DESIGN OF A NEW BATHLIFT CONSTRUCTION

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Abstract: *This paper presents the design process of a bathtub-entry-assist equipment, which can lift the person into the bath from the place beside the bath. Compared to similar products, which are not capable to do similar way of lifting or do it in a very complicated and expensive way, our device uses only a single drive and control system for this task. The device lifts the person into the bath on circular trajectory, which is an unique solution. The device has an utility model protection, which represents its novelty. The drive system of the device consists of a DC worm gear motor and an additional worm gear drive ensuring the necessary gear ratio for high output torque and self-locking of the mechanism, which is essential for safety requirements. It is powered by a 12 V battery, which is required for wet environments. The device has a stable and easily mounted supporting structure that ensures employability in bathrooms of different shape. The flexible seat provides comfortable usage for both slim and fat persons. The paper introduces the problem to be solved, then describes currently available products on the market and some patents related to the problem. The conceptual design process with a system-wide approach is the next part of the paper, which is followed by the description of the realized prototype.*

Keywords: BATHLIFT, CONCEPTUAL DESIGN, PROTOTYPE BUILDING

1. Introduction

The age structure of the population in the EU is becoming older and is expected to continue in the coming decades. Old people (aged 65 or over) made up 17.8 % (89757.2 thousand people) and 4.9% of the population (24887.5 thousand people) was 80 years old or older. The median age of the EU-27 population on 1 January 2012 was 41.5 years [2]. It is also a sign of an ageing population. In [4] it is projected that the rate of people aged 65 years or over in the total population will increase to 30.0% and the number will rise to 151.5 million in 2060. Similarly, the number of people aged 80 years or over will almost triple from 21.8 million in 2008 to 61.4 million in 2060. The change in the population pyramids can be seen in Figure 1.

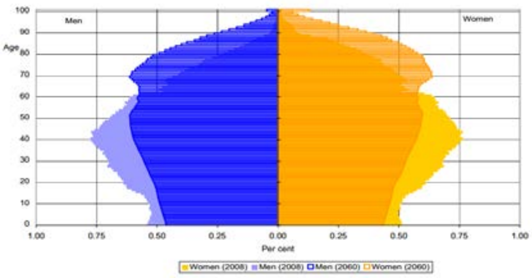

Fig. 1. *Population pyramids in 2008 (shaded) and in 2060 (striped) [4] in the EU*

In 2011, 44 million people in the EU had basic activity difficulties and in 2012, 42 million people were disabled [3].

For old and disabled people getting in and out of bath can be difficult and also dangerous. To solve this problem a new bath lift construction with an easy operating principle was developed to make bathing comfortable and safety.

This paper introduces the problem to be solved, then describes currently available products on the market and some patents related to the problem. The conceptual design process with a system-wide approach is the next part of the paper, which is followed by the description of the realized prototype.

2. Available solutions

One of the most common solution is the motorized retractable chair placed in the bathtub (Fig. 2). It's advantage is the simple construction, but it doesn't solve getting in and out of the bathtub, which can be dangerous because of slipping. For disabled people stepping over the edge of the bathtub is nearly impossible. Similar simple constructions such as water pressure inflatable balloons and harness stretched across the bath also do not provide solution for getting in and out of the bathtub.

The wall or celling mounted constructions (Fig 2.) are much more complicated, but they are capable lifting the person in and out of the bathtub. The advantage of these constructions is that they occupy no space from the floor or the bathtub, but they are expensive, so only rich people and premium hospitals can afford them.

Mobile patient lifts (Fig. 2.), which are even capable of moving the person from the bed into the bathtub are also common. They are often used in hospitals and retirement homes, where there is enough room for maneuver.

Fig 2. *Available solutions [6], [8], [11]*

2.1. Some patents related to the problem

In this section some related patents are described.

The invention described in US5903934 is a mobile armed lift and the bathtub was modified for easier accessibility [10]. The disadvantage of this solution is that a special bathtub, enough space and external aid is necessary.

US2011131720 patent notification describes a wall mounted bath lift with foldable and rotatable seat [1]. Advantage of this construction is that no space is occupied from the bathtub when it is not used. Disadvantage is that only the lifting is motor-driven, rotating into the bathtub requires manual force or external aid.

The invention described in US5263207 is a hydraulic, rotating, floor mounted column lift [5]. Disadvantage of this device is that high torques can occur and it occupies a lot of space from the bathroom.

The above described solutions either do not support getting in and out of the bath or are too complicated and expensive. Other disadvantage is that in most cases external help is necessary.

Our aim is to develop a construction, which can be built in an average bathroom retrofitted, ensures a safe getting in and out of the bathtub without external aid and has affordable price.

3. Systematic design process

3.1. System-based analysis

During development of such a device several viewpoints should be reconsidered. The device is a mechatronic system. It consists of the mechanical systems such as drive chain, motion system and supporting structure and also the electrical systems such as energy supply, control system and safety system. The task is complicated by several requirements, for example safety, easy mounting, simplicity, protection against moisture and condensation, economical considerations, etc. The requirements are described detailed in [7].

To simplify the design, the main function of the device was divided into subtasks [9]. Each subtask can be assigned to a subsystem of the device. The relationship between the subsystems is shown in Figure 3.

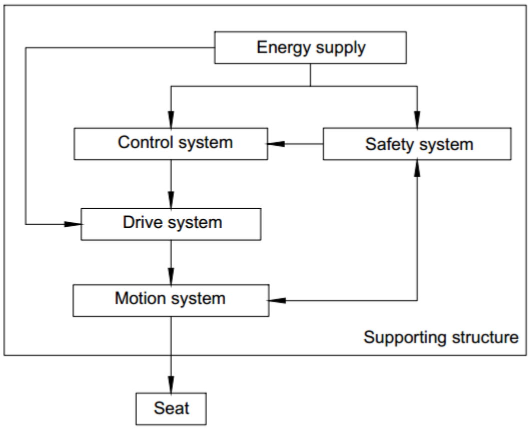

Fig. 3. *Subsystems of the bath lift*

3.2. Design of the motion system

The task of the motion system is to get the person sitting in a comfortable position from the place beside the bathtub into the bathtub without external aid. To solve the task different conceptual versions of the motion system were traced and the most appropriate one was chosen.

An obvious solution is a column lift (Fig. 4). The seat is moved along a cylindrical guide. The supporting column is mounted to the floor and the celling. For the movement two drive systems are necessary, one for lifting and the other one for rotating. There are several disadvantages of this solution: it occupies a lot of space in the bathroom, the person sits backwards at the beginning of the lifting and the rotation at the top of the path can cause insecurity feeling and dizziness.

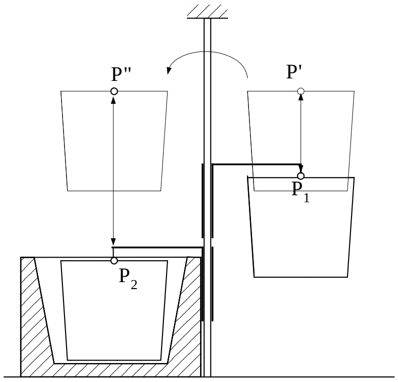

Fig. 4. *Movement with columned lift*

The seat can be moved along a planar curve $P_1P'P''P_2$ with synchronized coordinates, too. The movement of the seat can occur on linear or staged path (Fig 5.) This solution needs two driving system in both cases. The guide can be mounted to the wall if there is enough space and load-bearing wall. Otherwise the stable mount of the device can be a serious challenge.

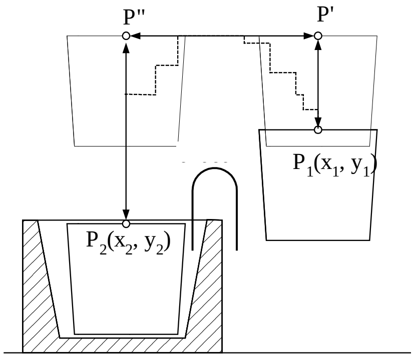

Fig. 5. *Movement in plane*

Moving the seat in circular trajectory is easily feasible with only one drive system, which is the greatest advantage of this solution (Fig. 6). The compact structure takes up relatively little space from the environment. Disadvantage of this concept is the relative difficulty of the stable mount and the limited lifting height.

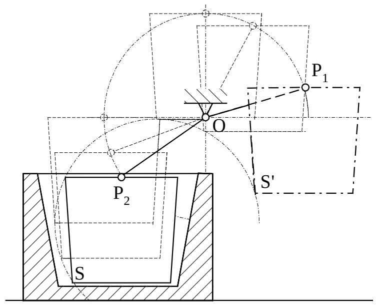

Fig. 6. *Movement on circular trajectory*

In theory bar mechanisms with fix or variable length arms can be taken into consideration, but the latter one is too much complex.

Analysing the concepts in terms of price, complexity, reliability and room, moving the seat on circular trajectory was chosen.

First step of the geometrical design was determination of the location of the center of rotation, which specified the main geometrical size of the device, for example the length of the arm.

3.3. Design of the drive system

For the drive system there were also several options to be chosen from. The drive system consists of a 12 V DC motor, which is prescribed in wet environment and a gear unit. From the length of the arm and the weight of the moved person the necessary torque was determined. The velocity was specified to 1 rpm. A 12 voltage, affordable priced DC worm-gear motor had a 30 rpm output velocity. From the rate of the velocities at least a thirty-fold reduction gearing ratio was necessary.

As first thought using a second worm-worm gear pair seemed obvious (Fig.7), but taken cost and efficiency into consideration other solutions were examined as well.

The arm could be moved with screw or electric cylinder, but this solution is suitable only for less than a half turn and at the end positions the power need is unrealistically high.

Similar solution would be a spindle-nut pair with a chain attached to the nut which drives a sprocket connected to the arm (Fig.7.). The advantage of this solution is that it extends barely beyond the side of the tub, but it was rejected because of complexity.

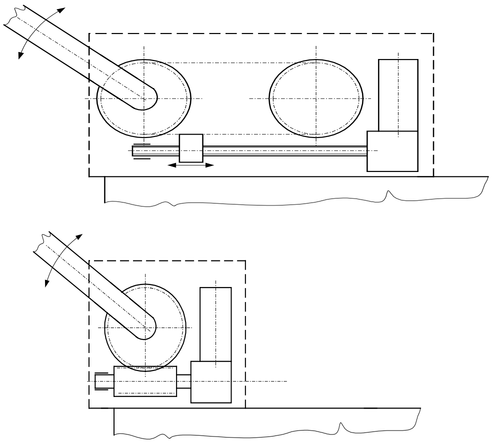

Fig.7. *Drive system concepts (above: spindle-nut gear with chain, below: worm-gear)*

Finally, a self-locking worm-gear reduction was used, which resulted in the most compact structure, but at the same time the lower efficiency and higher costs. The worm and the gear were custom designed and manufactured (Fig.8).

Fig.8. *Manufactured worm gear*

After designing the drive system other parts like shaft and bearings were scaled. The geometrical measures were determined in CAD environment as dependent models.

Our manufacturing possibilities were limited as device was created in a small workshop, so the parts should be manufactured as easily as possible.

The gearbox was made of aluminum to reduce weight and consisted of a baseboard and simple plates with a bore welded to the baseboard. The bearings are axially fixed with an easily manufactured bearing cap.

3.4. Design of the supporting structure

The design of the supporting structure was one of the greatest challenge. The supporting structure has to ensure the adequate stability and prevent the lateral and forward tilt of the structure under load. It has to be easily mounted to the wall or to the tub. The gearbox is fixed to it. Some support concepts can be seen in Figure 9. One of the very first support concepts (upper left) consisted of a tube bolted to the wall, a mounting plate and a supporting leg made from steel section. Although this concept is stable it is complicated and occupies a lot of space. For the next concepts the location of the motor was changed. As the motor got a lower position the gearbox had to be raised. The support first was made from welded steel sections (upper left). The gearbox was bolted to it. To reduce weight the support was simplified. It was made from tubes which were welded to a support plate (bottom left). In this concept a supporting leg was also used for the adequate stability. Using a supporting leg has some advantage, but it occupies space from the bathroom and can be dangerous if someone trips over it, so it was rejected. The last concept can be seen in Figure 9 bottom right. It is the least complicated and the best looking concept so far. It consists of welded steel sections instead of tubes.

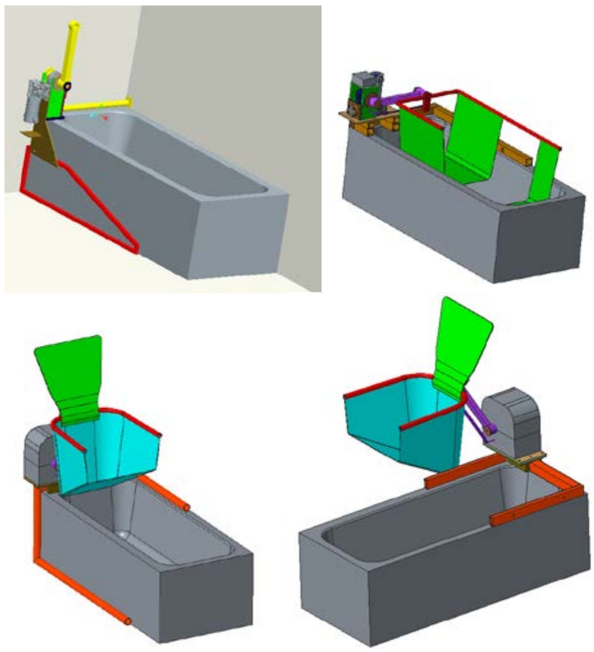

Fig 9. *Bathlift supporting structure concepts*

3.5. Design of the seat

There are two possibilities for the seat: harness or chair (Fig. 10). The main advantage of the harness is that it occupies less space from the bathtub and can be let down to the bottom of the bathtub. Since it takes the shape of a person sitting inside, it is comfortable. Other opportunity is a rigid chair. For using a seat a steel frame is necessary. It is more stable than the harness, installing the limit switches is much easier and it looks better. Disadvantage of it is that it occupies much more space because of the frame. To avoid collision with the edge of the bathtub the size of the seat is limited to 35 cm, so it is much more uncomfortable. As a result the harness was chosen in terms of comfort, design and safety.

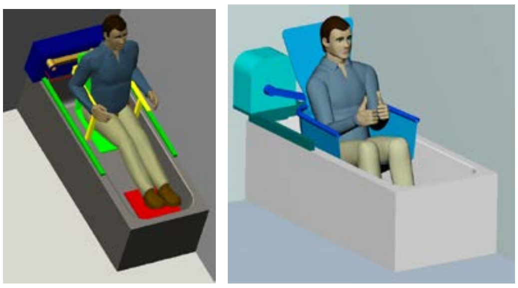

Fig. 10. *Possibilities for the seat (left: chair, right: harness)*

4. Realized prototypes

First a 1:2 scale model was created during the Széchenyi Duo grant for prototype building (Fig. 11). It gained positive reviews on some innovation exhibitions, which proved that there were a demand for such a device. This model only served demonstration purposes.

Fig. 11. *The 1:2 scale model*

The realized 1:1 prototype with real load capacity can be seen in Figure 12. First it was tested in laboratory without the seat. It could lift up a 80 kg person standing on the arm. It was powered by a 12 V battery. The prototype was completed with a harness later.

Fig. 12. *Realized 1:1 prototype with real load capacity*

Next task would be to test the prototype with the seat under load. For this a stable supporting structure and a bathtub model is necessary.

5. Conclusions

The aim of the project was to design a bathtub-entry-assist equipment. After a system based analysis a simple mechanism was chosen that moves the person on a circular trajectory in and out of the bathtub. For this concept only a simple drive and control system was created. As a drive system a worm gear was chosen. For a seat a comfortable harness was applied against chair.

Our bath lift proved to be an unique solution, which gained utility model protection in Hungary.

Two prototypes were realized so far: a 1:2 scaled demonstration prototype, which was only capable for showing the principle of operation and a 1:1 prototype with real loading capacity.

In the future there will be many tasks to be solved, like to make the device cheaper and lighter weight. Next step is to test the prototype with real load in real environment. For this a stable supporting structure made from welded steel sections and installation of the limit switches are necessary. Our final goal is to create an affordable price product, which can facilitate the life of elderly and disabled people.

6. Acknowledgments

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