Reliability and Robustness of Wheelchairs under Impact Loading

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The wheelchair reliability is granted through the conditions of ANSI/RESNA (American National Standards Institute/ Rehabilitation Engineering and Assistive Technology Society of North America). According to ANSI/RESNA, for protection of the occupant in a crash, frontal and direct impact process is important. For protection of the occupant, seat system strength, stiffness, energy absorbance, and position have been shown to have a direct influence on occupant kinematics. The only characteristic that will differ for the wide range of seating system designs available commercially is surface and chassis stiffness. Crash conditions pose more severe loads on wheelchair components and frame, than typical mobility conditions. For a reliable drive, wheelchairs have to be designed with high safety standard. In this study, the reliability, robustness and failure of wheelchairs under impact conditions were studied, tested and analyzed. Three types of commercial available wheelchairs were modeled and simulated, under frontal and direct impact loading conditions, using CAD and F. E codes. A1010 steel was used for the frames of the wheelchairs. According to the ANSI/RESNA standards for the frontal impact tests, wheelchairs must have a velocity of 13.4m/s. The frames of the wheelchairs were come towards the rigid wall, and chassis were hit directly to the wall. For comparing the frames, same frame base's critical spots are determined for each three wheelchairs. The critical areas of the chassis are selected from the front, middle and back side of the wheelchairs. The stresses and deformed shapes for all designs were obtained and compared. Furthermore, improvement in design was carried out to increase the reliability and safety standard of the wheelchair. The results showed that the Glide Series 4 Power Wheelchair is the most efficient and reliable design. Furthermore, the improvement in its design increased the safety and robustness standard.

Introduction

Under impact conditions, for protection of the occupant, seat system strength, stiffness, energy absorbance, and position have been shown to have a direct influences on occupant kinematics, and in particular on submarining risk. Crash conditions pose more severe loads on wheelchair components and frame, than typical mobility conditions. ANSI/RESNA WC-19: Wheelchairs Used as Seats in Motor Vehicles addresses the crashworthiness of wheelchairs, assessing complete wheelchair systems through a variety of tests including 20G and 13.4m/s dynamic frontal impact testing . Having said that non of the present wheelchair have been examined under this condition to show their reliability.
Electric powered wheelchair safety is important for disabled persons. For fast driving conditions, accidents can cause serious injuries or fatalities. Thus, the crashworthiness of the wheelchair is considered more detailed [1]. The most dangerous accident type is frontal impact scenario. For frontal impacts of the wheelchairs, standards are determined by the ANSI/RESNA (American National Standards Institute/ Rehabilitation Engineering and Assistive Technology Society of North America) [2, 3]. The frontal impact tests are carried as sledge or direct impact processes [4-7], In seldge impact test, the chair is mounted on a platform using seat belt system. The whole system is impacted to a rigid wall under high speed. In direct system the wheelchair is directly impacted to a rigid wall at high speed, see figure1 and 2.

In this study both “standard sledge tests” and “direct frontal impact tests” were simulated and analyzed using LSDYNA FEM explicit code. Furthermore, the impact analyses were carried out for different wheelchair materials. The developed stress levels, strains, forces and displacements were obtained and compared under sledge and direct frontal impact for different chassis materials. The reliable frame material was evaluated.

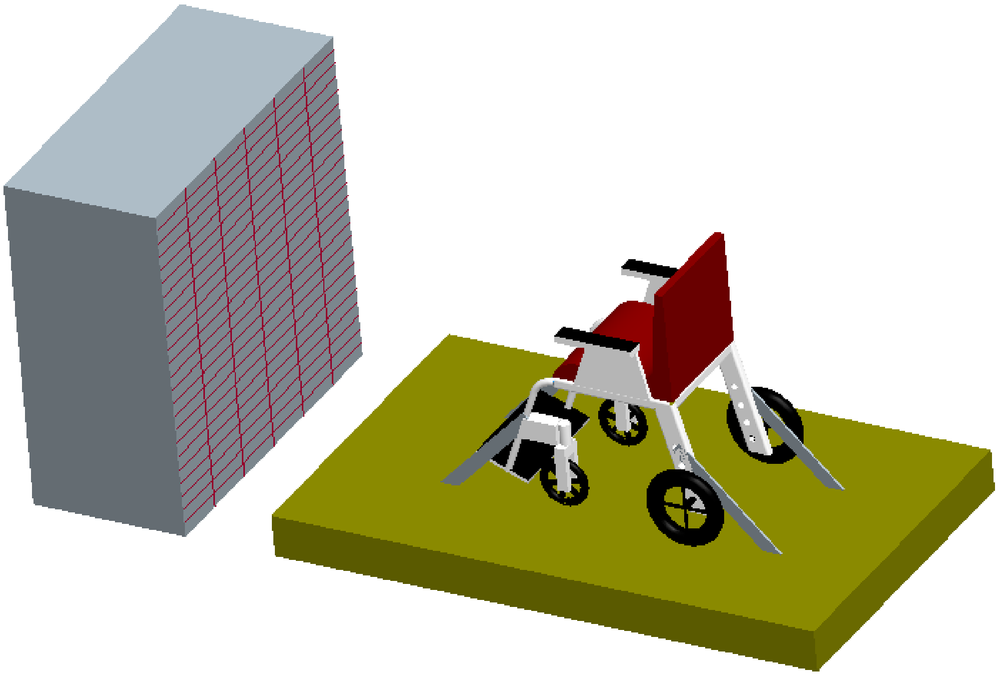


Figure 1. Sledge impact test.

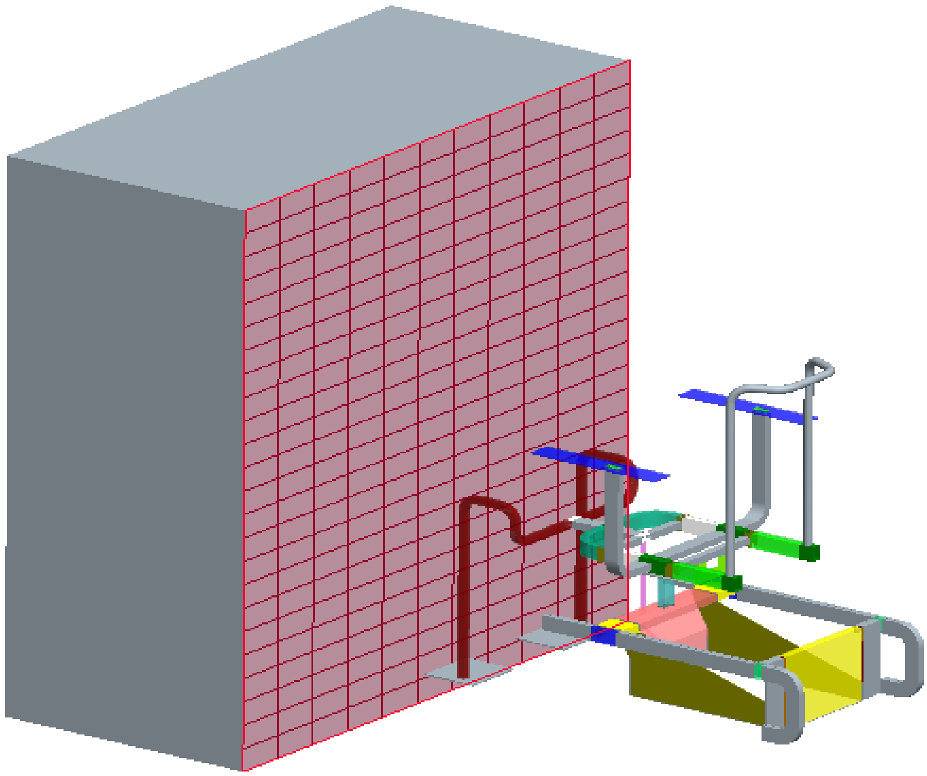


Figure 2. Direct impact test.

Modeling

In this study for impact simulations, Power Assist Wheelchair is modeled, analyzed and compared, using Pro_ENGINEER and CATIA V5. Both frontal and seldge crash systems were modeled and simulated. Figure 3, 4 present the F.E model of these frames. For these Models the frame material is A1010 steel and UHM-Carbon fiber materials, see table 1. In these models element type is solid 164 hexagonal. For number of elements and number of nodes, see table 2. The crash was carried at 13.4m/sec striking speed and for 85 millisecond time period. The analyses were carried out for A1010 and UHM Carbon Fiber chassis materials. For this study in the impact process, friction of the wheelchair, weight of the human body and weight of the wheelchair components except frames are neglected.

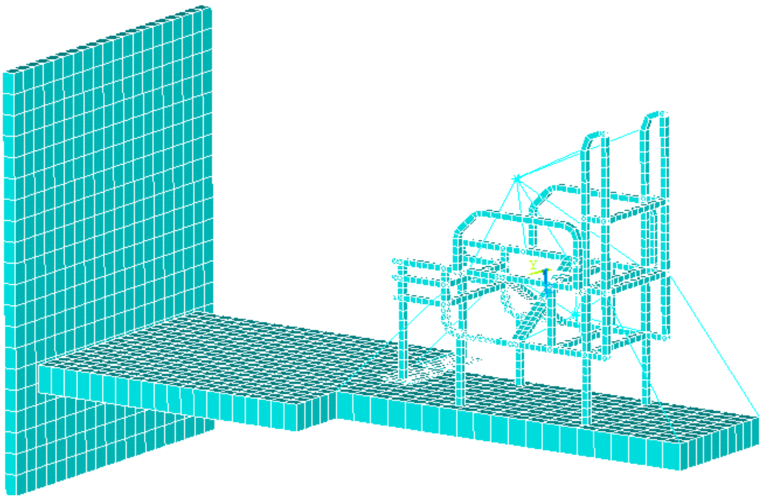


Figure 3. Sledge test finite element model.

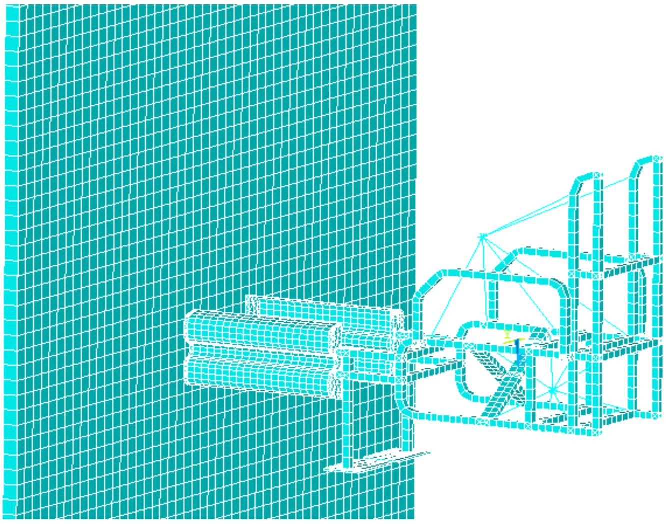


Figure 4. Modified model(direct frontal crash).

Table1: Frame Materials properties

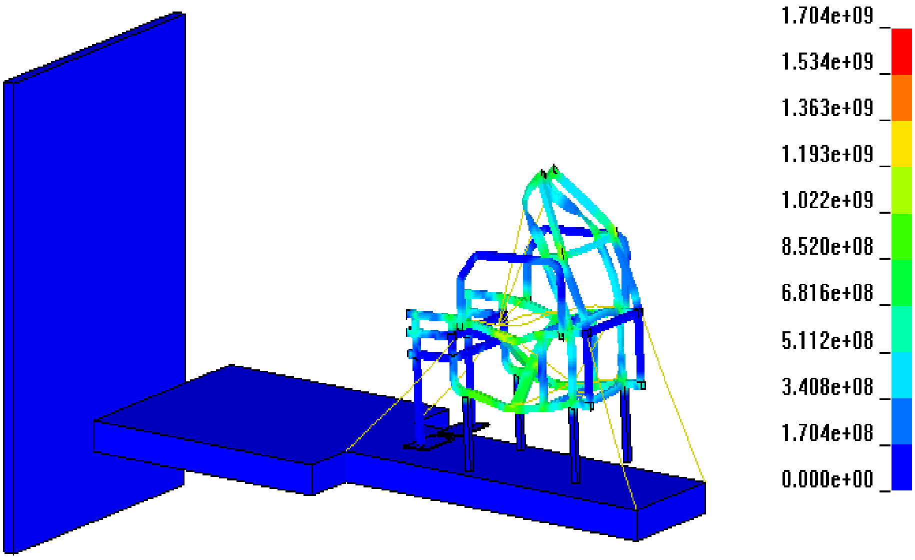
	Young Modulus (GPa)	Yield Stress (MPa)	Maximum Stress (MPa)	Maximum Strain (%)	Maximum Reaction Force (kN)	Displacement (mm)
A1010 Steel	200	305	929	0.14	142	379
UHM-Karbon-Fiber	590	3800	3800	0.0123	276	190

Table 2 F.E. model node and Elements numbers

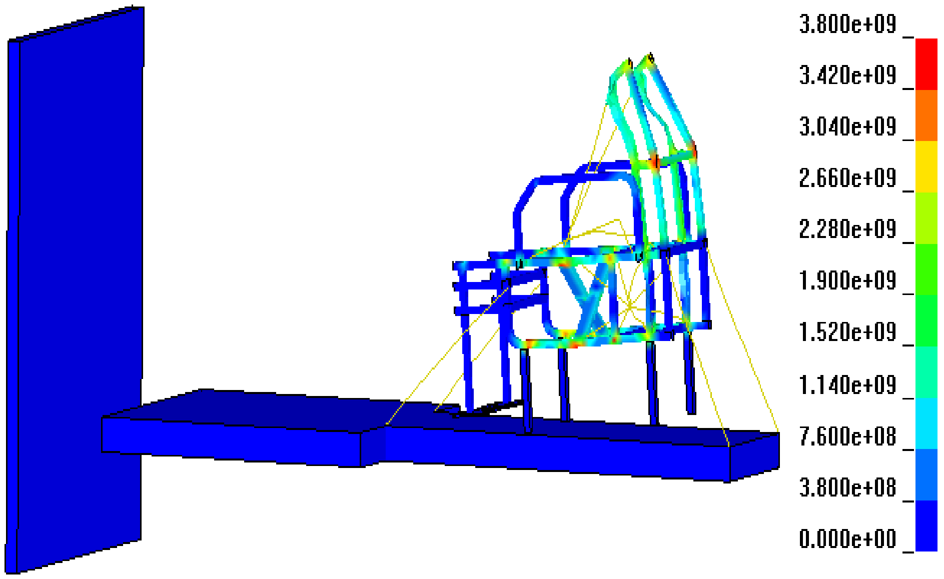
	Elements No.	Nodes No.
Wall	2499	5201
Chair 1	8153	13699
Chair 2	8277	6060

Results and Discussions

Figure 5(a, b) present the VonMises stress contour for wheel frame under seldge crash condition. It is clear from these figures that the level of streeses is low with UHM carbon fiber material. This means that the UHM carbon fiber frame is more robust but the material and production cost is 300% higher than that of A1010 steel. Therefore, A1010 steel frame was chosen as the reliable designchassis material for wheelchairs. Finally the T frame design was modified using u absorbers to reach more reliable and robust design of wheelchair as facing frontal impact loading conditions, see figure 6



(a) UHM Carbon



(b) A1010 Steel

Figure 5. Von Misses stress distribution (MPa) of wheelchair's sledge test in the 30th millisecond.

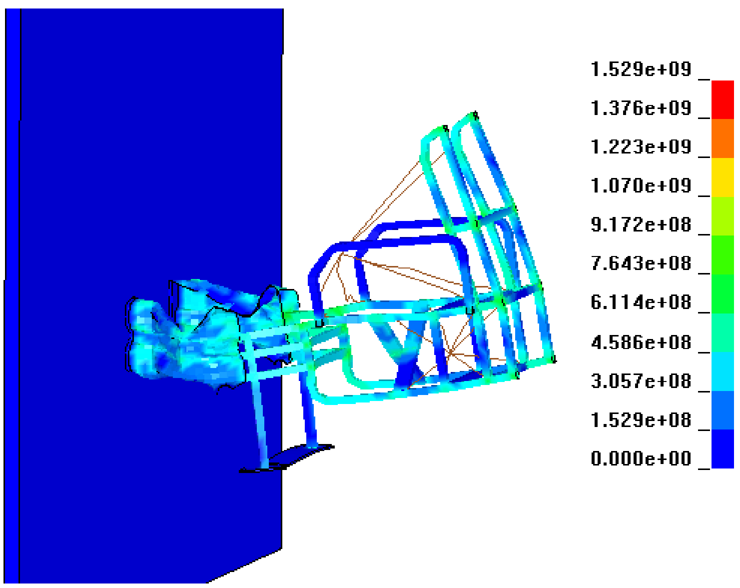


Figure 6. Von Misses stress distribution (MPa) of A1010 Steel wheelchair's protected direct impact test in the 30.8millisecond.

Conclusions

-It is concluded that the wheelchair chassis of A1010 steel material and with modified absorber is the most robust and reliable design under frontal impact loading.

-F.E. technique is a powerful route to model and analysis wheelchair frame design reliability and safety.

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