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Investigation on Hand Arm Vibration exposures of operators in construction industry

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Abstract: Hand arm vibration syndrome, also known as the white fingere effect, has become one of the most significant diseases seen in construction industry. A long term exposure of arms to high vibration levels causes to the vibration syndromes. Investigation of exposure levels associated with the hand arm vibration is necessary to prevent the white finger syndromes.

Objective of this research is to evaluate the vibration exposure levels which transfer through the human arm to the human body while engaging in civil engineering construction activities. Ten operators in civil engineering construction sites were selected as a study group. A questionnaire survey was conducted with the operators to identify whether they are diagnosed with hand arm vibration syndromes, their experiences and age. Vibration exposure levels transferred through the arms to the human body were measured using a vibration meter (SV 106) with a mounting tri axial accelerometer. It was found that operators were not aware about the vibration related syndromes, although they were exposed to the excessive vibration. Measured exposure levels were evaluated based on the standards.

Keywords: Hand arm vibration White figure effects Exposure levels Tri axial vibration meter

1. Introduction

People always used to build, create, and explore something new which is helpful to have a much easier way and find out the most suitable solution for particular problems. Most of these activities have involved exposure to vibration, with the source comes from power tools, industrial machines, trains, automobiles, etc. In the construction industry, most of major activities such as drilling, breaking, compacting, which are done by using the vibration. Also the apparatus used to build, create, and explore have used more energy, as a result, increased quantities of energy have been dissipated in the form of vibration, some of which has been transmitted to people through human body part that directly touched to the vibrator source. This is caused to some health hazards in the human body (Mansfield, [1]).

Human body vibration can be divided into two main categories: Hand arm vibration (HAV) and the Whole body vibration (WBV). Hand arm vibration is transmitted through the handles or surface of the work piece, via palms, and the fingers into the hands and arms while workers engage with the hand held or manually guided machines. Examples of machines that may cause hand-arm vibration are demolition hammers, drills, hammer drills, angle grinders, chain saws and hand-held circular saws.

Workers, who frequently exposed to this HAV, may suffer from hand arm vibration syndrome (HAVS). The period of time between exposure to HAV and development of symptoms is varied, ranging from months to years (Griffin, [2]). Workers who are exposed to hand arm vibration often suffered with white finger effect, which causes neurological and motor disorders in the hands and fingers (Nakamura et al, [3]). Risk of HAV caused by the use of such equipment is preventable, but once the damage is done it is permanent (Anon, [4]).

It has been reported that there are different corollary about the syndrome, but patients who are having HAVS are most commonly described as having neurological, vascular and musculoskeletal symptoms and signs such as disturbed sensation (numbness, tingling), cold intolerance, episodic finger blanching, pain and weakness in hands and arms (Buhaug, et al. [5]).
Loss of strength in the hand, in the cold and wet, the tips of fingers going white then red and being painful on recovery are the early signs of the white

finger effect. Symptoms of nerve damage include pain, tingling and reduced dexterity, (initially symptoms are intermittent, but it may become heavy, if the worker be exposed to continuous vibration), fingers turn bright red. When rewarming, musculoskeletal complications include reduced grip strength, osteoporosis of the wrist or elbow, and bone cysts.

The orthogonal which belongs to hand arm vibration measurements are based on the head of the third metacarpal. The x-axis is through the palm, the y-axis is across the palm towards the thumb, and the z-axis extends towards the fingers parallel with the back of the hand (Figure 1). Above definition of coordinate system has an advantage that is no confusion regarding axes for palm or power grips or any orientation of the hand (ISO 2631-1 [6])

According to the previous study (Maryanne, [7]),two quantitative analysis parameters, which are Root mean square value (RMS) and Vibration dose value (VDV), were suggested to evaluate the hand arm vibration exposure levels. Furthermore, comparing natural frequency of the human body (human resonant frequency) and the magnitude of the vibration in frequency range is necessary to get the awareness about how significances the vibration exposure levels which transfer to the human body.

Objective of this study is to investigate Hand arm vibration exposure levels of operators in construction industry.

2. Methodology

A questionnaire survey and vibration exposure measurements were conducted simultaneously. Chosen construction sites were visited with the permission of responsible persons. Suitable safety procedures were followed

2.1. Study group

Ten hand arm vibration related machine male operators were selected as a study group. These ten operators consist with two jack hammer operators, four plate compactor operators and four drilling machine operators. Operators, who participated for this study, were within the age range of 20 -40 years.

2.2. Questionnaire survey

Questionnaire survey was conducted for each operator to investigate their health levels and current situation of their profession. In addition, their work experience and age were recorded.

2.3. Instrument

A vibration meter, SVANTEK 106, was used as an instrument to measure the exposure levels of hand arm vibration which transfer to the human body. Vibration meter was calibrated according to ISO 2631-1 and ISO 5349-2 to measure both frequency weighted HAV exposure levels in three orthogonal directions: x axis, y axis and z axis (Figure 1).

2.4. Measuring exposure levels.

Measuring parameters such as start delay time, measurement duration, weighting factors for each axis was set into the vibration meter (SVANTEK 106) before commencement of recording exposure levels. After selecting appropriate operator to measure the exposure levels of the HAV via the vibration meter, the hand sensor was mounted (Figure 2(a)) following defined coordinate system (Figure 1).Operator was instructed to work usually assigned task and vibration exposures were measured (Figure 2(b)). The coordinate system which was indicated on the instrument should exactly follow the above defined coordinate system (Figure 1).

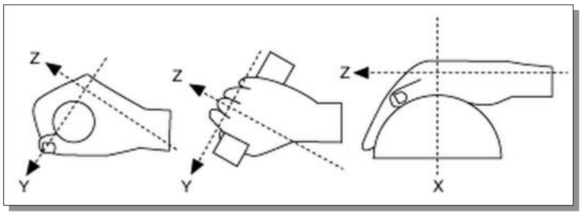

Figure 1: Defined Coordinate system for Hand arm vibration measurements

Figure 2: Measuring procedure of hand arm vibration exposures
(a) Sensor was placed on the hand
(b) Measuring the exposure levels

One operator from each category of equipment was instructed to wear a pair of gloves and let him to work, while the vibration exposures which transfer to his arm with the gloves were measured.

2.5 Analysis

Frequency-weighted hand-transmitted vibration (a_{hw}) for each direction was obtained from SV 106 analyser. Human exposure to hand arm vibration was evaluated by referring the guidelines for measuring and evaluating human exposure (ISO 5349-1(2001) and ISO 5349-2 (2001)). According to the ISO 5349-1 standard recommendations, the most important parameter used to describe the magnitude of the vibrations transmitted to the operator's hands is the root-mean square (rms) frequency-weighted acceleration, expressed in m/s^{-2}. The vibration total value, a_{hv}, or Frequency-weighted acceleration total value was determined as defined in Equation (1)(ISO 5349-1,2 [7]).

$$ah_v = \sqrt{ahw_x^{\ 2} + ahw_y^{\ 2} + ahw_z^{\ 2}} \text{ ---------- } (1)$$

Where ahw_x , ahw_y and ahw_z are frequency-weighted acceleration values for the single axis

Vibration exposure not only depends on the magnitude of the vibration total value, also depends on the duration of the exposure. Total time for which the hands are subjected to vibration during working day (Daily exposure duration) has been expressed in terms of Frequency-weighted acceleration total value as shown in Equation (2) (ISO 5349-1,2 [7]).

$$A(8) = ah_v \sqrt{\frac{T}{T_o}} \text{ ------------ } (2)$$

Where T is the total daily duration of the exposure in seconds, and T_o is the reference duration of 8 hours (28800 s)

HAV daily exposure action value (EAV) of 2.5 ms^{-2} , and HAV daily exposure limit value (EAV) of 5.0 ms^{-2} were considered.

3. Results and Discussion

3.1 Questionnaire survey

Table 1: Age, work experience, exposure duration and health issue of ten operators

Equipment	Operator	Age (year)	Work Experience (years)	Exposure duration (hours)	Health Issue
Jack Hammer	OP 1	45	15	8	Pain and weakness in hands
	OP 2	42	23	8	Numbness
Drilling Machine	OP 3	31	4	6	No
	OP 4	29	6	5	No
	OP 5	35	8	6	No
	OP 6	48	20	6	Pain and weakness in hands
Plate Compactor	OP 7	34	9	8	Normal daily tidiness
	OP 8	42	13	7	tingling
	OP 9	26	2	8	No
	OP 10	40	12	8	Pain and weakness in hands

It seems that operators' age and the working experience affect on the operator's health issues (Table 1). Jack hammer operator, OP1,, who has a 15 years of work experience is affected by the pain and weakness in hands. Jack hammer operator, OP2, who has 23 years of experience, has numbness. Among the drilling machine operators, OP6 has considerable work experience (i.e., 20 years), felt pain and weakness in hands. In addition, plate compacter operator, OP 7, OP 8 and OP 10, felt uncomfortable while operating drilling machine.

3.2. Vibration exposure levels

Frequency-weighted-hand transmitted vibration (a_{hw}) for each direction was obtained from SV 106 analyser. Figure 3 shows frequency-weighted hand-transmitted vibration (a_{hw}) for x, y and z directions of the drilling machine operator, OP3.

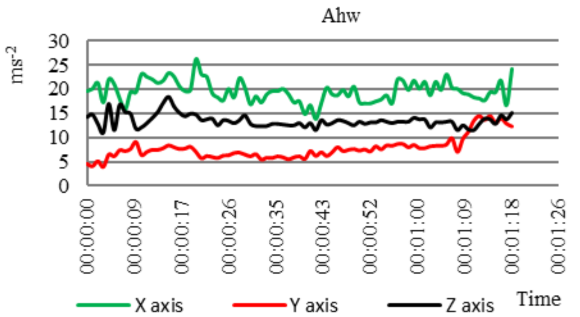

Figure 3: a_w variation of exposure levels of a drilling machine operator, OP3

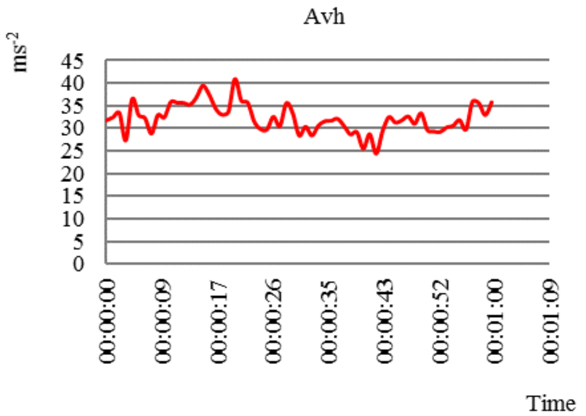

Figure 0: Frequency-weighted acceleration total value for a drilling machine operator, OP3

Frequency-weighted acceleration total value was obtained according to Equation (1) and is shown in Figure 4.

Table 2 summarises Frequency-weighted hand-arm vibration exposures (A_{hw}) for each direction, calculated Frequency-weighted acceleration total value (Ah_v) 8-hour exposure value, A(8) for operators in three different vibratory equipment. Eight-hour energy-equivalent frequency-weighted acceleration, A(8) for OP3,OP4 and OP6 are greater than the exposure limiting values. However, A(8) value of OP5 (2.44 ms^{-2}) is just below the exposure action value (2.5 ms^{-2}).

Table 2: Ahw_x, Ahw_y, Ahw_y, Ahv and A(8) values for all operators

Equipment	Operator	Ahw_x	Ahw_y	Ahw_z	Ah_v	A(8)
Jack Hammer	OP1	4.85	6.63	1.97	13.96	13.96
	OP2	2.11	3.18	9.60	9.86	9.86
Drilling Machine	OP3	7.45	11.18	11.18	24.09	20.86
	OP4	7.21	13.81	6.86	17.03	13.46
	OP5	2.53	1.19	0.32	2.81	2.44
	OP6	8.00	5.76	16.06	22.12	19.15
Plate Compactor	OP7	2.50	5.76	5.76	8.52	8.52
	OP8	6.79	9.87	9.63	15.3	14.38
	OP9	8.91	4.21	18.66	21.01	21.01
	OP10	15.63	15.63	16.08	25.25	25.25

Generally, vibration exposure in *x* axis was greater than the other two directions (Figure 3). It was found that the maximum vibration level induced in *z* axis is 18.66ms-^{2}. For both *y* axis and *x* axis maximum vibration level is 15.63 ms^{-2}. Maximum vibration exposure levels were observed from the plate compactor operators, OP 9 and OP10. It seems that more than 90% of hand arm vibration related equipment generates higher vibration exposure (Table 2) which exceeded the exposure limiting values of legislations: ISO 5349 (2001)

Figure 6 shows the Frequency-weighted acceleration total value (Ahv) work with gloves and the work without wearing the gloves for the operator,OP3.Vibration exposure decreased considerably while working wearing gloves. However, it has been observed that wearing gloves was not practice in civil engineering construction industry, letting operators in health risk.

Figure 5: Glove that used to experiment

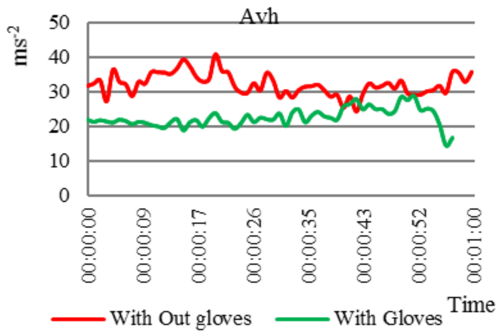

Figure 6: Avh values for with glove and without glove

4. Conclusions

More than 90% of hand arm vibration related equipment generates higher vibration exposure which exceeds the exposure limiting values of legislations: ISO 5349:2001. Majority of operators, who have more work experience and exposure to the higher vibration level, have felt tingling, pain and weaknesses in hand. Vibration exposure level which transfer to the human body decreased considerably while working wearing a pair of gloves.

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