taking into account the norm: -10°C to 30°C , measured with mercury thermometer), wind speed $0.0 \text{ m} \cdot \text{s}^{-1}$ (the norm: $5 \text{ m} \cdot \text{s}^{-1}$, measured with electronic wing anemometer).

All the brush cutters tested were scrupulously examined with regard to their technical condition, in line with the producer's recommendations. The completeness of utensils was checked and all the threaded connections were secured (including those of the head covers). At the

**Figure 4.** Distribution vibration sensors, with marked directions of their impact on the handles brush cutters to brushwoods and grass (K. Wójcik)

same time, shock absorbers were tested out. The carburetor was adjusted following the producer's instructions. The machine tested was brought to its normal operating condition as regards spark plugs, fuel and gearing lubrication. The same examinations were performed before each measurement cycle.

The speed of engine idling, clutch turning on and the maximal engine speed were set based on the manual for each model tested (adjustments were done using piezoelectric tachometer). The recommended normative rotation speed (nominal speed) was set based on oral communication with STIHL's representative. Before the measurements, the engine was warmed up for 3–5 min, to the moment of reaching idle engine rotation not higher than ± 100 turns/min and engine temperature about 200°C (measured using a pyrometer).

All the measurements included the following steps:

- Five measurements within more than 120 s (given that the norm recommends at least 20 s for four measurements).
- Each measurement signal lasted at least 15–30 s (the norm: 2 s).
- Turning on of the meter and measurement records were performed at the time when the engine rotation speed was at a steady level – ranging from ± 100 turns/min (idling) to ± 200 turns/min (the nominal speed), and the measurement was discontinued about 30 s later (the measurements were conducted with the time constant $1/8 = 8$ impulses/s);
- During short breaks in between the measurements, engine speed considerably changed – back and forth from the idle speed to the high speed, depending on the engine speed set for the measurement performed.

After vibration measurements, machine engine cooled down for 15–20 min. The same measurement procedure was applied to all the brush cutter models tested.

Measurement data were saved on the disc in the meter. After the last measurement, the records were printed and downloaded for further analyses.

The vector sum of the weighted root mean square acceleration values (a_{hw}) (Directive 2002/44/EC; Kowalski 2006) was calculated using the measured values of vibration components a_{hw_x} , a_{hw_y} , a_{hw_z} (directions presented in Fig. 6), following the equation (1):

$$a_{hwi} = \sqrt{a_{hwxi}^2 + a_{hwyi}^2 + a_{hwzi}^2} \quad [\text{m}\cdot\text{s}^{-2}] \quad (1)$$

where:

a_{hwxi} , a_{hwyi} , a_{hwzi} – weighted root mean square acceleration values, measured for axial directions x , y and z at performing every activity i when exposed to vibration, $\text{m}\cdot\text{s}^{-2}$.

Next the value of equivalent vibration a_{hweq} was calculated, following equation (2) (Christ 2002; Kowalski 2006):

$$a_{hweq} = \sqrt{\frac{1}{T} \sum_{i=1}^n a_{hwi}^2 \cdot t_i} \quad [\text{m}\cdot\text{s}^{-2}] \quad (2)$$

where:

a_{hwi} – weighted root mean square acceleration value, determined for i -activity when exposed to vibration (as in equation 1), $\text{m}\cdot\text{s}^{-2}$,

t_i – subsequent activity performed when exposed to vibration, min;

T – duration of i -activity performed when exposed to vibration, min;

n – number of i -activities performed when exposed to vibration at monitored workstation;

T – 480 min.

Next, the daily exposition to vibration $A(8)$ was computed based on the relationship in the equation (3) (Christ 2002; Directive 2002/44/EC):

$$A(8) = a_{hweq} \sqrt{\frac{T_{exp}}{8}} \quad [\text{m}\cdot\text{s}^{-2}] \quad (3)$$

where:

T_{exp} – daily duration of exposure to vibration, depending on the type of machine (here brush cutters for brushwood – 3.5 h).

4. Results and Discussion

The analysis of the averaged results of vibration measurements conducted on the models of brush cutters tested (3 each) (Table 4) showed that in almost all the machines, vibration acceleration (equivalent vibration) was higher on the left handle, regardless of the mode of engine operation (idle or nominal speed). Only in two (about 2%) of the 96 cases, a higher vibration on the right handle was observed. The latter concerned FS 500 brush cutter with four-line cutting head, at engine idling speed and FS 500 with double-line cutting head at the nominal speed.

Currently, the permissible limit of hand-arm vibration (point vibration) is $2.8 \text{ m}\cdot\text{s}^{-2}$, whereas the threshold value for mechanical vibration is $2.5 \text{ m}\cdot\text{s}^{-2}$.

The equivalent vibration values obtained for the machines tested in this study were never higher than $4 \text{ m}\cdot\text{s}^{-2}$. Nonetheless they exceeded the values given by the producer (Table 1).

Higher equivalent vibration values were found for the left handle when the engine operated on the idle speed. Vibration observed in FS 550 brush cutter with the one-line cutting head was $3.8 \text{ m}\cdot\text{s}^{-1}$. This machine type also showed the highest vibration values when other types of cutting heads were mounted. Vibration observed on the right handle was

Table 4. The averaged results of the measurements for the test brush cutters

Model	Working tool *	Rotation speed	Equivalent vibration		The daily vibration exposure A(8)	Rotation speed	Equivalent vibration		The daily vibration exposure A(8)
			a_{hweq}		max		a_{hweq}		max
			UL	UP			UL	UP	
FS 400	GŻ 1	$2800 \pm 100 \text{ obr}\cdot\text{min}^{-1}$ rpm	2.7	2.0	1.8	$8800 \pm 200 \text{ obr}\cdot\text{min}^{-1}$ rpm	2.4	1.9	1.6
	GŻ 2		2.0	1.9	1.3		1.9	1.2	1.3
	GN		2.8	2.2	1.9		2.6	2.1	1.6
	TN 1		2.3	2.0	1.5		2.1	1.7	1.4
	TN 2		2.5	2.1	1.7		2.3	1.8	1.5
	PT		2.8	2.2	1.9		2.6	2.2	1.6
FS 450	GŻ 1	$2800 \pm 100 \text{ obr}\cdot\text{min}^{-1}$ rpm	2.8	2.3	1.9	$8800 \pm 200 \text{ obr}\cdot\text{min}^{-1}$ rpm	2.4	1.8	1.6
	GŻ 2		2.1	1.9	1.4		2.0	1.7	1.3
	GN		2.9	2.1	1.9		2.7	2.1	1.8
	TN 1		2.4	2.2	1.6		2.2	1.9	1.4
	TN 2		2.5	2.2	1.7		2.3	1.8	1.5
	PT		2.7	2.3	1.8		2.5	2.0	1.7
FS 500	GŻ 1	$2600 \pm 100 \text{ obr}\cdot\text{min}^{-1}$ rpm	3.6	3.3	2.3	$9400 \pm 200 \text{ obr}\cdot\text{min}^{-1}$ rpm	3.0	3.2	2.1
	GŻ 2		2.9	3.0	2.0		3.1	3.0	2.1
	GN		3.2	2.9	2.1		3.1	2.9	2.1
	TN 1		2.9	2.7	1.9		2.7	2.3	1.8
	TN 2		3.0	2.8	2.0		2.8	2.5	1.9
	PT		2.8	2.5	1.9		2.5	2.1	1.7
FS 550	GŻ 1	$2600 \pm 100 \text{ obr}\cdot\text{min}^{-1}$ rpm	3.8	2.6	2.4	$9400 \pm 200 \text{ obr}\cdot\text{min}^{-1}$ rpm	3.4	2.5	2.2
	GŻ 2		3.6	2.9	2.3		3.5	3.0	2.3
	GN		3.3	2.9	2.2		3.3	2.8	2.2
	TN 1		3.5	2.4	2.3		3.3	2.5	2.2
	TN 2		3.7	2.5	2.4		3.5	2.6	2.3
	PT		3.1	2.9	2.1		3.0	2.5	2.0

* GŻ 1 – two-trimmers cutting head GŻ 2 – four-trimmers cutting head, GN – cutterhead, TN 1 – three-knife saw blade, TN 2 – eight-knife saw blade, PT – circular saw

slightly lower and its maximum was $3.3 \text{ m}\cdot\text{s}^{-2}$ observed in FS 500 with the one-line cutting head.

At the nominal speed of engine operation, vibration on the left handle was not higher than $3.5 \text{ m}\cdot\text{s}^{-2}$. This concerned the biggest brushwood cutter tested (FS 550) with the four-line cutting head or the grass cutting blade with eight cutters. Right-handle vibration observed was below $3.2 \text{ m}\cdot\text{s}^{-2}$ in FS 500 brush cutter with the one-line cutting head.

Yet, one should bear in mind that the permissible time limit for vibration exposure or that for daily exposure is always determined based on less favourable vibration values regardless of the status of brush cutter engine operation and the cutting head used.

In the present study, vibration of tested machines raised to some extent with increasing brush cutter size (larger engine displacement and power output). At the same time, the most

GŻ 1 – two-trimmers cutting head, GŻ 2 – four-trimmers cutting head, GN – cutterhead, TN 1 – three-knife saw blade, TN 2 – eight-knife saw blade, PT – circular saw

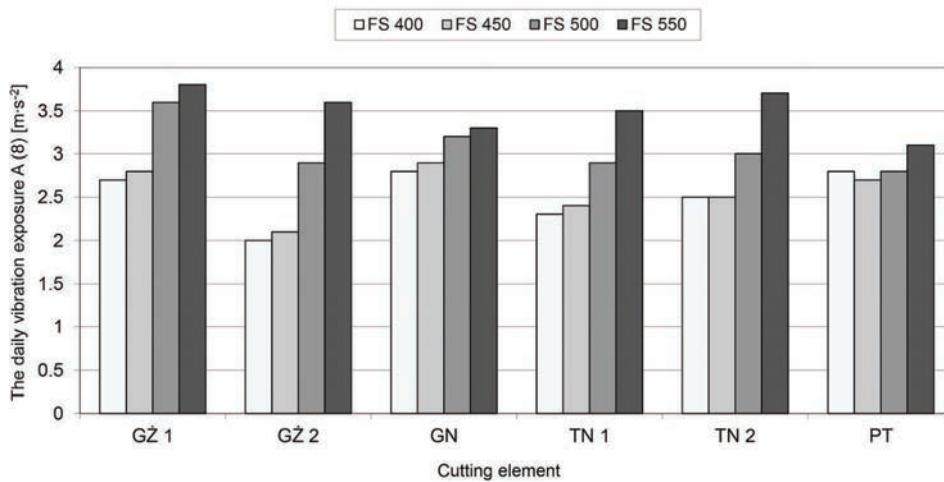


Figure 5. The magnitude of vibration equivalent on the left handle brush cutters studied using a variety of cutting elements (idling speed)

GŻ 1 – two-trimmers cutting head, GŻ 2 – four-trimmers cutting head, GN – cutterhead, TN 1 – three-knife saw blade, TN 2 – eight-knife saw blade, PT – circular saw

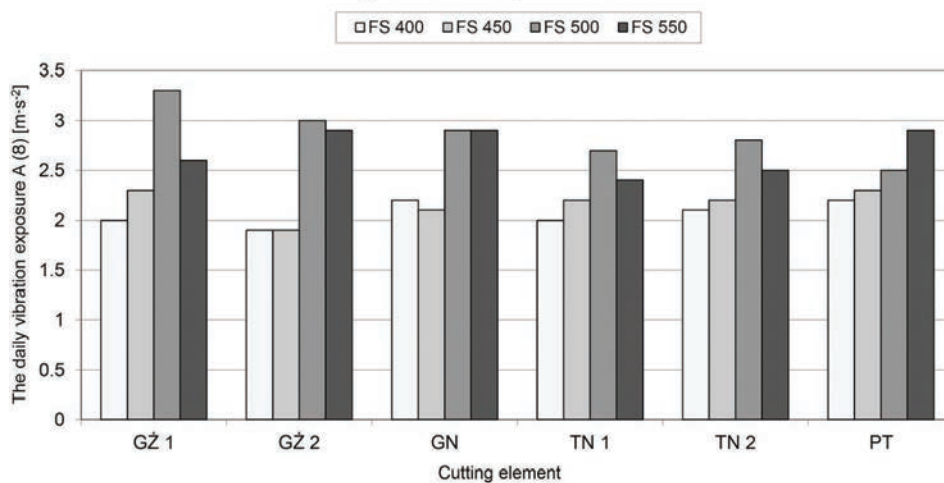


Figure 6. The size of the vibration equivalent on the right handle brush cutters studied using a variety of cutting elements (idling speed)

GŻ 1 – two-trimmers cutting head, GŻ 2 – four-trimmers cutting head, GN – cutterhead, TN 1 – three-knife saw blade, TN 2 – eight-knife saw blade, PT – circular saw

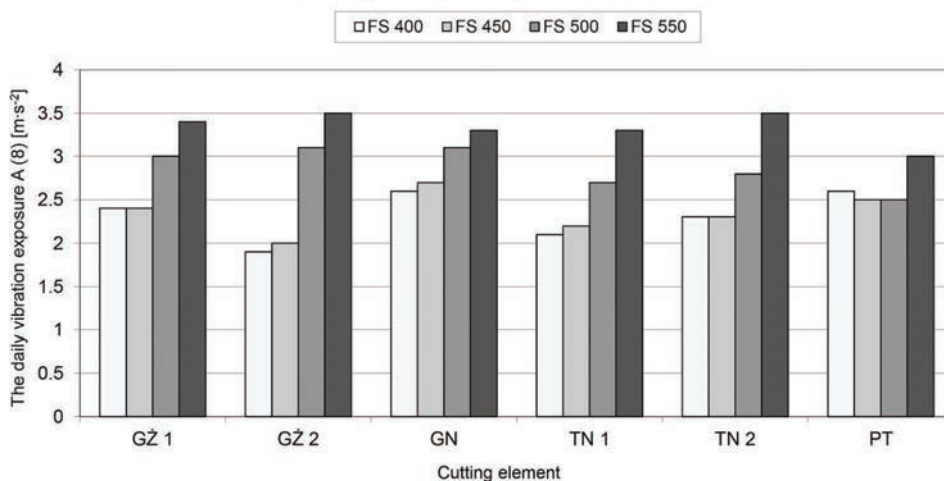


Figure 7. Magnitude of vibration equivalent on the left handle brush cutters studied using a variety of cutting elements (nominal speed)

GZ 1 – two-trimmers cutting head, GZ 2 – four-trimmers cutting head, GN – cutterhead, TN 1 – three-knife saw blade, TN 2 – eight-knife saw blade, PT – circular saw

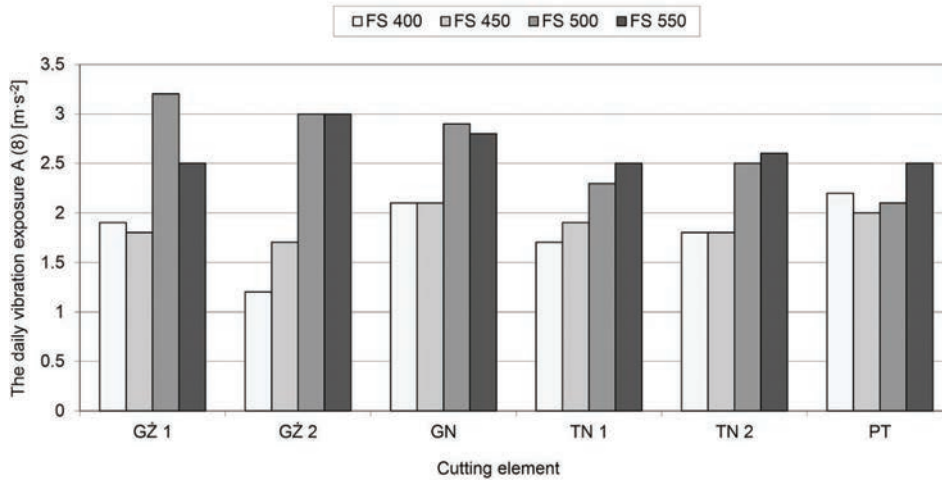


Figure 8. The size of vibration equivalent on the right handle brush cutters studied using a variety of cutting elements (nominal speed)

GZ 1 – two-trimmers cutting head, GZ 2 – four-trimmers cutting head, GN – cutterhead, TN 1 – three-knife saw blade, TN 2 – eight-knife saw blade, PT – circular saw, is – idling speed, ns – nominal speed

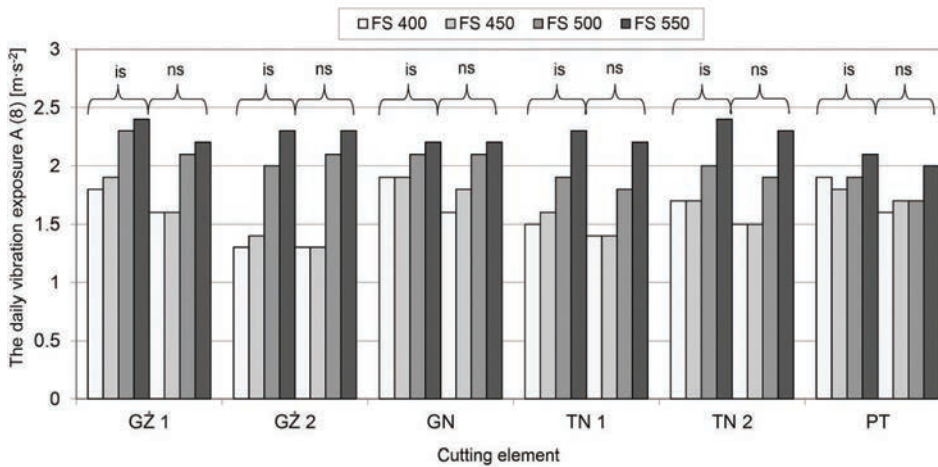


Figure 9. Daily exposure to vibration for maximum vibration values equivalent using different cutting elements (idling speed and nominal speed)

constructive results were obtained in all the cases with the standard cutting heads – those recommended by the producer. This pattern was predominantly evident at the nominal engine speed.

The least beneficial vibration parameters were observed in larger machines (FS 500, FS 550) when used with nylon line heads or PolyCut mowing head (with three pivoting blades), whereas in smaller machines (FS 400, FS 450), these were observed when working with the circular saw and also – the PolyCut mowing head.

In accordance with the Directive 2002/44/EC, exposure limit values and action values for hand-arm vibration are as follows:

- The daily exposure limit value standardised to an eight-hour reference period is $5 \text{ m}\cdot\text{s}^{-2}$ (exposure limit).

- The daily exposure action value standardised to an eight-hour reference period is $2.5 \text{ m}\cdot\text{s}^{-2}$ (action values for hand-arm vibration).

In the assumed exposure time $T_{\text{exp}} = 3.5 \text{ h}$, the determined daily exposure to vibration $A(8)$ – calculated based on the maximum equivalent vibration $a_{h\text{weq}}$ observed in the present study (98% cases pertaining to the left handle) – never exceeded $2.5 \text{ m}\cdot\text{s}^{-2}$ in any of the presented cases. The highest observed value was $2.4 \text{ m}\cdot\text{s}^{-2}$ (FS 550 brush cutter, at idle speed with the one-line head or the grass cutting blade with eight cutters) and the lowest was $1.3 \text{ m}\cdot\text{s}^{-2}$ (FS 400 brush cutter at the idle and nominal speed with the four-line head; FS 450 at the nominal speed with the four-line head).

5. Findings and conclusions

Based on the study results obtained, the following conclusions are drawn:

- The tested professional brushwood cutters emit vibration at a level at which daily exposure to vibration is considerably lower (more than half) than the daily exposure limit value ($5 \text{ m}\cdot\text{s}^{-2}$).
- Vibration hazard raises to some extent with increasing brush cutter size (larger engine displacement and power output).
- Vibration is lower at the nominal speed of engine operation (133% of rotation speed achieved at the maximum power) when compared to that at the idle speed.
- Higher vibration is recorded on brushwood cutter left handle when the engine operates either at the idle or nominal speed.
- The direct effect of the cutting attachment on vibration emitted by the brushwood cutter cannot be clearly concluded. However, it should be noted that, in view of unfavourable influence of vibration on the machine operator, brush cutters operated using standard cutting attachments (recommended by the producer) are safer, especially at the nominal engine speed.
- Taking into account vibration hazard levels, nylon line heads and brush knife/shredder blades for brushwood cutters should be recommended for engine capacity up to 45 cm^3 whereas for those with engine capacity above 50 cm^3 circular saws are mainly recommended.

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