WHEELCHAIR CASTER LOADING DURING FRONTAL MOTOR VEHICLE IMPACT

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ABSTRACT

Wheelchairs used as motor vehicle seats in para-transit or private vehicles are exposed to high level crash loading when engaged in motor vehicle crashes. Many wheelchairs are not typically designed to withstand the types of loading that may occur during impact. This study measured the normal and shear loading of front wheelchair wheels (casters) during a 48kph/20g frontal impact. Eight tests were run with a surrogate wheelchair base and a variety of wheelchair seat and back systems. The surrogate wheelchair base (SWCB) was secured with rear wheelchair securement anchors at three different heights (low, middle, high). Load cells were built into the sled test platform under the front casters. A test dummy representing a 50^{th} percentile male occupant was seated in the SWCB.

Average normal caster loading resulting from frontal impact was 4738N (SD= 1709N). Average shear caster loading from frontal impact was 1343N (SD=224N). Highest normal caster loading corresponded with low rear securement point height scenarios and seat failure, as well as with high rear securement point height scenarios and seat and back failure due to dummy loading. Results from this study can be used to aid manufacturers in the design of crashworthy wheelchair casters.

BACKGROUND

Individuals who rely on wheelchairs for their daily mobility needs often use their wheelchair as a motor vehicle seat during transit. The majority of wheeled mobility devices have not been designed with the safety features that are implemented in motor vehicle seats [1-3]. The ANSI/RESNA WC19 standard for 'Wheelchairs Used as Seats in Motor Vehicles' requires transport-option wheelchairs to be subjected to a 48kph/20g frontal impact testing [4]. Previous studies done on wheelchair components such as wheelchair seats, backs and attachment hardware show less than adequate performance of wheelchair components under crash loads [5-9]. Wheelchair casters and fork assemblies are designed to carry the weight of wheelchairs and to provide the wheelchair occupant with a comfortable ride during daily wheelchair use. When a wheelchair is being used as a motor vehicle seat, the casters function as a load bearing component during frontal impact. Frontal impact will cause caster loading due to forward and downward loading of the occupant onto the wheelchair seating system. Studies using computer simulations have also shown that factors such as rear wheelchair securement location, seat stiffness and seat angle can influence load patterns on wheelchair components in particular [3, 10] and may also influence caster loading [11]. Uncontrolled failure of the caster and/or caster fork may result in increased risk of occupant injury due to excessive forward occupant motion, as well as downward motion resulting in submarining (sliding of the pelvic belt onto the soft abdominal). Controlled caster assembly deformation (e.g energy absorbing characteristics integrated in caster assemblies) may reduce occupant risk of injury during frontal impact.

OBJECTIVES

The purpose of this study was to determine wheelchair caster loading during frontal impact testing. Additionally, the effect of rear securement point location and wheelchair seat system performance on caster loading was evaluated.

METHOD

To assess wheelchair caster loading, eight frontal sled impact tests were run with a 48kph/20g crash pulse using a surrogate wheelchair base (SWB) and a 50^{th} percentile Hybrid III ATD. The SWB is a rigid wheelchair base (representing a commercial power wheelchair) intended for repeated sled impact testing to evaluate wheelchair seating systems. The SWB was secured using a four point tiedown system. The rear tiedown anchor heights were varied in height to evaluate their effect on caster loading. Various types of seating systems were mounted to the SWB to evaluate seating system crashworthiness and design on caster loading magnitude (table 1). To record the caster loads during frontal impact, two tri-axial load cells per caster wheel were positioned on the sled platform under the front caster wheels (figure 1).

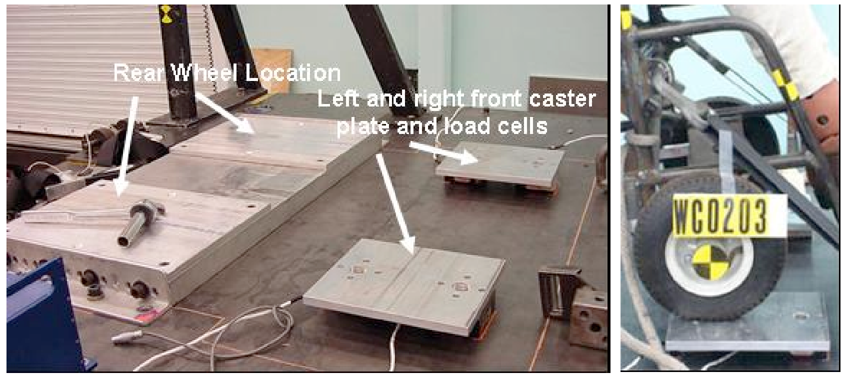


Figure 1: Load platform to measure tri-axial front caster loading

Table 1: Tested wheelchair seating system scenarios, wheelchair securement heights and peak downward and shear caster loads

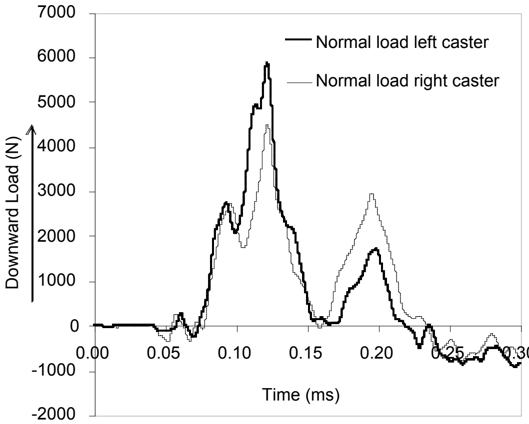
Wheelchair Seating System Scenario	Test No.	Floor to Securement Point Height (mm)	Failures	Peak Normal Load (N)		Peak Shear Load (N)	
				Left	Right	Left	Right
Invacare Personal Back	WC0203	Middle: 315	None	3601	3450	841	781
AliMed QualCare Seat	WC0212	Middle: 315	Seat	3092	3684	1510	1462
Jay2 Deep Contoured Back	WC0204	High: 457	Seat & Back	7209	5369	1348	1348
Jay 270 Seat	WC0211	High: 457	Seat & Back	5311	4679	1376	1500
E&J P2Plus Sling Seat	WC0205	High: 457	None	1950	769	1388	1336
E&J P2 Plus Sling Back	WC0206	Low: 229	None	5824	4495	1392	1392
Jay Fit Back	WC0207	Low: 229	Seat	5405	3360	1303	1337
Jay Fit Seat	WC0210	Low: 229	Seat	5514	4041	1437	1589
			Average load:	4738	3731	1324	1343
			Stand. Dev.:	1709	1376	205	244

RESULTS and DISCUSSION

Peak normal caster loads (7209N) were seen in test scenarios with a combination of high rear wheelchair securement and seat system failure. Low rear wheelchair securement scenarios also showed high caster loads (5405, 5514 and 5824N). Wheelchair securement below the wheelchair center of gravity causes forward rotation of the wheelchair, thereby increasing caster loading. For all tests except one, peak normal loading occurred in the left of the two casters. This can be explained by the fact that the shoulder belt anchor point was located at the left of the ATD, causing rotation of the ATD to the left side of the wheelchair. Peak shear loading (1500, 1510 and 1589N) occurred throughout the various securement scenarios (low, middle and high), but was the highest in the right caster for the scenario with a low wheelchair securement point and seat failure (1589N). Figure 2 shows the characteristic caster loading patterns during frontal impact.

CONCLUSION

Peak caster loads (7209 N) were seen in impact scenarios where the wheelchair was secured high above the floor (457mm) and where the seat and back failed during the test. In the case where no seat failure occurred, low rear securement points lead to the highest caster loading. This preliminary study shows that seating system integrity and rear securement position can affect caster loading. Caster load magnitudes and patterns obtained from this study may guide manufacturers of caster assemblies in the design of crashworthy products. Our future research includes the development of an instrument that dynamically tests the crashworthiness of caster wheels and caster forks using the impact load information reported in this study.



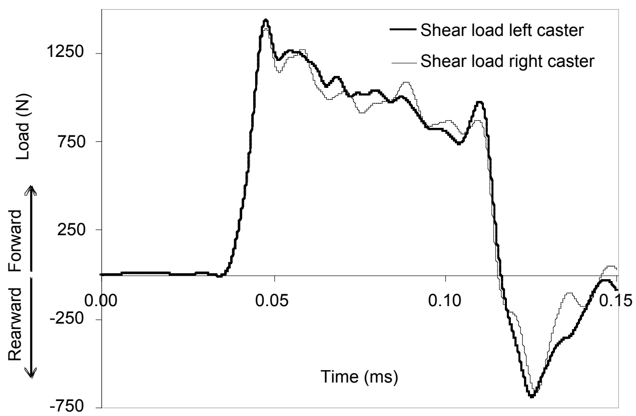


Figure 2 (left): Typical load versus time of normal caster loading during frontal impact Figure 3 (right): Typical load versus time of shear caster loading during frontal impact

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