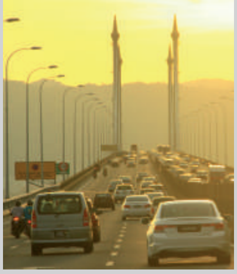
MRR No. 405

Research Report

Comparing CRS Performance between UN R44 and ASEAN NCAP CRS Sled Pulse



Yahaya Ahmad
Khairil Anwar Abu Kassim
Mohd Hafzi Md. Isa
Zanita Zainuddin
Mohd Rasid Osman
Salina Mustaffa
Siti Zaharah Ishak

MIROS
MALAYSIAN INSTITUTE OF ROAD SAFETY RESEARCH
ASEAN ROAD SAFETY CENTRE

Comparing CRS Performance between UN R44 and ASEAN NCAP CRS Sled Pulse

Yahaya Ahmad
Khairil Anwar Abu Kassim
Mohd Hafzi Md. Isa
Zanita Zainuddin
Mohd Rasid Osman
Salina Mustaffa
Siti Zaharah Ishak

MIROS
MALAYSIAN INSTITUTE OF ROAD SAFETY RESEARCH
ASEAN ROAD SAFETY CENTRE

Published by:
Malaysian Institute of Road Safety Research (MIROS)
Lot 125-135, Jalan TKS 1, Taman Kajang Sentral,
43000 Kajang, Selangor Darul Ehsan, Malaysia.

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Yahaya Ahmad
Comparing CRS Performance between UN R44 and ASEAN NCAP CRS Sled Pulse/
Yahaya Ahmad, Khairil Anwar Abu Kassim, Mohd Hafzi Md. Isa,
Zanita Zainuddin, Mohd Rasid Osman, Salina Mustaffa, Siti Zaharah Ishak.
(Research Report; MRR No. 405)
ISBN 978-967-2988-22-9
1. Automobiles--Safety measures.
2. Child restraint systems in automobiles.
3. Crash pulses.
4. Government publications--Malaysia.
I. Khairil Anwar Abu Kassim. II. Mohd. Hafzi Md. Isa.
III. Zanita Zainuddin. IV. Mohd. Rasid Osman.
V. Salina Mustaffa. VI. Siti Zaharah Ishak.
VII. Title. VIII. Series.
629.276

Printed by:
Malaysian Institute of Road Safety Research (MIROS)

Typeface: Calibri
Size: 11 pt.

Contents

List of Figures

Acknowledgements

The authors would like to express their appreciation to the Director-General of the Malaysian Institute of Road Safety Research (MIROS), Dr Siti Zaharah, and the Director of Vehicle Safety and Biomechanics Research Centre (VSB), Ir Mohd Rasid Osman for their support to this report; and to PROTON for providing the help and facilities for the test. Our gratitude also goes out to all the stakeholders, partners, relevant agencies/companies and research participants who have contributed their invaluable ideas, input, energy and time towards the production of this report. Last but not least, the authors would also like to express special thanks to those who have directly and indirectly contributed toward the success of this project.

Abstract

Crash severity is determined by the energy transfer to the occupant compartment during a crash event. This energy transfer is known as Delta V. It is defined as the maximum vehicle velocity change throughout the crash duration. Such a definition has been used to determine the severity of real-world crashes to correlate with occupant injury inside the vehicle. Delta V is normally obtained through a vehicle post-crash damage assessment for real world crashes.

This study will further explore the behaviour of ASEAN NCAP CRS pulse which has been developed based on ASEAN NCAP assessment protocol. The study was conducted using two (2) types of pulses, namely UN R44 frontal sled pulse and ASEAN NCAP CRS pulse. The pulse measurement was taken from the accelerometer mounted on the sled platform in x direction only. The injuries criteria were recorded using tri-axial accelerometers installed in the head and chest of the P-series dummies. Comparisons of the pulse behaviour were based on these measurements.

The analysis found that the main difference between both pulses was that UN R44 rose to the peak faster (with higher slope) than ASEAN NCAP CRS pulse. Besides, UN R44 reached its peak 25 ms earlier than ASEAN NCAP CRS pulse. This factor contributed to the dummy response in both cases. Different peaks duration could also be observed in all cases. The peak timing for the dummy head and chest therefore varied by 20 ms and 25 ms respectively. Such a difference was due to the kinematics between the head and chest.

Injury comparison between both pulses can be divided into the head and chest categories. In the head category for the P3 dummy, ASEAN NCAP CRS pulse recorded a higher peak value compared to the UN R44 by 4.78G. In the case of the P1.5 dummy, the head acceleration peak for UN R44 was higher than ASEAN NCAP CRS pulse by 2.43G. As for the chest acceleration, the trend is reversed. UN R44 pulse was higher by 1.04G for

the P3 dummy while ASEAN NCAP CRS pulse was higher by 6.41G for the P1.5. The contradicting trend in both cases may be due to the direction of CRS installation where P3 was installed in a forward-facing direction whereas P1.5 was facing rearward.

The limitation of the sled test facility to replicate a full-scale crash test was also studied by comparing the dummy response in both tests. The analysis showed that for all cases, the duration and shape of curves were similar. The first analysis was for the P3 dummy. The head acceleration comparison showed the curve matched for both test types with a slight difference of 1.27G. On the other hand, chest acceleration recorded a difference of 2.25G. In the case of the P1.5 dummy, the head resultant acceleration was similar for both tests, with a difference in peak value of 0.28G. However, the chest resultant acceleration registered a bigger difference by 4.64G. This was because the pitching of the vehicle in a full-scale crash test could not be replicated in the sled test.

1. Introduction

Road traffic deaths have become a major public health conundrum in Malaysia. Every year, over 6000 people are killed on Malaysian roads. Unfortunately, children are also part of such a high number of fatalities. This is because they normally travel with adults either in cars or on motorbikes.

According to Norlen et al. (2011), children aged 1-4 years old and 5-8 years old travelling in private vehicles make up the first and second leading groups of road casualties with 43.8% and 30.2% respectively (Mohamed, et al., 2011). These statistics and findings have highlighted the need to implement stringent measures to reduce road deaths among children.

The seatbelt is a proven intervention to reduce the risk of fatality during road crashes for adults. However, it is not meant to protect children. Therefore, special Child Restraint Systems (CRS) or child safety seats have been designed to protect children in the event of a road accident. A correctly installed child seat can reduce the risk of death by 71% for infants and 54% for children aged from 1 to 4 years, in addition to reducing the need for hospitalization by 69% for those aged below 4 years old (Parenteau & Viano, 2003).

During a road accident, the crash severity is determined by the energy transfer to the car occupant compartment. This energy transfer is known as Delta V and is defined as the maximum vehicle velocity change during the crash. Such a definition has been used to determine the severity of real-world crashes to correlate with occupant injury inside the vehicle. Delta V is normally obtained through a vehicle post-crash damage assessment (Roberts & Compton, 1993; Bahouth et al., 2004; Nance et al., 2006).

In designing the testing methodology for a vehicle crash test, Delta V is used as a reference where it has been transformed into a type of barrier and impact speed. In the laboratory crash test, Delta V is measured using an accelerometer mounted on the B-pillar compared to the real world crash investigation where it is used to assess the damage to the vehicle structure. The accelerometer calculates vehicle deceleration and crash duration to determine the crash energy transfer to the occupant inside the vehicle.

While a passenger vehicle typically undergoes a crash test to assess its crash safety performance, the Child Restraint System (CRS) performance is determined through a sled test. Such a test replicates the crash test without damaging the vehicle. In the sled test, the energy of the crash is measured through either the braking system for deceleration or hydraulic system for acceleration. The energy is calculated using the sled system accelerometer replicating the reading from the crash test vehicle or Delta V from real-world crashes.

In a previous study, the deceleration data from an ASEAN NCAP crash test vehicle were collected to determine the crash energy from the recently designed vehicle platform. The energy shapes were defined and developed. This study will further explore the behaviour of the new ASEAN NCAP CRS sled pulse which was developed based on the ASEAN NCAP crash test.

1.1 Aims and Objectives of the Study

The current study aims to provide a recommendation for the sled pulse to be used in the CRS development and rating programme. For this purpose, the latest ASEAN vehicle structure crash pulse and performance are reflected in the study.

The study also aims to fulfill two (2) specific objectives for ASEAN NCAP CRS sled pulse evaluation:

i. To compare the Child Occupant Protection (COP) performance between UN Regulation 44 (UN R44) Standard and ASEAN NCAP CRS sled pulse in terms of head and chest accelerations.
ii. To understand the effects of ignoring Y and Z directions due to limitations of the sled test capability.

The study was conducted according to the availability of the Body in White (BIW) and was based on only one (1) model. The Body in White is the main supporting structure of the vehicle compartment.

2. Literature Review

The focus of the literature review is to provide an explanation regarding the energy from a collision which is transferred to the car occupant. It should be noted that energy management during a crash is very important in minimising injury to the occupant, or in this case, a child occupant. Further, the sled pulse for evaluating and validating the Child Restraint System performance shall also be discussed.

2.1 Crash Pulse

A vehicle crash or collision can be divided into three (3) phases. The first phase is the collision between the vehicle and another object. The second phase is the collision between the occupant and the vehicle interior, while the final phase involves the collision between the occupant's internal organs. Various technologies have been developed to manage the crash energy with the aim to protect an occupant during a crash. This results in the energy of the crash being minimized through the crumple zone in the first phase whereas the supplementary system including the airbag protects and restricts occupant kinematics during the crash. Subsequently, the energy transfer to the human body and internal organs is limited within the capability of human injury tolerance.

The safety criteria of a vehicle must be considered from its developmental stage to protect an occupant during a crash. Its structural design is very important during the first phase of a collision. The vehicle structure is required to absorb the impact energy, reduce the impact severity and maintain compartment integrity for the occupant to survive. Occupant injuries inside the vehicle are influenced by vehicle deceleration (pulse); hence modifying the deceleration peak level will naturally reduce the impact to the occupant (Jiri, 2000; Motozawa & Tahahiro, 2000; Motozawa et al., 2003). In other words, the vehicle structural performance determines its safety. To date, various studies have been conducted to assess the relationship between vehicle pulse and the loading to the dummy using different parameters and tools (Gearhart, 2001; Huang, 2002; Lundell, 1984; Sparke & Thomas, 1994).

2.2 Sled Pulse for Child Restraint System Performance Evaluation

The dynamic performance of a Child Restraint System is typically evaluated through a sled test. Energy of the impact is replicated through the sled pulse; measured using an accelerometer which is mounted on the sled platform. There are many pulse ranges based on various evaluations which are used in different regions. These shall be discussed in the following sub-sections.

2.2.1 Regulations

There are two (2) main regulations available for the Child Restraint System approval, namely UN R44 for the European Community and FMVSS 213 for the United States. Both regulations specify their unique sled pulse for compliance. Based on the latest updates, the pulse must be within the upper and lower range set by the regulations for approval. FMVSS 213 previously only referred to one (1) unique curve before introducing the upper and lower limits in 2005 (Arsdell, 2005). Figure 1 shows the upper and lower limits for both UN R44 and FMVSS 213.

As shown in Figure 1, the corridor for FMVSS sled pulse is narrower than that of UN R44. Furthermore, its pulse duration is shorter than UN R44 with FMVSS 213 at 90 ms whilst UN R44 is at 120 ms. However, the upper and lower limits for UN R44 are higher compared to FMVSS 213 with the former upper limit at 28 g while the latter is at 25 g.

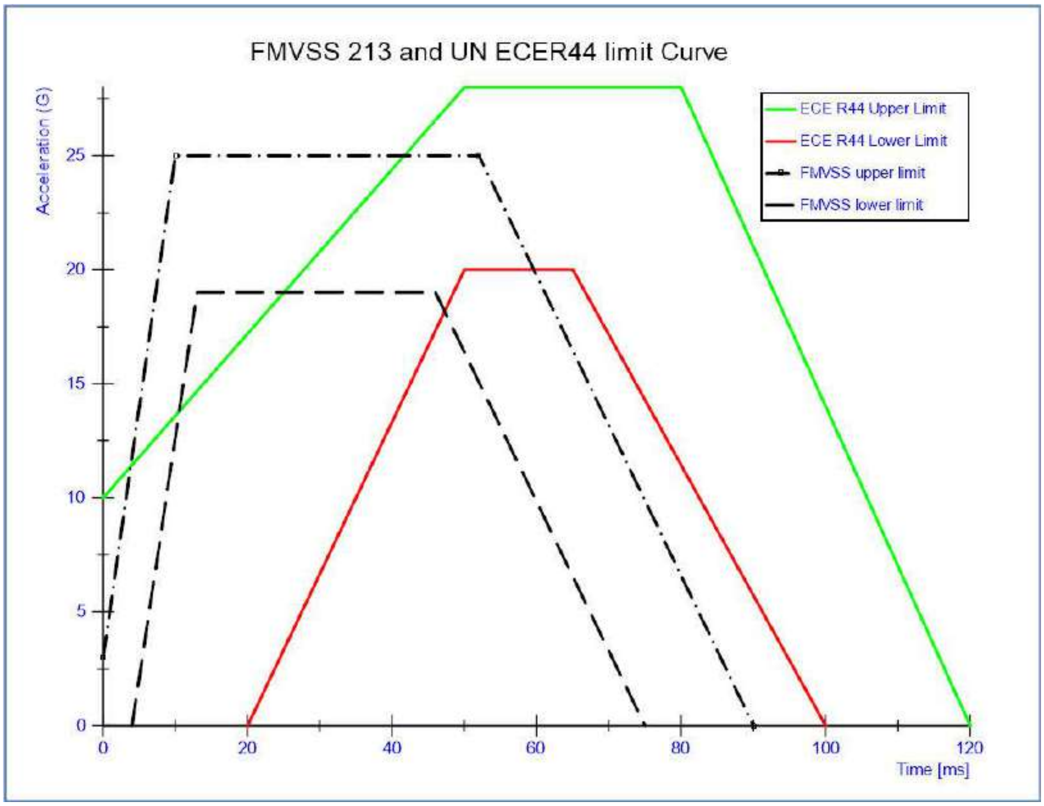


Figure 1 FMVSS 213 and UN R44 limit curve

2.2.2 Consumer Assessment Programmes

For a product to be in the market, it has to comply with certain regulations. However, the product does not necessarily need to provide information in terms of its safety level. On the contrary, a consumer assessment programme offers further information on the safety aspect of a certain product. This helps consumers to choose the best offerings in the market. Various consumer assessment programmes exist in different parts of the world with assessment requirements to suit each particular region. Because it is important for the assessment to simulate real-life incidences, the pulses for the consumer programme are usually more stringent compared to the regulatory requirements.

In Europe, the New Programme for the Assessment of Child Restraint Systems (NPACS) was established by the governments of the United Kingdom, the Netherlands, Germany, and the autonomous community of Catalonia; as well as five (5) non-governmental organisations. The pulse was developed based on the B-pillar acceleration results from EURO NCAP tests combined with accident data from EC Crest (Sandner, et al., 2009). NPACS introduces the 65 km/h pulse which has a similar shape to the UN R44 pulse but on a higher energy level. However, the pulse at the B-pillar is only available for X (forward) direction and is not measured in Y (yaw) and Z (pitch) directions. During the Offset Deformable Barrier (ODB) crash test, a car will rotate and pitch upon impact. Hence, the rotation and pitching can be captured through Y and Z directions.

Japan, through its Japan New Car Assessment Programme (JNCAP) has also established a local consumer programme for the Child Restraint System. Compared to NPACS, its approach in defining frontal impact pulse is different. The pulse is derived based on Japan's regulation that the impact speed be increased by 10% to 55 km/h (NASVA, 2008). However, no reason was given for the 10% speed increase.

In Australia, a special consumer programme called the Child Restraint Evaluation Programme (CREP) was introduced. The method of defining the pulse and speed also varies from the other programmes. The frontal impact speed at 56 km/h is defined based on the frontal impact regulation for vehicle (ADR 69). In addition, the deceleration peak is required to be in the range between 33 g and 34 g with 29 g being achieved in less than 30 ms and maintained for more than 20 ms. Deceleration levels lower than this range would be dismissed if the duration was less than 1 ms (CREP, 2015).

All the consumer programmes above have defined the pulse and impact speed based on different methods. Overall, the programmes use higher energy pulse and speed compared to the regulatory requirements.

3. Methodology

The test for this study was conducted using Body in White car structure instead of the test bench. BIW was selected to ensure comparison could be made between the crash test and the sled without the external factor of a different platform. Due to the limited availability of BIW, only one (1) model was used. The model was selected based on the availability of the full scale crash test data, BIW and the common CRS use.

To ensure sled pulse was the only variable in the test, the same CRS and P-series dummies were used for both sled test and crash test. Installation of the CRS and the dummies were based on ASEAN NCAP assessment protocol. In this case, Britax Duo plus was used for placing a 3-year-old dummy (P3) in a front-facing direction. Meanwhile, an 18-month-old dummy (P1.5) was installed using Britax Baby Safe SHR II in a rear-facing direction.

Figure 2 Sled test set up for CRS and dummies

The test was conducted with an accelerating sled which used a hydraulic system to replicate the crash test pulse. The pulse was measured with an accelerometer installed on the platform. As per Figure 2, the Body in White was cut in half. Only its rear section was used in the test to install the CRS using ISOFIX and top tether.

In this study, a test was conducted using two (2) types of pulses, namely UN R44 frontal sled pulse and ASEAN NCAP CRS pulse. The pulse measurement was based on the accelerometer mounted on the sled platform in X direction only. The injuries criteria were recorded using tri-axial accelerometers mounted to the head and chest of the dummies. Comparisons of the pulse behaviour were based on these measurements.

4. Results

This section discusses the study results and findings. They are presented by defining the crash pulse replication in the sled test. Comparison between the UN R44 sled test and ASEAN NCAP CRS pulse was based on the injuries to the 3-year-old (P3) and 18-month-old (P1.5) dummies.

4.1 Crash Pulse Tuning

The main variable in this study was the replication of the crash pulse. This was achieved through the accelerometer installed on the sled platform. To ensure the replication was done properly, additional weight was added to the platform to match the full scale crash test weight. This was necessary to compensate the weight loss as the BIW was cut in half.

The pulses for UN R44 and ASEAN NCAP tests are shown in Figure 3. The blue line represents ASEAN NCAP CRS pulse whereas the purple line represents R44 pulse. The corridor shown in the graph is the newly developed corridor based on a previous study. Both these pulses were used to compare injuries to the test dummies.

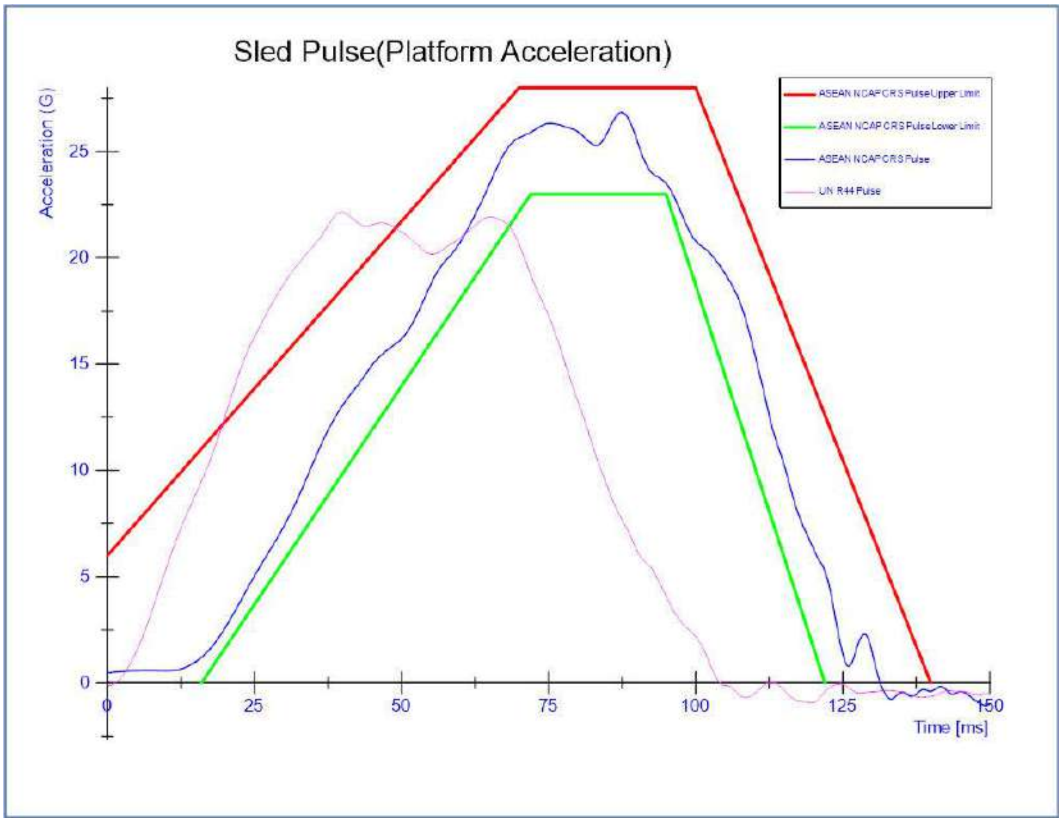


Figure 3 Sled test pulse for UN R44 and ASEAN NCAP based

UN R44 pulse is configured with a lower curve limit. The peak area is below the lower limit of ASEAN NCAP CRS pulse. The peak of UN R44 is also lower than ASEAN NCAP CRS pulse peak by around 5G. However, the acceleration of the UN R44 reaches a peak faster than ASEAN NCAP CRS pulse by around 30 milliseconds. The slope is also stiffer than ASEAN NCAP CRS pulse.

4.2 3-Year-Old Dummy Injury Comparison

As mentioned earlier, two (2) P-series dummies were used in this study to determine the influence of the new CRS pulse on occupant injury and kinematics. A P3 dummy representing a 3-year-old child was placed in the Britax Duo plus CRS. The CRS was attached to the vehicle using ISOFIX and top tether in a forward-facing direction. Hence the dummy was facing the front of the vehicle; in the driving direction.

4.2.1 Comparison between UN R44 Sled Pulse and ASEAN NCAP CRS Pulse

The injury comparison was based on two (2) tri-axial accelerometer readings on the head and chest of the dummy. Three (3) criteria were used for this purpose, namely the head resultant, chest resultant and chest acceleration in the Z direction. These were also the criteria used in both UN R44 and ASEAN NCAP assessment.

Head acceleration for both cases is shown in Figure 4. The red curve represents ASEAN NCAP CRS pulse while the green curve represents UN R44 pulse. It can be seen that the duration of the acceleration peaks is different in both cases. The peak for UN R44 occurs at around 75 ms while the peak for ASEAN NCAP CRS pulse is at 100 ms. The difference is about 25 ms. This also reflects the sled pulse peak timing for both cases. However, the peak timing for head acceleration for both cases occurs at the end of the sled pulse peak duration. The peak for both ASEAN NCAP CRS pulse and UN R44 is recorded at 47.96G and 43.18G respectively. The peak for ASEAN NCAP CRS pulse is higher than UN R44 pulse by around 5G.

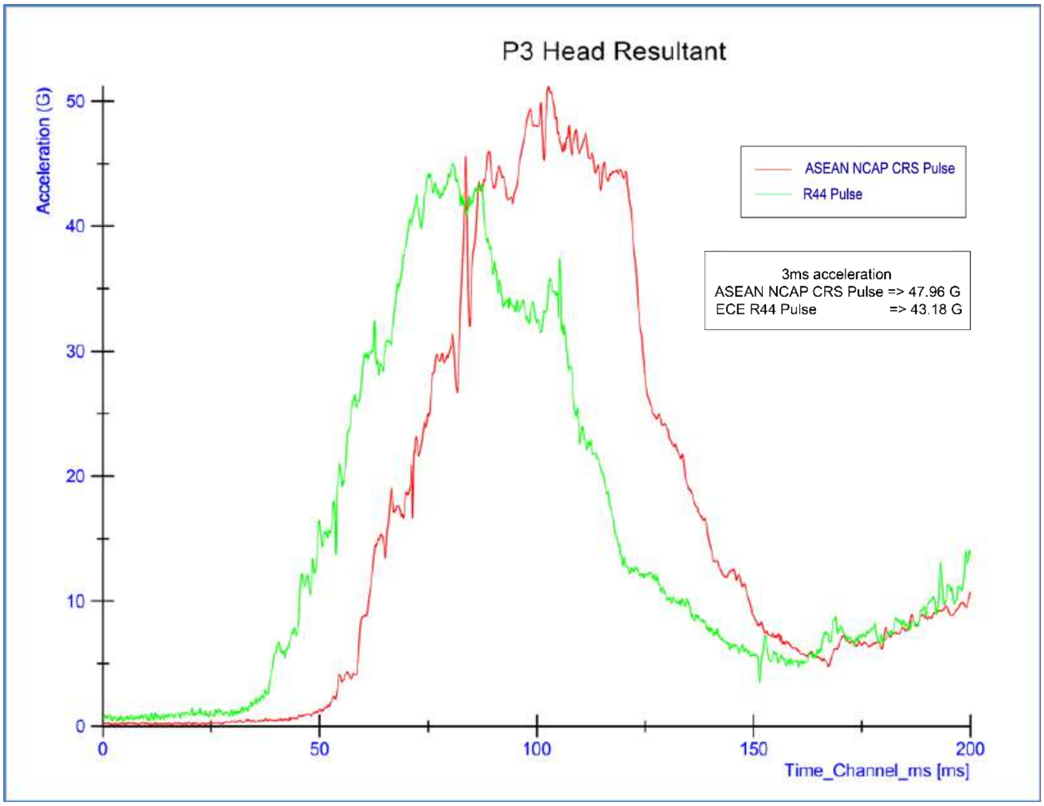


Figure 4 P3 head acceleration resultant comparison between UN R44 and ASEAN NCAP CRS sled pulse

The next injury criterion compared was the chest resultant measured using the tri-axial accelerometer inside the chest. Figure 5 shows the chest resultant acceleration for both ASEAN NCAP CRS pulse and UN R44 pulse. The peak for UN R44 pulse and ASEAN NCAP CRS pulse are 38.88G and 37.84G respectively. The chest resultant acceleration for R44 is higher than ASEAN NCAP CRS pulse by 1G. It can be observed that the peak timing for the chest resultant occurs midway through the sled pulse peak in both cases. This differs from the head acceleration where the peak occurs at the end of sled pulse peak duration.

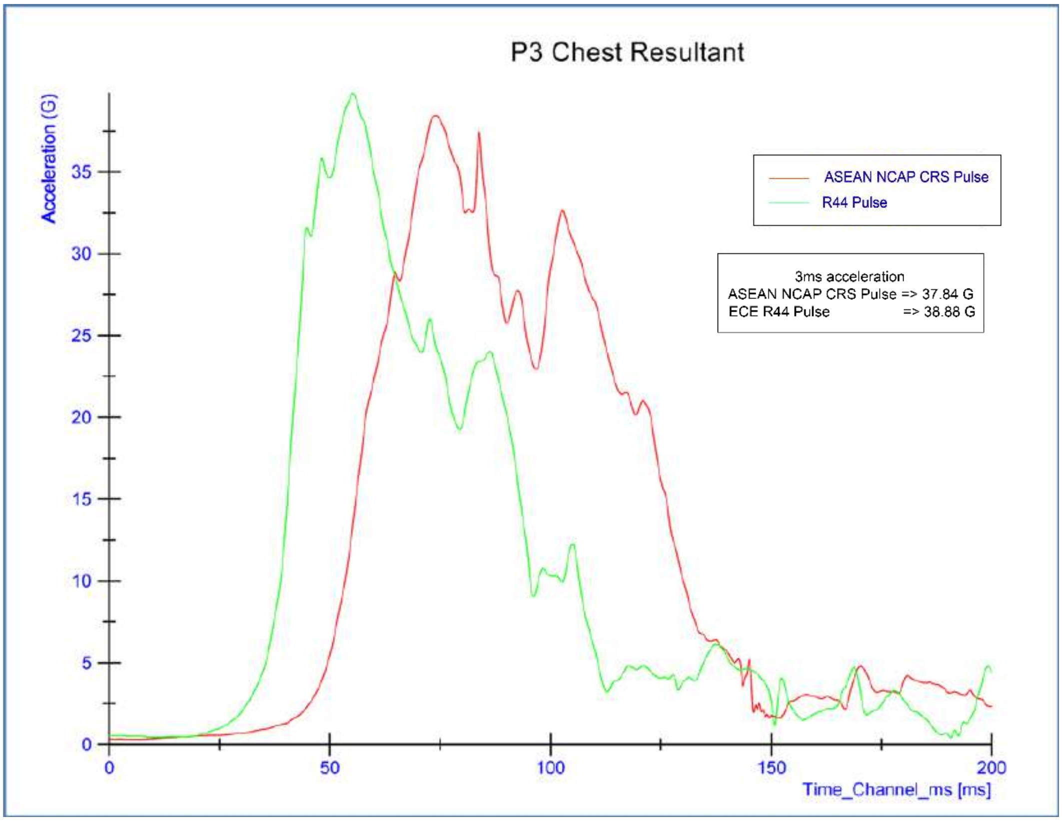


Figure 5 P3 head chest resultant comparison between UN R44 and ASEAN NCAP CRS sled pulse

The final injury criterion to the 3-year-old dummy was the chest acceleration in the Z direction. Figure 6 shows the comparison between both pulses. The chest acceleration curves show a similar trend and shape. However ASEAN NCAP CRS pulse registers a higher peak value compared to UN R44 pulse. On the other hand, by using a 3-ms criterion, the acceleration is lower than UN R44 pulse. This is because in the case of ASEAN NCAP CRS pulse, the 3-ms criterion is calculated using average acceleration in 3 ms.

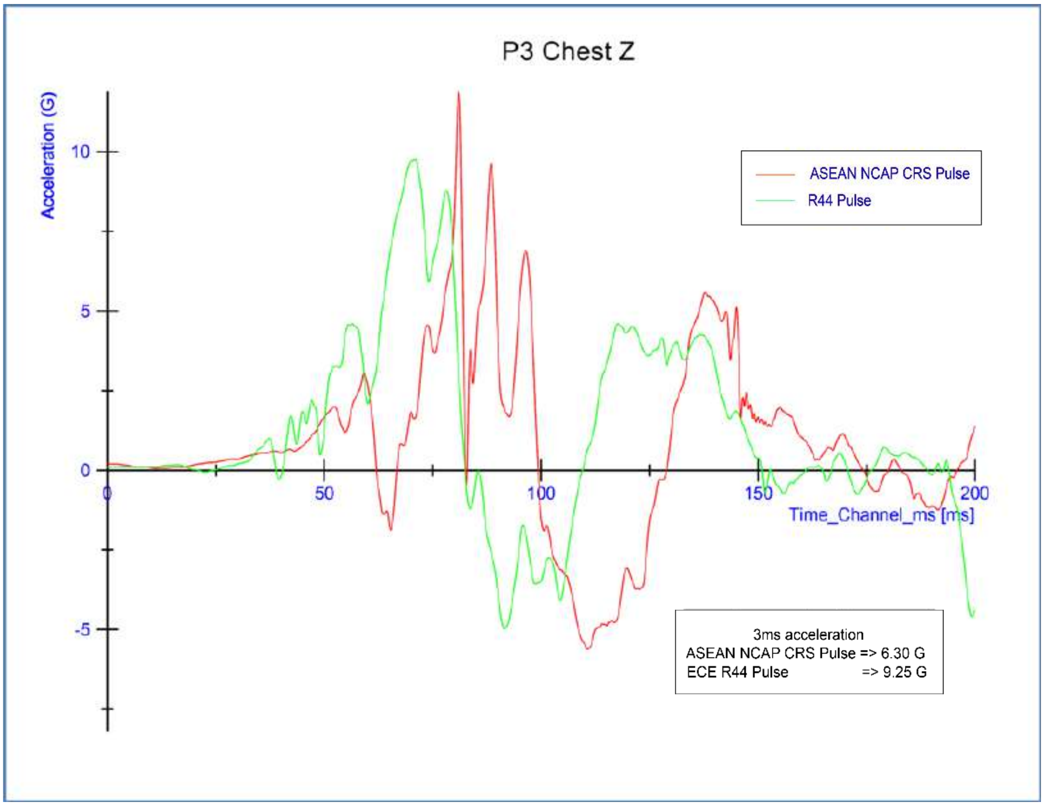


Figure 6 P3 chest Z comparison between UN R44 and ASEAN NCAP CRS pulse

4.2.2 Comparison between Full Scale Crash Test and Sled Test

A sled test is the simplified version of the full-scale crash test. It is a non-destructive test where the vehicle body can be used repeatedly. The consumable of the test includes vehicle equipment such as the airbag, seatbelt, car seat, CRS and others. A comparison is required to understand the influence of the Y and Z direction that cannot be integrated into traditional sled test facilities.

Similar to the previous section, three (3) criteria are used in comparing the influence of a single axis pulse in the X direction only. The criteria are head resultant acceleration, chest resultant acceleration and chest acceleration in the Z direction. These are the criteria required in UN R44 for the forward-facing seating arrangement.

The first criterion is the head resultant acceleration. Figure 7 provides the comparison between a full-scale crash test and sled test. The curve shape is similar in both cases. The duration and location of the peak also suggest both types of tests produce similar results. The 3 ms head acceleration registers 47.96G and 49.23G for the sled test and full-scale crash test respectively. The difference between the two tests is only 1G.

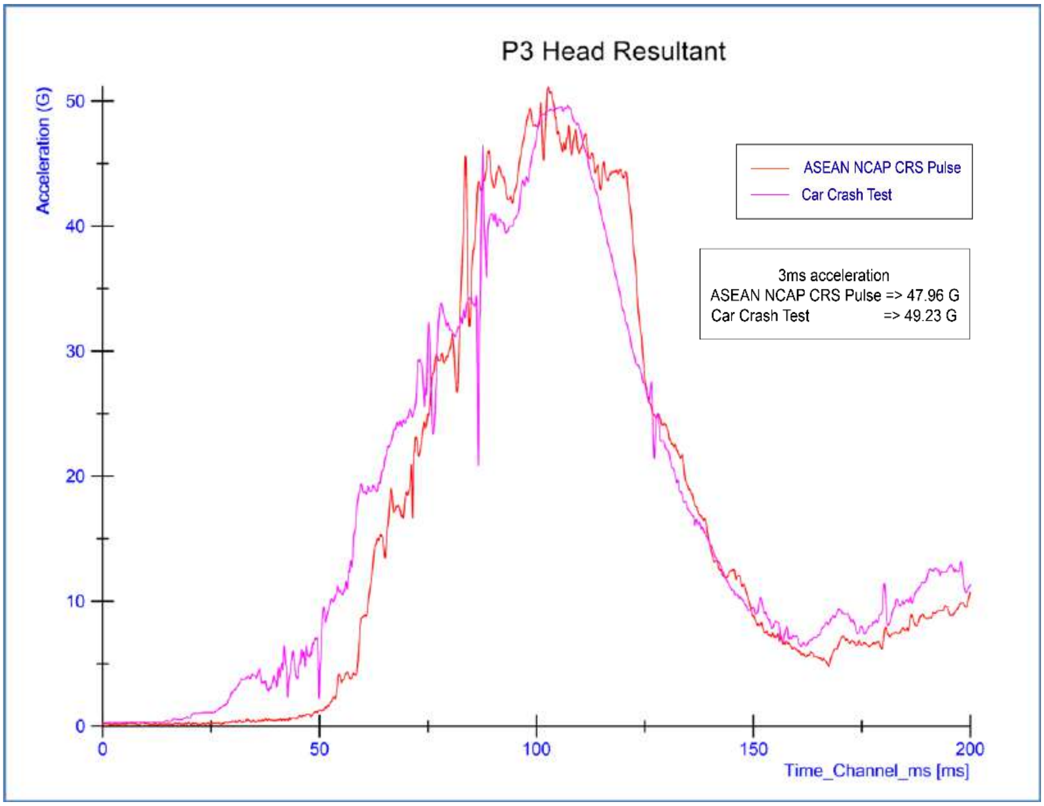


Figure 7 Head acceleration resultant comparison between full scale crash test and sled test

Chest acceleration for both tests is shown in Figure 8. Both the curves show a similar pattern of increasing and decreasing slope. There are two (2) peaks for both types of pulse. However, the highest peak is different in both tests. The highest peak for the sled test occurs at the first peak whereas in the full-scale crash test, it occurs at the second peak. The difference between the 3-ms acceleration values is about 2G.

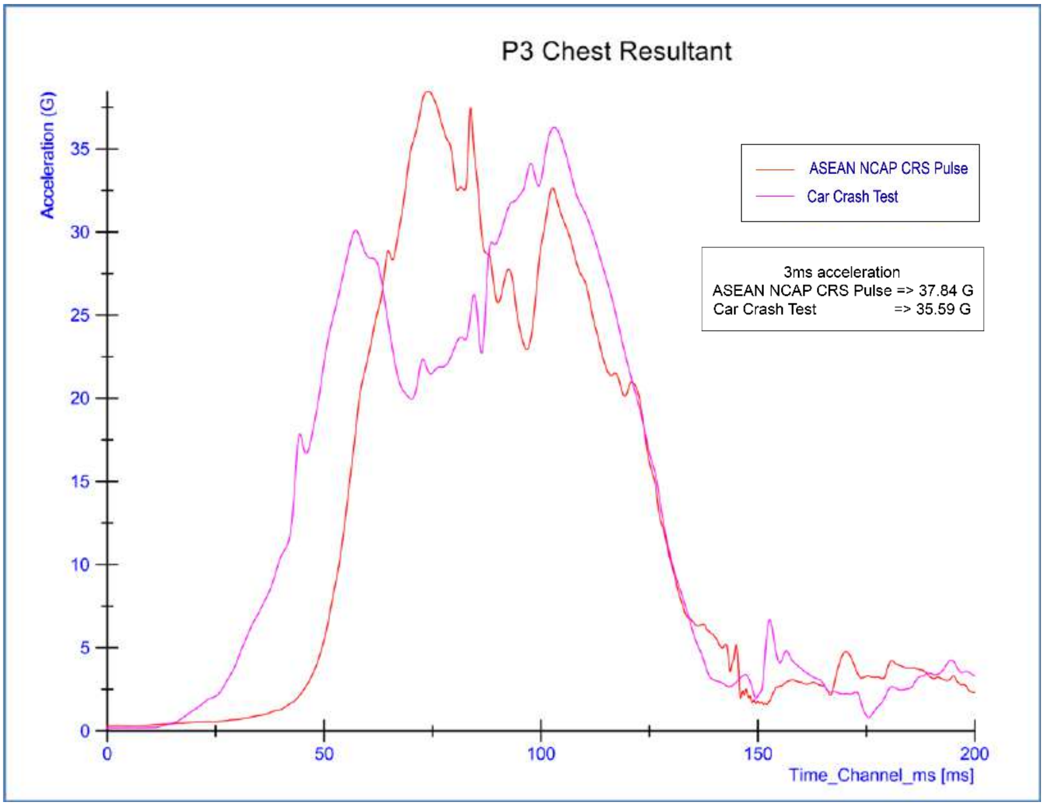


Figure 8 Chest acceleration resultant comparison between full scale crash test and sled test

4.3 18-Month-Old Dummy Injury Comparison

The second injuries comparison is based on the P1.5 dummy representing an 18-month-old baby. The dummy was placed inside the Britax Baby Safe SHR II Child Restraint System (CRS). The CRS was then integrated with the vehicle through ISOFIX bracket for fixing the CRS; and a support leg to prevent rotation movement. Finally, the CRS was placed in a rear-facing arrangement as stipulated in the regulation.

4.3.1 Comparison between UN R44 Sled Pulse and ASEAN NCAP CRS Pulse

Similar to the P3 dummy, the P1.5 dummy was equipped with two tri-axial accelerometers for measuring injury. The accelerometers were mounted inside its head and chest. The parameters used for comparison are the head resultant acceleration, head acceleration in Z direction and chest resultant acceleration.

Figure 9 compares the results of the head resultant acceleration between UN R44 and ASEAN NCAP CRS pulse. The green curve represents UN R44 sled pulse, and it reaches the peak earlier than ASEAN NCAP CRS pulse. This is due to the nature of the sled pulse where the pulse duration is shorter than the ASEAN NCAP CRS pulse. The 3-ms acceleration criterion for ASEAN NCAP CRS pulse is 43.07G, while for UN R44 it is 45.50G. In this case, ASEAN NCAP CRS pulse head acceleration resultant is lower than UN R44 pulse by 2.5G. The peak shapes are also different with ASEAN NCAP CRS pulse maintaining the higher average value longer than UN R44 pulse. The duration is around 25 ms compared to UN R44 with just around 5 ms.

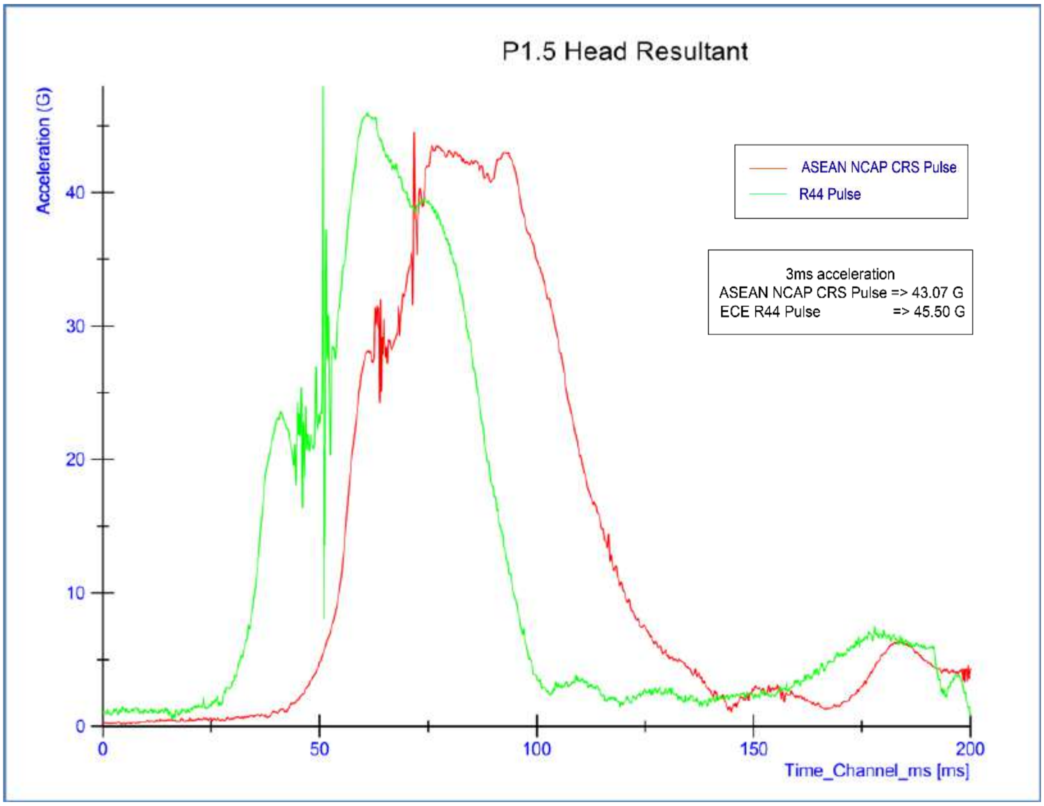


Figure 9 Head resultant acceleration comparison between UN R44 and ASEAN NCAP CRS pulse

Figure 10 compares the head acceleration in Z direction, representing the tension experienced by the neck where the head is moving in Z direction (top of head). The acceleration shape is similar in both cases. However, UN R44 pulse registers higher acceleration value compared to ASEAN NCAP CRS pulse by 2.7G.

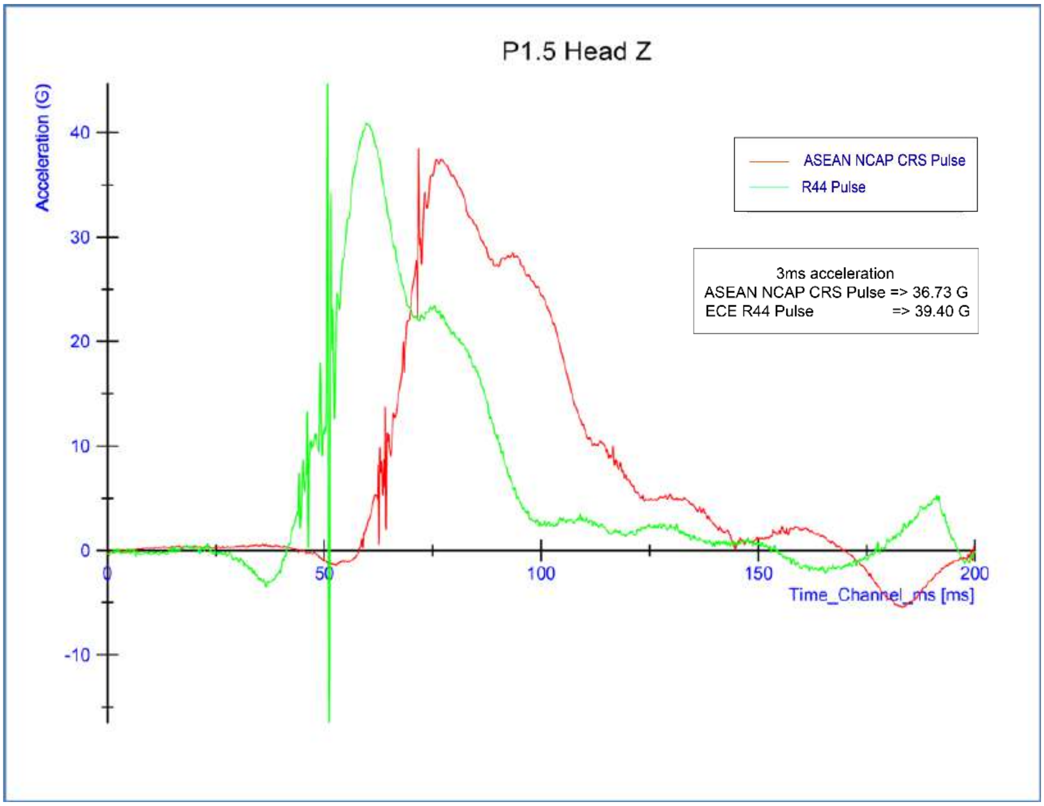


Figure 10 Head Z acceleration comparison between UN R44 and ASEAN NCAP CRS pulse

The third criterion being studied is the chest resultant acceleration. Figure 11 compares the results between UN R44 and ASEAN NCAP CRS pulse. The ASEAN NCAP CRS pulse registers a higher and sharper value by 6.4G. The UN R44 and ASEAN NCAP CRS pulse chest resultant acceleration are 31.94G and 38.35G respectively.

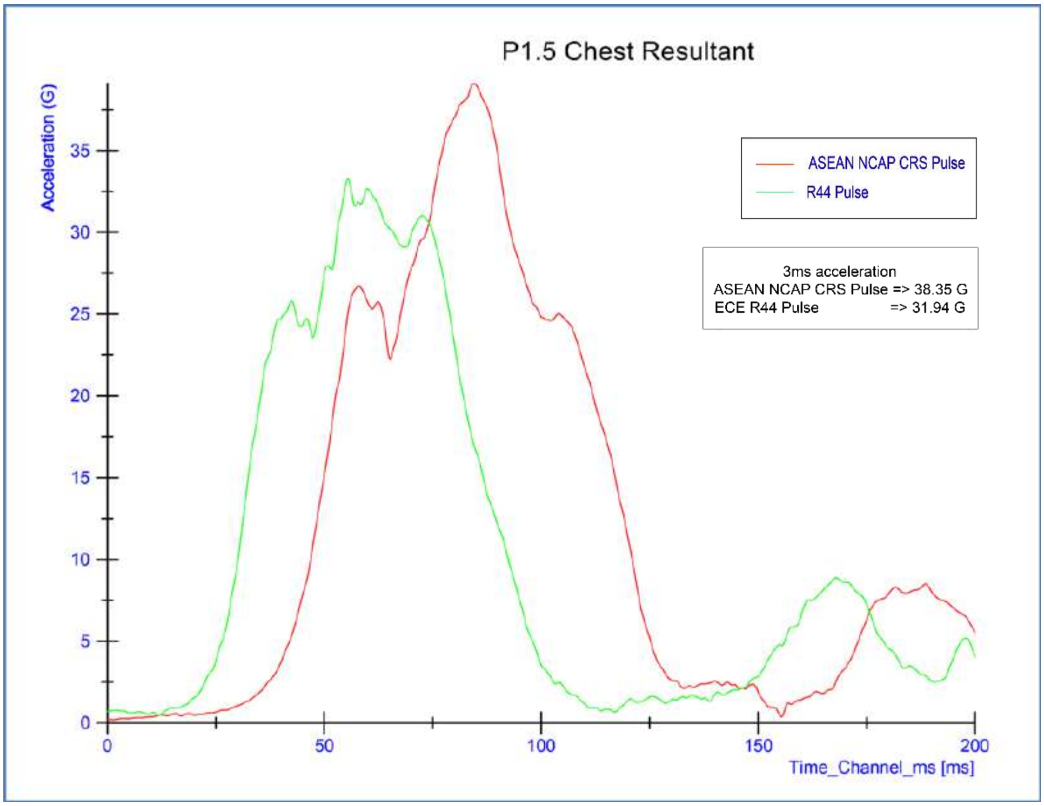


Figure 11 Chest resultant acceleration comparison between UN R44 and ASEAN NCAP CRS pulse

4.3.2 Comparison between Full Scale Crash Test and Sled Test

Finally, the head and chest resultant acceleration for the 18-month-old dummy were compared with the full-scale crash test results. This was done to understand and determine the limit and capability of the sled test to imitate a full crash test pulse.

Comparison of the head resultant acceleration is shown in Figure 12. The peak value for both pulses is similar; with a difference of only 0.3G. However, the peak timing and duration vary. The full-scale crash test reaches its peak earlier although the ascending rate is similar in both cases.

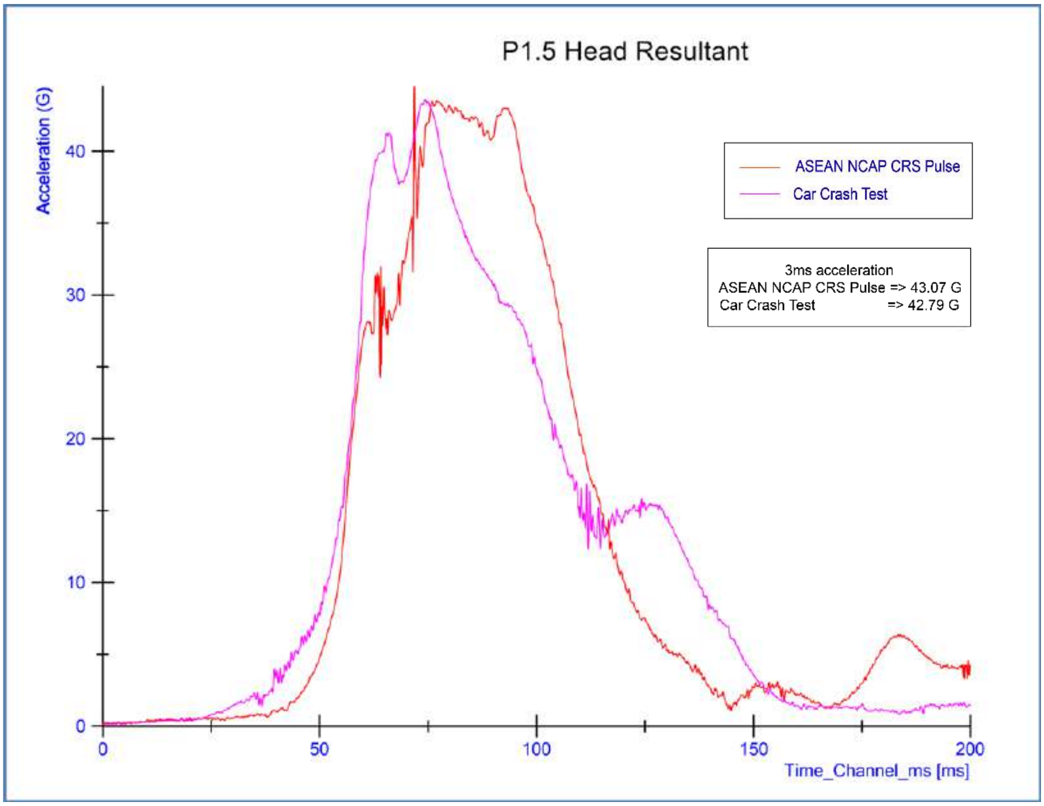


Figure 12 Head resultant comparison between full scale crash test and sled test

The next criterion is chest resultant acceleration. Figure 13 compares the chest resultant acceleration for both pulses. The shapes are different in both cases with the full-scale crash test producing two (2) similar value peaks. In the sled test, the first peak is lower than the second peak. Nevertheless, the timing and duration of the peak are the same for both pulses. Both ASEAN NCAP CRS pulse and the full-scale car crash test register 3-ms acceleration of 38.35G and 33.71G respectively.

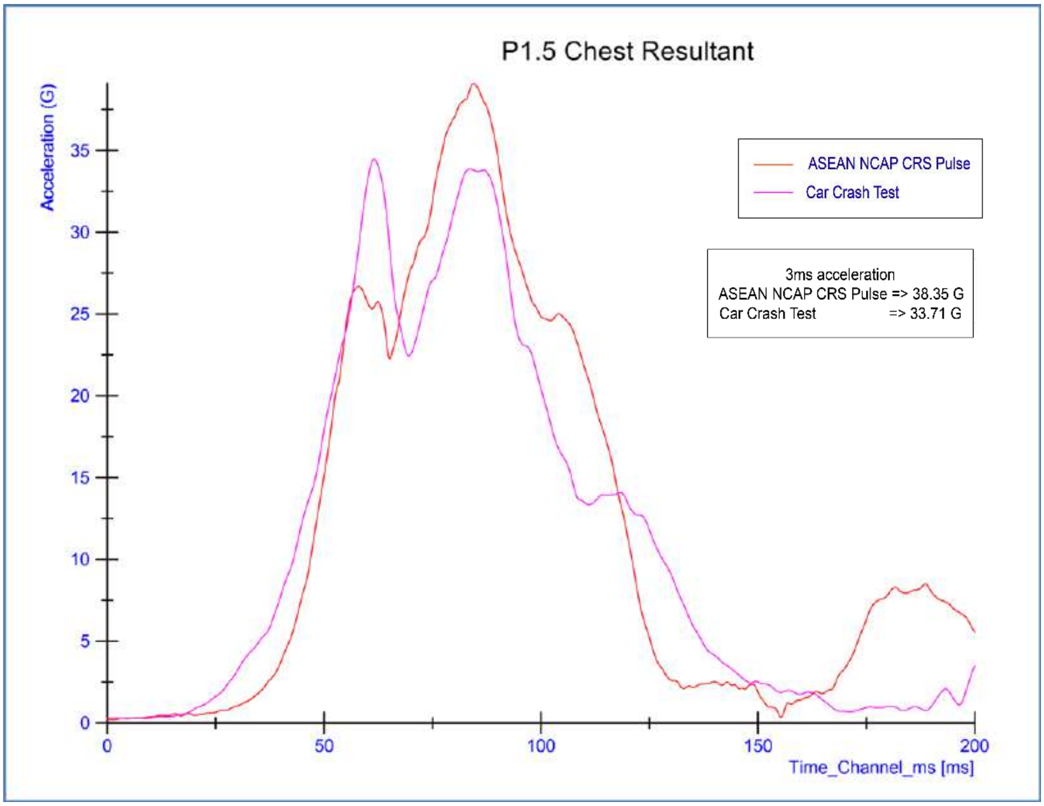


Figure 13 Chest resultant comparison between full scale crash test and sled test

5. Discussion

To produce the best CRS design, it is important to understand the latest energy management in the current vehicle design and structure. It is also imperative to realize the different levels of the new CRS pulse, based on ASEAN NCAP assessment protocol, versus the current UN R44 sled test pulse. Further, the limitations of the sled test facility compared to a full-scale crash test must be acknowledged. Only then can the comparison and the difference can be applied to the current CRS development.

There are two (2) limitations to this study. First, only one (1) vehicle model was used for comparison due to the availability of the Body in White vehicle structure. Second, only one (1) CRS model was used. The P3 dummy was placed inside a Britax Duo Plus CRS integrated with the vehicle using ISOFIX and top tether attachment. The P1.5 dummy was placed inside a Britax Baby Safe SHR II and integrated using ISOFIX and support leg. These CRSs were selected as they are widely used in full scale crash tests.

In interpreting the sled test results, it is important to note the capability of the laboratory to produce the sled pulse based on the upper and lower corridors. The pulse might vary between laboratories because of the tolerance between the upper and lower corridors. While one (1) laboratory is producing the sled pulse closest to the upper corridor, another test laboratory might be producing sled pulse at the lower corridor. This is also important to produce repeatability of results.

The analysis found that the main difference between both pulses is that UN R44 rose to the peak faster (with higher slope) than ASEAN NCAP CRS pulse. The UN R44 pulse reached its peaks 25 ms earlier than ASEAN NCAP CRS pulse. This factor has contributed to the dummy response in both cases. The dummies moved and responded faster in the case of UN R44 pulse compared to the new ASEAN NCAP pulse. Such a behaviour can be observed through the dummy head and chest acceleration peak. The peak for the head and chest were delayed by 20 ms and 25 ms in the case of the new pulse compared to

UN R44 pulse. However, the delay varied due to the kinematics between the head and chest.

Injury comparison between both pulses can be divided into the head and chest categories. In the head category for the P3 dummy, ASEAN NCAP CRS pulse registered a higher peak value than UN R44 by 4.78G. However, in the case of the P1.5 dummy, the head acceleration peak for UN R44 sled pulse was higher than ASEAN NCAP CRS pulse by 2.43G. As for the chest acceleration, the trend is reversed. UN R44 pulse was higher by 1.04G for the P3 dummy while ASEAN NCAP CRS pulse was higher by 6.41G for the P1.5. The contradicting trend in both cases may be due to the direction of CRS installation where P3 was installed in a forward-facing direction whereas P1.5 was facing rearward.

The limitation of the sled test facility to replicate a full scale crash test was studied by comparing the dummy response in both tests. The analysis showed that in all cases, the duration and shape of curves were similar. The first analysis was for the P3 dummy. The head acceleration comparison showed the curve matched for both test types with a slight difference of 1.27G. Chest acceleration curve shape was also similar in both tests with a difference of 2.25G peak recorded. In the case of P1.5 dummy, the head resultant acceleration was similar for both sled test and full-scale crash test. The difference in peak value was 0.28G. However, the chest resultant acceleration registered a bigger difference by 4.64G. This was because the pitching of the vehicle in a full scale crash test could not be replicated in the sled test.

6. Conclusion and Recommendation

In every collision, a car has been designed to absorb as much energy as possible. Nevertheless, there is still energy transfer to the occupant inside the compartment. It is important to understand the amount and shape of the energy to effectively mitigate the injury risk to the occupant. In this study, the influence of different energy in terms of crash pulse has been compared and analysed.

It can be concluded that the ASEAN NCAP CRS sled pulse based on an ASEAN NCAP crash test has contributed to the different energy management required in CRS design. This influence can be seen in terms of peak duration and timing. The dummy head and chest acceleration also registered different trends of peak and reverse effects between forward- and rear-facing CRS installation.

On the other hand, the sled test is capable of replicating the full-scale crash test in the X direction. However, the absence of the pitching effect contributed to the higher chest injury compared to the full-scale crash test. This study has achieved all its aims in comparing CRS performance between UN R44 frontal sled and ASEAN NCAP CRS pulse while comprehending the effects of ignoring Y and Z direction of a crash pulse.

Based on this study, it is recommended that ASEAN NCAP CRS pulse be used as the basis to determine the sled pulse in the evaluation scheme for a new CRS consumer programme. This sled test pulse can be used in CRS design with accurate energy management in response to the latest vehicle structure energy absorption capability. However, the new CRS pulse needs to be carefully used due to the absence of pitching effect.

References

Arsdell, & William W. Van. (2005). The evolution of FMVSS 213: Child restraint systems. s.l.: SAE, 2005. 2005-01-1840.

Bahouth, G. T., Digges, K. H., Bedewi, N. E., Kuznetsov, A., Augenstein, J. S., & Perdeck, E. (2004). Development of URGENCY 2.1 for prediction of crash injury severity. *Top Emerg. Med 26*(2), 157-165.

CREP. (2015). Child restraint evaluation program.

Gearhart, C. (2001). Recent progress in crash pulse analysis. *International Journal of Vehicle Design, 26*.

Huang, M. (2002). Vehicle crash mechanics. CRC Press.

Jiri, K. (2000). *Yet another look at crash pulse analysis.* SAE Technical Paper Series, 2006-01-0958.

Lundell, B. (1984). *Dynamic response of a belted dummy - A computer analysis of a crash pulse variation.* SAE Technical Paper Series, 840401.

Motozawa, M., Makoto, T., Yasushi, K., & Junya, N. (2003). *A new concept for occupant deceleration control in a crash – Part 2.* SAE Technical Paper Series, 2003-01-1228.

Motozawa, M., & Tahahiro, K. (2000). *A new concept for occupant deceleration control in a crash.* SAE Technical Paper Series, 2000-01-0881.

Nance, M. L., Elliot, M. R., Arbogast, K. B., Winston, F. K., & Durbin. D. R. (2006). Delta V as a predictor of significant Injury for children involved in frontal crashes. *Ann Surg., 243*(1),121-125.

NASVA. (2008). *Impact-shield type CRS in JNCAP.* s.l.: 43rd GRSP, 2008.

Norlen, M., et al. (2011). *An overview of road traffic injuries among children in Malaysia and its implication on road traffic injury prevention strategy.* Kajang: MIROS.

Parenteau, C., & Viano, D.C. (2003). *Field data analysis of rear occupant injuries part II: Children, toddlers and infants.* Detroit: SAE International, 2003.

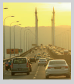
PDRM. (2013-2014). *Statistik kemalangan trafik.*

Roberts V. L., & Compton C. P. (1993). The relationship between Delta-V and injury. *Proceeding of the 37th Stapp Car Crash Conference* (pp. 35-41).

Sandner, & Volker, et al. (2009). *New program for the assessment of child restraint systems (NPACS) - Development/Research/Results - First step for future activities.* Stuttgart: Enhanced Safety of Vehicles (ESV), 2009. 09-0298.

Sparke, L., & Tomas, J. (1994). *Crash pulse optimization for minimum risk to car occupant.* SAE Technical Paper Series, 945162.





Research Report

Comparing CRS Performance between UN R44 and ASEAN NCAP CRS Sled Pulse

Designed by: MIROS

Malaysian Institute of Road Safety Research
Lot 125-135, Jalan TKS 1, Taman Kajang Sentral
43000 Kajang, Selangor Darul Ehsan
Tel: +603 8924 9200 **Fax**: +603 8733 2005
Website: www.miros.gov.my **E-mail**: dg@miros.gov.my

ISBN 978-967-2988-22-9