

Investigation of the Impact Phenomenon During Minor Collision

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ABSTRACT

ISO 12405-1,2 specifies international testing standards for lithium-ion batteries for vehicles. In the mechanical shock test is used to determine if the battery is damaged due to the shock imposed when the vehicle runs over a curb or similar minor accidents. Therefore, we conducted minor collision tests against a curb using an actual vehicle and compared the test results with the conditions specified in ISO 12405-1,2. The results confirmed that the impulse wave obtained using an actual vehicle within the range of the test in this study differs from the shape of the impulse wave specified in ISO 12405-1,2.

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INTRODUCTION

ISO 12405-1 [1] (high-power applications) and ISO 12405-2 [2] (high-energy applications) address packs and systems and were published in 2011 and 2012, respectively, as international standards testing methods for lithium-ion batteries for automobiles. Furthermore, international standards on battery safety are now being discussed at UN/ECE/WP29 as a unified international standard based on the 1998 agreement (EVS gtr). Thus, international standards and other standards concerning batteries for automobiles are being actively prepared.

ISO 12405-1,2 specifies international testing standards for lithium-ion batteries for vehicles, dewing, thermal shock cycling, vibration, and mechanical shock tests as reliability tests as well as short-circuit protection, overcharge protection, and over-discharge protection tests as abuse tests. The mechanical shock test is used to determine if the battery is damaged due to the shock imposed when the vehicle runs over a curb or similar minor accidents. The testing method specifies half-sinusoidal pulse with an acceleration of 500 m/s^2 and a duration of 6 ms for 10 times from maximum six directions. However, this test condition was not specified based on actual test data but was determined based on lithiumion battery testing manual 38.3 in the United Nations recommendations on the transport of dangerous goods [3], and the mechanical shock test condition specified in ISO 16750-3 [4], which is the standard for mechanical loads on automotive parts. ISO 16750-3 specifically addresses test conditions for relatively small automotive parts such as

electrical and electronic equipments. Thus, if the same condition is applied to relatively large battery packs and systems (e.g., batteries for electric vehicles), excessive test requirements may result.

Therefore, in order to optimize mechanical shock test conditions, we conducted minor collision tests against a curb using an actual vehicle and compared the test results with the conditions specified in ISO 12405-1,2.

EXPERIMENTAL PROCEDURE

The vehicles used for the test are shown in [Figure 1](#). These vehicles were prepared by modifying two 1,300-cc hatchback gasoline cars (Vehicle A and Vehicle B) and by installing different types of lithium-ion batteries.

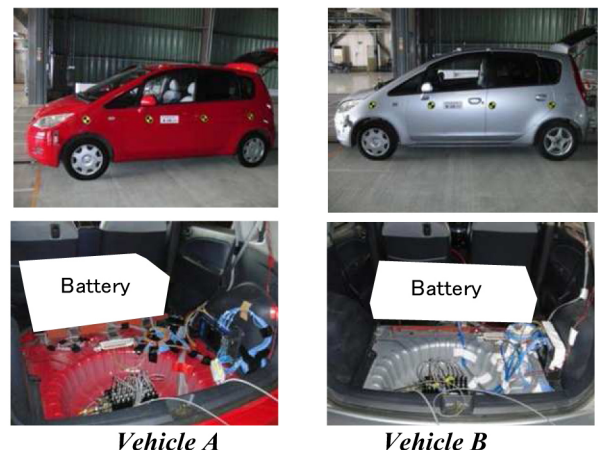


Figure 1. Experimental vehicles for curb collision

Battery modules composed of several cells were installed in a special metallic case and then fixed between the backseat of the car and the rear trunk by welding and bolting the battery fixing frame to the vehicle body. Each of the vehicles had a mass of 1,100 kg, and the total battery power was 7 kWh for Vehicle A and 5 kWh for Vehicle B. During the test, the state of charging (SOC) was set to 40%.

The accelerometers were installed in the vehicles as indicated in Figure 2. Three-axis accelerometers were installed in all five positions, including the left and right front side members, the center of gravity of the vehicle, the battery fixing frame, and batteries. The battery voltage and temperature also were measured to check for any abnormality in batteries during the test.

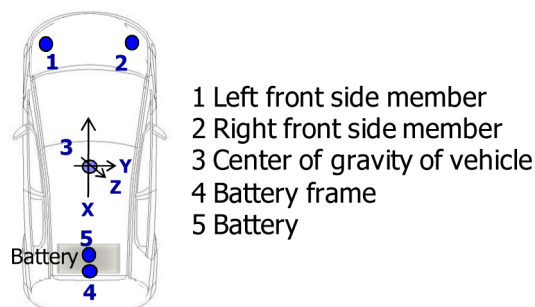


Figure 2. Measurement points of acceleration with three-axis accelerometer

Figure 3 depicts the test implementation, and Table 1 lists the test conditions. Curbs were simulated using metal angle pipes to enable their repetitive use. Curbs on common roads

Table 1. Test conditions

Vehicle No.	Battery energy [kWh]	Angle of vehicle travel [°]	Velocity [km/h]
Vehicle A	Approx. 7	30	10
			30
Vehicle B	Approx. 5	30	10
			20
			40

are 0.15 to 0.25 m high, so the curb heights for the test were set to 0.2 m. The angle of approach to the curbs was set to 30°, and the vehicle approach velocity was set to 10 and 30 km/h for Vehicle A and 10, 20, and 40 km/h for Vehicle B.

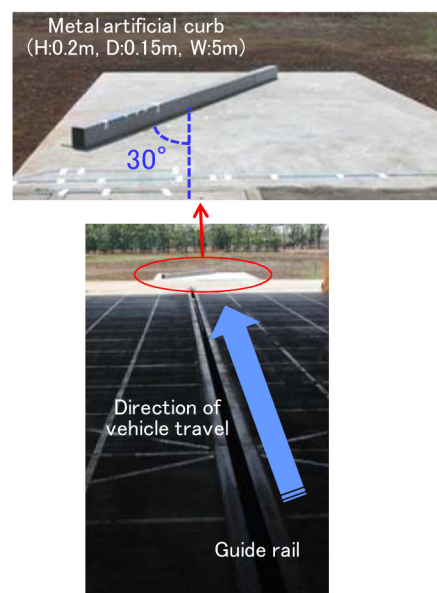


Figure 3. Test situation for curb collision

Results and Discussion

The acceleration indicated by accelerometers mounted on the vehicle body for collision testing should be measured through channel frequency class 60. During the test, acceleration was measured according to this specification. The impulse wave obtained during the test was also passed through the filter in accordance with the specification.

Test velocity of 10 km/h

Figure 4 presents a high-speed video image of Vehicle B at a test velocity of 10 km/h (actual measurement: 12.2 km/h). During the collision, the left front wheel overran the curb, the side sill contacted the curb, and the vehicle stopped with the left rear wheel touching the curb. Only the left front

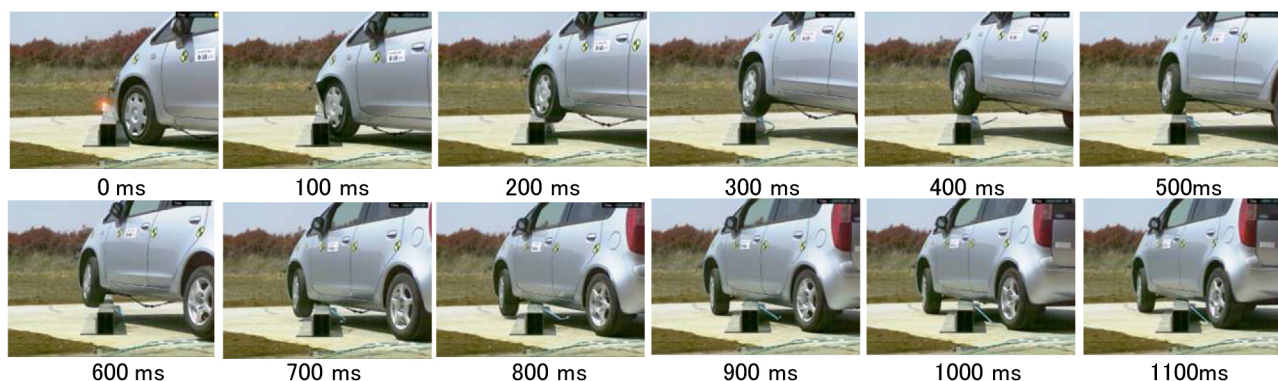


Figure 4. High-speed video images in velocity of 10 km/h by Vehicle B

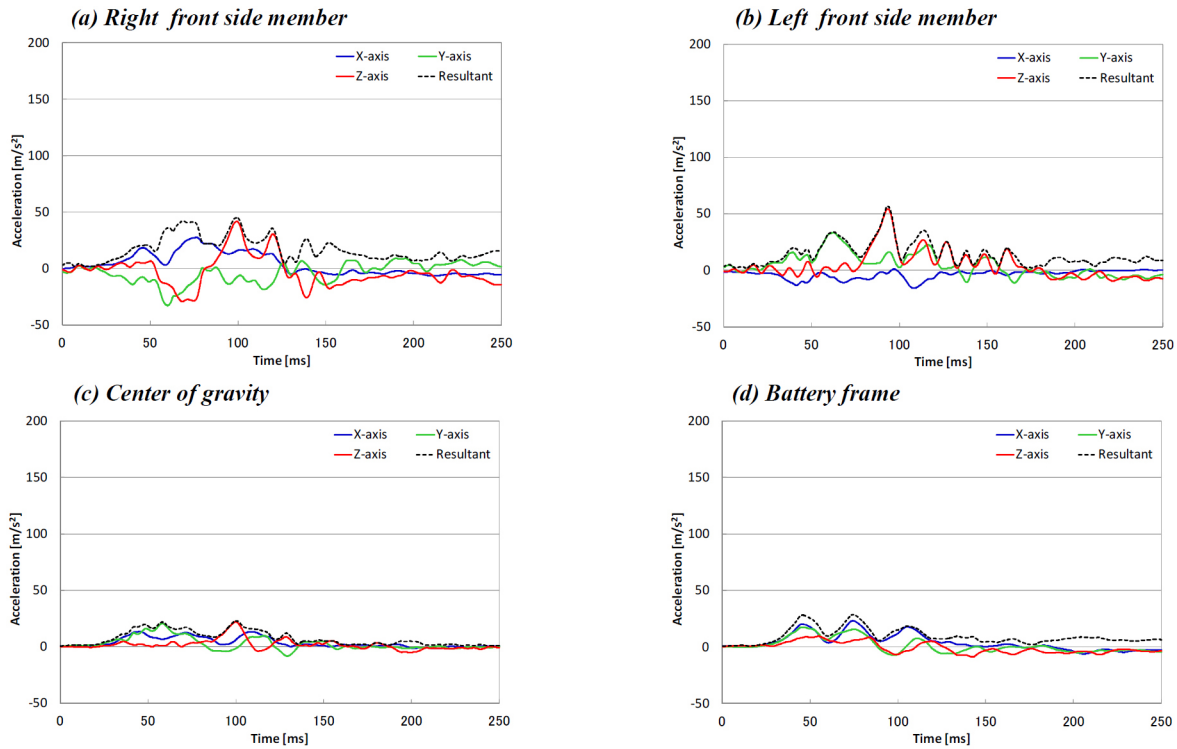


Figure 5. Acceleration waves when the left front wheel impacted the curb in velocity of 10 km/h by Vehicle B

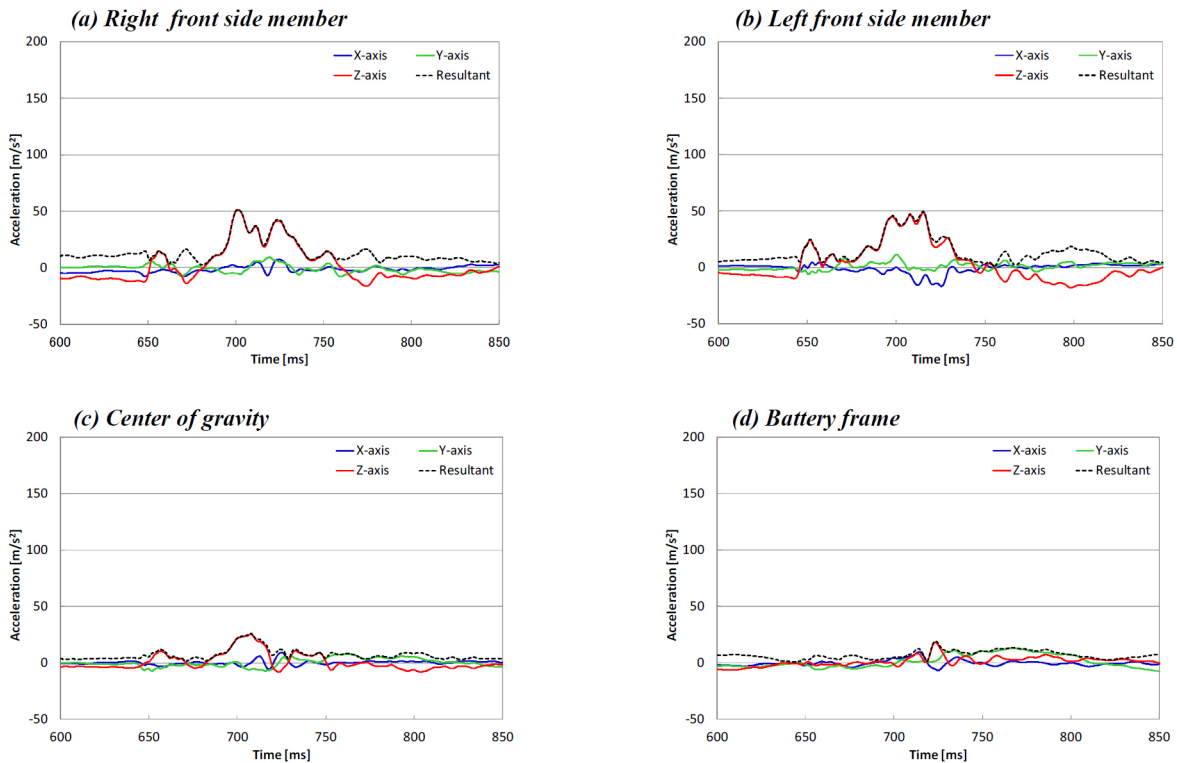


Figure 6. Acceleration waves when the side sill impacted the curb in velocity of 10 km/h by Vehicle B

wheel ran over the curbs; the right front wheel and rear wheels did not. Acceleration increased when the left front wheel and side sill impacted the curb.

The impulse waves at the left and right front side members, center of gravity, and the battery fixing frame measured at both timings are shown in Figure 5 and 6. There was no significant difference in the maximum acceleration