Ergonomic Parameters of Tasks Performed by Forest Machines Operators

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Abstract:
The paper aims on observing physiological and noise load during biomass preparation. Preparation of biomass consists of, ranging from raw material preparation to transportation of biomass to the storage space. Particular operations depend on selected work procedure. There are tasks which are physically demanding (motor-manual raw material preparation) and those which are relatively less physically demanding (operating an automatic wood chipper). We measured physiological load by means of MWE-1 device, which measures breathing air flow and measures energy expenditure based on correlation between ventilation and oxygen absorption. Another part of this paper takes aim on noise load. Again there are tasks with relatively low noise levels but most tasks are carried out in environment severely polluted by noise. Most severe noise levels were recorded when operating a wood chipper. We compared measured levels of physiological and noise load with current legislation concerning these issues and based on our findings we recommended measures to reduce negative impacts of these factors on employees.

Keywords: physiological load, noise load, biomass preparation, energy expenditure

1 Introduction

Energyutilization of biomass is gaining popularity in Slovakia. Regarding biofuels the energy sector utilizes wood chips the most, which is due to easy manipulation and storage and are relatively inexpensive in comparison with other biofuels (e.g. pellets, briquettes, biogas, etc.).

The intensification of wood chip utilization in the energy sector also means satisfying the demand and pressure on the wood chips producerswho then purchase various machines for biomass processing. These machines are of various construction and their parameters differ in many ways, be it performance, drive unit type etc. The aim of this study is to evaluate ergonomic parameters, specifically noise emissions and energy expenditure of wood chipper operators.

The operations in biomass processing pose multiple health threats. One of the major threats affecting the operators is noise emitted by the machines. The source of noise can be the drive unit, the chipping device and, if necessary, the auxiliary systems.

Noise can be characterized as unwanted sound signal emitted from different sources, which reduces operational safety (distortions or limited ability to distinguish sounds in operation) (Casali 2006).It constitutes of physiological (acoustic apparatus strain) and psychological load (Mohammadi 2008). According to European data, the loss of hearing caused by noise is the most common occupational illness in the EU (Fernández et al. 2009). Multiple legislative norms deal with the problem of noise management (act 596/2002 Z.z. on people's health protection, act 124/2006 Z.z. on operational, government regulation 115/2006 Z.z. on minimal health and safety requirements for worker protection against risks related to noise exposure), which are transposition of EU directives (2003/10/ES, 2002/49/EC, etc.). In order to limit exposure to high level occupational noise, International Standards Organization (ISO) suggests the maximum permissible occupational noise exposure limit of 85-90 dB(A) $L_{AEX,8h}$ (Shaikh 1999).

Slovak legislationsets limiting values of noise exposure:

Limit value of exposure (LV): $L_{AEX, 8h, a}$= 87 dB,

Upper action value of noise exposure (UAV): $L_{AEX, 8h, a}$= 85 dB,

Lower action value of noise exposure (LAV): $L_{AEX, 8h, a}$= 80 dB.

If the work shift noise exposure exceeds LAV the worker will be given personal protective equipment. If the work shift noise exposure exceeds the UAV, it is mandatory for the worker to wear the personal protective equipment.AsEleftheriou (2002) stated, very little attention is given to protecting the hearing of workers, as only 28.5% of population surveyed in his study habitually wear hearing protectors.

In industrial conditions of wood chip production diesel fueled wood chippers are the most common (in performance classes from cca2kW to 750 kW). The largest portion of noise is emitted by resonance of drive unit and chipping device components transmitted on the chassis. The noise exposure of machine operators was the object of many studies in Slovakia (Suchomel et al. 2007, 2009, Tullova 2007 etc.).

Another important ergonomic factor is energy expenditure, which along with the assessment of posture give information about physical strain of the operators. In this study we focus on energy expenditure. Long lasting strenuous physical work causes health problems. To assess the muscle activity a work shift energy expenditure study is carried out. Research determined that the upper limit of physical performance is 8,300 kJ of net work performance per shift. The net work performance bearable in the long term for Slovak conditions is 6250 kJ per shift for men and 4150 kJ per shift for women. (Tullova 2007) Workload measurements presentvarious problems, which relate to substantial interindividuality of people from the point of view of biology and their body functionality.

Measurement of energy expenditure can be performed using four different approaches: 1) direct measurement; 2) indirect calculation using standardized values; 3) estimation derived from the linear relationship between heart rate and VO_2 while performing at medium to high intensity effort under steady state conditions and 4) using predictive formulas of energy expenditure during elemental components of a complex work cycle (Balderrama et al. 2010). The VO_2 levels are highly correlated to maximal cardiac output and thus provide a measure of the maximal energy output. The tasks performed by biomass processing machinery operators are not presumed to be of high demand considering energy expenditure.

2 Material and methods

Three machines were picked out for evaluation – Peterson 4700B (PT), MorbarkWoodHog 3800 (WH) and Doppstadt Grizzly (DG). The PT and WH machines are drum hammer grinders, the DG machine is a drum chipper. These machines were operated by single operators. The PT and WH are not equipped with a loading mechanism, the input material was loaded into the feeding conveyer by a CAT TH 330Btelehandler.

Table 1: Technical parameters of drum grinders

Machine	Dimensions Length [mm]	Width [mm]	Height [mm]	Weight [kg]	Driveunit Type	Output [kW]	Chipper Width [mm]	Diameter [mm]	Speed [rev×min^{-1}]	Bits/knives [pcs]
PT	17.170	3.260	5.040	30.391	CAT C18	570	1.610	965	1.050	22
WH	17.881	5.181	3.251	26.045	CAT C18	522	1.533	711	No info	30
DG	5.060	2.500	3.740	12.280	CAT C11	287	670	No info	No info	2

*Source: petersoncorp.com, morbark.com, doppstadt.at

2.1 Peterson 4700B drum grinder

Peterson 4700B is a horizontal drum grinder utilized for material processing in form of compost, mulch or chips. The machine is mounted on a three axle chassis and it is possible to transport it as a trailer of a lorry. The drive unit is a diesel combustion engine Caterpillar C18 with 570kW of performance. The machine utilizes three stage grinding. Grinded material passes through a system of grates and if the dimensions of the grinded material are sufficient it passes tothe output conveyer.

The machine is designed for processing large quantities of waste material.It is not capable of producing high quality material. It is suitable for wood chips production for large combustion plants.

The output of the machine in ideal conditions of supply is 86t×h^{-1} in forest biomass processing and 59t×h^{-1}in large dimension wooden waste processing.

2.2 Morbark WoodHog 3800 drum grinder

As well as the PT machine it is a horizontal drum grinder, mounted on a two axle chassis transportable by a lorry. The drive unit is Caterpillar C18 with 522kW performance. The system of material processing is similar to the PT machine, but its more efficient system of gratesenables production of a more homogenous product with less small and large fraction of chips.

2.3 Doppstadt Grizzly DT 38

The Doppstadt Grizzly is a machine consisting of a Doppstadt DT38 carrier vehicle with an Erjo DC7/65 drum chipper mounted on the three point linkage. The machine is also equipped with a Cranab RC 45 hydraulic manipulator. The drive unit is CAT C11 and a great advantage is that the machine is self-transportable. The chipper is equipped with knifes mounted on a drum. This ensures production of better quality product than the two above mentioned grinders.

Figure 1: Woodhog 3800 grinder, Peterson 4700B grinder and Doppstadt Grizzly chipper in operation

2.4 Operation cycles of the machines

The PT machine operated in Marček, near Žilina, where it was processing varied types of wooden waste, mostly palettes and wooden packaging material. The operational cycle of the PT machine was as follows:

1. Grabbing the input material with the telehandler,
2. Carrying the material to the machine,
3. Loading the material on the input conveyer of the grinder,
4. Chipping,
5. Unloading the chips with the output conveyer onto the trailer.

The WH machineoperated in Zvolen, where it prepared wood chips for the adjacent heat and power plant. The input material was pulpwood. The operational cycle was structured as follows:

1. Grabbing the input material with the telehandler,
2. Carrying the material to the machine,
3. Loading the material on the input conveyer of the grinder,

4. Chipping,
5. Carrying the wood chips on the main pile.

The DG machine operated in Želiezovce, where it was processing exploitation remains, mostly smallwood. The operation cycle of the DG machine was as follows:

1. Loading the input material into the chipper feeder by the hydraulic manipulator,
2. Material chipping,
3. Wood chips unloading onto the trailer.

2.5 Noise exposure measurements

A Quest Edge eg4 noise dose meter was used, accuracy class II. The device was calibrated with an acoustic calibrator accompanied with the device.

The dose meter was installed on the operator within the 10 – 30cm interval of distance between the microphone of the dose meter and the ear.The record lasted for cca 2.5 hours. To prevent willful manipulation of the measurements from the operators we informed them that the measurements will start in randomly selected time. We recorded theL_{AEQ}, L_{CPK} and T parameters. Individual operations were recorded on a Panasonic HDC-HS60videocamera to enable us to assign the operations to recorded levels of L_{AEQ}.

Figure 2: Noise dose meter on the operator

Figure 3:The MWE-1 device for ventilation assessment

2.6 Energy expenditure measurements

The measurements of energy expenditure were carried out in accordance with the methods elaborated by Tullova (2007), Kirk and Sullman (2001) and modified methods according to Balderrama et al. (2010). The indirect calorimetry data was measured with a MWE – 1 device, which serves as a device for testing cardiovascular and pulmonary systems. It consists of a mask and a recording device.It enables recording pulmonary ventilation with an error of ±5% [l×min^{-1}] and gross or net energy expenditure with an error of ±10% [kcal×min^{-1}], [kJ×min^{-1}].

Before the measurements the mask of the device was sanitized by alcohol, as was the part of the face which came into contact with the mask. The measurement interval was cca 10 minutes, measurements were repeated 4 times. Conditions for measurements to be carried out on individual operators were:

1. Good health,
2. Working in accordance with relevant job description,
3. The work was carried out in accordance with work safety regulations.

Before the measurements the mask was installed on the face of the operators and the recording device was placed on them. The operator was working for cca 5 minutes with the device turned off to adapt to it. After this the measurement record was initiated.

3 Results

3.1 Noise exposure of observed machines operators

Summarized results of noise exposure are shown in table 2. Measured characteristics were: equivalent A-weighed noise level per shift and peak C-weighed level of noise. Figure 4 shows the development of equivalent noise level in all operators. It clearly shows that the DG operator is exposed to lower levels of noise, nevertheless the workshift $L_{AEX,8h}$ exceeds legally set limits and the operator is obliged to wear HEARING PROTECTORS. During our research the operator did not wear any HEARING PROTECTORS, although all of them were equipped with them. The noise level exceeded the LV in 34.67% of all effective measurements. The peak level of noise L_{cpk} did not exceed the limiting value in any of the measurements, although in one measurement interval the L_{cpk} was 139.7dB(C), which is only 0.3dB lower than the limit.

The operator of the PT machine was exposed to higher levels of noise. His shift $L_{AEX,8h}$ exceeded the LV by 7.88dB. The operator of this machine also was not wearing any ear protectors. The equivalent noise level exceeded the LV in 86.67% of the measurement intervals, the peak levels of noise did not exceed the legal limits as shown in figure 5.

The highest recorded $L_{AEX,8h}$was measured in the WH machine. The $L_{AEX,8h}$exceeded the legal limit by 8.1dB. The LV was exceeded in 93.33% of the measurements, L_{cpk} limits were not exceeded. The operator was wearing a Peltor protector with 27dB damping effect.

Table 2: Summarized table of measured noise exposure characteristics

Machine	$L_{AEX,8h}$	$L_{CPK\ max}$	$L_{CPK\ min}$
Peterson 4700B	94.88	130.5	84.7
Morbark WoodHog 3800	95.1	125.1	84.7
Doppstadt Grizzly	89.42	139.7	99.6

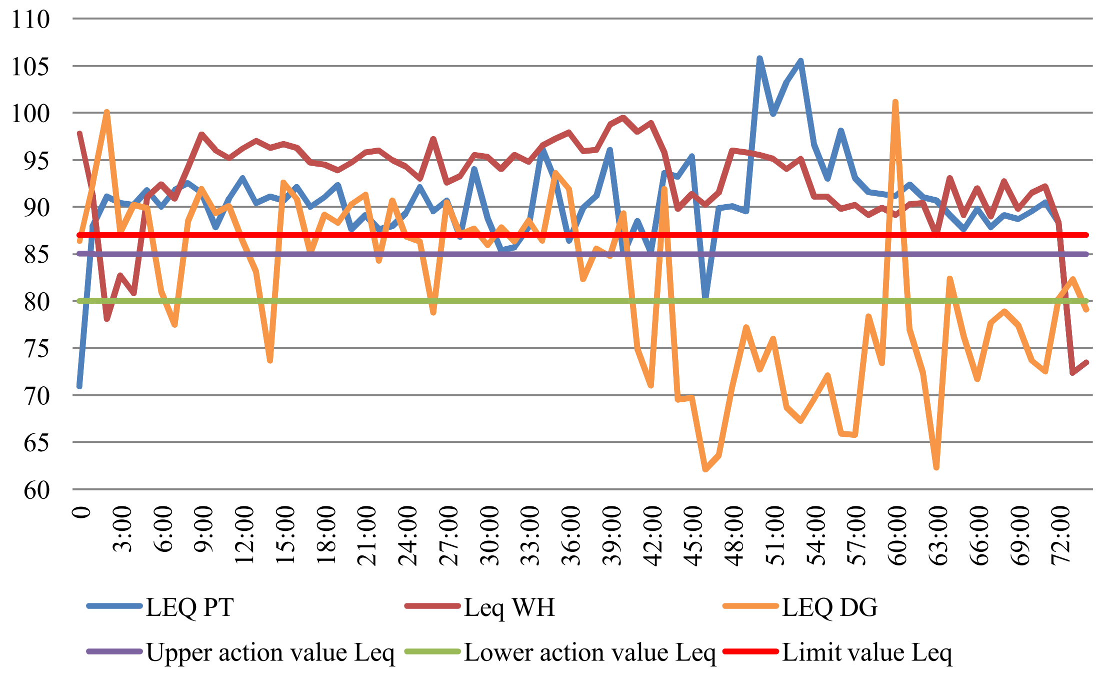

Figure 4: Equivalent noise exposure in Peterson 4700B, WoodHog 3800 and Doppstadt Grizzly machines

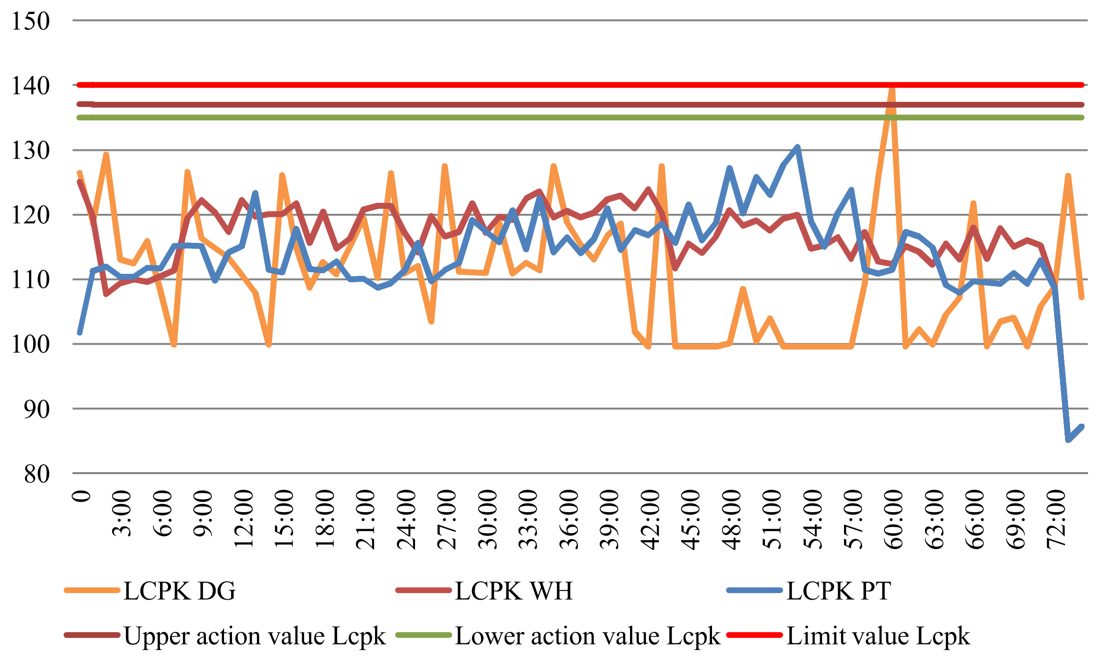

Figure 5: Peak noise exposure in Peterson 4700B, WoodHog 3800 and Doppstadt Grizzly machines

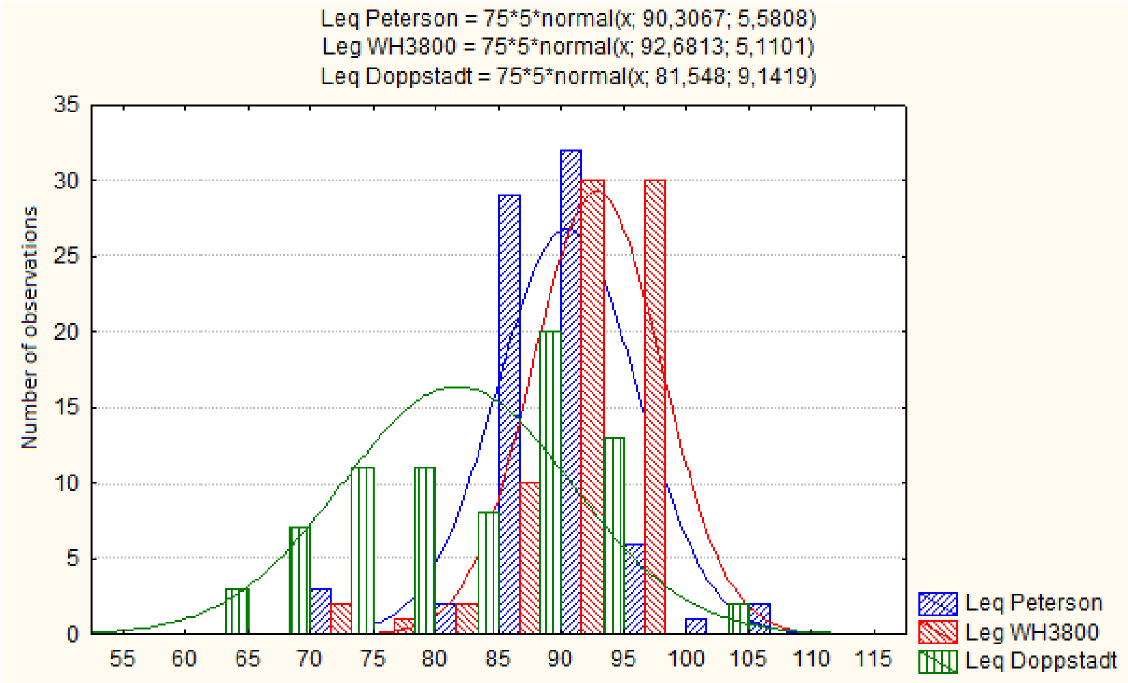

Figure 6: Absolute frequency of equivalent noise levels in PT, WH and DG machines

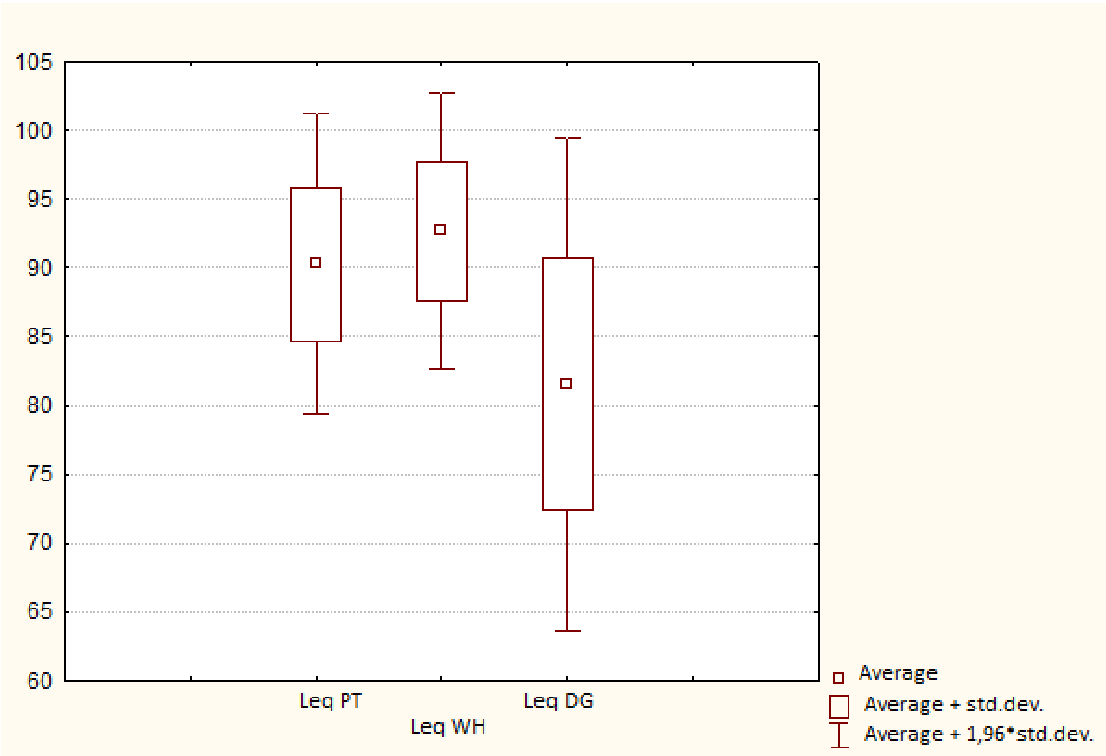

Figure 7: Comparisonofnoiseexposurebetween PT, WH and DG machines

3.2 Energy expenditure

Table 3 shows anthropometric data of the machine operators, recorded temperature and atmospheric pressure during the measurements and basal metabolic rate of particular operators. All of the operators were males with higher than average height. The BMI of the operators was higher than normal (>25) in two operators. The energy expenditure data is shown in table 4. Measured characteristics of lung ventilation and subsequently calculated net performance and net energy expenditure show that the work is not physically demanding. The most demanding is the operation of DG woodchipper, which required the operator to climb up and down a ladder in/out of the cabin of the tractor and to the chipping device.

There was also a slight difference between the PT and WH machine operators (Δ 0.55 $l \times min^{-1}$) which was due to the fact that the PT operator had to step into the chipping mechanism to clean out the debris lodged in it.

Table 3: Anthropometric data of the observed machine operators

Worker	Height [cm]	Weight [kg]	Sex	Age	BMI	Years in practise	Airtemperature [°C]	Atmospheric pressure [hearing protectorsA]
1	190	100	M	36	27	5	11°C	1.008
3	185	95	M	53	27	4	22°C	1.010
4	198	89	M	35	22	6	17°C	950

Table 4: Energy expenditure data of the observed machine operators

Machine	Average ventilation [$l \times min^{-1}$]	Network output [W]	Net energy expenditure [$kJ \times 8hrs^{-1}$]
Peterson 4700B	14.03	80.76	2 325.83
WoodHog 3800	13.48	68.98	1 986.63
Doppstadt DH 38	15.93	121.44	3 497.60

4 Discussion

The data obtained in this pilot study shows that the operations in biomass procession can be potentially harmful to hearing of the operators and other workers in the vicinity of the machines. All of the machines show higher than legally permitted levels of noise and require noise management procedures.

The highest noise exposure was recorded for the WH machine. The difference between the WH and PT machines can be partially affected by the distance from the machine (10m in WH vs. 15m in PT) and higher efficient load despite its lower declared performance. Another interesting fact is that the DG machine proved to be only 5.7dB less noisy than the WH machine although the operator worked from the cabin of the tractor most of the time.

Another fact is that the use of hearing protectors is very low although it is obligatory in the conditions observed in this pilot study. Slovak national laws (Regulation 115/2005) and EU directives (2003/10/EC) oblige the workers to wear such devices during the work and the company to ensure the availability of such devices at work. The company must also ensure that workers wear these devices. Although this is a small scale pilot study and as such does not claim to be representative, this phenomenon is described in studies in other countries and economy sectors such as Fernandez (2009) or Eleftheriou (2002).

The energy demand did not prove to be a major risk factor. This outcome was expected since the works included standing (PT & WH) or sitting (DG) with the usage of fine motor skills and occasional climbing a ladder. It is interesting that the most demanding is the work with the DG machine, which is operated from a seated position. This is possibly due to above mentioned ladder climbing. The work can be described as very light or light according to Ronay and Slama (1989) as the net performance does not exceed 210W. Operating the two grinders however has potential of muscle strain, as the operators acquire a quite rigid position – standing up straight. This can be prevented by equipping the operators with a portable seat on which they can sit when they feel exhausted. The work organization allows is and it is not a costly measure.

5 Conclusion

This pilot study carries out an analysis of noise exposure and energy expenditure in biomass processing. Due to its small scale it cannot be representative, but it indicates that biomass processing is a very noisy job.

Another notable finding was the fact that the workers do not wear hearing protectors. Only 1 out of 3 operators was wearing them. This points to limited awareness of the negative effects of noise on human health among the operators. It also points out to negligence on the side of the companies, since the conditions in which the workers carried out the operations require cooperation from their side. On the other hand, all of the operators had hearing protectors at their disposal and it was their decision not to wear them. In one case, when the management of the company was present at the site, the worker had his hearing protectors on.

As we anticipated, the operation of these machines is not physically demanding. The work can be classified as very light or light. In cases of the two drum grinders the work mainly consisted of operating the machines with a wireless controller. The operators were standing while operating the machines. The operator of the Doppstadt Grizzly machine operated the machine in a seated position, but had to climb out and back in the cabin several times to check on the chipper.

This paper is a part of a larger research of ergonomic parameters in Slovak forestry, which will lead to creation of a model describing how the risk factors behave in forestry operations.

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