

PROFICIENCY TEST AMONG CENTRIFUGE CALIBRATION LABORATORIES

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Abstract – A proficiency test was carried out to check proficiency of centrifuge calibration among four participants in Japan; KYOWA, TTDC, JARI and NICS, as a pilot laboratory of AIST. AIST provides reference value to the test by using primary shock calibration system. As a result, the proficiency for all participants was evaluated by using z-scores. The z value for respective participants is estimated to be below 2. This means all participants have enough proficiency for centrifuge calibration.

Keywords: Safety, Car crash test, Shock calibration, Centrifuge calibration, Piezoresistive accelerometer

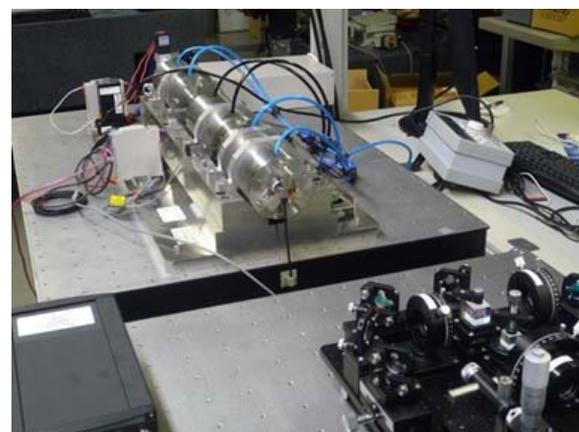
1. INTRODUCTION

Car crash test (Vehicle collision test) is carried out to keep safety of the car and save human life. Accelerometer is key component in the test. For example, head injury criteria (HIC), which is estimated from accelerometer output signal, is used as most important index of safety. Therefore, the calibration of accelerometer characteristics (especially frequency response and linearity) is a most serious issue for the related industry.

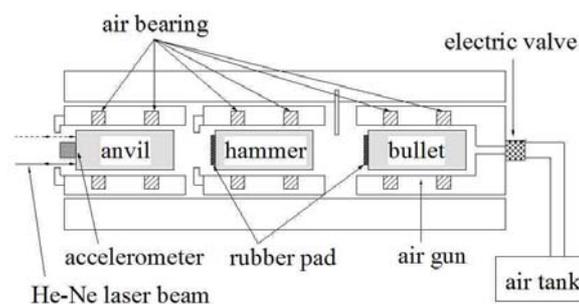
In Japan, vibration acceleration calibration in accordance with ISO 16063-11 [1] and -21 [2] has been used frequently applied to calibrate the frequency response of the accelerometers. On the other hand, centrifuge calibration in accordance with ISO 5347-7 [3] has been also used to calibrate linearity of accelerometer output to acceleration amplitude as de facto standard for long years in Japan. This method, to calibrate accelerometer by applying a uniform centrifuge acceleration using apparatus such a rotational table, is categorized as a static calibration method.

Recently, however, the validity on practical use of the centrifuge calibration would be doubtful by the related industry, due to that the shock acceleration signal from car crash test includes the various frequency series components. The proficiency of domestic centrifuge calibration laboratories has not been verified in Japan yet. In this paper, to clarify validity on its practical use, proficiency test is

carried
out
among
four



(a) photo of shock calibration system



(b) shock exciter element

Figure 1 Schematic drawing of shock calibration system

domestic private calibration laboratories by using reference value based on national shock acceleration standard in Japan.

2. CALIBRATION METHOD AND PROCEDURE

2.1. Shock acceleration calibration

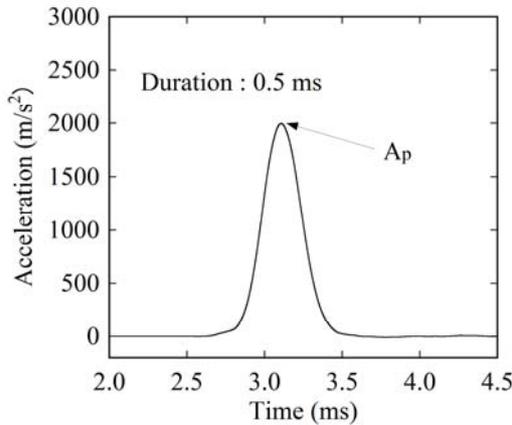


Figure 2 Shock waveform measured by laser interferometer

Shock acceleration calibration is categorized as dynamic calibration method, in which pulse acceleration consists of

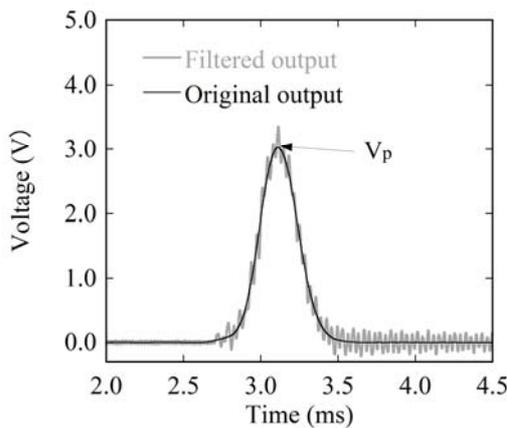


Figure 3 Voltage waveform from accelerometer

various frequency components is given to accelerometer. Figure 1 shows a schematic drawing of our shock acceleration calibration system [4]. This system is a primary calibration system in accordance with ISO 16063-13 [5]. In this system, pulse acceleration is generated by air gun using compressed air in air tank and a hammer takes a rigid body collision with anvil, in which accelerometer is attached on the top surface, a hammer, and a bullet are statically supported by air bearing with air gap of below 10 μm . Therefore this system enable to generate a smooth shock motion with high repeatability. Acceleration given to accelerometer is measured on the top surface of an anvil by laser interferometer system with He-Ne laser. Both output signals from laser interferometer and accelerometer are recorded by digitizer with high vertical A/D resolution of 16 bit, high sampling rate up to 50 MHz and full scale input voltage range of ± 32 V. Finally, sensitivity of the accelerometer is obtained through signal processing with recorded data.

Figure 2 shows a typical shock acceleration waveform measured by laser interferometer at nominal peak

acceleration of 2000 m/s^2 . Duration time of this waveform is about 0.5 msec. Figure 3 shows a voltage waveform from

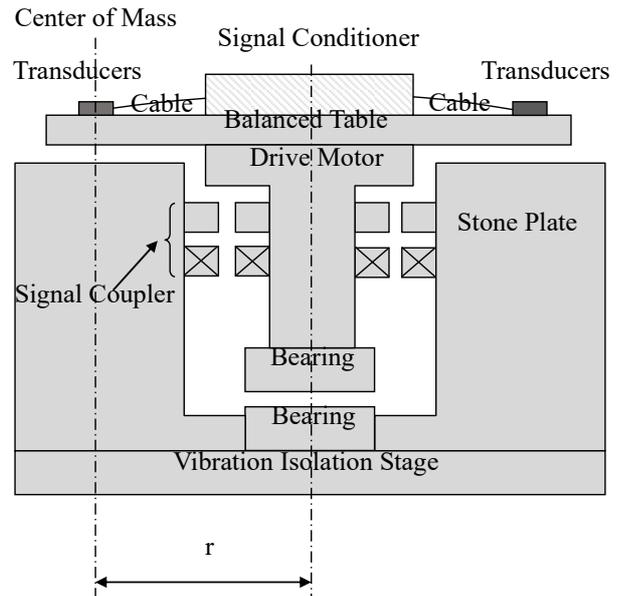


Figure 4 Schematic design of centrifuge calibration system

accelerometer, simultaneously recorded by digitizer. Shock sensitivity is obtained from ratio of peak value of the voltage waveform to that of acceleration waveform. In this proficiency test, the shock sensitivity is obtained as an average of 10 times measurement.

2.2. Centrifuge acceleration calibration

Centrifuge acceleration calibration is the method to obtain sensitivity of accelerometer by applying it a uniform centrifuge acceleration with apparatus such as a rotational table. The accelerometer to be calibrated by this method has zero-frequency response and is mainly strain gauge type or piezoresistive type of accelerometer. This method is applicable for a calibration range from 10 m/s^2 to 20000 m/s^2 .

In Japan, many calibration laboratories related automobile industry use centrifuge calibration systems as shown in figure 4. In this system, balanced table is supported by air-bearing. The accelerometer to be calibrated and its same type of dummy accelerometer are mounted on balanced table, to be symmetric with respect to a rotation axis of balanced table. The bridge voltage from signal conditioner is given to the accelerometer and output voltage from signal conditioner is amplified and modulated after conversion by ADC (analogue to digital converter). Then the output signal is transmitted via signal coupler (rotary transformer) to outside of rotational table and recorded in PC after demodulation. Applied centrifuge acceleration is obtained by multiplying radius of rotation to the centre of the accelerometer mass element with rotational frequency.

3. PROFICIENCY TEST

3.1. Participants and purpose

This proficiency test is carried out by AIST as pilot laboratory. Four domestic private calibration laboratories in Japan, KYOWA Electronic Instruments, TOYOTA Technical Development Corporation (TTDC), Japan Automobile Research Institute (JARI) and NISSAN Creative Service (NICS), participated in it.

Table 1 Devices under test

Type	Serial number	Manufacturer
ASD-B-1KV	GF3760022	KYOWA
ASD-B-1KV	GF4190169	KYOWA
7264C-2000	P80928	Meggitt
7264C-2000	P80929	Meggitt

The purpose of the proficiency test is to clarify validity of centrifuge calibration on practical use by comparing the results from the private calibration laboratories with reference value from national shock acceleration standard.

3.2. Device under test and Measurement conditions

Before the proficiency test, several kinds of accelerometer, which are frequently used in car crash test, were investigated as for frequency characteristics using primary vibration calibration in AIST. As a result, two kinds of accelerometer are selected as device under test (DUT). Table 1 shows a list of DUT. These DUT have stable frequency characteristics in less than 1 kHz. In the test, bridge voltage for DUT is fixed for 10 V. Gain for signal conditioner is specified according to kind of DUT. Cut off frequency of low pass filter for signal conditioner is also fixed for 100 kHz. Measurement quantity is voltage sensitivity. Acceleration level is agreed to be following point;

1000, 2000, 3000, 4000, 5000 m/s².

Ambient temperature during calibration and relative humidity are specified for 23 °C ± 3 °C and max. 50 % ± 25 %, respectively.

3.4. Analysis

In this test, the proficiency for all participants is evaluated by using z-scores [6]. The z value is obtained from following equation;

$$Z = \frac{x - X}{\sigma}$$

where x indicates measurement results from participants, X indicates reference value provided from AIST, and σ indicates standard deviation for this proficiency test.

In the z-score, proficiency of each participants is categorized on the basis of following criterion for judgement.

$|Z| \leq 2$: satisfactory result

$|Z| > 2$: questionable result

$|Z| \geq 3$: unsatisfactory result

4. COMPARISON RESULTS

Table 2, 3, 4 and 5 shows z values of participants for each DUT. The z values of all participants are estimated to be satisfactory results of below 2.

Figure 5 and 6 show typical linearity of voltage sensitivity between shock calibration and centrifuge calibration for respective kind of DUT. For ASD-B-1KV, the centrifuge calibration results is good agreement with the shock calibration results. For 7264C-2000, however, remarkable deviation of about 0.5 % between both calibration results is confirmed. The source of this deviation should be discussed in future.

5. CONCLUSIONS

A proficiency test was carried out to verify proficiency of centrifuge calibration among four participants in Japan;

Table 2 z score of ASD-B-1KV (sn:GF3760022)

Acceleration m/s ²	ASD-B-1KV (sn:GF3760022)			
	KYOWA	TTDC	JARI	NICS
1000	0.28	0.18	0.23	0.35
2000	0.08	0.10	0.03	0.17
3000	0.16	0.23	0.15	0.24
4000	0.12	0.21	0.11	0.20
5000	0.09	0.21	0.08	0.18

Table 4 z score of 7264C-2000 (sn:P80928)

Acceleration m/s ²	7264C-2000 (sn:P80928)			
	KYOWA	TTDC	JARI	NICS
1000	-0.77	-0.89	-0.74	-0.50
2000	-0.45	-0.61	-0.39	-0.29
3000	-0.64	-0.80	-0.56	-0.51
4000	-0.70	-0.87	-0.61	-0.51
5000	-0.83	-0.99	-0.75	-0.68

KYOWA, TTDC, JARI and NICS. AIST provides reference

Table 5 z score of 7264C-2000 (sn:P80929)

Acceleration m/s ²	7264C-2000 (sn:P80929)			
	KYOWA	TTDC	JARI	NICS
1000	-0.67	-0.60	-0.59	-0.38
2000	-0.69	-0.71	-0.54	-0.43
3000	-0.81	-0.87	-0.68	-0.57
4000	-0.63	-0.71	-0.48	-0.39
5000	-0.79	-0.89	-0.63	-0.55

value to this test by using primary shock calibration system. The proficiency of participants was estimated by using z-score. As a result, the z value for respective participant was

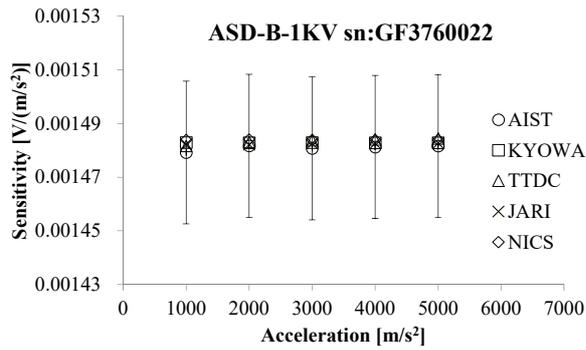


Figure 5 Typical comparison results for ASD-B-1KV

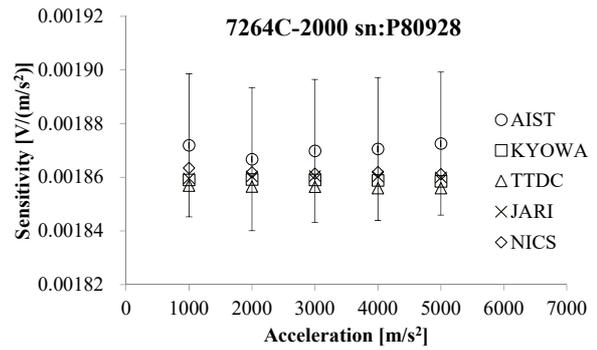


Figure 6 Typical comparison results for 7264C-2000

confirmed to be satisfactory result of below 2. For a kind of DUT, however, remarkable deviation of 0.5 % between centrifuge calibration results and shock calibration results was observed. The cause of them should be discussed in future.

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