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- Abstract -

Evaluation of Hand-Arm Vibration of Steel Processing Factory Workers

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This study was performed to evaluate the hand-arm vibration of the steel processing factory workers. Measurement, evaluation and assessment were based on the International Standard(ISO 5349). The frequency weighted accelerations of the various hand-held tools and total exposure time were measured to assess the periods for the white finger symptom to occur.

As a result, it was found that the air angle

grinder and the air baby grinder are more harmful than other hand-held tools. It was also found that using various vibratory tools together is more harmful than using a single tool.

key word : Hand-arm vibration, ISO 5349, Vibration-induced white finger(VWF), Energy equivalent frequency weighted acceleration ($(a_{h,w})_{eq}$)

† : 234

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I.

1911

19

1918 Hamilton(1918)

가

가

가

. 2

가

(Robert, 1984).

(

, 1995 : , 1996)

(Yamada et al., 1998). 1950

가,

가

가

가

가

(Robert, 1984: Cherniack et al.,

1990)

가가

가

가

5가

ISO

. Letz et al. (1992)

5349- 1986(E)

71%가 가

50%

(white finger syndrom)

84%가 가

(VWF) 가

(numbness)

(tingling)

가

Griffin (1990, 1997)

()

II.

(chronic disorders)

(Raynaud's 1.

phenomenon)

가

가

(grinder), (drill),

가

(screw driver), (impact

가

wrench), (chipping hammer)

2

Table. 1

(vibration white finger :

VWF)

Fig. 1

3 가

(病巢) (focal compression)

(piezoelectric accelerometer : B & K, type 4374),

(2- Ch amplifier : RION, UV- 06),

.(Letz et al., (tape recorder : TEAC, R- 71),

1992)

(RION, SA- 74A), 가 (handle

Table. 1 Conditions of the tool used in the factory

Category	Tools	Rate of usage(%)	Sub total(%)
Grinder	Air angle grinder	40.3	76.3
	Air baby grinder	26.4	
	Air straight grinder	3.8	
	Elect. angle grinder	4.8	
	Elect. straight grinder	0.2	
	Elect. bench grinder	0.8	
Drill	Air corner drill	1.1	8.5
	Air straight drill	1.5	
	Elect. straight drill	5.2	
	Magnet drill post(KCD- 3/4)	0.7	
Driver	Air screw driver	1.6	1.6
Impact wrench	Air impact wrench	7.8	7.8
Chipping hammer	Air chipping hammer(A)	1.3	1.3
etc.		4.5	4.5
Total			100.0

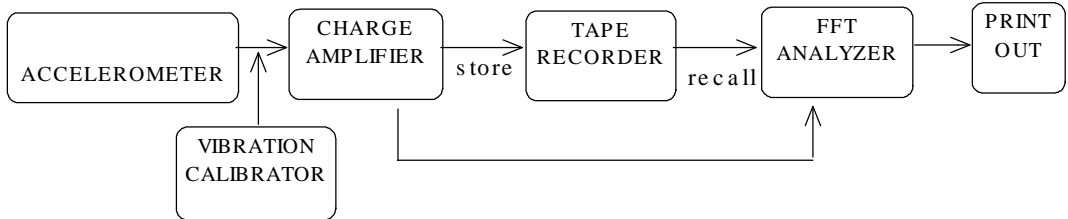


Fig. 1 Schematic diagram for measurement system

adaptor set : B & K, UA-0894),

(vibration (Fig. 2)

calibrator : RION, VE-10)

(Fig. 3)

가

가

1/3

1 Hz ~ 2000 Hz

가

가

159.2

3 Hz 10 m/sec²

ISO 5349-1986(E)

가 1000

(basicentric coordinate system)

10 m/sec²가 13.8 mV가

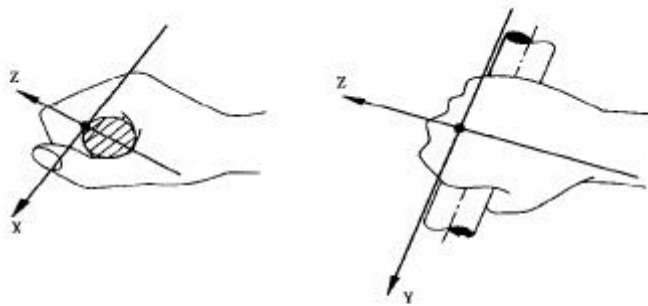


Fig. 2 Basicentric coordinate system



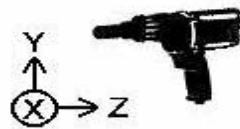
(a) Air angle grinder



(b) Elect. straight grinder



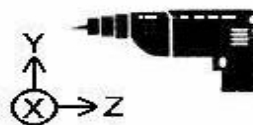
(c) Air baby grinder



(d) Air impact wrench



(e) Tucker



(f) Air screw driver

Fig. 3 Directions of x, y and z axis

(10000인 경우 1.38mV, 100인 경우 138mV). 사용한 가속도계의 측정범위 및 민감도는 Table. 2와 같다.

Table. 2 Specification of accelerometers
(B & K type 4374)

Serial No.	Max. acceleration*	Frequency range	Charge sensitivity
1 1871821			0.098 $\mu\text{C}/\text{ms}^{-2}$
2 1691631	50,000 m/s^2	1 Hz - 18,500 Hz	0.109 $\mu\text{C}/\text{ms}^{-2}$
3 1893789			0.163 $\mu\text{C}/\text{ms}^{-2}$

* Max. operational continuous sinusoidal acceleration (peak)
source : Transducer & Conditioning Catalogue 1997,
Brüel & Kjær

작업자들이 실제로 진동에 노출되는 시간을 파악하기 위하여 업무별/사용공구별로 현장에서 스톱워치를 사용하여 시간당 실노출시간을 측정하였다. 기준시간동안 작업자의 작업형태를 관찰한 후 스톱워치를 사용하여 휴식/장소이동/장비교체/실제 공구 사용시간 등으로 작업시간을 구분한 후 각각에 대한 시간을 측정하여 산출하였다.

하루 평균 공구 사용 시간에 있어, 에어 앵글 그라인더와 베이비 그라인더의 경우 전문적으로 이들 공구를 사용하여 연마 작업을 하는 작업자와 그렇지 않은 작업자로 분류하여 시간을 표시하였고 나머지 장비에 대해서는 설문 조사를 통하여 이들 장비를 사용한다고 응답한 작업자의 하루 평균 공구사용 시간에 대한 평균값을 사용하여 나타내었다.

2. 분석 및 평가방법

진동노출에 대한 분석 및 평가는 ISO 5349-1986(E)를 근거로 하였으며 주로 일일노출량에 기초하여 평가하였다.

진동의 인체 노출량에 대한 분석은 일반적으로 1일 8시간 작업할 경우, 진동이 손에 전달되는 총시간은 4시간을 넘지 않는다고 가정하여, 일일 노출량을 4시간 동안의 에너지 등가 주파수 가중 가속도 (energy-equivalent frequency-weighted acceleration)

로 표현한다. 만약 일일 총 노출량이 4시간과 다를 때는 아래의 식으로 구하게 된다.

$$(a_{h,w})_{eq(4)} = \left[\frac{1}{T_4} \int_0^{\tau} [a_{h,w}(t)]^2 dt \right]^{1/2} \dots (1)$$

여기서

$(a_{h,w})_{eq(4)}$ is the energy equivalent acceleration

for a period of 4 hour ;

$a_{h,w}(t)$ is the instantaneous value of the weighted acceleration ;

τ is the total duration of the working day, in hours ;

$$T_4 = 4 \text{ hour}$$

를 의미한다. 또한 에너지 등가 가속도값 (energy equivalent acceleration)이 4시간을 넘게 될 경우에는 식(2)로 환산하여 4시간 동안의 환산된 가속도값을 얻게 된다.

$$(a_{h,w})_{eq(T)} = \left(\frac{T}{T_4} \right)^{1/2} (a_{h,w})_{eq(T)} \dots (2)$$

여기서

$(a_{h,w})_{eq(T)}$ is the frequency-weighted energy equivalent acceleration for a period of T h.

이며, 만약 총 일일노출량이 여러 다른 주파수 가중 가속도값을 갖고 있을 경우(여러 진동공구를 사용할 경우)에는 식(3)으로 가속도값을 결정한다.

$$(a_{h,w})_{eq(T)} = \left\{ \frac{1}{T} \sum_{i=1}^n [(a_{h,w})_{eq(t_i)}]^2 t_i \right\} \dots (3)$$

$$T = \sum_{i=1}^n t_i$$

$(a_{h,w})_{eq(t_i)}$ is the frequency-weighted energy equivalent acceleration for the i th exposure component of duration t_i , in hours

$$(a_{h,w})_{eq(T)} \quad (4)$$

$$a_{h,w} = \left(\sum_{j=1}^n (K_j a_{h,j})^2 \right)^{1/2} \quad \dots (4)$$

K_j is the weighting factor for the j th one-third octave band or octave band given respectively in ISO 5349 ;

$a_{h,j}$ is the acceleration measured in the j th one-third octave band or octave band

n is the number of one-third octave or octave bands being used

가 ISO- 5349- 1986(E) 25

A (5) Fig. 4

$$C = \left[\frac{(a_{h,w})_{eq(4)} \times T_F}{95} \right]^2 \times 100 \quad \dots (5)$$

$(a_{h,w})_{eq(T)}$ is frequency-weighted energy equivalent acceleration for the period of 4 hours

C is percentile of exposed persons expected to show vascular disorders(inside the range(10 to 50 %)

T_F is exposure time before finger blanching, in years(inside the range 1 to 25 years)

가

가

4

가

가 가 $((a_{h,w})_{eq(4)})$ 2 m/s^2 가

15

10%가

, 가 50%

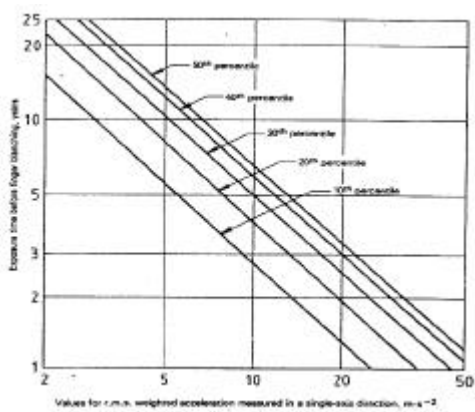


Fig. 4 Exposure time for different percentiles of population group exposed to vibrations in three coordinate axes(ISO 5349- 1986(E) Annex A)

III.

grinder

28 30

1.

baby grinder

9 30

. Chipping hammer

5 6

30

Table. 3

32 40

30

. 8 6

. air angle grinder

40

1

baby grinder

4 30

. Screw driver 1 3

750

. air

1

4 30

angle grinder

. Impact wrench 가

7.5 , 1.4

baby grinder 가 1.9 , 가

가 1.6 . impact

wrench 1.1 , 1 1.7 1

chipping hammer 0.6 , screw 57.9 1

driver 1.0 . 1 38 .

1

Table. 5

Table. 4 . air angle

Table. 3 Daily working period

Tools	No. of person	Daily working period(h)
Air angle grinder		
Professional worker	100	7.5(1.7)*
Non-professional worker	286	1.4(1.7)
Air baby grinder		
Professional worker	48	1.9(1.9)
Non-professional worker	106	1.6(1.6)
Impact wrench	90	1.1(1.4)
Chipping hammer	38	0.6(1.1)
Screw driver	9	1.0(1.4)

* : () is S.D.

Table. 4 Actual vibration exposure time per hour

Tools	No. of measurement	Exposure time per hour
Air angle grinder	6	28' 30"
Air baby grinder	4	9' 30"
Impact Wrench	7	1' 38"
Chipping Hammer	5	4' 30"
Screw Driver	5	4' 30"

Table. 5 Actual vibration exposure time per day

Tools	Exposure time per hour × Daily working period(h)	Actual exposure time(h)
Air angle grinder		
Professional worker	28' 30" × 7.5	3.6
Non-professional worker	28' 30" × 1.7	0.7
Air baby grinder		
Professional worker	9' 30" × 1.9	0.3
Non-professional worker	9' 30" × 1.6	0.3
Impact Wrench	1' 38" × 1.1	0.02
Chipping Hammer	4' 30" × 0.6	0.05
Screw Driver	4' 30" × 1.0	0.08

2. Table 6, air impact wrench
 가 25.7 m/s² 가 가
 chipping hammer가 24.2
 m/s² air baby grinder가 17.5 m/s² air angle
 grinder가 6.6 m/s² screw driver가 2.8 m/s²
 138
 가 Table. 6 7
 . 3 ISO-5349 가
 가 가 가
 가 dominant axis method
 'dom' ISSA
 (6) 3 International Section for Research(1989)
 frequency-weighted acceleration sum method
 ISO 5349
 가
 'sum' (Bovenzi et al., Fig. 6
 1997: Morioka et al., 1998) 가

$$ahws = (ahwx^2 + ahwy^2 + ahwz^2)^{1/2} \dots (6)$$

Table. 6 Average values of frequency weighted acceleration(m/s²) : (ah,w)eq

Tools	Ave. Accel.		min - max	
	dom.	sum.	dom.	sum.
Air Angle Grinder	6.6	9.9	2.3- 31.8	3.9- 43.7
Air Baby Grinder	17.5	24.4	4.3- 37.7	5.4- 54.2
Impact Wrench	25.7	39.0	4.8- 39.5	7.3- 54.4
Chipping Hammer	24.2	32.1	4.9- 45.9	5.9- 60.0
Screw Dirver	2.8	4.4	2.4- 3.2	3.7- 5.2

Table. 7 $(a_{h,w})_{eq(4)}$ according to actual exposure time

Tools	Actual E. T.	Ave. Accel.	$(ahw)_{eq(4)}$
Air Angle Grinder			
Professional worker	3.6 h	6.6	6.3
Non-professional worker	0.7 h	6.6	2.8
Air BaBy Grinder			
Professional worker	0.3 h	17.5	4.7
Non-professional worker	0.3 h	17.5	4.7
Impact Wrench	0.02 h	25.7	1.8
Chipping Hammer	0.05 h	24.2	2.7
Screw Dirver	0.08 h	2.8	0.4

Table. 8 $(a_{h,w})_{eq(4)}$ according to Actual exposure time(when exposed to several tools)

Tools	Actual E. T.	$(ahw)_{eq(T)}^*$	$(ahw)_{eq(4)}$
Air Angle Grinder			
+ Air Baby Grinder			
Professional worker	3.9 h	8.0	7.9
Non-professional worker	1.0 h	11.1	5.6
Air Angle Grinder			
+ Air Chipping Hammer	0.75 h	8.9	3.8
Air Angle Grinder			
+ Air Impact Wrench	0.72 h	7.8	3.3
Air Angle Grinder			
+ Air Baby Grinder	1.05 h	12.0	6.1
+ Air Chipping Hammer			

* total frequency-weighted accelerations

Air angle grinder
 가
 chipping hammer 80Hz
 chipping hammer
 (4500 beat/min) (75Hz)가
 가
 가
 Air baby grinder
 가 가
 4 가 가 가 (ah,w)eq(4)
 Table. 7 가
 가 air angle grinder
 가 가 , ISO- 5349 6.3Hz~1250Hz
 가 6.3 1/3 octave
 m/s² 가 가 (frequency weighted) 가
 air baby grinder
 4.7 m/s²
 chipping hammer, impact wrench, screw
 driver 가 8Hz ~ 15Hz
 가
 가 Table. 8
 가 air angle grinder 3. 가
 air baby grinder
 7.9 m/s² 5.6 m/s² air angle grinder , air angle grinder
 grinder chipping hammer
 3.8 m/s² air angle grinder impact wrench 50%
 3.3 m/s² air angle grinder air 11
 baby grinder chipping hammer 24 (Table. 9)
 6.1 m/s²
 Fig. 5 1/3 octave impact
 baby grinder가 1000 Hz wrench chipping hammer
 가 screw driver

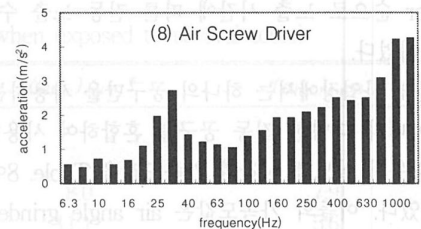
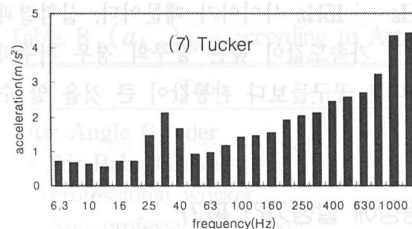
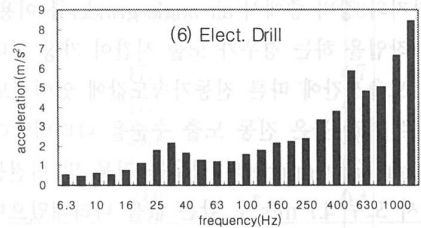
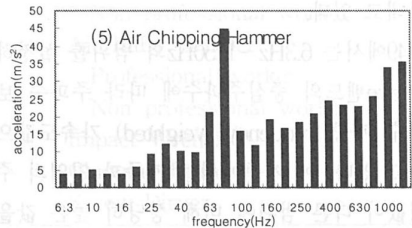
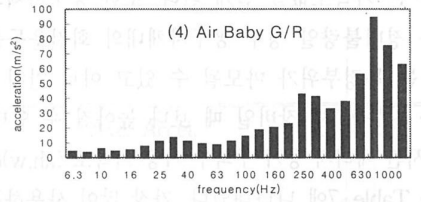
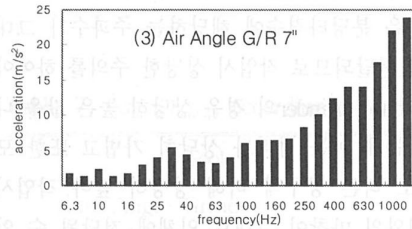
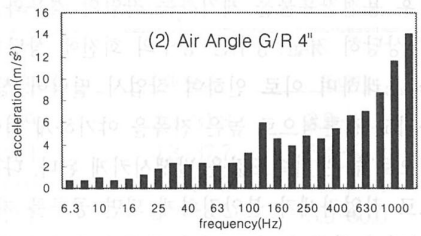
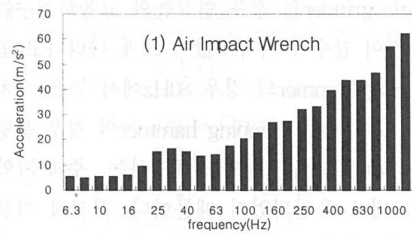


Figure. 5 One-third octave band histogram on vibratory tools

약 25년 이상인 것으로 나타났다. 즉 이 사업장의 작업자들이 평균 10년 이상을 근무하였다면 air angle grinder를 사용하는 전문 작업자는 절반 이상이 레이노드씨 현상을 나타낼 수 있으며 비전문 작업자는 약 10%가 이 현상을 나타낼 수 있는 것으로 판단된다.

Air angle grinder와 air baby grinder를 혼합 사용하는 전문 작업자의 경우 50% 이상이 레이노드씨 현상을 나타낼 수 있는 노출년수는 대략 8.5년으로

나타났고 비전문 작업자의 경우 12년으로 나타났다.(Table. 10) 이것은 air angle grinder 하나만을 사용하는 경우의 노출년수를 고려한다면 여러 가지 진동공구를 동시에 사용할 경우 진동에 대한 노출을 훨씬 더 가중시키고 있음을 나타내고 있다. 이외에 작업자의 절반 이상이 레이노드씨 현상을 나타낼 노출년수는 air angle grinder + chipping hammer가 17.8년, air angle grinder + impact wrench가 20.4년,



Fig. 6 Range of acceleration for various tools (ISSA International Section for Research 1989)

Table. 9 Exposure time & percentiles of population(when exposed to a single tool)

Tools	Weighted acceleration (ah_w) $\alpha(4)$ m/s ²	Percentile of population, C				
		10	20	30	40	50
		Exposure time, years				
Air Angle Grinder						
Professional worker	6.3	4.8	6.8	8.3	9.5	10.7
Non-professional worker	2.8	10.9	15.3	18.7	21.4	24.1
Air Baby Grinder						
Professional worker	4.7	6.5	9.1	11.1	12.7	14.4
Non-professional worker	4.7	6.5	9.1	11.1	12.7	14.4
Air Impact Wrench	1.8	16.9	23.8	>25	>25	>25
Air Chipping Hammer	2.7	11.3	15.8	19.4	22.2	>25
Air Screw Driver	0.4	>25	>25	>25	>25	>25

Table. 10 Exposure time & percentiles of population(when exposed to several tools)

Tools	Weighted acceleration (ah_w) $\alpha(4)$ m/s ²	Percentile of population, C				
		10	20	30	40	50
		Exposure time, years				
Air Angle Grinder + Air Baby Grinder						
Professional worker	7.9	3.8	5.4	6.6	7.8	8.5
Non-professional worker	5.6	5.4	7.6	9.3	10.7	12.0
Air Angle Grinder + Air Chipping Hammer	3.8	8.0	11.3	13.8	15.8	17.8
Air Angle Grinder + Air Impact Wrench	3.3	9.2	13.0	15.8	18.1	20.4
Air Angle Grinder + Air Baby Grinder + Air Chipping Hammer	6.1	5.0	7.0	8.6	9.8	11.1

air angle grinder + air baby grinder + chipping hammer가 11.1

가

NIOSH

(NIOSH, 1989). NIOSH(1989)

가 가

IV.

가 가 가 가

가

가 가 가 가

가

Letz et al.(1992)

, 50% (vibration induced white

가

finger : VWF) 가

, Griffin(1997)

(dominant

가

frequency)가 (250Hz)

가

가

가 가

가

가

ISO 5349

VWF가

, 가

가 가

가

가

가

가

가

가

가

REFERENCES

, 가

가 가 (frequency weighted acceleration)

가 가 (frequency unweighted acceleration) . 1/3 octave 가

3.6Hz ~ 16Hz

6(1): 1- 16

가 American

National Standards Institute[S3 · 34](ANSI, 1986),

American Conference of Governmental Industrial

Hygienist(ACGIH, 1990), International Organization

for Standards[ISO 5349](ISO, 1986), European

Standard[ENV 25349](ECS, 1992) British

Standards Institution[BSI 6842, 7482 part 2](BSI,

1987, 1991) 가

, : 가. 1996;

6(1): 1- 16

, : -

(Double-hammer type) -

(Oil-pulse type)

가 . 1995;

5(2): 147- 159.

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