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FEASIBILITY OF VIBRATION SENSOR ON-LINE CALIBRATION WITH BUILT-IN CALIBRATION COIL

Chenguang Cai/Presenter, Jingsheng Li, Lifeng Yang, Aibin Zuo, Qiao. Sun, and Hongbo Hu

National Institute of Metrology, Beijing, China, caichenguang@nim.ac.cn

Abstract: A kind of vibration sensors are widely used in seismic monitoring and environmental protection fields which have built-in calibration coils. But they could not be effectively calibrated or checked in the long term when they are placed on the monitoring locations. It is a choice to use the calibration coil to calibrate the senor on-line. In order to evaluate the feasibility, the sensitivities of the sensors are respectively calibrated by the low frequency vibration standard and calibration coils. The experiment results reveal the calibration coil method is effective in a certain frequency range depending on the dynamic characteristics of the structure of the sensor.

Keywords: vibration sensor, calibration coil, on-line calibration, sensitivity.

1. INTRODUCTION

Many vibration sensors are used in the fields such as seismic monitoring, environmental protection, fault diagnosis, which could not be calibrated or checked in the long term. So the early warning and fault diagnosis functions of the vibration monitoring system cannot effectively work.

In order to ensure the reliability of the vibration monitoring system, effective and feasible on-line calibration or check methods need be researched and applied.

In the seismic monitoring and environmental protection fields, a kind of vibration sensor has a built-in calibration coil, which is used to calibrate the sensitivity or other characteristics of the vibration measuring system.

It is a choice to use the calibration coil to calibrate this kind of senor on-line. In order to verify the feasibility of this method, in the paper the calibration results using low frequency vibration standard and the calibration coil methods are compared and analyzed. The experiment results reveal the calibration coil method is effective in a certain frequency range depending on the structure of the sensor.

2. OPERATION PRINCIPLE

The principle of servo velocity seismometers is illustrated in Fig 1 [1]. This kind of vibration transducers are based on inertia principle. A mass block, such as pendulum, vibrates under the inertia force which be produced by environmental vibration. The environmental vibration can be measured by measuring the vibration of the inertia mass. So in this kind of transducer, a coil is used to produce the equivalent electromagnetic force to simulate inertia force to vibrate the inertia mass.

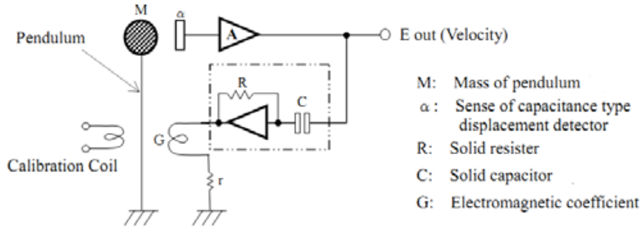

Figure 1 the principle of servo velocity seismometers

Similar to the servo velocity seismometers, all of seismometers, servo accelerometers, and electromagnetic vibration transducers based on inertia principle have sensing inertia mass to measure the inertia force. In this kind of vibration transducers, calibration coils are excited by sine electrical signals to produce the equivalent electromagnetic forces to simulate inertia forces, then the sensitivity, frequency responding and linearity of the vibration transducers can be calibrated.

Normally the function of the electromagnetic force and the vibration of the inertia mass are calibrated by gravity statically. Because of the system with several degrees of freedom, the dynamic and static characteristics are not totally same. As illustrated in Fig 2(a), the pendulum is installed on the shell of the transducer. Because the big shells, the resonance frequencies of the shells are lower. In frequency range, the effect of equivalent spring between the pendulum and the shell should be significant, illustrated in Fig 2(b); the electromagnetic force cannot truly simulate the vibration measured. In other words, the coil calibration method cannot reflect the effect of installing resonance on sensitivity.

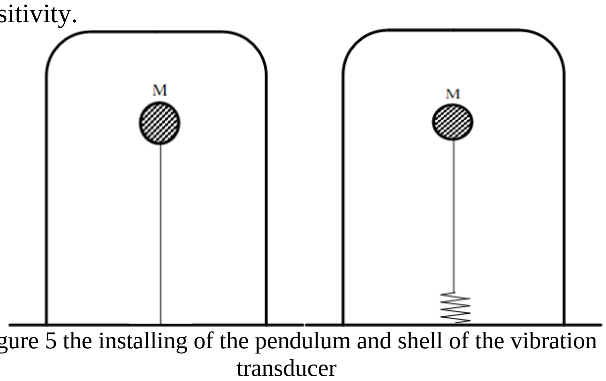

Figure 5 the installing of the pendulum and shell of the vibration transducer

So the experimental research is required to evaluate the effectiveness of the calibration coil method and the difference between calibration coil method and shaker calibration method.

3. EXPERIMENT RESULTS

Three triaxial vibration transducers with built-in calibration coils are respectively calibrated by NIM low frequency primary vibration standard and calibration coils. The experimental results are shown in Table 1 to Table 6 and Fig 3 to 11.

Table 1. the frequency response of senor 1 using coils

	Frequency (Hz)	Sensitivity (V/(m/s))		
1	0.01	4.36	4.47	4.40
2	0.1	5.06	5.08	5.08
3	1.0	5.07	5.08	5.07
4	10.0	5.18	5.16	5.17
5	30.0	5.15	5.13	5.13
6	70.0	5.08	5.05	5.04
Axis of the sensor		X	Y	Z

Table 2. the frequency response of senor 2 using coils

	Frequency (Hz)	Sensitivity (V/(m/s))		
1	0.01	4.31	4.39	4.47
2	0.1	5.10	5.10	5.04
3	1.0	5.10	5.09	5.04
4	10.0	5.18	5.19	5.13
5	30.0	5.14	5.17	5.10
6	70.0	4.99	5.12	5.03
Axis of the sensor		X	Y	Z

Table 3. the frequency response of senor 3 using coils

	Frequency (Hz)	Sensitivity (V/(m/s))		
1	0.01	4.50	4.48	4.44
2	0.1	5.06	5.08	5.04
3	1.0	5.06	5.08	5.04
4	10.0	5.13	5.16	5.14
5	30.0	5.10	5.12	5.11
6	70.0	5.01	5.03	5.04
Axis of the sensor		X	Y	Z

Table 4. the frequency response of senor 1 using shaker

	Frequency (Hz)	Sensitivity (V/(m/s))		
1	0.01	4.28	4.20	4.28
2	0.1	5.07	5.05	4.98
3	1.0	5.09	5.07	4.99
4	10.0	5.25	5.21	5.05
5	30.0	5.81	5.66	4.73
6	70.0	12.03	8.85	3.30
Axis of the sensor		X	Y	Z

Table 5. the frequency response of senor 2 using shaker

	Frequency (Hz)	Sensitivity (V/(m/s))		
1	0.01	4.33	4.12	3.88
2	0.1	5.07	5.10	4.96
3	1.0	5.08	5.11	4.97
4	10.0	5.22	5.23	5.04
5	30.0	5.77	5.46	4.77
6	70.0	10.78	8.43	3.80
Axis of the sensor		X	Y	Z

Table 6. the frequency response of senor 3 using shaker

	Frequency (Hz)	Sensitivity (V/(m/s))		
1	0.01	4.09	4.18	4.27
2	0.1	5.05	5.05	4.99
3	1.0	5.07	5.07	5.00
4	10.0	5.19	5.19	5.06
5	30.0	5.53	5.57	4.69
6	70.0	8.90	8.05	3.28
Axis of the sensor		X	Y	Z

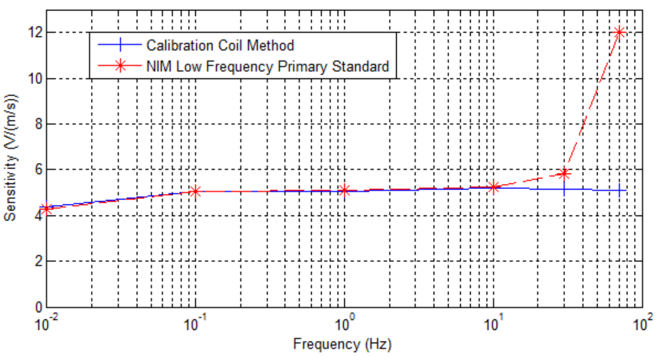

Figure 3 the frequency response of transducer 1 X direction calibrated by two calibration methods

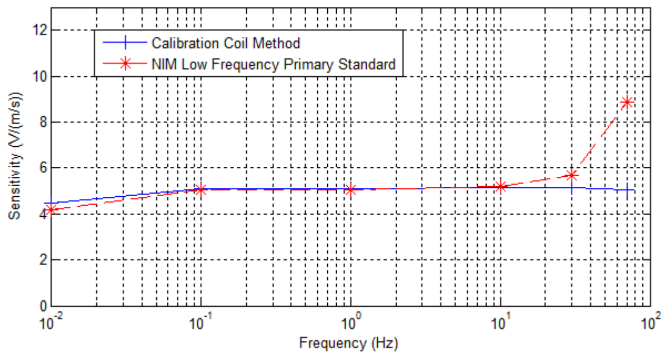

Figure 4 the frequency response of transducer 1 Y direction calibrated by two calibration methods

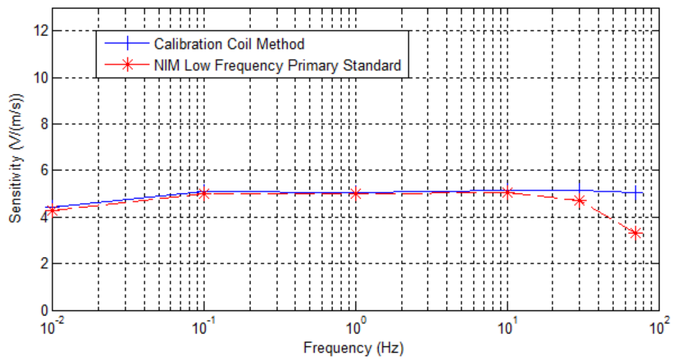

Figure 5 the frequency response of transducer 1 Z direction calibrated by two calibration methods

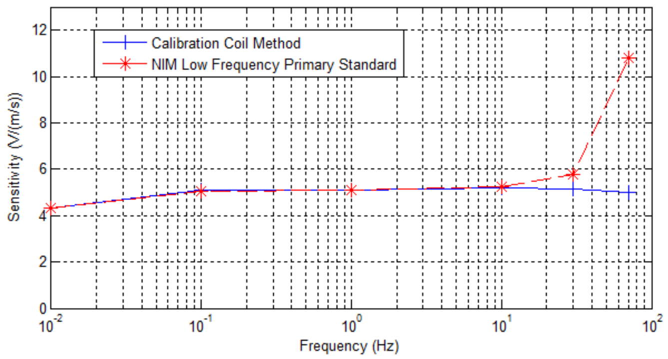

Figure 6 the frequency response of transducer 2 X direction calibrated by two calibration methods

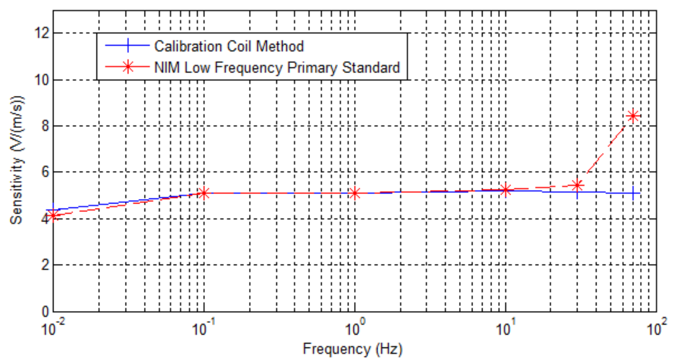

Figure 7 the frequency response of transducer 2 Y direction calibrated by two calibration methods

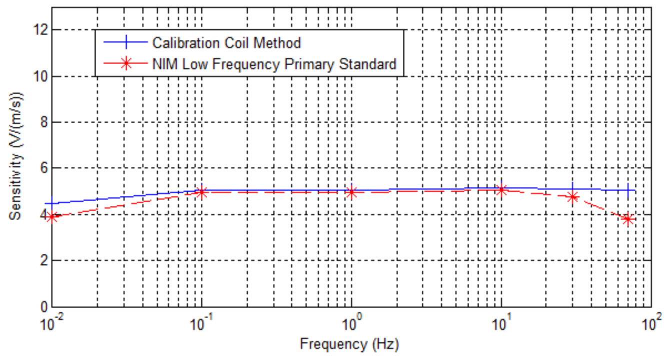

Figure 8 the frequency response of transducer 2 Z direction calibrated by two calibration methods

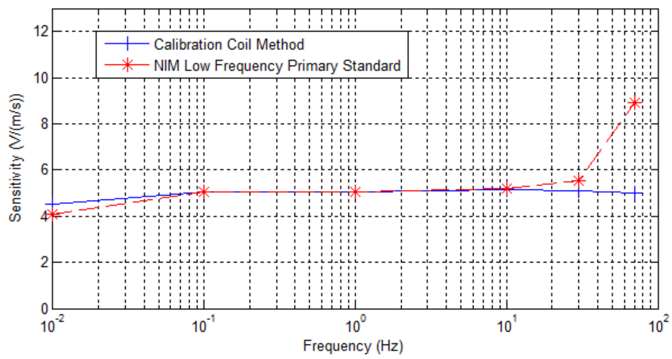

Figure 9 the frequency response of transducer 3 X direction calibrated by two calibration methods

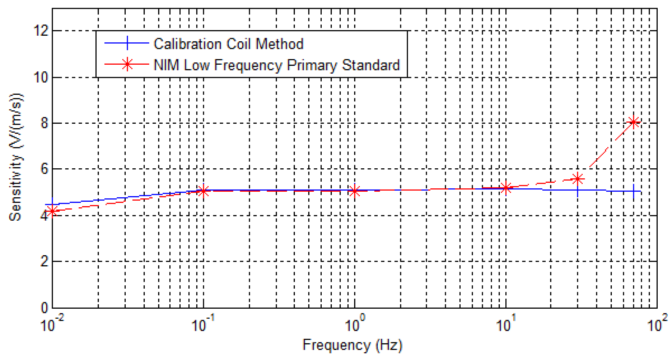

Figure 10 the frequency response of transducer 3 Y direction calibrated by two calibration methods

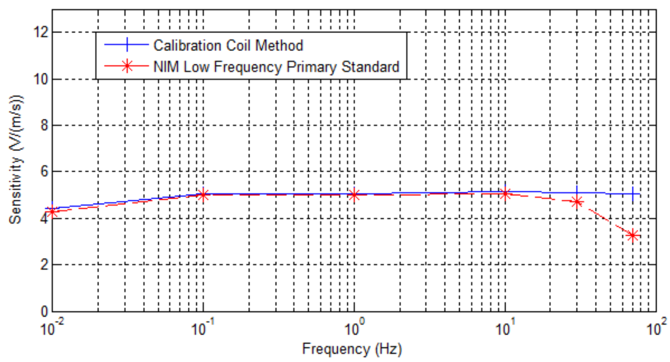

Figure 11 the frequency response of transducer 3 Z direction calibrated by two calibration methods

4. ANALYSIS AND CONCLUSIONS

The experimental results indicate:

1. There are system deviations between the two calibration methods from 0.1Hz to 30 Hz, but they can be revised.

2. At higher frequency (70Hz), the sensitivities gotten by calibration coils look good as other frequencies, but ones gotten by low frequency vibration standard have much big deviations. So it proves that at high frequencies the calibration coil method is not effective.

3. At 70Hz, the sensitivities of two horizontal axis of the sensors increase, but the sensitivities of the vertical axis of the sensors decrease. It proves that the structures of the sensors have different dynamic characteristics.

If the structures of the sensors are stable, the sensitivities of calibration coils can be calibrated using vibration standard in laboratories before the sensors are placed on the monitoring locations. Then the calibration coil method can be used to calibrate or check the sensors regularly on-line.

5. ON-LINE CALIBRATION METHOD

Requirements for vibration monitoring system with vibration transducers built in calibration coils:

1.) Calibration coil input ports of the vibration transducers must be provided.

2.) The monitoring system can display or output the responding signals of the vibration transducers, which can indicate the peak or RMS of the responding signals or has FFT function.

3.) The monitoring system need have a sine exciting signal output to excite the calibration coils, or a normal sine signal generator can be used to excite the calibration coils.

Calibration Process of the vibration transducers with built in calibration coils:

1.) Fist step: In a vibration calibration laboratory, the vibration transducer is calibrated by normal vibration standards with primary or comparison calibration method to get the sensitivity and frequency responding [2, 3].

2.) Second step: Using a sine signal generator to excite the calibration coil of the vibration transducer, the output of the vibration transducer is measured by a voltmeter or a DAQ system. According to the known sensitivity and frequency responding of the vibration transducer, the ratio (sensitivity) of the vibration magnitude of the inertia mass to the output signal magnitude of the transducer can be gotten.

3.) Third step: According to the ratio of the vibration magnitude of the inertia mass to the output signal magnitude of the transducer, adjusting the exciting signal magnitude, the sensitivity of exciting signal magnitude to the vibration magnitude of the inertia mass can be measured.

4.) Then, The function between the calibration results of normal vibration and the calibration coil can be determined, and the sensitivity of calibration coil can be calculated.

5.) On-line, just calibration coil method can be used to calibrate the vibration transducer regularly.

The example calibration system using calibration coil is illustrated in Fig 12.

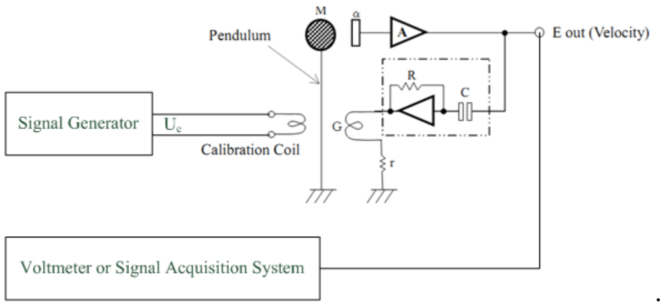

Figure 12 example calibration system using calibration coil

E out is the output of the vibration transducer with built in calibration coils.

Ue is the exciting signal of the calibration coils.

*S*v is the sensitivity of the vibration transducer calibrated by a vibration standard, *S*v =E out/Mv.

Mv is the motion of the vibration of the transducer.

*S*e is the sensitivity of the calibration coil, *S*e = Ue/Mi.

Mi is the motion of the inertia mass (such as a pendulum), velocity or acceleration.

According to the analysis, in the flat working frequency range of the vibration transducer, Mi = Mv is established. Then

$$S\text{e} = \frac{\text{Ue}}{\text{E out}} S\text{v} \qquad (1)$$

$$S\text{v} = \frac{\text{E out}}{\text{Ue}} S\text{e} \qquad (2)$$

Based on formula (1), the sensitivity of the calibration coil can be calibrated in a vibration metrology laboratory.

Based on formula (2), the vibration transducer can be calibrated on-line.

6. CONCLUSIONS

To evaluate the feasibility of on-line calibration of the vibration sensors with built-in calibration coils, three triaxial vibration transducers with built-in calibration coils are respectively calibrated by NIM low frequency primary vibration standard and calibration coils to compare the differences between the two calibration methods. The experiment results reveal the calibration coil method is effective in a certain frequency range depending on the dynamic characteristics of the structure of the sensor, which are inherent in the system. The sensitivities of calibration coils can be calibrated using vibration standard in laboratories before the sensors are placed on the monitoring locations. Then the calibration coil method can be used to calibrate or check the sensors regularly.

REFERENCES

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[2] ISO 16063-11-1999-Methods for the calibration of vibration and shock transducers -- Part 11- Primary vibration calibration by laser interferometry.

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