PROTECTION FROM HAND-ARM TRANSMITTED VIBRATION USING ANTIVIBRATON GLOVES

VLADO GOGLIA – IGOR ĐUKIĆ – JOSIP ŽGELA

Abstract
There are various ways of reducing the health-hazards of hand-transmitted vibration. One of the possible protective measures is the use of the anti-vibration gloves, but their effectiveness is still subject to discussion and many experts are questioning it. The procedure for measurement and evaluation of the vibration transmissibility of the anti-vibration gloves is given in ISO 10819-1996 and EN ISO 10819-1996 as well as in the National Standard HRN ISO 10819-2000. Due to the numerous objections on the testing procedure recommended by the above standards many researchers prefer field- testing. In order to assess the effectiveness of anti-vibration gloves of five different manufactures the Faculty of Forestry – University of Zagreb in co-operation with the public enterprise Hrvatske šume Ltd. carried out a field-testing. The paper reports on the testing results.

Key words: ergonomics, vibration, anti-vibration gloves, manufactures, measurement.

Classification JEL: Z13 – Economic Sociology

1. Introduction

Exposure to vibration of higher intensity over a longer period of time often causes permanent health damages. Occupational deseases play an important role in many activities in forestry, too. One of the numerous protective measures taken against excessive exposure to hand-arm transmitted vibration is the use of anti-vibration gloves. The assessment of their effectiveness is a complex procedure which doesn't always yeald expected results. As there is a number of anti-vibration gloves available on the market, it is a very responsible task to make the right choice. According to the official statistics of the Croatian State Health Institute vibration accounted for 11.4 % of the overall number of occupational deseases between 1990 and 1997 (Kocian, 1999). In order to assess the effectiveness of anti-vibration gloves of five different manufacturers the Faculty of Forestry, University of Zagreb, in co-operation with the public enterprise *Hrvatske šume Ltd.* carried out a field–testing.

2. Sensitivity of the hand-arm system to vibration

It is very well known that parts of the human organism have different natural frequences. Exposure to vibration the frequency characteristics of which are in resonance with a part of human body can multiply the consequences, especially in the case of the hand-arm system where vibration is directly transmitted to the body. It is also a known fact that maximum sensitivity of the hand-arm system lies in the frequency range from 6.3 to 16 Hz (Goglia, 1997). Beside frequency characteristics there are two more parameters that are important in predicting the hazard rate of exposure to vibration:

- vibration level or intensity, and
- time of exposure.

The real vibration intensity should be weighted simultaneosly taking into account frequency characteristics as well as vibration level. According to the ISO 5343-12001 recommendations the vibration level in all three co-ordinate axes schould bi noted in the vibration measurement report. The weighted accelerations should be counted in accordance with the Annex A of the same standard using the following equation:

$$a_{hw(x,y,z)} = \sqrt{\sum_{i=1}^{h} (W_{hi} a_{hi})^2}$$

where: W_{hi} is the weighting factor for the i-th one-third-octave band, and
a_{hi} is the r.m.s. acceleration measured int the i-th one-third-octave band, m/s^2.

The evaluation of the total exposure to vibration transmitted to the hand-arm system is defined as the root-sum-of-square of the three component values:

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

The daily vibration exposure is expressed in terms of the eight-hour energy-equivalent frequency-weighted total vibration value, *A(8)*, as shown in the following equation:

$$A(8) = a_{hv} \cdot \sqrt{\frac{T}{T_o}}$$

where: T is total daily duration of exposure to the vibration a_{hv} and
T_0 is the refernce duration of 8 hours (28800 s).

If the total daly exposure to vibration consists of several operations with different vibration magnitude, the daily vibration exposure, A (8), shall be obtained using the equation:

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

where: a_{hvi} is total vibration value fot the i-th operation;
n are number of individual vibration exposures, and
T_i is duration of the i-th operation.

3. Reduction of the daily exposure to hand-arm transmitted vibration

The above equations show clearly that there are three possibilities to reduce operator's daily exposure to hand-arm transmitted vibration:

a) by organizing the work-site as to combine the different activities during the work day,
b) by reducing the exposure time,
c) by damping the vibration, particularly in the frequency range in which the hand-arm system is most sensitive.

All three possibilities are used in practice. This article discusses the possibility of reducing the exposure to the hand-arm transmitted vibration by damping. The use of anti-vibration gloves is suggested to operators exposed to higher levels of vibration, but it has to be pointed out that many researchers and scientists are sceptical towards the their effectiveness (Koton, 2002). What type of gloves shoulod be used has been discussed for years. The choice of the best anti-vibration gloves is not easy. There are many manufacturers who offer anti-vibration gloves made of various materials for vibration damping, which makes the damping efficiency of anti-vibration gloves necessary. In our opinion, the best way to define the damping characteristics of the anti-vibration gloves is to test them in real work-site conditions.

4. Measuring method and measuring equipment

The vibration level was at first measured on the operator's grip handle of the motor chain saw in all three directions at 3 different working conditions:

- at idling,
- at full load, and
- at maximum rotational frequency.

After that, the vibration level on operator's hand was measured in all three axes simultaneously at the same three working codnitions. The anti-vibration gloves were placed between the grip handle and the operator's hand. The damping characteristics of the anti-vibration gloves can be expressed in verious ways:

1) By the **ratio between the weighted acceleration sum measured** on the grip handle and the ones measured directly on the operator's hand:

$$\alpha_p = \frac{WAS_2}{WAS_1}$$

where: α_p is damping factor expected to be < 1;
WAS_1 is weighted acceleratiion sum on the grip handle, m/s^2, and
WAS_2 is weighted acceleratiion sum on the operator's hand, m/s^2

2) The damping can be axpressed also by the **ratio between the weighted accelerations in different directions** on the grip handle and the operator's has as follows:

$$\alpha_{x,y,z} = \frac{a_{hwx,y,z2}}{a_{hwx,y,z1}}$$

where: $\alpha_{x,y,z}$ is damping factors in the particular directions expected to be < 1;
$\alpha_{hwx,y,z1}$ is weighted acceleration in specific direction ont he grip handle, m/s^2;
$\alpha_{hwx,y,z2}$ is the same on the operator's hand, m/s^2.

3) For detailed damping characteristics ot the particular anti-vibration gloves the **frequency characteristics of the vibration level** on the grip handle and the operator's hand can be calculated.

A special holder for the threeaxial accelerometer has been designed for these measurements. The threeaxial accelerometer with holder is shown in Fig. 1. As it was mentioned before, the measurements were first carried out on the grip handle in all three co-ordinate axes simultaneously and at three operating conditions.

Figure 1: Threeaxial accelerometer with the holder

The same was then repeated on the operator's hand. The threeaxial accelerometer was positioned in accordance with the ISO 8725 – 1985 recommendations. A measuring chain as shown in Fig. 2 was used for the measurements. For each working codition several samples were used. The averaging times during analysis ware taken in accordance with the above recommendations.

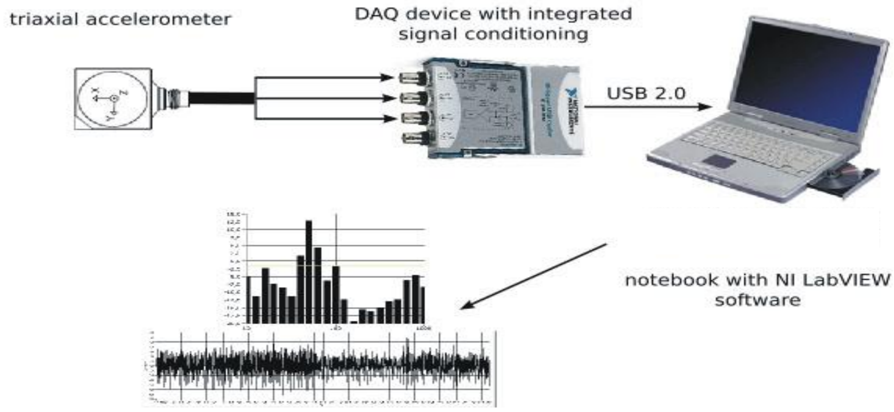

Figure 2: Shematic representation of the measuring chain

5. Measurement and measurement results

In accordance with the ISO 7505 a fresh beech-prism was cut for the measurement. For each of the three axes in all three working conditions the values of weighted accelerations were calculated. Then the WAS-values (weighted acceleration sum) were calculated. The velaues for all three axes as well asWAS-values are graphically represented in diagrams in Fig. 3 – 6.

From Fig. 3 it is clear that during idling only one type of anti-vibration gloves have shown relatively good damping characteristics, two types have shown negligible damping characteristics and the last two tested types have shown unexpected characteristics: the vibration levels were increased. The tested gloves have shown similar characteristics in WAS-values as well as in particular axes.

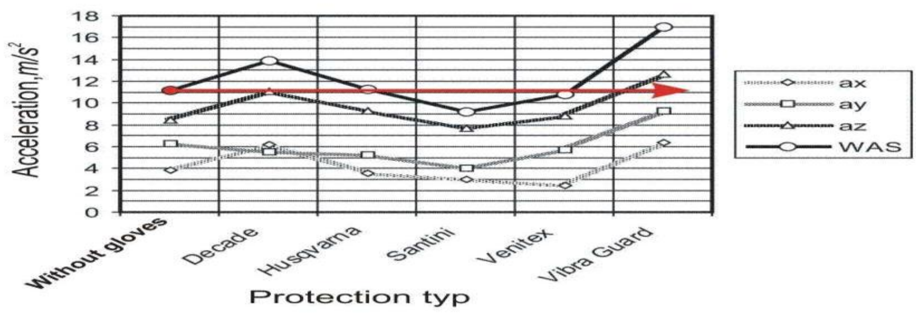

Figure 3: Graphical representation of the weighted acceleration in all three single axis and the WAS values at idling
Sorce: own

At maximum rotational frequency the anti-vibration gloves have shown significantly better damping characteristics. The WAS-value is shown in Fig. 4. From the five tested types of anti-vibration gloves four have shown good damping characteristics. These results correspond to the results obtained in some independent researches of this problem. It has been known already that the most anti-vibration gloves show good damping characteristics at higher frequencies only.

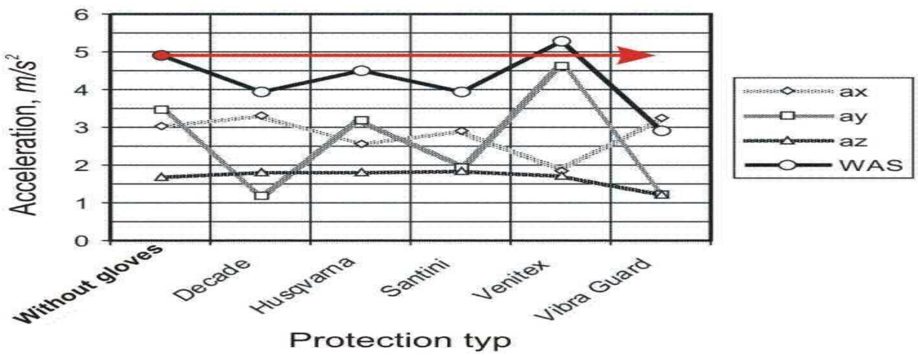

Figure 4: Graphical representation of the weighted acceleration in all three single axis and the WAS values at full load
Sorce: own

Fig. 5 shows the weighted vibration level in all three co-ordinate axes as well as the WAS-value at cutting. It is evident that only one type of the tested anti-vibration gloves has shown good damping characteristics. Two types have shown weak and two types negligible damping characteristics.

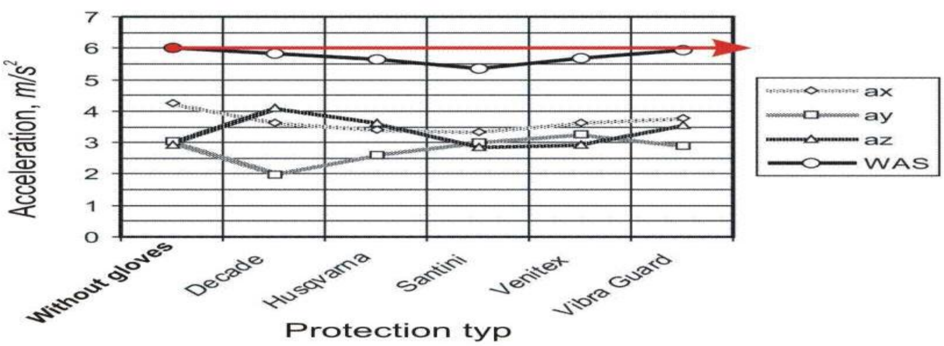

Figure 5: Graphical representation of the weighted acceleration in all three single axis and the WAS values at cutting
Sorce: own

The cumulative representation of the WAS-values for all three cutting conditions is shown in Fig. 6. It shows clearly that compared to the vibration level obtained by measurements on the grip handle, the use of anti-vibration gloves makes a negligible difference. The differences are so small, that they might as well be the consequence of the measuring error. On the other hand, the same figure shows also that during maximum rotational frequency all types of the anti-vibration gloves tested show good damping characteristics. One type of anti-vibration gloves has shown particularly good damping characteristics. It has to be pointed out that two types of anti-vibration gloves have shown totally unexpected damping characteristics at idling. Their damping factors were greater than 1, which means that the vibration level increases at idling when using these types of anti-vibration gloves.

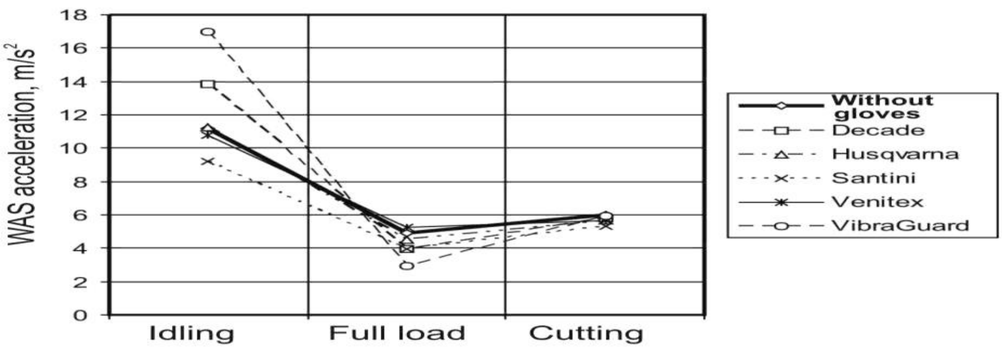

Figure 6: Cummulative representation of the WAS values
Sorce: own

6. Conclusion

The measurement have shown that there are significant diferences in damping charecteristics between deferent tzpes of anti-vibration gloves. At idling some of anti-vibration gloves have shown completely unexpected charecteristics. During idling only one type of anti-vibration gloves have shown relatively good damping characteristics, two types have shown negligible damping characteristics and the last two tested types have shown unexpected characteristics: the vibration levels were increased. The tested gloves have shown similar characteristics in WAS-values as well as in particular axes. At maximum rotational frequency the anti-vibration gloves have shown significantly better damping characteristics. From the five tested types of anti-vibration gloves four have shown good damping characteristics. At cutting it is evident that only one type of the tested anti-vibration gloves has shown good damping characteristics. Two types have shown weak and two types negligible damping characteristics. These results correspond to the results obtained in some independent researches of this problem.

References:

[1] DONG, R. G. – WELCOME, D. E. – McDOWELL, T. W. – WU, Y. Z.: *Measurement of biodynamic response of human Hand-arm system.* Journal of Sound and Vibration, 2006, 294, p. 807 – 827. ISSN 0022-460X

[2] DONG, R. G. – McDOWELL, T. W. – WELKOME, D. E. – SMUTZ, W. P. – SCHOPPER, A. W. – WARREN, C. – WU, J. Z. – RAKHEJA, S.: *On-the hand measurement methods for assessing effectiveness of anti-vibration gloves.* International Journal of Industrial Ergonomics, 2003, 32, p. 283 – 298. ISSN 0169-8141

[3] GOGLIA, V.: *Ergonomske značajke šumarske mehanizacije – problemi njihova mjerenja i vrednovanja*. Mehanizacija šumarstva, 1997, 22 (4), p. 209 – 217. ISSN 0352-5406

[4] GOGLIA, V. – GOSPODARIĆ, Z. – BELJO, R. – ĐUKIĆ, I. – KOVAČEV, I.: *Izloženost vozača malog poljoprivrednog traktora vibracijama.* Zbornik radova Actual tasks on agricultural engineering. 2004. Opatija. ISSN 1333-2651

[5] GRIFFN, M. J.: *Evaluating the effectiveness of gloves in reducing the hazards of hand-transmitted vibration.* Ocupational and Environmental Medicine, 1998, 55, p. 340 – 348. ISSN 1351-0711

[6] HEWITT, S. *Assessing the performance of anti-vibration gloves – a possible alternative to ISO 10891-1996.* Annals of Occupational Hygiene, 1998, 42, p. 245 – 252. ISSN 0003-4878

[7] KACIAN, N.: *Occupational diseases in Croatia*. Work and Safety 1999, 3 (1), p. 83 – 89. ISSN 0352-3675

[8] KOTON, J: *Prevention of hand-arm vibration syndrome by using antivibration gloves*. Medycyna Pracy, 2002, 53, p. 423 – 431. ISSN 0465-5893

[9] REYNOLDS, D. D. – WOLF, E.: *Evaluation of antivibration gloves test protocols associated with the revision of ISO 10819*. Industrial Health, 2005, 43, p. 556 – 565. ISSN 0019-8366

[10] SUCHOMEL, J. – SLANČÍK, M.: *Influence of some ergonomic criterims on modelling and optimization technology in forestry*. In: Proceedings of the International Conference Management of Human Potential in a Company. Žilina. University of Žilina. 2005, p. 354 – 359. ISBN 80-8070-360-4

[11] WARREN, C. – WU, J. Z. – RAKHEJA, S.: *On-the hand measurement methods for assessing effectiveness of anti-vibration gloves.* International Journal of Industrial Ergonomics, 2003, 32, p. 283 – 298.

Address of authors:

Prof.dr.sc.dr.h.c. Vlado GOGLIA
Faculty of Forestry
University of Zagreb
Svetošimunska 25
10 000 Zagreb
Croatia
e-mail: goglia@sumfak.hr

Mr.sc. Igor ĐUKIĆ
Faculty of Forestry
University of Zagreb
Svetošimunska 25
10 000 Zagreb
Croatia
e-mail: i_dukic@yahoo.com

Mr.sp. Josip ŽGELA
Public Enterprise „Hrvatske Šume“, Ltd.
Vukotinovića 2
10000 Zagreb
Croatia
e-mail: josip.zgela@hrsume.hr