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A ROUND ROBIN TEST OF SHOCK ACCELERATION CALIBRATION AMONG TWO PRIVATE LABORATORIES AND NMIJ

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Abstract – Shock acceleration measurements are required for evaluating product drop tests and automobile collision tests, and the need for precise shock acceleration measurements continue to increase in the Japanese industries. Thus, it is important to confirm the equivalence of measurement technology among manufacturing corporations, private testing laboratories and national metrology institutes. For this purpose, a round robin test of shock acceleration calibration was carried out among the two Japanese private laboratories (“Foresight Techno”, “Shinyei Technology”) and the National Metrology Institute of Japan (NMIJ). In the round robin test, the calibrated sensitivities were compared in shock accelerations from 500 m/s² to 5000 m/s², and agreed with a difference of less than 0.17% and $En < 0.1$.

Keywords: shock acceleration, pick-up, accelerometer, round robin

1. INTRODUCTION

Primary calibration of pick-ups for vibration and shock acceleration [1, 2] is prescribed by either transient mechanical excitation or optical measurement in standards published by the International Organization for Standardization (ISO). Although private testing companies in industries calibrate pick-ups using a reference pick-up which is given with the calibration uncertainty by other private laboratories, the calibration results on the same testing conditions are not particularly compared among the private testing companies. Thus, it is important to confirm the equivalence of measurement technology among private testing companies and national metrology institutes. For this purpose, a round robin test of shock acceleration calibration was carried out among the companies Foresight Techno, Shinyei Technology and the National Metrology Institute of Japan (NMIJ). In the round robin test, calibration results were compared for peak accelerations of 500 m/s², 1000 m/s², 2500 m/s² and 5000 m/s². Each shock

acceleration has a duration ranging from 0.6 ms to 1.8 ms in which the time scale corresponds to several hundreds Hertz. The Device Under Test (DUT) is a back-to-back type pick-up of model 8305 (Brüel & Kjær). The pick-up outputs an electric voltage through a model 2525 charge amplifier (Brüel & Kjær) which acts as an accelerometer. The pick-up generally has the charge sensitivities for flat frequency characteristics less than 1 kHz band. In the results of the round robin test, the effect of the frequency characteristics on the DUT was negligible.

2. THREE SHOCK ACCELERATION CALIBRATION SYSTEMS

NMIJ developed a shock acceleration calibration system [3, 4] for the primary calibration of instruments using transient accelerations with a peak from 200 m/s² to 5000 m/s². That range is appropriate for various industries involving mechanical as well as electrical applications based on MEMS technology. In particular, the calibration technology in this range is in strong demand by the Japanese automobile industry.

As shown in Fig. 1, the calibration system uses a shock exciter which generates shock accelerations using collision motion between two rigid bodies supported by air bearings for high stiffness. A modified Homodyne He-Ne laser interferometer with two quadrature outputs is installed for displacement measurements. The quadrature outputs are recorded by a digitizer with a maximum sampling frequency of 125 MHz and a vertical resolution of 16 bits (with a maximum input voltage of ± 16 V). The sampling frequency is controlled by an external clock which is in sync with the national time standard. To obtain an appropriate sensitivity of the pick-up, a low-pass filter with a cut-off frequency of 5000 Hz is applied to the signal processing of the quadrature outputs and the accelerometer output. In most cases, the typical calibration uncertainty using the NMIJ setup appears to be less than 0.8%.

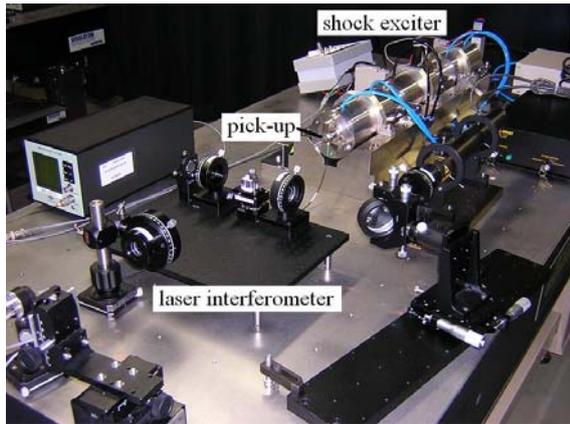


Fig. 1 Shock acceleration calibration system of NMIJ

Two private companies, Foresight Techno and Shinyei Technology, provide accelerometer calibration equipment using shock acceleration. These companies also provide services for product evaluations, such as drop tests, and field support of electric measurements.

The Foresight Techno’s system (see Fig. 2) is a secondary calibration system using the company standard of 2270 (Endevco), and generates peak accelerations from 200 m/s² to 100000 m/s² with a duration of 3 ms to 0.1 ms. The shock accelerations are adjusted by air pressure for the hammer excitation and the anvil mass. The pick-up to be calibrated is attached on the top surface of the anvil.

The Shinyei Technology’s calibration system, PST-300, (see Fig. 3) generates peak accelerations from 50 m/s² to 50000 m/s² with a duration ranging from of 11 ms to 0.2 ms. The shock accelerations are induced by a pendulum hammering, and the magnitude of the shock acceleration is controlled by changing the pendulum angle and a programmer. This calibration system is also used for secondary calibration using the 2270 (Endevco) pick-up as the company standard.



Fig. 2 Shock acceleration calibration system of Foresight Techno.



Fig. 3 Shock acceleration calibration system of Shinyei Technology.

3. INVESTIGATION OF SENSITIVITY DEPENDENCE ON FREQUENCY

The round robin test was carried out on the basis of shock accelerations of 500 m/s², 1000 m/s², 2500 m/s² and 5000 m/s². Table 1 shows the duration used for the three calibration systems. Since pick-ups generally have sensitivity dependence on frequency, duration strongly affects the charge sensitivity of the pick-up [5, 6]. As shown in Fig. 4, the charge sensitivity of the pick-up increases when the frequency is greater than 1 kHz. Meanwhile, the charge sensitivity is flat when the frequency is less than 1 kHz. Figure 5 (a) shows each typical acceleration waveform of 500 m/s² and 5000 m/s² on the NMIJ calibration system. Since it is important to investigate the frequency component of the shock acceleration, the frequency component of the two acceleration waveforms is calculated by Fast Fourier Transform (FFT), as shown in Fig. 5 (b). The longest duration is 8.8 ms for acceleration of 500 m/s² on the Shinyei Technology calibration system. Even the duration of 0.6 ms for an acceleration of 5000 m/s² on the NMIJ does not contribute to the frequency component above 1 kHz. Therefore, the sensitivity change due to high frequencies is probably small.

	NMIJ	Foresight techno	Shinyei technology
500 m/s ²	1.8 ms	3.7 ms	8.8 ms
1000 m/s ²	1.5 ms	3.1 ms	4.7 ms
2500 m/s ²	1.2 ms	2.2 ms	2.4 ms
5000 m/s ²	0.6 ms	1.4 ms	1.9 ms

Table 1 Durations of shock acceleration in each calibration system among NMIJ, Foresight Techno and Shinyei Technology.

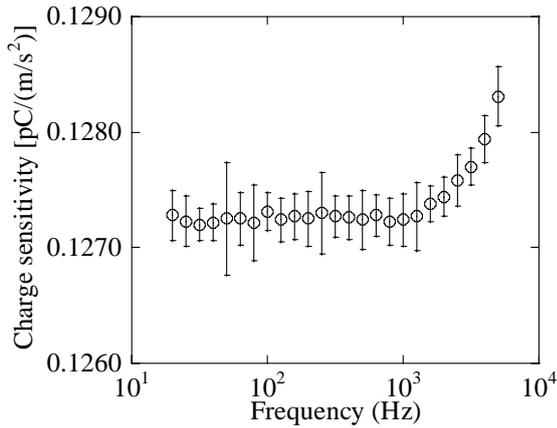


Fig. 4 Charge sensitivity with expanded uncertainty for $k = 2$ in the vibration calibration from 20 Hz to 5 kHz.

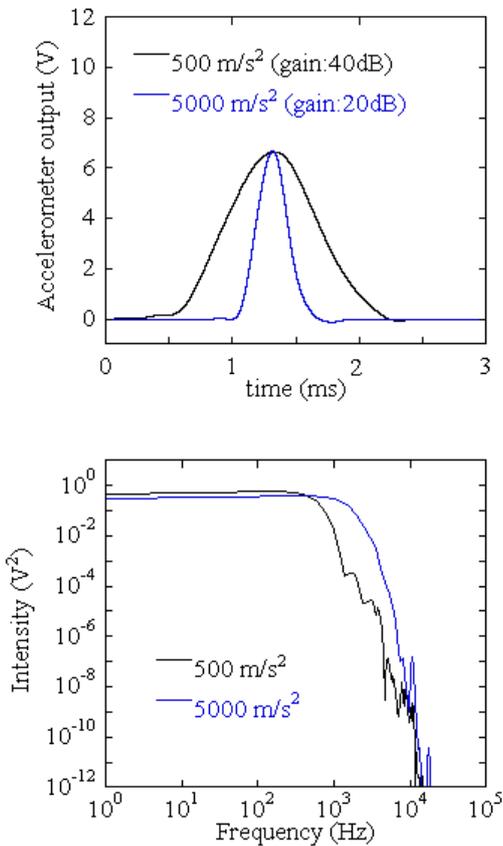


Fig. 5 (a) Typical accelerometer outputs for 500 m/s^2 and 5000 m/s^2 . Each output is filtered using a low-pass digital filter with a cut-off frequency of 5 kHz. (b) Spectrum of the two accelerometer outputs obtained using FFT.

4. COMPARISON RESULTS

Figure 6 presents a comparison of the results in shock calibration among the NMIJ (red), Foresight Techno (blue) and Shinyei Technology (green) calibration systems. As reference values, the charge sensitivities (pink) to be calibrated by vibration accelerations of 10 m/s^2 (160 Hz), 50 m/s^2 (500 Hz) and 100 m/s^2 (1kHz) are also plotted. Each error bar stands for the expanded uncertainty with a coverage factor of 2 ($k = 2$). In the data from the NMIJ system, the expanded uncertainties in vibration and shock calibrations are roughly 0.3% and 0.6%, respectively. To evaluate consistency among the calibrated charge sensitivities, En values are calculated as follows:

$$En = \left| \frac{S_a - S_b}{\sqrt{U_a^2 + U_b^2}} \right|, \quad (1)$$

where S is the charge sensitivity and U is the expanded uncertainty. The subscripts a and b refer to any two data points in either the NMIJ, Foresight Techno or Shinyei Technology. Therefore, all the comparisons are consistent with $En < 0.17$.

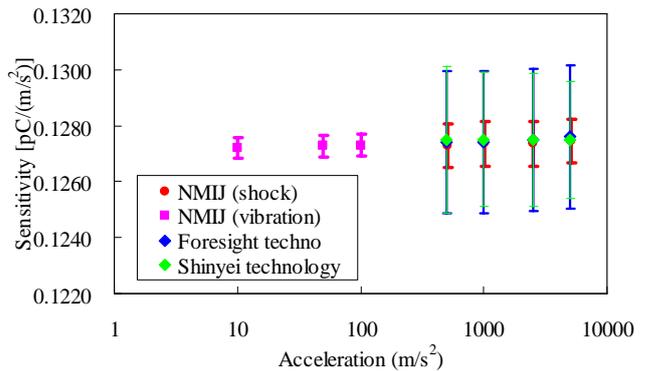


Fig. 6 Comparison of charge sensitivity with expanded uncertainty for $k = 2$ in shock calibration among the NMIJ, Foresight Techno and Shinyei Technology calibration systems.

5. CONCLUSIONS

This report describes the consistency in shock calibration values among NMIJ, Foresight Techno and Shinyei Technology calibration systems. In the vibration calibration for the case of the pick-up model 8305 (Brüel & Kjær), it is observed that a frequency bandwidth of less than 1 kHz does not affect the sensitivity change. In this comparison, since frequency components less than 1 kHz is dominant in the shock acceleration calibration result of NMIJ, the sensitivity change due to high frequency components more than 1 kHz would be negligible. Furthermore, since the duration of NMIJ is the shortest among the three laboratories, the charge sensitivities of Foresight Techno and Shinyei Technology do not probably include high frequency

components more than 1 kHz. Thus, in the relevant frequency bandwidth of the shock accelerations, the charge sensitivity dependence on the acceleration magnitude is small between 10 m/s^2 and 5000 m/s^2 , and the difference of the charge sensitivities between 10 m/s^2 and 5000 m/s^2 is around 0.2%.

As developmental future work, we plan further comparison of shock acceleration calibration on various excitation conditions and accelerometer types in Japanese industries.

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