XVIII IMEKO WORLD CONGRESS
Metrology for a Sustainable Development
September, 17 – 22, 2006, Rio de Janeiro, Brazil

CURRENT SITUATIONS ON VIBRATION METROLOGY IN JAPAN

Takashi Usuda [1], *Tamio Ishigami* [1] *Akihiro Ohta* [1], *Hideaki Nozato* [1], *Hisayuki Aoyama* [2], *Sojun Sato* [1]

[1] National Institute of Advanced Industrial Science and Technology, National Metrology Institute of Japan (AIST/NMIJ)
AIST Central 3, 1-1-1, Umezono, Tsukuba, Ibaraki, 305-8563, Japan
[2] University of Electro-Communications
1-5-1 Chofugaoka Chofu Tokyo182-8585

Abstract: We present the current situations and activities related to vibration metrology in Japan. It includes national metrology standard, traceability system, laboratory accreditation scheme, legal metrology regulated by measurement low, and earthquake measurements in Japan.

Keywords: vibration, metrology, national standard, accreditation, mutual recognition, legal metrology, measurement low

1. INTRODUCTION

Precise and reliable measurements of vibration and acceleration are frequently required from diverse fields of industry and science. Reliable vibration measurements are also requested in variety fields of safe and commerce which is the entirety of the legislative, administrative and technical procedures established by, or by reference to public authorities.

In Japan, the National Metrology Institute of Japan (NMIJ) is responsible for the establishment, maintenance and dissemination of most of the national standards of various physical quantities including vibration acceleration. It is also responsible for providing reference value in the laboratory accreditation scheme, for providing verification of instruments specified by legal metrology regulated by measurement low.

There are other issues in vibration measurement which is related to other regulators such as metrology (earthquake observation), occupational safety, vehicle safety, etc.

This paper outlines the current progress of measurement standards for vibration at the NMIJ as well as the current status of laboratory accreditation scheme. This paper also describes legal structure for various field related to vibration measurement in Japan.

We also conclude our expectation for IMEKO new technical committee namely TC22, “Vibration Measurement”.

2. VIBRATION METROLOGY STANDARD

In this chapter, calibration systems of national metrology standard developed at NMIJ, national traceability system and accreditation scheme of calibration laboratory are described.

2.1. National metrology standard at the NMIJ

NMIJ has developed four calibration systems for the national standard of vibration acceleration[1]-[4]. They calibrate accelerometers as a transfer of vibration acceleration standard to the users. All of the systems are in compliance with ISO 16063-11 (Methods for the calibration of vibration and shock pick-ups. Part 11: Primary vibration calibration by laser interferometry)[5]. They are classified for their calibration frequency range as follows.

System 1; Very low frequency range: 0.1 Hz – 2 Hz.

System 2; Low frequency range: 1 Hz – 200 Hz.

System 3; Middle frequency range: 20 Hz – 5 kHz.

System 4; High frequency range: 5 kHz – 10 kHz.

Figure 1 shows the apparatus of the system 1. It is realized by a combination of Michelson laser interferometer for fringe-counting method in compliance with ISO-16063-11[5] and an electro dynamic vibrator with air-born slider which maximum stroke is 36 cm. The motion of vibrator is horizontal direction. Applicable acceleration range lies from 0.03 m/s^2 to 10 m/s^2.

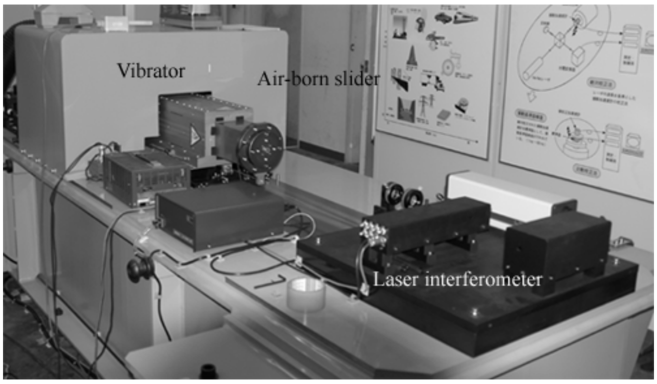

Fig. 1. Apparatus of the vibration acceleration standard for very low frequency range.

Figure 2 shows the apparatus of the system 2. It is realized by a combination of Michelson laser interferometer for fringe-counting method and an electro dynamic vibrator. The moving part of the vibrator is supported and lubricated by pressurized oil. The motion of vibrator is vertical direction. Applicable acceleration range lies from 0.5 m/s^2 to 10 m/s^2.

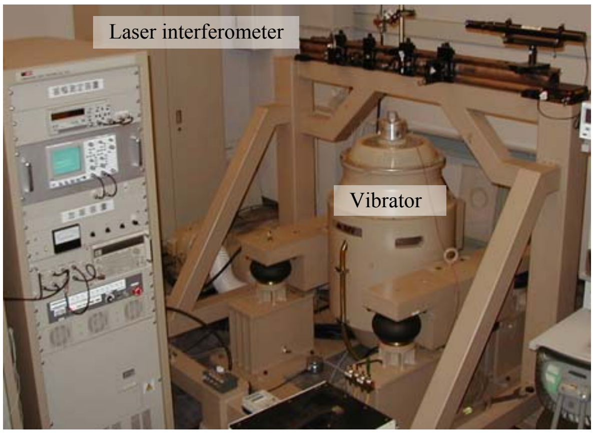

Fig. 2. Apparatus of the vibration acceleration standard for low frequency range.

Figure 3 shows the apparatus of the system 3. It is realized by a combination of modified Michelson laser interferometer and an electro dynamic vibrator. The motion of vibrator is horizontal direction. The modified Michelson laser interferometer was specially designed to apply the Sin-approximation method [5] and to realize high signal-to-noise ratio, robustness to acoustics and vibration noise, high frequency response, and easy operation for optical alignment [2]. The system can also perform fringe-counting method. Those two methods (sine-approximation and fringe-counting) are selected for calibration frequency and acceleration amplitude. Applicable acceleration range lies from 10 m/s^2 to 100 m/s^2.

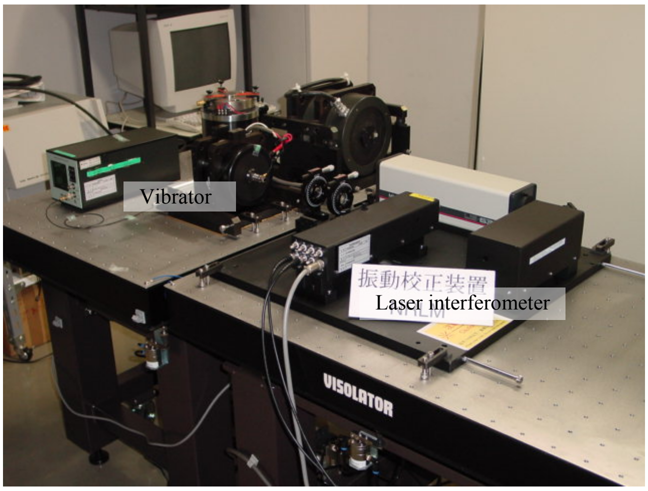

Fig. 3. Apparatus of the vibration acceleration standard for middle frequency range.

System 4 is realized by a combination of modified Michelson laser interferometer and an electro dynamic vibrator with air-born slider. The motion of vibrator is vertical direction. To obtain high resolution laser interferometer for displacement measurement in vibration, we developed two types of interferometer of the modified Michelson type with a multifold optical path which can be applied for Sin-approximation method. The multiple displacement amplitudes detected by them enable calibration with high accuracy at high frequencies. Figure 4 and 5 show the developed optical setups of the interferometers with a twofold and a fourfold optical path, respectively. Figure 6 shows details of the optical path of the fourfold laser interferometer

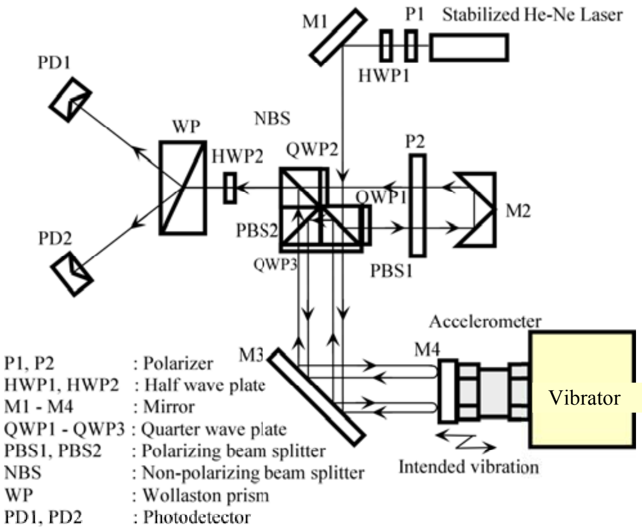

Fig. 4. Laser interferometer with twofold optical path of the system 4.

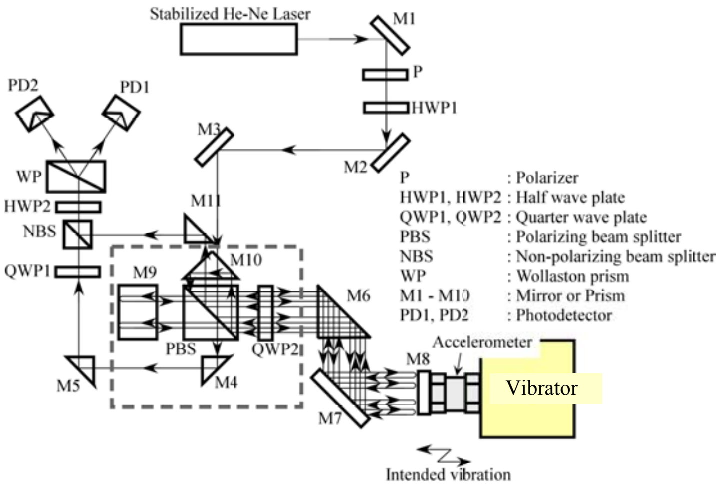

Fig. 5. Laser interferometer with fourfold optical path of the system 4.

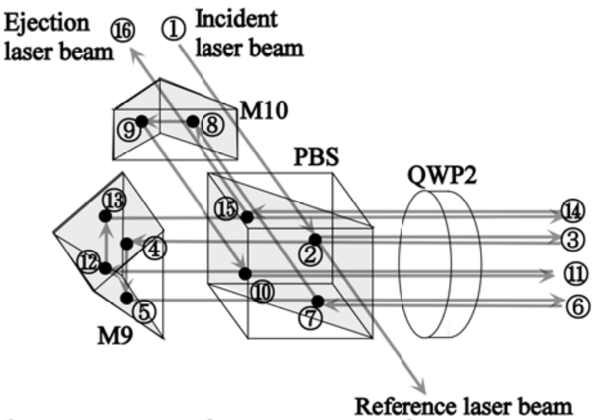

Fig. 6. Details of the optical path.

The system 4 is developed recently and the calibration service will be started in the year 2006. NMIJ is also developing shock acceleration calibration facility

Equivalency of National metrology standard is demonstrated by a result of international comparison. NMIJ has participated international comparisons of vibration and acceleration (CC Key comparison: CCAUV.V-K1 and regional key comparison: APMP.AUV.V-K1). We demonstrated our equivalency successfully.

2.2. Measurement low and Accreditation scheme of calibration laboratories

To ensure traceability to national standards, it is essential to maintain the reliability of calibration, in which a standard device is calibrated by a higher standard device, between national measurements and ones used at various locations such as factories and research institutes.

Japan Calibration Service System (JCSS) consists of the National standards provision system and the Calibration laboratory accreditation system introduced by the amended Measurement Law enforced in November, 1993. It was established for the purpose of ensuing the high precision measurement and the confidence of quality control on industrial production process. Laboratories are accredited by the National Industry of Technology and Evaluation (NITE, an incorporated administrative agency) when they meet technical requirements and pass the examination conducted by NITE. JCSS Accredited Calibration Laboratories meet the requirements laid down in the Measurement Law as well as those of ISO/IEC 17025 [6].

The JCSS plays an important role as an infrastructure for the measurement traceability to the National standards, however, accreditation scheme under ILAC (International Laboratory Accreditation Corporation) becomes also important. To date, there are two accreditation bodies in Japan who are signatories of ILAC MRA[7]. One is IA-Japan (Accreditation program of the NITE) and the other is JAB (Japan Accreditation Body). Those two accreditation bodies conduct accreditation process with the system conforming to ISO/IEC 17011 [8] and relevant international criteria. The JCSS also includes international recognition program. Thus, calibration certificate with JCSS logo issued by Accredited Calibration Laboratories assure the traceability to National Measurement Standards as well as a laboratory's technical and operational competence which is acceptable in the world market through the ILAC MRA.

As for the calibration laboratory accreditation in vibration and acceleration, NITE issued specific technical guideline document (JCT22201 Vibration & Acceleration) based on ISO 16063 including for the application laboratories. NMIJ provides reference value for technical assessment. The BMC (Best Measurement Capabilities) of the calibration laboratory is determined based on the result of this technical assessment. Figure 7 shows the outline of the process from application to accreditation of JCSS.

With recent internationalized economical activities, the traceability of measurement has being increased its importance as the technical infrastructure which forms the basis for various conformity assessment procedures on international trade. Accreditation scheme of calibration laboratories in Japan performs well such requirements from industries like other accreditation schemes such as DKD in Germany, UKAS in UK, A2LA, NVLAP in US and NATA in Australia, etc.

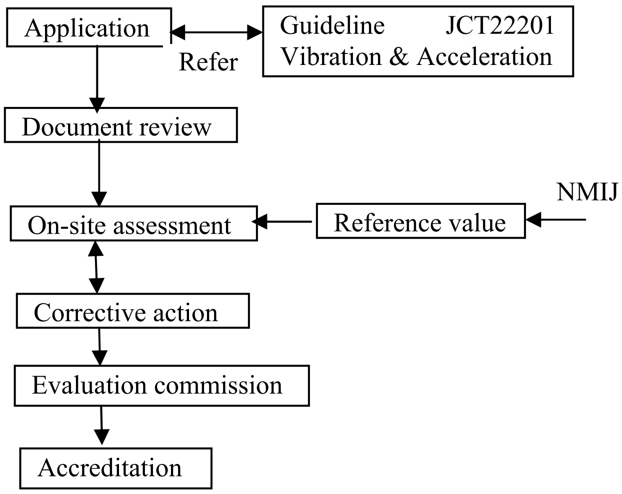

Fig. 7. Outline of the process from application to accreditation of JCSS

3. LEAGL METROLOGY IN VIBRATION MEASUREMENT

Measuring instruments significantly related to human safety and the appropriateness of commercial dealings, such as various meters and clinical thermometers are legally controlled by the Measurement Law. Legally controlled measuring instruments must undergo type approval and verification before they can become legally certified instruments. Verification, type approval and inspection of verification standard as specified by the Measurement Law. Of the services to which the Measurement Law applies, the NMIJ carries out type approval and inspection of Verification standard as well as tests on measuring instruments.

As for vibration measurement, an equipment to be used for the assessment of whole-body vibration of human beings is specified in the Low. The equipment for such purpose is named “Vibration level meter” and the requirements of the instrument are specified in Japan Industrial Standard (JIS), Vibration level meters [9]. It is used for environmental assessment such as safety and working environment, which is completely legislative field. The similar instrument is described in the ISO, Human response to vibration-Measuring instrumentation [10]. However, some important specifications are different in those two standards. Table 1 shows major differences or similarities of those two standards. For example, the reference vibration acceleration of the JIS is defined as 10^{-5} m/s^2, while it is defined as 10^{-6} m/s^2 in the ISO. Thus the measurement values measured by equipment specified in JIS and one specified in ISO are inconsistent.

Table 1. Major differences of vibration measurement equipment specified in JIS and ISO

	JIS	ISO
Document. No	C 1510	8041
Unit	dB	dB
Reference acceleration	10^{-5} m/s^2	10^{-6} m/s^2
Frequency scope	1 Hz to 80 Hz	1 Hz to 80 Hz (For whole-body)
Frequency weightings	Partly consistent to ISO 2631	Consistent with ISO 2631 series

Today, some legally controlled measuring instruments also become an item for mutual recognition with other countries or economies. In such cases, consistencies of measurement result are important for acceptance. Academic and legal activities for mutual acceptance in liaisons such as IMEKO and OIML (International Organization of Legal Metrology) are highly expected.

4. REGULATIONS IN SEISMOMETORY

To ensure public safety and to prevent natural disasters, observation of earthquake is conducted by public authorities in many countries. In Japan, JMA (Japan Meteorological Agency) is responsible for carrying out meteorological service including earthquake observation. There are many scales used to classify the intensity of an earthquake. In Japan, JMA seismic intensity scale is used. The scale runs from 0 to 7, with 7 being the strongest. Table 2 shows abbreviated description of the JMA intensity scale [11].

Table 2. JMA scale and examples of description

JMA Scale	Examples of description
7	In most buildings, wall tiles and windowpanes are damaged and fall. In some cases, reinforced concrete-block walls collapse.
6+	In many buildings, wall tiles and windowpanes are damaged and fall. Most unreinforced concrete-block walls collapse.
6−	In some buildings, wall tiles and windowpanes are damaged and fall.
5+	In many cases, unreinforced concrete-block walls collapse and tombstones overturn. Many automobiles stop due to difficulty in driving. Occasionally, poorly installed vending machines fall.
5−	People notice electric-light poles swing. occasionally, windowpanes are broken and fall, unreinforced concrete-block walls collapse, and roads suffer damage.
4	Electric wires swing considerably. People walking on a street and some people driving automobiles notice the tremor.
3	Felt by most people in the building. Some people are frightened.
2	Felt by many people in the building. Some sleeping people awake.
1	Felt by only some people in the building.
0	Imperceptible to people.

For our reference, Table 3 shows description of the 12 levels of Modified Mercalli intensity scale which is currently used in the United States of America [12].

Table 3. Modified Mercalli scale and examples of description

Modified Mercalli Scale	Examples of description
XII	Damage total. Lines of sight and level are distorted. Objects thrown into the air
XI	Few, if any (masonry) structures remain standing. Bridges destroyed. Rails bent greatly
X	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent
IX	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations
VIII	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned
VII	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken
VI	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight
V	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop
IV	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably
III	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration

	estimated.
II	Felt only by a few persons at rest, especially on upper floors of buildings
I	Not felt except by a very few under especially favorable conditions

Today, world wide earthquake observation network is available. However, there are numbers of seismic intensity scales locally. In most cases, they are not inconsistent.

5. CONCLUSION

Precise and reliable measurements of vibration and acceleration are frequently required from diverse fields of industry and science. Reliable vibration measurements are also requested in variety fields of safe and commerce which is the entirety of the legislative, administrative and technical procedures established by, or by reference to public authorities. In this report, we described current situation of vibration measurement in Japan. Metrology standard is compatible internationally in terms of traceability to SI. However, some instruments used regulators are not compatible internationally.

Under the metre convention, National metrology standard has been effectively harmonized. Today, the harmonization in industrial standards, legal metrology and laboratory accreditation is progressing. In such activities, Global liaisons in each party including academia are very important. Figure 8 shows global liaisons on metrology. The IMEKO new technical committee TC22, "Vibration Measurement" is appreciated to materialize credibility and transparency of vibration measurement result in variety fields.

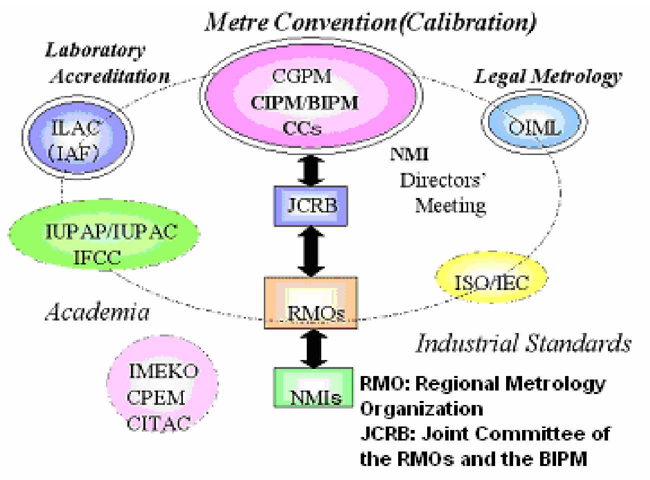

Fig. 8. Global liaisons on metrology

REFERENCES

[1] T. Usuda and T. Kurosawa, "Calibration methods for vibration transducers and their uncertainties", Metrologia, 36, pp. 375-383, 1999.

[2] T. Usuda, E. Furuta, A. Ohta and H. Nakano, "Development of laser interferometer for a Sine-approximation method", Proc. SPIE 4827, (Proc. of the 5th International Conference on Vibration Measurements by Laser Techniques: Advances and Applications) pp. 29-36, 2002.

[3] T. Usuda, A. Ohta, T. Ishigami, O. Fuchiwaki, D. Misaki, H. Aoyama, and S. Sato, "The current progress of measurement standards for vibration in NMIJ/AIST", Proc. SPIE 5503, (Proc. of the 6th International Conference on Vibration Measurements by Laser Techniques: Advances and Applications) pp. 30-38, 2004.

[4] Akihiro Ohta, Takashi Usuda, Tamio Ishigami, Hisayuki Aoyama, and Sojun Sato, DEVELOPMENT OF PRIMARY CALIBRATION SYSTEM FOR VIBRATION ACCELERATION STANDARD EXTENDING TO HIGHER FREQUENCY RANGE, Proc. of 12th International Congress on Sound and Vibration, 11-14th July, Lisbon Portugal, 2005.

[5] ISO16063-11: Methods for the calibration of vibration and shock pick-ups. Part 11: Primary vibration calibration by laser interferometry, International Organization for Standardization, 1999.

[6] ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories, 2005.

[7] ILAC Mutual Recognition Arrangement, http://www.ilac.org/.

[8] ISO/IEC 17011: Conformity assessment -- General requirements for accreditation bodies accrediting conformity assessment bodies, 2004.

[9] JIS C 1510: Vibration level meter, 1995.

[10] ISO 8041: Human response to vibration - Measuring instrumentation, 2005.

[11] Explanation Table of JMA Seismic Intensity Scale: http://www.kishou.go.jp/know/shindo/explane.html.

[12] USGS Earthquake Hazards Program, The Modified Mercalli Intensity Scale: http://earthquake.usgs.gov/learning/topics/mercalli.php.