Evaluation of the Seat Belt Anchorage Strength of a Prototype Wheelchair Integrated Occupant Restraint System

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Abstract

Seat integrated occupant restraint systems used in automotive applications have shown improved occupant safety and a decreased risk of injury during motor vehicle impacts. Research is being done to study the feasibility of seat-integrated restraint technology in the wheelchair industry. Previous studies using crash simulation software have shown an increase in wheelchair occupant crash protection when using a wheelchair occupant integrated restrain system (WIRS) versus vehicle mounted wheelchair occupant restrain systems. In this study, a solid model WIRS assembly was designed and analyzed using a Finite Element Analysis (FEA). The seat belt strength of a WIRS prototype was evaluated using the FMVSS 210 protocol. Loads and deformation on the WIRS prototype were measured as a result of an applied static load of 3000 lbs. on both shoulder and pelvic belt anchorage points. No rupture or failure of the integrated restrain system (IRS) or the wheelchair frame occurred.

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Wheelchairs are designed to provide mobility to individuals. Since many wheelchair users use their wheelchairs as motor vehicle seats, there is a growing demand for wheelchairs that can be safely used in transportation.

This means that design criteria need to be established for wheelchairs and occupant restraint systems. Design criteria in the areas of crash protection, seat design characteristics, usability and comfort.

This all needs to be done to provide individuals using a wheelchair comparable level of safety and user comfort as individuals seated in an original equipped and manufactured (OEM) vehicle seat and restraint system when exposed to crash conditions.
Background

Occupant Restraint Facts: (NHTSA Website, 1999)
- Reduce fatal injury by 45%
- Reduce serious injury by 50%
- 70% of Americans use seat belts
- Every hour, at least one American dies because he or she didn’t buckle up
- 980 children were injured every day in 1996 on US roadways
- An average of eight children <15 years old were killed

Wheelchair Standards Development:
- ANSI/RESNA WC-19 requires a wheelchair mounted pelvic belt (with a 2 year phase-in period)

These are some facts that show the necessity of seat belt use. The national highway traffic safety administration showed that the use of seat belts reduces fatal injury by 45% and serious injury by 50%.

The study also showed that in the US 70% of the Americans uses seat belts.

In spite of this percentage, every hour at least one American dies because he or she didn’t buckle up.

In addition, in 1996 an average of eight children younger than 15 years old were killed and 980 were injured every day on the US roadways.
Individuals using wheelchair occupant restraint systems were observed during the engagement process. Poor belt fit and unsafe restraint engagement was observed for each individual in the field study.

ACCESS in a paratransit service for persons who use wheelchairs.
Seat Integrated Restraint Advantages

Restraint effectiveness
Early crash participation/protection
Decreased torso rotation
Pelvic and shoulder belt anchors on the seat:

- Eliminates incorrect adjustment
- Optimizes belt geometry and user comfort
- Increases acceptance level of belt
- Improves ease of handling of the occupant restraint
- Improves protection in all incident situations

(Haberl et al. @ BMW, Germany, 1989; Wainwright et al., 1994; Cremer, 1986; Ruter & Hontschik @ Batelle Ins. Germany, 1979)

Extensive research has been done in the automotive industry to optimize the effectiveness and comfort of seat belts by integrating both torso and pelvic belt in the car seat. Haberl et al. @ BMW, Ruter & Hontschik @ the Batelle Institute, Wainwright et al, and Cremer, all studied restraint effectiveness when integrating a 3 point belt in the seat of a car.

They found that restraint effectiveness was improved by a shorter belt length and a decrease in belt stretch, reducing the forward displacement of the upper body.

Keeping the belt close and horizontal to the shoulder causes the occupant to participate early in the crash, whereas and the belt wraps well around the body which causes the body to rotate less around the belt.

Integrating the torso and pelvic belt in the seat has the following benefits:

No belt adjustment necessary when moving the seat for/rearward, optimized belt geometry results in optimum comfort and a higher user acceptance of the seat belt. Furthermore integrated seat belts feature improved protection in frontal as well as side, rear, and rollover impact.
Research Plan

- Prototype Wheelchair Integrated occupant Restraint System
- **Evaluate strength of seat belt anchors of a concept WIRS**
- Evaluate capability of seating system to withstand occupant restraint loads
- Evaluate occupant safety
- Optimize WIRS characteristics

The plan of research is as follows:

First the need for a wheelchair integrated restraint system was established through a field study, a survey and literature review.

Then a prototype WIRS was developed.

This study presents the strength evaluation of the seat belt anchors of the concept WIRS.

After this the effect of a dynamic impact on a WIRS will be evaluated as well as occupant safety.

Finally the design characteristics of a WIRS will be optimized using computer simulation techniques.
This slide shows the concept of WIRS
Both a FEA was done as well as a static strength test using the Instron loading instrument.
Seat Belt Anchorage Strength Test Setup (FMVSS 210)

A torso and pelvic body block are positioned on the prototype WIRS.

![Torso Body Block](image1)
![Pelvic Body Block](image2)

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An upward load of 3000 lb. is applied onto the pelvic and torso seat belt anchors.

This slide shows the test setup of the WIRS on the instron loading instrument. The WIRS was loaded using an upper torso and a pelvic body block. Load cells were used to collect load data from the upper torso belt and pelvic belt.
A preload of 300 lb was posed onto the WIRS.
A final load of 3000 lb was posed onto the WIRS.
This graph shows both the load data from the pelvic body block (lap belt anchors) and the data from the upper torso block (shoulder anchor point).

As you can see the load for the shoulder anchor point appears to reach 5400 lb. instead of the required 3000 lb. The pelvic anchors reached 1500 lb.
Conclusion

- Test was successful.
- A load > 3000 lbs. was applied to shoulder belt anchor point (5400 lb.!)  
- A load < 1489 lbs. was applied to the lap belt anchor points.
- No rupture or failure of the anchors.
Future Research

- Evaluating the seating system and occupant safety:
- WIRS versus fixed vehicle mounted ORS
- Compliance with Wheelchair 19 Standard
- Compliance with SAE J2249 and GM IARV’s
- Dynamic Sled Impact Setup (20g/30mph)
- Hybrid III 50th % male dummy (172.3lb)
- Surrogate belt type wheelchair tie-down system

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After the static strength test, a dynamic load test is needed to determine the effect of a 20g/30mph impact on the WIRS and the occupant.

This slide shows the test setup for a vehicle mounted occupant restraint system. The anchor of the upper torso belt is mounted onto the post on the sled, and the pelvic belt anchors are mounted to the sled floor plate.
The second test setup is that of the WIRS. Here you can see that the pelvic anchors as well as the shoulder belt anchors are mounted onto the wheelchair itself.
Future Research

- Analyze sled test data
- Build computer simulation model according to sled impact information
- Optimize restraint characteristics
- Optimize wheelchair seat design criteria

We are now in the process of analyzing the sled impact test data of both restraint scenarios. After that, a computer simulation model will be developed and validated to optimize the restraint characteristics of the WIRS.