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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

Farhad Forouharmajd, Hiva Azmoon, Jafar Akbari, Shiva Soury

Department of Occupational Health Engineering, School of Public Health, Isfahan University of Medical Sciences, Isfahan, Iran

Address for correspondence:
Eng. Shiva Soury,
Department of Occupational Health Engineering, School of Public Health, Isfahan University of Medical Sciences, Isfahan, Iran.
E-mail: Sh.soury@hlth.mui.ac.ir

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

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,

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respectively.[5] Reduction in firm grip, paresis, and locking grip are the muscular complications of regular experience of vibration.[5] 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.[6]

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.[7] Rothfleisch and Sherman were the first people who found out the relationship between CTS and vibrating tools.[8]

Many researchers have point out the outbreak of CTS among workers who have been involved in vibrating tools.[9,10] 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.[11]

To decrease the side effects of vibrations to workers' hands, various safety gloves have been designed.[12-14] This is because wearing gloves while working with manual tools causes pressure on forearm.[15]

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/s^2, the operational level 2.5 m/s^2, and permissible exposure limit 5 m/s^2. In addition, frequency range of effective vibration is 2–15 Hz.[9,10]

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.[16,17] Various gloves have been made as anti-vibration gloves.[17,18] To integrate the testing of anti-vibration gloves, ISO has established a laboratory testing in accordance to ISO-10819, 1996.[19]

A few studies have point 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.[20] 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.[21,22]

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.[23]

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.[20] 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.[24]

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.[25] Wimer *et al*. have pointed out the criteria changes in classifications of anti-vibration safety gloves.[26]

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) Vibration 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 5349:1-2 standards in the case of the operator handles the hand-held tools. ISO 5349 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 5349:1-2 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

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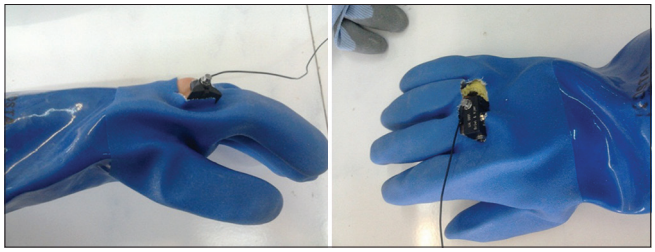

Figure 1: Placing the transducer inside the gloves

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.[27] 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.

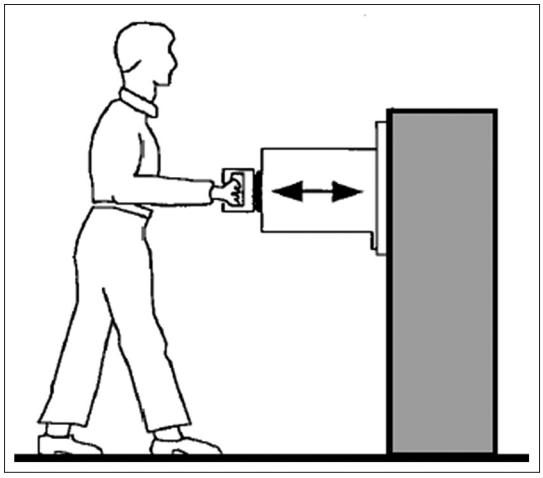

Figure 2: Schematic of the glove transmissibility measurement according to International Standard Organization-10819

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/s^2)	Y (m/s^2)	Z (m/s^2)	R.M.S (m/s^2)	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	-

RMS: Root mean square

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

Testing sample	X (m/s^2)	Y (m/s^2)	Z (m/s^2)	R.M.S (m/s^2)	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	

RMS: Root mean square

Glove of C grouped had a reduction of vibration less than two other groups. The gotten results show the most accelerated vibration was happened in axis Y for handle drill while

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Table 5: Results of measured vibration in drill working with MDF

Testing sample	X (m/s^2)	Y (m/s^2)	Percentage of deceleration
With glove			
A	0.127	0.197	93
B	1.22	1.35	50
C	2.1	2.20	19
Without glove	2.57	2.7	

MDF: Medium-density fibreboard

Table 6: Results of measured vibration in drill working with Plexiglas

Testing sample	X (m/s^2)	Y (m/s^2)	Percentage of deceleration
With glove			
A	4.16	1.52	21
B	4.36	1.96	17
C	5.01	2.33	5
Without glove	5.28	2.57	

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.[28]

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 30–50 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.

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