Method Development for Evaluating Wheelchair Seating System (WCSS) Crashworthiness using FMVSS-207 Testing

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Abstract

- Recognition of the importance of the vehicle seat in providing crash protection has increased significantly in recent years. Automotive seats need extensive testing to ensure compliance with government crashworthiness and occupant protection regulations. This study proposes to evaluate the crashworthiness of various Wheelchair Seating Systems (WCSS) using FMVSS 571.207 for Seating Systems [3]. The crashworthiness of three WCSS was tested applying a forward and rearward load at the seating system's center of gravity (CGSS), and applying a moment to the upper most point of the seat back. The magnitude of the applied loads was established using FMVSS-207 guidelines. None of the tested WCSS or attached hardware showed significant permanent deformation or damage.

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ABSTRACT. Recognition of the importance of the vehicle seat in providing crash protection has increased significantly in recent years. Automotive seats need extensive testing to ensure compliance with government crashworthiness and occupant protection regulations. This study proposes to evaluate the crashworthiness of various Wheelchair Seating Systems (WCSS) using FMVSS 571.207 for Seating Systems [3]. The crashworthiness of three WCSS was tested applying a forward and rearward load at the seating system's center of gravity (CGSS), and applying a moment to the upper most point of the seat back. The magnitude of the applied loads was established using FMVSS-207 guidelines. None of the tested WCSS or attached hardware showed significant permanent deformation or damage.

Introduction to the problem

- Wheelchair seats are often used as motor vehicle seats
- ANSI/RESNA Vol.19-Sect.1 tests crashworthiness of complete wheelchairs used in transportation
- Addition of after-market add-on wheelchair seating voids ANSI/RESNA-19 certification
- No low cost standardized tests available yet to evaluate crashworthiness of add-on wheelchair seating
- Standardized tests available in automotive industry to evaluate strength of motor vehicle seats and their floor anchorages are:
  - FMVSS 207 (static load test)
  - FMVSS 208 (dynamic load test)

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Due to the impact of the ADA in the seventies, society has become more accessible and made many individuals use their wheelchairs to get around. Most of these individuals tend to use their wheelchair in motor vehicles where their wheelchair seat functions as a motor vehicle seat when in transport. At this moment, individuals using their wheelchair seat as a motor vehicle seat don't experience the same level of safety as people using Originally Equipped Manufactured Vehicle Seats do. To address this issue and to test wheelchairs used during transportation in motor vehicles, standards are being developed. The SOWHAT workgroup of the American National Standard Institute (ANSI) developed a voluntary standard for wheelchairs (Volume 1- Section 19). Since this standard only looks at the strength of wheelchair frames with independent seats, individuals using add-on wheelchair seating systems won't comply to these standards and additional testing methods are necessary to evaluate these add-on WCSS.

FMVSS 571.207-Seating Systems

Specifies requirements for seats, their attachment assemblies, and their installation

- Implemented in 1968 for passenger cars
- Minimum requirements for:
  - Seat to Back strength
  - Anchorage strength between seat and vehicle
- Requires forward and rearward loading on the seat back of 20 times the weight of the seat
- Requires a moment of 3,300 in-lbs (373 Nm) about the SRP (Seat Reference Point)

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To develop a low cost test method to test add-on WCSS, the existing Federal Motor Vehicle Safety Standard number 207 was adapted.

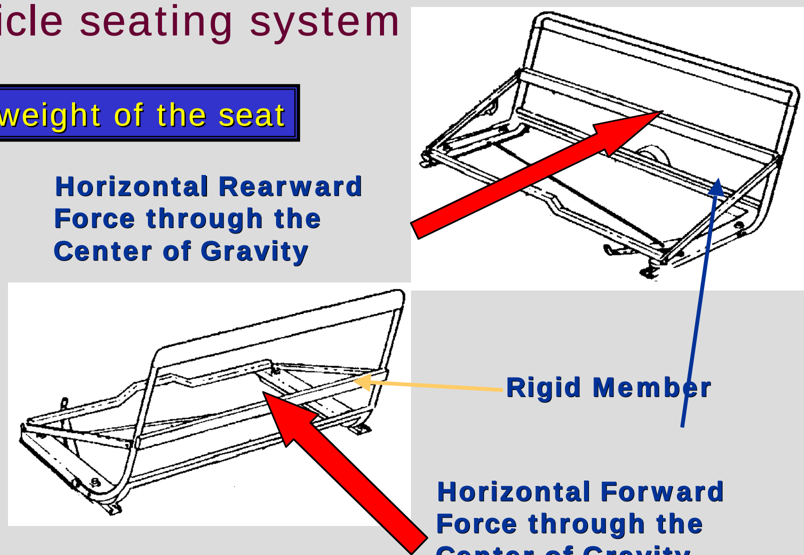
This standard was implemented in 1968 for passenger car seats and established minimum requirements for the seat to back strength and the anchorage strength between the motor vehicle seat and the vehicle.

The required loads acting on the seat in forward and rearward direction were 20 times the weight of the seat.

The required moment about the Seat Reference Point were 3,300 in-lbs

FMVSS 207: Load applied to the motor vehicle seating system

Force=20 x weight of the seat



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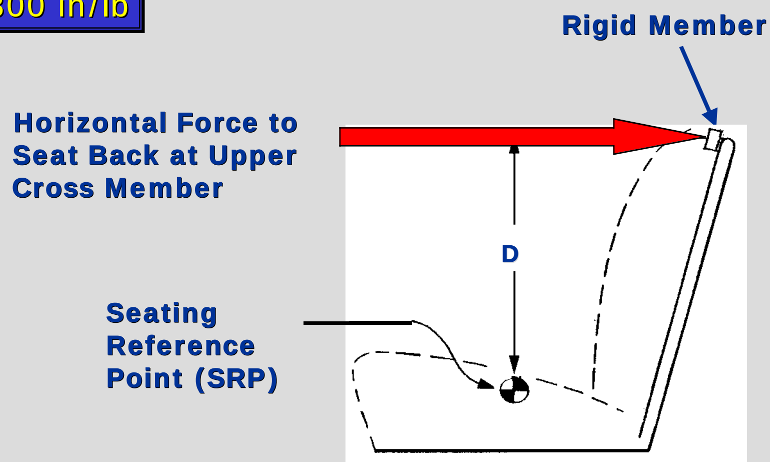
The following figures show these required loads and how they are applied to the motor vehicle seat back.

The forces are to be applied through the plane of the center of gravity of the seat.

FMVSS 207: Moment applied to the motor vehicle seating system

Moment=3,300 in/lb



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The following figure shows the required moment and how is is applied to the motor vehicle seat back at the most upper point. The arm D, is measured from this upper most point to the Seat Reference Point.

Add-on wheelchair seating systems

1:

Seat frame independently mounted onto the wheelchair frame

2:

Seat support surfaces mounted onto the wheelchair frame

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For this testing two types of add-on WCSS were considered, of which the left one was tested first.

This add-on WCSS consists of a seat frame which is independently mounted onto the wheelchair frame.

Tested WCSS

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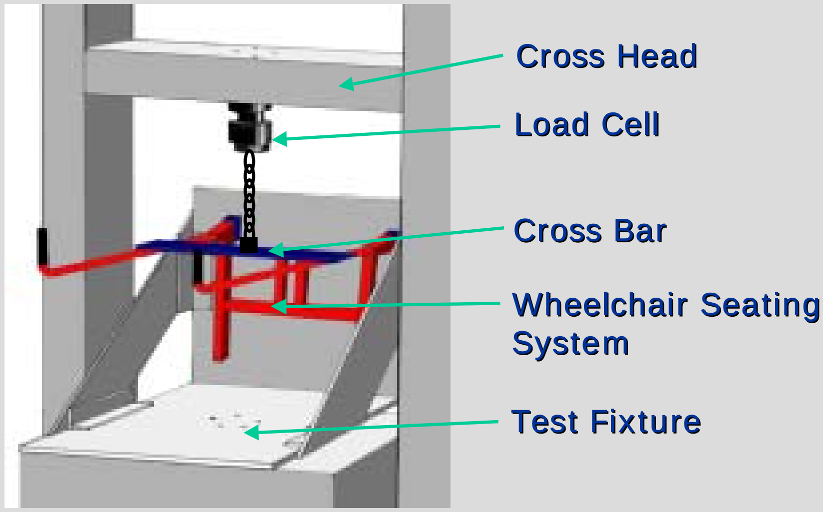
The WCSS used in this study were the LaBac, made by La Bac, the Tarsys, and the Orbit a pediatric chair, both made by Invacare.

Test setup on the Instron 2404



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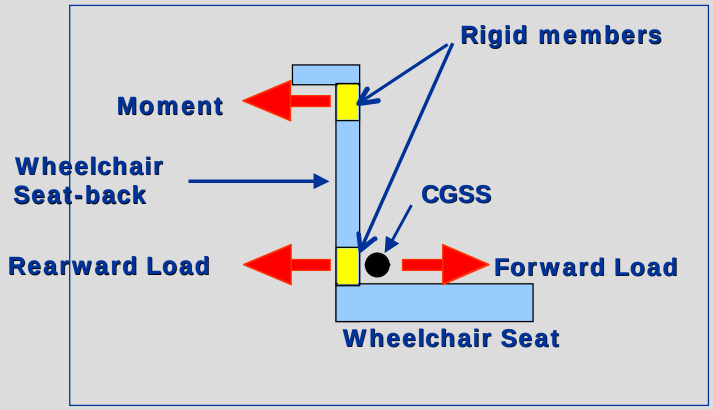
A rigid test fixture was mounted on an Instron loading machine, and each WCSS was mounted with customized hardware to this test fixture. The original hardware was used to attach the WCSS to the test fixture.

A load cell, attached to the Instron, measured the applied load on the WCSS. Customized load bars were developed for each WCSS to apply the required load or moment to each WCSS.

Location and direction of loads on WCSS



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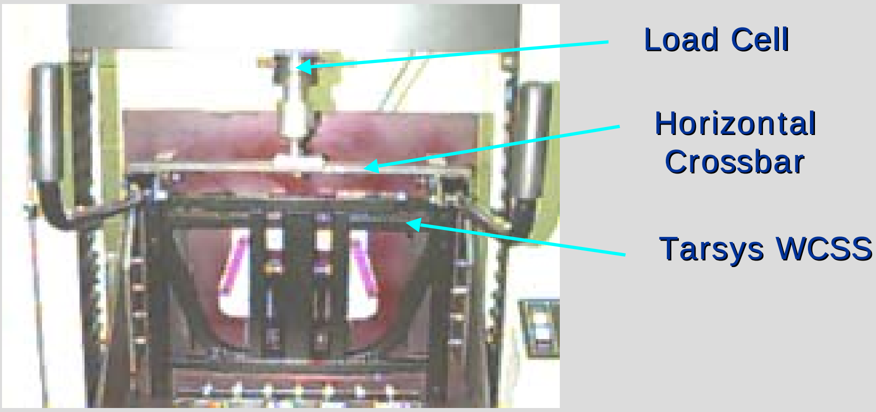
This figure shows the configuration of the loads acting on each WCSS. Each load and moment is a separate test. For this test first the rearward load, then the forward load and finally the moment was applied to the WCSS.

Forward load setup



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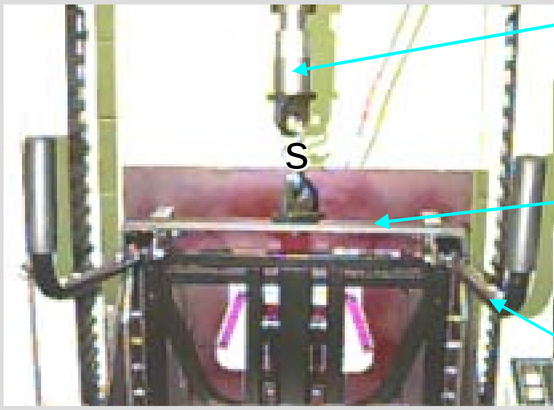
The following slides show the tarsys WCSS and how the load of the Instron was applied to the WCSS.

Rearward load setup



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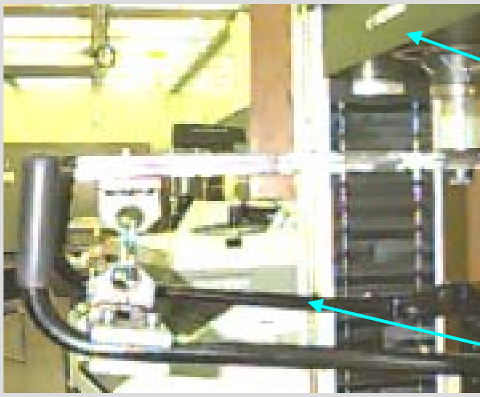
The pull load through the Center of Gravity was established by attaching an 'S' chain to both the load cell and the horizontal crossbar attached to the WCSS.

Moment setup



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The moment was applied to the WCSS with the use of a stiff bar, which was connected to the Instron's load-cell. This bar was adjusted in length for the three different WCSS.

Applied loads and moments

	Parameter	Tarsys	Orbit	LaBac
Loads	Weight Seating System (lb)	24.5	7.75	38.6
	Forward load (lb)	500	151	812
	Rearward load (lb)	499	170.5	772
Moment	Distance from CGSS to upper crossbar of the seat back (in)	15	16	15
	Load applied to generate 3,300 in-lb moment about the CGSS (lb)	233.5	222.5	225

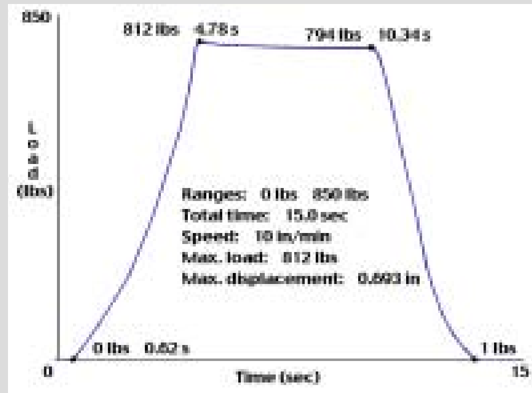
This table gives an overview of the applied loads and moments for the various WCSS, dependent on the weight of the systems. As you can see, the LaBac has the highest and the Orbit has the lowest weight, which reflects in the amount of load applied in forward and rearward direction.

The moment is for all three WCSS pretty similar.

Method

- Following data was recorded:
  - Load (lb)
  - Crosshead Excursion (in)
  - Deflection Angle of WCSS (deg)
  - Loading Time (sec)
  - Time-Force History Plot

LaBac



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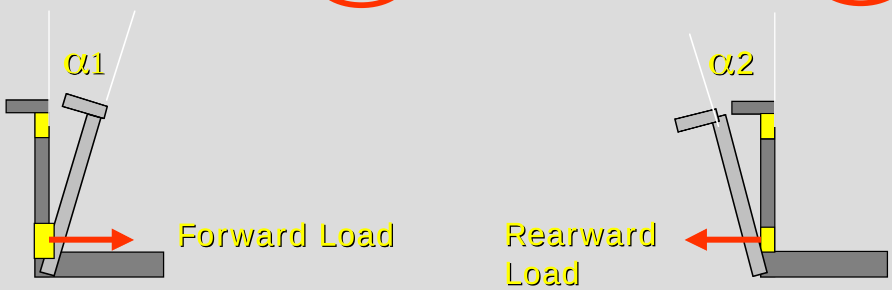
During the load testing with the Instron loading instrument, the load was measured, the load cell translation or crosshead excursion, the deflection angle of the WCSS before, at the peak and after loading. And the loading time was measured.

A time-force history plot was generated.

Results

Seating System	Weight (lb)	Forward Load: Peak Load (lb)	Forward Load: Peak Ext. (in)	Forward Load: Peak Ext. (deg)	Rearward Load: Peak Load. (lb)	Rearward Load: Peak Ext. (in)	Rearward Load: Peak Ext. (deg)
Tarsys	24.5	500	0.1	0.9°	505	0.2	0.3°
Orbit	7.75	151	0.2	1.1°	170.5	0.4	2.7°
LaBac	38.6	812	0.7	3.5°	772	0.6	3.5°



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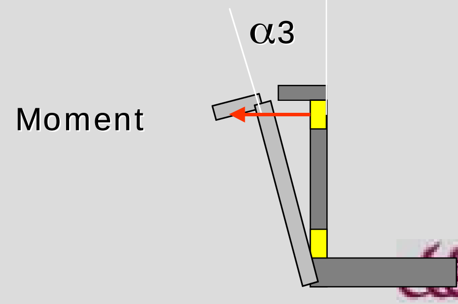
Results

		Moment upper seat back			
Seating System	Weight (lb)	Applied load (lb)	Peak Ext. (in)	Peak Ext. (deg)	Permanent Seat Back Deflect.(deg)
Tarsys	24.5	233.5	1.6	2.0°	1.2°
Orbit	7.75	222.5	3.4	8.8°	0.1°
LaBac	38.6	225	1.9	4.0°	1.0°



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Conclusions

- All WCSS withstood the applied loads of 20x the weight of the WCSS.
- All WCSS withstood the applied moments of 3,300 in-lb.
- No severe damage to the WCSS nor to the anchorages was detected.

Further research

- Optimize the WCSS crashworthiness test based upon:
  - Weight of WCSS + occupant.
  - Test WCSS with all attached hardware such as armrests, headrests, restraint systems etc.
- Evaluate how the stiffness of WCSS can be measured systematically.
- Evaluate the influence of WCSS stiffness on occupant protection.

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