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Recreation Assistive Technology for Children with Crouch Gait in Cerebral Palsy

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ABSTRACT: *This paper involves the areas of Mechanical Engineering and Assistive Technology (TA). The project consists of the purpose of uniting this theme with playful activity, promoting the inclusion of people with cerebral palsy at the crouch gait level. The need for adapted toys and how much they influence of child's social integration, playfulness, fun, and learning become of great importance to the development of a toy that becomes fits the needs of a child with cerebral palsy at crouch gait level. A physical therapist aided the research. A case study performed having the notion of a child's daily life with crouch gait. The theoretical foundation of this project were used as references: scientific articles, books, consultation with professionals in the field of mechanical engineering, physiotherapy, and assistive technology. Calculations were performed to size the device according to its material, beyond as projection in 3D CAD software, simulations to verify if the device could withstand the loads it was subjected to, and 3D printing of a small scale prototype model. From the simulations, it was possible to verify that the toy resists the loads that will be applied, obtaining a good safety coefficient, being able to stimulate the inclusion, helping in the physical therapy process, meeting the project objectives.*

KEYWORDS: *Inclusion, Cerebral palsy, Crouch March.*

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I. INTRODUCTION

This paper aims to unite this theme with playful activity by the projection of a toy based on the existing giraffe, making it possible for it to be used by children at the crouch gait level in cerebral palsy. Aiming at the need for adapted toys in Brazil, mainly in Novo Hamburgo, and how much they influence social inclusion, playfulness, and the development of a child's fun and learning, the importance of carrying out this project.Inclusion can bring undeniable benefits for the development of people with disabilities, provided that it is submitted in traditional schools, necessarily, a Special Education that, in a broader sense, 'means to educate, sustain, accompany, leave marks, guide, lead [1].

Cerebral palsy at crouch gait affects the balance of these people, which ends up making it difficult to use certain toys available in playgrounds, thus running the risk of getting an injury. A toy in itself should encourage playful activities to be performed by those who use them [2]. The playful activity can significantly favor the advancement of man regardless of his age, helping him not only in learning but also in his development involving aspects (social, global, and cultural) providing more fair means in the processes of socialization, communication, and construction of thought [3].

Currently, the number of free toys for people with disabilities in Brazil is minimal. They are considering that these toys installation does not occur in the city squares, the city of Novo Hamburgo created a substitute law that deals with the installation of toys for people with disabilities and reduced mobility in the city squares.

II. LITERATURE REVIEW

Cerebral Palsy CP is a group of symptoms characterized by difficulties in controlling posture and movement, which may or may not affect the cognitive system, depending on the location and extent of the lesion in the brain [4]. The causes of infantile cerebral palsy can vary widely. A lack of oxygen, complications with the umbilical cord, infections, cerebral hemorrhage, and accidents can lead to infantile cerebral palsy during pregnancy, but more often during childbirth [5]. The effect of cerebral palsy on functional abilities varies widely. Some people can walk while others do not. Some people show normal or almost normal intellectual capacity, but others may have intellectual disabilities [6]. Ribeiro (s.d.) explains the classifications within cerebral palsy: Cerebral palsy can be mild, moderate, or severe, according to the International Classification of Functionality, Disability, and Health of the World Health Organization (WHO). There is also a classification as to the type of involvement of the nervous system: the problem can be only motor, cognitive, or mixed (when both the motor and cognitive parts are affected) [7].

The brain disorder that causes cerebral palsy does not change over time, so symptoms generally do not get worse with age. However, muscle shortening, and muscle stiffness can worsen if they are not treated aggressively [6]. Also, society needs to understand the limitations of people with cerebral palsy and understand the difficulties they face. At the same time, it is also essential to recognize their capacities for social interaction, production, and work, thus allowing them to have an everyday life [8].

Children with cerebral palsy who can walk may have motor disorders that hinder their ability to move. Gait with a flexed knee, also known as a crouch gait in cerebral palsy, is a gait disorder common among ambulatory adolescents with diplegia and quadriplegia [9]. Crouch walking is when the child has difficulty fully extending the knee when the foot is resting on the floor. One reason for this to occur is hypertonia (spasticity) or shortening of the posterior thigh muscles [10]. These muscles do not achieve adequate relaxation, not allowing the complete extension of the knees during gait, leading to significant impairment of the child's motor performance.

The cause of the "crouching" pattern usually stems from the excessive stretching of the Achilles tendon without the adequate decrease in hyperactivity/stretching of the spasticity/contracture of the knee and hip flexors [11]. The Crouch March is progressive and, if left untreated, can lead to a loss of independence. Conservative treatment consists of physical therapy, reduction of spasticity, and the use of orthoses. Surgical treatment consists of correcting contractures, restoring the extensor mechanism, and improving the lever arm [12].

The turntable made for children to walk on their feet (Fig. 1). A carousel that houses around the plane at the height of 1400mm, with a support beam and four metal bars that children can hold for support.

Figure 1. Roundabout disk for walking upright.

The Roundabout disk proportions a significant acceleration when it receives a strong impulse, but surrounding the carousel offers children a fun way to develop their sense of balance.

Projects developed using 3D modeling software, simulation, and computational support are suitable for Assistive Technology (AT) [13] or improvements in hospital devices and devices to support people with disabilities [14-15].

III. MATERIALS AND METHODS

The sizing of the toy happened so that it can support the loads in conformity with the standard established by ABNT NBR 14350-1 [16], which establishes requirements for the safety, installation, maintenance, and use of playground toys.

The central tube determined from the existing rotating gauges has an external diameter of 3 ”(76.2 mm) and a wall of 3.75 mm—buckling (Eq. 1). Critical stress calculated from the critical load considered an average weight force of 4 children aged 6 to 10 years old (1400 N), added to the weight of the device (1000N), thus totaling a total weight force of (2400 N). A safety coefficient k = 4 was used, and the area of the pipe section was 853.53 mm², resulting in a slimness index greater than 105 (minimum index) what guarantees that the tube is following the stipulated.

$$\sigma_{cr} = \frac{\pi^2 \times E}{\lambda^2} \quad \text{(Eq. 1)}$$

The support axis dimensioning occurs using buckling calculations (Eq. 2).

$$P \times k = \frac{\pi^2 \times E \times J}{Lf^2} \quad \text{(Eq. 2)}$$

In equation 2, the force used is the weight force used previously. The modulus of elasticity used is that of steel, and Lf = 2L (300mm) considered that the shaft would be free and set. From the calculation result, a diameter of 35 mm for the axis. The circular tubes dimensioning considered the worst cases: the lateral tube suffering from shearing or buckling. A base measure occurs that of the tubes of the existing rotating wheels, an external diameter of 1" (25.4 mm) and a wall of 2 mm, to check if they would resist the applied stresses. Equation 2 shows the buckling calculation and equation 3, the shear.

$$\tau = \frac{Q}{A_c} \quad \text{(Eq. 3)}$$

In both cases, the child was considered to rest entirely on top of the tube. Then, for equation 3, the mean load force of 1 child (350 N), a safety coefficient k = 4, and the tube section (147.03 mm²) were used as the critical load. The modulus of elasticity is that of steel. They are resulting in a slimness index greater than 105 (minimum index), which guarantees that the tube is following the stipulated.

For equation 4, the safety coefficient was calculated. They were relating the tangential stress to the normal allowable stress for 1020 L steel, which resulted in 210 MPa divided by k, with "k" being the safety factor in finding out. The cutting force considered was equal to the average weight of a child (350 N) and the tube section (147.03 mm²). Thus, a safety coefficient greater than 4 was obtained (used as a reference), which guarantees that the tube will support the requested loads. Bending calculations were used to design the rectangular tubes. Using equation 4, and considering an initial tube measuring 40 x 40 mm and a 3.75 mm wall.

$$\sigma_{adm} = \frac{M}{W} \quad \text{(Eq. 4)}$$

The force used to calculate the moment was the child's weight force (350 N) in a 600 mm long tube. The resistance modulus calculated from the initial dimensions of the tube occurs after finding the allowable stress value. The safety coefficient calculation occurs by dividing the yield stress for 1020 L steel by the allowable stress, finding a good safety coefficient with a value of 6.59. The bearings were defined based on the stipulated diameter for the support axis (35 mm), this being the bearing's internal diameter was verified if the bearing could withstand the loads established from equation 5.

$$L_{10} = \left(\frac{C}{P}\right)^p \quad \text{(Eq. 5)}$$

This calculation verified the expected life of the selected bearing (bearing 30207) according to the SKF general catalog (1989). A dynamic load capacity "C" of 51200 N was used. The equivalent dynamic load was considered equal to the average weight of 4 children and the device's weight. The exponent of the life formula for roller bearings is equal to 10/3. Thus, a nominal bearing life of 26,927 million revolutions was obtained, proving the feasibility of using this bearing. In the design of the rivets, shear calculations were used, as in equation 6.

$$\sigma_{adm} = \frac{Q}{n \times A_{cis}} \quad \text{(Eq. 6)}$$

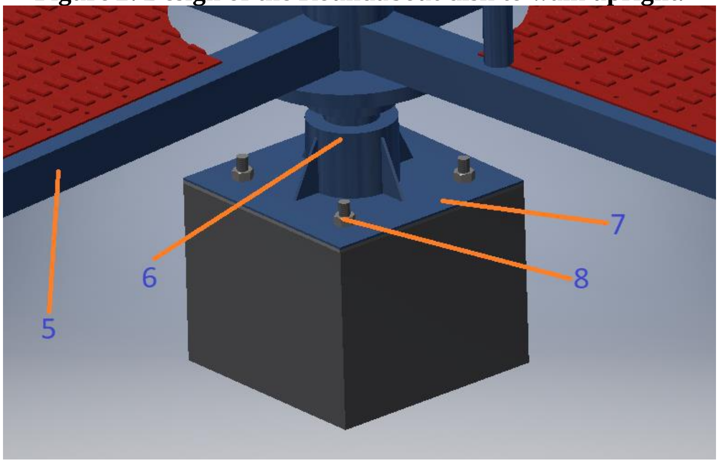
For the verification calculation, 8 rivets with a diameter of 3.2 mm befall that two children would climb on the same side resulting in a load of 700 N. The number of rivets equal to 8, and the area was calculated from the diameter of the rivets (8.04 mm²). The safety coefficient was calculated from 1020 L steel and equivalent normal and tangential stresses. They were resulting in a safety coefficient of 19. This rivet was finally chosen to generate confidence for those who use the device. These screws were dimensioned for a shear force according to equation 7.

$$\sigma_{adm} = \frac{Q}{n \times A_{cis}} \quad \text{(Eq. 7)}$$

In this calculation, it was assumed that the child supports all their weight on the seat belt. Therefore, the shear force is the weight of a child (350 N). The "n" is equal to the number of screws that, in this case, is 2. The allowable tangential stress was calculated for 1020 L steel and a safety factor 4. This resulted in a screw core diameter of 2.1 mm. However, to demonstrate more security, an M8 screw was chosen, whose core diameter is between 7.76 and 7.88 mm.

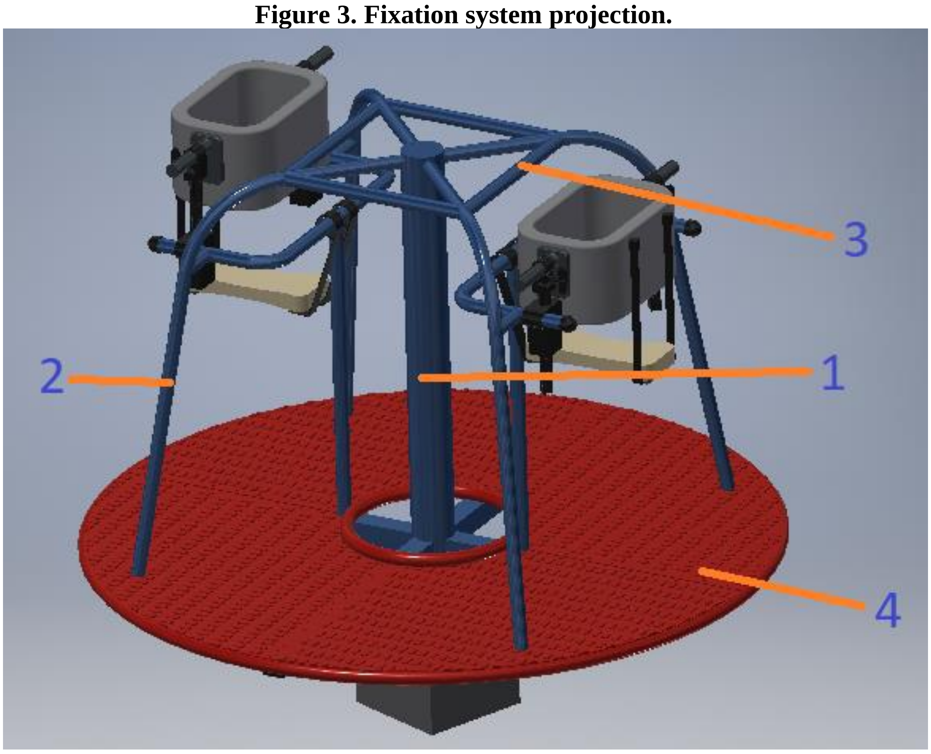
After choosing materials and sizing, it was possible to make the toy's final projection in the 3D CAD software Autodesk Inventor 2019, aiming to provide, above all, the inclusion and fun of children with disabilities. Figure 2 illustrates the final projection of the toy.

Figure *2*. Design of the Roundabout disk to walk upright.



In figure 3 some numbers were placed to reference the components of the projection. 1 - Central tube: it is the part where the whole toy should fix, having sufficient mobility to provide its rotation; 2 - Lateral tube: delimits the space of each child; 3 - Intermediate tube: serves for children to be able to support themselves while the toy is in motion; 4 - Toy base: it is a segmented repressed plate, thus having a non-slip surface, where children will climb up to use the toy. For the installation of the toy, a concrete fixation system projection (Fig. 3).

Figure 3. Fixation system projection.



Following the numbering in figure 4: 5 - Rectangular tube: it will serve as a support for the base fixed to the central axis; 6 - Central shaft cover: a device whose function is to fix the external surface of the bearings, making the axis always rotate in the same center; 7 - Fixing plate: which aims to fix the structure to the concrete, having a cavity for the replacement of the bearings; 8 - Threaded bar: Threaded bars designed to be used to fix item 7 using nuts Aiming at the 2 places adapted for children with cerebral palsy at crouch gait level, a safety system designed for them (Fig. 4).

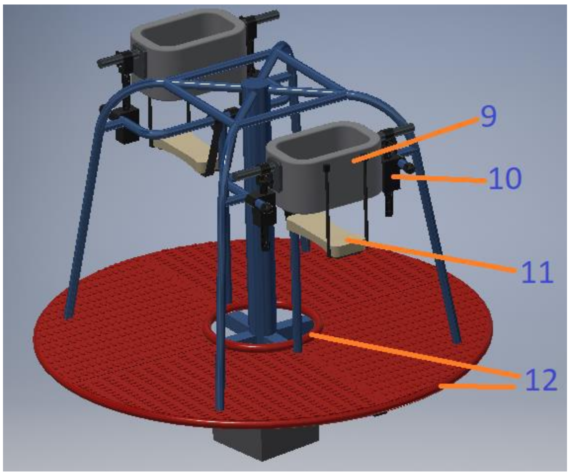


Figure 4. Safety system.

Following the numbering in figure 5: 9 - Belt: designed so that the child with Cerebral palsy can play safely; 10 - Height regulator: this device aims to make it possible to adjust the height of the belt so that children of different heights can use the toy peacefully; 11 - Seat belt: Server to support part of the child's weight; 12 - Calendered tubes used to remove the sharp edges of the base plates. A projection of the toy's full support would be like was also made (Fig. 5).

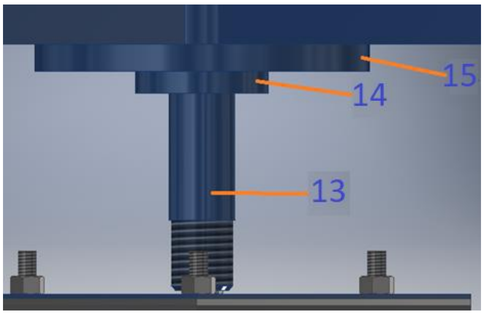
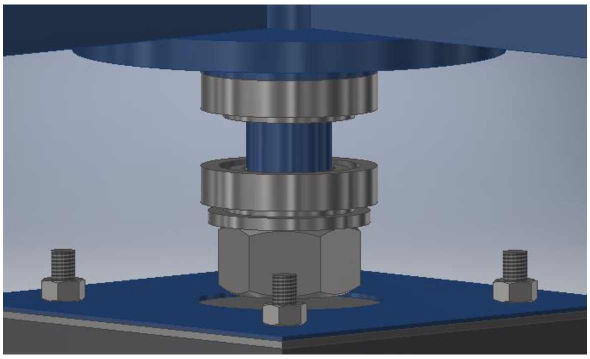


Figure 5. Toy support.

Following the numerical order, we have a system that promotes the support of the device, composed by: 13 - central axis, and the bearings have a thread for the nut that next to the pressure washer will keep the bearings in place, in addition to facilitating the exchange of bearings, if necessary; 14 - connector tube, a tube used to connect the central axis (item 12) to the central tube (item 1), in addition to limiting the location of one of the bearings; 15 - fixing ring, a ring with an internal diameter equal to the external diameter of the central tube, the tube serves to support the rectangular tubes (item 5), giving more excellent stability.Figure 6 shows how the central axis assembling next to the bearings, the pressure ring, and the nut, and in the space between the bearings, there will be a part of the central axis cover.

Figure 6. Mounting the central shaft and bearings.



IV. RESULTS

As a result of the Autodesk Inventor 2019 software's structural analysis, the maximum displacement of the structure, weight, safety coefficient, and the disposition of stresses, the structure of the toy weighs 89.011 kg. As shown in figure 7, it is possible to visualize the maximum displacement of the toy structure when considering four children's weight, being 0.513 mm.

Figure 7. The maximum displacement of the toy structure.

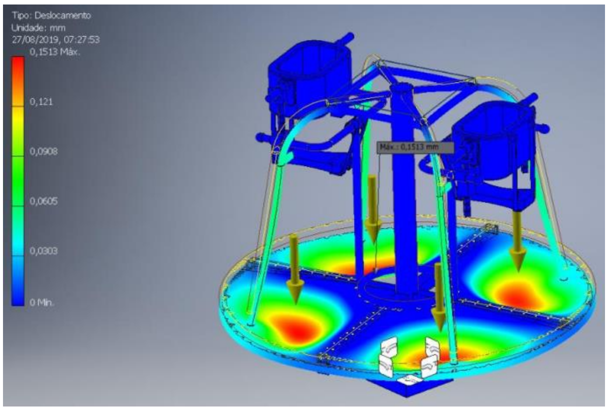
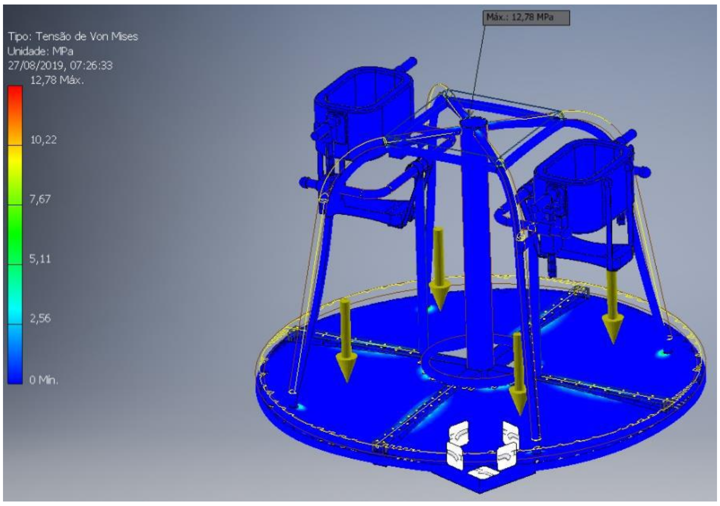


Figure 8 shows the stress analysis of the toy structure to visualize the stresses acting with the loads and efforts applied, with the maximum stress, by the method of Von Misses, 12.78 MPa.

Figure 8. Von misses stress of the toy structure.



The minimum safety factor of the toy structure was analyzed, as shown in figure 8. The minimum factor is in the place of greatest effort, being 3.31. These analyses are happening from a normal situation, where the four places of the toy are each occupied by a child.

V. CONCLUSION

With the results of this project, it was possible to arrive at a concept of functioning of a toy that promotes the inclusion of children with cerebral palsy at the level of crouch gait. In addition to that, this toy also manages to help in the physiotherapeutic process of these children. With the realization of this research, the importance of this toy for these children was noticeable. That is why the project's relevance, which seeks to reduce the difficulties that these children face, makes playfulness stronger, regardless of differences. The general and specific objectives of the research occur. They promote the inclusion of children with crouch gait in cerebral palsy through the projection of a toy that allows them to play in the same environment as other children, collect bibliographic information on crouch gait, perform sizing calculations, sketching the device in Autodesk Inventor 2019 3D CAD software (educational version), performing stress analysis on the designed device using Autodesk Inventor 2019 3D CAD software (educational version), printing a model of the device on the 3D printer and promote the safety of the child with cerebral palsy at the crouch gait level when using the device. As a continuation stage of the project, improvements will occur to some items, in addition to the construction of the full-scale prototype, and then tests will occur.

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