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THE BILATERAL COMPARISON FOR CHARGE SENSITIVITY OF STANDARD ACCELEROMETER BETWEEN OLD SYSTEM AND NEW SYSTEM AT NIMT

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Abstract: National Institute of Metrology (Thailand), NIMT has two primary accelerometer calibration systems, old and new systems, using methods according to ISO16063-11. The differences between both systems are the calibration methods and the moving direction of exciter. This paper presents the comparison for charge sensitivity of standard accelerometer between two systems in order to investigate the effects of calibration methods and moving direction of exciter on the calibration results, to confirm the capability of the new system and to provide a link between two systems. Also the comparison results at the frequency range of 40 to 5,000 Hz are illustrated.

Keywords: calibration, standard, comparison, accelerometer.

1. INTRODUCTION

All National Institutes of Metrology in vibration filed use the standard methods for the primary calibration of accelerometer calibration according to ISO 16063 Past 11: Primary vibration calibration by laser interferometry [1]. This standard has three calibration methods for primary vibration calibration level. These methods are fringe-counting method, minimum-point method and sine-approximation method.

National Institute of Metrology (Thailand) (NIMT) has two systems for primary vibration calibration according to ISO16063-11. First system (old system), NIMT has used this system as a primary calibration standard system since 1990. This system uses the fringe-counting method in frequency range 40 Hz to 800 Hz and the minimum point method in frequency range 1,000 Hz to 5,000 Hz. The moving direction of exciter is horizontal direction. For second system, NIMT has used this system from 2005. This system uses the sine-approximation method in frequency range 0.4 Hz to 20,000 Hz. The moving direction of exciter is vertical direction.

Both systems can be used to calibrate the pickup sensor in primary level. But the difference things between both systems are the calibration methods and the moving direction of exciter. NIMT needs to investigate the effects of calibration methods and moving direction of exciter on the calibration results. Also NIMT needs to confirm the capability of the new system and to provide a link between two systems by performing the comparison for charge sensitivity of standard accelerometer between two systems.

2. METHODS AND CALIBRATION SYSTEMS IN COMPARISON

For this comparison, a set of two standard piezoelectric accelerometers are assigned as the artefact. These transducers are a “single ended” (SE) type, namely a Brüel & Kjær 8305-001, s/n 2644378 and a “back to back” (BB) type, namely a Brüel & Kjær 8305, s/n 2691032. In this comparison, no additional mass was attached to the top surface of BB type accelerometer. These accelerometers are calibrated for the complex charge sensitivity according to the procedures in conformance with ISO 16063-11 and the guide method in the Technical Protocol of the APMP Key Comparison APMP.AUV.V-K1.1 [2]. The frequency range of the measurements was from 40 Hz to 5 kHz at the following frequencies (all values in Hz):

40, 50, 63, 80, 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1,000, 1,250, 1,600, 2,000, 2,500, 3,150, 4,000, 5,000 (160 Hz is reference frequency).

Two primary calibration systems are used in this measurement. Both of them have details as shown in the following subsections.

2.1 OLD CALIBRATION SYSTEM

The Primary Vibration Transducer Calibration System of NIMT (old system) is Bruel & Kjaer, type 9636 [3]. The system was transferred from Department of Science Service, Thailand to NIMT in 1998. This system can be used for the calibration in the middle frequency range (40 - 5,000 Hz). Figure 1 shows the apparatus of this system. This system is a common Michelson laser interferometer with a single detector and an electro dynamic vibrator follows the guidelines given in ISO16063-11. The motion of vibrator is in the horizontal direction. Figure 2 shows the common Michelson laser interferometer. The calibration methods of this system are the fringe-counting method for the frequency range of 40 Hz – 800 Hz and the minimum point method for the frequency range of >800 Hz – 5,000 Hz.

Figure 1: Primary Vibration Transducer Calibration System of NIMT Type 9636

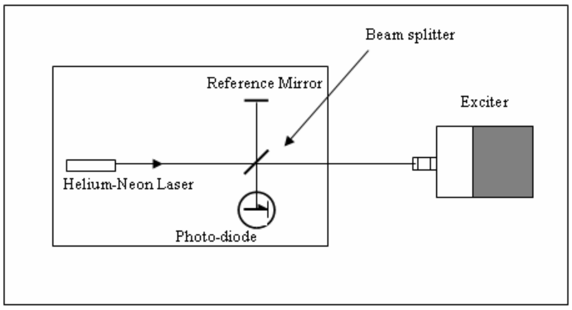

Figure 2: The common Michelson Laser Interferometer

2.2 THE NEW CALIBRATION SYSTEM

The new system is the Primary Calibration System for low-high frequency range from SPEAKTRA type CS18P HF&STF. This system can be used for low to high frequency range (0.4 Hz – 20,000 Hz). The calibration method is the sine approximation method for the frequency range of 0.4 Hz – 20,000 Hz according to ISO16063-11. However this system is used for 40 Hz to 5,000 Hz in this comparison. Figure 1 shows the apparatus of system. This system uses a Polytec vibrometer model CLV1000 as a reference standard and an Endevco air-bearing vibrator model 2911 by following the guidelines given in ISO16063-11. The motion of vibrator is in the vertical direction. Figure 3 shows the photograph of the new system. And Figure 4 illustrates the diagram of new calibration system.

Figure 3: Primary Calibration System for low-high frequency range of NIMT Type CS18P HF&STF

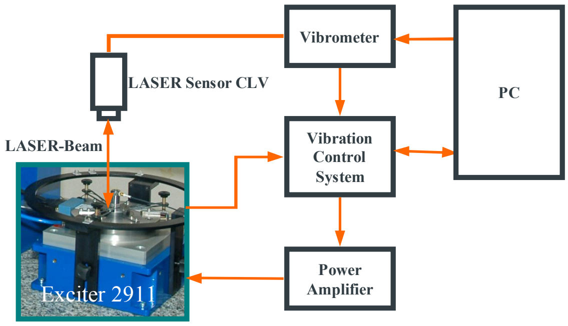

Figure 4: Diagram of new calibration system

3. RESULTS OF MEASUREMENTS

The measurement results for charge sensitivity of standard accelerometers between old system and new system are presented as the difference in charge sensitivity. The uncertainty budget of measurement for charge sensitivity with the coverage factor of k=2 are also illustrated. The value of uncertainty for each system is shown in percentage.

The difference of charge sensitivity is defined as the following equation.

$$\text{Diff}_{\text{sensitivity}} = S_{\text{old system}} - S_{\text{new system}}$$

where: $\text{Diff}_{\text{sensitivity}}$ is the Difference in charge sensitivity between old system and new system

$S_{\text{old system}}$ is the measured charge sensitivity of accelerometer done by old system.

$S_{\text{new system}}$ is the measured charge sensitivity of accelerometer done by new system.

3.1 RESULTS OF SINGLE END TYPE ACCELEROMETER

The sensitivity of single end type accelerometer model 8305 s/n 2644378 are approximately 0.1289 pC/m/s^2 for the frequency range 40 Hz to 1,000 Hz. However some deviations of the sensitivity exist from frequency 1,000 Hz to 5,000 Hz. The difference in charge sensitivity of both systems is shown in Table 1 and Figure 5.

The measured different charge sensitivity between old system and new system are between -0.00019 and 0.00019 pC/m/s^2. The highest difference is 0.0019 pC/m/s^2 or 0.15% at frequency 40 Hz and 1,600 Hz respectively for single end type accelerometer. The result of uncertainty is also shown in Table 1. The expanded uncertainty is between 0.31% - 0.74% for old system and between 0.48% - 0.54% for new system.

Frequency (Hz)	Difference in Charge Sensitivity (pC/ms^2)	Uncertainty of old system (%)	Uncertainty of new system (%)
40	-0.00019	0.33	0.48
50	-0.00008	0.32	0.48
63	-0.00003	0.32	0.49
80	0.00001	0.32	0.48
100	0.00000	0.32	0.49
125	0.00005	0.31	0.48
160	0.00017	0.31	0.48
200	0.00011	0.31	0.49
250	0.00006	0.31	0.49
315	0.00008	0.31	0.48
400	0.00009	0.31	0.49
500	0.00003	0.33	0.49
630	0.00017	0.33	0.48
800	0.00011	0.34	0.48
1000	0.00015	0.73	0.48
1250	0.00007	0.73	0.48
1600	0.00019	0.73	0.54
2000	0.00007	0.73	0.54
2500	0.00014	0.73	0.54
3150	0.00017	0.73	0.54
4000	0.00009	0.73	0.54
5000	0.00018	0.74	0.54

Table 1: The result of the difference charge sensitivity and uncertainty budget of single end type accelerometer model 8305 s/n 2644378 from old system and new system

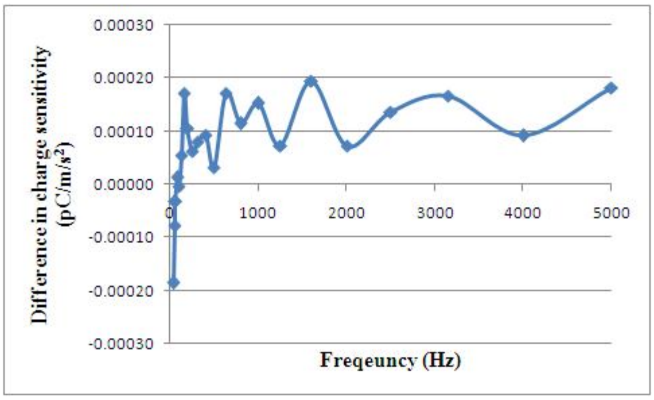

Figure 5: The difference charge sensitivity of single end type accelerometer model 8305 s/n 2644378 is measured from old system and new system.

3.2 RESULTS OF BACK TO BACK TYPE ACCELEROMETER

The value of back to back type accelerometer model 8305 s/n 2691032 are approximately 0.1276 $pC/m/s^2$ form 40 Hz to 1,000 Hz and there exist some deviation of the value from 1,000 Hz to 5,000 Hz.

The value of difference charge sensitivity between old system and new system are between -0.00009 – 0.00012 $pC/m/s^2$. The highest difference is 0.0012 $pC/m/s^2$ or 0.093% at frequency 160 Hz for back to back type accelerometer. The expanded uncertainty is between 0.31% - 0.73% for old system and between 0.49 % - 0.56% for new system. The result of difference charge sensitivity and uncertainty is also shown in Table 2.

Frequency (Hz)	Difference in Charge Sensitivity (pC/ms^2)	Uncertainty of old system (%)	Uncertainty of new system (%)
40	-0.00009	0.33	0.49
50	-0.00002	0.33	0.49
63	0.00003	0.32	0.49
80	0.00007	0.32	0.49
100	0.00006	0.32	0.49
125	0.00005	0.31	0.49
160	0.00012	0.31	0.49
200	0.00011	0.31	0.50
250	0.00010	0.31	0.49
315	0.00009	0.31	0.49
400	0.00006	0.31	0.49
500	0.00000	0.33	0.49
630	0.00009	0.33	0.49
800	0.00002	0.33	0.49
1000	0.00006	0.73	0.49
1250	0.00003	0.73	0.49
1600	-0.00001	0.73	0.54
2000	0.00011	0.73	0.56
2500	0.00004	0.73	0.55
3150	0.00005	0.73	0.55
4000	-0.00007	0.73	0.55
5000	0.00003	0.73	0.55

Table 2: The result of the difference charge sensitivity and uncertainty budget of back to back type accelerometer model 8305 s/n 2644378 from old system and new system

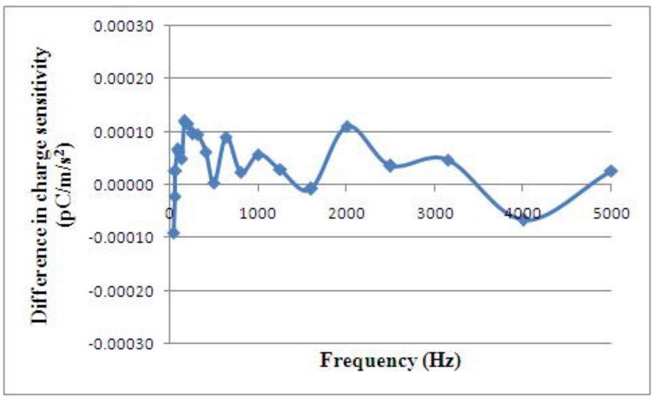

Figure 6: The difference charge sensitivity of back to back type accelerometer model 8305 s/n 2644378 is measured from old system and new system

For this experiment, the EN value is used to confirm the capability of the new system and to assess the calibration proficiency of new system. The EN value[4] is defined as the following equation.

$$E_n = \left| \frac{M_{new} - M_{old}}{\sqrt{U_{new}^2 + U_{old}^2}} \right|$$

where : M_{new} and M_{old} are the measured charge sensitivity of standard accelerometer done by new system and old system respectively.

U_{new} and U_{old} are expanded uncertainty of measurement declared by new system and old system respectively with the coverage factor = 2.

The calculated EN values of single end type accelerometer are shown in Table 3. The values are between 0.00 – 0.25. And the calculated EN values of back to back type accelerometer are shown in Table 4. The values are between 0.00 – 0.16.

Frequency (Hz)	En ratio
40	0.25
50	0.10
63	0.04
80	0.02
100	0.00
125	0.07
160	0.23
200	0.14
250	0.08
315	0.11
400	0.12
500	0.04
630	0.23
800	0.15
1000	0.14
1250	0.06
1600	0.17
2000	0.06
2500	0.12
3150	0.14
4000	0.08
5000	0.15

Table 3: The En ratio between old system and new system for single end type accelerometer model 8305 s/n 2644378.

Frequency (Hz)	En ratio
40	0.12
50	0.03
63	0.04
80	0.09
100	0.08
125	0.07
160	0.16
200	0.15
250	0.13
315	0.13
400	0.08
500	0.00
630	0.12
800	0.03
1000	0.05
1250	0.03
1600	0.01
2000	0.09
2500	0.03
3150	0.04
4000	0.06
5000	0.02

Table 4: The En ratio between old system and new system for back to back type accelerometer model 8305 s/n 2644378.

4. CONCLUSTION

The results of this bilateral comparison for charge sensitivity of a set of two standard accelerometers shows that the EN value is less than 1.0 for entire frequency range and the charge sensitivity between old system and new system are slightly different. The results are shown that the performance of new system is conforming with the performance of old system in frequency range 40 Hz to 5,000 Hz.

5. REFERENCES

[1] International Standard ISO16063-11:1999 “Methods for the calibration of vibration and shock transducers, Part 11: Primary vibration calibration by laser interferometry”

[2] Technical Protocol of the APMP Key Comparison APMP.AUV.V-K1.1.

[3] Bruel & Kjaer: Technical documentation : Primary Vibration Transducer Calibration System Type 9636.

[4] International Standard ISO/IEC Guide 43-1, Proficiency testing by interlaboratory comparisons Part1: Development and operation of proficiency testing schemes(1997).