An Investigation of Manual Wheelchair Seat Pan and Seat Back Loading Associated with Various Wheelchair Design Parameters Using Computer Crash Simulation

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Abstract

The ANSI/RESNA Subcommittee on Wheelchair Transportation is currently developing a wheelchair seating system (WCSS) standard which will evaluate WCSSs crashworthiness independent of a specific wheelchair frame. A surrogate wheelchair base (SWCB) which WCSSs would be attached to for evaluation will be a part of this standard and is under development. To assist in the development of the SWCB, the influence of various wheelchair design parameters (seat back angle, securement location, and seat to back intersection) on manual wheelchair seating system loading was investigated in this study using a validated computer model. All design parameters investigated in the study influenced seat back loading, but had little affect on seat pan loading.

Background

As the number of individuals using wheelchairs as seats in motor vehicles increases, wheelchair occupant safety in a crash and wheelchair crashworthiness become critical. The Subcommittee on Wheelchairs and Transportation (SOWHAT) of ANSI/RESNA has developed WC-19: *Wheelchairs Used as Seats in Motor Vehicles*, a standard which specifies requirements and test methods for the design and performance of complete wheelchairs (1). This standard evaluates complete wheelchair systems consisting of a seating system and wheelchair frame. However, wheelchairs are often prescribed such that seating systems may be after-market or add-on components. Therefore, wheelchair seating systems (WCSSs) may not in all cases be tested to WC-19 with the wheelchair frames that they are mated to.

SOWHAT is currently developing a standard which will account for this scenario and will evaluate the design and performance of wheelchair seating systems independent of a specific wheelchair frame. The standard requires frontal impact sled testing of a WCSS using a surrogate wheelchair base (SWCB). The surrogate wheelchair base is a repeatable and reusable wheelchair frame to which WCSSs can be attached. Since manual wheelchairs present unique loading challenges to seating systems, the SWCB must replicate these same loading conditions. When developing the SWCB, issues related to the characteristics of manual wheelchairs and their impact on failure mechanisms of WCSSs during crashes must be considered.

Research Objective

A SWCB should produce worst-case seating system loading conditions and failure modes for a range of commercial manual wheelchair bases. To assist in the development of the SWCB, the influence of various wheelchair design parameters (seat back angle, rear securement point vertical location with respect to wheelchair center of gravity (CG), and seat-to-back intersection location with respect to rear hub) on wheelchair seat pan and seat back loading in manual wheelchairs was investigated in this study using computer simulation.

Methods

A computer model of a 50th percentile male Hybrid III anthropomorphic test device (ATD) seated in a manual wheelchair during a 20g/30mph frontal impact was developed using Dynaman 4.0/ATB 3[I] computer simulation programs and was used in this study (2). The ATD was restrained by a vehicle mounted three-point occupant restraint system, and the wheelchair was secured by a four-point tiedown system (see Figure 1). Baseline conditions of the wheelchair model are described in

Table 1. The model was validated using six 20g/30mph frontal impact sled tests (2).

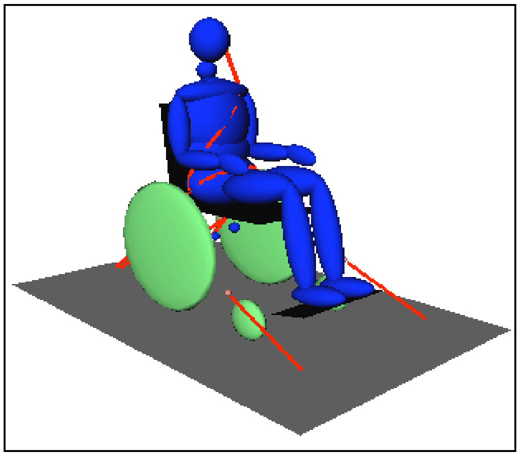


Figure 1
Dynaman/ATB 3[1] Model-baseline

Table 1 Manual Wheelchair Baseline Conditions

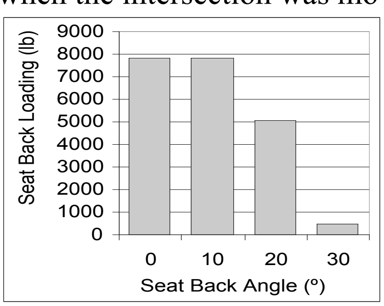
Wheelchair Weight	46 lb.
Rear Hub Height	12" above floor
Wheelchair CG wrt Rear Hub	4.75" fore; 2.75" above
Seat Back Angle	20 º
Seat Pan Angle	2 º
Seat-to-Back Intersection Location wrt Rear Hub	2" aft
Rear Tiedown Location	1.25" below WC CG

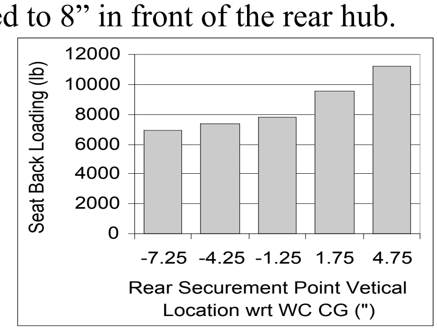
To assess the effect of wheelchair design parameters on wheelchair seat pan and seat back loading, a parametric sensitivity analysis was conducted. Each parameter (seat back angle, rear securement point vertical location, and seat-to-back intersection location) was varied independently while all other parameters remained at their baseline. Seat back angle was varied from 0º to 30º, rear securement point vertical location was varied from 7.25" below the WC CG to 4.75" above the WC CG, and seat-to-back intersection location ranged from 2" behind the rear hub to 8" in front of the rear hub.

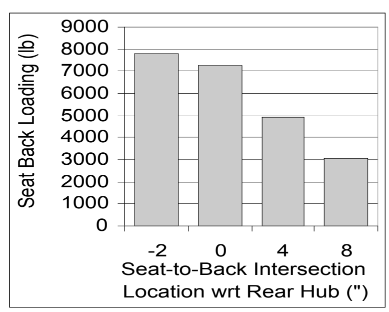
RESULTS

The results of the parametric sensitivity analyses are shown in Table 2 to Table 4. The seat pan load was slightly affected by the seat-to-back intersection location, but the seat back angle and the rear securement point vertical location did not have a large impact on the seat pan load. As the seat-to-back intersection location moved horizontally toward the front of the wheelchair, the seat pan load was decreased slightly from 3799 lb to 3164 lb (17% decrease).

Different from the seat pan load, the seat back load was influenced by all design parameters. (See Figure 2) As the seat back angle increased, the seat back load decreased – a 94% decrease in the seat back load was observed as the seat back angle increased from 0º to 30º. As rear securement point vertical position was moved from the low to high position, the seat back load increased substantially from 6881 lb to 11,216 lb. The seat back load decreased as the seat-to-back intersection location was moved horizontally toward the front of the wheelchair. Seat back loading was 7796 lb when the intersection was located 2" behind the rear hub, but decreased to 3085 lb when the intersection was moved to 8" in front of the rear hub.







(a) **(b)** **(c)**

Figure 2 Seat Back Loading vs. (a) Seat Back Angle, (b) Rear Securement Point Vertical Location, and (c) Seat-to-back Intersection Location

Table 2 Seat Back Angle vs. Seat and Seat Back Loadings

Seat Back Angle	Seat Pan Loading (lb)	Seat Back Loading (lb)
0º	3741	7834
10º	3799	7796
Baseline (20º)	3819	5055
30º	3825	469

Table 3 Rear Securement Point Vertical Location vs. Seat and Seat Back Loadings

Rear Securement Point Vertical Location with Respect to Wheelchair CG	Seat Pan Loading (lb)	Seat Back Loading (lb)
-7.25"	3598	6881
-4.25"	3657	7369
Baseline(-1.25")	3799	7796
1.75"	3718	9550
4.75"	3825	11216

Table 4 Seat-to-back Intersection Location vs. Seat and Seat Back Loadings

Seat-to-back Intersection Location with Respect to Rear Hub	Seat Pan Loading (lb)	Seat Back Loading (lb)
Baseline (~ -2”)	3799	7796
0”	3673	7252
4”	3434	4939
8”	3164	3085

CONCLUSIONS

The effect of seat back angle, rear securement point vertical location, and seat-to-back intersection location on wheelchair seat pan and seat back loading in a manual wheelchair was investigated using computer simulation. Seat back loading was influenced by all three parameters: the seat back load increased as the seat back angle was decreased, the height of the rear securement point location was increased, and the seat-to-back intersection location was moved horizontally toward the back of the wheelchair. The effect of these three design parameters on seat pan loading was not substantial, except for the seat-to-back intersection location, which had a slight influence on the seat pan load.

The results of this study could assist in the development of a SWCB representing manual wheelchairs to produce worst-case seating system loading conditions and failure modes for those wheelchairs. According to our study, a SWCB which has a small seat back angle, high rear securement attachment point and the seat-to-back intersection located behind the rear hub will produce high loads on seating systems. Loading conditions described in this study can also aid manufacturers in the design of manual wheelchair seating systems.

REFERENCES

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