Child Restraint Headrest Conformity Test Document

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1 Purpose and Scope

This document proposes an additional test to supplement the regulations concerning child restraint headrests. The Minister of Justice of Canada has published its regulations and required standards in [1]. Subsection 213 of the current legislation states that every surface of a child restraint system that is contactable by the head of an anthropomorphic test device must be covered with slow-recovery, energy-absorbing material [1]. The material must undergo a 25% compression-deflection test to determine the resulting resistance [1]. The material used in the child restraint seat must have a thickness in accordance with the recorded resistance during the test. At 25% of compression deflection the resistance should fall between 4kPa and 70kPa [1]. The necessary thickness of the slow-recovery, energy-absorbing material is shown in Table 1.

Table 1: Required thickness as a function of the recorded resistance for the slow-recovery, energy-absorbing material contactable by the head in a child restraint system [1].

Resistance r kPa	Thickness t mm
$4 \leq r \leq 12$	$t \geq 12$
$12 \leq r \leq 70$	$t \geq 19$

We investigate the feasibility of supplementing the Canadian standard with the regulations proposed by the United Nations and adopted across Europe detailed in [2]. The regulation sets a maximum acceleration of 60g recorded when dropping a headform weight from a distance of 100mm above the child restraint system [2]. The specific clauses of the regulations are outlined in this section.

Child Restraint System

All child restraint systems must have internal structures which consist of energy absorbing material for all areas contactable by the head [2]. This area is determined by using the child restraint system positioned upright and by positioning the smallest dummy in accordance with the manufacturer's instructions [2]. A point A is marked on the backrest at the same height as the shoulder at a point 2cm inside the outer edge of the arm [2]. All internal surfaces above the horizontal plane passing through point A must be covered in energy absorbing material [2].

Headform

The energy absorption of the material is tested by dropping a headform and recording the resulting acceleration. The headform consists of a solid wooden hemisphere with an added smaller spherical segment as shown in Figure 1 [2]. The headform must be outfitted such that an accelerometer can be embedded within its structure. The headform and the accelerometer must have a total mass of 2.75 ± 0.05kg.

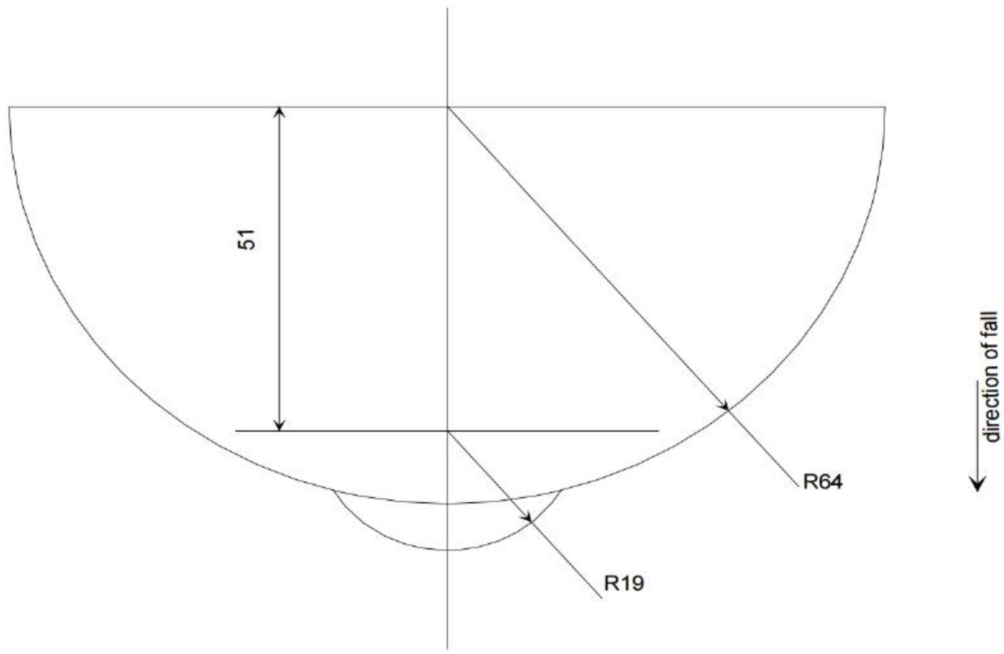

Figure 1: The geometry of the headform (reproduced from [2]).

Instrumentation

The accelerometer fitted to the headform must record the changes in acceleration occurring along the direction of fall. The sensor must be in accordance with channel frequency class 1000 as specified in the latest version of ISO 6487 [2].

Procedure

The test is intended to be conducted on a completely assembled child restraint system [2]. The seat is to be fully supported on its outer surface in the region of the impact by a smooth rigid base [2]. The headform is to be raised to a height of 100 $-0/+5$mm and allowed to fall in free-fall [2]. The acceleration throughout the duration of the fall is to be recorded. The resulting acceleration should be maintained below 60g throughout the entirety of the procedure.

2 Test Requirement

Every surface of a child restraint system that is contactable by the head of an anthropomorphic test device positioned in the restraint system in accordance with Section 4 must be covered with slow-recovery, energy-absorbing material that, when tested in accordance with Section 4, has a peak acceleration less than 60g.

3 Test Setup and Equipment

The compliance test intends to determine the maximum acceleration registered when dropping a hemispherical headform in free-fall onto the center area of the child restraint system which is contactable by the head.

Headform

The headform consists of a solid wooden hemisphere with an added smaller spherical segment. The dimensions of the headform can be found in Figure 1. In order to reach the weight requirements described in the European regulations [2] a metallic structure is added to the base of the hemisphere. The total weight of the headform is 2.72kg. The accelerometer is embedded into the metallic piece such that it records in the direction of the fall.

A photograph of the constructed headform is shown in Figure 2. The solid wooden hemisphere is shown in Figure 3 and 4. The added metallic structure to achieve the desired weight is shown in Figure 5 and 6.

Figure 2: Photograph of the assembled headform.

Figure 3: Photograph of the solid wooden hemisphere of the headform (top view).

Figure 4: Photograph of the solid wooden hemisphere of the headform (bottom view).

Figure 5: Photograph of the metallic structure of the headform (top view).

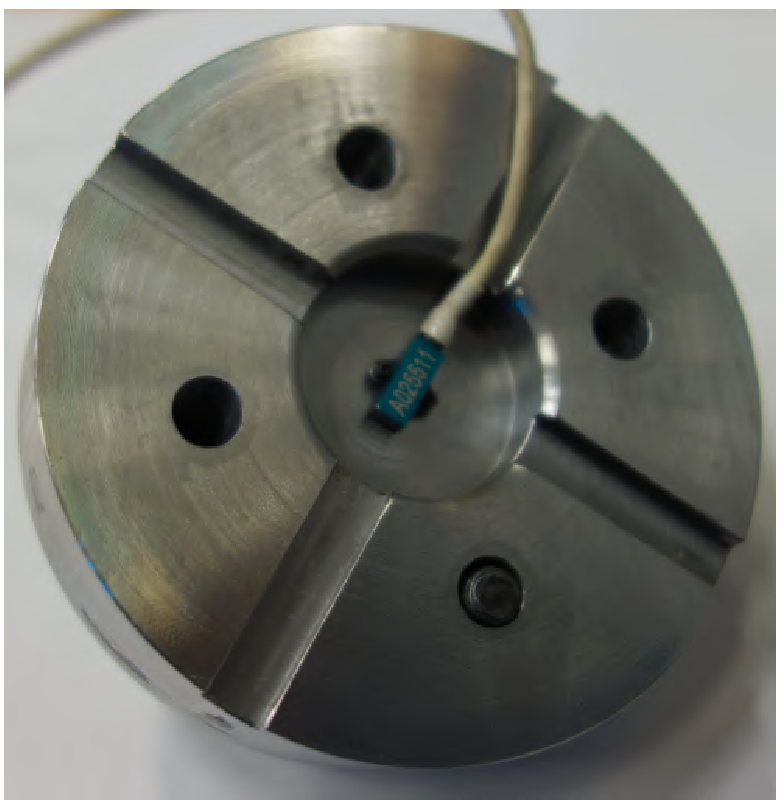

Figure 6: Photograph of the metallic structure of the headform (bottom view) with the embedded accelerometer.

Instrumentation

The accelerometer is positioned in the headform between the metallic plate and the solid wooden hemisphere. The accelerometer used is the 68CM1-2000 manufactured by MEAS. It is a single axis accelerometer. Thus, its recording axis is positioned along the direction of the fall. The accelerometer is secured inside the metallic structure placed above the solid wooden hemisphere. The sensor is shown fastened to the headform in Figure 7.

Figure 7: Photograph of the accelerometer fastened inside the headform.

Drop-test Structure

The structure is designed such that the headform can be dropped directly in the center of the contactable area of the child restraint system. The headform can be positioned by adjusting the structure in all three dimensions. Moreover, a base plate placed on a pivot angle can be used to ensure that the drop-test occurs perpendicular to the target surface. A photograph of the drop-test structure is shown in Figure 8. The headform is held up using a clip which is released using a switch. The headform held by the structure is shown in Figure 9.

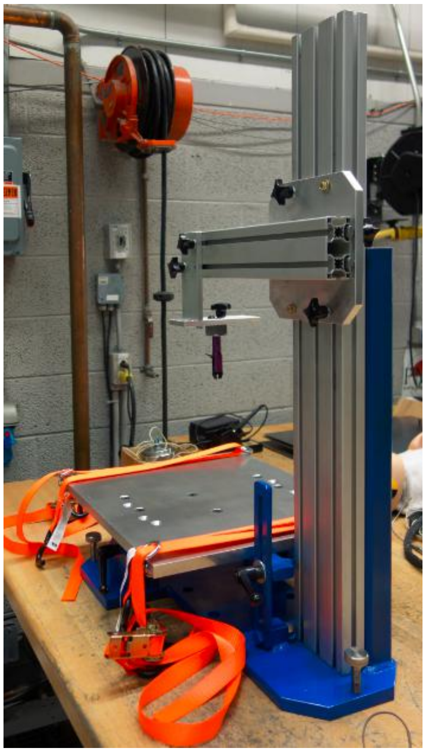

Figure 8: Photograph of the drop-test structure.

Figure 9: Photograph of the apparatus which holds up the headform on the drop-test structure.

4 Test Procedure

The test must be conducted in accordance with the instructions outlined in this section.

4.1 Information About Child Restraint System

Record the following information pertaining to the child restraint system under test.

1. Seat project number
2. Manufacturer name
3. Model number

4.2 Determining the Drop Target on the Child Restraint System

The drop target on the child restraint system is at the center of the area contactable by the head. This location is determined by placing the smallest dummy securely into the child restraint system according to the manufacturers instructions. Two points A and B are identified on the backrest at the same height as the shoulder at a point 2cm inside the outer edge of the arm. A third point C is identified at the top of the head. The headform should be centered to fall on a target positioned at the midpoint between these points. Figure 10 shows the placement of these markers in relation to the dummy.

Figure 10: Photograph of the dummy positioned in the child restraint system showing the three marker positions.

4.3 Positioning the Child Restraint System

The child restraint system must be securely fastened to the drop test apparatus such that it is not subject to movement throughout the impact. Figure 11 shows a sufficiently attached child restraint system.

Figure 11: Photograph of the accelerometer fastened inside the headform.

Furthermore, the target area should be perpendicular to the headrest's direction of movement. Thus a level is used to determine the correct inclination of the drop test apparatus' base plate. Next, the headrest's height is adjusted such that it is 100 $-0/+5$mm above the target area.

4.4 Dropping the Headform

The headform is dropped from the drop test apparatus using a switch which ensures the headform falls uniformly in the direction of fall.

5 Experiment Descriptions

Four experiments are detailed in this Section to compare the consistency and performance of the drop-test outlined in Section 4. The test procedure must result in repeatable trials which consistently assess a sample's compliance. The results of the drop-test at 100mm require that the accelerations experienced by the headform are maintained below 60g. This information is extracted from the recorded signals obtained using the accelerometer embedded within the headform. Every experiment uses a drop height of 100mm except for the fourth experiment when it is explicitly noted. The results of the experiments are shown in Section 6.

The first, drops the headform on two energy absorbing material samples detailed in Table 2. This test is used to compare the results of the proposed compliance test with the current standard used in Canada. The first sample (Sample 1) was found to be compliant in accordance with the Canadian standard whereas the second sample (Sample 2) was not.

Table 2: Description of the foam samples used to validate the drop-test.

	Foam Type	Company Name	Sample ID	Result of the Canadian Standard	Pressure (kPa)
Sample 1	EPP	Peg Perego	HR16-0130	Pass	6.4
Sample 2	Eurethane	Baby Trend	FO15-0015	Fail	74.6

The second experiment is performed using two different seat and foam configurations detailed in Table 3. The seat used in these tests is not outfitted with energy-absorbing foam. This experiment is aimed to identify the acceleration curves that would result from different worst-case scenario target configurations. The first configuration used the hard plastic shell of a flat child restraint system and the second configuration covered the hard plastic shell with a non-energy absorbing comfort foam.

Table 3: Description of the foam samples used to validate the drop-test.

	Seat Type	Foam Type
Configuration 1	Hard Flat	N/A
Configuration 2	Hard Flat	Comfort Foam

The third experiment performs three drops on three assembled child restraint systems described in Table 4.

Table 4: Description of the child restraint systems used to validate the drop-test.

	Manufacturer	Model	Type	UN Number
Seat 1	Evenflo	Embrace 35	Infant	SE16-0375
Seat 2	Evenflo	Tribute	Convertible	SE16-0395
Seat 3	Safety 1st	Alpha Omega Elite 65	Convertible	SE17-0063

Lastly, the fourth experiment performs drop tests at variable heights in order to identify the energy required to attain the threshold set by the European standard. The test is repeated using the hard plastic shell and an assembled child restraint system (SE16-0395). The drop heights for the hard plastic shell are 100, 200, 300 and 400mm. The drop heights for the assembled child restraint system are 100, 200, 300 and 370mm. The difference is caused by the maximum test height achievable with the drop test apparatus.

6 Result

Experiment 1: Drop Test with Foam Samples

The currently used Canadian standard requires a compression test as described in Section 1. The two selected samples to test the European standard are described in Section 5. The first sample (Sample 1) was found to be compliant in accordance with the Canadian standard whereas the second sample (Sample 2) was not. Due to the different results obtained using the Canadian standard the samples are expected to show different accelerations measured as the g-force.

It should be noted that the energy-absorbing foam which is compliant according to the Canadian standard resulted in higher accelerations than the foam sample which was deemed non-compliant. This discrepancy can be attributed to the different material compression forces as a result of a sudden impact and a uniform compression.

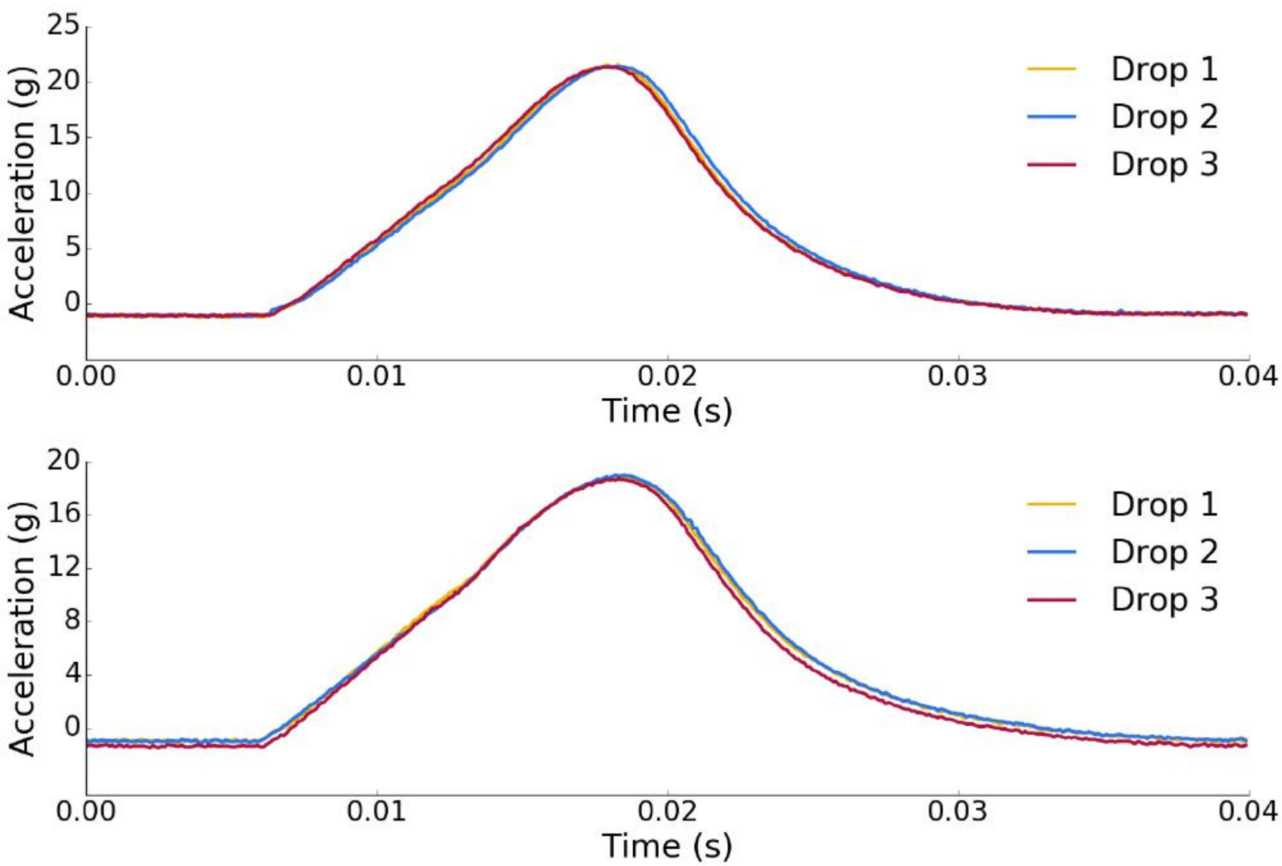

Figure 12: Recorded acceleration for Sample 1 (top) and Sample 2 (bottom) as a result of the drop test.

Experiment 2: Drop Test with Different Targets

This test was conducted using an assembled child restraint system which does not have energy-absorbing foam. This represents the worst case scenario for a child restraint system. The drop test was conducted on the hard plastic shell with and without the comfort foam (non-energy absorbing). Figure 13 shows the accelerations recorded for the two test configurations. It can be seen that the addition of the comfort foam does reduce the maximum acceleration recorded during the drop test.

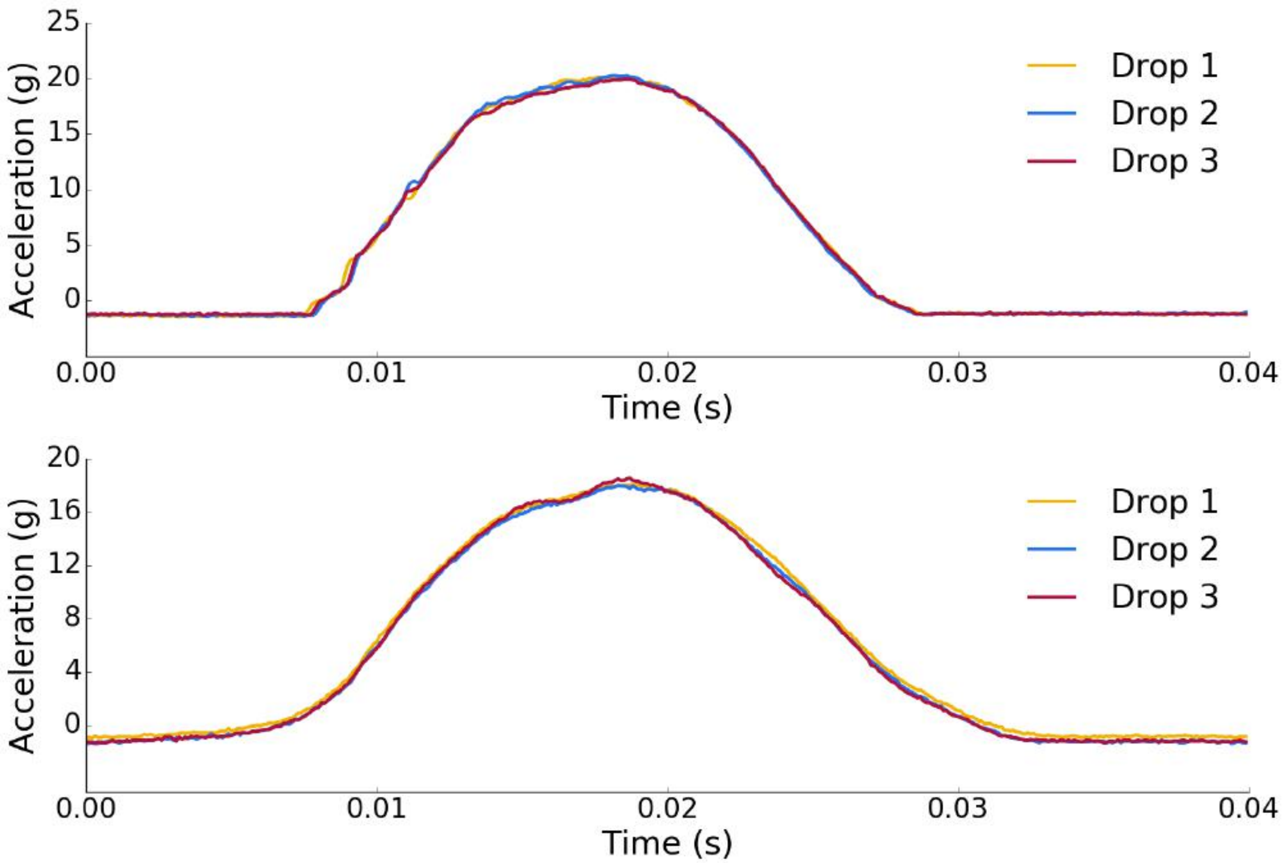

Figure 13: Recorded acceleration for the worst-case child restraint system on the hard plastic shell (top) and the comfort foam (bottom) as a result of the drop test.

Experiment 3: Drop Test with Different Child Restraint Systems

The drop test was repeated using three fully assembled child restraint systems. Details pertaining to the manufacturer and model number for the child restraint system is provided in Section 5.

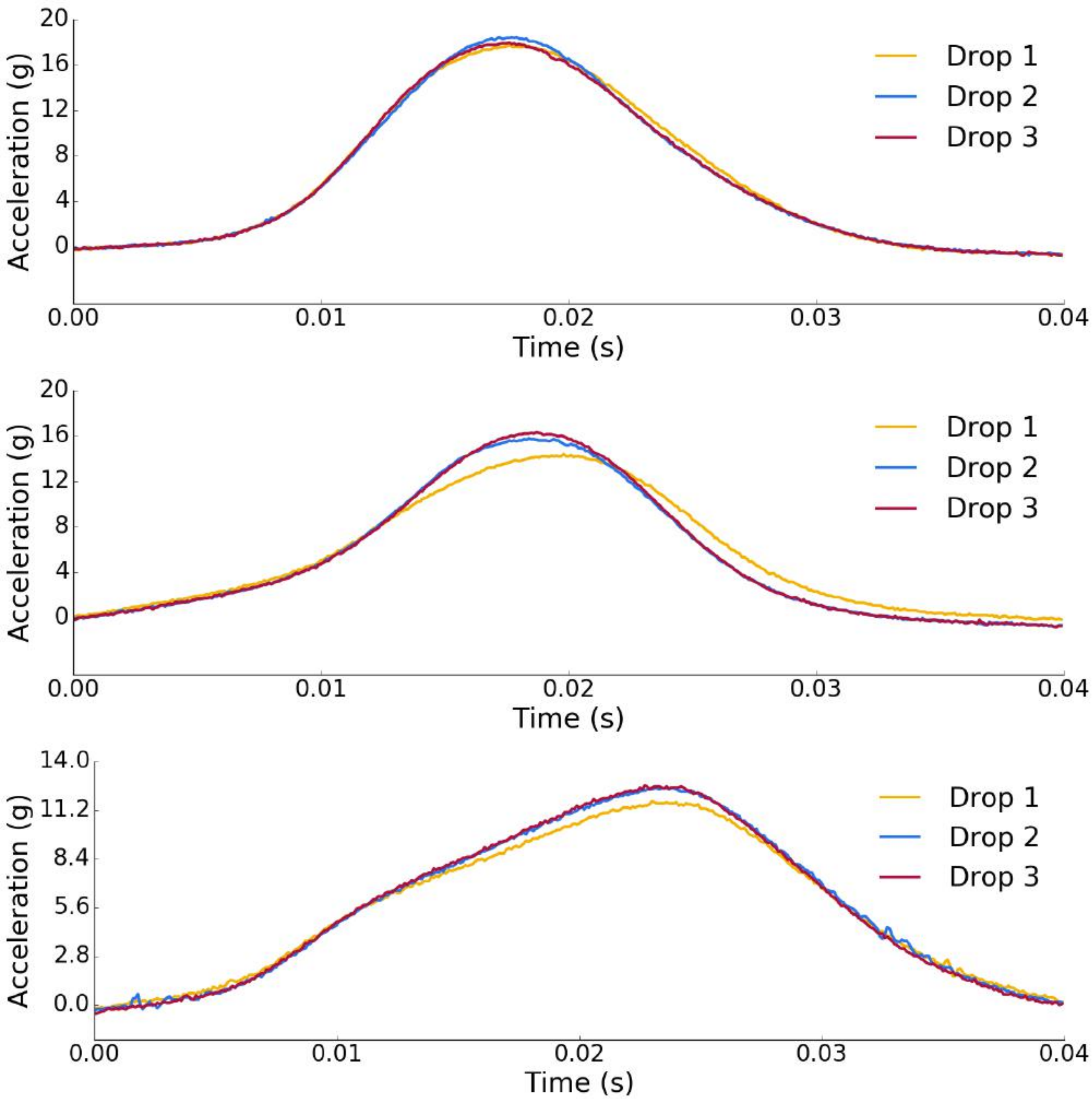

Figure 14: Recorded acceleration for Seat 1 (top), Seat 2 (middle) and Seat 3 (bottom) as a result of the drop test.

Experiment 4: Drop Test with Varying Heights

This experiment aimed to identify the force required to attain the threshold of 60g outlined by the European Standard. The drop height of the headform was varied using a ard plastic shell and a fully assembled child restraint system. It can be seen that the 60g threshold was only reached at a 400mm height using the hard plastic shell.

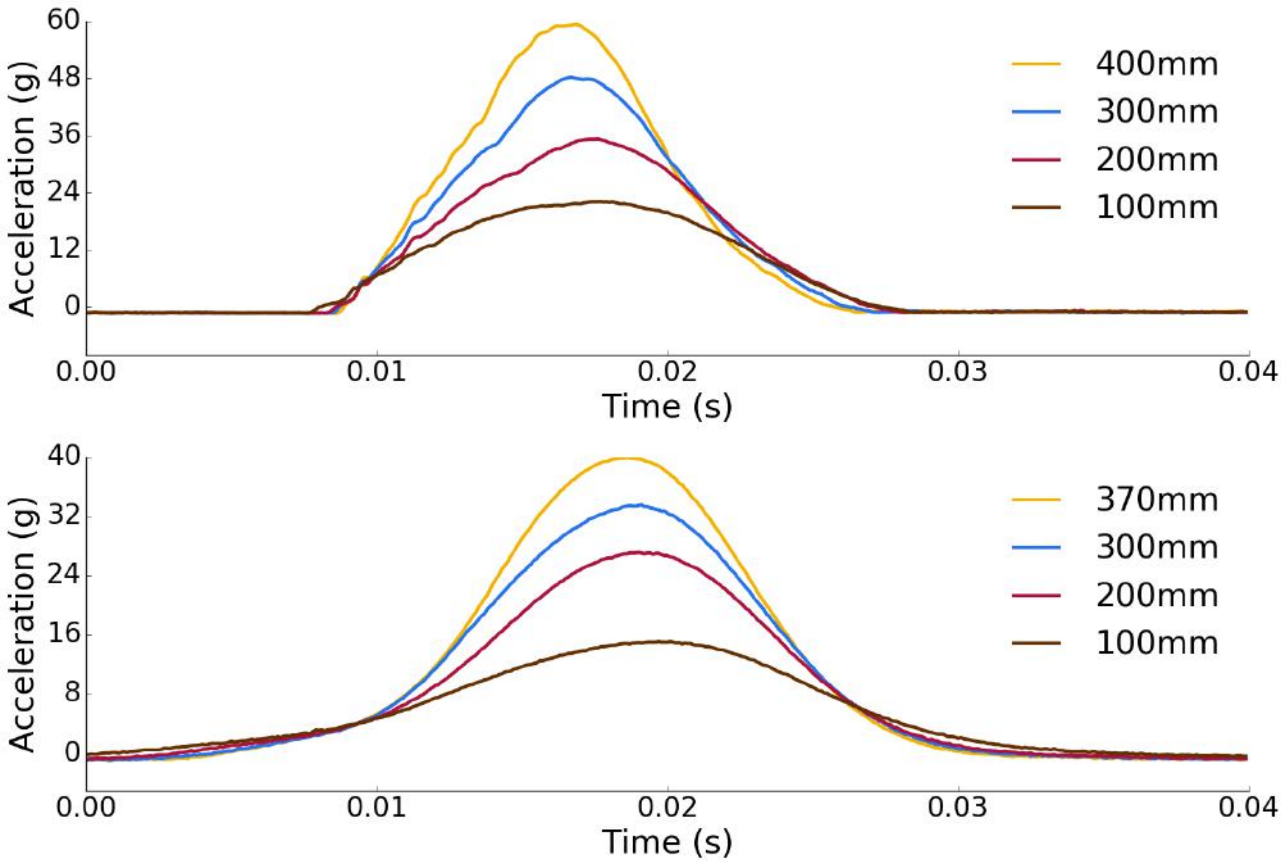

Figure 15: Recorded acceleration for the hard plastic shell (top) and the assembled child restraint system (bottom) as a result of the drop test at varying heights.

7 Conclusions

This report investigates the feasibility of supplementing the Canadian standard for child restraint systems with the regulations proposed by the United Nations and adopted across Europe. The current Canadian standard uses a compression test which is conducted on foam samples obtained from the manufacturer. This document describes a technique which can be used to test the entire assembly of a child restraint system as designed by its manufacturer. The European standard details a test which drops a headform onto the headrest of a child restraint system and records the acceleration throughout the impact.

The European standard uses a maximum threshold of 60g for a child restraint system to be compliant. It was shown in Section 3 that no child restraint system reached the maximum threshold. This includes the hard plastic shell. The highest acceleration measured throughout our experiments was with the hard plastic shell at a height of 400mm (300mm above the recommended height). It is evident that this should not be compliant, thus the threshold in the European standard must be revised accordingly.

Furthermore, the shape and stiffness of the headform are not the same as that of a human child's head. This document shows that the procedure detailed in the European standard does not discriminate between materials which are and aren't energy-absorbing. Due to the results observed in this set of experiments and the observable shortcomings of the test procedure outlined in this report the use of this standard cannot be recommended at this time.

References

[1] Government of Canada, "Motor vehicle restraint systems and booster seats safety regulations," 2015.

[2] United Nations, "Uniform provisions concerning the approval of enhanced Child Restraint Systems used on board of motor vehicles (ECRS)," 2013.