TECHNOLOGY AREA

As with any product, the selection of materials for wheeled mobility products impacts both the manufacturer and the enduser. Materials impact characteristics such as durability, strength, cost, appearance, design and manufacturing flexibility, and weight. Although there have been significant improvements in materials for wheeled mobility, excellent improvement opportunities still exist. Some of the areas that could benefit from new technologies include:

- Frames — Strength-to-weight ratio, reduced manufacturing steps, finish characteristics.
- Tires and Wheels —Improved wear without compromising ride and traction, non-conductive, non-marking, durable.
- Seating Materials — Comfort, durability, appearance, ease of cleaning, fire retardant qualities.

THE NEED

Materials have been the basis of major evolution in wheelchair products. Newer chairs benefit from specialty designs originally intended for sports activities — racing, basketball, etc. Specifically, the development of lighter-weight products based on advanced materials has been one of the biggest breakthroughs in wheelchair technology. High-performance materials have enabled designs offering comparable strength with greatly reduced weight and thus smaller and more maneuverable products, a direct benefit to users. Most of the users who have benefited from reduced weight materials have been in manual chairs, where the frame is a major portion of the mass. For power wheelchairs, unfortunately the frame is often a small part of the total mass, which is dominated by components like batteries. In many cases, costs have been reduced when materials have enabled new manufacturing methods and reduced material, machining, and assembly costs. Reduced costs translate into benefits not only for manufacturers but also endusers and third-party reimbursers. One example of this is the use of injection-molding processes for power scooter bodies that greatly reduces not only weight but also assembly time and thus manufacturing costs.

Today, even with the excellent material improvements over previous product generations, there are still significant needs for materials. Some of the newer, lighter chairs have not maintained previous levels of durability required for long-term use. In addition to improvements in the frame, both manual and power chairs stand to benefit from better materials for wheels, tires, and seating. Increased chair and component life translates to reduced costs for endusers, third-party reimbusers, and manufacturers, especially if parts fail within a product's warrant period. Material cost has often been a direct trade-off with certain performance improvements. For example, the use of composite materials may require hand lay-up or other expensive fabrication processes. These higher costs may translate into significantly higher retail sale prices, or more frequently result in selection of a cheaper, lower-performance material. During the stakeholders' forum, we will be discussing these types of trade-offs related to materials.

BASIS FOR DISCUSSION

The following problems have been identified from literature and communication with experts, endusers, and manufacturers. The goal of the forum discussions is to select a priority, high-impact problem and to begin to develop a problem statement that specifies the requirements for a commercially viable solution. The problem statement will be used to solicit solutions from technology producers. Please come prepared to discuss these topics and to choose the most important. It would greatly benefit discussions if manufacturers come prepared to discuss non-competitive issues regarding materials and related manufacturing methods that are limiting manufacturing and design improvements.

FRAMES

Statement of the Problem

There is a need for frame materials that reduce weight, increase aesthetics, enable novel designs including modular components, maintain durability, fit manufacturing requirements, and do not increase cost.

Current Solutions

Most chairs today are made of tubular aluminum or alloy steel. Some frame designs have incorporated advanced materials such as plastics, titanium, composites, and alloys like chrome-moly; however, the majority of chairs do not use these high-performance materials due to the high cost. A good example of how advanced materials and manufacturing methods can reduce cost is the reduced assembly and associated costs resulting from the use of injection molding to create a unibody for power scooters.

Issues to Consider

Material improvements can enable frame designers to reduce weight and cost while increasing durability, functionality and aesthetics of the chair. This can be achieved by using materials that offer a greater strength-to-weight ratio, improved processing characteristics, and better mechanical performance; however, incorporating high-performance materials, such as titanium, results in increased cost. Also, the strength and durability of a frame design is not strictly dictated by material strength; fatigue strength is strongly influenced by tubing dimensions and shape, welding characteristics, and other assembly-related design aspects. Modular design may provide the solution. There are several advantages associated with modular design, the biggest one being the ease of replacement and repair. Modularity may provide for easy transportation and handling of chairs, especially light weight chairs. Modularity may not address some of the issues relating to product customization and specific end user needs. One expert reported that up to 50 % of chairs are customized. Also, to ensure the safety of the wheelchair users when they are travelling in public or private transportation, caster assemblies and frames should be strong enough to withstand the shocks which they are subjected to during a crash.

Aesthetics of a wheelchair are directly related to the frame design and materials. Chairs in the European market are aesthetically better than in the U.S. This is largely due to the fact that the higher-cost aesthetic features are not accepted by third party reimbursement agencies in the U.S. Based on these issues, please consider the following questions:

- Are aesthetics, strength, weight, and cost of the wheelchair frame issues for both manual and power wheelchairs?
- Is there market potential for improvements to wheelchair frames in general? Will third party reimbursers fund these improvements?
- Is modularity a good option for addressing the need for customization and serviceability? How modular would a design need to be? What would the benefits be to: manufacturing? use? cost?
- Will manufacturers be willing to adopt modularity, considering that modularity might open gates for the competition from low-end manufacturers?

Also, a better understanding of frame dynamics, especially for power chairs, is needed. It is still unknown whether frame design can help in reducing or perhaps eliminating vibration. There is a need to determine a vibration standard for the wheelchair industry. The current vibration standards are based on standards for trucks and other heavy vehicles. A wheelchair user has different stability requirements than a heavy vehicle user and so there is a need to develop a more appropriate standard.

- Is vibration still a problem in manual and/or power chairs?
- Does the frame design contribute to vibration? If yes, then how can vibration damping be achieved with respect to frame design and materials?
- How should the vibration standards for wheelchairs be defined and who should define them?

Both limited sales volume and small production volume, resulting from limited commonality in parts across product lines, contribute to manufacturers' hesitation to develop and implement novel designs. Manufacturers will often hesitate in redesign without proven demand, a situation that delays design evolution. The evolution of frames based on designs originally developed for high-performance sports models illustrates the tendency to introduce revolutionary concepts into niche, rather than broad markets. Standardization of components/frame across

various product lines could help increase production volume of any component/frame.

- What is the barrier that prevents manufacturers from standardizing their components across various product lines?
- Are current issues related to frame designs and materials related more to material performance, manufacturing processes, or design demands?
- Is there a need for adjustability options such as multiple axle placements?

TIRES / WHEELS

Statement of the Problem

There is a need for improved tire wear without compromising ride and traction. Tires must be functional on varied surfaces — sand, rugs, snow, and smooth and rough surfaces — and must be non-marking. Tires should allow discharge of static electricity to prevent shocks to the user and damage to the electronics associated with power chairs. At the same time, tires and wheels should be light and inexpensive. In a 1994 study related to power wheelchairs, users reported that tires were the second most frequent repair behind batteries. Wheels have yearly maintenance problems 24% of the time. Although significant research has had a positive impact on manual wheelchair tires, little advancement has occurred with power chairs tires. This problem stems from the varied wheel diameter and the design and performance parameters associated with power chairs. Also, power wheelchairs introduce much larger stresses on the wheels and tires than manual chairs due their heavier loads.

Current Solutions

Common materials used include rubber, urethane, polyurethane, composite nylons, and kevlar-reinforced thin tubes. Research is in process on solid polyurethane foam tires, which combine the best features of the pneumatic (comfort, low rolling resistance) and solid tires

(low maintenance). These materials have a microcellular structure that reduces weight while maintaining wear and rider comfort. One problem with the new solid tire designs is the tendency for the tire to become unseated from the rim. Radial tires, semi-pneumatic designs, and inserts are also being researched.

Issues to Consider

In the area of tire and wheel performance, the main issues are reliability and durability without losing comfort and safety. Pneumatic tires provide great comfort but are a potential inhibitor of independent living, due to flat tire etc. The goal is to achieve the comfort level offered by pneumatic tires along with the reliability and durability offered by solid tires. Increase in durability will also provide economic relief to the enduser. At present, power wheel chair tires cost almost $100. This is a big expenditure considering that present tires have a short life span and are therefore replaced quite frequently. There is a need to innovate or use materials and design that can bring down the cost of the tire, increase the durability of the tire while maintaining reliability and comfort level. And most importantly, tires should be non-marking. Black tires meet most of the requirements of an ideal tire but suffer from the big disadvantage that they are marking and are therefore not used in the industry.

- Are the problem of static charge build up and durability more critical to the power wheelchair industry than manual wheelchair industry?

- Are the newer solid urethane and polyurethane foam tires meeting users' needs adequately? If not, why not?

An issue relating to wheel improvement brings into question if it is beneficial to reduce the wheel weight for power chairs. Spoke wheels performs well but requires a lot of maintenance. Probably an ideal wheel will be one that has the weight and power of spoke wheels while the cost and maintenance of plastic wheels. A misaligned wheel requires a lot more effort to push. It is frame structure that mainly controls wheel alignment. For manual wheelchairs, wheels should require minimum effort to push. Technology innovation, like geared hub wheels, is required to make the wheels easier to push. Though considerable improvements have been done in the wheel bearing, it is still a high maintenance item. Further improvement is required in this field.

- For power chairs, is weight irrelevant? Is the goal for wheel materials to merely match the weight and strength of spoke wheels but improve in the area of cost and maintenance?

- Wheel misalignment affects tires wear rate as well as rolling resistance. Is this a serious problem?

In the literature we found articles that cited the major barrier in the area of tires and wheels as the fact that the total market is not large enough to support investment in R&D by traditional tire and wheel manufacturers. Some believe that development of better tires will require government funding for research at universities. Another concept discussed in the literature is that all wheelchair manufacturers should cooperate to develop a specification with a single tire supplier who could then address the industry's problem.

- Is an industry consortia on tires and wheels feasible as a means to develop adequate R&D to meet the industry's needs?

- Are varied customer needs a problem inherent in tire and wheel product selection? Could modularity apply to tires/wheel systems?

SEATING

Statement of the Problem

Seating materials and components have a significant impact on cost and customer satisfaction. Pressure sores is a very big problem for wheelchair users. The chair needs to fit the user well even when there are changes with clothing, physique, or age. Seating materials must withstand daily use in varied weather and climate and thus must be durable. Customer preference regarding aesthetics and comfort also are important variables. A well-designed suspension can contribute a lot towards the designing of a comfortable seating system. Cushions can reduce shocks considerably. Upholstery must allow for air circulation and provide user comfort, yet it also must be able to be wiped clean or laundered easily for hygienic and aesthetic reasons. Fire retardance is essential for users who smoke or are around smokers; seating material must not ignite. Ride quality and durability are tightly linked to selection of seating materials and design of seating systems.

Current Solutions

Seating comes in many forms: sling-type, armchair, plastic bucket, automotive-type, and custom. The materials used for these seating systems vary greatly, including wood, leather, plastics, textiles, foams, and gels. Simple seats can be made from plastic molding with no cushioning or upholstery; whereas others, like the automotive-type, may incorporate a sophisticated design with subforms, multiple types of cushioning materials, and upholstery. Air permeable fabrics based on a pore size that does not permit liquid to pass have best solved the conflicting needs for comfort — relating to breathability of a seating material — and for waterproof characteristics.

Issues to Consider

To accommodate the various requirements of the enduser, seating system needs to be adjustable/adaptable. Modular seating can lead itself to adaptive seating. Seating is most comfortable when there is a zero shear force for back upholstery and head rest. Sensors and actuators could be used on the seating system to achieve this zero shear force target. Similarly there is a need for an improved suspension system which can improve the ride quality. An active suspension system can reduce vibration a lot but due to the cost factor is suitable for niche market only. A suspension system that is variable — capable of being soft for mobility comfort and hard for enduser transfer — may have benefit to the end user.

- Have aspects of custom seating, that could benefit the broader market, been adopted by manufacturers? If not, what prevented their use?
- Is the “pressure sore” problem being adequately addressed by the industry? If no, why not?
- Is there a need for adjustability / adaptability features in seating systems? If yes, how could these features be best integrated?
- Are varied customer needs a problem inherent in seating designs?
- What are the issues regarding shock absorption at the casters versus shock absorption at the main axle?

REFERENCE LIST

Clifford E.Brubaker (1989). Wheelchair IV, Report of a conference on the state-of-the-art of Powered Wheelchair Mobility, December 7-9, 1988. RESNA Press.