New therapy device for occupational therapy

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Abstract: **This paper deals with the development of a new therapy device, so called "bicycle saw". Since existing therapy devices do not offer the desired amount of features and functions, a new therapy device had to be developed. Many therapy requirements had to be fulfilled. Moreover, this big amount of new functions is packed into a consistent PLC-concept, in order to provide easy adjustment possibilities with the help of RFID technology. One important reached goal is, of course, the fulfilling of the therapy requirements in form of several technical functions and features. The electrical adjustments of seat, table and the multifunctional pedal-system are providing an added value. But only the user-friendly touch-interface makes this vast amount of new functions for therapists and patients tangible. However, the overall reached goal is the increasing of the efficiency of occupational therapies.**

I. INTRODUCTION

In 2011 the rehabilitation center in Tobelbad, Styria, asked the Degree Program Automation technology at *CAMPUS* 02 University of Applied Sciences to develop a new innovative therapy device to improve their rehabilitation possibilities in the field of occupational therapy.

Figure 1. Client (AUVA) and Contractor (CAMPUS 02).

The main function of a so called "bicycle saw" is based on the function of a conventional ergometer. Nevertheless, there exist several fundamental differences.
Firstly, the pedal system is coupled with a saw. Secondly, instead of bicycle handlebars, there is a working table installed. These functions make it possible for patients to therapy themselves and process wooden pieces at the same time and, as a result, to forget the effort of sports.
Unfortunately, there exists no manufacturer of bicycle-saws anymore. But, since the therapy device demand at the rehabilitation center in Tobelbad has increased a new therapy device with several new functions has to be developed.

II. THERAPY REQUIREMENTS

To understand the motivation for the development of this new therapy device, the therapy requirements should be known.

A. Easy Patient-handling

Since there is no time plan for patients in the workshop area of the occupational therapy, patients are coming and going all time. Patients do not have the chance to choose their favorite bicycle saw, they are just choosing the device, which is available. As patients are constantly changing the therapy devices, they do not adjust the bicycle saws in order to have a correct seat position. The reason for this is that it is just too effortful and time-consuming.
So, one main goal of this development is to make it easy for therapists and patients to adjust the therapy device in an easy way. Consequently, with the help of this development each patient will only work with bicycle saws which are individually adjusted.

B. Adjustable pedal-system and sitting position for occupational therapy claims

Existing bicycle saws do not offer the amount of possibilities to adjust the table, the seat or the pedal-systems, as it would wish the therapists. As a result, a therapy device should offer the following adjustment possibilities for an efficient occupational therapy:

- electrical table adjustment horizontal and vertical
- electrical seat adjustment horizontal and vertical

Special forms of therapies necessitate a special pedal-system. Existing bicycle saws do not offer these functions. The listed pedal-system-functions below are necessary to be able to individually therapy also patients with foot injuries:

- constant gradient of the pedals during the rotation
- electrical adjustment of the gradient
- manual adjustment of the pedal-radius

C. Coupling of pedal-system and saw

Patients are different, especially if it comes to performance in the field of sports. The current bicycle saws do not offer the possibility to handle these performance-differences. The main issues are:

- the missing adjustment-possibilities at the number of revolutions for the saw (ratio of pedal-revolution to drive-revolution of saw)
- counter torque to reduce or increase the level of difficulty

These problems should be solved with a new concept of coupling the pedal-system with the drive of the saw.

III. NEW THERAPY DEVICE ("BICYCLE-SAW") CONCEPT

As mentioned in the Introduction, the basic function of this therapy device is to couple the pedal system with a saw. As a result, patients are able to work and therapy at the same time. Unfortunately, actual bicycle saws do not offer many

features. As a consequence, therapists do not have the possibilities to medicate their patients as good as possible.
So, new features have been elicited with the therapists. The basic therapy device concept is imaged in Figure 2. This concept is based on the fulfilling of the therapy requirements, stated in chapter II.
The overall goal is to integrate all sensory and actuatory components into a PLC-concept, due to easy maintenance possibilities and to provide a great safety concept with safety-PLC.
Visualization with a Touchpanel gives the therapists, patients and the service staff the possibility to handle with the therapy in an easy and intuitive way.
Automated adjustment possibilities for table, seat and pedal system have major priorities. All these adjustments are integrated into the PLC-concept with a database behind it, to be able to provide the patients with an easy RFID-access.

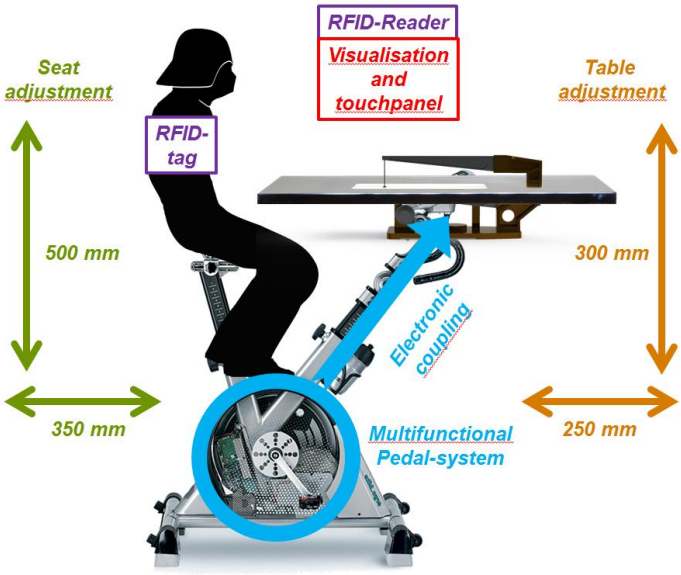

Figure 2. Basic therapy device concept.

As already mentioned, therapists did not have the possibilities to medicate their patients as good as possible with the existing therapy devices. The RFID-concept in the new therapy device allows the therapists to concentrate on their real task – the therapy. Therapists only have to adjust the therapy device once per patient. Everything is saved in the database and each patient has a RFID-tag for the data-access. This results in a major time-saving for therapists and patients.

IV. REALIZATION

All the therapy requirements, which are mentioned in chapter II will be fulfilled in this chapter. The section-letters (A, B, C) of chapter II are directly connected to the section-letters in this chapter.

A. Consistent PLC-concept with included RFID

All adjustment possibilities are integrated in a consistent PLC-concept in form of servo drives and stepper motors. The fundament of this control-concept is a PLC and a safety-PLC.
The Visualization with a user-friendly Touchpanel-interface allows patients and therapists to adjust the therapy device in an easy way. Figure 3 reveals the whole PLC- concept with all control- visualization- and drive-components.

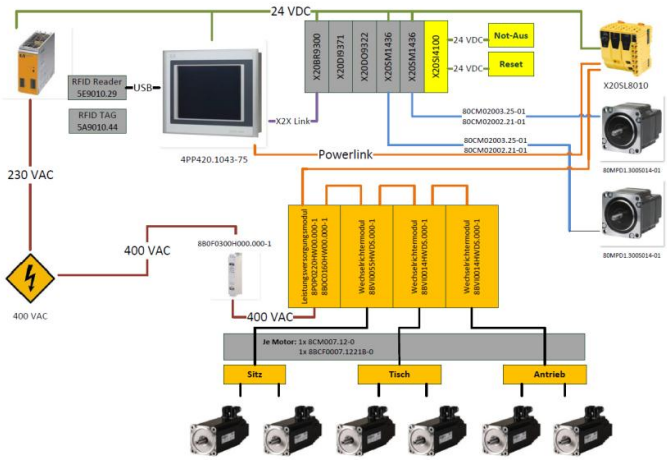

Figure 3. PLC-concept with all control- visualization- and drive-components.

As claimed in chapter II therapists complain about the effortful and time-consuming adjustments of the current bicycle saws. The new bicycle saw allows the saving of adjustment position values of each patient in a database. Patients get their own RFID-tags, which identifies them and allows to easily restoring saved adjustment position values. Consequently, no effortful adjustments are necessary, since coded algorithms in combination with RFID-technology within the framework of a consistent control-concept are doing automated adjustments.

B. Multifunctional pedal-system and fully adjustable sitting position

The major task was the solving of the problems of the complex pedal-system, which is shown in Figure 4.

Figure 4. Multifunctional pedal-system with gradient- and radius-adjustment.

The mentioned requirements in chapter II has to be fulfilled. The vastest challenges in the design of the multifunctional

pedal-system were the restricted space and the complex kinematic situation.
To adjust the pedal-radius a spindle inside the crank was installed, which allows a very space-saving design.
The next step was the constant gradient of the pedals during the rotation. This problem was solved with a special form of a parallel-gear-system. Unfortunately, this parallel-gear-system generated a singularity-problem, which had to be solved with a special design of a space-saving drive-belt-system. This solution is shown in Figure 5.

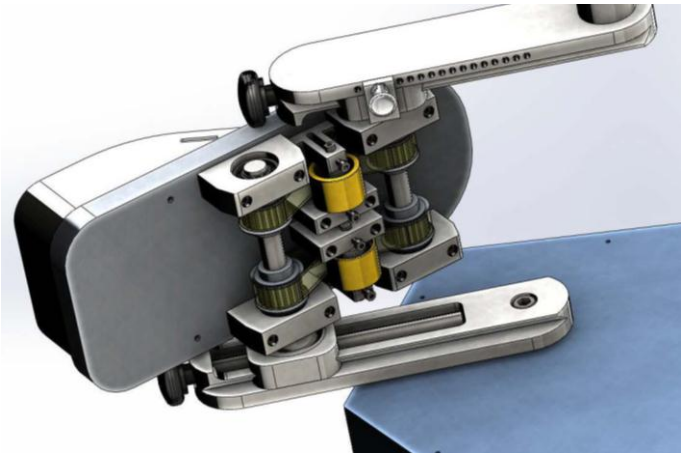

Figure 5. Solving of the Singularity problem.

Since, the gradient of the pedals is already constant during rotation; this gradient also has to be adjusted electrically. Figure 4 also reveals the special design of a gear-segment, where the parallel-gear-system is mounted. When turning the gear-segment and, as a result, changing the gradient, then the gradient of the pedal is also changing. Stepper motors in combination with a worm gear-system allows an electrical and self-locking gradient adjustment.

Figure 6. Realization of pedal-system.

The seat- and table-adjustment is realized with synchronic drives. All guide rails and spindles are maintenance-free and cost-saving synthetic-systems. These systems fit optimally in the field of Medical engineering.

C. Generator as a flexible exchanger between pedal-system and saw

The requirements mentioned in chapter II state that there is a need of technical improvements in dealing with patients with different levels of performance.
Figure 7 shows a concept of coupling a generator with the drive of the saw.

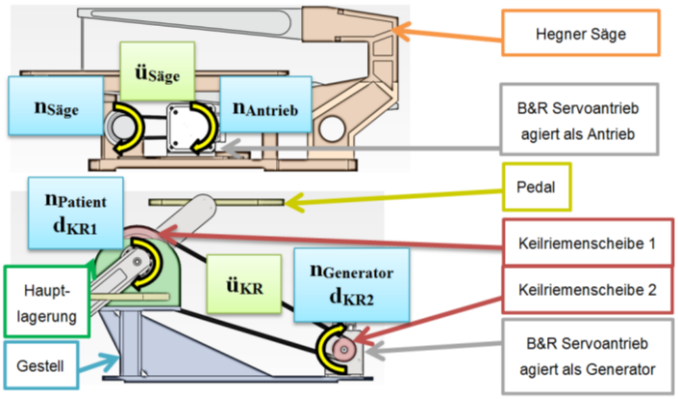

Figure 7. Concept for coupling generator with the drive of the saw.

This concept opens many new possibilities. Since the generator is also able to generate a counter torque, one requirement is fulfilled. Furthermore, the electronic coupling is more space-saving than mechanical solutions with cardan joints.
In addition, this electronic coupling is more flexible. This means, that the number of revolutions is directly proportional to the number of revolutions of the drive of the saw. So, a simple modification of a gain factor is needed, to optimize the velocity of the saw individually for each patient.

D. Result therapy device

The new therapy device “bicycle saw” was fully developed with a 3D CAD software tool. Especially, when it comes to a high level of complexity and a very complex kinematic, 3D CAD is the best and most effective way to develop products. Consequently, there are basically two results, one virtual, and one real.
Figure 8 shows the virtual therapy device developed with the 3D CAD Software tool, called SolidWorks.

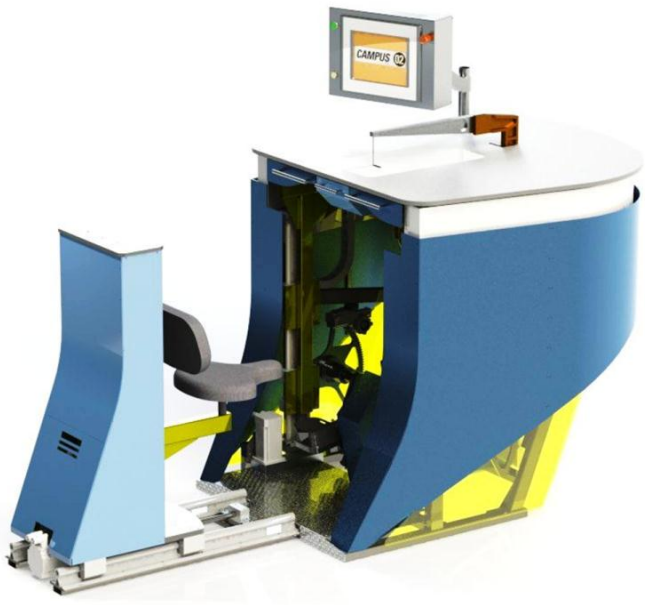

Figure 8. Kinematic CAD-model of therapy device.

Figure 9 reveals the real therapy device, which is already commissioned at the rehabilitation center in Tobelbad.

Figure 9. Commissioned therapy device.

V. Conclusion and Prospect

This new therapy device, called bicycle saw, is a great step towards in providing more efficient, more qualitative and more individualized occupational therapies.

Since, this therapy device offers a consistent PLC-concept, there are also possibilities to extend the range of functions very easy in future. For example, also tools for different analysis and performance-progresses could be implemented.

This new therapy device, where the pedal-system is installed as a central component, is to facilitate the work of the therapist with the patient in the rehabilitation center considerably. Especially the patients should benefit because of the wide range of new functions. By the correspondingly good preparation of the technical documentation in all levels of development, it is also very easy to be prepared in the future to build identical devices. At best, the workshop AUVA Tobelbad must be extended in future to provide more space for the patients for the creation of their remarkable work pieces.

VI. References

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