Student Design Project: Roller Bench for Disabled Persons

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ABSTRACT

In the final years of design engineering training, the Department of Machine and Product Design of the Faculty of Mechanical Engineering at BUTE supports the practical training of students through the solution of industrial design problems in teamwork. In addition to presenting our experiences, we would like to illustrate the design process through the overview of a specific problem. The problem is a roller bench design, which helps the rehabilitation of people in wheelchairs, from the first steps to the final design. After the determination of the list of requirements the conceptions were developed. Parallel with conceptual design, the future form design of the equipment was started to be elaborated. The detail of the final construction shows how to achieve real drive conditions with a very simple mechanism and an attractive design.

Keywords: student design project, design engineering, roller bench, rehabilitation equipment, wheelchair

1. INTRODUCTION

Design engineering students have been trained at the Department of Machine and Product Design of BUTE for several decades. The process involves familiarization with numerous aspects of design sciences and with methodology skills to provide efficient tools and procedures to be used by students. The final years of design engineering training are increasingly characterized by practical skills development to seek for solutions in the form of design tasks. These are characterized by teamwork as well as industrial composition and the direct involvement of industrial experts in resolving design problems. This manuscript summarizes our efforts and experiences in this respect, illustrating them by presenting the resolution of a project task of industrial origin.

2. DESCRIPTION OF DESIGN PROJECTS

2.1. Type and selection of project tasks

The Department's industrial relations are based on regular design assignments as well as on thesis works and degree projects. 60 to 80 companies are involved in each semester. Problems raised by companies are frequently intended to be solved in the form of design tasks for students. In this latter case, it is important to harmonize the type and level of difficulty of a task with students' knowledge and skills acquired; in addition, problems should be possible to solve in 10 to 12 weeks. It is important that companies are required to provide regular consultations to familiarize with the technologies applied and to avoid initial misunderstandings.

Problems raised can often be classified into conceptual design or detail design tasks. In the first case, expected solutions can be outlined to a lesser degree by industrial and university supervisors, while they can be more precisely estimated in case of detail design tasks.

2.2 First steps of a design task

The task is briefly defined and then students get acquainted with the company's operations, profile, and solutions so far. Familiarization with critical remarks is followed by a discussion and documentation of requirements performed jointly by students and supervisors according to regular classifications.

It is a more difficult problem to present the role of the market in respect of a specific design task. This requires an overview of existing product solutions, their advantages, disadvantages and market status. Industrial consultants play a dominant role in this aspect.

Schedule	1		3		5		7		9		11		13	
Define basic design tasks	●													
Distribute design tasks	●													
Familiarize with company		●												
Produce list of requirements		●	●											
Preliminary task plan, first tasks			●											
Market environment, competition		●	●	●										
Develop first solutions				●	●	●	●							
Discuss solutions, deliver presentation						●	●							
Select solutions appearing to be successful							●	●						
Elaborate geometric details								●	●	●				
Implement correct design for manufacturing									●	●				
Optimal solution										●	●	●		
Draw up documentation												●	●	
Closing presentation													●	●

Table 1. Main steps of completing a design task

A preliminary task plan is drawn up based on the list of requirements (Table 1). It is a preliminary one because there is little information available for implementation; at the same time, in order to be able to launch a team project, it is required to select a student team leader and to work out the first tasks together.

2.3. First solutions and presentation

First solutions (conceptual designs, ”akin solutions” at the level of notions or detail designs) are developed both in teamwork and as individual tasks. Time needs to be devoted to both. Discussions of ideas frequently generate new and more clear-cut ideas.

The first presentation can include freehand sketches, provided they are ”retouched”, properly understandable notions. Preliminary motion simulations are of great value today, showing schematically modelled draft solutions in motion. The presentation is required to include a summary of the positive and spectacular features of the solutions presented.

2.4 Solution – from outlines to detail designs

It is expedient to select at least two or three versions from the solutions appearing to be successful, as this is only an early phase in the design process. Several promising solutions may end up in failure. Detailed elaboration of possible solutions may require more accurate geometry and preliminary behaviour simulation. At other instances, successful design may be promoted by modification / analysis / repeated modification of an existing version.

Cost analysis is particularly reasonable in the latter case, as the most economical version should be selected from a number of similarly reliable solutions. This issue can be radically influenced by the implementation of correct manufacturing design as costs are mostly determined in the design phase [1].

2.5 Correct manufacturing / optimal solution

Numerous consultations with industrial supervisors are required during detail design development to present the company’s technological criteria, with a view to production capacities, deadlines, expected production accuracy levels, etc.

The design phase as outlined can be made even more valuable if it is coupled with optimization, most frequently aimed to reduce weight and peak stresses, following shape optimization or ”dimensioning” optimization. On the whole, cost optimization prevails in these cases as well.

2.6 Documentation and closing presentation

The documentation expected is obviously in conformity with the nature of the design project. Most frequently, the documentation expected is based on a 3D CAD model. ”Report-type” documentation is often a further expectation to

summarize all the steps of the design task completed. In a number of cases it is expedient to present new solutions on posters, perhaps to prepare an information leaflet on the product.

The closing event of a design project is a presentation to discuss the main steps based on 15 to 20 slides, from engineering problems to engineering solutions.

Presentations are followed by an evaluation of students' work as well as contributions by industrial and university supervisors, who were supposed to help students' initiatives and ideas to "wing their flight", to facilitate implementation according to schedule and to fully complete their engineering product.

3. ROLLER BENCH DESIGN

Unfortunately, more and more people are forced into wheelchairs as a consequence of the increased number of public road and other accidents today. The rehabilitation of people in wheelchairs is a high priority.

Nowadays there are only a few numbers of equipment available in the markets which are providing an opportunity onto practicing at home. But these equipment are very expensive and some of them too large and heavy.

Therefore we set as an objective to design a device to assist patients who are newly forced into wheelchairs how to drive the chair and to provide opportunities for daily exercise, possibly training both at home and in hospitals. A further objective is to design an apparatus to reproduce real drive conditions, including various load conditions and lateral displacements, ensuring a convenient feeling of freedom for users.

3.1 List of requirements

After an analysis of competitive products, requirements for the equipment to be designed were set up following discussions with external consultants. Guidelines were set to clearly determine the line of design. The most important requirement is the compliance of IFI standard [2], [3] and [4]. Table 2-3. contain some further requirements.

3.2. Conceptual design

As a first step of design, several concept versions were developed, satisfying earlier requirements. Our most important task was to design the tread (the running surface of the wheel), for which the following two solutions were selected for further investigation after assessing a number of manual sketches. Figure 1 shows the two initial devices.

#	Name	Numerical value
1.	External dimensions	max: 800x1500x2000 mm
2.	External dimensions in closed position	max: 250x1500x700 mm
3.	Foldable design	-
4.	Weight	cca. 50 kg
5.	Track width	560 - 660 mm

Table 2. List of geometrical requirements

Ergonomic		
#	**Name**	**Numerical value**
1.	IFI Stage II compliance	-
Maintenance		
#	**Name**	**Numerical value**
1.	Lifetime	7 years
Costs		
#	**Name**	**Numerical value**
1.	Production cost	Max 100,000 HUF (360 EUR)

Table 3. List of further requirements

3.3. A brief summary of the structure of the bench with rolling surface

The training bench of this design is operated by a central cylinder of torque transmission. In the rest position, this cylinder is located under the shaft of the wheelchair in the middle. This cylinder is responsible for torque transmission between the wheelchair and the brake and the flywheel.

During exercises on the training bench, subjects can move freely to the sides as well as forward and backward, thereby the device restores the feeling of freedom of movement. The former motion is feasible because transversal displacement is not restricted along the roller; there is a device to hinder rundown only at the edge. Longitudinal motion is made possible by auxiliary rollers and tilting arms supported by spring-controlled members. One end of spring-controlled members is connected to the arms and the other end to a link groove in the frame, therefore they do not produce tensile resistance, and they can only be loaded by pressure.

One must be able to bend the tilting arms forward and then back and fix them steadily in order

to take up training position at the beginning of the training and to leave it at the end. After finishing exercises, the structure can be fold to the smallest size possible; it can be squeezed in a small place and moved by one person. Structural design is characterized by the fact that there is no main frame within which roller members can be moved; both halves constitute a separate unit.

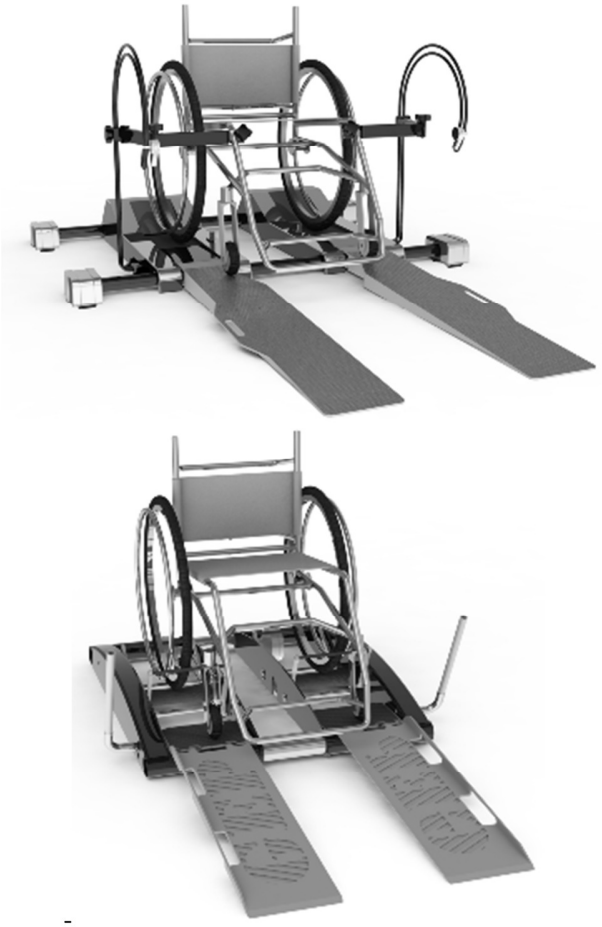

Figure 1. Roller bench concepts

3.4. A brief summary of the structure of the bench with striped tread

Equipment tread design greatly differs from that of the device presented in the earlier point. A ribbed belt with metal thread reinforcement is driven by a cylinder embedded with two deep-groove ball bearings. It is a point of interest in its design that the wheelchair serves as a tension roller, thereby ensuring the strip tightness required for secure driving. Striped surface design enables to balance load differences arising from different wheel pressures in the wheels of the wheelchair.

A realistic drive experience is provided by a built-in load control brake system and a flywheel. The 1 kg flywheel of 100 mm diameter is mounted on a separate shaft with bearings due to the low-height design required from the equipment (Figure 2). The connection between the roller and the flywheel is ensured by a standard ribbed belt.

Load control is provided by a gradually adjustable mechanical brake apparatus. As drive design does not provide for the safe fastening of the wheelchair during exercises, a fixing arm system was also developed by which the wheelchair can be safely latched during equipment use.

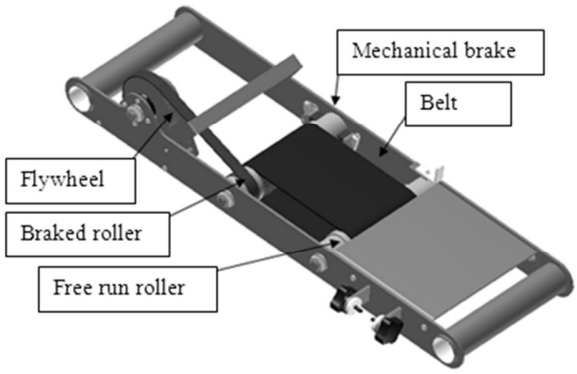

Figure 2. Structure of the drive system

3.5. Final Design

For the final design, the benefits of the two devices just presented were taken into account together with cost requirements. Consequently, a simpler roller tread device was designed, combined with the frame structure of a striped treadmill training machine.

3.5.1 Form design: Parallel with concept design, the final product design of the equipment was started to be elaborated. The form design concept is based on the interrelationship of the basic components, and is intended to create an object which is as compact, safe, manageable, and thereby as usable and loveable as possible by breaking these interrelationships down, using their comparative adjust and motions, at the smallest space possible and with the least possible materials used. Figure 3 shows a draft form design.

3.5.2. Detailed solutions of the equipment designed: Figure 4 shows the equipment designed. The device can be divided into main components as follows: the frame system constituting the skeleton of the equipment and the torque transmission devices including the magnetic break (see in Figures 5 to 7).

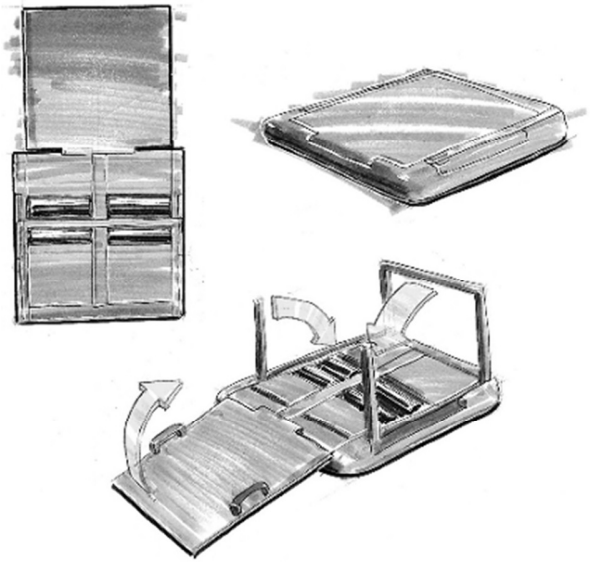

Figure 3. Conceptual form design

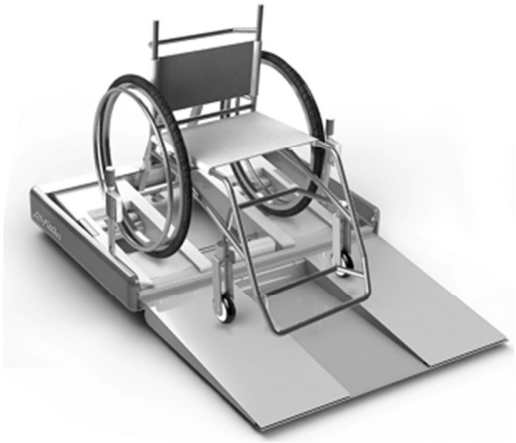

Figure 4. The final equipment

3.5.3. Frame structure design: Several aspects had to be taken into consideration for frame structure design. On the one hand, strength criteria had to be met, and adjustability to the appropriate track width had to be ensured. Consequently, using the solution applied in earlier concept drafts, a two-step frame structure was developed, as shown in Figure 5. It can be observed that the frame consists of a main frame and an auxiliary frame. The main frame is intended for load bearing, and it also includes support stands and movable rollers. The auxiliary frame accommodates the roller system with the load control brake system and the roller latch device.

It was an important aspect in design to ensure the adjustability of the track width of the equipment within the limits set out in the list of requirements. To enable this, a latching device for adjustment was developed. The structure is shown in the Figure 6

The structure is operated very simply. By drawing the arm, latching on the main frame discontinues and the auxiliary cart holding the rollers can be easily moved into the appropriate position. The design ensures central adjustment; therefore users can adjust auxiliary rollers easily, without them being jammed in. In order to facilitate displacement of the two frames on each other, polymer sliding bearings were applied at the connection points of the two frame parts (Figure 6).

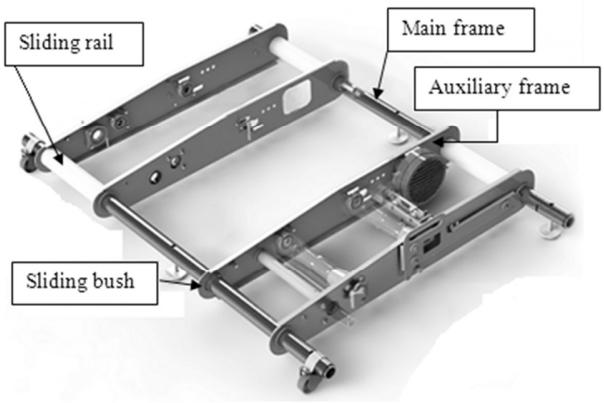

Figure 5. Frame structure design

The track width adjustment structure automatically bounces back into the grooves on the main frame as a result of the retracting spring. Thereby it can be ensured that auxiliary frames be properly fixed in each position.

3.5.4. Torque transmission device: A drive system of two rollers was developed for roller bench drive transmission (Figure 7). Rollers are provided with deep-groove ball bearings on both sides. This ensures an easy, jam less drive and a long life.

Another important criterion for the equipment, that the degree of roller braking should be easily adjustable during use. A Tacx magnetic brake was built in for this purpose, separately for each roller pair. The brake is connected to the rear rollers by a round belt.

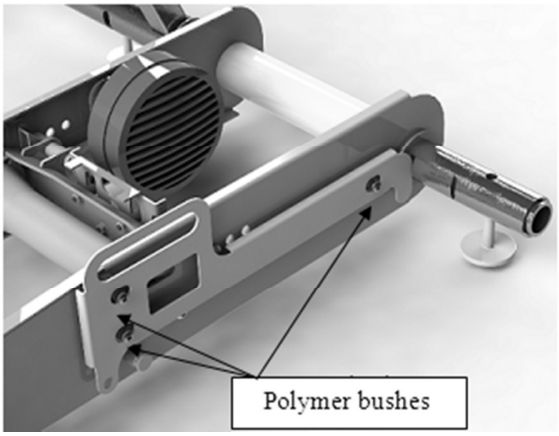

Figure 6. Layout of latching structure

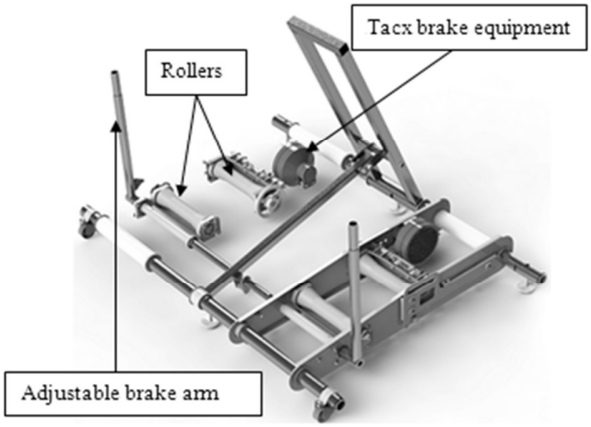

Figure 7. Drive structure

The conical design of rollers ensures that the wheels of the wheelchair always stay in the middle of the roller during exercises, and that they return to the middle in case of any displacement. As a result of the mounting arrangement, the person using the bench can set different levels of braking on each side, thus increasing the number of exercises to be performed.

In roller design, particular attention was paid to the fact that they should be manufactured easily and cost-effectively in case of large series. Consequently, rollers are produced by moulding.

4. CONCLUSION

The student design project presented, illustrates an integrated approach of the design process, learned in the final years of design engineering training.

With the help of the designed roller bench the rehabilitation of people in wheelchairs can be done efficiently at home or in institutional environment. In addition the built-in various load drive chain, and the wide range of adjustability provides that the equipment satisfies all the users' demands from children to adults or from beginners to sportsmen.

5. ACKNOWLEDGEMENT

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