Durability Over Time of Skin Used for JAMA–JARI Pedestrian Headform Impactor Measured by Biofidelity Certification Testing

Yasuhiro Matsui
Japan Automobile Research Institute
Masaaki Tanahashi
Japan Automobile Manufacturers' Association, Inc.
Japan

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ABSTRACT

Head injuries are the most common cause of pedestrian deaths in car–pedestrian accidents. To reduce the severity of such injuries, the ISO, IHRA and Japan MLIT proposed subsystem tests in which a headform impactor is impacted upon a car bonnet top. JAMA and JARI have developed the headform impactors in compliance with the ISO standard, the IHRA recommendation and the Japan MLIT safety regulation. The impactor consists of the core and skin. Since the skin is made of nonferrous material, the stiffness of the skin would be changed due to time elapse. The stiffness of the skin was confirmed by assessing the peak resultant acceleration of the gravity center measured in the biofidelity certification test, the so-called drop certification test. The ISO, IHRA and Japan MLIT specified the corridor of the peak acceleration impact must range from 245 to 300 G for a child headform impactor. In the present study, the newly developed skin durability over time at 0 month, 13, 16, 19, 22, 25, 28 and 31 months after manufacture was investigated in a room either with or without control of temperature and humidity. The results indicated that the peak acceleration impact using the two skins immediately after manufacture was 270 G. The peak acceleration of 287 G using the skin kept in a room with control of temperature and humidity increased 17G at 31 months after manufacture. The peak acceleration impact of 288 G using the skin kept in a room without control of temperature and humidity increased 18 G at 31 months after manufacture. The respective increases of 17 G and 18 G correspond to 31% and 33% of the range of certification test corridor (55 G), respectively. These results indicate that if the acceleration is close to the middle of the drop certification corridor (272.5 G) immediately after purchase by a testing facility, the skin is available for pedestrian impact test use with a storage period of at least 31 months. The results also suggest that if the acceleration is close to the upper limit of the drop certification corridor (300 G), the skin expiration time may be drawing very near. The findings also indicated temperature and humidity did not significantly affect the skin durability over time.

INTRODUCTION

Head injuries are the most common cause of pedestrian deaths in car-pedestrian accidents, and countermeasures against them are of the highest priority in traffic safety strategy [1]. The key element in this strategy is improvement of the safety performance of the car front. To reduce the severity of pedestrian head injuries in bonnet top contacts, the International Organization for Standardization (ISO) [2][3] and International Harmonized Research Activities (IHRA) [4] have proposed subsystem tests in which a headform impactor is impacted upon a car bonnet top. The ISO and IHRA have specified the biofidelity requirements for the headforms in terms of the peak value of the resultant centre of gravity (CG) acceleration measured in biofidelity certification tests (hereafter referred to as the drop certification test).

In 2004, the Japan Ministry of Land, Infrastructure and Transport (Japan MLIT) officially announced the Japanese safety regulation for the evaluation of car–front safety performance in terms of pedestrian head protection. The Japanese standard requires headform impactors to be in compliance with the IHRA specification. The IHRA required the specification of headform impactor for mass, diameter, moment of inertia, location of center of gravity, seismic mass location of accelerometer, first natural frequency and resultant acceleration in the biofidelity certification test as listed in Table 1. The same table also indicates that any impactor built according to the IHRA proposal [5] fulfills the ISO specifications [2][3]. The Japan Automobile Manufacturers' Association (JAMA) and the Japan Automobile Research Institute (JARI) have thus far jointly developed headform impactors which are compliant with the ISO/IHRA/Japan MLIT requirements (hereafter referred to as the JAMA–JARI headform impactor) [6]. The JAMA–JARI headform impactor consists of the core (sphere and baseplate) and the skin which is made of polyvinyl chloride (PVC) (Figure 1). Skin stiffness was confirmed by assessing the peak resultant acceleration of the gravity center measured in the drop certification test. Since the skin material is nonferrous, the skin impact durability and

Table 1 Pedestrian headform impactor measurement parameters required by ISO, IHRA, Japan MLIT, and parameters measured in present and other [6, 7] studies

Measured parameter	Required by ISO	Required by IHRA	Required by Japan MLIT	Investigation: Prototype JAMA-JARI headform
1) Mass	✓	✓	✓	Reference [6]
2) Diameter	✓	✓	✓	
3) Moment of inertia		✓	✓	
4) Location of centre of gravity	✓	✓	✓	
5) Seismic mass location of accelerometer		✓	✓	
6) First natural frequency		✓	✓	
7) Resultant acceleration in biofidelity test (drop test)	✓	✓	✓	
8) Shore hardness of skin				Reference [7]
9) Quasi-static compression characteristic of skin				
10) Resultant acceleration in high velocity certification test				
11) Impact durability of skin				
12) Durability over time of skin				Present study

ISO: International Organization for Standardization
IHRA: International Harmonized Research Activities
Japan MLIT: Japan Ministry of Land, Infrastructure and Transport

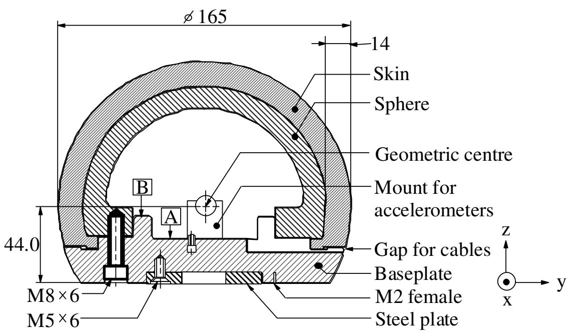

Figure 1. Schematic design of JAMA-JARI child headform impactor (unit: mm).

skin durability over time should be clarified. Matsui et al. [7] investigated some skin characteristics (see Table 1: measured parameters from eighth to eleventh) used for the JAMA–JARI headform impactor, which involves the skin impact durability against a car bonnet. This result indicated that when the drop certification test was run following a total of 50 impacts of the JAMA–JARI headform impactor against the car bonnet, the peak resultant acceleration decreased a mean 13 G. However, the durability over time of the skin used for the JAMA-JARI headform impactor has not been investigated to date, since a certain time must elapse after the development of the skin. Therefore, the aim of the present study is to clarify the durability over time of the skin used for JAMA-JARI headform impactors (see Table 1: twelfth measured parameter). The present study first discussed the suitable method for the durability over time of the skin, and second investigated the durability over time of newly developed skin for 31 months after manufacture.

METHOD

Verification of Biofidelity Certification Test

The purpose of this section is to determine a suitable method to measure the skin durability over time. A drop certification test was utilized by ISO/IHRA/Japan MLIT (Figure 2) to investigate scatter in drop certification testing, scatter in skin reproducibility and recovery of skin after impact by means of the JAMA–JARI child headform impactor.

Scatter in drop certification testing

The drop certification test setup was shown in Figure 2. The headform impactor was dropped by instant release from a height of 376 mm onto a rigidly–supported, flat horizontal steel plate (55 mm thick and 610 mm^2) with a clean dry surface using a drop angle of 60°, i.e., close to the mean drop angle proposed by the ISO (54°) and category 1 of the IHRA (65°). To investigate possible scatter in the drop certification testing, we performed fifteen repeated tests of the headform impactor. One newly manufactured skin was employed. The skin was not removed from the sphere of the headform impactor during the present investigation. The impact point of the skin surface was the same throughout all fifteen tests. The time interval of each test was 24 hours to avoid the possible effect of delayed recovery of skin after impact on the present test results. To avoid the

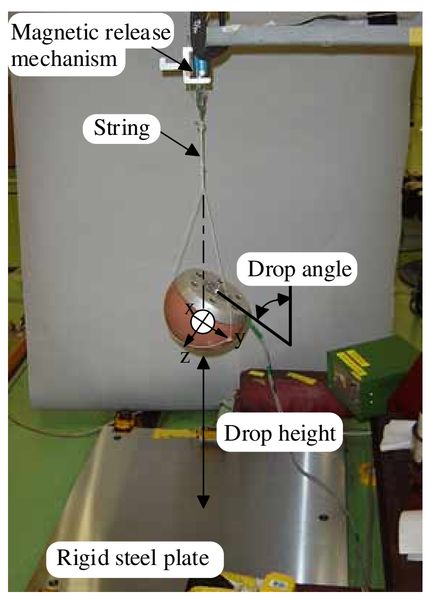

Figure 2. Drop certification test setup.

possible effect of temperature on the skin stiffness, the skin was left in the test room for 24 hours before the first test. The room had a constant temperature of about 21.4°C.

In the present research, three ENDEVCO type 7264B accelerometers [8] were employed. In the process of acceleration recording, each datum measured by the accelerometer was sampled at 10 kHz, and batch data processing was performed with a channel filter class (CFC) 1000. The results of the drop certification test were assessed by means of the peak resultant acceleration calculated from three axis accelerations. The standard deviation of the 15 peak resultant acceleration was calculated.

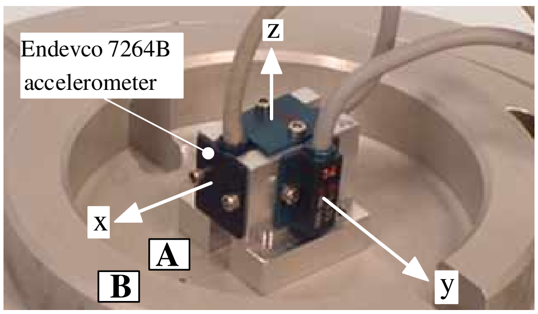

Figure 3. Accelerometers mounted on JAMA-JARI headform impactor.

Scatter in skin product repeatability

To investigate possible scatter in skin product repeatability, the drop certification tests were performed for the headform impactor employing nine newly manufactured skins. The headform impactor was rotated 120° around z–axis after each test. Therefore, three locations on one skin were impacted as shown in Figure 4. The time interval of each test was 24 hours. The standard deviation of 27 impact test results (3 impact locations for 9 skins) was calculated.

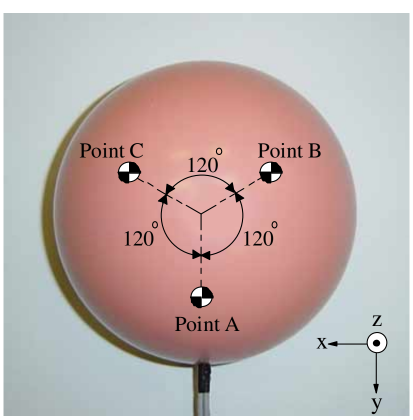

Figure 4. Impact points (View from top).

Recovery of skin after impact

To investigate the recovery of skin after impact, the drop certification tests were performed for the headform impactor employing one newly manufactured skin. The point A (Figure 4) was impacted 4 times, repeatedly. The time interval of each impact test was put at 24, 6 and 2 hours, respectively. On the contrary, the test results will appear in the order of 0, 2, 6 and 24 hours. Point B (Figure 4) was also impacted 4 times using the same procedure employed for the investigation at point A. The presently employed skin was not removed from the sphere of the headform impactor during this investigation.

Skin Durability Over Time

To investigate the skin durability over time, the drop certification tests were performed for the child headform impactor employing two newly manufactured skins. The headform impactor in which each skin was equipped was kept in a room either with or without control of temperature and humidity to investigate the effect of atmosphere on skin durability over time. The investigation period was 31 months after factory shipping. The temperature and humidity over a day in a room with control of temperature and humidity, where one skin (hereafter referred to as skin A) has been kept in are shown in Figure 5. The temperature and relative humidity were controlled at 21.4±0.8°C and 45±15% for 31 months, respectively.

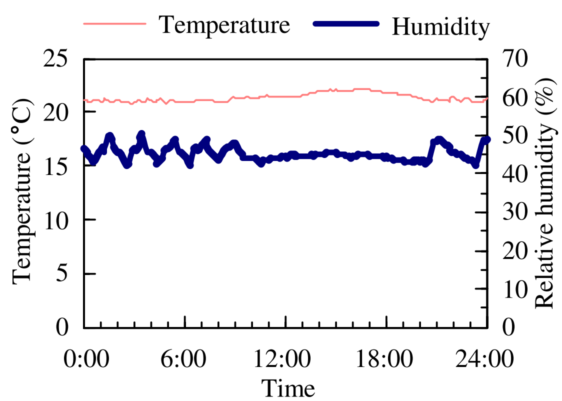

Figure 5. Temperature and humidity over a day in a room with control of temperature and humidity where skin A was kept.

The temperature over one year in a room without control of temperature and humidity, where another skin (hereafter referred to as skin B) has been kept, is shown in Figure 6. The highest temperature (36°C) was recorded in August, and the lowest (4°C) in December. The humidity over one year in room without control of temperature and humidity where skin B has been kept is shown in Figure 7. The highest relative humidity (81%) was recorded in July, and the lowest (8%) in March. Overall, a relative high

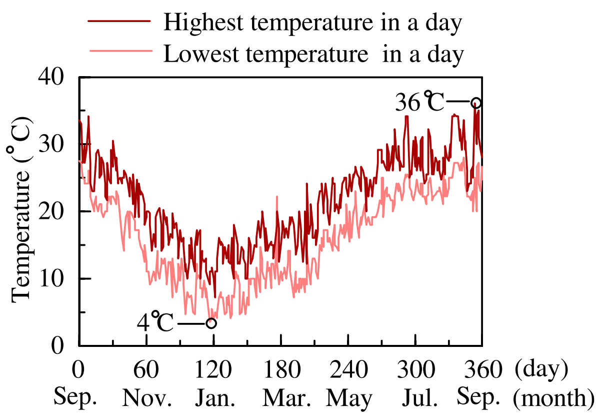

Figure 6. Temperature over one year in a room without control of temperature and humidity where skin B was kept.

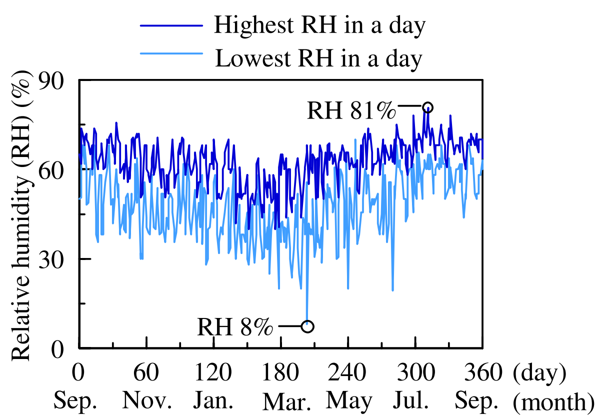

Figure 7. Humidity over one year in a room without control of temperature and humidity where skin B was kept.

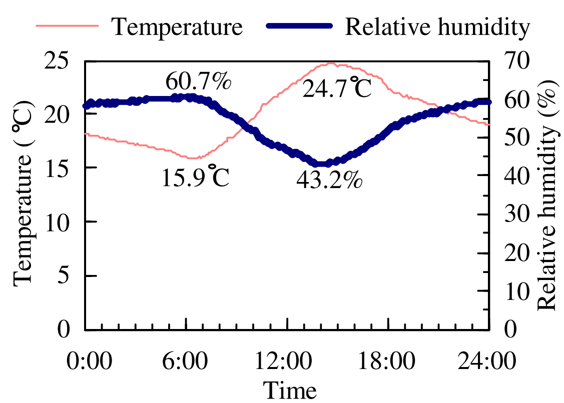

Figure 8. Temperature and humidity over one day in a room without control of temperature and humidity where skin B was kept.

humidity of sometimes over 70% was frequently observed during the monsoon months of June and July. On a day in October, the temperature ranged from 15.9°C to 24.7°C and the humidity from 43.2% to 60.7% (Figure 8). Therefore, skin B was stored in the condition in which the temperature and humidity always ranged widely over 31 months.

The drop certification tests were performed for the child headform impactor at 0 month, 13, 16, 19, 22, 25, 28 and 31 months after manufacture. Skin B was put in the test room for 24 hours before the test. The room had a constant temperature of about 21.4°C.

The headform impactor was rotated 120° around z–axis after each test, so three locations on one skin were impacted as shown in Figure 4. Based on the results obtained through preliminary investigations, the time interval of each test was put at 2 hours, and the skins were not removed from the spheres of the headform impactor during this investigation (31 months).

RESULTS

Verification of Biofidelity Certification Test

<u>Scatter in drop certification testing</u>

The peak resultant acceleration measured by fifteen drop certification tests employing one newly manufactured skin is shown in Table 2. The mean peak resultant acceleration was 272.7 G, which corresponds to the middle of the drop certification corridor (272.5 G). The standard deviation was 3.6 G, while the coefficient of variance was 1.3%. Thus, there was good repeatability.

Table 2 Peak resultant accelerations measured from fifteen drop certification test for one newly manufactured skin (time interval of each test was 24 hours)

Peak resultant accel. (G)					
n=15			Mean	SD	CV (%)
268	268	275	272.7	3.6	1.3
271	277	276			
268	277	271			
273	277	271			
276	268	274			

<u>Scatter in skin product repeatability</u>

The peak resultant accelerations measured from twenty-seven drop certification tests employing nine newly manufactured skins are shown in Table 3. The mean peak resultant acceleration was 268.0 G, the standard deviation 2.4 G with a coefficient of variance of 0.9%.

When we focused on the standard deviation obtained in the previous section on “scatter in drop certification testing,” it was higher (3.6 G) than the standard deviation obtained in the present section on “scatter in skin product repeatability” (2.4 G). Therefore, we should focus on the scatter in drop certification testing, since it was higher than that in skin product repeatability. Approximately 95% of the scatter in the drop certification testing was calculated to be 7.2 G (2*SD). The 95% scatter (7.2 G) corresponds to 26% of the half range (27.5 G) of the biofidelity certification test corridor (55 G) proposed by ISO/IHRA/Japan MLIT. Thus, scatter did not have a significant influence on the drop certification test results. Therefore, the test condition in the previous section was employed for the section on “investigation of skin durability over time,” where the skin was not removed from the sphere of the headform impactor during the investigation.

Table 3 Peak resultant accelerations measured from drop certification test for nine newly manufactured skins (time interval of each test was 24 hours)

Skin	Peak resultant accel. (G)					
	Point A	Point B	Point C	Mean	SD	CV (%)
#1	270	265	264	266.3	3.2	1.2
#2	270	267	268	268.3	1.5	0.6
#3	270	268	271	269.7	1.5	0.6
#4	269	266	266	267.0	1.7	0.6
#5	269	272	265	268.7	3.5	1.3
#6	263	268	270	267.0	3.6	1.4
#7	269	269	268	268.7	0.6	0.2
#8	266	267	272	268.3	3.2	1.2
#9	266	266	271	267.7	2.9	1.1
Total				268.0	2.4	0.9

Recovery of skin after impact

The peak resultant accelerations measured by four drop certification tests at different time intervals at impact point A of one newly manufactured skin are shown in Table 4. The differences in peak resultant acceleration measured between the initial and repeated tests performed at 2, 6 and 24 hours were 1 G, 1G and 3 G, respectively.

Regarding the results measured at impact point B, the differences in peak resultant acceleration measured between the initial and repeated tests performed at 2, 6 and 24 hours were 0 G, 1G and 4 G, respectively (Table 5).

These results indicated that 2 hours is sufficient for skin recovery after the impact. Thus, the present study employed 2 hours as the time interval for the three drop certification tests (impact points A, B and C as shown in Figure 4) for skin durability over time.

Table 4 Peak resultant accelerations for different time intervals at impact of point A

Time interval	Peak resultant accel. (G)	
	Measured	Difference
Initial	268	-
2 hours	267	-1
6 hours	267	-1
24 hours	271	3

Table 5 Peak resultant accelerations for different time intervals at impact of point B

Time interval	Peak resultant accel. (G)	
	Measured	Difference
Initial	271	-
2 hours	271	0
6 hours	270	-1
24 hours	267	-4

Skin Durability Over Time

The peak resultant accelerations measured at 0 month, 13, 16, 19, 22, 25, 28 and 31 months after manufacture of skin A and B are shown in Tables 6 and 7 and Figures 9 and 10. Note that the headform impactor with skin A was kept in a room with control of temperature and humidity and the headform impactor installing skin B was kept in a room without control of temperature and humidity.

The results indicated that the peak resultant acceleration measured using the two skins immediately after manufacture was 270 G. The peak resultant acceleration of 279 G measured using the skin A increased 9 G at 13 months after manufacture, while the peak resultant acceleration of 275 G measured using the skin B increased 5 G at 13 months after manufacture. The increase of 9 G and 5 G correspond to 16% and 9% of the range of the certification test corridor (55 G), respectively.

The peak resultant acceleration of 287 G measured using the skin A increased 17 G at 31 months after manufacture, while the peak resultant acceleration of 288 G measured using the skin B increased 18 G at 31 months after manufacture. The increases of 17 G and 18 G correspond to 31% and 33% of the range of the certification test corridor (55 G), respectively. These results indicate that if the acceleration is close to the middle of the drop certification corridor (272.5 G) immediately after purchase by a testing facility, the

Table 6 Peak resultant accelerations measured using skin A kept in a room with control of temperature and humidity

Time (month)	yy/mm	Results				
		Impact point	Peak resultant accel. (G)			
			Measured	Mean	Increase from 0 month	SD
0	2002 Aug.	A	272	270	0 (0%)	1.7
		B	269			
		C	269			
13	2003 Sep.	A	279	279	9 (16%)	0.0
		B	279			
		C	279			
16	2003 Dec.	A	281	279	9 (16%)	2.0
		B	279			
		C	277			
19	2004 Mar.	A	280	283	13 (24%)	3.6
		B	287			
		C	282			
22	2004 Jun.	A	280	283	13 (24%)	3.5
		B	283			
		C	287			
25	2004 Sep.	A	282	284	14 (25%)	1.5
		B	284			
		C	285			
28	2004 Dec.	A	284	287	17 (31%)	2.5
		B	287			
		C	289			
31	2005 Mar.	A	284	287	17 (31%)	2.3
		B	288			
		C	288			

*( ) represents ratio of increased peak resultant acceleration from 0 month to the range of the ISO/IHRA/Japan MLIT corridor (55 G)

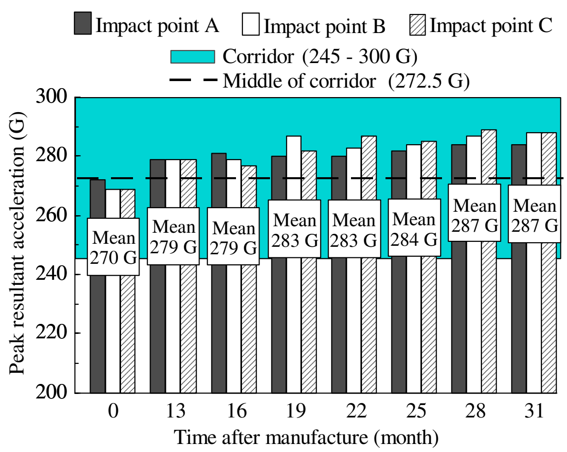

Figure 9. Peak resultant accelerations measured using skin A kept in a room with control of temperature and humidity.

skin can be available for use in a pedestrian impact test with a storage period of at least 31 months (2 years and 7 months). These results also suggest that if the acceleration is close to the upper limit of the drop certification corridor (300 G) immediately after purchase by a testing facility, the skin expiration time

Table 7 Peak resultant accelerations measured using skin B kept in a room without control of temperature and humidity

Time (month)	yy/mm	Results				
		Impact point	Peak resultant accel. (G)			
			Measured	Mean	Increase from 0 month	SD
0	2002 Aug.	A	272	270	0 (0%)	2.1
		B	269			
		C	268			
13	2003 Sep.	A	273	275	5 (9%)	3.2
		B	279			
		C	274			
16	2003 Dec.	A	278	280	10 (18%)	1.5
		B	280			
		C	281			
19	2004 Mar.	A	280	283	13 (24%)	3.8
		B	281			
		C	287			
22	2004 Jun.	A	280	284	14 (25%)	3.5
		B	286			
		C	286			
25	2004 Sep.	A	283	285	15 (27%)	2.1
		B	286			
		C	287			
28	2004 Dec.	A	283	288	18 (33%)	4.0
		B	290			
		C	290			
31	2005 Mar.	A	284	288	18 (33%)	3.2
		B	289			
		C	290			

*( ) represents ratio of increased peak resultant acceleration from 0 month to the range of the ISO/IHRA/Japan MLIT corridor (55 G)

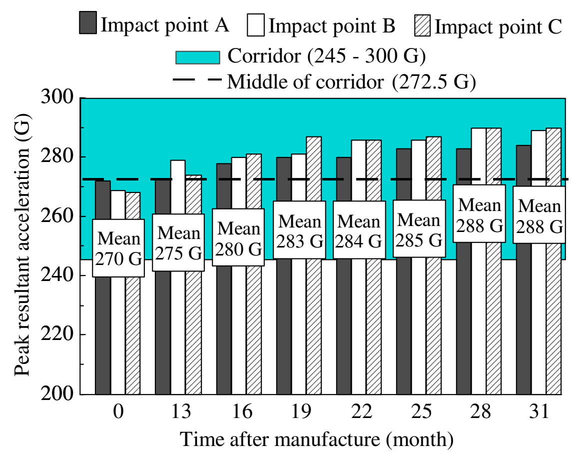

Figure 10. Peak resultant accelerations measured using skin B kept in a room without control of temperature and humidity.

may be drawing very near. The results also indicated that one need not keep skins in a room where the temperature and humidity are well controlled when storing them for a certain period.

DISCUSSION

In the present study, the durability over time of skin was investigated by the drop certification testing proposed by ISO/IHRA/Japan MLIT for the certification test of pedestrian headform impactor. On the other hand, the draft of the European regulation, EEVC/WG17 [9] employed the other certification test in which the headform impactor is impacted laterally by a ram with a mass of 1 kg (Figure 11). The purpose of this lateral impact certification test is to simultaneously investigate the skin performance and the vibration characteristics. However, a result with high repeatability using this lateral impact certification test method is unlikely, because matching up the ram line of impact through the center of gravity of the headform impactor could be difficult. Since the repeatability of this method has not been verified so far, we did not use it in the present study. If we investigate the durability over time employing this lateral impact certification test, the results would tend to be the same as that obtained in the present study.

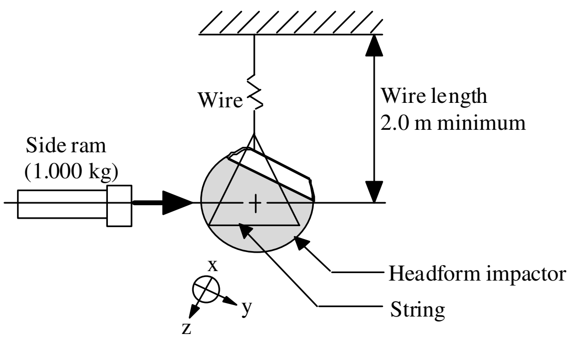

Figure 11. Setup for headform impactor high-velocity certification test.

JAMA and JARI developed child and adult headform impactors complying with the ISO/IHRA/Japan MLIT specifications. The same developed skin can be used with both child and adult headform impactors [6]. Since the mass of a child headform impactor is smaller (3.5 kg) than that for an adult (4.5 kg), its head acceleration at the impactor center of gravity is higher than for the adult headform. Therefore, in the present study, the skin durability over time was investigated employing the JAMA–JARI child headform impactor. If we employ the JAMA–JARI adult headform impactor for the investigation of the skin durability over time, the results would show the same tendency evidenced by the present study.

Regarding the storage period, the skin durability over 31 months was investigated in the present study. The investigation period of 31 months was more than twice the usual storage period, e.g., from a half year to the maximum one year employed by the Japanese New Car Assessment Program (J–NCAP) pedestrian head protection test which was conducted in JARI. Therefore, the period employed in the present study would obviously suffice to obtain information on skin durability over time.

CONCLUSIONS

JAMA and JARI have developed pedestrian headform impactors fulfilling the ISO/IHRA/Japan MLIT standards. The present study investigated the durability over time of skin used for JAMA–JARI pedestrian headform impactor measured by the biofidelity certification testing. The results indicated that the peak acceleration impact using the skins immediately after manufacture was 270 G. The peak acceleration of 288 G increased 18 G at 31 months (2 years and 7 months) after manufacture. The increase of 18 G corresponds to 33% of the range of the certification test corridor (55 G). These results indicate that if the acceleration is close to the middle of the drop certification corridor (272.5 G) immediately after purchase by a testing facility, the skin is available for pedestrian impact test use with a storage period of at least 31 months. The results also suggest that if the acceleration is close to the upper limit of the drop certification corridor (300 G), the skin expiration time may be drawing very near. The findings also indicated that temperature and humidity did not significantly affect the skin durability over time.

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