Harvesting System Efficiency in Relation to Directive 2002/44/EC

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Abstract:
The Human Vibration Directive 2002/44/EC, officially known as the "Directive 2002/44/EC of the European Parliament and the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration)" will soon become obligatory for all EU member states. Its most vital regulations are those establishing the action values (whereby certain protective procedures must be set in place) and the limits values (which must never be breached). For the hand-arm transmitted vibration the vibration directive has the single action value set at 2.5 m/s^2, and the limit value of 5 m/s^2. The Directive also specifies employers' obligation to determine and assess risks and sets out the measures to be taken. As it is well known, the factors that govern workers' daily exposure are the frequency-weighted level of vibration and the exposure duration.
During harvesting operation several forestry workers are exposed to vibration. The most serious problem appears in chain-saw operators because of the high level of transmitted vibration and the relative long exposure time. As the harvesting system efficiency is limited by vibration action and limit values, a complex research project was carried out in order to find out the relation between these two factors. The paper presents some results of this research project.

Keywords: hand-arm transmitted vibration, harvesting, daily exposure, health risk

1 Introduction

It is a known fact that portable chain saws are a very dangerous source of hand-arm transmitted vibration (Goglia et al. 2011, Žgela et al. 2003). The measurement results and vibration acceleration analyses confirm that the risk of permanent health damage to chain saw operators is real. Numerous disabled workers in the state enterprise *Croatian Forests,* who were overexposed to vibration, are the living proof. In order to determine the risk for the chain saw operators at work on forest harvesting, complex measurements were carried out.

As the work with chain saws consists of several different activities, the measurement of the total effective working time was carried out. All activities during which the operator is exposed to vibration and individual duration of each one of them occuring during ordinary working day were determined. The frequency-weighted r.m.s. acceleration value for all single activities was measured in the work-shop under controlled conditions. As the daily vibration exposure *A(8)* should be expressed in terms of 8-h energy-equivalent frequency-weighted vibration total value, its value was calculated in accordance with ISO 5349.

2 Method and equipment

During harvesting in *Croatian forests*, where the beech is the dominant species, the workers mostly use the STIHL MS650 chain saw type**.** The same type of chain saw was used in our measurements. Basic technical characteristics of the STIHL MS650 are:

⇒ Motor power, kW: 4,8

⇒ Weight (without guide and chain), kg: 7,3
⇒ Specific power, kW/kg: 0,65
⇒ Chain type: *Oilmatic, Rapid Micro Comfort*
⇒ Chain pitch: 0.325"
⇒ Guide length, cm: 45
⇒ Equipped with: antivibration system, *Elasto-Start*, *Quick-Stop* brake, decompression valve.

In order to determine activities during which the operator is exposed to vibration, as well as the duration of each single activity during ordinary working day, the movie camera ***Sony mini DV*** was used. The measurement procedure is shown in Fig. 1.

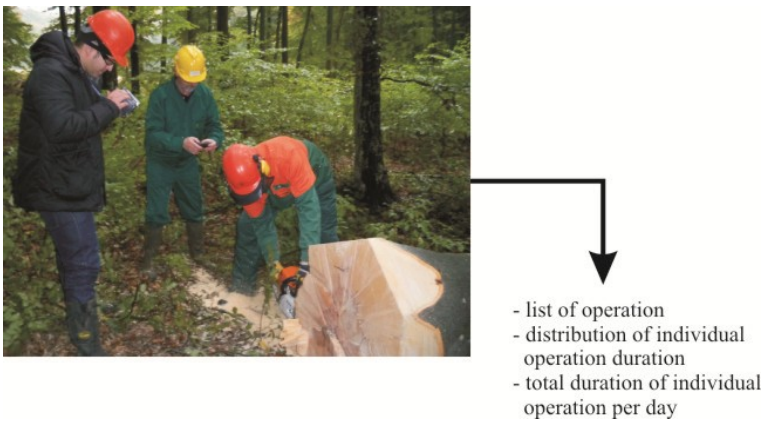

Figure 1: Schematic representation of the time study

The vibration measurement for all activities during which the operator is exposed to vibration was performed in the test field under controlled conditions. The measurements were carried out on the front and rear handles according to recommendations given in the International Standard ISO 7505. In Fig. 2 some typical activities during handling the chain saw are shown.

Figure 2: Some activities during handling the chain saw: a) at idling, b) preparing to turn down, c) turning down, d) cross cutting

In such work, where the total vibration exposure consists of several activities with different vibration magnitudes, the daily vibration exposure *A(8)* shall be obtained using the following equation:

$$A(8) = \sqrt{\frac{1}{T_0}\sum_{i=1}^{n} a_{hvi}^2 \cdot T_i}$$

where

⇒ T_i is the total daily duration of exposure to the vibration of the i^{th} activity,

⇒ n is the number of individual vibration exposures and

⇒ a_{hvi} is the vibration total value for the i^{th} activity obtained as

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

where a_{hvx}, a_{hvy} and a_{hvz} are frequency-weighted r.m.s. acceleration values in the single axes, *x, y* and *z*. The measurements were carried out in all three axes simultaneously.

The whole research was carried out in three areas. Basic characteristics of the areas are given in Table 1.

Table 1: Basic characteristics of the areas in which the research was carried out

Basic characteristics	Area		
	Stražbenica	**Lijepa Gorica**	**Mali Siselj**
Dominant species	beech	beech	beech
Average ages, years	92	103	96
Size, ha	15.92	11.07	11.98
Elevation, °	15 - 35	5 - 30	5 - 15
Altitude, m	160 - 340	170 - 250	420 - 460

In order to define all the activities during working time as well as their durations, the recorded data were processed on personal computer. The data were analyzed using *Windows Media Player 9*. There were analyzed 415 recorded intervals of the effective working activities. The durations of the recorded intervals were from 3 to 5 minutes.

Four different ways of handling the chain saws at idling were found. The vibration levels for all four possibilities of handling the chain saws were measured in real working conditions, as it is shown in Fig. 2. The following vibration levels were found:

⇒ Front handle
  ⇒ At idling – 8,74 m/s^2
  ⇒ At cutting – 10,71 m/s^2

⇒ Rear handle
  ⇒ At idling – 8,52 m/s^2
  ⇒ At cutting – 8,75 m/s^2

⇒ Carrying the chain saw with the right hand on the rear handle: 9,65 m/s^2

⇒ Carrying the chain saw with the left hand on the front handle: 7,98 m/s^2

⇒ Carrying the chain saw with the right hand on the front handle: 7,97 m/s^2.

The working activities take place in conditions as shown in Fig. 3. The vibration levels at cutting were measured in the same conditions, as it is shown in Fig. 4.

Figure 3: The real conditions at harvesting

Figure 4: Vibration measurement at cutting in real conditions

The measurement results were analyzed in the Laboratory for sound and vibration at the Faculty of Forestry, University of Zagreb. Finally, the 8-h energy-equivalent frequency-weighted vibration total value was calculated in accordance with ISO 5349 -1 - 2001. The measuring chain shown in Fig. 5, as well as three axial vibration meters of *Bruel&Kjaer 4447* type**,** were used during vibration measurement. As already mentioned above, the measurements were carried out simultaneously in all three coordinate axes.

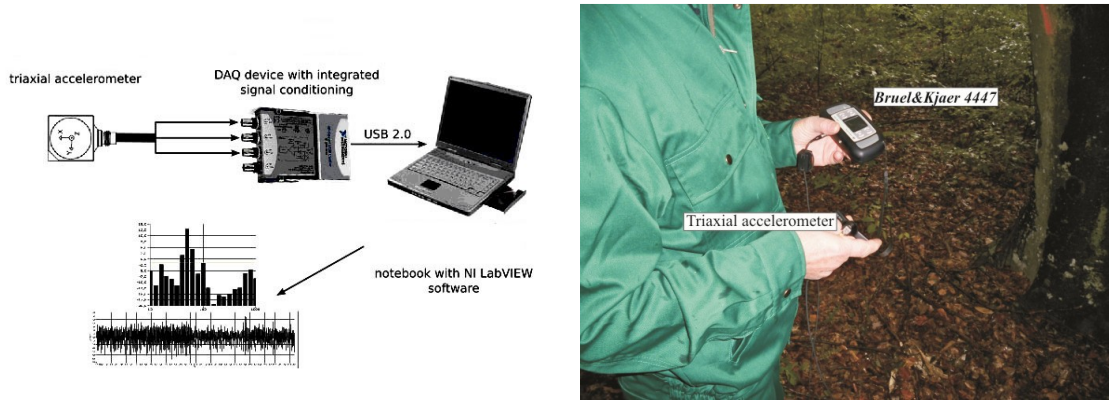

Figure 5: Schematic representation of the measuring chains used for vibration measurement

3 Results

The results obtained by measuring data analyses are given in Tables 2 – 10.

Table 2: Vibration levels at harvesting (area Lijepa Gorica) – three working days

Handling the chain saw	**Duration [s]**	**%**	
Left hand – front handle	1281	18,92	Efficiency: **31,86 m^3**
Right hand, rear handle	55	0,81	Worker: Posavec Gabriel
Right hand - front handle	206	3,04	Total time: 6771 s;
Cutting	3248	47,97	i.e. 1h 52min 51s
Both hands - idling	1981	29,26	
Handling the chain saw	**Duration [s]**	**%**	
Left hand - front handle	1392	27,91	Efficiency: **30,91 m^3**
Right hand - rear handle	18	0,36	Worker: Novosel Karlo
Right hand - front handle	-	-	Total time: 4987 s;
Cutting	2354	47,21	i.e. 1h 23min 7s
Both hands - idling	1223	24,52	
Handling the chain saw	**Duration [s]**	**%**	
Left hand - front handle	1286	24,23	Efficiency: **32,75 m^3**
Right hand - rear handle	79	1,49	Worker: Branjug Danijel
Right hand - front handle	12	0,22	Total time: 5308 s;
Cutting	2509	47,27	i.e. 1h 28min 28s
Both hands - idling	1422	26,79	

Table 3: Vibration levels at harvesting (area Lijepa Gorica) – for all workers together

Handling the chain saw	**Duration [s]**	**%**	
Left hand - front handle	3959	23,20	Total efficiency: **95,52 m^3**
Right hand - rear handle	152	0,9	Total time: 17 066 s;
Right hand - front handle	218	1,28	i.e. 4h 44min 26s
Cutting	8111	47,52	
Both hands - idling	4626	27,11	

Table 4: Energy-equivalent frequency-weighted vibration total value – A(8) at harvesting

Activity	**Left hand**		**Right hand**	
	Time [s]	**a_{hvi} [m/s^2]**	**Time [s]**	**a_{hvi} [m/s^2]**
Left hand - front handle	3959	7,98		
Right hand - rear handle			152	9,65
Right hand - front handle			218	7,97
Cutting	8111	10,71	8111	8,75
Both hands - idling	4626	8,74	4626	8,52
A(8), m/s^2		4,22		3,38

Table 5: Vibration levels at road side landing (area Lijepa Gorica) – four working days

Handling the chain saw	**Duration [s]**	**%**	
Left hand – front handle	1157	23,00	Efficiency: **52,58 m^3**
Right hand, rear handle	57	1,13	Worker: Knapić Dražen
Right hand - front handle	-	-	Total time: 5030 s;
Cutting	2143	42,61	i.e. 1h 23min 50s
Both hands - idling	1673	33,26	
Handling the chain saw	**Duration [s]**	**%**	
Left hand – front handle	909	21,27	Efficiency: **42,88 m^3**
Right hand - rear handle	87	2,04	Worker: Knapić Dražen
Right hand - front handle	6	0,14	Total time: 4273 s;
Cutting	1724	40,34	i.e. 1h 11min 13s
Both hands - idling	1547	36,21	
Handling the chain saw	**Duration [s]**	**%**	
Left hand - front handle	695	13,32	Efficiency: **36,3 m^3**
Right hand - rear handle	54	1,03	Worker: Knapić Dražen
Right hand - front handle	6	0,11	Total time: 5218 s;
Cutting	2352	45,08	i.e. 1h 26min 58s
Both hands - idling	2111	40,46	
Handling the chain saw	**Duration [s]**	**%**	
Left hand - front handle	2447	39,92	Efficiency: **51,95 m^3**
Right hand - rear handle	26	0,42	Worker: Jakopčić Anđelko
Right hand - front handle	-	-	Total time: 6130 s;
Cutting	2911	47,49	i.e. 1h 42min 10s
Both hands - idling	746	12,17	

Table 6: Vibration levels at road side landing (area Lijepa Gorica) – for all workers together

Handling the chain saw	**Duration [s]**	**%**	
Left hand - front handle	5208	39,92	Total efficiency: **183,71 m^3**
Right hand - rear handle	224	0,42	Total time: 20 651 s;
Right hand - front handle	12	-	i.e. 5h 44min 11s
Cutting	9130	47,49	
Both hands - idling	6077	12,17	

Table 7: Energy-equivalent frequency-weighted vibration total value – A(8) at road side landing

Activity	Left hand		Right hand	
	Time [s]	a_{hvi} [m/s^2]	Time [s]	a_{hvi} [m/s^2]
Left hand - front handle	5208	7,98		
Right hand - rear handle			224	9,65
Right hand - front handle			-	7,97
Cutting	9130	10,71	9130	8,75
Both hands - idling	6077	8,74	6066	8,52
A(8), m/s^2		3,99		3,17

4 Discussion

Worker's exposure to hand-arm transmitted vibration at harvesting was tested in typical Croatian Forests working area. The working activities during which the vibration exposure occurs, as well as their duration were identified. The methods of time study were applied. There were five such activities found:

⇒ left hand – front handle,
⇒ right hand - rear handle,
⇒ right hand - front handle,
⇒ cutting,
⇒ both hands – idling.

With a movie camera and time analysis the duration of each activity during ordinary working day was identified. The vibration measurement for all activities during which the operator is exposed to vibration was performed on the test field under controlled conditions. All measurements were carried out in the ordinary working conditions. Using vibration levels obtained by measurements for related activities and their average durations during working day, the daily vibration exposure *A(8)* expressed in terms of 8-h energy-equivalent frequency-weighted vibration total value was calculated in accordance with ISO 5349-1. The *A(8)* values such obtained were compared with the limit values set for the worker's exposure to hand-arm transmitted vibration at 2.5 m/s^2 (action value), i.e. 5 m/s^2 (upper limit value). The comparison clearly shows that the work at harvesting as well as at the side road landing can be classified as dangerous viewed from the aspect of exposure to vibration. Among five tested workers none was exposed to permitted level of vibration. Therefore the research results have to be looked at with special attention. They indicate that some steps must immediately be taken in order to prevent further undesirable consequences.

5 Conclusion

The research carried out in order to define the vibration exposure level at work at harvesting and at road side landing has shown some interesting and unexpected results. All workers are exposed to vibration levels that are above the limit of 2,5 m/s^2 set as an action value in the Directive 44/EC from 2002 – *On the Minimum Health and Safety Requirements Regarding to Exposure of Workers to the Risk Arising from Physical Agents: Vibration*. In order to prevent serious health problems some steps have to be taken immediately.

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