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Measurement System used MEMS Acceleration Sensor with ZigBee

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Abstract

This paper is an introduction of measurement system used MEMS acceleration sensor with ZigBee.

1. Introduction

It is requested to control not to exceed daily vibration limit value of vibration exposure in the field. However, it is sometimes happen to over work even he or she knows it consciously or unconsciously. Therefore, not only for the operator, but also it is need to know for "the administrator vibration tools" by the warning system when he or she reaches a daily vibration limit value. This paper introduces the measuring system based on ZigBee which is featured an excellent long time battery power and excellent data forwarding.

2. Outline of the used device

This device which is called Simple DAQ consists of 3-axis MEMS accelerometer, calculation part and a radio communication by ZigBee. A basic part of ZigBee is defined by IEEE 802.15.4 that is wireless PAN (Personal Area Network) of the low transmission speed standard.

ZigBee is low power consumption and this is appropriate for the wireless sensor network construction. A 65535 nodes (terminal) can be connected with one network though the transmission speed is slower than 250kbps and other wirelesses PAN. Node of ZigBee can be ad-hoc to another node without complex settings. And also it can be awake from sleep quickly.

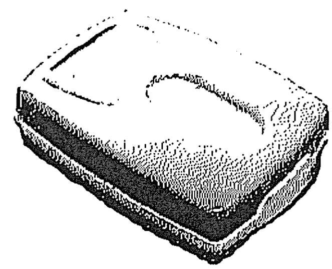
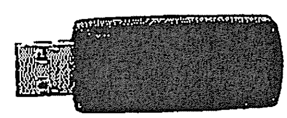
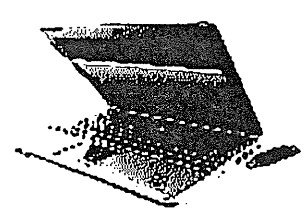
There is 2 type of node for the ZigBee. One of them is called FFD (Full-function device).

FDD is able to be a coordinator and a router in the network. FDD is able to forward data by request of another node. The other type of node is called RFD (Reduced-function device) which only can be an end point node.

Therefore, ZigBee, it is easy to configure the sensor network and each node helps sending data each other.

3. Specification of Simple DAQ

Table 1 shows the specification of Simple DAQ. [1]

<table>
<tr><th colspan="2">Simple DAQ M1 wireless measurement module</th></tr>
<tr><td>- A tri-axial MEMS sensor
- Resolution up to 4 mg
- Wireless range up to 200 meters
- Internal memory (30 minutes at 100 Hz using 3 axes)
- Sampling frequencies from 100 Hz up to 1 kHz
· Memory Bank 5,522, 239 sample (3 axis 1,000Hz 348seconds)
-anti aliasing filter
-resolution 4mG
-IP67</td><td></td></tr>
<tr><th colspan="2">A USB-RF unit and PC software</th></tr>
<tr><td>- Plug and play connection to PC
- PC software to configure parameters, control measurements and download data
- Drivers for Windows operating systems
- Wireless range up to 200 meters
- Synchronous start of measurement for all sensor modules in range
- Power from USB port (USB 2.0 compatible)
-PC software is written by Python</td><td></td></tr>
<tr><th colspan="2">Wireless technology</th></tr>
<tr><td>-2.4 GHz wireless communication (801.15.4 standard)
-Range 200/50 m (outdoor/indoor)
Basic package includes
-2 simpleDAQ M1 modules
-1 USB-RF unit
-PC software (Windows XP, Vista and 7)
-Batteries
-USB extension cable for USB-RF</td><td></td></tr>
</table>

The main usage of Simple DAQ is to measure and store the vibration data. Table 1 shows the specification of Simple DAQ.

4. Evaluation of Simple DAQ

Vibration exciter was used to know the frequency response of Simple DAQ.

4.1 Measuring condition.

Simple DAQ is mounted to the jig by rubber band. The jig is fixed to the table of exciter by screw bolt as shown as figure1.Simple DAQ is configured by changing variable value in the text file which is named configure.txt. Figure 2 shows the configuration txt for the evaluation of this time.

The vibration magnitude of exciter set to 5 m/sec^2 and the vibration frequency sweep up from 4 Hz to 1 kHz and sweep down from 1kHz to 4Hz.

After running Simple DAQ, the three axis (x, y, and z axis) vibration was measured.

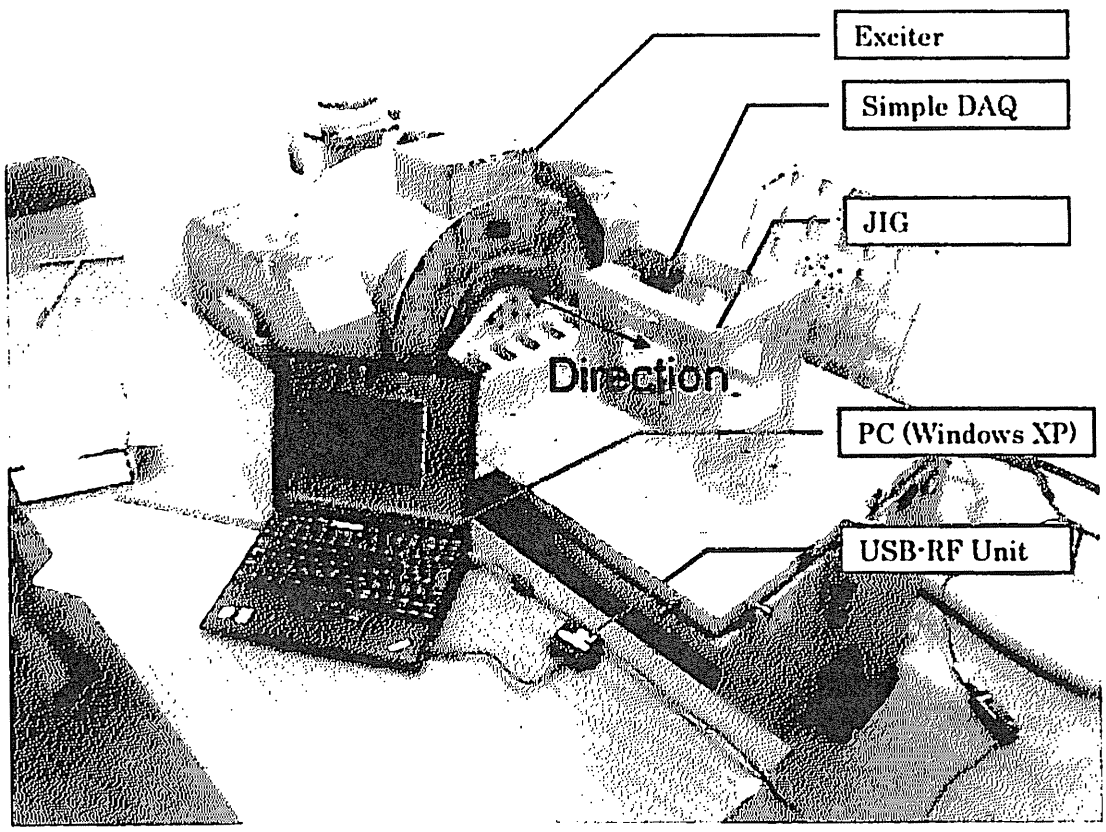


Figure1. Vibration exciter system for evaluating the Simple DAQ.

```
[parameters]
#select receiver module id for the message ('all' for all modules)
set_receiver = all

#sensor amplitude range - 2, 4 or 8 g
set_amplitude = 2

#sensor sample rate - 100, 250, 500, or 1000 Hz
set_sample_rate = 1000

#measured axes - xyz, x, y or z
set_axes = xyz

#maximum measurement duration in seconds - e.g. 10.3
set_max_duration = 25.0

#default calibration values of a module - used as a divider of the sensor data - e.g. 25.6
#the calibration values are for 2g amplitude range and multiplied for other amplitudes
set_calibration_value_x = 26.0
set_calibration_value_y = 26.0
set_calibration_value_z = 26.0

[trimming values]
#these are used for trimming the raw data of the acceleration values
#another file is created with '_trim' suffix

#select if trimming is used - e.g. True or False
set_trimming = True

#select highpass filtering - e.g. from 0.0 to sample_rate/2
set_highpass = 0.4

#select lowpass filtering - e.g. from 0.0 to sample_rate/2
set_lowpass = 0.0
```

Figure2. The used configuration to evaluation of Simple DAQ [1]

4.2 Result.

Wave form of X axis, Y axis and Z axis are shown by Figure 3.

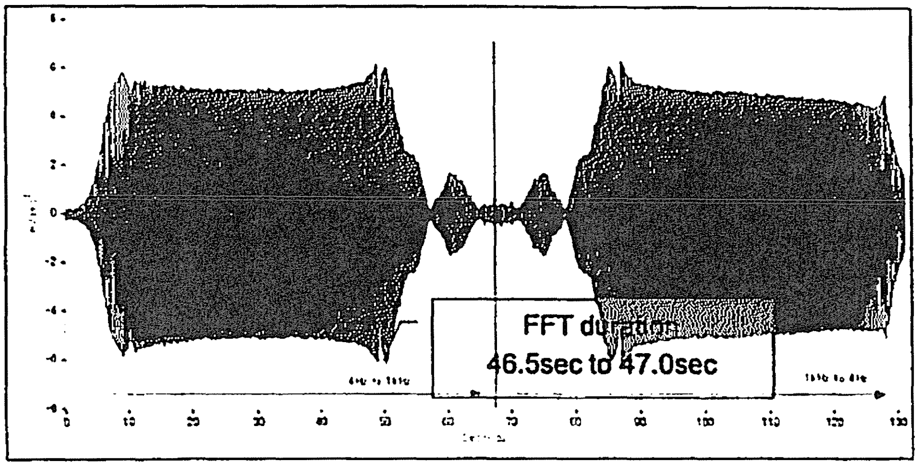
a. From Figure 3, the three axis are haring the same characteristics.

b. It seems to be no weighted wave form of human vibration.

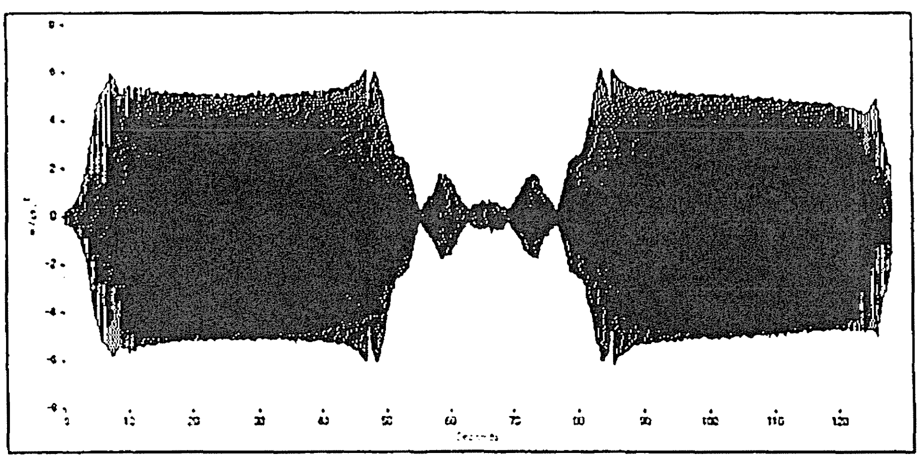
c. Simple DAQ follows up to approx.140 Hz by shown Figure6.

From the measurement result as shown Figure 3, it was found the followings:

X axis



Y axis



Z axis

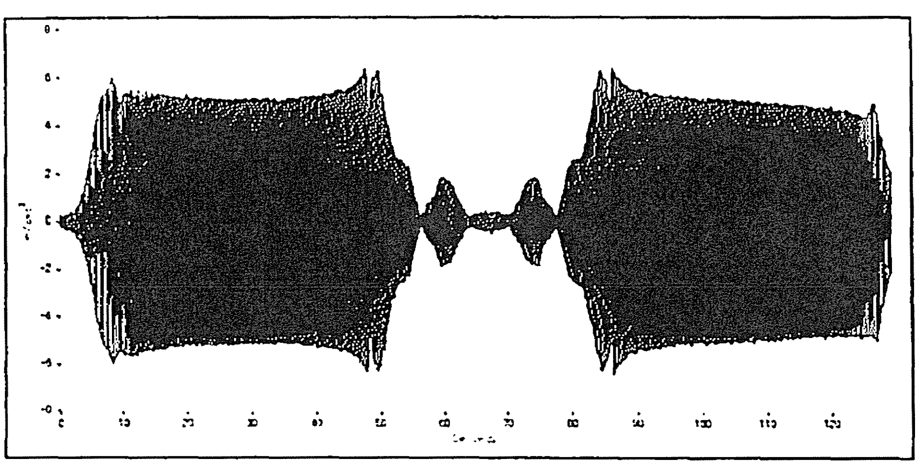


Figure 3. Three axis vibration measurement results.

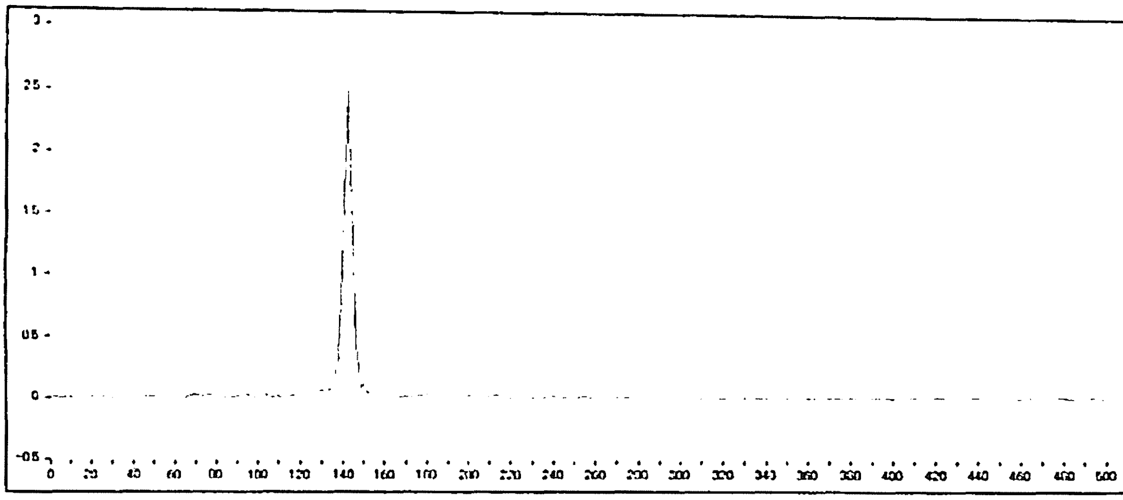


Figure 4. Result of FFT (All axis)

5. Idea of the scheme of the wireless measuring system

ahv and A(8) are measured and calculated inside of the node. Nodes in work place warn instantly to an operator in case of over dose to vibration.

Warning is received by not only the operator in workplace but also the administrator vibration tools that is monitoring PC. The example is shown by Node 5 of Figure 7.

PC logs the ahv and A(8) history each nodes with software for the administrator vibration tools to control and manage by company.

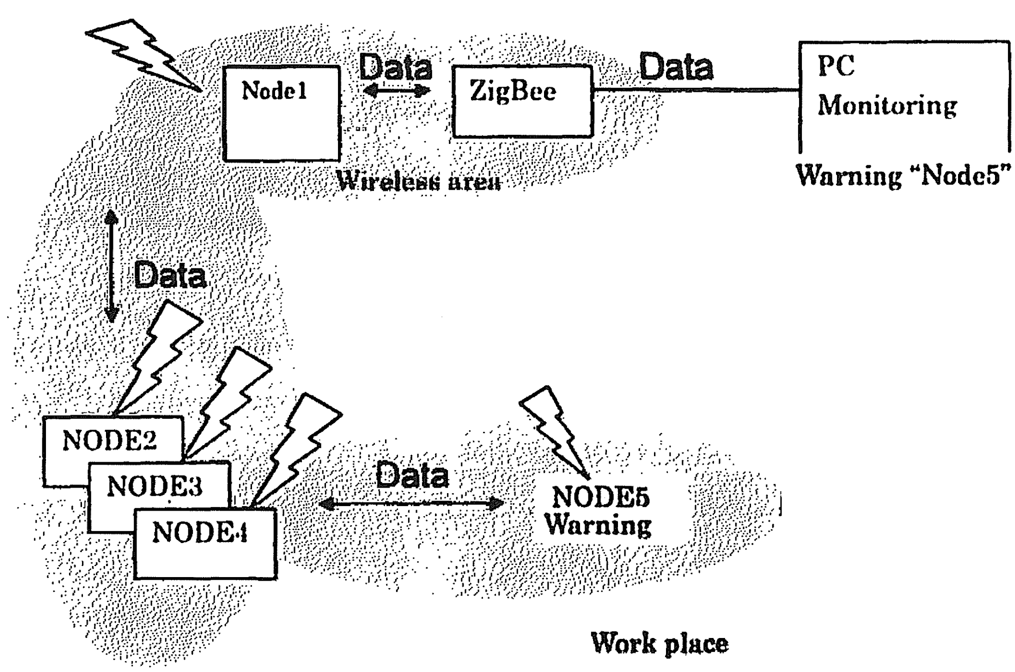


Figure7. An ideal scheme

6. Current Issues of the wireless measuring system

From an ideal scheme and the test results, it is clear to following things;

a. The nodes are necessary to be build as a router (FDD) which is defined by ZigBee Alliance to forward the data cooperatively.

b. It is necessary to calculate a_{hv} and A(8) in the local node to let an operator know exposure value.

c. It is necessary to make GUI software using provided API from vender for easy to use to the administrator of vibration tools.

7. Conclusion

Frequency response of currently used Simple DAQ is still too low to apply to the hand –arm vibration by result of evaluation. However, the technology of MEMS accelerometer for frequency response has been progressed much faster to higher frequency. There is already provided the MEMS accelerometer to applicable hand-arm vibration from the other study.

To control the vibration exposure in the field, this kind of system which is shown by Figure7 is going to be necessary for the operator in the field of vibration environment and for administrator of vibration tools.

Reference

[1] Simple DAQ A Wireless Vibration Data Acquisition System Version 1.0 User Guide

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Transition of Frequency-Weighting Curves of Hand-Arm Vibration Evaluation

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Abstract

In the ISO/TC108/SC4/WG3, the new frequency-weighting curve has been considered to revise the ISO 5349-1 standard as PWI 18570: HAV frequency weighting. Moreover, many frequency-weighting curves based on the biodynamic responses or on the epidemiological data of the hand-arm vibration experiments are proposed by many researchers. In this study, the history of Frequency-Weighting curves of Hand-Arm Vibration Evaluation was investigated.

1. Introduction

In the ISO/TC108/SC4/WG3, the new frequency-weighting curve has been considered to revise the ISO 5349-1 standard as PWI 18570: HAV frequency weighting. Moreover, many frequency-weighting curves based on the biodynamic responses or on the epidemiological data of the hand-arm vibration experiments are proposed by many researchers. And the Frequency-Weighting Curves of ISO 5349 on 1979 [1], 1986 [2], 1996 [3], 1997 [4], 1999 [5], 2000 [6], and 2001 [7] are defining by the different standard for evaluating the Hand-Arm Vibration. Also, the Frequency-Weighting Curves have been discussed by ISO/TC108/SC4/WG3 meetings in Malta 2007 [8], Oslo 2008 [9], Las Vegas 2009 [10], London 2010 [11], and Ottawa 2011 [12].

The purpose of this research is to summarize the history of the Frequency-Weighting curves from 1979 to 2011.

2. Frequency-Weighting Curves of ISO/DIS 5349:1979 [1] and ISO 5349: 1986 [2]

The frequency-weighting curves have been defined by ISO/DIS 5349 [1] and ISO 5349 [2]. The frequency-weighting factors are also defined by the Table 1 and 2.

Table 1 – Weighting factors for conversion of one-third octave band measurements to weighted measurements of ISO/DIS 5349 [1] and ISO 5349 [2].

Frequency Hz	Weighting factor
6.3	1.0
8.0	1.0
10.0	1.0
12.5	1.0
16	1.0
20	0.8
25	0.63
31.5	0.5
40	0.4
50	0.3
63	0.25
80	0.2
100	0.16
125	0.125
160	0.1
200	0.08
250	0.063
315	0.05
400	0.04
500	0.03
630	0.025
800	0.02
1000	0.016
1250	0.0125

Table 2 – Weighting factors for conversion of octave band measurements to weighted measurements of ISO/DIS 5349 [1] and ISO 5349 [2].

Frequency Hz	Weighting factor
8.0	1.0
16.0	1.0
31.5	0.5
63	0.25
125	0.125
250	0.063
500	0.03
1000	0.016

The ISO/DIS 5349 [1] and ISO 5349 [2] standards are recommended that the vibration should be investigated in each of the three coordinate axes and that the assessment should be based upon the component with largest vibration acceleration. Dose-response relationships have been studied for industrial vibration exposure which involves complex three-dimensional acceleration. Characterization of the vibration exposure through the largest single component is generally regarded as adequate on these standards.

3. Frequency-Weighting Curves of ISO 5349-1 standards

The following Tables are shown the frequency-weighting factors of different standards.

Table 3 – Weighting factors for conversion of octave band measurements to weighted measurements of ISO/CD 5349-1:1996 [3].

Frequency Hz	Weighting factor
8	1
10	1
12.5	1
16	1
20	0.8
25	0.63
31.5	0.5
40	0.4
50	0.3
63	0.25
80	0.2

100	0.16
125	0.125
160	0.1
200	0.08
250	0.063
315	0.05
400	0.04
500	0.03
630	0.025
800	0.02
1000	0.016

Table 4 – Weighting factors for conversion of octave band measurements to weighted measurements of ISO/CD 5349-1:1997 [4].

Frequency Hz	Weighting factor
8	1
10	1
12.5	1
16	1
20	0.8
25	0.63
31.5	0.5
40	0.4
50	0.3
63	0.25
80	0.2
100	0.16
125	0.125
160	0.1
200	0.08
250	0.063
315	0.05
400	0.04
500	0.03
630	0.025
800	0.02
1000	0.016

Table 5 – Weighting factors for conversion of octave band measurements to weighted measurements of ISO/DIS 5349-1:1999 [5].

Frequency Hz	Weighting factor
6.3	0.727
8	0.873
10	0.951
12.5	0.958
16	0.896
20	0.782
25	0.647
31.5	0.519
40	0.411
50	0.324
63	0.256
80	0.202
100	0.160
125	0.127
160	0.101
200	0.0799
250	0.0634
315	0.0503
400	0.0398
500	0.0314
630	0.0245
800	0.0186
1000	0.0135
1250	0.00894

Table 6 – Weighting factors for conversion of octave band measurements to weighted measurements of ISO/FDIS 5349-1:2000 [6].

Frequency Hz	Weighting factor
6.3	0.727
8	0.873
10	0.951
12.5	0.958
16	0.896
20	0.782
25	0.647
31.5	0.519
40	0.411
50	0.324
63	0.256
80	0.202
100	0.160
125	0.127
160	0.101
200	0.0799
250	0.0634
315	0.0503
400	0.0398
500	0.0314
630	0.0245
800	0.0186
1000	0.0135
1250	0.00894

Table 7 – Weighting factors for conversion of octave band measurements to weighted measurements of ISO 5349-1:2001 [7].

Frequency Hz	Weighting factor
6.3	0.727
8	0.873
10	0.951
12.5	0.958
16	0.896
20	0.782
25	0.647
31.5	0.519
40	0.411
50	0.324
63	0.256
80	0.202
100	0.160
125	0.127
160	0.101
200	0.0799
250	0.0634
315	0.0503
400	0.0398
500	0.0314
630	0.0245
800	0.0186
1000	0.0135
1250	0.00894

The Frequency-Weighting factors are different between ISO/CD 5349-1: 1996, ISO/CD 5349-1: 1997 and ISO/DIS, FDIS 5349-1:1999-2001. But, from 1996 standard of ISO 5349-1, the measurements should be made for all three directions by using the frequency-weighting as shown in Tables 3-7. The frequency-weighted r.m.s. acceleration values for the x-, y- and z-axes, a_{hwx}, a_{hwy} and a_{hwz}, shall be reported separately. The evaluation of vibration exposure is based on a quantity that combines all three axes. This is the vibration total value, a_{hv}, and is defined as the root-sum-squares of three component values:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

4. Histories of ISO/TC108/SC4/WG3 meetings

The report of the ad-hoc WG3 meeting held in St. Julians, Malta in October 2007 was summarized by the convenor [8].

1. Wh (defined in ISO 5349-1) was based on research by Miwa in the 1960s.
2. Evidence that "flat" weighting better predicts vascular and sensorineural HAVS risks.
3. New information had come forward from the European VIBRISKS project.
4. France proposed adding an informative Annex to ISO 5349-1:2001 define a procedure for measuring "unweighted vibration". Careful consideration of the bandwidth would be needed.
5. Dr Maeda (Japan) was suggested as Project Leader.
6. Dr Maeda started work on ISO/PWI 18570. Issued questionnaire to WG experts.
7. Change of responsibilities means that Dr Maeda has to step down as ISO/PWI 18570 project leader.

The report of ISO/TC108/SC4/WG3 meeting held in Oslo in September 2008 was summarized by the convenor [9].

1. The meeting agreed that the current Wh is well used, and embedded in national legislation and national and international standards. Short-term change of Wh was recognized as being unlikely.
2. It was agreed that additional (alternative) weighting were desirable, but that current knowledge is insufficient to justify any specific weightings.
3. It was noted the justification for change must come from material based on a range of specialist inputs, including;

   A: Biodynamics

   B: Epdemiologists

   C: Physiologists

   D: Pathologists
4. Canadian delegation informed the meeting that the 12th International Conference on Hand-Arm Vibration is planned for Ottawa in 2011. In conjunction with this the organizer is intending to organize a meeting of experts to discuss and move progress developments of the hand-arm frequency weightings.

The report of ISO/TC108/SC4/WG3 meeting held in Las Vegas in September 2009 was summarized by the convenor [10].

1. The convenor presented a review of PWI 18570 activities since the Oslo meeting, i.e. the development of the frequency weightings defined in document N196"Candidate Supplementary Frequency Weightings".
2. The importance of understanding the history of the current frequency weighting Wh.
3. That Wh has been around for over 40 years and is now embedded in standards and

national legislation.

4. There is no need to remove Wh as it attempts to assess the whole hand-arm vibration risk.
5. New frequency weightings may have specific functions, e.g. for sensorineural, vascular and musculoskeletal issues.

RESOLUTION 1: The working group agreed to continue working with the current candidate frequency weighting (doc N198), and to continue to encourage working group members and other experts to contribute to the debate on hand-arm vibration frequency weightings.

RESOLUTIONS 2: To ask for additional information from Germany to explain the basis for the methodology used in VDI 2057.

RESLUTIONS 3:The convenor to ask Professor Bovenzi to establish whether his data could be re-analyzed usind the candidate frequency weightings Whf and WhT.

The report of ISO/TC108/SC4/WG3 meeting held in London in September 2010 was summarized by the convenor [11].

There was a useful discussion on the options and issues of a new frequency weighting. Some of the views expressed were:

1. The importance of good quality measurement when considering high-frequency vibration.
2. Low-frequency compared to high-frequency may not be a good way of considering issues, better to consider musculoskeletal and vascular/neurological risks.
3. Wh must stay, need an alternative Perhaps and annex to ISO 5349-1.
4. Where is the evidence of failing of Wh? Wh has been effective reducing exposures and risk for many machines. Need more evidence before providing an annex.
5. Bovenzi work on limited machines, not a clear-cut outcome.
6. Concern about possible confusion of new weighting in ISO 5349-1 (informative or not)
7. Possible better as a Technical Report or Technical Specification.
8. Four issues affecting risk: vibration magnitude, ergonomics, environmental and personal factors. Vibration magnitude may not be the most important.

RESOLUTIONS 1: The working group agrees that there is now sufficient information to propose an additional frequency weighting for hand-arm vibration that may be a better indicator of risks of neurological and vascular effect and agree to advance PWI 18570 to begin developing a document on this topic. The project leader for this work will be Tony Brammer supported by Ren Dong.

The report of HAV2011 Workshop for Frequency Weighting held in Ottawa, Canada in June 2011 was summarized [12].

1. Evidence that "flat" weighting better predicts vascular and sensorineural HAVS risks.
2. The meeting agreed that the current Wh is well used, and embedded in national

legislation and national and international standards. Short-term change of Wh was recognized as being unlikely.

3. It was noted the justification for change must come from material based on a range of specialist inputs, including;

   A: Biodynamics

   B: Epdemiologists

   C: Physiologists

   D: Pathologists

   E: Psycologists

5. Conclusions

From the results of summary of the ISO/TC108/SC4/WG3, it was clear that one researcher's work was on limited machines, and not a clear-cut outcome. Therefore, it was found the justification for change must come from evidences based on a range of specialist inputs.

6. References

[1] International Organization for Standardization (1979) Mechanical vibration – Guideline for the measurement and the assessment of human exposure to hand-transmitted vibration, ISO/DIS 5349.

[2] International Organization for Standardization (1986) Mechanical vibration – Guideline for the measurement and the assessment of human exposure to hand-transmitted vibration, ISO 5349.

[3] International Organization for Standardization (1996) Mechanical vibration – Guideline for Measurement and assessment of human exposure to hand-transmitted vibration-Part 1: General guidelines, 1st Committee Draft ISO/CD 5349-1.

[4] International Organization for Standardization (1997) Mechanical vibration – Guideline for Measurement and assessment of human exposure to hand-transmitted vibration-Part 1: General guidelines, 2nd Committee Draft ISO/CD 5349-1.

[5] International Organization for Standardization (1999) Mechanical vibration – Guideline for Measurement and evaluation of human exposure to hand-transmitted vibration-Part 1: General guidelines, ISO/DIS 5349-1.

[6] International Organization for Standardization (2000) Mechanical vibration – Guideline for the measurement and the assessment of human exposure to hand-transmitted vibration-Part 1: General guidelines, ISO/FDIS 5349-1.

[7] International Organization for Standardization (2001) Mechanical vibration – Guideline for the measurement and the assessment of human exposure to hand-transmitted vibration – Part 1: General requirements, ISO 5349-1.

[8] ISO/TC108/SC4/WG3 N183 (2007)

[9] ISO/TC108/SC4/WG3 N194 (2008)

[10] ISO/TC108/SC4/WG3 N208 (2009)

[11] ISO/TC108/SC4/WG3 N219 (2010)

[12] ISO/TC108/SC4/WG3 N222 (2011)

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Implementation and Influences of Machinery Safety Directive of 2006/42/EC

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Abstract

The purpose of this paper is to introduce the implementation and application of the new Machinery Safety Directive of 2006/42/EC for preventing Hand-Arm Vibration Syndrome to Japanese tools manufacturers.

1. Introduction

Figure 1 shows the relationships among Machinery Directives, the EU directive, International Standards and National Standards. The goal of this directive is to introduce measures that promote the improvement of worker's health and safety in the workplace. It provides for a general framework that executes European principles while at the same time honoring common international principles.

The guiding principles of the content are as follows.

1) This directive applies to the activities of all public and private sections.
2) The employer's responsibilities
3) Responsibilities of workers and workers rights

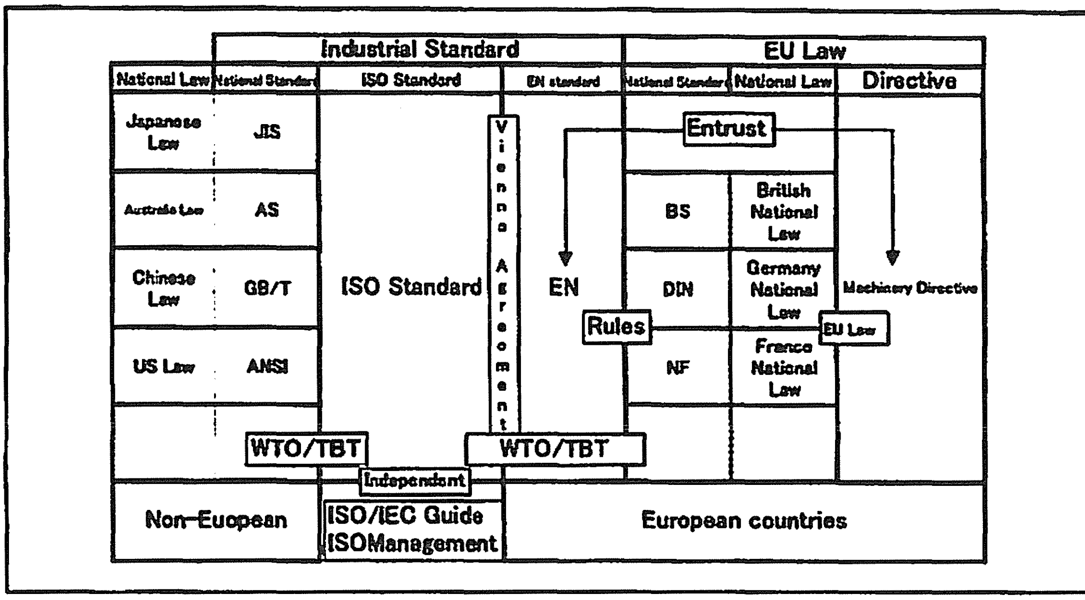

Figure 1. The relationships among Machinery Directives, EU Directives, International Standards and National Standards

As a result of the market integration of Europe, standards were adopted through the "Framework instructions", which included Machinery Directive 2006/42/EC and labor safety hygiene listed as Board of Director's Instruction 89/391/EC. Board of Director's Instruction 89/391/EC introduced measures to promote the improvement of labor safety hygiene and was revised in Board of Director's Instruction 98/37/EC: (1998). These two directives are the foundation of EC safety hygiene policy. These directives stipulate that in the design and the production of machines, it is mandated that consideration be given to both limiting the dangers associated with vibration in the vibratory source and improved methods that would allow workers to use the machines in ways that minimize injury. The vibration in the tool or equipment should be suppressed to the lowest level consistent with the presently available vibration reduction technology. The Machinery Directive 89/37/EC has been revised in Machinery Directive 2006/42/EC. EU countries were required to revise their laws to conform to the latest Machinery Directive for preventing Hand-Arm Vibration Syndrome.

The purpose of this paper is to clarify and encourage the implementation and application of the Machinery Safety Directive 2006/44/EC by Japanese tool manufacturers.

2: Machinery Safety Directive 98/37/EC of the European Parliament and of the Council of the European Union of 22 June 1998 on the implementation of the laws of Member States relating to machinery. (Machinery Safety Directive)

Vibration

Machinery must be so designed and constructed so that risks resulting from vibration produced by machinery are reduced to the lowest possible level by incorporating the latest technologies for reducing vibration that are available. It is important for designers and manufacturers that the vibration reduction takes place in the machinery at the source of the vibration.

Apart from the minimum requirements set out in 1.7.4 of this Directive, the instruction handbook must contain the following information:

The manufacturer's instructions must provide the following information concerning vibrations transmitted by hand-held and hand-guided machinery:

— the weighted root mean square acceleration value, to which the arms are subjected, if it exceeds 2.5 m/s^2 as determined by the appropriate test code. Where the acceleration does not exceed 2.5 m/s^2, this must be mentioned.

If there is no applicable test code, the manufacturer must indicate the measurement methods and conditions under which measurements were made.

3. Machinery Safety Directive 2006/42/EC [6]

As mentioned above, machinery must be so designed and constructed so that risks resulting from vibration produced by machinery are reduced to the lowest possible level by incorporating the latest technologies for reducing vibration that are available. It is important for designers and manufacturers that the vibration reduction takes place in the machinery at the source of the vibration.

The level of vibration emission may be assessed with reference to comparative emission data for similar machinery.

The instructions must include the following information concerning vibration transmitted by portable handheld and hand-guided machinery:

— the vibration total value to which the hand-arm system is subjected, if it exceeds 2,5 m/s2. Where this value does not exceed 2,5 m/s2, this must be mentioned.

— the uncertainty of measurement.

These values must be either those actually measured for the machinery in question or those established on the basis of measurements taken for technically comparable machinery which is representative of the machinery to be produced. If harmonized standards are not applied, the vibration data must be measured using the most appropriate measurement code for the machinery. The operating conditions during measurement and the methods used for measurement, or the reference of the harmonized standard applied, must be specified.

Directive 98/37/EC (Machinery Safety Directive) or 2006/42/EC and Directive 2002/44/EC (Physical Agent Directive-Vibration) have been in force since December 29th 2009 and July, 2005 respectively, and thus, the effort target value of the vibration reduction are well established and have been incorporated by hand-transmitted vibration tool manufacturers. The manufacturers use international standards and make international adjustments to test and classify the hand-transmitted vibration value tools. Moreover, the company has the additional obligation to protect the worker from possible danger to