Dynamic Performance of Add-On UDIG Wheelchair Attachments for Four Commercial Wheelchairs

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INTRODUCTION

Automated and driverless vehicles (AVs) offer potential for improving independent transportation options for people with disabilities. Many vehicle manufacturers are considering integrated wheelchair stations and seek solutions that allow people seated in their wheelchairs to secure wheelchairs independently in AVs to allow solo travel in a shared, on-call, vehicle fleet. Consequently, there has been renewed interest in the Universal Docking Interface Geometry (UDIG) [1]–[3]. UDIG allows any wheelchair with UDIG-compatible hardware to dock without third-party assistance in any vehicle with a UDIG-compatible anchor. Only the geometry of the interface is standardized, so there are minimal limitations on the design of the wheelchair or the in-vehicle securement system. Because AV fleets are likely to include passenger-sized vehicles, securement system must be crashworthy for high deceleration vehicle environments meaning that many solutions appropriate for large accessible transit vehicles are not robust enough to provide safety in crash events for smaller, lighter vehicles.

Recent research efforts by the University of Michigan Transportation Research Institute [4]–[6] have designed and tested add-on UDIG-compatible attachments for four commercial wheelchairs. This paper summarizes results of successful crash testing of these attachments under frontal and side impact testing conditions, demonstrating the viability of developing UDIG-compatible attachments for wheelchairs that meet current WC19 requirements.

METHODS

As shown in Figure 1, UDIG-compliant attachments were designed and constructed for four different commercial wheelchairs that had been designed to meet requirements of ANSI/RESNA standard WC19. All the added hardware was included in the original wheelchair footprint and did not increase the size or reduce the ground clearance of the wheelchair. Each set of attachments was connected to the wheelchair near the location of the rear tiedown securement points. Based on feedback from volunteers on the appearance of the first two prototypes, subsequent versions were designed to be less conspicuous, lighter, and more integrated with the wheelchair design.

Figure 1. Photos of UDIG-compatible attachments for (from left to right, top row) Ki Mobility Catalyst 5 (versions K1, K2, K3), (bottom row), Quantum Rehab Q6 Edge 2.0, Sunrise Quickie 2, Permobil F3 Corpus.

Crash tests were performed with a heavy-duty UDIG-compatible anchor fixture that allowed measurement of securement loads, developed in an earlier research project [3]. Frontal impact tests used a Hybrid III midsize male ATD, while the side impact tests used an ES2-re ATD. Table 1 contains a matrix of the tests used to evaluate the performance of the prototype attachments. For the Ki Mobility Catalyst 5, three different styles of UDIG were tested to reduce mass and improve appearance.

Table 1: Test matrix

Test ID	Wheelchair	Direction	Restraint System	Version + mass (kg)
AW2111	Ki Mobility Catalyst 5	Frontal	Vehicle mounted lap+shoulder belt with pretensioner and load limiter, SCARAB	K2,1.8
AW2113	Ki Mobility Catalyst 5	Frontal	Vehicle mounted lap+shoulder belt with pretensioner and load limiter, SCARAB	K2,1.8
AW2115	Quantum Rehab Q6 Edge 2.0	Frontal	Vehicle mounted lap+shoulder belt with pretensioner and load limiter, SCARAB	Q2,4.4
ID2201	Sunrise Quickie 2	Frontal	Vehicle mounted shoulder belt	S1, ~1.0
ID2202	Permobil F3 Corpus	Frontal	Vehicle mounted shoulder belt	P1, 6.2
AW2118	Ki Mobility Catalyst 5	Farside	Farside vehicle-mounted lap+shoulder belt with pretensioner, CATCH-V' airbag	K1, 2.9
WX2210	Ki Mobility Catalyst 5	Nearside	Vehicle mounted shoulder belt, WC-attached lap belt, simulated intruded vehicle interior wall	K3, 1.0

RESULTS

The UDIG attachments performed well in all of the tests. Table 2 shows key ATD and excursion measures for each test; reference values from frontal WC18 performance standards are also included. All of the excursions met the requirements. Figure 2 shows the time of peak excursion for the frontal tests for the manual wheelchair tests, while Figure 3 shows this for the power wheelchairs and Figure 4 shows side impact tests. The lower shoulder belt forces in the AW frontal tests compared to the ID tests comes from using a production seatbelt with load limiter and pretensioner rather than a belt with fixed anchor points. Figure 5 shows posttest samples of deformation.

Table 2. Key excursions and peak measurements (FS=farside impact, NS=nearside impact)

Test ID	WC18 frontal limit	AW2111	AW2113	AW2115	ID2201	ID2202	AW2118	WX2210
Crash Direction		Frontal	Frontal	Frontal	Frontal	Frontal	FS	NS
Mean sled decel (g)		22.5	21.6	20.9	21.0	20.3	20.8	10.2
Sled delta V (km/hr)		49.2	48.8	47.7	49.0	48.8	30.4	21.9
Peak Res Head Accel (g)	80	32.3	44.3	57.1	74.7	57.1	33.6	197
HIC (15 ms)	700	78	172	231	564	260	82.9	675
3 ms clip Chest Accel (g)	60	37.2	31.6	44.5	41.1	44.3	28.0	22.7
Peak lap belt load (N)		8819	9271	7142	7850	6473	3920	1508
Peak shoulder belt load (N)		4732	3580	3710	9211	10724	9290	1663
LSLR UDIG Force (N)		3728	3895	11804	3690	16480	3032	1920
RSLR UDIG Force (N)		3569	3581	10832	3095	19905	7626	1632
LSRR UDIG Force (N)		4446	4055	12363	3562	20589	2820	1685
RSRR UDIG Force (N)		3710	3732	10218	2772	15061	2899	4859
Forward excursion of Point P	200	32	23	107	75	199		
Forward knee excursion	375	313	322	189	221	194	627	
Forward head excursion	650	513	517	510	472	352	440	

Figure 2. Kinematics at time of peak head excursion in frontal tests for two different UDIG designs for the Ki Mobility Catalyst, and the Sunrise Quickie 2. Occupant protection systems also vary.

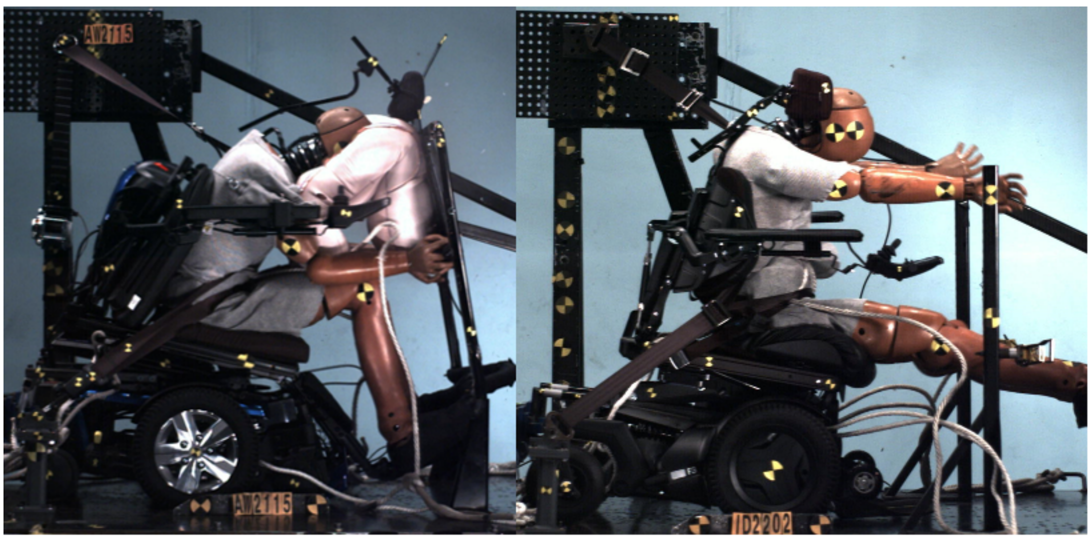

Figure 3. Kinematics at time of peak excursion in frontal tests for AW2115 (left) and ID2202 (right).

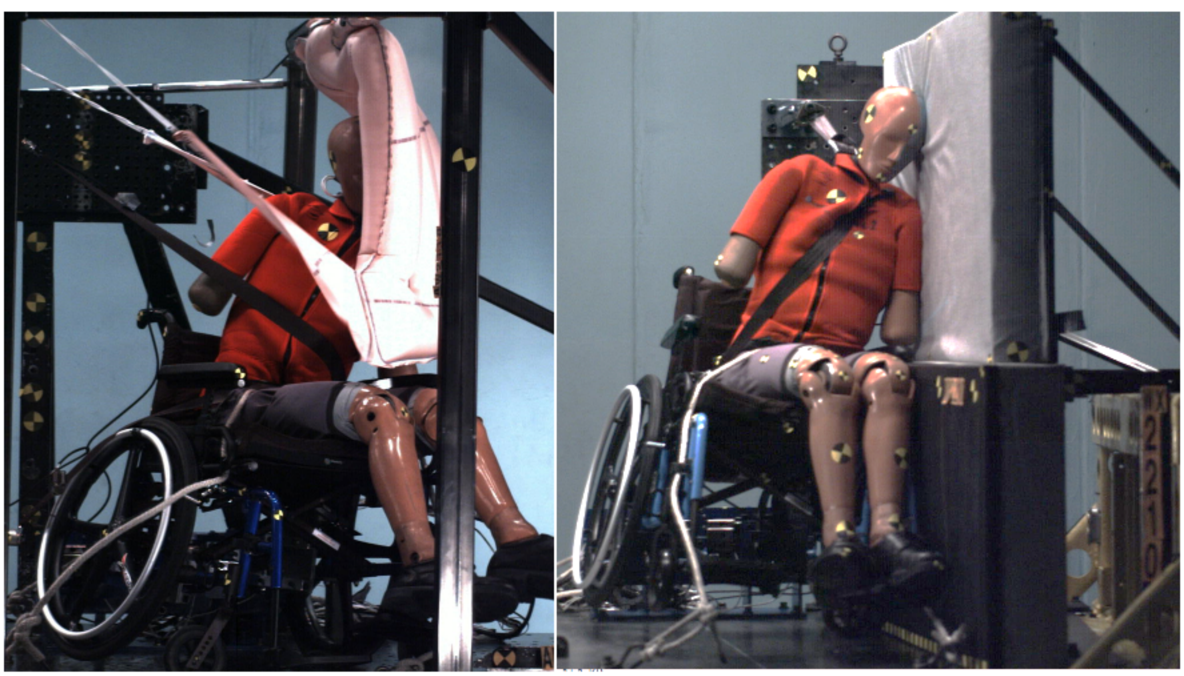

Figure 4. Kinematics at time of peak excursion for farside test (left) and nearside test (right) with Ki Mobility Catalyst 5.

Figure 5. Post-test photos showing examples of attachment deformation.

DISCUSSION

Several different styles of UDIG-compatible attachments for four different commercial wheelchair models. Were designed and tested. All of the frontal dynamic tests met the requirements of WC18 for WTORS. While there was some deformation in the attachments post-testing, all of them secured the wheelchair as intended.

The strategy of mounting the attachments near the locations of the rear WC19 securement points was effective. In addition, the attachments were connected to the wheelchair components using standard bolts, indicating that they could be a removable option to fit a user's different transportation needs. On all of the wheelchair models, there were components suitable for mounting the UDIG at the appropriate location specified in the Annex F of WC19.

The initial UDIG designs focused on functionality and strength. Based on feedback on our first designs from wheelchair users, the mass of the attachments on the manual wheelchairs was reduced to 1 kg. Improvements to the appearance of the UDIG hardware were also made so the attachments were less conspicuous and matched with other wheelchair elements.

IMPLICATIONS

This paper demonstrates the feasibility and safety of the UDIG approach to encourage wheelchair, WTORS and vehicle manufacturers to consider this strategy to create transportation options for people seated in wheelchairs where a single wheelchair can be secured independently in a wide variety of vehicles.

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