original article

Evaluating the transmitted vibration to operator’s hands hand and effect of protective gloves in real condition, based on International Standard Organization 5349 standard

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INTRODUCTION

About 1.5–2 million of workers in the US and millions of workers around the world are involved with vibrations of hand and arm.\(^1\) The jobs which require continuous and regular vibrating tools and equipment are developing every day.

Vibration is a pendulous movement about an equilibrium point of an object and frequency, transportation domain, and time period are the characteristics of it.\(^2\) Some occupational factors have been implicated in the development of disorders manifested as hand pain.\(^3\) The complications of hand-arm vibration are divided into three categories: Vascular, neural, and skeletal-muscular.\(^4\) In some literature, these complications are divided into five categories such as A, B, C, D, and E which are relating to vascular, osteoarticular, neural, muscular complications, and other complications.

ABSTRACT

Aims: The objective of this research was an evaluation of hand-held tools vibration acceleration such as circular saw and drill transmitted to operator’s and also to determine the role of glove in vibration reduction of those tools.

Materials and Methods: In this study, Bruel and Kjaer Vibration meter with a model of 2231 and its analyzer, 2522, along three types of gloves have been used. Accelerometer transducer installed according to International Standard Organization (ISO) 5349:1-2 standards in the case of the operator handles the hand-held tool. In next step, the transducer was placed inside the glove.

Results: The results show the most accelerated vibration in axis Y for circular saw while working on Plexiglas. All of the used gloves show a reduction of vibration transmission from tools to hands. Glove of C grouped had a reduction of vibration less than two other groups.

Conclusion: Based on ISO 5349-1, 10% of workers who are working with circular saw and drill without using glove will be affiliated to white finger after about 7–12 years. As a whole, the results showed that the anti-vibration gloves should be tested in real conditions before using them.

Key words: International Standard Organization 5349, International Standard Organization-10819, hand-arm vibration syndrome, hand-transmitted vibration, protective glove, vibration
respectively. Reduction in firm grip, paresis, and locking grip are the musculoskeletal complications of regular experience of vibration. Raynaud’s phenomenon or discoloration of the fingers resulted by vibration is one of the vascular demonstrations of vibration, among the others, and neural complications have gotten much more attention recently. Among these complications, paresthesia, tingling of the fingers, reduction in sense of touch, and insomnia can be named.

In 1974, the National Institute of Occupational Safety and Health has estimated that 8 million people in the US industries are in exposure to vibration of hand-arm. Rothfleisch and Sherman were the first people who found out the relationship between CTS and vibrating tools.

Many researchers have pointed out the outbreak of CTS among workers who have been involved in vibrating tools. In a research which has been done on rock drill in one the stone mines of Iran, this issue has observed that the root mean square values of acceleration, especially in Z axis is higher than threshold value proposed by BS and International Standard Organization (ISO) standards.

To decrease the side effects of vibrations to workers’ hands, various safety gloves have been designed. This is because wearing gloves while working with manual tools causes pressure on forearm.

According to the sensibility of this subject, different organization around world have set standards and policies for vibration management and to reduce vibration exposure.

The limits for hand–arm vibration in an 8-h work day are as follows: Threshold 1 m/s², the operational level 2.5 m/s², and permissible exposure limit 5 m/s². In addition, frequency range of effective vibration is 2–15 Hz.

According to problems which may happen for a worker who is in exposure to vibration, different organizations around the world have set standards and instructions for measuring and evaluating the vibration. If the applied vibration is higher than the allowed limit, the physical harmful factor for hand or arm should be controlled somehow. One way to prevent this case is using the anti-vibration gloves. Anti-vibration gloves can reduce the transferred vibration to the hands. Various gloves have been made as anti-vibration gloves. To integrate the testing of anti-vibration gloves, ISO has established a laboratory testing in accordance to ISO-10819, 1996.

A few studies have pointed out the technical problems of this test and they proposed some solutions for it, which made some changes into the test. For example, a pair of gloves may be recognized as a pair of anti-vibration gloves, but it cannot provide the adequate attenuation while using a special manual tool. Because of the vibration attenuation, effect of the gloves does not singly depend on dynamic characteristics of it, and biodynamic characteristics of hand-arm can also be effective.

The biodynamic of the human hand-arm system is a branch of biomechanics that applies laws of physics and engineering concepts to describe the motions and forces on the system, as well as their relationships.

Dynamic performance of a pair of gloves depends on characteristics of the substance of both sides of it (especially the side of hand) and also vibration frequency. Biodynamic characteristic of gloves depends on few factors including hand force, hand posture, and physical characteristics of the individual who is wearing them. Thus, the transferred vibration to the hand which is measured in laboratory, based on standard differs from real conditions in work.

Most of the international experts believe that the real performance of the gloves depends on the forces which are coming from hand to surface (grip power). BS EN ISO-10819 standard evaluates the anti-vibration gloves with a controlled force and gives no information about predicting the amount of attenuation while using the gloves in real conditions. In fact, the main problem is that not being clear which characteristics of vibration is the cause of discoloration of the fingers in workers. Wimer et al. have pointed out the criteria changes in classifications of anti-vibration safety gloves.

Hand–arm vibration measurements are necessary for vibration exposure risk assessment and for the determination of vibration emission values in hand-guided machines. Hence, due to the issue which have discussed, we determine to evaluate the transferred vibration from the gloves to operator’s hands in real condition.

**MATERIALS AND METHODS**

In this study, B and K (Bruel and Kjaer, Naerum, Denmark) Vibrator meter model 2231 and its analyzer, model 2522, were used. Accelerometer transducer installed on handle of a hand drill (KINZO 25C17) and a circular saw (BOSCH-GWS 7-115), according to ISO 5549:1-2 standards in the case of the operator handles the hand-held tools. ISO 5549 specifies general requirements for measuring and reporting hand-transmitted vibration exposure in tree orthogonal axes. It defines a frequency weighting and band-limiting filters to allow uniform comparison of measurements. The installing location of the transducer was also determined based on ISO 5549:1-2 standards. The vibration transmitted to the hands shall be measured and reported for three directions of an orthogonal coordinate system. The positions of the transducers shall preferably be on the underside of the handles (60 mm from the handle end).

In next step, as it is shown in Figure 1, the seam of gloves was opened and the transducer was placed inside them and
then the amount of transferred vibration was measured. Anti-vibration gloves have been used as an alternative approach to reduce hand-transmitted vibration exposure.

The present study has been carried out on two models of a circular saw and a manual drill. The work materials of them were marble and Medium-density fibreboard (MDF). The properties of the tools have been summarized in Table 1.

In addition, in the present study, according to Table 2, three types of gloves, that are widely used, have been selected. Two of them are anti-vibration and the third is ordinary.

The vibration transferred to the hand was measured in three perpendicular axes. Accelerometer was installed on the handle of the tool in a way which its axes was corresponding to the three (X, Y, and Z) axes.

Testing the gloves in the laboratory according to ISO-10819: 1996, Figure 2 could not be achieved, so that we cannot compare the results with those in the field.

RESULTS

The results of measuring the vibration in a circular saw working with marble in X, Y, and Z axes have been presented in Table 3. The results of measuring the vibration in a circular saw working with Plexiglas in X, Y, and Z axes have been presented in Table 4.

The results of measuring the vibration in drill working with MDF in X, Y, and Z axes have been presented in Table 5.

The results of measuring the vibration in drill working with Plexiglas in X, Y, and Z axes have been presented in Table 6.

DISCUSSION

The objective of this research was an evaluation of hand-held tools vibration acceleration such as circular saw and drill. Another objective was to determine the role of glove in vibration reduction of those tools. As said before, the results show the most accelerated vibration in axis Y for circular saw while working on Plexiglas. All of the used gloves show a reduction of vibration transmission from tools to hands.

Table 1: Properties of vibrating tools

| Tool    | Model       | Power (w) | Parts            | Storage conditions |
|---------|-------------|-----------|-------------------|--------------------|
| Circular saw | BOSCH-GWS 7-115 | 750       | 180 mm Metal Cutting Disc | Medium |
| Drill   | KINZO 25C17 | 710       | Diameter drill: 5HS | Good |

Table 2: Properties of the gloves

| Glove | Type       | Material                                   | Size |
|-------|------------|--------------------------------------------|------|
| A     | Anti-vibration | Chloroprene                              | XL   |
| B     | Anti-vibration | Cotton coated with nitrile               | XL   |
| C     | Ordinary    | Polyester coated with nitrile             | XL   |

Table 3: Results of measured vibration in a circular saw working with marble

| Testing sample | X (m/s²) | Y (m/s²) | Z (m/s²) | R.M.S (m/s²) | Percentage of deceleration |
|----------------|----------|----------|----------|--------------|----------------------------|
| With glove A   | 0.113    | 1.55     | 0.102    | 1.56         | 64                         |
| B              | 0.122    | 1.67     | 0.185    | 1.68         | 61                         |
| C              | 0.184    | 3.56     | 0.192    | 3.57         | 17                         |
| Without glove  | 0.189    | 4.3      | 0.198    | 4.31         | -                          |

Table 4: Results of measured vibration in a circular saw working with Plexiglas

| Testing sample | X (m/s²) | Y (m/s²) | Z (m/s²) | R.M.S (m/s²) | Percentage of deceleration |
|----------------|----------|----------|----------|--------------|----------------------------|
| With glove A   | 0.102    | 1.395    | 0.092    | 1.40         | 64                         |
| B              | 0.110    | 1.503    | 0.167    | 1.52         | 61                         |
| C              | 0.166    | 3.204    | 0.173    | 3.21         | 17                         |
| Without glove  | 0.179    | 3.87     | 0.178    | 3.88         | -                          |
working on MDF. More reduction of vibration was seen by the means of using A grouped glove. Drilling on Plexiglas has been shown acceleration vibration in axis X more than two other axes. The value of vibration reduction in B grouped glove was similar to A type. In a comparison among vibration accelerations when using circular saw on Plexiglas parts or using drill for Plexiglas and MDF; more vibration acceleration gotten by applying Plexiglas. Pinto et al. in a study showed that the real isolation of safety gloves in work sites vary with those done in a laboratory.\[23\]

The test method specified in ISO-10819 (1998) only requires measuring the transmissibility at the palm of the hand. While it may be acceptable for screening the gloves, it cannot provide sufficient information on how effectively a glove can reduce the transmitted vibration when the glove is used with a specific tool.\[20\] Hand-transmitted vibration and the associated potential injuries are dependent on hand-arm posture, hand forces, and other factors.\[29\]

Based on the results of this study and ISO 5349-1, 10% of workers without using glove who are working with circular saw will be affiliated to white finger after about 7 years. Like those people, there are many workers about 10% working with drill without glove who are affiliated to white finger in a period of 11–12 years.\[30\] The guidance on vascular effects given in this part of ISO 5349 is based on epidemiological studies involving power tools with vibration predominantly above the range 50–50 Hz (e.g., chain saws, grinders, and rock drills). Therefore, measurements which are dominated by components of frequency-weighted acceleration at lower frequencies, particularly below about 20 Hz, should be treated with caution.\[30\] Effective reductions or controls of the vibration transmitted to hand and the exposure duration are probably the most effective approach for preventing hand-arm vibration syndrome.\[23\] Anti-vibration gloves have been applied in industry to reduce the vibration transmitted into the hand and arms through the palms and fingers. Anti-vibration gloves should be made according to ergonomic principles. Anti-vibration gloves may increase forearm fatigue in the posterior forearm and decrease forearm fatigue in the flexor digitorum superficialis muscle during operation with tools.

Based on the results of a study by Welcome et al., some other further revisions in the test procedures, evaluation methods, and Anti-vibration glove criteria were also proposed and discussed.\[31\] However, a user of thicker, stiffer gloves, such as some Anti-vibration gloves, could be trading one health risk for another. Knowledge of the effects of gloves on grip strength can help workers, managers, and safety professionals make informed decisions about glove selection and use in the workplace.\[26\]

**CONCLUSIONS**

Unfortunately, testing the gloves in the laboratory according to ISO-10819, 1996, could not be achieved, so that we cannot compare the gotten results in this study with those in the field.

The important point about anti-vibration safety gloves is that they should be made according to ergonomic principles so that the worker can wear them, hold tools or parts. Using glove is generally recommended to keep the hands warm and dry and to protect them from many other hazards. However, the workers believe that some safety gloves with good damping are not comfortable.

The standard BS EN ISO-10819 defines the least conditions of anti-vibration safety gloves in a controlled way of force, but gives no prediction about damping produced while using in the field. Likewise, their use over time can effect on vibration damping of acceleration. Therefore, the test results of safety gloves in a laboratory should not be the base for their protection function.

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**Conflicts of interest**

There are no conflicts of interest.

**REFERENCES**

1. Pelmea r P, Wasserman D. Hand-arm Vibration: A Comprehensive Guide for Occupational Health Professionals. Beverly Farms: OEM Medical Press: 1998.
Forouharmajd, et al.: Evaluating the transmitted vibration

2. South T. Managing Noise and Vibration at Work. Vol. 5. Oxford, UK: Butterworth Heinemann Books; 2004. p. 80-5.
3. Andréu JL, Otón T, Silva-Fernández L, Sanz J. Hand pain other than carpal tunnel syndrome (CTS): The role of occupational factors. Best Pract Res Clin Rheumatol 2011;25:31-42.
4. John B, Gary R, Bovenzi M. Clinical Environmental Health and Toxic Exposures. 2nd ed. Philadelphia: Lippincott Williams and Wilkins; 2001.
5. Wasserman DE, Badger DW, Doyle TE, Margolies L: Industrial vibration-An overview. Am Soc Saf Eng J 1974;19:38-43.
6. Radwin RG, Armstrong TJ, Vanbergeijk E. Vibration exposure for selected power hand tools used in automobile assembly. Am Ind Hyg Assoc J 1990;51:510-8.
7. Jack RJ. The effectiveness of using two different types of anti-vibration gloves compared to bare hand condition at dampening the frequencies associated with hand-arm vibration syndrome. Work 2005;25:197-203.
8. Rothfleisch S, Sherman D. Carpal Tunnel Syndrome – Biomechanical aspects of occupational occurrence and implications regarding surgical management. Orthop Rev 1978;7:107-9.
9. Bovenzi M, Zadini A, Franzinelli A, Borgogni F. Occupational musculoskeletal disorders in the neck and upper limbs of forestry workers exposed to hand-arm vibration. Ergonomics 1991;34:547-62.
10. Boyle JC, Smith NJ, Burke FD. Vibration white finger. J Hand Surg Br 1988;13:171-6.
11. Forouharmajd F, Nassiri P. The evaluation of hand-arm vibration levels. Int J Ind Ergon 2001;21:565-70.
12. Hao KY, Ean OL, Ripin ZM. The design and development of suspended handles for reducing hand-arm vibration in petrol driven grass trimmer. Int J Ind Ergon 2010;41:257-70.
13. Cabeças JM, Milho RJ. The efforts in the forearm during the use of anti-vibration gloves in simulated work tasks. Int J Ind Ergon 2011;41:289-97.
14. Adewusia S, Rakheja S, Marcotte P. Biomechanical models of the human hand-arm to simulate distributed biodynamic responses for different postures. Int J Ind Ergon 2012;42:249-60.
15. Estimation of tool specific protection
16. Effectiveness of Anti-vibration Gloves: Field Evaluation and Laboratory Performance Assessment, in 9th International Conference on Hand-arm Vibration. Nancy, France; 5-8 June, 2001.
17. Pinto I, Stacchini N, Bovenzi M, Padden GS, Griffin MJ. Protection Effectiveness of Anti-vibration Gloves: Field Evaluation and Laboratory Performance Assessment, in 9th International Conference on Hand-arm Vibration. Nancy, France; 5-8 June, 2001.
18. Muralidhar A, Bishu RR, Hallbeck MS. The development and evaluation of an ergonomic glove. Appl Ergon 1999;30:555-63.
19. ISO, 10819. Mechanical Vibration and Shock Hand–arm Vibration, in Method for the Measurement and Evaluation of the Vibration Transmissibility of Gloves at the Palm of the Hand. Geneva, Switzerland: International Organization for Standardization; 1996.
20. Griffin MJ. Evaluating the effectiveness of gloves in reducing the hazards of hand-transmitted vibration. Occup Environ Med 1998;55:340-8.
21. ISO, 13753. Mechanical Vibration and Shock Hand-arm Vibration Method for Measuring the Vibration Transmissibility of Resilient Materials when Loaded by the Hand Arm System. Geneva, Switzerland: International Organization for Standardization; 1999.
22. Dong RG, McDowell TW, Smutz WP. The correlation between biodynamic characteristics of human hand-arm system and the isolation effectiveness of anti-vibration gloves. Int J Ind Ergon 2005a;35:205-16.
23. Dong RG, Wu JZ, Welcome DE. Recent advances in biodynamics of human hand-arm system. Ind Health 2005;43:449-71.
24. Rakheja S, Dong R, Welcome D, Schopper AW. Estimation of tool specific isolation performance of anti-vibration gloves. Int J Ind Ergon 2002;30:71-87.
25. Griffin M. Handbook of Human Vibration. London: Academic Press; 1990.
26. Wimer BM, McDowell TW, Xu XS, Welcome DE, Warren C, Dong RG. Effects of gloves on the total grip strength applied to cylindrical handles. Int J Ind Ergon 2010;40:574-83.
27. International Standards Organization, ISO 5349. In Mechanical Vibration and Shock Hand-arm Vibration – Measurement and Evaluation of Human Exposure to Hand Transmitted Vibration. Indian: International Standards Organization; 2001. p. 1-2.
28. Pinto I, Stacchini N, Bovenzi M, Padden GS, Griffin MJ. Protection Effectiveness of Anti-vibration Gloves: Field Evaluation and Laboratory Performance Assessment, in 9th International Conference on Hand-arm Vibration. Nancy, France; 5-8 June, 2001.
29. Adewusia S, Rakhejaj S, Marcotte P. Biomechanical models of the human hand-arm to simulate distributed biodynamic responses for different postures. Int J Ind Ergon 2012;42:249-60.
30. International Organization for Standardization, ISO 5349-1. In Mechanical Vibration – Measurement and Evaluation of Human Exposure to Hand-transmitted Vibration. Geneva, Switzerland: International Organization for Standardization; 2001.
31. Welcome DE, Dong RG, McDowell TW, Xu XS, Warren C. An evaluation of the proposed revision of ISO 10819. Int J Ind Ergon 2012;42:143-55.