EXPOSURE TO HAND-ARM TRANSMITTED VIBRATION AT FOREST NURSERY AND THINNING

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Abstract

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* , became obligatory for all EU member-states after 2014. As it is well known, it sets limits 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). It is also known that daily vibration exposure shall be expressed in terms of 8-h energy-equivalent frequency-weighted vibration total value *A(8)*. In order to determine the level of daily exposure two parameters have to be measured: frequency-weighted r.m.s. acceleration value and the total daily duration of exposure to the vibration (Suchomel et.al., 2010).

When the work consists of several activities with different vibration magnitudes, in order to determine the daily vibration exposure *A(8)*, the frequency-weighted r.m.s. acceleration value for all single activities and duration of all individual vibration exposure should be measured according to ISO 5349-1:2001. The paper reports the results of measurement of the chain saw operator's exposure to vibration at forest nursery and thinning.

Key words: hand-arm transmitted vibration, daily exposure, health risk.

Classification JEL: Z13 Economic Sociology, M12 Personnel Management

1. Introduction

It is well known that portable chain saws are a very dangerous source of hand-arm transmitted vibration (Goglia et.al., 2008, 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 nursery and thinning, 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 activity during ordinary working day were determined. The frequency-weighted r.m.s. acceleration value for all single activities were 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 nursery and thinning in *Croatian forests* the workers mostly use the chain saw type ***STIHL MS260.*** The same type of chain saw was used in our measurement. Basic technical characteristics of the ***STIHL MS260*** are:

- motor power, kW 2.6
- weight (without guide and chain), kg 4.8
- specific power, kW/kg 0.54
- chain type – *Oilmatic, Rapid Micro Comfort*
- chain pitch 0.325"
- guide length, cm 37
- 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 duration of the individual activity during ordinary working day, the movie camera ***Sony mini DV*** was used. The measurement procedure is shown in Figure 1.

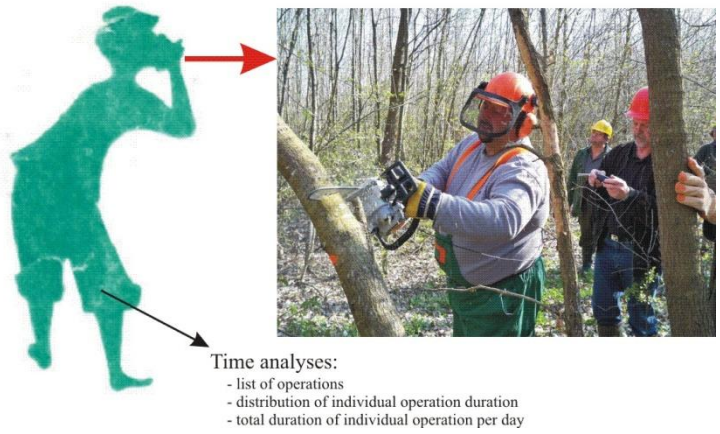

Figure1: Schematic representation of the ime study

Source: own study

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

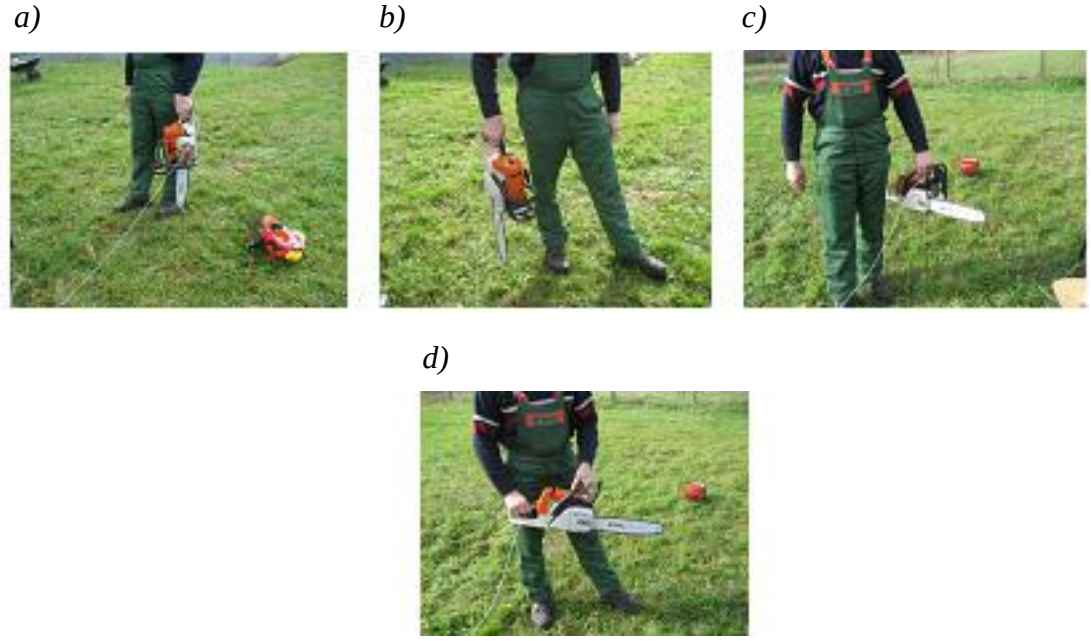

Figure 2: Some activities during handling the chain saw at idling: a) left hand-rear handle, b) right hand-rear handle, c) left hand-front handle, d)transport with both hands

Source: own study

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,
T_0 is referenceduration of 28 800 s (8 hours),
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 on four areas. Basic characteristics of the areas are given in Table 1.

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

Basic characteristics	**Area**			
	Lešće	***Sesvećka***	***Molve***	***Ljevača***
Dominant species	oak	oak	oak	oak
Average ages, years	11	18	10	14
Size, ha	12.94	23.66	20.33	25.55
Elevation, °	0 – 5	5 – 30	0	0
Altitude, m	140 – 155	170 – 220	118	117

Source: own study

In order to define all the activities during working time as well as their durations the recorded data were processed on the personal computer. The data were analyzed using ***Windows Media Player 9.*** There were analyzed 205 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 simulated conditions on the training ground for forestry mechanization as shown on Figure 2. The following vibration levels were found:

a) Front handle:

- at idling 5,43 – 5,85 m/s^2
- at cutting 4,30 – 5,05 m/s^2

b) Rear handle:

- at idling 7,61 – 10,38 m/s^2
- at cutting 4,83 – 5,06 m/s^2

c) Carrying the chain saw with the right hand on the rear handle at idling:

- at idling 7,61 m/s^2

d) Carrying the chain saw with the left hand on the front handle at idling:

- at idling 5,43 m/s^2

The working activities take place in conditions as shown in Figure 3. Obviously, it is nearly impossible to measure the vibration level at cutting in real conditions. Thus the vibration levels at cutting were measured in simulated conditions as it is shown in Figure 4.

Figure 3: The real conditions of forest nursery and thinning
Source: own study

Figure 4:Vibration measurement at cutting in simulated conditions
Source: own study

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. The measuring chain shown in Figure 5 was used during vibration measurement. As it was mentioned earlier, the measurements were carried out simultaneously in all three coordinate axes.

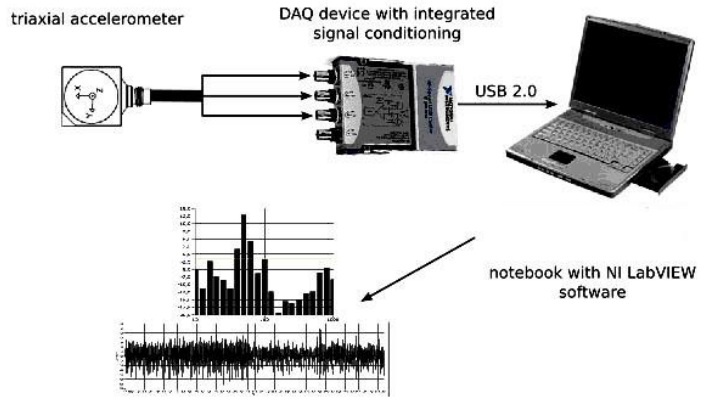

Figure 5:Schematic representation of the measuring chain used for vibration measurement
Source: own study

3. Results

The results obtained by measuring data analyses are given in Tables 2 – 13.

Table 2: Vibration levels at nursery (area Križevci):

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	449	8.41	J-K-B-D 43 a Nursery by Z. Kolarić 25 time intervals Total: 5340 s
Right hand, rear handle	181	3.39	
Right hand – front handle	-	-	
Cutting	1061	19.87	
Both hands – idling	2329	43.61	
Chain saw on the ground	1320	24.72	

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	421	7.88	J-K-B-D 43 a Nursery by Z. Ivanić 23 time intervals Total: 5340 s
Right hand – rear handle	326	6.10	
Right hand – front handle	-	-	
Cutting	889	16.65	
Both hands – idling	1959	36.69	
Chain saw on the ground	1745	32.68	

Source: own study

Table 3: Both workers together (in Križevci):

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	870	8.15	J-K-B-D 43 a Nursery by
Right hand – rear handle	507	4.75	

Right hand – front handle	-	-	both workers 48 time intervals Total: 10680 s
Cutting	1950	18.25	
Both hands – idling	4288	40.15	
Chain saw on the ground	3065	28.70	

Source: own study

Table 4: Average exposure to hand-transmitted vibration at forest nursery
- average total effective working time: **13 287 s**

Activity	**Left hand**			**Right hand**		
	%	**Time, *s***	**a_{hvi}, m/s^2**	**%**	**Time, *s***	**a_{hvi}, m/s^2**
Transport	8.15	1083	5.43			
Transport				4.75	631	7.61
Cutting	18.25	2425	5.05	18.25	2425	5.06
Idling	40.15	5334	5.85	40.15	5334	9.00
A(8), m/s^2			**3.1**			**4.3**

Source: own study

Table 5: Vibration levels at thinning (area Križevci):

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	500	9.36	J-K-B-D 87 a Thinning by Z. Kolarić 25 time intervals Total 5340 s
Right hand – rear handle	117	2.19	
Right hand – front handle	118	2.21	
Cutting	1545	28.93	
Both hands – idling	2969	55.60	
Chain saw on the ground	91	1.70	

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	907	16.99	J-K-B-D 87 a Thinning by Z. Ivanić 25 time intervals Total 5340 s
Right hand – rear handle	195	3.65	
Right hand – front handle	30	0.56	
Cutting	1631	30.54	
Both hands – idling	2410	45.13	
Chain saw on the ground	167	3.13	

Source: own study

Table 6: Both workers together:

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	1407	13.17	J-K-B-D 87 a Thinning Both workers 50 time intervals Total: 10680 s
Right hand – rear handle	312	2.92	
Right hand – front handle	148	1.39	
Cutting	3176	29.74	
Both hands – idling	5379	50.37	
Chain saw on the ground	258	2.42	

Source: own study

Table 7: Average exposure to hand transmitted vibration at forest thinning
- average total effective working time: **11 093 s**

Activity	Left hand			Right hand		
	%	**Time, *s***	**a_{hvi}, m/s^2**	**%**	**Time, *s***	**a_{hvi}, m/s^2**
Transport	13.17	1461	5.43			
Transport				2.92	324	7.61
Transport	1.39	154	5.43			
Cutting	29.76	3301	5.05	29.76	3301	5.06
Idling	50.37	5588	5.85	50.37	5588	9.00
A(8), m/s^2			**3.3**			**4.5**

Source: own study

Table 8: Vibration levels at nursery (area Repaš)

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	921	27.91	Sušinski berek 68 c Nursery by M. Ferenčić 17 time intervals Total: 3300 s
Right hand – rear handle	12	0.36	
Right hand – front handle	3	0.09	
Cutting	840	25.45	
Both hands – idling	1510	45.76	
Chain saw on the ground	14	0.42	

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	283	8.58	Sušinski berek 68 c Nursery by Z. Pavišić 17 time intervals Total: 3300 s
Right hand – rear handle	198	6.00	
Right hand – front handle	77	2.33	
Cutting	911	27.61	
Both hands – idling	1814	54.97	
Chain saw on the ground	17	0.52	

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	**127**	**3.85**	Sušinski berek 68 c Nursery by P. Špoljar 17 time intervals Total: 3300 s
Right hand – rear handle	**430**	**13.03**	
Right hand – front handle	-	-	
Cutting	**756**	**22.91**	
Both hands – idling	**1949**	**59.06**	
Chain saw on the ground	**38**	**1.15**	

Source: own study

Table 9: All workers together

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	1331	13.44	Sušinski berek 68 c Nursery – all workers together 51 time intervals Total: 9900 s
Right hand – rear handle	640	6.46	
Right hand – front handle	80	0.81	
Cutting	2507	25.32	
Both hands – idling	5273	53.26	
Chain saw on the ground	69	0.70	

Source: own study

Table 10: Average exposure to hand-transmitted vibration at forest nursery (area Repaš)
- average total effective working time: **12 301/2 s = 6 150.5 s**

Activity	**Left hand**			**Right hand**		
	%	**Time, *s***	**a_{hvi}, m/s^2**	**%**	**Time, *s***	**a_{hvi}, m/s^2**
Transport	13.44	827	5.43			
Transport				6.46	397	7.61
Cutting	25.32	1557	5.05	25.32	1557	5.06
Idling	53.26	3275	5.85	53.26	3275	9.00
A(8), m/s^2			**2.47**			**3.37**

Source: own study

Table 11: Vibration levels at thinning (area Repaš):

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	1785	37.66	Ljevača 21 b Thinning by M. Ferenčić 25 time intervals Total: 4740 s
Right hand – rear handle	76	1.6	
Right hand – front handle	44	0.93	
Cutting	1098	23.16	
Both hands – idling	1737	36.65	
Chain saw on the ground	-	-	

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	366	7.53	Ljevača 21 b Thinning by Z. Pavišić 25 time intervals Total: 4860 s
Right hand – rear handle	464	9.55	
Right hand – front handle	19	0.39	
Cutting	1243	25.58	
Both hands – idling	2768	56.95	
Chain saw on the ground	-	-	

Source: own study

Table 12: Both workers together:

Handling the chain saw	**Duration, *s***	**%**	
Left hand – front handle	2151	22.41	Ljevača 21 b Thinning Both workers 50 Time intervals Total: 9600 s
Right hand – rear handle	550	5.73	
Right hand – front handle	63	0.66	
Cutting	2341	24.39	
Both hands – idling	4505	46.93	
Chain saw on the ground	-	-	

Source: own study

Table 13: Average exposure to hand-transmitted vibration at forest thinning
- average total effective working time: **13 385 s /2=6 692.5 s**

Activity	**Left hand**			**Right hand**		
	%	**Time, *s***	**a_{hvi}, m/s^2**	**%**	**Time, *s***	**a_{hvi}, m/s^2**
Transport	22.41	1500	5.43			

Transport				5.73	383	7.61
Transport				0.66	44	7.61
Cutting	24.39	1632	5.05	24.39	1632	5.06
Idling	46.93	3141	5.85	46.93	3141	9.00
A(8), m/s^2			**2.59**			**3.35**

Source: own study

4. Discussion

Worker's exposure to hand-arm transmitted vibration at forest nursery and thinning was tested on two workplaces typical for Croatian lowland forests. The working activities during which the vibration exposure occur, as well as their duration were identified. The methods of time study were applied. There were five such activities found:

1. Left hand – front handle.
2. Right hand – rear handle.
3. Right hand – front handle.
4. Cutting.
5. 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 as earlier mentioned. All measurements were carried out on the training ground for forestry mechanization. Real working conditions were simulated. 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 forest nursery and thinning can be classified as dangerous viewed from the aspect of exposure to vibration. Among eight tested workers only one was exposed to permitted level of vibration. It must be pointed out that in Croatia work at nursery and thinning is considered suitable to partly disabled persons. Therefore the research results must 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 on forest nursery and thinning has shown some interesting and unexpected results. The 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 problems some steps must be immediately taken.

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