A concept of support system for the disabled person's wheelchairs: presentation of a 3D print solution

Koncepcja systemu podparcia wózka dla osób z niepełnosprawnością ruchową - prezentacja rozwiązania z zastosowaniem druku 3D

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DOI: https://doi.org/10.14814/mechanik.2017.5-6.60

An innovative concept of the seat of the wheelchair for persons with disabilities is discussed. The solution is presented as a CAD model as well as in the form of a real model. Additionally, prospects of consolidation of electronic actuators are shown providing for visualization of concepts and principles of operation.
KEYWORDS: RP/AM, MEM methods, wheelchair for people with disabilities

Designing each device is a complex process, requiring the cooperation from teams and people involved in it, starting from the concept development. This is due to the fact that the next stages of project implementation depend on the adoption of correct assumptions and on the manner of presentation of the proposed solution. The way of the presentation and visualization of the idea (photorealistic images, 3D visualizations, animations, physical model, etc.) can have a big impact on decision-making by investors.

Spatial visualization - a three-dimensional model and physical model (made in incremental technology, for example), demonstrating the principle of operation of the device and verifying the correctness of the adopted design assumptions - provides effective communication between cooperating designers, investors, potential users, etc. The use of CAD systems enables visualization of the idea. The early stage, and 3D CAD models are a valuable source of information in the design process of the device - until it is put into production.

The efficiency of the whole process is greater through the use of the design thinking method. Feedback, providing feedback from the potential recipient to the designer while still in conceptual work, can help reduce costs and risk of error. This is particularly important in the design of individualized transport for people with disabilities having specific needs that the designer must take into account from the very beginning [1, 8]. The vehicle for a person with a disability on the one hand must be tailored to the individual needs of the user (to meet the requirements of ergonomics) and, on the other hand, to have universal functions and features to reduce production costs.

When developing a device that does not have a commercial counterpart (and the designer can not directly relate to existing solutions), the 3D model and physical model are of particular importance. They are used in this article to provide a new concept vehicle for people with disabilities. The effectiveness of this message has been confirmed by the authors at conferences and innovation fairs, e.g. in Brussels (2014) and Geneva (2015).

As it is known, the use of conventional manufacturing methods to implement fully functional prototypes or models on a certain scale often entails significant costs. Fortunately, rapid prototyping, such as the FDM (*fused deposition modeling*) method, is used to obtain a physical model with a low cost of manufacturing [7].

Innovative seat layout

As part of the research work at the Department of Machine Design of the Rzeszów University of Technology, the concept of an innovative seat solution was developed [2, 3]. The classic seat with backrest was replaced by a system supporting the chest, thigh and leg (fig. 1), offering a number of facilities [4]. Adjustable seat height gives the option of switching to a bed or chair without the help of third parties. The support means lowering the center of gravity, which increases stability, especially when overcoming obstacles. In the case of classic wheelchairs even a few centimeter barriers can be dangerous [5, 8].

One of the main advantages of the proposed support system is the ability to change the distribution of seat surface pressure on the human body to relieve the areas most vulnerable to damage due to prolonged pressure.

In order to ensure simultaneous change of seat height and tilt of the shank support, a single drive was used to connect the support elements by means of a mechanism. By August 2016, this solution was granted patent protection [2].

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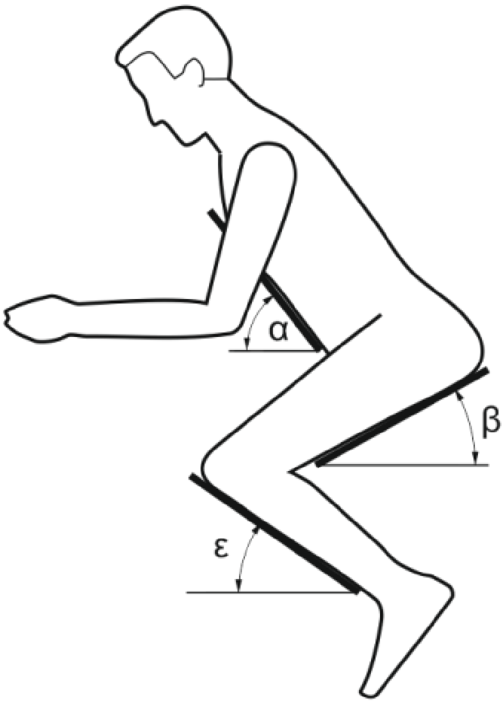

Fig. 1. Concept of wheelchair support system for people with disabilities (*α, β, ε* - angle of inclination of individual seat components)

CAD model of a wheelchair

Applying the SolidWorks, a CAD model for the support system and the suspension of the truck and its enclosure, has developed [6]. The size of the model was chosen on the basis of human dimensions - its model was also created in a CAD environment (fig. 2). The optimum angles *α, β* and *ε* have not been optimized so far - their ranges must be selected on the basis of the effects of the placement of the support elements on the distribution of pressure on the human body and in addition they should be medically consulted. The point is to reduce the pressure on the buttocks at the expense of increasing the load on the chest and lower leg.

The computer animation, based on the CAD model, is a more advanced form of presentation of the innovative support system, including its basic features, the mutual positioning of the individual components of the system relative to the body part, and the concept of movement of both the mechanical and the functional components (due to ergonomic conditions) of limbs in extreme positions. Animation has made it possible to prevent possible mistakes and to incorporate many conceptual assumptions into one multidisciplinary project.

Fig. 2. CAD model of the wheelchair together with the user

Physical model of the wheelchair

Functional prototyping is a form of presenting a helpful model at the stage of fine-tuning utility features and verifying accepted assumptions. The prototype of the 1:1 support system was developed as a part of the research. This enabled us to determine the comfort of use and the distribution of surface pressure on the human body. During further work, the support system will be extended to a full wheelchair construction that will drive the test drive to gather feedback from users.

For demonstration purposes, model in 1:4.5 scale was created - this value was adjusted to the dimensions of the available 3D printer and dimensions of the dummies available.

The accuracy of the models depends on the chosen RP method (*rapid prototyping*). With the UPplus2 model, the model can be assumed to be approximately 0.2 mm, which is included in the CAD model (all diameters of the screw holes are increased by 0.2 mm). The size of the wheelchair case was divided into eight parts. The model has been converted to STL format, which provides direct reading in the UP! v. 2.13 3D printer software.

Printing of all parts of the wheelchair took more than 63.5 hours. The individual elements were then linked together. For durable connections (e.g. component parts), epoxy resin based adhesives were used, and M3 screws of varying lengths, depending on the application area, for movement joints.

Incremental elements are characterized by surface roughness, resulting from the specificity of the printing process. On the curvilinear surfaces, the surface profile is mapped in the form of steps, and flat surfaces show the characteristic texture. In order to compensate for unevenness, the surface can be smoothed mechanically, e.g. with grinding wheels, using filler material (filler) or by combining these two methods for best results. In the case of the truck model the roughness was first filled with a putty knife and then the entire surface was smoothed with sandpaper and painted.

The model was equipped with electronic circuits. Consolidation of electronic actuators and electric drives enables better visualization of concepts and operating

Fig. 3. Placement of the arm drive

principles. An example of a wheelchair model was a servo mounted to change the position of the support elements. Already at the design and printing stage of the wheelchair components, it was necessary to use a series of intermediaries in the transfer of the servo movement to the moving parts of the wheelchair. The drive was located in the rear of the vehicle (fig. 3).

The servo control is provided by a driver that communicates with the computer via the COM port. Motion parameters - such as the angular range of rotation of the servo and its speed and the ability to operate in a loop - are determined by a special software that allows for easy script generation that can be loaded into the controller and executed without connecting to the computer. Final results are shown in fig. 4 and fig. 5.

Fig. 4. Physical model

Fig. 5. Physical model with mannequin

Conclusions

With additional functionality, the vehicle in question can be both a universal means of communication and a rehabilitation device.

Developing a new solution requires public consultation, especially with the environment of people with disabilities. The effective transfer of ideas is a virtual 3D visualization and a physical model made with the chosen incremental method. Using this technology enables rapid prototype development and validation of accepted assumptions, and the models themselves influence a better exchange of information between the people involved in the project. A very important step in the development of the physical model is the final machining. It depends on the aesthetics of the model implementation and thus the quality of the presentation of the concept.

The solution described in the article was presented at the International Inventory Fairs *Brussels Innova 2014* and at the 43nd International Exhibition of Inventions *Geneva Inventions*, where it received medals and awards.

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