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HUMAN VIBRATIONS EFFECTS, MEASUREMENT AND PROTECTION

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Abstract: *In this paper, measurements of mechanical vibrations are carried out at different working conditions by using different tools. Measurements were committed with a 4447-type Human vibration analyzer, with vibrations measured from the source to the receiver. Measurements are made in real time, by using a specific tool, and worker for whom minimization of vibrations at work is needed. Vibrations which can vary in large measure regarding the excitation frequencies and levels, can also depend from the employee's weight and conduct. The time of exposure to vibrations can be determined with proper measurement in real terms, which is one of the most important factors in preserving the health of the employee.*

Keywords: *human vibrations, measurement, protection*

INTRODUCTION

Man, throughout his life is often influenced by mechanical vibration. Prolonged exposure to high levels of vibration of the body leading to premature fatigue and lower productivity, and often the incidence of occupational diseases.

In numerous studies that have been done for the assessment of human vibration, especially for vibrations that occur in the work environment are observed international standard values used for evaluating the allowable vibration. European Directive EU 2002/44/EC introduced the minimum health and safety requirements for workers to protect them from possible exposure to vibration in their work activity. Standard applications include measurement of whole-body vibration and the vibration of the upper limbs in humans, with an instrument that meets the standard requirements.

INDUSTRIAL VIBRATION

Industrial vibration with its physical characteristics has complex classification. Vibration depending on the nature of contact with the source of vibration is divided into:

- *Vibration, which people are exposed through the support surface (the surface on which a person stands, sits or lies) that have an effect on the whole body and are called general. This whole-body vibration and occur in all types of transport and industrial zones.*
- *Vibration, affecting only part of the body are called local. The transfer of vibration is usually of the hands (fingers) and occur where the vibrating tool.*

Vibrations often occur in combination of local and general vibration. Table 1 presents the two types of vibration: hand-arm vibration and vibration transmitted to the whole body, with their meaning and implications. Table 2 shows the limits of exposure to vibration according to Regulation for Safety and Health of Employees at risk of mechanical vibrations (Official Journal of R.M. No. 26/2008).

Table 1. Division of vibration during exposure

Terms	*Meaning*
1. Hand-arm Vibration	*Mechanical vibration which when transmitted to the human hand-arm system, causing risks to health and safety of employees (vascular, bone or joint, neurological or muscular disorders)*
2. Whole-body vibration	*Mechanical vibration which when transmitted to the whole body, causing risks to health and safety of employees, especially of immobility lower of the back, and damage to the spine*

Table 2. Allowed limits of exposure to vibration

Limits of exposure and values at work	
1. Hand-arm Vibration	*- Limit value of daily exposure at work, the default for a period of 8 hours is* ***5m/s²****.* *- The value of daily exposure at work, the default for a period of 8 hours is* ***2,5 m/ s².***
2. Whole-body vibration	*- Limit value of daily exposure at work, the default for a period of 8 hours is* ***1,15m/ s².*** *- The value of daily exposure at work, the default for a period of 8 hours is* ***0,5 m/ s²***

METHOD AND METHODOLOGY FOR MEASURING THE VIBRATION OF HAND-ARM SYSTEM

Today, the intensity of vibration is measured objectively using appropriate encoders (sensors) and additional testing equipment. Encoders are used for measuring vibrations: for measurement of displacement (contact and without contact), to measure the speed and accelerate measurement.

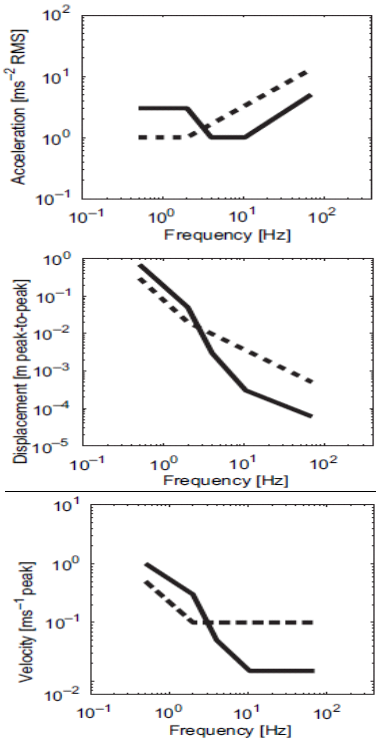

Figure 1. Vibration can be expressed through acceleration (left), velocity (right) and feed (center) [1]

According to ISO 5349:2001, values of human vibration are acceleration (a), indicated as RMS (mean square value of vibration acceleration). Results of the measurements are expressed in m/s².

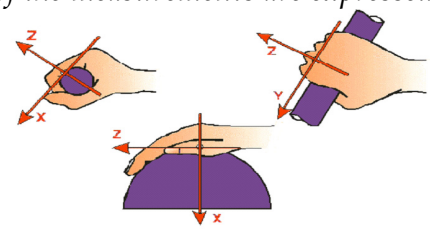

Figure 2. The principle of measurement, location and axial-orientation of hand system

The standard ISO 5349 1:2001 recommends setting the frequency in three directions: the axis direction of the arm and two other axes in the plane between the hand and the tool (Figure 2). The best solution is using a miniature triaxial accelerometer, which receives vibrations from all three directions at one point. Frequency range of the analysis is 8-1000 Hz. Weight factor of frequency, Wh, (Figure 3) is used for all three axes, although anatomy, sensitivity along the arm and in transverse direction are different.

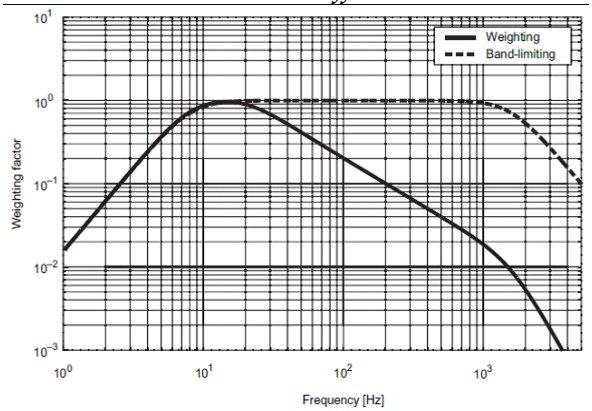

Figure 3. The size of the frequency weighting factor according to ISO 53491 or ISO 8041 [1]

The three components of frequency of acceleration are marked with a_{hwx}, a_{hwy} and a_{hwz} while the root of the sum of their squares give total vibration a_{hv}:

$$a_{hv} = \sqrt{(\text{kxa}_{\text{hwx}})^2 + (\text{kya}_{\text{hwy}})^2 + (\text{kza}_{\text{hwz}})^2} \qquad (1)$$

Calculation of daily vibration exposure A (8), for one worker during 8 hours will be:

$$A(8) = a_{hv}\sqrt{\frac{T_{exp}}{T_0}} \qquad (2)$$

where T_0 is the reference time of 8 hours, T_{exp} duration of exposure to vibration or the duration of the operation, including breaks, depending on the measurement approach.

MODERN MEASUREMENT SYSTEMS FOR MEASURING VIBRATION

The principle of operation of modern equipment for measuring and analysis of vibration will be shown to the device- Human vibration analyzer - type 4447 of Bruel&Kjaer.[1]

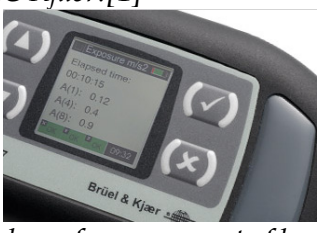

Figure 4. Analyzer for assessment of human vibration Type 4447, Bruel & Kjaer [1]

Analyzer - Type 4447 is portable systems designed to control and eliminate potential vibration in accordance with EU Directive 2002/44/EC. [3]

Type 4447 - Bruel & Kjaer, provides integrated solutions for measuring and analyzing vibration.

The graphic display (figure 4) of 124x124 pixels provides continuous, detailed feedback on exposure to vibration and allows assessment of the measurement immediately.

MEASUREMENTS OF VIBRATION

In this paper, measurements are performed of exposure to vibration, of the employee who works with Hand Drilling Machine Φ5 in concrete MB30 (Machine A and B) and Cordless Drill Driver, in wood (Machine C). Measurements were performed in accordance with recommendation of the International Standard ISO 5349:2001 (local vibration, hand-arm).

Figure 5. Equipment that was made measurement: type 4447 analyzer and computer processing of measurements in 4447 Vibration Explorer-software

The main accent in the measurement is the position of the Z axis, set as vertical and horizontal component when measuring.

Results of measurement 1

Figure 6. Machine A- Large Hand Drill (Φ5) Measuring exposure to vibration in the horizontal and vertical position when working in concrete

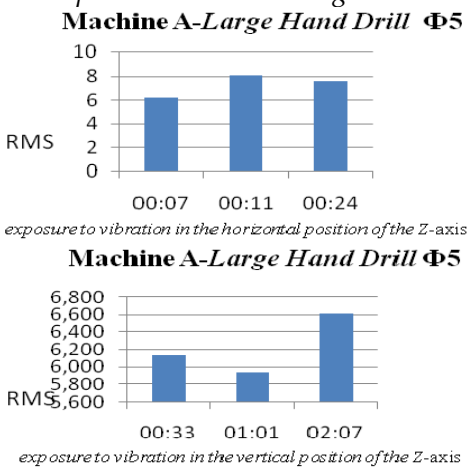

Figure 7. Machine A- Large Hand Drill (Φ5) Displaying RMS vs. time of exposure, at horizontal (left) and vertical (right) posicion of the Z-axis

The measured vibration exposures of Large Hand Drill, the results show a daily average exposure of 6,738 (RMS). Relying on allowable limit values [6], the exposure of this machine is reduced to 6 hours in accordance with ISO 5349-1/2 [7] [8].

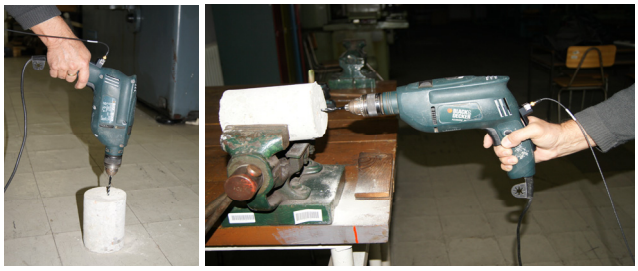

Figure 8. Machine B- Small Hand Drill (Φ5) Working with Small Hand Drill Machine in vertical and horizontal positions

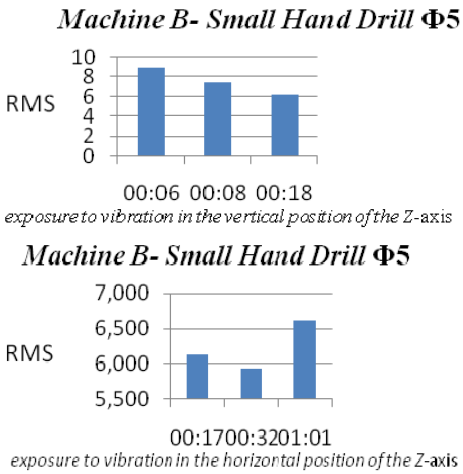

Figure 9. Machine B- Small Hand Drill (Φ5) Displaying RMS vs. time of exposure, at horizontal (right) and vertical (left) position of the Z-axis

Results for Little Hand Drill Machine for daily exposure A (8), according to measurements of exposure to vibration, shows the average value of 8,341 (RMS), and for overcoming the limit value, time of work optimize up to 5 hours.

Results of measurement 2

Figure 10. Machine C- Cordless Drill Driver (Φ5) Working with Cordless Drill Driver in vertical and horizontal positions

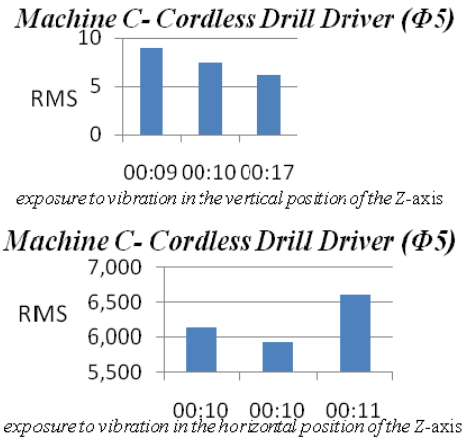

Figure 11. Machine C- Cordless Drill Driver (Φ5) Displaying RMS vs. time of exposure, at horizontal (right) and vertical (left) position of Z-axis

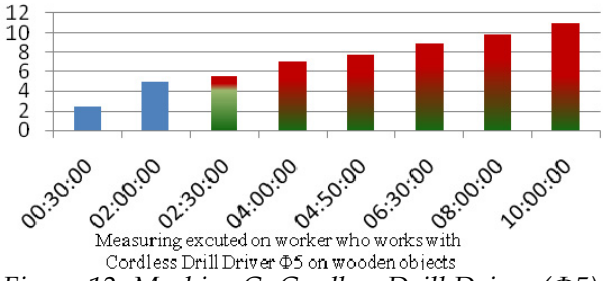

Figure 12. Machine C- Cordless Drill Driver (Φ5) Displaying RMS vs. time of exposure at horizontal position of Z-axis (No.7-2HOR)

According to the exposure limit values (Figure 12), allowable working action with this machine is 4 hours. Any continuously overcoming above the daily exposure can lead to professional illness.

	Color	Action value EAV (2,5m/s²)	Limit value ELV (5m/s²)
0 to 5 m/s²	Green	More than 2 hours	More than 8 hours
5 to 10 m/s²	Amber	30 minutes to 2 hours	2 to 8 hours
>10 m/s²	Red	Less than 30 mins	Less than 2 hours

Figure 13. Allowed Maximum exposure by the hand-arm vibration (ISO 5349)

Note in respect of position in which the worker is exposed. The vertical component of the vibration is unfavorable for people who work in a sitting position, and the horizontal component of the standing working position of.

VIBRATION PROTECTION & CONCLUSION

It can be concluded that the full elimination of vibrations from the environment in general, is not possible. In any case, employees should not be exposed above the exposure limit value. There are several methods used to prevent vibration. Action for preventing vibrations [4], [5]:

- *Elimination;*
- *Replacement;*
- *Isolation;*
- *Engineering controls (the source of vibration and their progress);*
- *Administrative control (exposure to vibration and training);*
- *Regular health checkups and*
- *Supply of personal protective equipment.*

References

[1.] *Human Vibration Analyzer Type 4447-User Manual, Good Practice Hand Arm, Good Practice Whole body*

[2.] *CEN Technical Report - "Notes on the assessment of exposure to vibration based on information supplied by the manufacturer of the machine"*

[3.] *Reaction of human to vibration (ISO 8041:2005)*

[4.] *GOST 12.4.002-74 "Hand protection from vibration-General requirements."*

[5.] *GOST 12.4.024-76 "Shoes for protection against vibration"*

[6.] *Regulation on Safety and Health at Work of employees at risk of mechanical vibrations (Official Journal of R.M. No. 26/2008).*

[7.] *ISO 5349-1 Mechanical vibration. Measurement and evaluation of vibration exposure in man hand. Part 1: General requirements*

[8.] *ISO 5349-2 Mechanical vibration. Measurement and evaluation of vibration exposure in man hand. Part 2: Practical Guide for measuring workplace*

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