

THE COMPARATIVE STUDY OF HAND ARM VIBRATION USING ANTI-VIBRATION GLOVES AND INSULATED HANDLES AMONG STONE GRINDING WORKERS

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Abstract

Hand - arm vibration among grinding workers with bare hands, wearing three types of gloves (lycra cotton with viscoelastic, polyurethane with viscoelastic and upholstery leather) and using insulated handle with the same three glove materials were compared in each octave band center frequencies (16, 31.5, 63, 125, 250, 500, 1000 and 2000 Hz) and vibration total value for all three axes (Xh, Yh and Zh). The study revealed that the lycra cotton and polyurethane materials in the form of gloves and insulated handle type could reduce vibration at frequencies of 16, 125, 250 and 500 Hz. The upholstery gloves could reduce vibration at the frequency of 16 Hz, but the upholstery insulated handle could reduce at the frequencies of 16, 125, 250, 500 and 1,000 Hz. Regarding to maximum vibration reduction, the lycra cotton gloves could reduce vibration total value compared to bare hands for 39.96%, while upholstery leather insulated handle reduced for 38.84%. The lycra cotton and polyurethane material were not significantly different, but both of them were significantly different compared to upholstery leather at frequencies of 125, 250 and 500 Hz. The insulated handle type could reduce vibration more than glove type at frequencies of 63, 125, 250 and 500 Hz. The workers were more satisfied with insulated handle type than gloves type for lycra cotton and upholstery leather type. The result can be used as guidance to apply damping materials as insulated handle to reduce hand arm vibration.

Key words : Vibration, Anti-vibration gloves, insulated handle, grinding workers

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การเปรียบเทียบค่าความสั่นสะเทือนที่มือ เมื่อใช้ถุงมือและวัสดุหุ้มด้ามจับของคณงานเจียรหิน

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บทคัดย่อ

เปรียบเทียบความสั่นสะเทือนที่เกิดกับคณงานเจียรหินเมื่อใช้มือเปล่ากับการสวมถุงมือสามชนิด คือ ถุงมือไลคราคอทตอนที่มีแผ่นช่วยให้ยืดหยุ่นที่บริเวณฝ่ามือ ถุงมือโพลียูรีเทนที่มีแผ่นช่วยให้ยืดหยุ่นที่บริเวณฝ่ามือ และถุงมือหนังเฟอร์นิเจอร์ และเมื่อนำวัสดุที่ใช้ทำถุงมือทั้งสามชนิดมาหุ้มที่ด้ามจับของเครื่องมือ โดยวัดค่าความสั่นสะเทือนแยกแต่ละความถี่ที่ 16, 31.5, 63, 125, 250, 500, 1000 และ 2000 รอบต่อวินาทีทั้ง 3 แกน คือแกน X, Y และ Z พบว่าถุงมือและวัสดุหุ้มด้ามจับชนิดไลคราคอทตอนและโพลียูรีเทน สามารถลดความสั่นสะเทือนที่ความถี่ 16, 125, 250, 500 รอบต่อวินาที สำหรับถุงมือหนังเฟอร์นิเจอร์ลดเฉพาะที่ความถี่ 16 รอบต่อวินาที แต่วัสดุหุ้มด้ามจับหนังเฟอร์นิเจอร์ลดได้ที่ 16, 125, 250, 500, 1000 รอบต่อวินาที ทั้งนี้ถุงมือที่มีประสิทธิภาพดีที่สุดในการลดความสั่นสะเทือนเมื่อเทียบกับมือเปล่า ได้แก่ ถุงมือไลคราคอทตอน ลดความสั่นสะเทือนได้ร้อยละ 39.96 สำหรับวัสดุหุ้มด้ามจับคือหนังเฟอร์นิเจอร์ลดค่าความสั่นสะเทือนได้ร้อยละ 38.84 วัสดุชนิดไลคราคอทตอน และ โพลียูรีเทนไม่มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ ในการลดความสั่นสะเทือนในทุกความถี่ แต่ทั้งสองชนิดมีความแตกต่างจากวัสดุหนังเฟอร์นิเจอร์ที่ความถี่ 125, 250, 500 รอบต่อวินาที วัสดุหุ้มด้ามจับมีประสิทธิภาพดีกว่าถุงมือที่ความถี่ 63, 125, 250 และ 500 รอบต่อวินาที การเปรียบเทียบความรู้สึกของคณงาน พบว่าคณงานมีความพึงพอใจวัสดุหุ้มด้ามจับมากกว่าถุงมือ ทั้งชนิดไลคราคอทตอนและหนังเฟอร์นิเจอร์ การนำวัสดุลดแรงสั่นสะเทือนมาประยุกต์ใช้ในรูปแบบของวัสดุหุ้มด้ามจับสามารถลดค่าความสั่นสะเทือนที่มือได้

คำสำคัญ : ความสั่นสะเทือน, ถุงมือลดการสั่นสะเทือน, วัสดุหุ้มด้ามจับ, คณงานเจียรหิน

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Introduction

People who work regularly with powered hand-held tools expose to vibration through their hands and arms. They are at risk of developing permanent disability diseases of the hands and arms referred as Hand Arm Vibration Syndrome, HAVS. HAVS is a condition, which can affect circulation, sensory and motor nerves and cause musculo-skeletal problem. The ability to work and pursue leisure activities can be impaired; moreover, extreme cases are painful and could lead to white finger disease¹.

Stone mortar factories are located in Chonburi province. In the process of manufacturing stone mortars, vibration from grinder is a major risk for workers. Bovenzi² examined cross-sectional HAVS in 145 quarry drillers and 425 stone carvers exposed to hand-transmitted vibration, along with a referent group of 258 polishers and machine operators who did not exposed to hand-transmitted vibration. Prevalence of HAVS were 30.2% in the exposed and 4.3% in the unexposed groups (OR, 9.33; 95% CL, 4.9 –17.8).

The strategies either to improve or to prevent hazard from vibration exposure are the use of lightweight hand tools, equipment with built in damping materials, equipment allowing fingers to fit on the tool's entire handle and tools with soft coatings on handles to reduce stress. The work schedule should also incorporate rest periods into shifts, alternate between short periods of stressful and less stressful task. Workers should wear anti-vibration gloves because these gloves are able to reduce vibration through their hands. However, the anti-vibration gloves are very expensive in Thailand. Wearing gloves may reduce hand dexterity result in reduced work performance. The gloves may not fit to their hands. Some workers cannot afford to have their own gloves and they have to share gloves with others. For these reasons alternate way to reduce vibration through their hands is to use gloves material wrapped or insulated at the handle of the tool instead.

The purpose of this study is to compare hand-arm vibration between barehanded vibrations, gloves-wearing vibration and vibrations from gloved material insulated at the handle of the grinder.

Materials and Methods

Instrumentation and equipments

The instrument used was listed as follows:

1. Hand-arm vibration meter (Model GA 2001, Castle Co., Ltd., England)

2. Angel grinder (12,000 rpm from Makita Co., Ltd.)
3. Hand dynamometer (Model 78010, Lafayette Co., Ltd., USA)
4. Three types of gloves were tested; two types of anti-vibration gloves and one type of upholstery leather gloves. The first type of gloves made by lycra cotton having visco-elastic polymer supported at the palm area (Steel grip model CT 30-01, USA). The second gloves with polyurethane nitrile coated having visco-elastic polyurethane polymer supported at the palm area (Model 2833 AV, Vibrex Co., Ltd., USA) and the third gloves, upholstery leather gloves (furniture gloves, 1.22 mm thickness, Thailand).
5. Insulated handle with gloves materials, three types of gloves material were cut at the palm area and sewn with elastic to wrap around the grinder handles.

Test procedures

The test procedure comprised several steps as follows:

Subject preparation

A subject sat on the floor and held a grinder with both hands. He cut a block of stone by a grinder for 1 min each time. He practiced cutting a block of stone several times using hand dynamometer to control the same grip force. He had to practice until the vibration total values for five consecutive experiments not exceed mean \pm 2SD.

Gloves and insulated handle preparation

Gloves were perforated at dorsal right hand for acceleration transducer to protrude from that hole. Concerning insulated handle preparation, gloves were cut at the palm area and sewn with elastic to fit around the handle.

Subjective feeling of workers

Workers have to record their satisfaction feeling onto a simple rating scale. The scores were assigned as follows: 5 = extremely, 4 = very much, 3 = moderate, 2 = slightly and 1 = very slightly. The subjective feeling of workers is presented in terms of handy-clever, well-fitting, feeling vibration in hands, manual dexterity, irritation and satisfaction for use.

Test protocols

The accelerometer transducer attached with tri-axial mounting block was placed on the fixed position of dorsal right hand of workers. The subject ground the block of stone following the procedure trained with bare hand. Hand arm vibration in each octave

band center frequency at 16, 31.5, 63, 125, 250, 500, 1,000 and 2,000 Hz (root mean square, rms-m/s^2) and vibration total value (frequency weighting acceleration, rms-m/s^2) were measured for all three axes (X-Y-Z). Each experiment took one min for each frequency and axes. The experiment was carried out for three replications and the subject was rest for 10 min between each test.

The subject repeated the experiment by wearing three types of gloves and three insulated handle materials, namely lycra cotton, polyurethane and upholstery leather. After each experiment, the subject was interviewed about subjective feeling while grinding.

Data analysis

The hand-arm vibration of twelve workers was averaged. The mean and standard deviation of hand-arm vibration were used for comparison. The comparison of hand-arm vibration for bare hand and vibration support (glove and insulated handle) and comparison of hand arm vibration in each independent factor (three types of materials, type of vibration support and axes) and interaction effect among these factors at each octave band center frequency from 16 to 2,000 Hz and vibration total value were determined by analysis of variance (Randomize block design) and followed by multiple comparisons (LSD: Least significant different). The comparison of subjective feeling when using different vibration supports was determined by Wilcoxon Signed rank test at 95% confident limit.

Results

Characteristics of subjects

Twelve subjects without any sign and symptoms of hand arm vibration were included in this study. Their ages ranged from 27 to 37 years with an average of 31.3 years.

Comparison of hand arm vibration between bare hand and vibration support (gloves and insulated handle)

Grinding with bare hand gave highest vibration of 7.15 m/s^2 at frequency of 125 Hz in Xh direction. Although workers wearing different types of gloves and using insulated

handle with glove materials, the vibration was considerably high at frequency of 63-250 Hz in all three axes. The maximum vibration was at 125 Hz in Xh direction in all types of vibration supports while low level of vibration was at frequency of 16 and 500 Hz in all three axes.

When workers used lycra cotton vibration supports compared to bare hands, the gloves and insulated handle could significantly reduce vibrations at 16 Hz frequency for Yh and Zh directions, 125 Hz for Xh direction, 250 Hz for Xh and Zh directions at 95% confident limit. With regard to 500 Hz frequency, gloves significantly reduced vibration for Xh direction but insulated handle type could significantly reduce for all three axes.

Considering polyurethane vibration supports compared to bare hands, the gloves and insulated handle could significantly reduce vibration at 125 Hz frequency for Xh direction, 250 Hz frequency for Xh direction, 500 Hz frequency for all three axes at 95% confident limit.

With regards to upholstery vibration supports compared to bare hands, the gloves could significantly reduce hand-arm vibration only at 16 Hz frequency for Yh and Zh axes at 95% confident limit. When using upholstery insulated handle, it significantly reduced vibration at frequencies of 16Hz for Yh and Zh directions, 125 and 250 Hz for Xh direction and 500 Hz for all three axes.

Comparison of vibration total value between bare hand and vibration support (gloves and insulated handle)

The vibration total value (frequency weighting acceleration, rms, m/s^2) for bare hand was 1.1900, 1.2500 and 1.2200 m/s^2 in Xh, Yh and Zh directions, respectively. The vibration reduction by different types of gloves and insulated handle materials is shown in Table 1. Considering three types of gloves, the gloves having maximum efficiency in reduction of vibration total value compared to bare hands was lycra cotton gloves. Polyurethane gloves could reduce vibration total value only in Xh and Yh directions and upholstery gloves could reduce in Yh and Zh directions.

All insulated handles with gloves materials, compared to bare hands, could reduce vibration total value for all three axes, except that lycra cotton material could reduce only in Yh and Zh directions. The insulated handles having greatest efficiency in reduction of the vibration total value for all three axes was upholstery leather materials.

Table 1 Comparison of hand arm vibration reduction of grinding workers between using gloves and insulated handles compared to bare hands

Anti-vibration material	Axes	Bare hand	Gloves		Insulated handle	
		Vibration (m/s ²)	Vibration (m/s ²)	Vibration reduction (%)	Vibration (m/s ²)	Vibration reduction (%)
Lycra cotton	Xh	1.1900	0.7850	34.04	1.2325	- 3.45
	Yh	1.2500	0.7505	39.96	1.2000	4.00
	Zh	1.2200	0.8850	27.45	0.8575	29.71
Polyurethane	Xh	1.1900	1.0200	14.28	0.8825	25.84
	Yh	1.2500	0.8825	29.40	0.7670	38.64
	Zh	1.2200	1.3325	-8.44	0.9675	20.69
Upholstery leather	Xh	1.1900	1.2275	-3.05	0.7600	36.13
	Yh	1.2500	0.8575	31.40	0.7645	38.84
	Zh	1.2200	0.7975	34.63	0.8600	29.50

Comparison of hand-arm vibration among types of materials, vibration supports and axes

The significant different hand-arm vibration in each independent factor among three types of materials (lycra cotton, polyurethane and upholstery leather), two types of vibration supports (Gloves and insulated handle) and three axes (X, Y and Z directions) in each octave band frequency were tested by ANOVA. The result showed significant different hand-arm vibration at 95% confident for three types of materials, two types of vibration supports and three axes at frequencies of 125, 250 and 500 Hz but at frequency of 63 Hz, two types of vibration supports and three axes showed significant difference. The 2 and 3-way interactions did not show significant difference (no interactions effect) among types of materials, vibration supports and axes for all frequencies.

Regarding to multiple comparisons, the results showed that lycra cotton and polyurethane materials were not significantly different for all frequencies. Both of them were significantly different compared to upholstery leather material at frequencies of 125, 250 and 500 Hz. The vibration between Xh and Yh, Xh and Zh was significant different at frequencies of 125, 250 and 500 Hz, but the vibration between Yh and Zh was not. The insulated handle type could reduce vibration more than glove type at the frequencies of 63, 125, 250 and 500 Hz.

Comparison of workers subjective feeling scores between wearing gloves and using insulated handle

The subjective feeling scores when workers wearing gloves and using insulated handle is shown in table 2. The subjective feeling scores of workers while using insulated handle type were greater than those using glove types for all materials. The results also showed that subjective feeling scores of workers using gloves and insulated handle were significantly different for lycra cotton and upholstery leather at 95% confident limit, but polyurethane was not.

Table 2 Comparison of average subjective feeling scores when workers wearing gloves and using insulated handle

Type of material	Gloves		Insulated handle		P-value
	Mean	SD	Mean	SD	
Lycra cotton with viscoelectric	3.04	0.93	3.58	1.25	<0.001*
Polyurethane with viscoelectric	3.28	0.89	3.69	1.37	0.346
Upholstery leather	3.11	1.08	3.67	1.25	<0.001*

Discussion

The measurement of vibration should be performed in accordance with the procedure specified by ISO 5349-1986³ or ANSI 3.34-1986⁴. The measurement should be presented in octave band center frequencies from 6.3 – 1,250 Hz. The limitation of this study was that the specification of vibration instrument in this study has a filter set for octave band frequency at 16 - 8,000 Hz.

The hand-arm vibration when workers grinding with bare hands or using vibration supports, was considerably high at frequencies of 63 – 250 Hz because the frequency of grinder is 12,000 rpm (200 Hz). That is why the maximum vibration when workers grinding in this study was at 125 Hz frequency in Xh direction. This might be due to the nature of grinding work having a dominant axes for Xh direction corresponding to axis perpendicular to the palm of hand.

The maximum vibration found when a worker grinding with bare hand was 7.1542 m/s² for 125 Hz frequency in Xh direction. The American National Standard Institute (ANSI) 3.34-1986⁴ recommends the acceleration shall not exceed 20 m/s² at 125 Hz for 4 hours and less than 8 hours of daily exposure. The maximum hand arm vibration of

grinding workers with bare hand, all types of gloves and insulated handles was considerably lower than the standard recommended by ANSI 3.34-1986⁴. The American Conference of Governmental Industrial Hygienist⁵ has published TLVs for exposure of hand arm vibration in either Xh, Yh or Zh directions, the value of the dominant axes, frequency-weighted acceleration shall not exceed 4 m/s^2 for 4 hours and less than 8 hours daily exposure. The maximum vibration total value of grinding workers for bare hand, all type of gloves and insulated handle (Table 1) was also significantly lower than the standard recommended by ACGIH⁵.

The significant reduction of hand-arm vibration when using vibration supports compared to bare hands at frequencies of 16, 125, 250 and 500 Hz might be due in part to viscoelastic material used as damping material on gloves and insulated handles. The upholstery gloves without viscoelastic material reduced vibration only at 16 Hz frequency, but the upholstery insulated handle could reduce at frequencies of 16, 125, 250, 500 and 1,000 Hz. This is because insulated handle have a good handy clever and well fitting which can help to reduce vibration.

Type of vibration support as gloves and insulated handle was significantly different at 95% confident limit at frequencies of 63, 125, 250 and 500 Hz. It was found that average hand-arm vibration when using gloves type greater than insulated type. This might be due to the vibration damping material, viscoelastic was located at the palm area of lycra cotton and polyurethane gloves. It supported only at the palm area but not at fingers and a thumb area.

The subjective feeling scores of workers while using insulated handle type were greater than those using glove types in all materials. It is because when workers use gloves, they have sweat in their hands from hot humidity, which would reduce dexterity of hand.

In conclusion, insulated handle type could reduce vibration and workers satisfy with insulated handle more than gloves type. The result can be used as guidance to apply damping material as insulated handle to reduce hand-arm vibration.

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