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Short Communication

Effect of shelf aging on vibration transmissibility of anti-vibration gloves

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Abstract: Anti-vibration gloves have been used in real workplaces to reduce vibration transmitted through hand-held power tools to the hand. Generally materials used for vibration attenuation in gloves are resilient materials composed of certain synthetic and/or composite polymers. The mechanical characteristics of the resilient materials used in anti-vibration gloves are prone to be influenced by environmental conditions such as temperature, humidity, and photo-irradiation, which cause material degradation and aging. This study focused on the influence of shelf aging on the vibration attenuation performance of air-packaged anti-vibration gloves following 2 yr of shelf aging. Effects of shelf aging on the vibration attenuation performance of anti-vibration gloves were examined according to the Japan industrial standard JIS T8114 test protocol. The findings indicate that shelf aging induces the reduction of vibration attenuation performance in air-packaged anti-vibration gloves.

Key words: Anti-vibration glove, Shelf aging, Vibration transmissibility, Degradation, JIS T8114

Introduction

Prolonged exposure to hand-arm vibration arising from the operation of hand-held power tools has been associated with the development of hand-arm vibration syndrome (HAVS)[1)]. Anti-vibration gloves are widely used as a personal protective equipment (PPE) to reduce the vibration transmitted to the hand. A variety of materials are used for a vibration attenuation material in anti-vibration gloves, most of which are resilient materials composed of certain synthetic and/or composite polymers. Thus anti-vibration gloves with different vibration attenuation materials show different vibration attenuation performance in vibration frequency contents, in useful life and so forth.

There have been concerns regarding the long-term stability of vibration isolation performance and the useful life of anti-vibration gloves. Those who occupationally use anti-vibration gloves in power tool operation empirically know that long-term use of anti-vibration gloves makes the gloves aged and degenerated resulting in reduction of vibration attenuation performance of anti-vibration gloves. However these glove users do not know how extent the vibration attenuation performance of anti-vibration gloves in the present situation is enough to reduce exposure to hand-arm vibration or when the useful life of anti-vibration gloves is reached.

The aim of this study was to investigate the influence of shelf aging on the vibration attenuation performance of anti-vibration gloves following 2 yr of shelf aging by assessment of the vibration transmissibility in accordance with the Japan industrial standard JIS T8114[2)] test protocol. This study addressed the issue of shelf stability of air-packaged anti-vibration gloves, the hypothesis being that shelf storage leads to reduced vibration attenuation performance of anti-vibration gloves.

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Methods

A single-axis hand-arm vibration test rig[3] was used to examine the glove attenuation performance. The test rig has one electro-dynamic exciter (VE-100S; IMV Corporation, Osaka, Japan) aligned to vibrate horizontally to which an experimental handle was mounted. The handle vertically oriented, is cylindrical with a size of 40 mm in diameter and of 100 mm in grip length. Also the handle consists of two parts, the handle base and the measuring cap, between which two piezoelectric single axis force sensors (9212; Kistler Inc., Winterthur, Switzerland) were sandwiched on the handle centerline to measure the grip force. The resonance frequency of the handle is beyond the range up to 1,250 Hz. An accelerometer (356A12; PCB Piezotronics Inc., New York, USA) was fixed to the center of the measuring cap to measure the vibration acceleration at the handle in the fore-aft direction. A force plate was secured on the floor to measure the reaction force acting horizontally between subjects' feet and the plate surface. This reaction force is balanced with the push force acting at the handle.

Vibration isolation performance of anti-vibration gloves was measured according to the test protocol specified in the domestic standard JIS T8114, which is identical to a previous version of the international standard ISO 10819[4]. The standard JIS T8114 requires subject posture, coupling conditions of push and grip force, vibration spectra to be excited, and the evaluating method. Each subject was asked to stand upright on the force plate and grasp the handle with the right hand and then to bend the elbow to 90 ± 10 degrees with a wrist angle between 0 and 40 degrees and the upper arm not in touch with the subject's body. In grasping the handle, each subject was asked to place the adapter in the palm. The subjects were asked to monitor the grip and feed forces through displays located in front of the subjects so that the grip and feed forces can be controlled in the range of 30 ± 5 N and 50 ± 8 N, respectively during the experiment.

Two types of random vibration spectra M and H were used as the test signal, which covers a middle frequency range of 16–400 Hz and a high frequency range of 100–1,600 Hz, respectively. For each test spectrum, the vibration transmissibility of the bare hand TR_{sb} and that of the gloved hand TR_{sg} can be given in the following equations[5]:

$$TR_{sb} = \frac{\sqrt{\Sigma_i \{w(f_i) \cdot A(f_i)_{br}\}^2}}{\sqrt{\Sigma_i \{w(f_i) \cdot A(f_i)_{hdl}\}^2}} \quad (1)$$

$$TR_{sg} = \frac{\sqrt{\Sigma_i \{w(f_i) \cdot A(f_i)_{adp}\}^2}}{\sqrt{\Sigma_i \{w(f_i) \cdot A(f_i)_{hdl}\}^2}} \quad (2)$$

Where $w(f_i)$ is a frequency weighting factor at the i th one-third octave band center frequency specified in ISO 5349-1[6], $A(f_i)$ an acceleration magnitude at the i th one-third octave band center frequency. Subscriptions denote the position where the acceleration is measured: *adp*, *br*, and *hdl* means the adapter, the bare hand, and the handle, respectively. Thus the corrected vibration transmissibility of anti-vibration gloves TR_s is calculated as follows:

$$TR_s = \frac{TR_{sg}}{TR_{sb}} \quad (3)$$

TR_s values calculated twice for each subject were averaged to obtain the mean vibration transmissibility *TR*. The *TR* values required for anti-vibration glove in JIS T8114 are less than 1.0 for spectrum M and less than 0.6 for spectrum H.

According to the test requirement specified in JIS T8114, three healthy male subjects were participated in this study. The size of the subjects' hands is stipulated as between size 7 to 9 as specified in the European standard EN420[7] that regulates the general requirements of personal protective gloves. None of the subjects had been exposed to high levels or long periods of hand-arm vibration occupationally or in their leisure time activities. All the subjects underwent an explanation of the test procedure and gave their written informed consent to participate in this study. The experiment was approved by the Research Ethics Committee of the National Institute of Occupational Safety and Health, Japan.

Three types of anti-vibration gloves, nominally denoted by Gloves 1, 2, and 3, were prepared for samples to be measured in this study. These anti-vibration gloves use different types of vibration attenuation material. The main characteristics of these gloves were summarized in Table 1. These glove samples consists of the three types of anti-vibration gloves that have been available in the Japanese market and have been satisfied with the requirement of anti-vibration glove specified in JIS T8114 (2007). Shelf aging was performed for these gloves under normal ambient conditions in an air-conditioned laboratory for periods of 1 and 2 yr. The air conditioner was automatically powered on at 8:30 am and was powered off at 7:00 pm in summer and winter.

Table 1. Anti-vibration glove samples prepared in this study

		Glove 1	Glove 2	Glove 3
Vibration attenuation material		Gel foam	Chloroprene rubber	Synthetic rubber with bamboo charcoal fibers embedded
Outer surface material		Nitrile rubber	Nitrile rubber	Cow skin
JIS T 8114 test requirement	TR_M	OK	OK	OK
	TR_H	OK*	OK	OK

*According to the manufacturer's statement, Glove1 is satisfied with the vibration transmissibility requirement specified in JIS T8114. However the measurement result in this study did not support the statement.

Table 2. Change in the vibration transmissibility (TR) values of three anti-vibration glove samples up to 2 yr of shelf aging in air

		TR_M			TR_H		
		Control	1 yr of shelf aging	2 yr of shelf aging	Control	1 yr of shelf aging	2 yr of shelf aging
Glove1	Av.	0.916	1.087*	1.034*	0.744	0.773*	0.816*
	SD	0.023	0.0044	0.015	0.031	0.013	0.0095
Glove 2	Av.	0.850	0.890*	0.892*	0.504	0.531*	0.585*
	SD	0.073	0.0030	0.024	0.047	0.016	0.014
Glove 3	Av.	0.867	0.863	0.885*	0.460	0.475*	0.545*
	SD	0.0021	0.059	0.034	0.0035	0.035	0.050

*$p<0.05$

TR values in gray cells shows that the TR values were not satisfied with the vibration transmissibility requirements specified in JIS T8114.

Table 3. Percentage reduction in the vibration transmissibility (TR) values of three anti-vibration glove samples up to 2 yr of shelf aging in air

	Percentage change in TR values (%)			
	TR_M		TR_H	
	1 yr of shelf aging	2 yr of shelf aging	1 yr of helf aging	2 yr of helf aging
Glove 1	18.8	13.0	3.87	9.63
Glove 2	4.74	4.99	5.28	16.1
Glove 3	−0.40	2.15	3.44	18.6

Percentage change of TR values in gray cells shows that the TR values have fallen to more than 10% below the initial TR values.

Results

Table 2 shows change in the vibration transmissibility (*TR*) values of three anti-vibration glove samples up to 2 yr of shelf aging in air. In the control condition, all the glove samples showed the *TR* values less than 1.0 at M spectrum, being satisfied with the vibration transmissibility requirement at M spectrum specified in JIS T8114. In contrast, only Glove 1 sample showed the *TR* value more than 0.6 at H spectrum, which was not satisfied with the vibration transmissibility requirement at H spectrum specified in JIS T8114.

After 1 yr of shelf aging, Glove 1 sample showed the *TR* value more than 1.0 at M spectrum, which was not satisfied with the vibration transmissibility requirement at M spectrum. The *TR* values of Gloves 2 and 3 at M spectrum were less than 1.0; the TR value of Glove 2 increasing significantly from 0.850 to 0.890 and that of Glove 3 decreasing a bit from 0.867 to 0.863 (not significant). In contrast all the glove samples showed increase in the *TR* values at H spectrum.

After 2 yr of shelf aging, Glove 1 sample showed the *TR* value more than 1.0 at M spectrum. The *TR* value of Glove 1 reduced a bit from 1.087 after 1 yr of shelf aging to1.034 (no significant). The *TR* value of Glove 2 did not change during the second yr of shelf aging. The *TR* value of Glove 3 significantly increased from 0.863 after 1 yr of shelf aging to 0.885. In contrast all the glove samples showed marked increases in the *TR* values during the second yr of shelf aging.

Table 3 shows percentage reduction in the vibration transmissibility (*TR*) values of three anti-vibration glove samples up to 2 yr of shelf aging in air. After 1 yr of shelf aging, Glove 1 sample showed the *TR* value reduced by more than 10% below the initial *TR* value at spectrum M. The percentage reductions in the TR values of Glove samples 2 and 3 up to 2 yr of shelf aging were less than 5.0% at spectrum M. In contrast at spectrum H the percentage reductions in the TR values of Glove samples 2 and 3 steeply increased to more than 15.0% during the second yr of shelf aging.

Discussion

The major findings obtained in this study were that shelf aging up to 2 yr reduced the vibration attenuation performance of air packaged anti-vibration gloves. Also two types of glove samples (Gloves 2 and 3) were satisfied with the JIS requirement event after 2 yr of shelf aging. In contrast, Glove 1 was not satisfied with the JIS requirement after 1 yr of shelf aging. Aging effect on the TR values depends on the vibration attenuation materials used in gloves. Only Glove 1 sample showed steep degradation of the TR value at spectrum M after 1 yr of shelf aging. In contrast steep degradation of the TR value appeared at spectrum H after 2 yr of shelf aging in Gloves 2 and 3. One reason why Glove 1 began to degrade earlier than the other two glove samples did is that the vibration attenuation material used in Glove 1 consists of multi layers of viscoelastic gel foamed materials[8, 9], whose mechanical and chemical characteristics are more sensitive to the ambient temperature and humidity than those of rubber materials used in Gloves 2 and 3. Another reason to be considered is related to the period of shelf aging. Among the glove samples used in this study Glove 1 only has been manufactured in a foreign country. It takes long time for gloves shipped from oversea to be delivered to domestic end users, which suggest that Glove 1 has been shelf-aged longer than Gloves 2 and 3.

The vibration transmissibility (TR) values, measured at the time when the anti-vibration glove samples were taken delivery of, were defined as the control TR values in this study. However shelf aging starts just after anti-vibration gloves are manufactured. At this point this study underestimates the period of shelf aging, which does not include a period when the gloves are kept in stock in manufacturers before shipment and in retailers after shipment. The reduction of vibration attenuation performance of anti-vibration gloves due to shelf aging is associated with oxidative degradation of vibration attenuation material used in the gloves. Alternatively vacuum packaging might be effective in minimizing shelf aging to maintain the initial vibration attenuation performance until the gloves are delivered to end users.

According to the EU standard EN 420, the useful life of gloves that is reached when the TR values have increased by 20% beyond the initial TR values has to be stated with the condition of use. However the author insists that the useful life of 20% performance loss should not be inevitably applied to anti-vibration gloves. The useful life of anti-vibration gloves has to be appropriately determined in relation to the initial TR values of the gloves and be announced to end users with helpful information about the condition of use of anti-vibration gloves in real workplaces. For example an anti-vibration glove with the initial TR values less than 0.83 and 0.50 for spectrum M and H, respectively, can afford to be satisfied with the TR value requirements specified in JIS T8114 even after 20% of degradation in the glove vibration transmissibility. According to the initial TR values at spectrum H obtained in this study, the calculated TR value of Glove 3 at spectrum H after 20% performance loss is 0.552, which is still satisfied with the JIS requirement. In contrast, the calculated TR values of Gloves 1 and 2 at spectrum H after 20% performance loss are 0.893 and 0.606, respectively, which are not satisfied with the JIS requirement. If the EN 420 statement of useful life is applied to all anti-vibration gloves, Glove 3 cannot be used after 20% vibration attenuation performance loss in spite of the TR values at spectrum H less than 0.6.

This study is the first step of a research that focused on the change in the vibration attenuation performance of anti-vibration gloves and its useful life. This study examined the effect of shelf aging on degradation of vibration attenuation performance of anti-vibration gloves. The mechanical and chemical characteristics of the resilient materials used in anti-vibration gloves are prone to be influenced by environmental conditions such as temperature, humidity, and photo-irradiation, which result in oxidative degradation during shelf aging. Also the vibration attenuation performance of anti-vibration gloves disperses individually and depends on manufacturing conditions. Moreover in usage of anti-vibration gloves in workplaces, the vibration attenuation performance is affected by many factors: aging, the ambient temperature and humidity, creeping, high contact pressure and so on. Future works are required to examine the effect of other factors mentioned above on the vibration attenuation performance and useful life of anti-vibration gloves.

Conflict of Interest Statement

The author has no conflict of interest.

References

1) Bovenzi M (1998) Exposure-response relationship in the hand-arm vibration syndrome: an overview of current epidemiology research. Int Arch Occup Environ Health **71**, 509–19.
2) Japan Standards Association (2007) JIS T8114. Vibration isolation gloves (in Japanese).
3) Shibata N, Hosoya N, Maeda S (2008) Establishment of one-axis vibration test system for measurement of biodynamic response of human hand-arm system. Ind Health **46**, 629–34.
4) International Organization for Standardization (1996) ISO 10819. Mechanical vibration and shock – hand-arm vibration method for the measurement and evaluation of the vibration transmissibility of gloves at the palm of the hand.
5) Shibata N, Maeda S (2008) Vibration-isolating performance of cotton work gloves based on newly issued JIS T8114. Ind Health **46**, 477–83.
6) International Organization for Standardization (2001) ISO 5349-1. Mechanical vibration and shock – Measurement and evaluation of human exposure to hand-transmitted vibration – Part 1: General requirements.
7) European Committee for Standardization (2003) EN 420. Protective gloves. – General requirements and test methods.
8) Chase DD, Talonn AD (1997) Antivibration glove. United States Patent No. 5,632,045.
9) Chase DD, Talonn AD (1997) Vibration attenuating member and method of making same. United States Patent No. 5,673,437.