COUNTERMEASURES TO ADDRESS MISUSE IN CHILD RESTRAINT INSTALLATIONS: FROM TECHNICAL SOLUTIONS TO REAL WORLD EVALUATION

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ABSTRACT

Misuse has been reported in various studies as an important issue in countries where local legislation requires a mandatory use of child restraint systems. It has been shown that the rate of incorrect fitting of the CRS to the car may vary between 60 to 80% (1 Bendjellal, 2006).
However research has not confirmed that all misuse scenarios result in critical occupant loading but a combination of several misuse situations may lead to an improper occupant restraint (2 Bilston, Brown, 2011). It is therefore important to develop technical solutions aiming at reducing the risk of misuse in real-world. Slack in vehicle seat belts when securing the CRS to the vehicle and improper occupant restraint within the CRS are among the top 5 misuse situations according to Bennett study (3 Bennett, 2011) and in NHTSA 2005 survey (4 NHTSA, 2006).
Two technical solutions are presented in this paper, these are:

- A system (called A) that enables improving the attachment of the CRS to the vehicle by assisting the user to tighten properly the vehicle seatbelt
- A system (called B) that was developed: to improve the attachment of the CRS to the vehicle by tightening the vehicle seat-belt (mechanical solution); and (for harness seats) to reduce slack in the harness in riding conditions (electronic solution).

Operating modes of both systems are described. User trials were conducted to assess further the functionality of the systems as well as getting consumer feedback when utilizing them in real world. Key findings from these are also provided in the paper. Both systems show promising results in terms of assisting the users in installing CRSs.

INTRODUCTION

In previous papers, mechanical and / or visual systems were presented and these enabled the tension of the harness of the CRS to be adjusted by the caregiver. The Safe Strap system was developed in 2006 with the aim to provide such indication. The system is mounted on one of the straps of the CRS harness and comprises 2 members which are pivotally coupled. The upper member as shown in Figure 1 is equipped with visual pictograms illustrating the status of the harness tension. When the desired tension is not achieved the member is in a raised position thereby indicating that the tension is not correct. Pulling the adjuster strap of the CRS will reduce the slack and increase the tension in the harness; the upper member is then deflected to a flat position that is parallel with the harness strap. Pictograms are provided as indicators of the correct or incorrect tension.

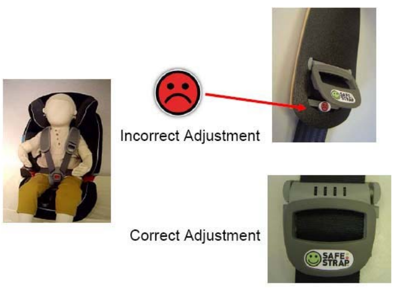


Figure 1: Safe Strap System

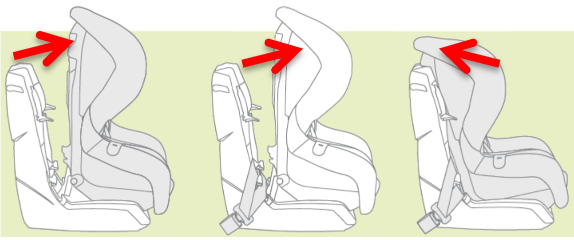
Figure 2: Audible system to help user adjusting correctly the harness

Another technical solution consists in providing the user an audible signal that indicates a correct level of harness adjustment was reached. Such a solution, called Click & Safe™ was introduced in 2008 on Group 1 seats. When pulling the adjuster strap forward and upwards audible clicks indicate that there is no slack or a minimum slack and, that an optimum tension in the harness was achieved. An illustration is provided in Figure 2. Based on lessons learned with these systems, new features were developed which are presented in the following. This paper focuses on CRS systems which use: the vehicle's 3-point seat belt to secure the CRS to the vehicle; and an integrated harness system to secure the child occupant within the CRS.

Installing car seats in vehicles requires 3 steps – First reading the user guide of both the vehicle and the CRS by the caregiver; second- installing the seat into the car and securing the CRS with the seat-belt with a properly routed belt, third-installing the child in the seat and placing the harness and tightening it. It is important that all these 3 steps are carried out properly. But in reality parents tend to speed up the first step, hence the risk to oversee important information. User manuals in general contain a lot of information, required by regulation but can be intimidating for parents. The second step is essential to ensure that the CRS is adequately secured to the car. That means a correct belt routing and getting the belt tight enough to retain the CRS. This part of the installation can be challenging as parents, once the belt is properly routed, often exert less or much effort to tighten the belt, only to find as they check their work that the child restraint still feels loose. Isofix system was introduced to address this potential problem and provide an effective solution for parents. However there are still many countries around the world where this attachment is not available in vehicles. For seats which use harness systems, the 3rd step involves tightening the harness with sufficient force to properly restrain the child.

ENHANCING THE CHILD ATTACHMENT WITH THE SEAT-BELT- SYSTEM A

Introduced in 2000 on a forward facing CRS, the system features a tensioning arrangement for the lap strap of a vehicle seat belt, consisting of side limbs and levers. When the seat shell is moved from the raised position illustrated in Figure 3 by the letter (a), to its position of normal use (c) , the levers are pushed downwards so that the side limbs (position b) deflect the lap strap from the direct path of the belt guides.

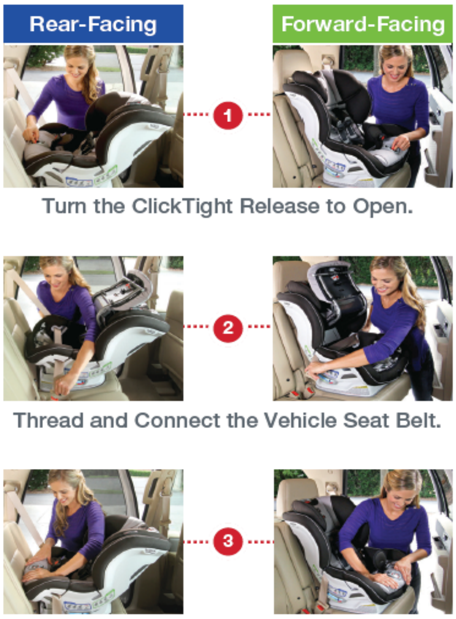


a b c

Figure 3: A tensioning system of the seat-belt introduced in 2000 on a Forward Facing CRS

Recently a system called Click-Tight (System A) was developed and introduced on a US convertible platform. It features a large tensioning arm that opens completely to allow for easy and clear routing of the belt from the front of the seat with easy access forward or rearward facing. With the system, there is only one installation method necessary regardless of the size of the child, or which orientation (FWF or RWF).

Once the belt is routed properly through the simple and accessible belt path, the tensioning arm can be easily closed over the vehicle belt. Once the tensioner clicks closed, the mechanism is locked and the belt is properly tensioned. Figure 4 illustrates the operating mode of the Click Tight.



Closing the tensioning arm over the seatbelt

Figure 4: Click Tight Feature

ENHANCING THE CHILD TO CRS ATTACHMENT - SYSTEM B

The system was developed for child restraint systems with integrated harness and was introduced in EU in 2014 on a Group I platform (9-18 kg mass range). The CRS was equipped with seat-belt tightening system. The feature described here is included in the 'safety loop' of the integral harness and comprises harness straps, an adjuster, a buckle, energy absorbing chest pads and 4 key elements that are part of the innovation, called Automatic Tensioning System:

- A bezel as the communication interface to consumers showing the status of the child restraint system,
- An integrated retractor system that bridges the harness and the adjuster,
- Sensor that detects the occupant presence and controls automatically power supply,
- Software and electronic components.

The Automatic Tensioning System supports the installation of the child by a real time measured tension control on the integrated harness with respective feedback to the caregiver. The resulting tension on the safety loop of the child restraint system is kept over time by the Automatic Tensioning System in real time as well, independent from movements of the child or any other unintentional effect, which could cause loss of tension.
For extreme situations, e.g. unintended buckle release, the system is equipped with electromechanical alert devices, communicating with the caregiver. The key steps in utilizing the ATS are shown in Figure 5.
Once the user has placed the child into the seat, the system is automatically detecting that a child has been placed into the seat. The seat can detect this by the means of a sensor that is located underneath the seating surface. After a pre-defined time the bezel lights up red, as shown in Figure 6, which indicates to the user that the system is activated.

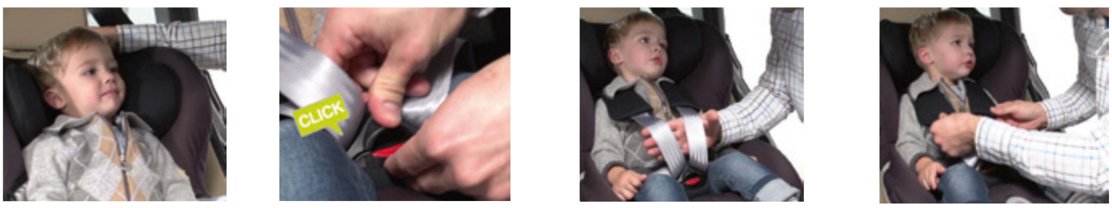


Figure 5: Key steps in utilizing the Automatic Tensioning System

Figure 6: The bezel lights up red and no audible signal indicates that the system is activated.

Figure 7: The bezel lights up green and audible signal can be heard.

Would the user leave the child un-buckled in the child seat or would not harness the child to the correct harness tension an audible alert will be activated after a pre-defined time. This is comparable to the seat belt reminder installed in vehicles that will deliver an audible alert if the driver forgets to buckle up.

In normal operating, a user would harness the child in a similar process as for comparable 5 point safety harnesses. The shoulder straps would be placed over the shoulders and the buckle tongs would be brought together and placed into the buckle. The tightening of the harness can be done by pulling the adjustor strap. The user needs to pull the adjustor strap till the bezel, as shown in figure 7, is lighting-up green and giving an audible signal.

Besides that the system is guiding the user to a proper harness fit the system has two additional functions. The mechanical part of the system has the capability to take slack out of the harness system. The system is able to remove this slack or looseness of the harness within a defined range. The system is designed to ensure that the harness fit remains at the same level of tension as at the moment of harnessing or increases in tension to the required level over time. In case the defined range of compensation has been reached the system will alert the user that the system will not compensate further. Where further tension is required (in normal usage, this should not be necessary as the fit should be equal or better than the original harness tension) or desired by the user, the system can be reloaded again by pulling again the adjustor strap, till the bezel lights-up green, as shown in Figure 7.

Another function that the system provides is that, once the system is fully loaded, it can alert the user in case the child is escaping or unbuckling itself. The bezel will light up red and an audible signal will alert the user. Allowing users to pull over and harness the child correctly.

CLICK TIGHT SYSTEM VALIDATION

The system A was evaluated in consumer trials that took place in different geographic locations. Consumers were asked to read the user guide, install the CRS in the vehicle and then use the Click Tight system. Both rear facing and forward facing installation were used. The key result: participants found the system easy to understand and operate, and felt satisfied with the resulting tension of the seat-belt once the tensioning arm was locked.

AUTOMATIC TENSIONING SYSTEM VALIDATION

The ATS system has been tested during the development multiple times in various conditions, ranging from mechanical tests to electronic tests. Besides all relevant component / seat testing related to the homologation of the seat has been tested as well with consumer at different development stages. Some of the main research questions were: would users be able to use the ATS system, would the comfort of the child be influenced by the continuous retracting of the ATS system, would the perceived fit of the harness be rated as sufficient?

The system has been tested with consumers in two different ways. Pre-homologation of the seat the test took place in a car clinic environment. Multiple groups with more than 30 users tested different models during the development in this controlled environment, as shown in Figure 8. The consumers were asked to perform predefined tasks like placing the child into the seat while the car seat was installed into a car. During this test children wore different types of clothes. Children age ranged from 9 months to 4 years.

Figure 8: Car clinic of fitting test.

After the seat has been homologated it has been tested in a large scale combined qualitative and quantitative test. More than 100 consumers participated for a prolonged period of time. The main objective of the research was to gain a deep understanding of the user experience. The field investigation consisted of 3 different stages.

In the first stage the consumers have been trained similar to the training they would get in a retail environment. After this the same predefined tasks has been performed as in the car clinic tests. In the second stage the test persons tested the seat in their own car for more than 3 weeks. During this period a group of 40 users had an application installed on their smart-phones to give real-time feedback about the ATS. They have been asked to perform some predefined tasks of harnessing their child before and after their journey, to rate this and make pictures of these situations. As last stage of the field test all test persons have been interviewed to gain quantitative and qualitative feedback on the seat.

FINDINGS /RESULTS

The system A (Click Tight) shows very good results in terms of:

- Facilitation the task of seat-belt routing and seat-belt tensioning when installing a convertible CRS,
- Reducing the slack in the vehicle seat belt
- This holds true for both rear facing and forward facing installation as the same tensioning arm is utilized for both configurations.

For the system B (ATS) results of the research highlighted that all users understood the functions of the system and could perform the task to harness their child correctly. In summary:

- 96% of the users rated the harness fit as correct.
- 27% of the users responded even that they would harness their child now tighter than before after discovering and using the ATS system.
- 90% of the users rated that the ATS system fulfilled the comfort expectations for their children.

CONCLUSIONS/PERSPECTIVE

The objective of this study was to present 2 features that were developed respectively to enhance the CRS to vehicle attachment, and to improve both CRS to vehicle attachment and securing the child to the CRS. The first system, called Click-Tight, was developed to help the user to get the appropriate tension of the vehicle seat-belt. A key component of the feature, i.e. a large tensioning arm helps to reach the correct tension of the seat-belt. In addition, the system works for both rear facing and forward facing installation. Feedback from consumer trials allowed assessing the system at various stages of the program. The system was launched in 2014 on a convertible CRS.

The 2nd system called “Automatic Tensioning System” was developed to help the care giver to install the child into the seat by providing a real time feedback on the harness tension. The ATS includes electronic as well as mechanical components, and has been developed and introduced on a R44 Group I platform. That platform was already equipped with a seat-belt tensioning system. The ATS among others features a sensor that detects the occupant presence. Once the child is installed and attached with harness, the ATS assists the user, when the later pulls the adjuster strap, with visual and sound indicators to reach the appropriate harness tension. The system has also the capability to remove the slack in the harness in real time. In addition an alert signal is initiated when a large slack is detected or when the seat buckle is released.

The ATS has been validated during various evaluation trials with consumers which were divided into 2 phases: a pre-homologation phase where the consumer trials took place in a car clinic environment. The second phase (post-homologation) involved more than 100 consumers. The key results from the whole consumer trial research shows that 96% of the participants rated the harness fit as correct and about one third responded that they would harness their child now tighter, and 90% of the users rated the ATS fulfilling the comfort expectations for their children.

Based on the consumer trials and experience gained in developing both systems; the next step will be to extend their application to other platforms.

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