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Mechanical Design of a Standing Frame adapted for Children with mental deficiency

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Abstract

The present paper presents the conceptual mechanical design of a Standing Frame for children with mental deficiency. Those children deal with great difficulties in maintaining a correct biped posture, hindering certain system organs to work in its fullness. Thus, the target goal of this project is to provide a correct biped posture to the child with mental deficiency. To achieve this goal there were defined the main goals that the standing frame should fulfil: safety, comfort, adaptability, attractiveness and accessibility. After the definition of certain functions and specifications the final solution comes up. For this solution it was selected metallic materials (structure of the Standing Frame) and polymeric materials (supports). It was also needed to select a lifting system, to lift the child from the seat to the biped position. The best solution found was an hydraulic, linear and single acting actuator. In order to ecologically guide the project it was chosen materials with fabrication and recycling processes that allow the final solution to be the most ecologic as possible.

Keywords: Wellbeing; Mechanical Design; Standing Frame; Children with mental deficiency

1. Introduction

The manufacturing industry is recognized as the backbone of advanced economies, driver of economic growth, employment and innovation. A Standing frame is a technological assistive device which provides correct biped position and stance of children with mental handicaps which show severe motor incapacity. The correct position on this device is the first step to facilitate de bone and muscular development, distributing correctly the body's weight for all limbs. Consequently it is prevented the appearance of contractures on lower limbs, the muscular lost and even the appearance of pressure ulcers due to long periods of time on lying and sitting positions. Besides this advantages, standing frame also cooperates for the better functioning of internal organs, allowing them to operate as a natural way, for example gastrointestinal, respiratory and circulatory systems. This aspects show obvious advantages of the using of standing frame, providing a higher range of movements [1-4].

Additionally, the use of this device contributes not only to a better interaction between the child and other people using interactive activities but also to their cognitive development. The increase of self-esteem, self-confidence, self-image and quality of life are therefore crucial aspects taking into consideration [1, 2].

This way, to select the more suitable standing frame it is necessary to define and analyse several parameters related to the child, such as: age, height, degree of handicap and consequent limitations. Weight will be considered, affording a maximum of 90 kg. The stature chosen is between 140cm and 170cm, which corresponds approximately to the range of ages from 8 to adult age. Regarding to the chosen device, it is central that it satisfies certain criteria which embraces: comfort, security, attractiveness, adaptability and accessibility.

Currently many types and models of standing frames can be found on the market. According to the mobility's degree, they are classified as: passive, of movement or active. Concerning to the passive Stander (static), it presents a fixed position and can have wheels in its structure although it does not move autonomously. Relatively to the movement Stander (dynamic), this allows the user to move autonomously, controlling the direction of the dislocation. About the active Stander (dynamic), it provides movement to higher and lower limbs during the vertical position. In this case study, given that the user has mental handicap and is not autonomous, there is a lake of capacity for dislocation by own initiative. Thus the user will need a fixed and secure support for de lower limbs which means the passive device is the most suitable [3].

The devices also can be classified as: prone, supine and vertical. The type of Stander is chosen according to the specific pathology of the user. Like this, the prone Stander (figure 1) gives a frontal support to the body, being appropriated for people with good control of the head, in order to sustain the weight with the arms. The adjustment of the system is possible consonant to the child's growth or other change in the body, presenting in the structure a stable base [2] [5] [6].

Fig. 1. prone stander [a].

Fig. 2. stander supine [b].

As to the ***supine Stander*** (figure 2), it contains lateral supports, belts and pillows to place the feet, knees and trunk so the symmetric biped position is guaranteed. There is also available a table which can be used for entertainment in the case of children. This type is therefore the most appropriate for children with mental handicap once they don't have the capacity of remaining totally standing. This *Stander* can be subdivided into: *large supine board, mini supine Stander* and *upright Standing Frame* [2] [5] [6].

Finally, the ***vertical Stander*** (figure 3) is presented. It provides supports for knees, hip and trunk, thus is appropriate for users with good control and equilibrium of trunk, or for children with insecure posture. Comparing with prone or supine, this one does not exert a total support on limbs [2] [5] [6].

Fig. 3. vertical stander [c].

1.1 Project methodology

The project work is based primarily on research, analysis and problem solving among a group of people, who plan to present always new solutions [7].

The project methodology consists of establishing all the procedures, techniques, supports or "tools" that the designer should follow/combine to realize the project [7].

The methods used are based on increasingly new procedural inventions, however they can be adjustments to other fields of knowledge [7].

In respect to methods of researching conceptual situations, in a first stage has been established the need for a comfortable, safe, adaptable, attractive Standing frame which does not exhibit obstacles to placement of the child.

Through literature search, including a detailed analysis of these devices and the target public's characteristics, it was possible find the equipment already sold. After the market research was chosen a type of Standing Frame more suitable for children with mental disabilities and in which was based our project [8].

The type of *Standing* Frame selected was the Vertical Stander, although all types of equipment presents advantages and disadvantages, this was what most resembled our goal, as it ensures the stability of main support areas (supports for knee, hip and trunk) when the child is in biped position [9].

Having as an object of study children with mental disabilities, interviews were made to professionals with experience in Standing frame equipment, a physical therapist and a special education teacher. The purpose of the interviews was understand the behaviour of these children and allow the improvement of device functionality. The main difficulties that professionals faced were the difficult transportation of the device due to its weight and size, the user's discomfort, high price, problems that have tried to rectify.

However, solutions are generated in the form of schemes that are placed in a morphological map. For the implementation of the schemes, they must be improved in detail, reduces information and if there is more than one solution should be defined just a final one. The final product is usually a combination of designs of the solution described with application of a criteria of selection/classification. In the detail phase, the essential points should be clarified and defined, and made the writing of specifications [8].

1.2 Project Objectives

During the elaboration of a project it is essential to define the target objective that should be achieved. Thus, the target objective of this project is to allow a correct posture and biped position of the child, which has severe disabilities. To achieve this target goal, the main goals that standing frame should fulfil were defined.

Security was the first objective do be defined, and should be reached decreasing assistant's mistakes as well as promoting absence of falls. The decrease of assistant's mistakes should be achieved through the use of an easy- to- manipulate- device that will immobilize the standing frame. Through the use of seat belts in the main support areas falls will be avoided.

Appealing to sound reproduction and visual interactivity it is possible to make the standing frame attractive. To achieve this goal, it was incorporated in the versatile table touch technology, coated with a white board magnetic layer allowing the child to draw and put ludic paramagnetic objects. Thus, with this layer it is easier to clean the table. Furthermore it will also integrated touch technology (removable tablet).

Due to its functionality it's important for the standing frame to be comfortable. Thus, it should be ensured a good structural stability, damping in the areas with more pressure, the use of structures that avoid scabs, as well as anti-sweat materials.

The standing frame should be adaptable, providing a few sizes for the structure, with some different colours and templates, according to the child's gender, and also a versatile table suitable for either didactic or daily activities. Finally, it's needed for the standing frame to be accessible as far as weight, stowage, cleaning, locomotion, manipulation and child's placement is concerned.

It is important to state that it has been assigned, by the designers, a relative importance for each objective. The descending order established was: security, comfort, adaptability, attractiveness and accessibility.

1.3 Production of solutions

The production of solutions to the device is an issue with a high level of importance to the project, as it gives the possibility to propose a range of applicable innovations. This production must pass through by the reorganization and recombination of existents elements/components, making this way a new feasible solution [10].

In this project there are eight fundamental functions that give a way to the target objective (biped position). These eight fundamental functions, as well the solution designed are:

1) **Sitting the child**
   For this function the component selected is a sit that has a hole to the coccyx as well the anatomic form for the thigh.
2) **Tie the pelvic region**
   A seat belt was chosen. The aim for this belt is to be fixed to the under region of the seat. This way the belt can be easily placed by the assistant and the children cannot get off the belt.
3) **Lean the trunk**
   This component has a particularity, it is anti-scab. The child stays for a long period of time with the trunk leaned (in the wheelchair for instance) and there is some possibility to the appearance of scabs on child's back. With this special particularity this possibility is diminished.
4) **Tie the abdominal region**
   This kind of children has a special behaviour and it's extremely important foresee all of type of acts. So, to prevent this, is needed a belt that ties all the abdominal region, and it must be fixed in the rear of the standing frame. In this way, the child is disabled to take out of the belt.
5) **Tie the feet**
   The feet must be well tied to enable the child of all movements with the feet. To achieve this it is needed a strap that ties the ankle and the instep, avoiding this way any type of feet's movements.
6) **Protect knees**
   The knees support a majority of the body's load, so it is important assure to relief the pressure under those with a special knee support.
7) **Table placement**
   The table allows two different tasks: didactic and daily activities, such as eating. The table should not be an obstacle to child's placement, it must be removable.
8) **Lift the child**
   As the child is initially sited on the standing frame, it is needed to lift the child. This is achieved by a lifting hydraulic system.

1.4 Final solution

In this section the aim is describe the new components/systems presented in the standing frame. The final solution is described as well as the form, materials, mechanisms as well as the main mechanical properties are also specifically detailed. The specifications of the *Standing Frame* are presented in the table 1.

The standing frame has a versatile table with double function: provide didactic tasks as well as daily tasks.

For didactic tasks the table has touch technology (removable tablet), allowing different visual stimulus to the child. The tablet also provides a sound system, allowing the reproduction of sounds. This way, the child has the ability to interact with different images, videos, sounds and all kind of technology liable to be reproduced, as well all type of didactic games.

For daily tasks the table should be constituted by a resistant and water-proof material, because it allows eating, designing and all type of manual arts. The selected material for this table's side is polyvinyl chloride (PVC), coated with a white board magnetic layer.

The table has a specific ergonomic form, as show in the figure 5. Thus, the child can easily lay back and realize the tasks comfortably. This table is also removable, through tubes placed in the standing frame structure, allowing this way the child's placement and removal without any obstacles.

Table 1. Specifications and dimensions of the standing frame.

Specifications	Dimensions
Height	140 - 170 cm
Maximum child's weight	90 kg
Feet support (height)	14 cm
Height from the floor to the seat	70 cm
Height from the knee support to the seat	38,45 - 52,45 cm
Cushion's dimensions	40 x 40 cm
Knee supports (width)	6 cm
Knee supports (height)	10 cm
Knee supports (depth)	14 cm
Table regulation (height)	22 cm
Table regulation (depth)	22 cm
Back support (height)	9 cm
Head support (height)	6 cm
Head support (depth)	6 cm
Table dimensions	39,25 x 62,70cm
Feet support dimensions	32 x 35 cm
Device's weight	48 kg

At figure 4 it is possible to observe the final structure of the *Standing Frame*, projected in the software *SolidWorks*. The device has around 48kgf of weight, a height and width of around 1770mm e 630mm.

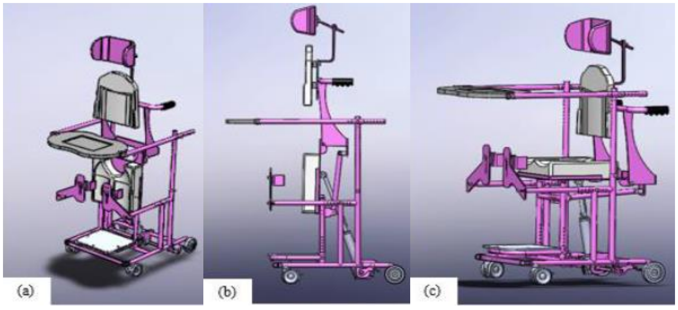

Fig. 4. final structure of the standing frame (a); biped position (b); seat position (c).

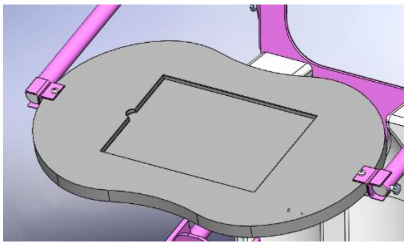

Fig. 5. versatile table.

Seat

The seat used in the Standing Frame was designed in order to prevent pressure ulcers (bedsores) and coccyx pain and injury. Thus, the seat has an inverted horseshoe shape to avoid pressure on the coccyx. The weight distribution in this type of cushions is made uniformly, ensuring the user greater convenience, comfort and correction of body posture [11].

Knee supports

To stabilize the knees and thus promote structural stability of the child, knee supports have been designed. These have a concave shape that surrounds the front part of the knee and a Velcro system for the back.

Trunk supports

As fair as the trunk supports is concerned, this equipment must be ergonomic, with anti-scab properties. Thus this support should have adequate dimensions in order to promote a higher stability as well as protection barrier between the child and the metallic structure.

Feet straps

Relatively to feet straps, its mainly function is provide security and stability to child. The material used is *Kevlar* because it presents properties like high resistance, hardness and thermic stability. Furthermore it provides safety as well as comfort.

Pelvic Belts

The best solution found to the pelvic belts is *Kevlar* made, for the same reasons mentioned above. About the geometry, the belt provides a large adaptability once it has double adjustment with two points of fixation. This adjustment also provides comfort to the user. Security is also guaranteed by the locking in the frontal zone (Figure 1) [12].

Abdominal Belts

With regard to the abdominal belt, it's made of *Kevlar* because of the reasons previously mentioned for the pelvic belt.

The belt is composed by 2 points of adjustment in the front, easily accessible which provide the modification in terms of width and height. The system is composed by two strips that cross on the back, providing more stability, security and comfort. Due to its characteristics, it is adjustable to a large range of shoulders width.

Stop system

To stop the standing frame it was selected a stop system, which is manipulated by the assistant. Thus it provides an immobilization with high safety to the child. This system offers an easy mounting and has three main components:

- Hand brake: is manipulated by the assistant and allows to control stop velocity (figure 6) [13] [14];

Fig. 6. hand brake [d].

- Brake (model *V-Brake*): is fixed on wheel axis, above the tire. As the applicate force on the hand brake increases, bigger is the stop force in the tire (figure 7 and 8) [15] [16];

Fig. 8. brake *V-brake* Shimano XT BR-T780 [f].

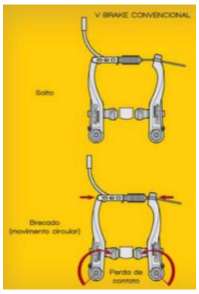

Fig. 7. operating sketch of conventional brake *V-brake* [e].

Lifting system

The lifting system is an important component because allows the transfer from the seated position to the biped position. This task should be performed without any physical difficulty to the assistant. The best solution for this component is a hydraulic system. This system is fully autonomous i.e., does not need any type of external energy source (as battery or electricity), decreasing the system's weight, as well as the probability of external occurrences and provides a highly ecology to the device. The hydraulic systems provides as well as a high position precision, which is an advantage when dealing with children with mental deficiency. The hydraulic system chose was the linear actuator *RH 1250* from *Römheld*, shown in figure 10 [18-21].

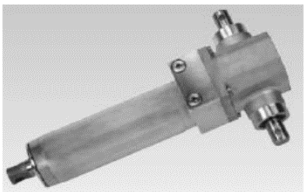

Fig. 9. linear actuator RH 1250 from Römheld [h].

Its main advantage is the fact that it can be designed according to the desired properties, making it possible to get suitable dimensions for this application. The *RH 1250* actuator will have to bear a maximum force of 4777 N and a pressure of 20 bar. Its piston diameter is 55 mm and its piston rod diameter is 19 mm.

According to the maximum force to bear (4777N) the actuator chose has a maximum lifting force of 6500N. With 23 pump strokes it is possible do lift the child 250mm (maximum distance needed to get to the biped position).

Furthermore, with this hydraulic lifting system it is possible to choose a pedal or crank (Figure 11), according to the costumer's preferences.

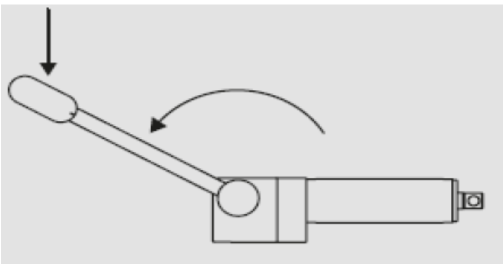

Fig. 10. pedal of linear actuator [h].

Table 2 sums up the main characteristics of the hydraulic actuator *RH 1250* compared with the desired ones.

This actuator must be placed in the *Standing Frame* making connection with the seat in order to lift the child. In order to achieve this condition the actuator is placed forming an angle of 80º with the horizontal line.

Recycling: ecologically oriented design

Nowadays it is crucial to take into account an ecologically orientation in the development of a project. This concern is due to the ecological implications of the decomposition time of the products in water and earth. Therefore, it is necessary to appeal to environmental assessment tools, EcoDesign strategies and to the ecology of products [22-25]. In table 3 the used materials are presented with the respective processing technique and recycling hypothesis [26-35].

Table 2. Specifications and dimensions of the *Standing*.

Desired	RH 1250
Type: linear	Type: linear
Piston diameter: 34.9 mm	Piston diameter: 55mm
Maximum force: 4777 N	Maximum force: 6500 N

Table 3. Materials utilized and its respective energy, waste and emissions.

Materials	Processing technique/ Energy	Waste and Emissions	Recycling
PVC	Extrusion; Injection	Petroleum use	After the life cycle (50 years): possible recycle and reuse for other materials
Kevlar	Extrusion in solution of sulphuric acid	_________	________
Polyurethane	Injection moulding (low energy consumption)	_________	________
Nylon	Melt Spinning; Drawing	Excessive use of energy and water. Petroleum use	Recycling process to obtain raw material in pure state
Fe/C alloy	Electric probing-high frequency (saving and efficient use of energy)	_________	_________
Al alloy	Extrusion (energy economy, due to CA motor)	_________	_________

Conclusion

The development of the present project was only possible analysing several complex parameters, from the structure's mechanical design, use of standards, used materials, technical drawing and forces simulation, among others.

Regarding to the structure and respective materials, metallic materials were selected for the structure and polymers for the supports.

About the lifting system, the objective was to maintain all the initial proposed parameters, such as: safety, comfort, adaptability, attractiveness and accessibility. This required the precise analysis of parameters like, forces, tensions, areas and rays, proceeding to inevitable adjustments to previously device designed. Therefore, the linear actuator *RH 1250* from *Römheld* was chosen. In its structure are integrated: the piston pump, the valve technology, as well as the oil tank, having a pedal attached.

Even more, there is the necessity of an ecological orientation of the project. Nowadays this point is fundamental due to the environmental crises in the all world. For this, the designer must take into account several aspects, such as creating an "ecological conscience", reducing materials and energy involved in the process as well as the emission of harmful substances into the environment. Concerning to the *Standing Frame*, certain producing processes and materials were chosen in order to achieve an ecological project. An example is the fact that a hydraulic actuator was chosen, instead of another solution depending on electricity.

Briefly, the pre-defined objectives were reached and a conceptual design of an efficient device was developed, demonstrating a high industrialization potential.

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